CHAPTER III. TECHNICAL SPECIFICATIONS AND REQUIREMENTS

EMPLOYER’S REQUIREMENTS

PART A: GENERAL REQUIREMENTS Annex 1-A to the Agreement

PART B: TECHNICAL REQUIREMENTS Annex 1-B to the Agreement

PART C: FINANCING REQUIREMENTS Annex 1-C to the Financing Agreement

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CHAPTER 1. GENERAL TECHNICAL SPECIFICATIONS AND REQUIREMENTS

If the technical specifications, requirements, works, and quantities of the Works stipulated in Annex 1 [Employer’s Requirements] of the Contract are not specified or are unclear in this Annex, the technical specifications, requirements, works, and quantities set forth in the Feasibility Study (FS) shall prevail and be followed.

Furthermore, the Contractor shall be responsible for preparing and financing all other necessary reports and studies required for the implementation of this Project under EPC+F conditions, including but not limited to the Environmental and Social Impact Assessment (ESIA) and related detailed assessments.

Table 1. Key Indicators of the “First Ring Road” project

№	Үзүүлэлт	Хэмжих нэгж	
1	Project Name:	First Ring Road	
2	Location:	The road alignment will pass through: TPP-4 Road, Peace Avenue, Tolgoit, Ard Ayush Road, Bayankhoshuu Intersection, Songinokhairkhan District, Khoroo No.10 territory, Denjiin Myanga Road, Khailaast Street, Doloon Buudal Road, Baruun Altan-Ölgiin Street, Da Khüree Street, Border Street, Police Academy Avenue, and Dunjingarav Street.	
3	Starting Point of Road	Thermal Power Plant- 4 Road	
4	Ending Point of Road	Dunjingarav Street	
5	Road Length	km	24.793 kms
6	Road Class		International standard expressway
7	Design Speed	km/ h	100-120
8	Number of Traffic Lanes	pcs.	6
9	Multi-Level Intersections (with entry/exit ramps)	pcs.	6
10	Two-Level Intersections (without entry/exit ramps)	pcs.	14
11	Total Length of Bridges	meters	9,034
12	Number of Tunnels	pcs.	1
13	Number of Curves	pcs.	19
14	Minimum Curve Radius	meters	450
15	Maximum Curve Radius	meters	6,500
16	Total Curve Length	meters	12,766.78
17	Share of Curves in Alignment (%)	%	50.95
18	Minimum Radius of Vertical Convex Curve	meters	4,000
19	Maximum Radius of Vertical Convex Curve	meters	60,000
20	Minimum Radius of Vertical Concave Curve	meters	3,000
21	Maximum radius of vertical concave curve	meters	6,000
22	Maximum longitudinal slope	%	4

23	Length of maximum longitudinal slope	meters	1,910
24	Width of right-of-way (from the centerline to both sides)	meters	40
25	Width of embankment	meters	29
26	Width of roadway (carriageway)	meters	25
27	Slope of embankment side	m:n	1:1.5
28	Slope of excavation side	m:n	1:1.5
29	Pavement structure	Cantimeters	Subbase layer h=20 cm
30		Cantimeters	Cement-stabilized base h=20 cm
31		Cantimeters	Cement-stabilized crushed stone base h=20 cm
32		Cantimeters	Bitumen-treated crushed stone base h=8 cm
33		Cantimeters	Coarse-graded asphalt concrete h=6 cm
34		Cantimeters	Fine-graded asphalt concrete h=4 cm

The technical specifications of the First Ring Road set forth in Table 1 may differ from those indicated in the Feasibility Study (FS).

Figure 1. Route Alignment of the First Ring Road

Table 2. Coordinates of the First Ring Road

№	km	Координат		Description
		X	Y	
1	K0+000	636917.4222	5306229.837	Start Point
2	K1+000	636847.2436	5307223.66	
3	K2+000	636812.7219	5308222.662	
4	K3+000	636894.3251	5309216.296	
5	K4+000	636693.6227	5310173.891	
6	K5+000	636217.9494	5311053.513	
7	K6+000	636096.9366	5312021.396	
8	K7+000	636776.8479	5312638.228	
9	K8+000	637774.685	5312702.468	
10	K9+000	638763.7882	5312849.01	
11	K10+000	639754.7072	5312978.159	
12	K11+000	640749.6721	5312894.531	
13	K12+000	641742.9241	5312789.201	
14	K13+000	642737.377	5312893.346	
15	K14+000	643736.6315	5312927.869	
16	K15+000	644724.0294	5313054.425	
17	K16+000	645675.9302	5313360.831	
18	K17+000	646557.2964	5313125.416	
19	K18+000	647058.3189	5312281.761	
20	K19+000	647201.406	5311322.308	
21	K20+000	648079.1544	5310856.359	
22	K21+000	648902.6069	5310317.482	
23	K22+000	649070.833	5309351.819	
24	K23+000	648889.0644	5308390.939	
25	K24+000	649028.0379	5307404.466	
26	K24+793.006	649226.9251	5306636.805	End Point

**The alignment of the First Ring Road indicated in Table 2 corresponds to the location determined during the preparation of the Feasibility Study (FS). Appropriate modifications may be made during the detailed design stage.*

CHAPTER 2. DESIGN BASIS, STANDARDS AND TECHNICAL REQUIREMENTS

2.1 Design Basis

(1) Basis for the Preparation of Documents

1) Terms of Reference for the Consulting Services on the Feasibility Study (FS) Report and Design of the "New Ring Road (Ulaanbaatar)";
2) "General Development Plan of Ulaanbaatar City 2040";
3) Government Resolution No. 476 of 2022 of Mongolia on the Construction of the "New Ring Road" in Ulaanbaatar City, and Order No. A/720 of the Governor of the Capital City dated June 19, 2024;
4) Law on Urban Development;
5) Law on Roads (may not apply to the new type of expressways);
6) Law on Land;
7) Law on Road Traffic Safety and Related Legislation (may not apply to the new type of expressways);
8) Law on Geodesy and Cartography;
9) Law on Environmental Protection;
10) Law on Environmental Impact Assessment;
11) Law on Water;
12) Law on Minerals (with respect to the use of commonly distributed minerals);
13)
13. Order No. 295 of the Minister of Finance of Mongolia dated December 25, 2018;
14. Road Traffic Regulations (may not apply to the new type of expressways);
15. Law on Energy;
16. Other relevant laws and regulations of Mongolia.

2.2 Road Works Standards and Technical Requirements

The road design shall be prepared in consultation with the Employer, in accordance with the applicable road design codes and regulations in force in Mongolia, as well as relevant international standards, codes, and regulations.

2.3 Bridge and Drainage Culvert Works

(1) Load capacity classification: Vehicle load: NK-80
(2) Road clearance: railway line ≥ 7010 mm; urban roads ≥ 4900 mm; underpasses/tunnels ≥ 2500 mm
(3) Lane width for vehicular traffic: 3.75/3.5 m per lane
(4) Standard cross-section layout:
Standard width of the main line cable-stayed bridge section: 26.5 m, cross-section: 0.5 m (barrier) + 12.25 m (traffic lane) + 1.0 m (barrier) + 12.25 m (traffic lane) + 0.5 m (barrier) = 26.5 m.
Standard width of the main line cable- stayed bridge section: 19.5 m, cross-section: 0.5 m (barrier) + 8.75 m (traffic lane) + 1.0 m (barrier) + 8.75 m (traffic lane) + 0.5 m (barrier) = 19.5 m.

(5) Seismic requirement: Earthquake resistance 7–8 magnitude, peak ground acceleration 0.15g–0.20g
(6) Design flood frequency: Bridges: 1/100; Flood drainage culverts: 1/50

(7) Design service life: 100 years
(8) Design safety level: Level 1
(9) Environmental classification: Upper structure designed for Class I environment (general environment); Substructure designed for Class II environment (freeze–thaw environment).
(10) Estimated operational lifespan: Main line cable-stayed bridges and interchanges: 100 years; Overpasses: 50 years; Drainage culverts and underpasses: 30 years; Barriers, expansion joints, bearings, etc.: 15 years.

2.4 Tunnel Works

(1) Tunnel Construction Works

1) Road classification: Primary Class I highway;
2) Design speed: 80–100 km/h;
3) Cross-sectional dimensions of tunnel roadway:
Clear width: 0.75 m + 0.5 m + (3 × 3.75 m) + 0.75 m + 0.75 m = 14.00 m
Clear height: 5.0 m
4) Design service life of main structure: 100 years;
5) Fire resistance grade of structure: Grade I;
6) Table of tunnel monitoring/control elements;

Table 3. 1. Tunnel Monitoring and Control Elements

Name	Length Classification	Distance Type	Category	Design Service Life	Safety Grade of Supporting Structures	Waterproofing Grade	Environmental Impact Grade	Seismic Grade	Seismic Resistance Grade
New Ring Road Tunnel	Long Tunnel	Large-span, shallow-buried Tunnel	Class I	100 years	Grade I	Grade II	B	7 (points)	Grade B

7) Fire Resistance Requirements

Planned in accordance with the *"Fire Protection Design Code for Buildings"*. The safety level of the tunnel is classified as a Class I tunnel.
Fire resistance limit of load-bearing structures: ≥ 2.0 hours (the RABT standard heating test curve shall be applied)

(2) Tunnel Ventilation Sanitary Standards

1) Permissible CO Concentration (δ):
① Under normal operation, the calculated CO concentration in the tunnel: δ ≤ 150 ppm;
② When road traffic is closed, with all lanes in idle condition, average vehicle speed Vt ≤ 30 km/h, and congestion duration not exceeding 20 minutes, the calculated CO concentration in the tunnel shall be δ = 150 ppm;
③ In tunnels where both people and vehicles pass together, the calculated CO concentration shall not exceed 70 ppm.
2) Permissible Smoke Concentration (K):
The light sources used for tunnel illumination shall all be LED light sources. According to the *"Design Code for Ventilation of Highway Tunnels"*, the permissible smoke concentration K for tunnels using LED light sources is shown in the table below.

2.5 Working Drawings

The working drawings shall consist of the set of documents including sketches, technical drawings, and construction drawings submitted to the Employer’s Representative in accordance with the Employer’s Requirements related to the technical specifications.

The Contractor shall be responsible for preparing the working design drawings for foundation works, bridges, tunnels, roads, ancillary road structures, sites, power supply, occupational safety, and other subsystems. The Contractor’s design shall be based on the standards and explanatory documents specified in Annex 1(b) [Technical Requirements] of the Contract Conditions. During the design process, where further detailed study or mutual agreement between the Parties is required, the approved Feasibility Study shall serve as the reference.

These documents shall be interpreted in conformity with the Particular and General Conditions of Contract, the Technical Requirements, other Annexes, and any other documents forming part of the Contract.

2.6 Standards, Rules, Regulations, Norms, and Codes

The working design and construction works shall comply with the Employer’s approval as well as with applicable laws, documents, rules, regulations, and standards.

Since Mongolia does not have national standards for the design of highways or expressways (understood in terms of international standard terminology such as freeway, highway, expressway), and such works have not previously been implemented in the road sector of Mongolia, the Contractor shall apply international standards or the standards, norms, rules, and regulations of its own country. Such standards shall be adjusted to Mongolia’s natural and climatic conditions and agreed with the Employer to ensure that quality requirements are fully met in carrying out the construction works.

The working drawings, Technical Specifications, and Information shall reflect the Employer’s overall concept and objectives in relation to the scope, purpose, and form of the Works. While the Contractor shall base its design on the information provided by the Employer, the Contractor shall not be limited thereby and shall remain fully responsible for the completeness of the design.

2.7 Design Review Procedures

The Contractor shall submit the working design documents to the Employer in accordance with the procedures for document submission, response, and review specified in the Contract Conditions, and shall obtain responses accordingly.

During the design stage, the Contractor shall present and explain the design solutions to the Employer, the Employer’s Representative, or the Employer’s Engineer as confirmed in the Communication Matrix and shall keep the Employer fully informed. The purpose of such presentations and information is to enable the Employer to understand the proposed design solutions and opinions and to finalize the design decisions. Unless otherwise provided in the Contract, all meetings related to design discussions shall be convened at the Employer’s office, the Contractor’s head office, the Site office, or any other location determined by the Employer.

In the event that new products or technological solutions are to be applied, the Employer shall provide a response to the documents submitted by the Contractor under Annex 1

[Employer’s Requirements] of the Contract Conditions within the period stipulated, counted from the date the Employer receives the relevant information from the Contractor.

2.8 Climatic Requirements

In the project region, the maximum summer temperature reaches +45°C, while the absolute minimum winter temperature drops to –45°C. The average precipitation is 9.6 mm, and the area is subject to dust storms and strong winds, with an average wind speed of 5.0–5.2 m/s and a maximum wind speed of up to 40 m/s. Therefore, the Ring Expressway shall be designed and constructed to ensure continuous and reliable operation under these climatic conditions.

CHAPTER 3. Road and Planning

3.1. Planned Road

3.1.1. Principles of Motor Road Planning

(1) Reliability and Safety

1) Principle for earthquake and flood protection: The bridge foundations are designed to withstand a magnitude 7 earthquake, and drainage is planned for floods with a 100-year return period.
2) Side slope stabilization: In mountainous regions, slope protection shall be executed by reducing the slope gradient and employing geotextile concrete reinforcements. In flat areas with soft foundation sections, anti-pressure protection measures shall be applied.
3) Road traffic safety: Collision prevention barriers, intelligent lighting systems, warning systems in fog zones, as well as signage and road markings shall be installed throughout all sections of the road.

(2) Reduction of Carbon Emissions:

1) Use of Green Eco-Materials: Endeavoring to utilize local stone and recycled asphalt concrete to reduce carbon emissions from transportation.
2) Utilization of Stormwater Resources: Collecting stormwater through permeable pavements and reservoirs for irrigation of roadside green spaces.
3) Biodiversity conservation: To prevent fragmentation of ecological corridors, animal migration corridors shall be maintained (e.g., by covering corridors with soil and preserving their natural pristine state).

(3) Economic efficiency and opportunities

1) Optimal planning of earthworks: Excavated rock from the northern section of the tunnel may be used for embankment fill in the southern section, thereby reducing soil removal and excavation costs.
2) Optimizing phased planning: Initially, it is essential to construct and commission the main road first, prioritizing the subsequent construction of auxiliary roads. This strategy will facilitate the continuation of construction of other planned motor roads.
3) Reducing the impact of land acquisition: The planned motor roads should avoid densely populated areas by utilizing available vacant land and aligning with existing motor roads during planning, thus minimizing the effects of land acquisition.

(4) Adaptive flexibility:

1) Climate- resilient design: Utilize cold-resistant asphalt and cold-resistant pavement base structures to withstand extremely low temperatures (-40℃).
2) Expandable space: Design intersections with access points to accommodate urban expansion or the requirement for new highway construction.
3) Dynamic operation: During the development of the plan, the bridge length or tunnel foundation calculations were carried out in accordance with the geological exploration report and optimally designed.

(5) Social and cultural integration

1) Incorporating national characteristics: The bridge railings and noise barriers integrate traditional Mongolian motifs, thereby emphasizing the regional culture.

2) Public participation and transparency: To publicly promote the road plan and mitigate social conflicts, the opinions of residents along the road alignment shall be solicited.

3.1.2. Planning solution

(1) General planning principle:

1) In accordance with the objectives of the Ulaanbaatar City master plan, after studying the current development trends of the capital, environmental protection, and social conditions, the most suitable option for the city's motor road network has been developed.

2) Considering the project's geographical location and material properties, optimizing the design of the road foundation fill by improving the soil characteristics is the most effective solution. The motor road shall be designed with a stormwater drainage system.

3) In developing the motor road design, measures and materials suitable to the regional characteristics shall be selected in accordance with traffic volume and operational requirements to ensure unobstructed construction, while adhering to principles that minimize future maintenance and investment costs. The design drawings were developed in accordance with the experience of Ulaanbaatar City and local regions.

4) The project scope and content were defined based on traffic load, capacity throughput, and socio-economic benefit assessments.

5) This planning optimizes the bridge design drawings, construction technology, and methods, taking into account feasibility, engineering economic efficiency, structural safety, visibility, aesthetic appearance, and technological advancement.
6) Implemented in accordance with the Master Plan of Ulaanbaatar City and adapted to actual conditions, commencing from the short term, optimising pipeline planning for this project with integration of both near-term and long-term considerations, and conducting an in-depth analysis of the feasibility and necessity for establishing comprehensive pipeline corridors in certain sections.
7) The measures will be adapted to local conditions, prioritizing ecological green spaces and highlighting the distinct features of Ulaanbaatar City, fully taking into account road traffic safety requirements and visibility, optimizing the selection of plant and tree species, and establishing the urban motor road green landscape system in accordance with high standards.

(2) Definite Planning Concepts

1) Improving Road Traffic Capacity
① Ensuring unobstructed road traffic capacity: Complying with the standards for main streets in Ulaanbaatar City, reducing at-grade intersections, and planning for grade-separated and segregated intersections to secure unobstructed traffic flow on main streets.
② To facilitate rapid access and service functions in areas adjacent to the road network, a rapid transit system combined with a service road system has been implemented. The urban section utilizes elevated roads and service roads to reduce land acquisition.
③ Multi-layered connectivity: establishing the 'ring + radial' road network structure consisting of existing roads, the planned Tuul Highway, and the city sub-center (Bayansukh), while allowing for future extensions.
2) Planning Adapted to Natural Conditions
① Aligning the territorial boundaries: The northern mountainous area combines tunnels

and transmission pipelines to mitigate ecological damage resulting from mountain excavation; The eastern and western sections traverse urban residential areas. Given the high density of the existing motor road network, the use of service roads on elevated bridge structures not only reduces demolition but also effectively eliminates obstructions to the existing road, thereby enabling faster traffic flow.

② Prevention of geological risks: To resolve issues such as frozen soil and soft soil foundations, composite foundation treatment technologies (gravel embankment, geogrid, etc.) and frost-protected roadbed structures shall be utilized.

③ Prevention and mitigation of hydraulic disasters: When crossing the Selenge River and its tributaries, avoid channel constriction by employing large bridges; Installation of ecological slope protection and infiltration blind drains to mitigate runoff erosion on the pavement.

(3) Integration of ecology and urban development

1) Mitigation of ecological degradation: avoiding ecologically sensitive areas (such as wetlands and forests), employing low-noise pavement, utilizing ecological noise barriers, and protecting biological habitats along the road corridor.

2) Filling urban space: Connecting the Bayansukh sub-center and the city core area to support regionally coordinated development by utilizing three-dimensional green infrastructure and fundamental landscape planning (e.g., sudden landscape platforms).

(4) Comprehensive control of the total life cycle cost

1) Prefabrication method: Prefabricated components shall be utilized to shorten the construction duration of works such as bridges and retaining walls and to minimize environmental impact.

2) Intelligent operation and maintenance: Integrate traffic control and structural health monitoring systems to establish and preserve provisions for future intelligent road management solutions.

3.1.3. General Organizational Plan

(1) Principle of Planar Planning

1) The road alignment shall comply with the requirements of the Ulaanbaatar City 2040 Development Plan.
2) The planar lines shall be straight, continuous, and smooth, adapted to the terrain and landform, and harmonized with the surrounding environment.
3) Minimize impact on cultural immovable monuments, water sources, and natural resource areas.
4) Comply with fundamental requirements of driving mechanics, as well as visual and psychological standards.
5) Ensure balance and continuity of the horizontal alignment.
6) Fully consider all factors affecting land development along the route.
7) Rational organization of entrances, exits, and segregated intersections.

(3) Evaluation of project commencement and completion

In accordance with the requirements specified in the assignment for project location, alignment, and scope of work: TEC-4 road, Peace Avenue–Tolgoit, Ard Ayush road, Bayankhoshuu intersection, 10th residential district of Sukhbaatar district, Denjiin Myangyn terminus, Khailaast

street, Doloon Buudal, Baruun Altan-Ulgii street, Da-Khuree street, Khilchingiin street, Police Academy Avenue, Dunjingarav street.

Selection of the project starting point: Point 1, the intersection of the existing new road and the TPP-4 road, has been chosen. This may be connected southward to the Tuul Expressway, facilitating the development of an efficient rapid transit system.

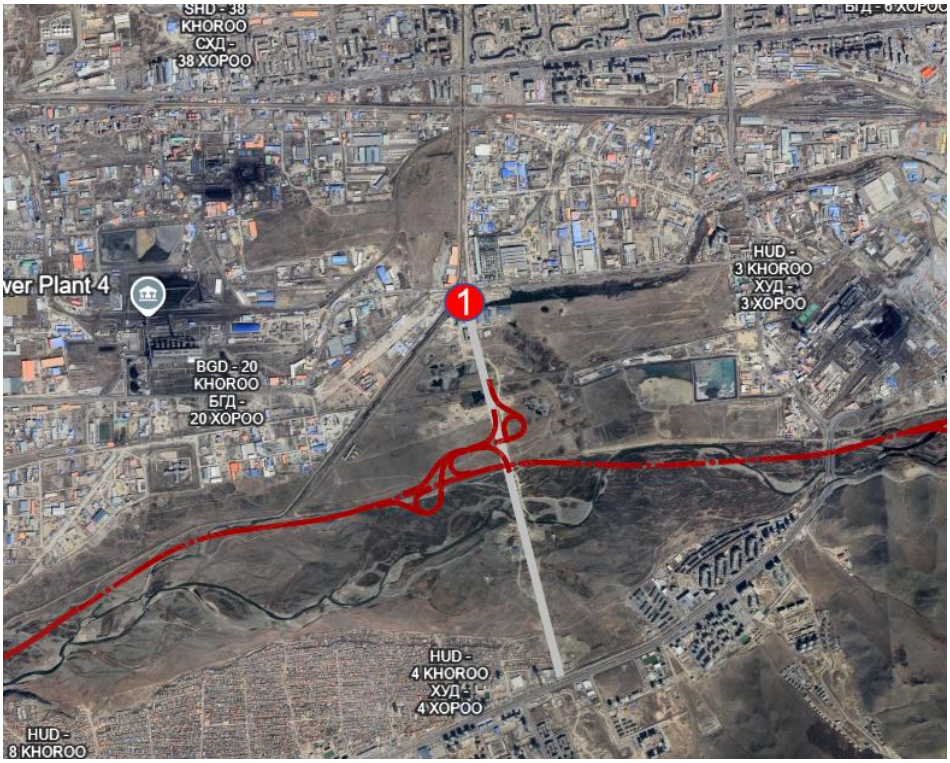


Figure 3. 1.Diagram illustrating the selection of the project starting point location.

Figure 3.2 Current condition of the project starting point.

Selection of the project terminus: avoiding the boundary of the water source protection zone, connecting to the Tuul Highway via a single intersection, and situated centrally.

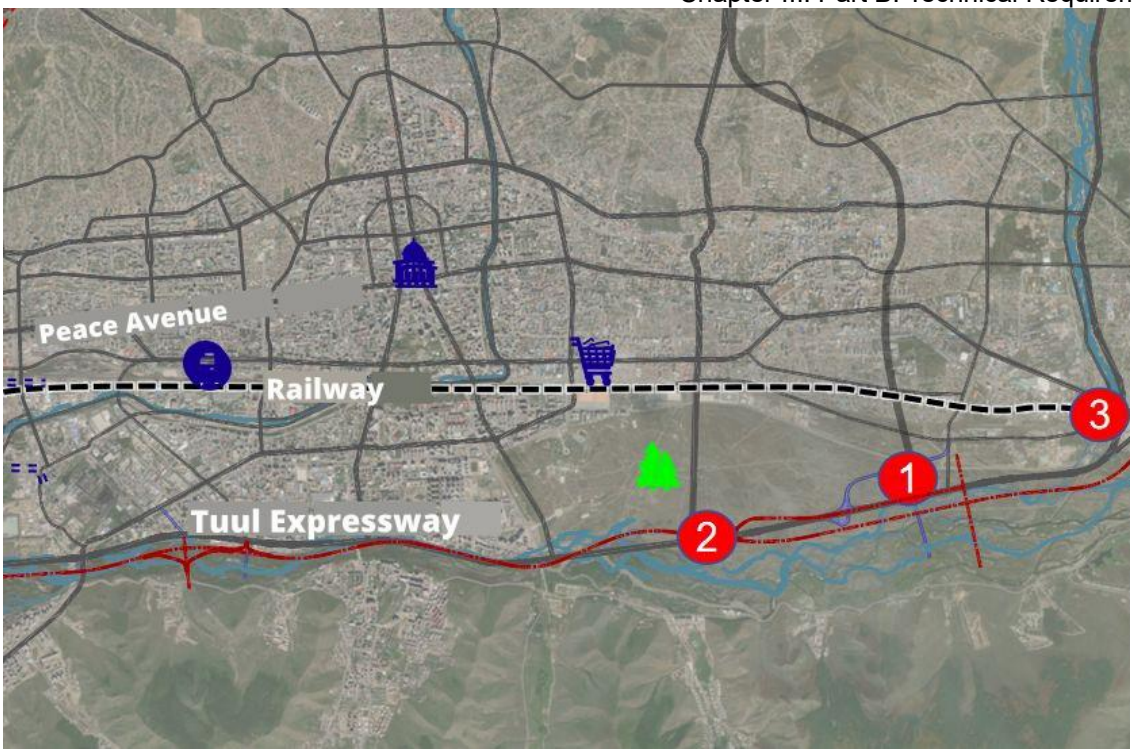
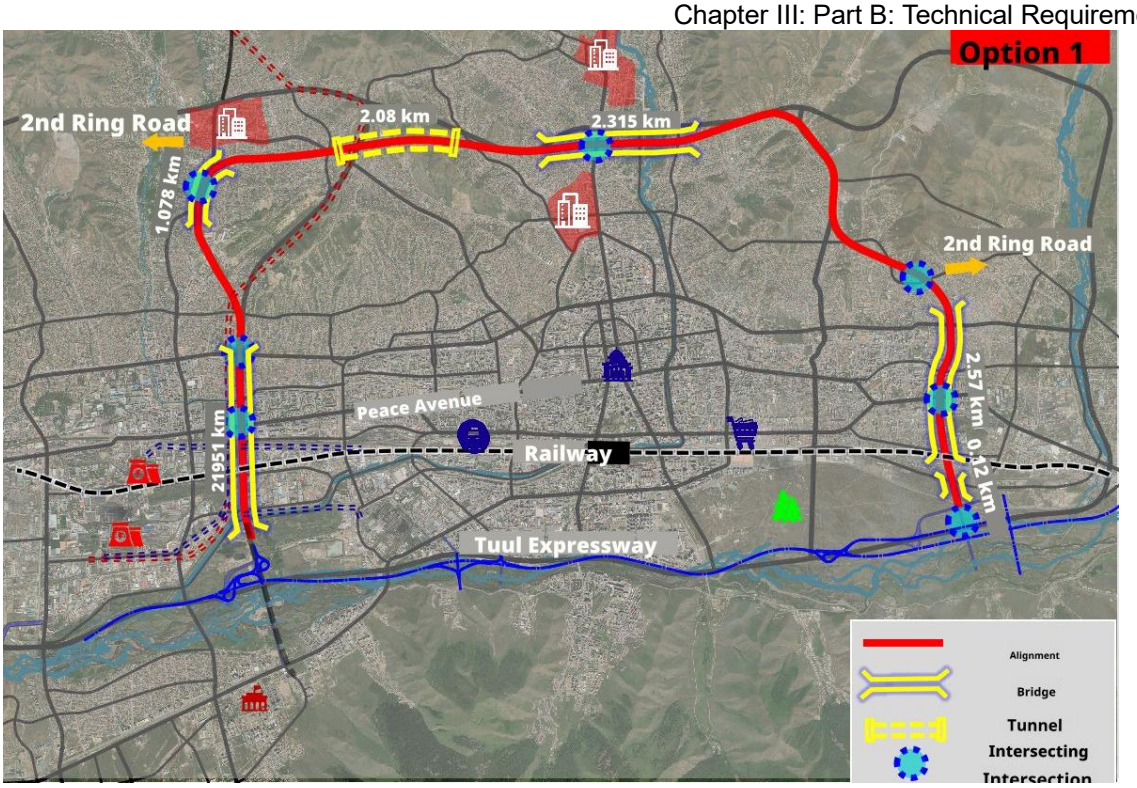


Figure 3. 2. Outline drawing of the project terminus

(4) General layout plan of the road alignment

Beginning from an intersection of the Tuul Expressway, a high bridge is planned to span the high-voltage corridor, the railway, and the existing urban roads along the river's left bank. The road extends northwestward toward the sub-center, turns westward passing Sambalkhundev Mountain, crosses the Selbe River, runs between two sub-centers, avoids high-rise buildings to the south, crosses via a high bridge, surpasses the existing road, and at the end of the alignment connects to the Tuul Expressway and the planned canal in the southern section. Except for the section of the railway-connected high bridge at bridges Nos. 2 and 3 crossing the Selbe River and the absence of a service road system at bridge No. 5, all other structures are overpasses comprising a main road plus service road configuration. The service road on the right side of the road intersects the existing railway at grade and is controlled by signal lights, whereas the main road passes over it via a high bridge. The left side of the road alignment crosses the railway by means of a bridge. Owing to the proximity to the Tuul Expressway, the demand for local land services is minimal, and the land system has not been established.

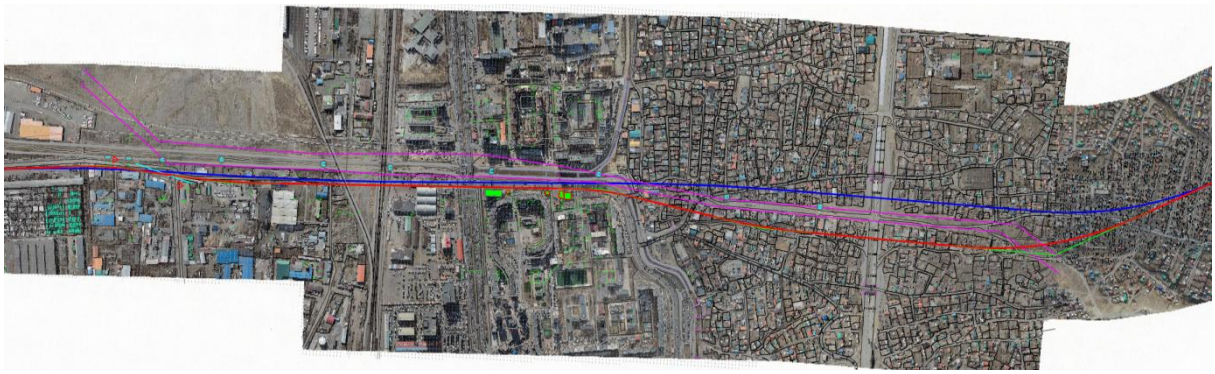
The total length of this road alignment is 24.793 km, comprising 13.679 km of road subgrade, 9.034 km including 5 bridges, and 2.08 km of tunnel section. This route is planned to comprise 7 intersections, 12 isolated intersections, 3 overpasses, and 4 underpasses. Key elements include the Tuul Expressway, railway, Peace Avenue, high-voltage transmission towers, sub-center urban planning, Sambalkhundev Mountain, Selbe River, and the water source protection zone. This planning is more aligned with the urban development plan. It is located near the city center, enhances vehicular traffic flow, serves a larger number of urban sub-centers, and connects seamlessly with both planned and existing roads. With the exception of certain sections related to the relocation of the high-voltage line, it is not necessary to demolish major buildings. This alignment avoids the water source protection zone, minimizes environmental impact, and is straightforward to implement.



Drawing 3. 3. Version-1 construction drawing

(5) Planning study of the initial section of the route

Comparison of planning options for the initial section: The section between K0+000 and K4+000, constituting the initial segment of the route, represents the most complex part of the project drawings. Previous design drafts considered the possibility of relocating the support poles of the 205, 206, 208, and 220 kV high-voltage overhead power transmission lines. Four transmission options, including an electric transmission tunnel, have been developed to reduce the need to relocate buildings on the left side of the route.



Drawing 2.2.1-9 Comparative illustration of flat (horizontal) planning variants for the initial section

Table 3. 2. Coordinates of the road alignment intersection points

Intersection number	Intersection stake number	Intersection coordinate		Value of the deflection angle
		N (X)	E (Y)	
BP	-K0+100	5306133.867	636945.4944	
PI1	K0+067.915	5306294.404	636896.2647	11°17′58″(Y)

PI2	K0+743.890	5306967.785	636828.4698	9°59′11.3″(Y)
PI3	K1+105.526	5307328.884	636855.2243	6°57′35.9″(Z)
PI4	K2+209.139	5308431.565	636802.7879	12°37′23″(Y)
PI5	K2+693.255	5308909.243	636886.1604	8°22′38.4″(Z)
PI6	K3+559.166	5309775.264	636909.1883	29°55′34.9″(Z)
PI7	K5+397.266	5311402.957	636028.9806	34°36′54.9″(Y)
PI8	K6+585.466	5312603.498	636159.657	80°33′31.9″(Y)
PI9	K8+001.811	5312694.749	637777.0626	5°39′23″(Z)
PI10	K10+084.699	5313016.552	639835.4701	16°29′16.6″(Y)
PI11	K11+910.225	5312774.109	641651.8961	14°00′03.7″(Z)
PI12	K13+090.330	5312905.875	642826.8921	5°00′49.1″(Y)
PI13	K14+643.068	5312943.411	644379.5114	16°27′45.2″(Z)
PI14	K16+566.505	5313534.455	646215.1731	67°56′17.1″(Y)
PI15	K17+823.367	5312493.844	647085.5479	43°39′40.8″(Y)
PI16	K18+936.326	5311347.26	647010.357	69°04′57.3″(Z)
PI17	K21+098.304	5310397.947	649077.2179	65°35′47″(Y)
PI18	K22+099.446	5309252.339	649071.9036	30°07′21.8″(Y)
PI19	K22+489.679	5308910.411	648871.3876	32°20′14.8″(Z)
PI20	K23+518.417	5307872.822	648906.6951	12°34′33.7″(Z)
EP	K24+793.006	5306636.805	649226.9251	

Table 3. 3Table of Planned Technical Specifications

No.	Indicator	Unit	Road Technical Specifications
1	Climatic Zone	-	II B
2	Road Classification	-	Relevant International Classification
3	Design Speed	km/h	Minimum 100 km/h
4	Road Length	m	24,793
5	Turning Frequency	quantity	19
6	Minimum Curve Radius	m	450
7	Maximum Curve Radius	m	6,500
8	Total Length of Curved Sections	m	12,685.052
9	Curve Ratio	%	50.958
10	Minimum radius of convex vertical curve	m	4,000
11	Maximum radius of convex vertical curve	m	60,000
12	Minimum radius of sag vertical curve	m	3,000
13	Maximum radius of sag vertical curve	m	60,000
14	Minimum superelevation	%	0.35
15	Maximum superelevation	%	4
16	Maximum length of superelevation	m	1,910

17	Lane width	m	3.75/3.5
18	Number of lanes in the carriageway	sh	6
19	Total Number of Lanes	sh	8/10
20	Width of Non-Motorized Vehicle Lane	m	2.5
21	Pedestrian Walkway Width	m	4.5
22	Pavement Cross Slope	%	2
23	Type of Scope	-	Advanced Types of Pavement Structures

Table 3. 4Comparison of Economic Indicators

1. Technical Basis	
Road route length, meters	24,793
Bridge length, meters	9,034
Tunnel length, meters	2,080
Roadbed length, meters	13,679
Backfill, 10,000 m³	337.14
Earth excavation, 10,000 m³	420.43
Land clearance requirement, 1,000 m²	1,653.935
Construction duration (months)	30

3.1.4. Selection of detour and motor road work routes

The "First Ring Road" project is located in the central settlement of Ulaanbaatar City, with suitable conditions for vehicle movement and favorable access routes from nearby stone quarries to the project site. According to the on-site survey and inspection, the temporary roads and motor road construction works encompassed by this project are generally suitable for utilizing existing roads as temporary roads for project execution during the period in which the road foundation has not yet been established and bridges and underpasses are under construction. A total of eleven road design drawings have been prepared for this project, with the specific locations indicated in the drawing below.

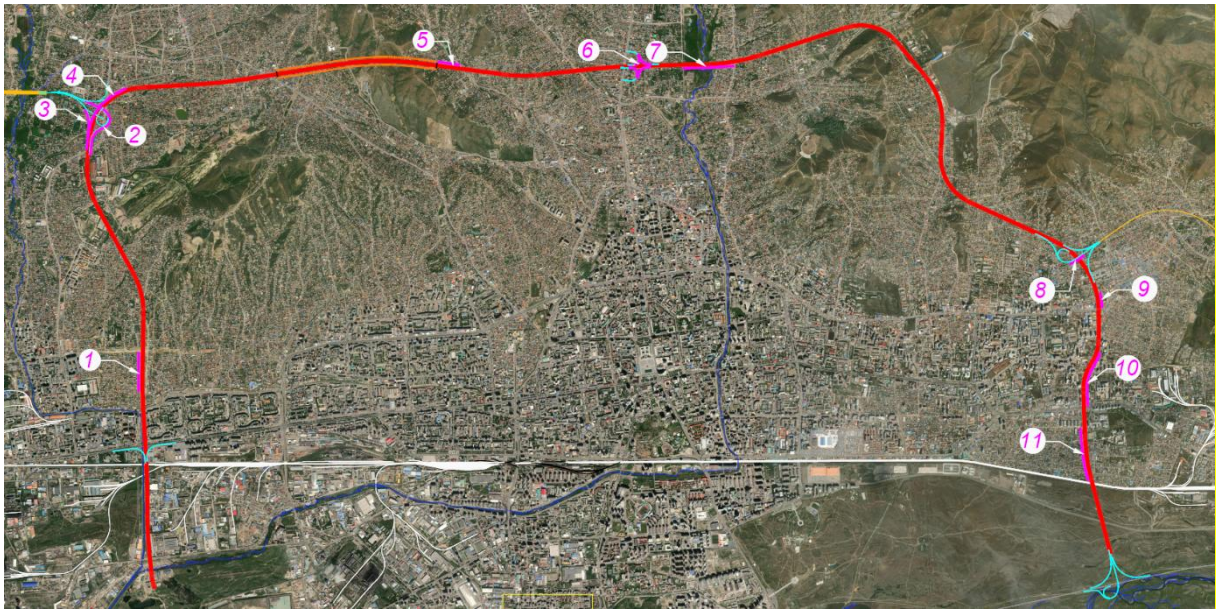


Figure 3. 4.Alignment of the road to be constructed

Pursuant to the conditions for motor road construction, the road number given in Drawing 2.2.1-8 is described as follows.

Table 3. 5Explanation concerning the conditions of the motor road

No.	Designation of the motor road to be constructed	Description of the location of the temporary road
1	①	Bridge No. 1 shall connect to the existing road during construction
2	②	The new ring road shall connect to the existing road during the works at the intersection on the right side of the 2nd ring road
3	③	The new ring road shall connect to the existing road during the works at the intersection on the right side of the 2nd ring road
4	④	The new ring road shall connect to the existing road during the works at the intersection on the right side of the 2nd ring road
5	⑤	The western portal of the new ring road tunnel shall connect to the existing road during construction
6	⑥	The new ring road shall be connected to the existing road during the works linking the 7th intersection and Bridge No. 3.
7	⑦	During the construction of Bridge No. 3 over the Selbe River.
8	⑧	The new ring road shall be connected to the existing road during the works linking the intersection on the left side of the 2nd ring motor road.
9	⑨	During the construction of Bridge No. 4, it shall be connected to the existing road.
10	⑩	During the construction of Bridge No. 4, it shall be connected to the existing road.
11	⑪	During the construction of Bridge No. 4, it shall be connected to the existing road.

Road construction companies shall precisely calculate and design temporary roads during the execution of work and coordinate with the relevant governmental authorities for approval.

3.2. Cross-sectional planning along the road

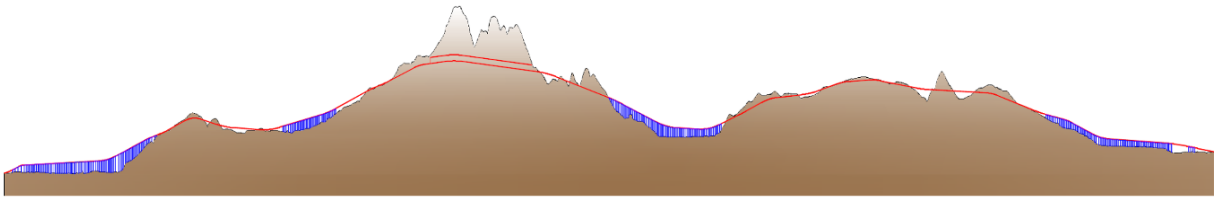
3.2.1. Principles of cross-sectional design

(1) Shall comply with the technical requirements of internationally valid standards, norms, and regulations.
(2) Aligning the ground level with the design elevation reduces the volume of embankment filling and excavation, thereby minimizing earthworks and conserving project investment.
(3) The road level shall be coordinated with the elevation of the drainage system.
(4) The slope of the cross-section shall comply with the requirements of the relevant standard.
(5) When designing the cross-section along the constructed urban area, coordination shall be made with the relevant authorities to align the design with the existing engineering utility networks.
(6) The vertical clearance beneath the steel suspension bridge section shall comply with the prescribed height requirements at the intersections with the motor road and railway; furthermore, if an auxiliary road is provided, it shall also satisfy the specified height requirements for the auxiliary road.

3.2.2. Longitudinal section planning

In planning the vertical curve radius, the corresponding section design shall be developed in accordance with the applicable standards and norms, fully considering factors such as sight distance and slope. During the development of the design drawings, the planning of the road section fully satisfies traffic safety requirements and other conditions.

Planning shall be developed in accordance with the project, fully complying with the standards and regulations pertaining to road drainage channels, bridge elevations, railway intersections, and urban roads. To satisfy the technical specifications prescribed by the standard, planning shall integrate the length of the slope’s straight section, the length of the vertical curve, and both horizontal and longitudinal cross-sections. When planning the longitudinal section, the alignment is bounded on the right side by the intersecting road, on the northern side by the mountainous area, and on the left side by the existing motor road, railway, and the planned motor road levels.



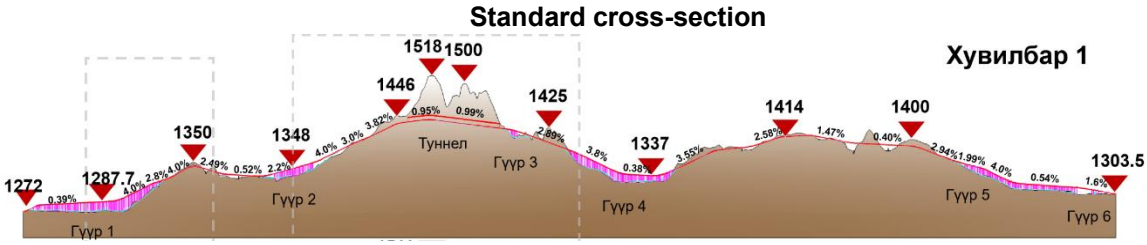
Drawing 3. 5. Longitudinal l section scheme according to version 1.

Considering the slope requirements along the road in the international cold climate region with high frost susceptibility, the maximum planned slope for the motor road alignment is 4%. The minimum longitudinal slope of the road drainage pipeline is 0.38%. The minimum radius of the vertical curve is 3,500 meters, and the maximum radius is 60,000 meters. The detailed technical specifications of the design drawings are as follows.

Table 3. 6. Diagram of longitudinal profile and vertical curve slope along the road

No.	PK	Vertical curve			Longitudinal slope	Distance between slope change	Length of the straight slope
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
0	-K0+100	1272.35					
					-0.520	72.661	10.248
1	-K0+27.339	1271.9722		3000			
					3.641	367.339	225.107
2	K0+340	1285.3468	4000				
					-0.350	780	596.743
3	K1+120	1282.6168		23000			
					0.549	1080	874.879
4	K2+200	1288.551		6000			
					3.939	820	632.713
5	K3+020	1320.85	10000				
					2.227	410	218.006
6	K3+430	1329.98		12000			
					4.000	570	335.934
7	K4+000	1352.78	4000				
					-2.384	530	215.947
8	K4+530	1340.146		20000			
					-0.520	910	518.983
9	K5+440	1335.414		15000			
					2.209	1220	881.000
10	K6+660	1362.358		15000			
					4.000	860	654.595
11	K7+520	1396.758	14000				
					2.985	240	106.359
12	K7+760	1403.9222		15000			
					3.820	740	562.615
13	K8+500	1432.188	8000				
					0.950	720	459.712

14	K9+220	1439.028	15000		-0.990	1910	1593.788
15	K11+130	1420.119	18000		-2.887	1390	1059.478
16	K12+520	1379.9925	35000		-3.800	1050	676.440
17	K13+570	1340.0925		12500	-0.380	880	469.985
18	K14+450	1336.7485		10000	3.545	680	410.982
19	K15+130	1360.8565		32000	4.000	550	318.171
20	K15+680	1382.8565	10000		0.818	830	494.676
21	K16+510	1389.6498		20000	2.581	690	388.244
22	K17+200	1407.4583	12000		0.489	640	396.907
23	K17+840	1410.5887	12000		-1.471	980	733.788
24	K18+820	1396.1767		24000	-0.399	1420	1177.016
25	K20+240	1390.5149	9000		-2.940	990	780.387
26	K21+230	1361.4091		20000	-1.987	570	374.115
27	K21+800	1350.0808	10000		-4.000	660	369.064
28	K22+460	1323.6808		11000	-0.540	1470	1211.637
29	K23+930	1315.7448	20000		-1.220	410	247.435
30	K24+340	1310.7411	50000				
31	K24+793.006	1303.5			-1.598	453.006	358.496



Drawing 3. 14. Longitudinal section and elevation with limited maximum longitudinal slope

Table 3. 7. Comparison of the economic key indicators for planning various maximum longitudinal slopes

No.	Indicator	Option 1
	1. Technical Specifications	
1.1.	Maximum longitudinal slope of the main road	4%
1.2.	Bridge length (m)	9,034
1.3.	Tunnel Length (m)	2,080
1.4.	Embankment Length (m)	13,679
1.5.	Filling Volume (10,000 m³)	337.14
1.6.	Excavation Volume (10,000 m³)	420.43
1.7.	Construction Period (months)	30
№	2. Economic and Financial Status	
2.1.	Investment USD (billion)	0.919
2.2.	Operating and Maintenance Costs USD (billion)	5.40
№	3. Environmental and Social Impact	

3.1.	On the Environment	Minimal
3.2+-.	Traffic Safety Status Assessment	Good

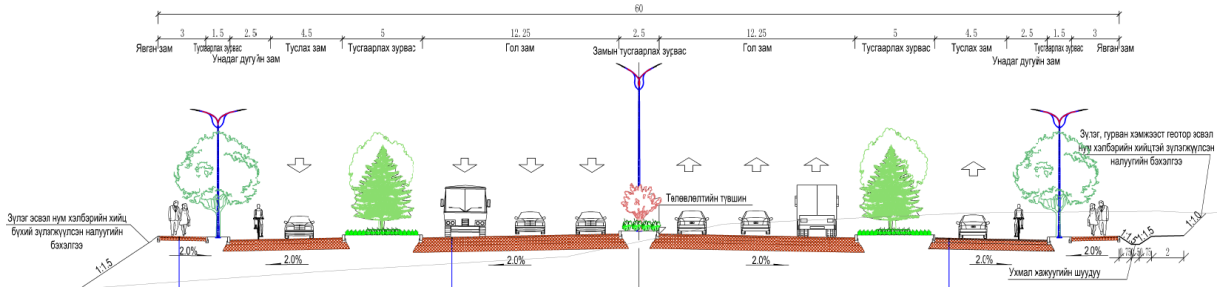
3.3. Road Cross-Section Planning

This project determines the road cross-section based on the road capacity, planned alignment width, adjacent land use, road landscaping standards, and current land clearance on both sides of the road, in accordance with the prescribed road standards.

3.3.1. Cross-section of the main road standard

(1) Work stages and cross-section of a 60 m wide road

The planned road traverses suburban residential districts with favorable road conditions. The embankment width is 60 m. The cross-section includes a six-lane road with two-way traffic for both the main road and the auxiliary road. The uniform cross-sectional profile consists of: 3.0 m (pedestrian walkway) + 1.5 m (green zone) + 7 m (service road carriageway) + 5 m (lateral separation strip) + 12.25 m (main carriageway) + 2.5 m (central separation strip) + 12.25 m (carriageway) + 5 m (lateral separation strip) + 7 m (service road carriageway) + 1.5 m (green zone) + 3.0 m (pedestrian walkway), totaling 60 m; where 7 m (service road carriageway) = 2.5 m (bicycle lane) + 4.5 m (service road carriageway), and 12.25 m (carriageway) = 0.5 m (safety strip) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.5 m (safety strip).

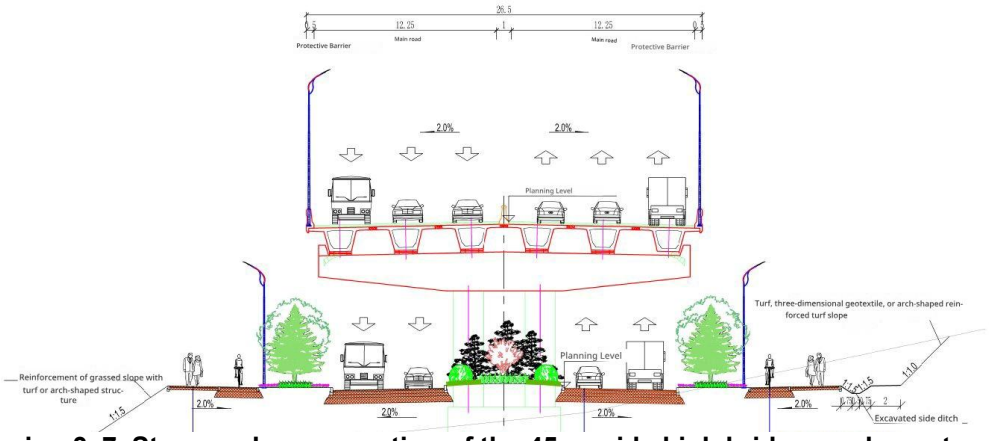


Drawing 3. 6. Standard cross-section of a 60 m wide road

(2) Cross-section of a 45 m wide road

The planned road passes through the city center, where the roadbed conditions are constrained, and the embankment width is 45 m. The width of the bridge cross-section is 26.5 m. The road consists of two carriageways with six lanes. The cross-sectional distribution is as follows: 0.5 m (parapet) + 12.25 m (bridge carriageway) + 1 m (median strip) + 12.25 m (bridge carriageway) + 0.5 m (parapet) = 26.5 m. This includes: 12.25 m (carriageway) = 0.5 m (safety strip) + 3.75 m (traffic lane) + 3.75 m (traffic lane) + 3.75 m (traffic lane) + 0.5 m (safety strip);

The cross-sectional width of the auxiliary road is 45 m, comprising two carriageways and four lanes. The configuration is as follows. This consists of: 3.5 m (pedestrian path) + 2.5 m (bicycle lane) + 5 m (separation strip) + 7.5 m (auxiliary road carriageway) + 8 m (separation strip) + 7.5 m (auxiliary road carriageway) + 5 m (separation strip) + 2.5 m (bicycle lane) + 3.5 m (pedestrian path) = 45 m. Each 7.5 m auxiliary road carriageway comprises 0.25 m (safety strip) + 3.5 m (vehicle lane) + 3.5 m (vehicle lane) + 0.25 m (safety strip).



Drawing 3. 7. Stage and cross-section of the 45 m wide high bridge road construction

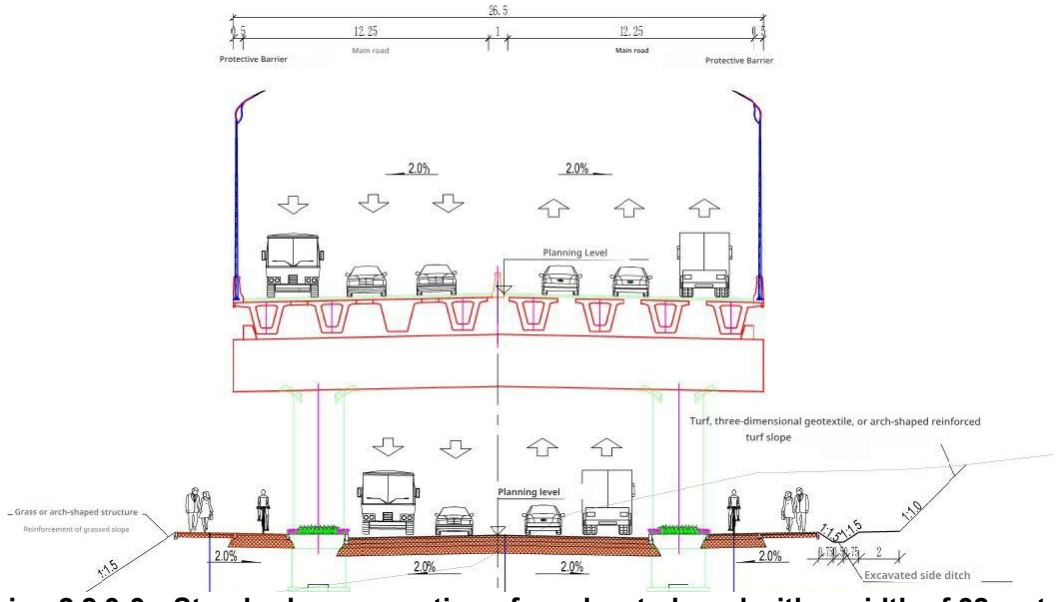
(3) Layout of the standard cross-section for a 32-meter-wide elevated motor road

The section from the beginning of this project up to K3+240 is affected by the 220 kV high-voltage power transmission line; consequently, the road soil conditions are restricted. Therefore, the road red line width is limited to 32 m, with a cross-sectional design comprising an elevated main road and a ground-level auxiliary road.

Cross- section of the elevated road:

Total width: 26.5 m
Six lanes, two-way
Structure:
0.5 m (crash barrier) + 12.25 m (three-lane carriageway in one direction) + 1 m (central crash barrier) + 12.25 m (three-lane carriageway in the opposite direction) + 0.5 m (crash barrier) = 26.5 m
The following:
12.25 m (one direction of the main road) = 0.5 m (roadside strip) + 3.75 m + 3.75 m + 3.75 m (three lanes) + 0.5 m (roadside strip)
Cross-section of the ground-level auxiliary road:

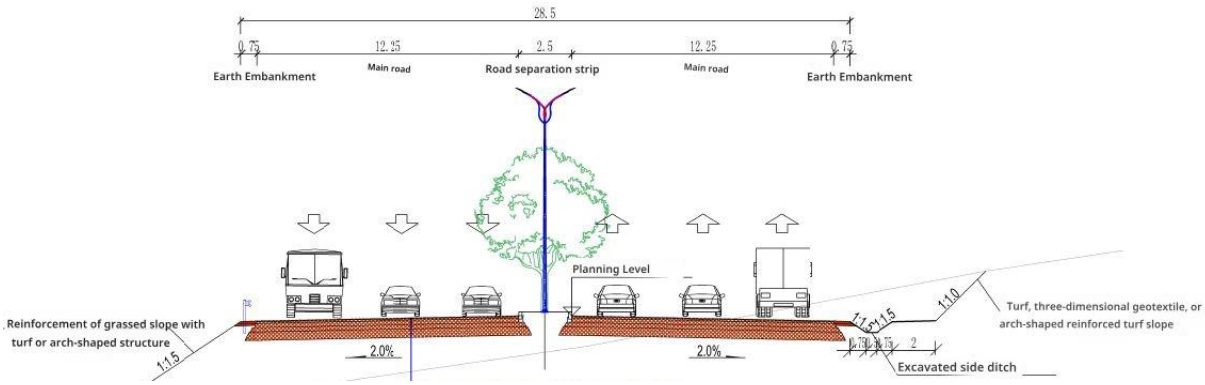
Total width: 32 m
Four lanes over two directions
Structure:
3 m (pedestrian path) + 2.5 m (bicycle lane) + 3 m (side separator) + 15 m (auxiliary road) + 3 m (side separator) + 2.5 m (bicycle lane) + 3 m (pedestrian path) = 32 m
The following:
15 m (service road) = 0.25 m (road edge strip) + 3.5 m + 3.5 m (two lanes) + 0.5 m (central median strip) + 3.5 m + 3.5 m (two lanes) + 0.25 m (road edge strip)



Drawing 2.2.3-3 Standard cross-section of an elevated road with a width of 32 meters

(4) Cross-section with a width of 28.5 m

The planned road features an embankment width of 28.5 m, extending from K23+975.437 to the terminal point. Dual carriageway with six lanes, cross-sectional composition: 0.75 m (shoulder) + 12.25 m (carriageway) + 2.5 m (median strip) + 12.25 m (carriageway) + 0.75 m (earth shoulder), totaling 28.5 m. Each 12.25 m carriageway comprises 0.5 m (safety strip) + 3.75 m (traffic lane) + 3.75 m (traffic lane) + 3.75 m (traffic lane) + 0.5 m (safety strip).

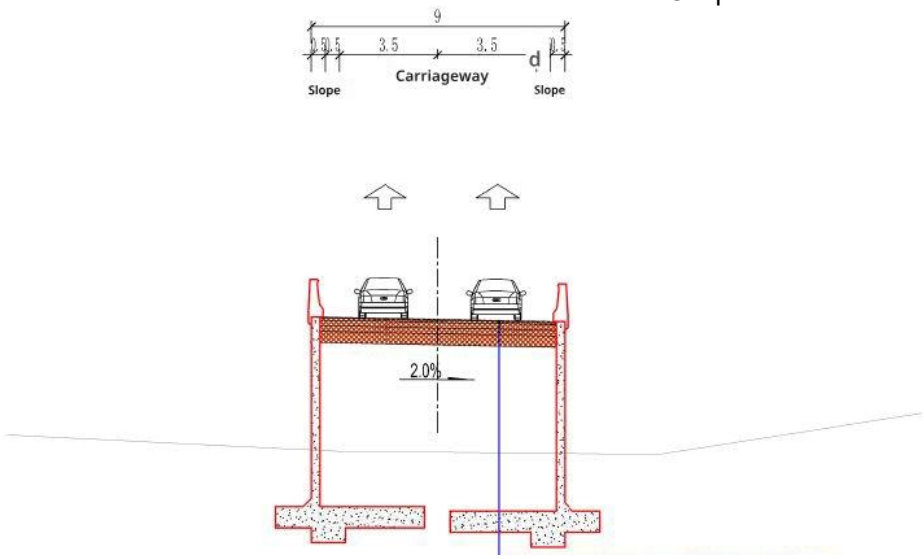


Drawing 3. 8. 928.5 m Road Standard Cross Section

3.3.2. Standard Cross Sectin of an Intersecting Junction Road

(1) Upper and Lower Ramps of Section K1+090

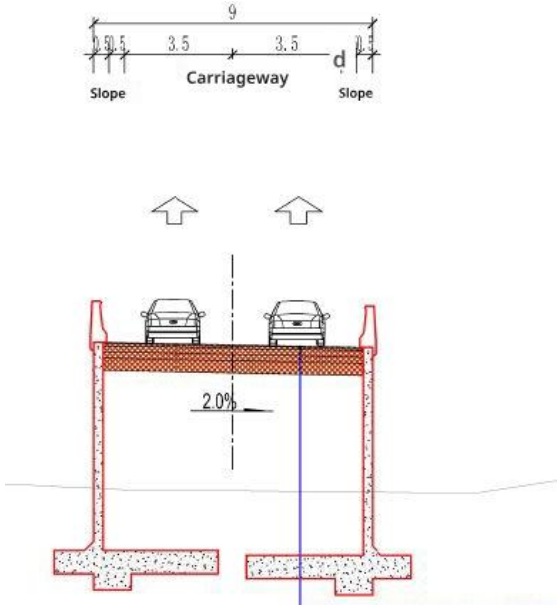
The widths of the upper and lower ramps in section K1+090 are 9 m, comprising two lanes in one direction. The cross section comprises: 0.5 m (shoulder) + 0.5 m (width of stabilized shoulder) + 3.5 m (traffic lane) + 3.5 m (traffic lane) + 0.5 m (width of stabilized shoulder) + 0.5 m (shoulder) = 9 m.



Drawing 3. 10. Standard cross- section of the grade-separated interchange at section K1+090

(2) Intersection of the new ring road and Ard Ayush Street

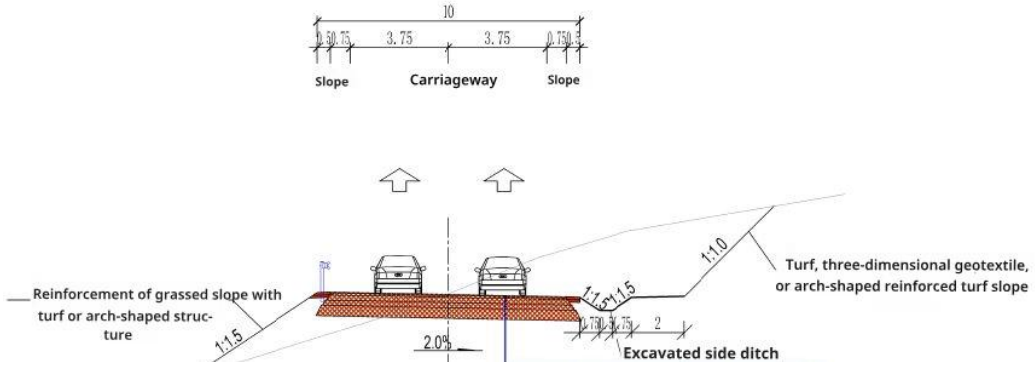
The width of the ramp at the intersection of the new ring road and Ard Ayush Street is 9 meters, consisting of one direction and two lanes. The cross-section consists of: 0.5 m (earthen shoulder) + 0.5 m (shoulder width) + 3.5 m (traffic lane) + 3.5 m (traffic lane) + 0.5 m (shoulder width) + 0.5 m (earthen shoulder) = 9 m.



Drawing 3. 11. Standard cross-section of the new ring road and ramp at the intersection with Ard Ayush Street

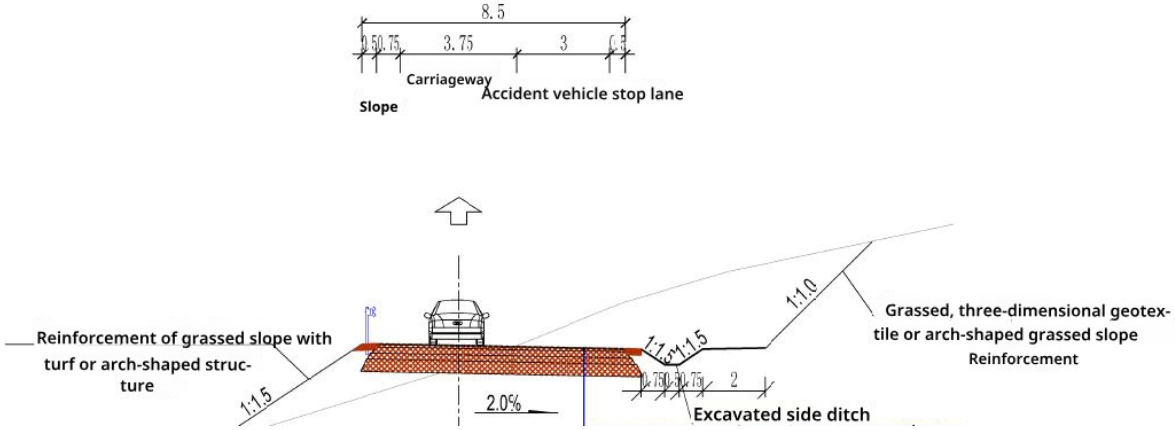
(3) Intersection on the right side of the Second Ring Road

1) The width of the C ramp at the intersection of the new ring road and the right section of the Second Ring Road is 10 meters, consisting of one direction with two lanes. The cross-section is: 0.5m (earth shoulder) + 0.75m (shoulder width) + 3.75m (vehicle lane) + 3.75m (vehicle lane) + 0.75m (shoulder width) + 0.5m (earth shoulder) = 10 m.



Drawing 3. 12. Standard cross-section of the C ramp at the intersection of the New Ring Road and the western section of the Second Ring Road

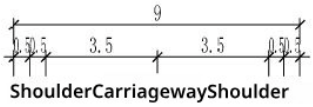
2) The width of ramps A, B, and D at the intersection of the New Ring Road and the western section of the Second Ring Road is 8.5 meters, single lane. The cross-section is as follows: 0.5 m (earth shoulder) + 0.75 m (shoulder width) + 3.75 m (vehicle lane) + 3 m (emergency stopping lane) + 0.5 m (earth shoulder) = 8.5 m.

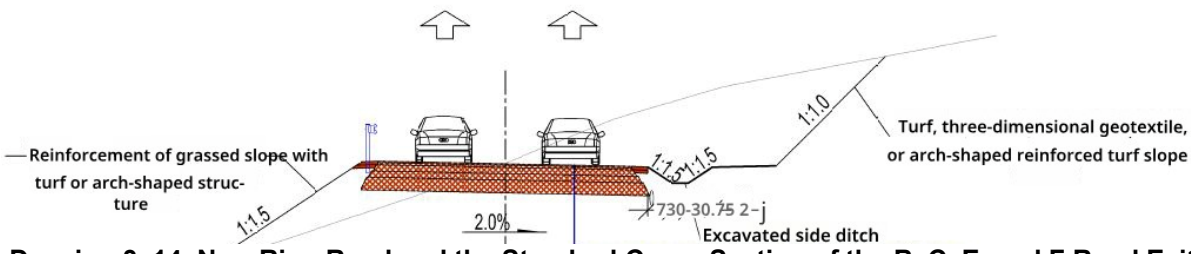


Drawing 3. 13. Standard cross-section of ramps A, B, and D at the intersection of the New Ring Road and the western section of the Second Ring Road

(4) Doloont Bus intersection of the New Ring Road

1) The B, C, E, and F exit roads at the intersection between the New Ring Road and Route 7 are 9 m wide, consisting of one-way two lanes. The cross-section is: 0.5 m (earth shoulder) + 0.5 m (shoulder width) + 3.5 m (vehicle lane) + 3.5 m (vehicle lane) + 0.5 m (shoulder width) + 0.5 m (earth shoulder) = 9 m.

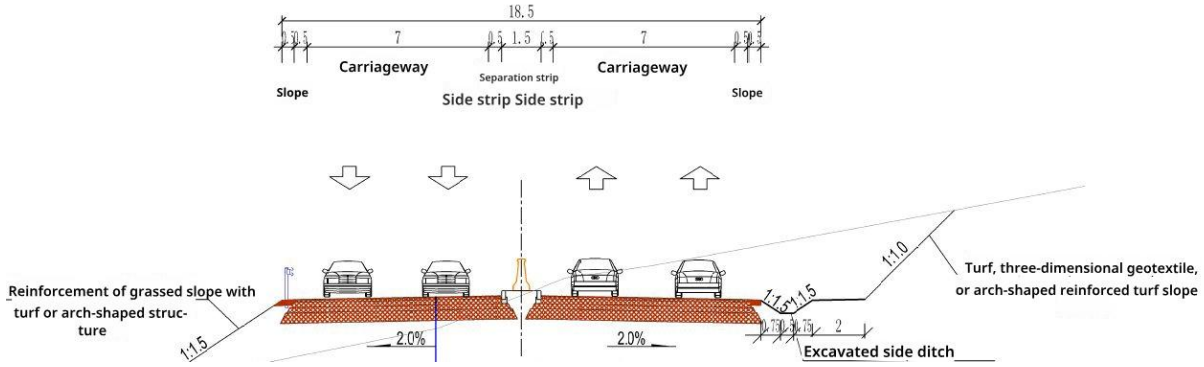




Drawing 3. 14. New Ring Road and the Standard Cross-Section of the B, C, E, and F Road Exits at the Doloon Buudal Intersection

2) The width of the A and D exit roads at the New Ring Road and Doloon Buudal Intersection is 18.5 m, consisting of two-way four lanes. The cross-section is as follows: 0.5 m (earth shoulder) + 0.5 m (shoulder width) + 3.5 m (vehicle lane) + 3.5 m (vehicle lane) + 0.5 m (roadside strip) +

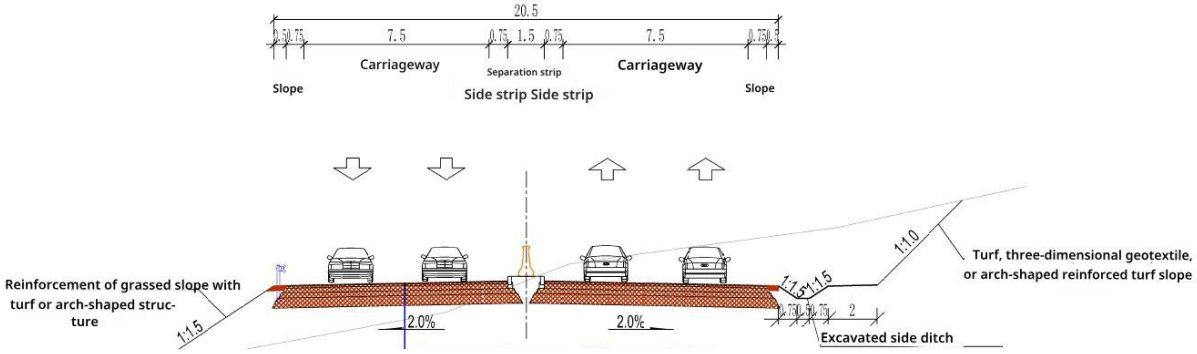
1.5 m (median strip) + 0.5 m (roadside strip) + 3.5 m (vehicle lane) + 3.5 m (vehicle lane) + 0.5 m (shoulder width) + 0.5 m (earth shoulder) = 18.5 m.



Drawing 3. 15. Standard cross-section of the new ring road and the A, D road exits at the Doloon Buudal intersection

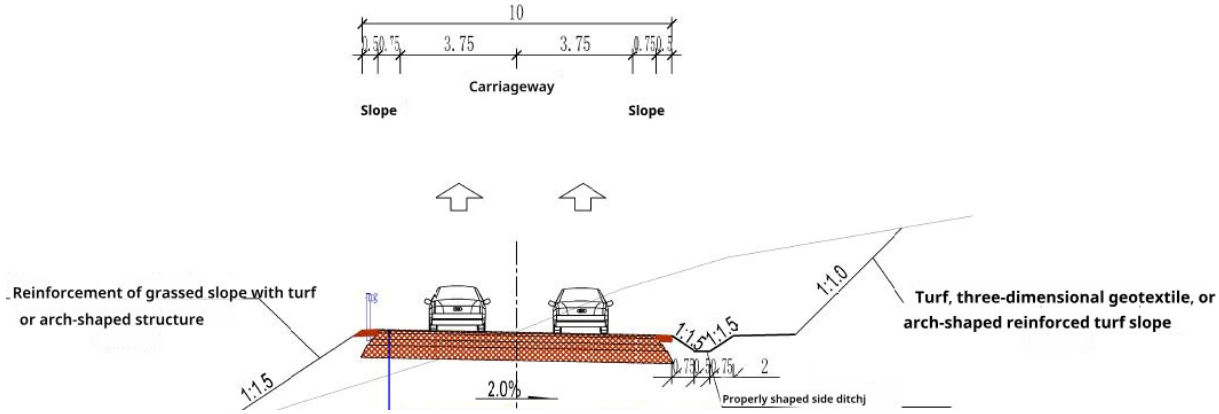
(5) Intersection of the new ring road with the eastern section of the Second ring road

1) At the intersection of the new ring road and the eastern section of the Second ring road, the width of the A ramp is 20.5 meters, featuring two-way traffic with four lanes. The cross-section comprises: 0.5 m (earthen shoulder) + 0.75 m (shoulder width) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.75 m (roadside strip) + 1.5 m (median strip) + 0.75 m (roadside strip) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.75 m (shoulder width) + 0.5 m (earthen shoulder), totaling 20.5 m.



Drawing 3. 16. Standard cross-section of ramp A at the intersection of the New Ring Road and the eastern section of the Second Ring Road

2) The width of ramps B, C, D, and E at the intersection of the New Ring Road and the eastern section of the Second Ring Road is 10 meters, with one direction comprising two lanes. The cross-section is: 0.5 m (earthen shoulder) + 0.75 m (shoulder width) + 3.75 m (traffic lane) + 3.75 m (traffic lane) + 0.75 m (shoulder width) + 0.5 m (earthen shoulder) = 10 m.

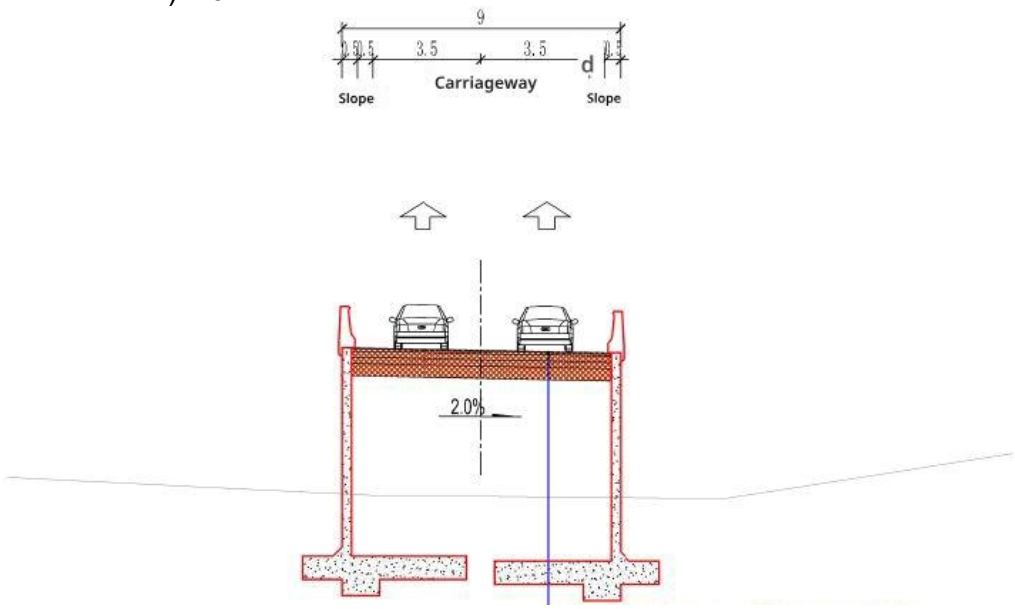


Drawing 3. 17. Standard cross-section of ramps B, C, D, and E at the intersection of the New Ring Road and the eastern section of the Second Ring Road

(6) Intersection of the New Ring Road and Police Academy Avenue

The ramp width at the intersection of the New Ring Road and Police Academy Avenue is 9 meters,

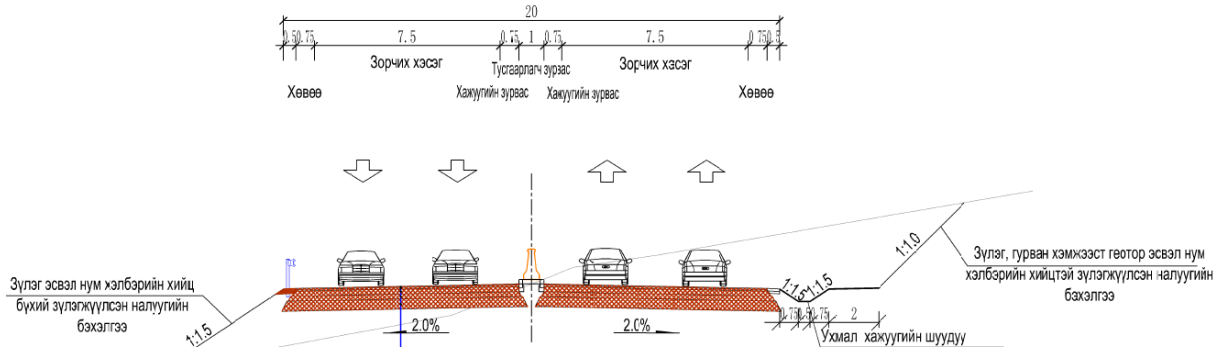
accommodating one lane per direction. The cross-section consists of: 0.5 m (earthen shoulder) + 0.5 m (shoulder width) + 3.5 m (traffic lane) + 3.5 m (traffic lane) + 0.5 m (shoulder width) + 0.5 m (earthen shoulder) = 9 m.



Drawing 3. 18. Standard cross-section of the ramp road at the intersection of the New Ring Road and the Police Academy Avenue

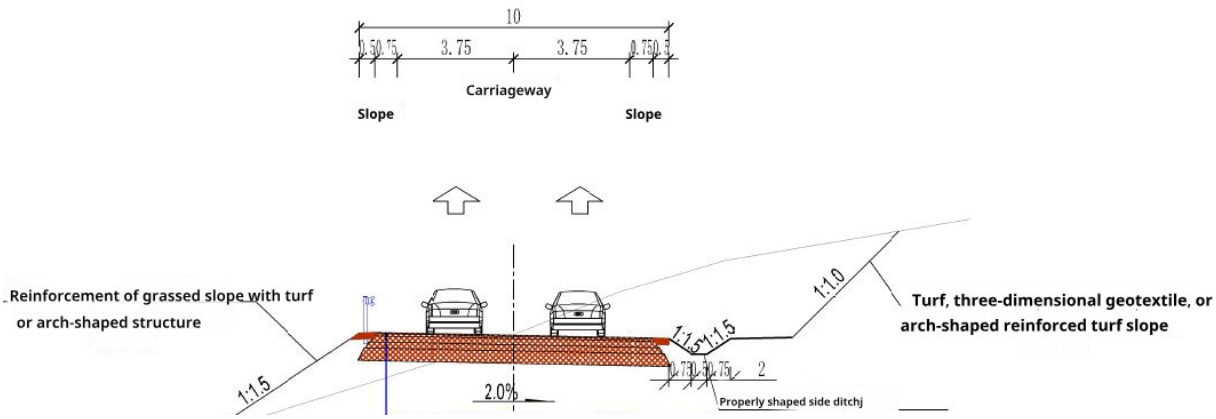
(7) Western Intersection of the New Ring Road and Tuul highway

1) The width of the A exit road at the western intersection between the New Ring Road and Tuul Highway is 20 m, consisting of two directions with four lanes. The cross-section is as follows: 0.5 m (earthen shoulder) + 0.75 m (shoulder width) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.75 m (side strip) + 1 m (median strip) + 0.75 m (side strip) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.75 m (shoulder width) + 0.5 m (earthen shoulder) = 20 m.



Drawing 3. 19. Standard cross-section of the A access road at the left intersection of the New Ring Road and Tuul Highway

2) The width of the B, C, D, and E access roads at the left intersection between the New Ring Road and Tuul Highway is 10 m, comprising two lanes in one direction. The cross-section is as follows: 0.5 m (earth shoulder) + 0.75 m (shoulder width) + 3.75 m (vehicle lane) + 3.75 m (vehicle lane) + 0.75 m (shoulder width) + 0.5 m (earth shoulder) = 10 m.



Drawing 3. 20. New ring road and the B, C, D, and E exit roads at the left intersection of Tuul Highway

3.4. Road Intersection Planning

3.4.1. Planning Principles

(1) Considerations for plan development

The intersection constitutes a critical structure with respect to traffic volume. The plan shall comply with the following traffic requirements.

1) To ensure road traffic safety and reduce traffic accidents at intersections;
2) The objective is to minimize the number of potential points of misunderstanding in intersection design, ensuring unobstructed passage for vehicles traveling straight or turning, adapted to their size and speed.
3) Intersections must comply with the motor road planning, design, and normative standards.
4) To ensure a steady traffic flow on the main street road;
5) The traffic capacity of the road shall be sufficiently large to meet the traffic demands of long-term planning periods.

(2) Principle of frugality

The scope of intersection planning work shall be economically efficient and optimized to ensure cost savings while meeting the operational requirements of road traffic.

1) Low capital investment and minimal operational costs;
2) Minimal demolition and limited land acquisition;
3) Reduced operational costs, fuel consumption, tire wear, and vehicle damage;
4) Minimized maintenance and management costs.

(3) Principle of Adaptation

The most important aspect of intersection planning is to comply with the requirements of the respective region according to the traffic intensity in that area. The fundamental requirements are:

1) The planning of the intersection variant must be flexible in organization, adapted to local conditions, and comply with the surrounding environment, natural conditions, and socio-economic circumstances.
2) The intersection planning must be appropriately positioned within the road network and exhibit a high capacity to facilitate unobstructed traffic flow;
3) The intersection shall correspond with the surrounding land use, urban development, and economic growth;
4) The intersection shall be aligned with the partial master plan of the respective area and the general motor road development plan;

(4) Visibility

The intersection constitutes an artificial structure of the motor road. Therefore, the intersection design shall comply with the following requirements:

1) The form and structure shall be architecturally unique, possessing a distinctive style;
2) It shall preserve the characteristics of the region and the natural landscape, and harmonize

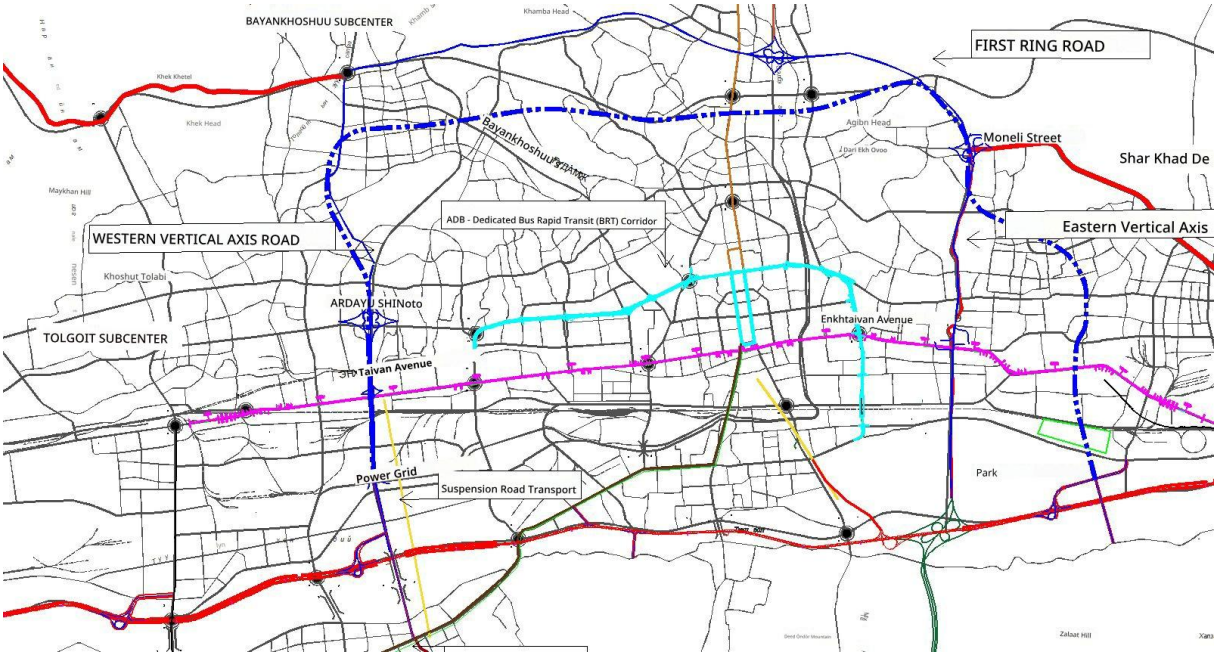
with the surrounding environment;

3) The intersection construction shall not impair the natural landscape of the site.

3.4.2. Selection of locations for intersections at nodal junctions

(1) Basis of Planning

According to the “General Development Plan of Ulaanbaatar City until 2040,” the street and road network of Ulaanbaatar City consists of main roads forming horizontal, vertical, and circular axes connecting residential zones, building complexes, industrial zones, mixed-use zones, urban public centers, and green spaces. This network comprises 8 horizontal and 12 vertical motor roads. By constructing grade-separated intersections at congestion points specified in the "General Development Plan of Ulaanbaatar City until 2040," the motor road traffic within the city has been balanced, and traffic throughput capacity has been enhanced. Drawing 2.2.4-2 depicts the most recent planning version of the new ring road project. The drawing indicates a total of seven planned intersections within the project: the existing intersection with Moscow Street, the intersection of the ongoing Ard Ayush Road, the intersection on the western side of the 2nd ring road, the intersection with the existing Doloon Buudal Road, the intersection on the eastern side of the 2nd ring road, the intersection at the existing Police Academy, and the planned intersection with the Tuul Expressway.



Drawing 3. 21. New Ring Road Project’s Newly Planned Route

(2) Classification of the Intersecting Motor Roads

As observed in Drawing 3.30, there are six and seven intersections of main street roads intersecting the new ring road. The intersecting main street roads are presented in the table below.

Table 3. 8. Main Roads Intersecting Along the Alignment

No.	Name	Classification	Number of lanes (two-way traffic)	Current status
1	Moscow Street	1st-class main road	6	Existing
2	Ard Ayush Road	1st-class main road	6	Under construction
3	2nd Ring Road	Highway	6	Planned

4	7th Road	1st-class main road	4	Existing
5	Police Academy Avenue	1st-class main road	6	Existing
6	Tuul Highway	Highway	6	Planned

The new ring road, together with the roads above it, forms a critical component of Ulaanbaatar City's primary motor road network and functions as a vital carrier for both urban and suburban transit traffic. Considering the central position of nodes within the city motor road network and the importance of the functional traffic role of those nodes, it is necessary to establish intersections at these locations.

(3) Selection of intersection locations as a whole

Based on the locations of intersections specified in the General Development Plan of Ulaanbaatar City up to 2040, the classification of intersecting roads along the routes, and the preliminary traffic volume forecast for major intersections, intersections will be constructed at the following junctions.

1) New ring road, Moscow Street intersection;
2) New ring road, Ard Ayush Street intersection
3) New ring road, western intersection of the 2nd ring road
4) New ring road, Doloon Buudal intersection
5) New ring road, eastern intersection of the 2nd ring road
6) New ring road, Police Academy Avenue intersection
7) New ring road, intersection with Tuul Highway

3.4.3. Intersection type

The new ring road project was developed based on the "Ulaanbaatar City Development Master Plan until 2040," with the alignment plan optimized prior to the preparation of the intersection layout. The intersection configurations in this design drawing and planning are presented in the following table.

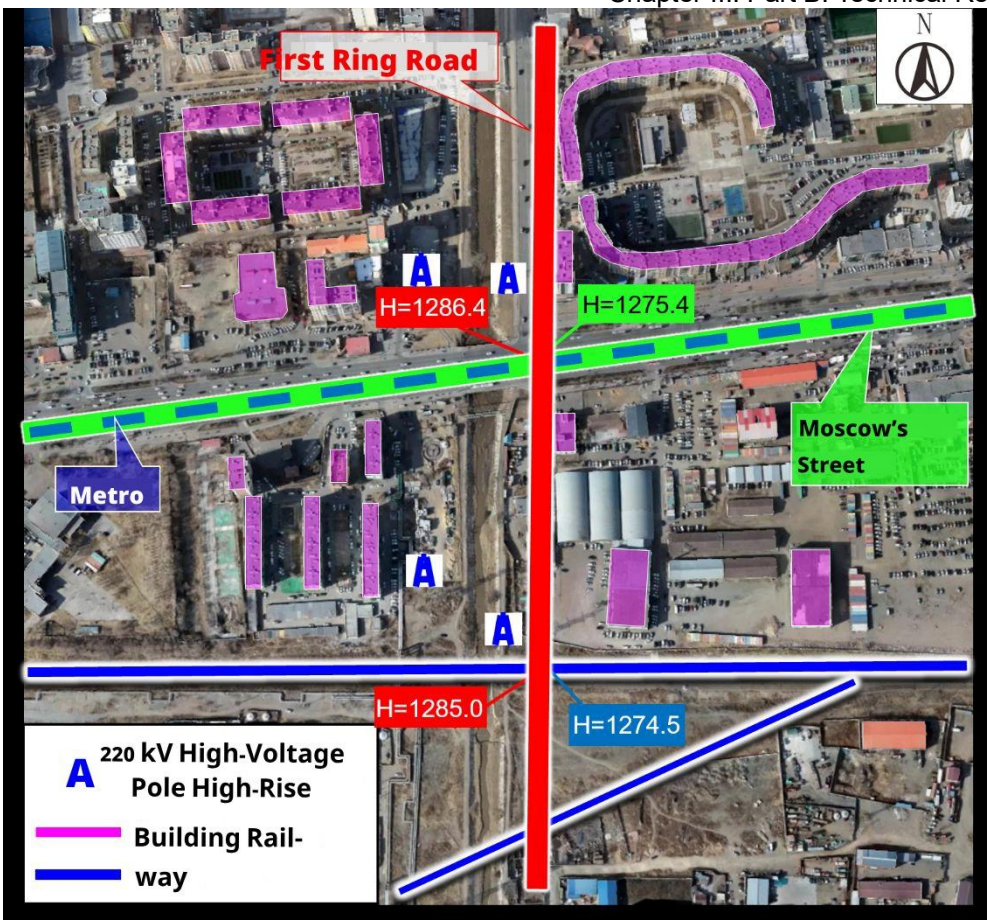
Table 3. 9. List of Intersections

No.	PK	Name of Intersecting Road	Classification of Intersecting Road	Condition of Intersecting Road	Number of Lanes of Intersecting Road	Intersection type	Type of Intersection
1	K0+355	Road to Power Plant No. 4	Second-class main road	Existing	Two-way, 2 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
2	K0+962	Planned road	Second-class main road	Planned	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
3	K1+457.982	Ulaanbaatar Railway	Diesel Railway	Existing	Single track	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
4	K1+566.775	Ulaanbaatar Railway	Diesel Railway	Existing	Double track	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
5	K1+817.494	Moscow Street	First-category main road	Existing	Two-lane, 6	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
6	K2+276.092	Planned road	Second-class main road	Planned	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
7	K3+024.8	Ard Ayush Road	First-category main road	Under construction	Two-lane, 6	Signalized intersection	Transversely intersected by the main line;

8	K5+794	Bayanhushu Street	Second-class main road	Existing	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
9	K6+366	2nd Ring Road	Highway	Planned	Two-lane, 6	Signalized intersection	Transversely intersected by the main line;
10	K6+480	Bayanhushu Street	Second-class main road	Existing	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
11	K8+587	Revolution Street	First-category main road	Existing	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
12	K11+124	Terminus road of Dendzhii 1000 bus stop	Second-class main road	Existing	Two-way, 2 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
13	K12+620	Khailaast Street	Service roads	Existing	Two-way, 2 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
14	K13+232	7th Road	First-category main road	Existing	Two-way, 4 lanes	Signalized intersection	Transversely intersected by the main line;
15	K13+979	Selber Gerelt Project Road	Second-class main road	Existing	Two-way, 2 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
16	K14+658	Dari-Ekh Street	Second-class main road	Existing	Two-way, 2 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
17	K20+835	2nd Ring Road	Highway	Planned	Two-lane, 6	Signalized intersection	Passing beneath the main line
18	K22+856	Police Academy Avenue	First-category main road	Existing	Two-lane, 6	Signalized intersection	Transversely intersected by the main line;
19	K23+817	General 9th Street	Second-class main road	Repair Works	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line; Auxiliary road crosses at grade
20	K23+874	Ulaanbaatar Railway	Diesel Railway	Existing	Single track	Separated intersection	Transversely intersected by the main line;
21	K24+337	Dunjingarav Street	Second-class main road	Existing	Two-way, 4 lanes	Separated intersection	Transversely intersected by the main line;
22	K24+793	Tuul Expressway	Highway	Planned	Two-lane, 6	Signalized intersection	Transversely intersected by the main line;

3.4.4. Interchange Intersection Planning

(1) New Ring Road and Moscow Street Intersection



Drawing 3. 22. Working Conditions for the New Ring Road and Moscow Street Intersection

Grade- separated intersection

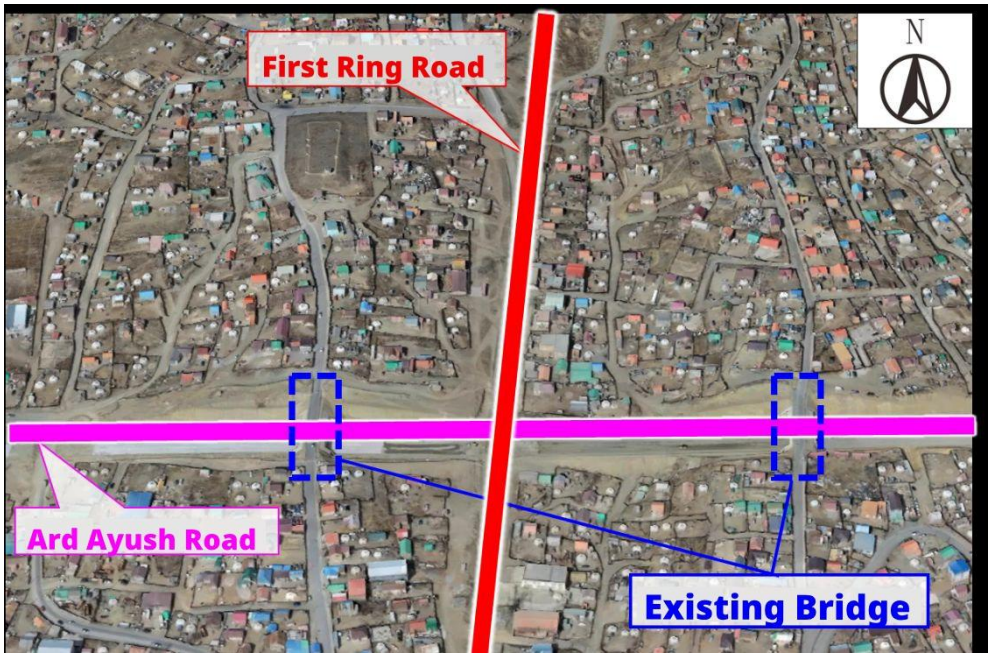
According to official letter No. 02/603 from the State-owned Joint Stock Company of the National Power Transmission Grid of Mongolia, it is not feasible to relocate the 220 kV high-voltage support poles positioned on the right side of the road, and the high-voltage line is located only 13.27 meters above ground level.

Drawing 3. 23. New Ring Road and Intersection with Moscow Street (Planning Option 1)

Table 2.2.4-3 Comparison of Advantages and Disadvantages of Variants

Indicator	
Engineering Cost	0 (Ramp road not planned; therefore, no separate cost incurred)
Land Acquisition Area	0 (Ramp road not planned; therefore, no land acquisition required)
Relocation site	0 (No ramp road planned; therefore, no relocation is necessary)

(2) New ring road and Ard Ayush Intersection



Drawing 3. 24. Construction conditions for the intersection of the new ring road and Ard Ayush Road

Diamond interchange system

Considering the road traffic load and the presence of recently constructed frame bridges in the vicinity, a diamond-shaped interchange was planned for the intersection of Ard Ayush Road with

the new ring road.

A new two-lane bridge will be constructed ahead, parallel to the main axis of the new roundabout connecting to the intersection on Ardi Ayush Street. Since the area north of the intersection is topographically elevated, the slope of the main street at the new roundabout is planned to be 2.8% along the ascending gradient. If the two-lane northern road is connected to the main street by a bridge, under Article 1.6 of Mongolia’s BnBD 32-02-12 'Design of Motor Road Bridges and Culverts', which requires that 'the slope along the bridge shall not exceed 4%', the bridge length will be excessively long, resulting in prohibitively high project costs. Therefore, the two rear sloped roads ascend according to the horizontal road design and subsequently connect to the main street.

Drawing 3. 25. Intersection between the new ring road and Ard Ayush road (Planning 1)

Name	
Project Cost	3,903,831 USD
Area	0 (The crossing is parallel to the main alignment and is located within the land acquisition boundaries of the main alignment; therefore, no separate land acquisition will be required.)
Demolition area	0 (The access lane is parallel to the main alignment and is located within the land acquisition limits of the main alignment; no separate demolition will be conducted.)

(3) New ring road and the intersection on the right side of the second ring road

Drawing 3. 26. Working conditions for the intersection on the right side of the new ring road and the second ring road

Cloverleaf Intersection

The capacity of the intersection with the 2nd ring road has been calculated, and access points have been reserved and planned in accordance with regional planning, the road network structure, and land conditions.

Based on the projected traffic volume and surrounding construction conditions, a cloverleaf intersection has been planned on the new ring road adjacent to the 2nd ring road. The auxiliary roads to be constructed at the northern and southern intersections will connect with the existing Bayan Khoshuu Street.

Exit A is planned as a one-way exit to manage left-turn traffic from south to west. Exit A branches off the main road of the new ring road, crosses Bayan Khoshuu Street, then passes beneath the main road of the new ring road to enter the second ring road. **To resolve the left-turn movement from the 2nd ring road into the new ring road at entrance B, traffic will proceed via a roundabout. Entrance B passes beneath the main street of the new ring road, crosses Bayankhoshuu Street, and connects to the main street. Entrance D facilitates traffic moving from west to east entering the new ring road from the 2nd ring road. The E exit facilitates traffic movement from the second ring road eastbound onto the new ring road. Simultaneously, traffic between Bayanhoshuu Street and the second ring road can be redirected via exits F and G.**

Drawing 3. 27. The intersection on the right side of the new ring road and the second ring road.

Table 3. 10Advantages and Disadvantages of Planning

Name	New ring road and the intersection on the right side of the second ring road
Project Cost	23,688,763 USD
Area	54,869 m^2
Demolition area	21,900 m^2

(4) New ring road, Doloon Buudal intersection

Drawing 3. 28. Work Conditions for the New Ring Road and Doloon Buudal Intersection

Simplified Double-Leaf Cloverleaf Intersection System

Due to the elevated terrain on the right side of the intersection, the main street's gradient was set at 3.8%. If a sloped road is constructed on the western side, the bridge will become excessively long, resulting in increased project costs. Therefore, Option 1 utilizes a simple at-grade diamond intersection where the seven-lane road crosses the new ring road. Access roads A and D intersect the seven-lane road at grade, allowing vehicles to turn right and left and subsequently enter or

exit the new ring road via access roads B, C, E, and F.

Drawing 3. 29. Intersection between the new ring road and Road No. 7

Name	New ring road, Doloon Buudal intersection
Project Cost	23,349,046 USD
Area	13,378 m^2
Demolition area	3,099 m^2

(5) New ring road, western intersection of the Second Ring Road

Drawing 3. 30. Working conditions at the intersection of the new ring road on the left side and the Second Ring Road

Intersection with a single exit

The originally planned alignment of the Second Ring Road passes through mountainous terrain,

resulting in extensive earthworks at the new ring road intersection. It also traverses military units and cemeteries, rendering land acquisition impossible. Considering these factors, to efficiently connect the new ring road with the second ring road, this design drawing incorporates an access point, plans to avoid the mountain, and reduces the project scope.

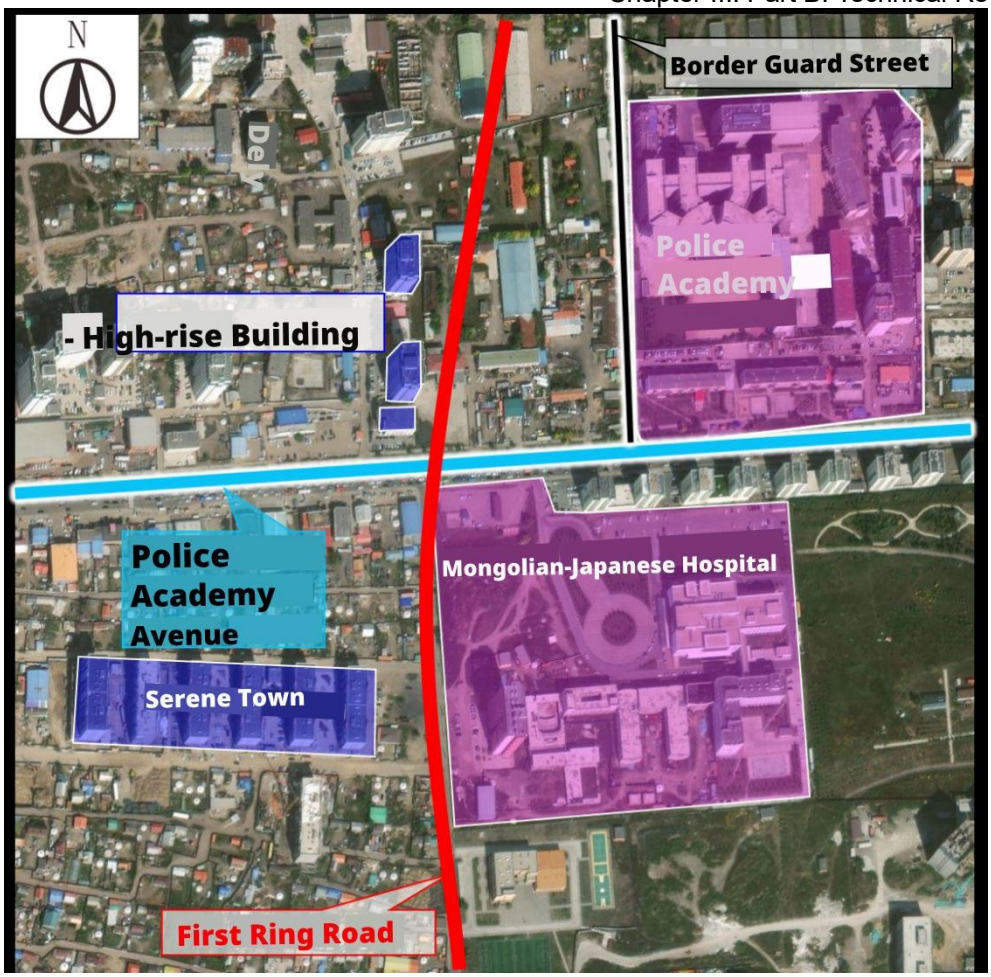
Based on the preliminary traffic volume forecast and the local terrain conditions, the first plan utilizes an intersection design where the new ring road passes beneath the second ring road via a single underpass. Ramp B utilizes a circular sloped ramp to accommodate the traffic flow turning left from the second ring road onto the new ring road. Ramp C employs a sloped ramp to accommodate the traffic flow turning left from the new ring road onto the second ring road. Vehicles turning right from the new ring road onto the second ring road may proceed via crossings D and E. The auxiliary road was constructed outside the intersection along the ring road.

Drawing 3. 31. Intersection at the left side between the new ring road and the second ring road

Table 3. 11. Strengths and weaknesses of the planning

Name	New ring road, western intersection of the Second Ring Road
Project Cost	10,653,700 USD
Area	74,736 m^2
Demolition area	23,165 m^2

(6) Intersection of the new ring road and Police Academy Boulevard



Drawing 3. 32. Working conditions at the intersection of the new ring road and Police Academy Avenue

Diamond-shaped intersection

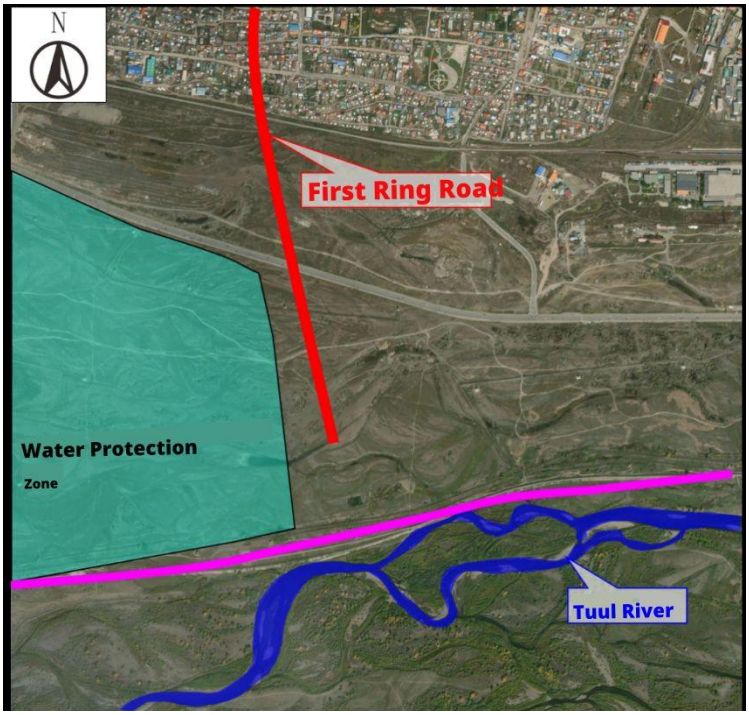
Based on traffic forecasting results and the distribution of adjacent buildings, Plan 1 proposes the construction of a diamond-shaped intersection on the new ring road along Police Academy Avenue. Intersections A, B, C, and D provide ingress and egress to the main alignment of the new ring road and permit right and left turns at the at-grade intersections.

Drawing 3. 33. Intersection of the New Ring Road and Police Academy Boulevard

Table 3. 12.

Name	Intersection of the new ring road and Police Academy Boulevard
Project Cost	14,523,514 USD
Area	0 (The crossing is parallel to the main alignment and is located within the land acquisition boundaries of the main alignment; therefore, no separate land acquisition will be required.)
Demolition area	0 (The access lane is parallel to the main alignment and is located within the land acquisition limits of the main alignment; no separate demolition will be conducted.)

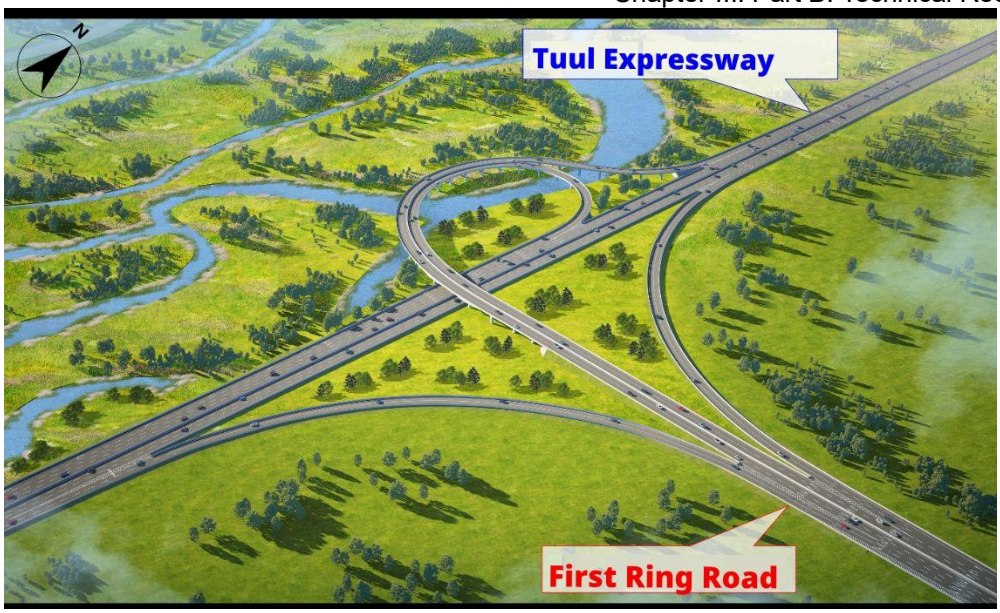
(7) Intersection between the New Ring Road and Tuul Highway



Drawing 3. 34. Working conditions for the intersection of the New Ring Road and Tuul Highway

Planned single-access intersection

Based on the preliminary traffic flow calculation results, Plan 1 utilized a single-access intersection on the new ring road of the Tuul Expressway. Access B employs a circular ramp serving left-turn traffic flow from the new ring road onto the Tuul Highway. The exit utilizes the pedestrian crossing serving the traffic flow turning left from the Tuul Expressway onto the new ring road. Vehicles turning right between the new ring road and the Tuul Highway may use exits D and E.



Drawing 3. 35. The intersection between the new ring road and the Tuul Highway

Table 3. 13. Planning

Name	Intersection between the new ring road and the Tuul Highway
Project Cost	18,821,567 USD
Area	39,357 m^2
Demolition area	0 m^2

3.5. Road foundation and embankment works

3.5.1. General planning of road embankments

(1) The properties of materials used for embankment construction shall be specified in detail within the technical requirements, based on geological survey results.
(2) The technical specifications of the embankment shall be determined based on the bearing capacity of the foundation soil. The soil is classified as hard soil, soft soil, compressible soil, and non-subsiding soil. If a soft soil layer of thickness ≥ 0.5 m is present in the active layer of the foundation soil, the foundation shall be considered soft. The thickness of the active layer shall be approximately calculated based on the width of the embankment base. A natural foundation is classified as a settlement foundation when the relative settlement exceeds 0.01 and the soil consists of clay.
(3) For embankment construction, the use of soil with normal moisture content that does not lose its strength due to climatic influences shall be permitted.
(4) The pavement design of the road has been developed with full consideration of geographical, geological, climatic, and hydrological natural conditions; aligned with the terrain surface and surrounding environment; and based on a comprehensive assessment of the effects of uneven settlement in geologically weak and special sections of the road foundation, adapted to local conditions.
(6) Propose an economically justified plan for the road base filling and excavation works, strictly controlling the properties of materials used for filling and excavation to ensure the strength and density of the road subgrade, and aligning the road surfacing with the road surface. When traversing sloped sections of the roadbed, anti-skid measures, including cutting anti-slip platforms, shall be implemented. To ensure the durability of the road pavement and effective drainage systems, areas with zero fill and zero cut shall be reinforced.

(7) The road foundation design drawing must ensure soil and water conservation, as well as environmental protection.
(8) Excavation slope: Excavation primarily serves to reduce slope angles and is compensated through management and the restoration of vegetation.

3.5.2. Embankment filling

(1) Control Factors for Embankment Planning

1) The embankments on both sides of large and medium-sized bridges, as well as the edges of pavement embankments, shall be designed at no less than 0.5 m above the calculated water level accounting for wave height. The edges of water discharge embankments and foundations shall be projected no less than 0.25 m.
2) The required density shall be determined by the density confidence factor, expressed as the ratio relative to the maximum standard density, with the minimum compaction level for embankment layers precisely specified in the technical requirements.
3) At the section where the embankment adjoins the bridge, it is more effective to design the embankment with a non-settling drainage soil layer positioned at least 2 m below the embankment, with the embankment height plus an additional 2 m clearance.
4) To ensure the required strength and stability of the embankment crest and road pavement, the pavement must be raised no less than the values specified in the table below above the calculated groundwater and surface water levels, or above the ground surface where surface water drainage is not provided.

Table 3. 14. Minimum required elevation of the motor road pavement (m) relative to the subterranean groundwater level

Type of soil in the working layer	Minimum standard pavement thickness by road climatic zone (meters).				
	Zone IA	Zone IB	Zone IIA	Zone IIB	Zones IIIA; IIIB
Fine sand, coarse granular sandy soil, light sandy soil	1.4	1.1	0.9	0.75	0.5
Clayey sand, clay soil	1.8	1.5	1.2	1.1	0.8
Heavy silty sand, light silty clay, heavy silty clay	2.5	2.2	1.8	1.5	1.1
	0.5	0.4	0.3	0.3	0.2
Light or heavy sandy soil, or clay	2.7	2.4	2.1	1.8	1.2
	0.6	0.5	0.4	0.4	0.3

***Note: 1**. The upper value in the table represents the minimum pavement elevation relative to the groundwater or long-term stable (≥30 days) surface water level; The lower value in the table specifies the required replacement thickness of the layer. 2. The groundwater level shall be calculated based on the maximum water level attainable before freezing and thawing in the autumn season. 3. The application of a protective waterproofing layer may reduce the aforementioned lifting height requirement. 4. The compaction degree of the working layer shall be no less than 98%, and its thickness must be determined by structural calculation to satisfy the road surface stability and strength requirements.*

(2) Requirements for Backfill Materials

1) Preferred options: gravel mixture (gravel content 65%–70%), crushed stone soil (particle size ≤ 150 mm, continuously graded), or lime-stabilized soil (suitable for frost-susceptible areas).
2) Prohibited materials: organic soil, peat soil, frozen soil blocks (diameter 2100 mm), saline soil (Cl content > 0.5%).

Table 3. 15. Requirements for Road Embankment Fill Material

Indicator	Requirement	Test Method
Maximum Particle Size	≤ 2/3 of the Compaction Layer Thickness	MNS 5325 Annex A Sieve Test
Liquid Limit (LL)	≤35%	ASTM D4318
Plasticity Index (PI)	≤12	ASTM D4318

(3) Sequential Filling and Compaction

Table 3. 16. Density and Requirements for Road Embankment Fill

Project Title	Depth below Road Pavement (cm)	Compaction Percentage (%)	Minimum Aggregate Strength (CBR) (%)
Embankment filling	0～30	≥95	≥8
	30～80	≥95	≥5
	80～150	≥93	≥4
	＞150	≥92	≥3
Waste-Free and Ditch Excavation	0～30	≥95	≥8
	30～80	≥95	≥5

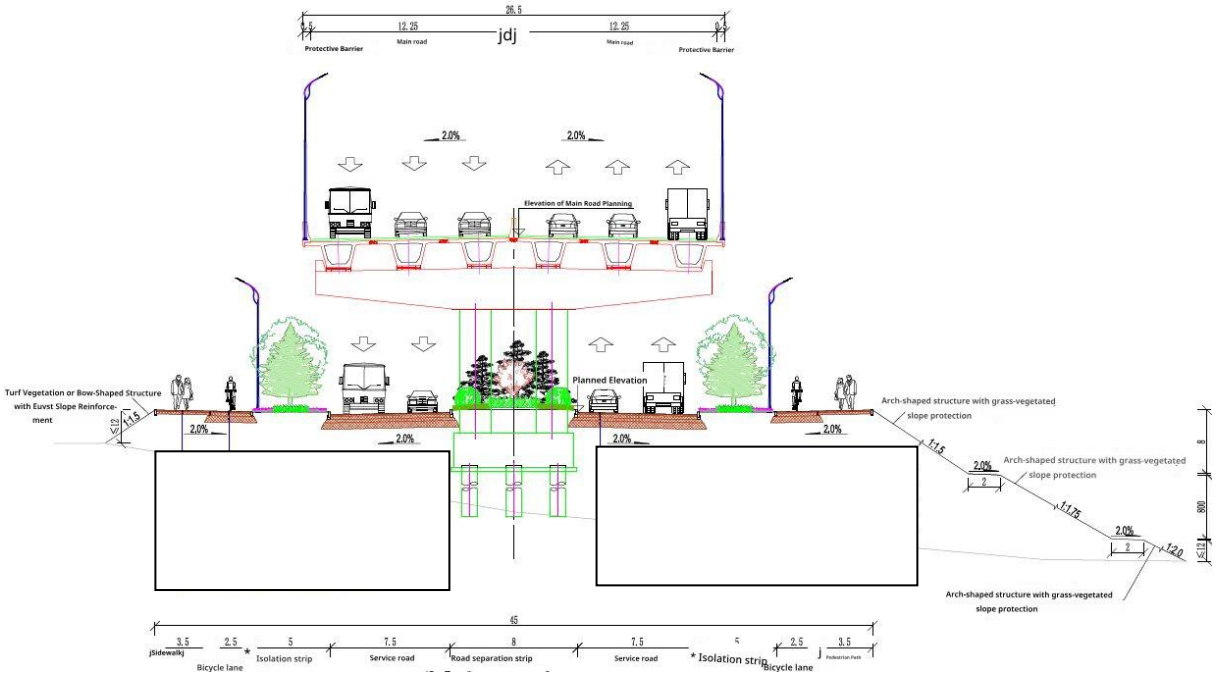
Moisture Content Control: The optimum moisture content shall be maintained within ±2%. Construction activities in frozen soil zones must ensure that moisture content does not exceed the plastic limit during the winter season.

Table 3. 17Layer thickness

Type of compaction roller	Maximum loose thickness to be laid
20-ton vibratory roller	≤ 300 mm
Impact roller	≤ 500 mm

(4) Design of embankment slope

For embankment fill heights H ≤ 12 meters, depending on the embankment height and spacing, a slope ratio of 1:1.5 with a linear slope was applied. If the height of the roadside slope is 12＜H≤20 meters, a terraced slope shall be employed; the slope gradient shall be 1:1.5 for slopes exceeding 8 m and 1:1.75 for slopes less than 8 m. At the point of slope transition, a 2 m wide slope bench shall be constructed, with a transverse slope featuring a 2% outward gradient. If the height of the fill slope H＞20 meters, a terraced slope shall be implemented with a slope gradient of 1:1.5 for slopes exceeding 8.0 m, 1:1.75 for slopes between 8.0 m and 16 m, and 1:2.0 for slopes less than 16 m. A 2 m wide slope bench shall be provided every 8 m, incorporating a transverse slope with a 2% outward gradient.



Drawing 3. 36. General drawing of the foundation ditch for the embankment of the road

Foundation excavation works

(1) For a stable soil layer impermeable to water (whose strength is not reduced by climatic effects), the excavation slope shall be adopted according to the table below.

Table 3. 18. Maximum excavation slope

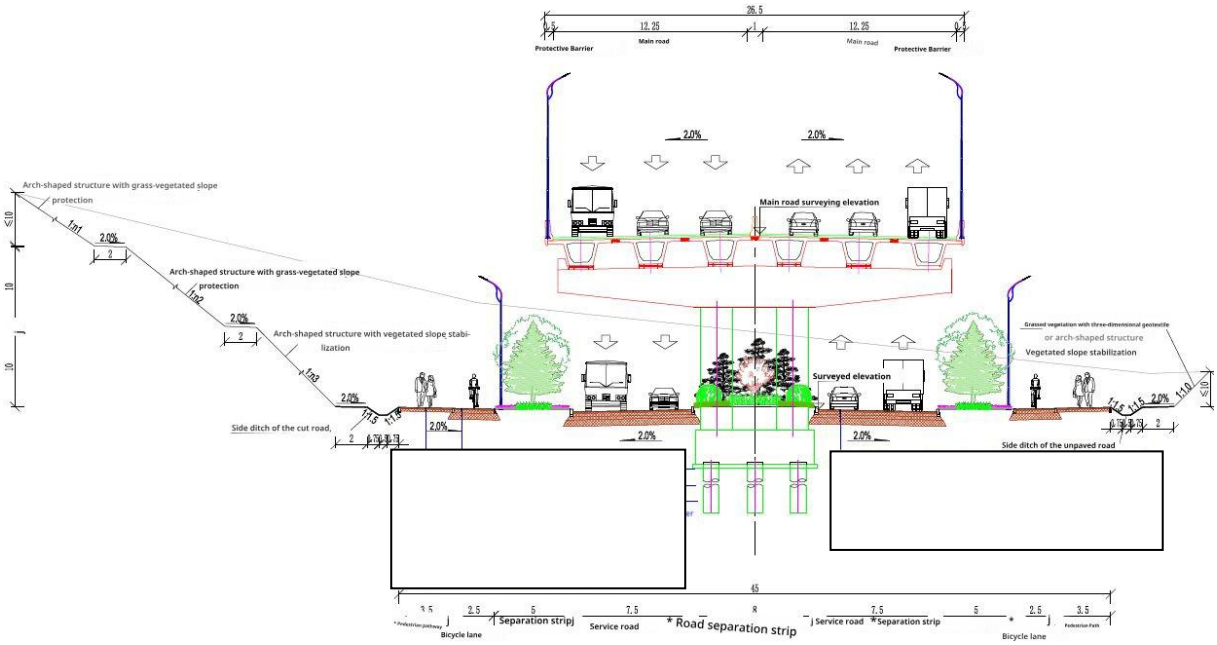
Soil Type	**Excavation Depth (m)**	**Maximum Slope**
Undisturbed Bedrock	＜16	1：0.2
Slightly Weathered, Unsoftened Bedrock	＜16	1：0.5-1：1.5
Softened Bedrock	＜16	1：1
Gravelly Soil	＜12	1：1-1：1.5
Sand, Clay (Uniform; Hard Plastic – Semi-Rigid Plastic; Plastic – Soft Plastic)	＜12	1：1.5
Mobile sand dune	＜2	1：10
	2-12	1：2
Clay soil	＜12	1：0.1-1：0.5*
		1：0.5-1：1.5**

Note: 1. **The upper values in the table correspond to arid climate zones; **The lower values in the table correspond to non-arid climate zones. 2. For unaltered bedrock, the construction of vertical walls is permitted. 3. On sandy terrain stabilized by vegetation, for side slopes not exceeding 2 meters in height, a vertical slope with a ratio of 1:2 shall be permitted. 4. The height of the excavated side slope shall be determined by the difference in elevation between its upper and lower edges. 5. For fine sand with pcs., excessively wet clay (coefficients of assistance > 0.3), weathered or fissured bedrock, and similar soils, when excavations exceed a depth of 2 meters, it is necessary to install a berm on the outside of the side trench. The width of the sandy scree with fine particles is 1 meter; for the aforementioned other soil types, when the lateral slope height is ≤12 meters (for bedrock ≤16 meters), it shall be 2 meters.*

The excavation slope angle shall be determined in accordance with the aforementioned technical conditions and the geological survey report. It is recommended to implement the 'dynamic design method' to adjust technical specifications in response to geological conditions encountered during construction and to simultaneously undertake vegetation restoration works to ensure safety

throughout the service life cycle.

The soil in the planned excavation section consists of clayey soil with gravel. The planned excavation slope adopts a slope configuration with a height of 10 m per slope; the design slope ratios are 1:1.0 for the first slope, 1:1.25 for the second, 1:1.5 for the third, and 1:1.75 for the fourth.



Drawing 3. 37. General design drawing for the excavation of the road embankment

3.5.3. Planning of the specialized road embankment

(1) Design of the road foundation and embankment in areas with peat soil

1) Technical specifications for the Ulaanbaatar region

Frost penetration depth: The maximum seasonal frost depth ranges from 1.8 to 2.2 m.

Maximum temperature: -45 °C in winter, short-term +45 °C in summer; annual freezing and thawing cycles ≥50.

Typical soil: clayey silt (highly susceptible to frost heave, liquid limit >35%).

The frost index of Ulaanbaatar City is F ≥ 2000 (°C·d). Pursuant to the technical conditions for the design and construction of highways in seasonally frozen regions, Ulaanbaatar City is classified as an area with severe frost conditions.

2) Special plan for clearing seasonally frozen soil

Pursuant to the 'Technical Conditions for the Design and Construction of Motor Roads in Seasonally Frozen Areas,' if the soil subgrade in heavily frozen sections fails to meet the critical elevation requirements for pavement frost heave, the following measures shall be implemented to prevent freezing.

① Enhance the design elevation of the road foundation.

② Install anti-frost blankets and separation layers; where necessary, construct drainage ditches and water runoff channels.

③ Replace the fill within the frost penetration depth with materials that are either non-frost-susceptible or exhibit low frost susceptibility.

If the filling height of the roadbed does not meet the critical frost heave height requirements for the road embankment foundation, this model shall follow the seasonal frost-affected soil treatment plan: establishing a permeable insulating layer composed of crushed stone with less than 5% passing the 0.075 mm sieve and between 10% and 30% passing the 4.75 mm sieve. A geotextile filter layer shall be installed above and below the insulation layer. The upper and lower cross slopes shall be no less than the transverse slope of the road surface; the lower surface of the

insulation layer shall be located at least 0.3 m above the groundwater or surface water level; and the effective thickness shall be no less than 0.3 m.

3.5.4. Protection of the Road Foundation

(1) Planning Principle

1) The protection of the road foundation and supports shall be considered comprehensively, based on the climate, geographical location, geology, and local materials along the route, and closely coordinated with the designs of drainage facilities. The general principles of the model shall be founded on slope stability, aesthetically pleasing slope configurations, and environmental protection. It is appropriate to select a practical, justified, economical, aesthetically pleasing, and environmentally friendly protection method tailored to local conditions to prevent surface erosion and degradation of slopes caused by rainwater and atmospheric effects, ensure the stabilization of the motor road foundation, preserve the ecological environment, and arrange the road right-of-way.

2) To facilitate construction works and reduce project costs, domestic materials shall be utilized as much as possible, combined with protective methods traditionally used in local Mongolian customs.

3) For sections where road foundation stabilization is inadequate and adverse geological factors exist, a comprehensive assessment of engineering geology, hydrogeology, slope height, surrounding environmental conditions, and construction circumstances shall be conducted. A complete design for slope protection and reinforcement armature of the road foundation shall be approved. The structural design shall be based on economic optimization and principles conducive to construction and maintenance, taking into account various design load combinations.

(2) Protection of Road Subgrade

1) The embankment fill shall be constructed with slopes according to the designed gradient, after which the slope surface shall be protected. For slopes with a height H ≤ 6 m, grass shall be planted to provide slope protection. For slopes exceeding 6 m in height, grass reinforced with arched framing shall be planted to ensure slope stability.

2) After excavation of the slope, the slope shall be protected according to the calculated slope velocity: for soil slopes with a height H ≤ 3 m, grass planting shall be employed for slope protection; for slopes with a height 3 m < H ≤ 6 m, three-dimensional geonet shall be used; and for slopes with a height H > 6 m, arched frames shall be implemented for slope protection.

3) Utilized to protect retaining walls where there are no conditions permitting slope reduction. The configuration, material selection, and precise dimensions of the retaining wall shall be determined following detailed calculations based on actual site conditions. The main road and auxiliary road are separated, with reinforced anchored retaining walls and counterfort retaining walls.

3.6. Pavement Works

3.6.1. Principles of Road Pavement Design

Throughout Mongolia, in accordance with the supply of road construction materials, road traffic load, and operational requirements, materials shall be selected and adapted to local conditions, following principles of comfortable construction, maintenance, and cost-efficiency. The scheme shall employ advanced technological and economic rationale to ensure safety, reliability, and construction compatibility. The road design drawing shall comply with requirements for road traffic safety, service comfort, and overall convenience. To ensure the durability and quality of the project, and to reduce project costs. The road design shall be executed in accordance with the following principles.

(1) Fully considering road operational requirements, the pavement design shall ensure structural load capacity, prevent cracking at high temperatures, and mitigate cracking at low temperatures.

(2) This design drawing is based on the local pavement design specification of Mongolia,

supplementing the International "Technical Conditions for Asphalt Pavement Design of Motor Roads", and pertains to the theoretical and calculation methods of asphalt pavement design.
(3) When designing the pavement structure, the geological, hydrological, and climatic conditions of Ulaanbaatar City were fully taken into account.

3.6.2. Drawing Design standard

Climatic zoning for asphalt pavement execution: average maximum temperature of the hottest month (℃): +22℃; Minimum temperature (℃): -45℃; Annual precipitation (mm): 300; Design drawing for asphalt pavement climatic zoning: 2-1-3 (hot summer, severe winter, semi-arid).

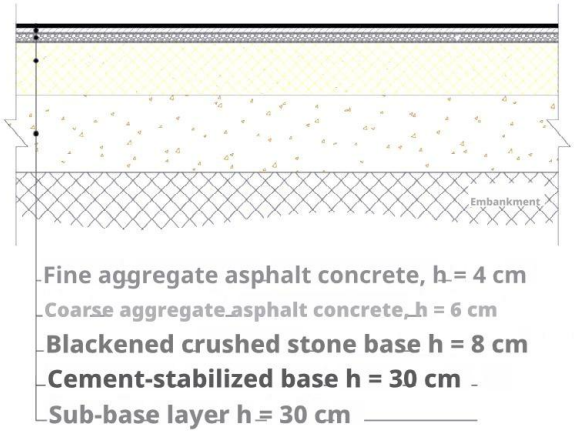
Standard axle load: The standard axle load for a dual-tire assembly is 100 kN, denoted as BZZ-100kN.

Design service life: Asphalt pavement, 20 years.

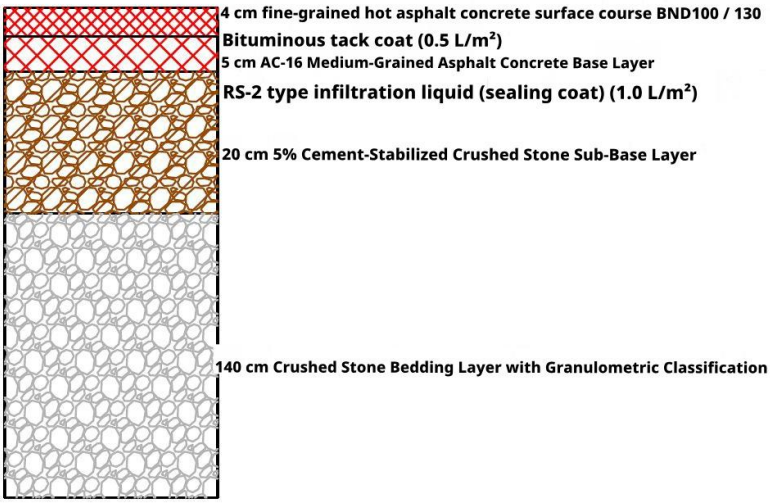
3.6.3. Pavement structure design drawing

In the tensile strength calculation of flexible pavements for motor roads, the pavement structure shall be verified against permissible localized buckling conditions, stability criteria against slippage of the pavement structure, and the tensile resistance of the concrete structure under bending. The strength coefficient, serving as the criterion for the strength calculation, shall be established based on the road classification, pavement type, strength coefficient, and the purpose of the calculation.

Drawing 3. Type 1 Pavement Structure Drawing



Pavement Structure of the Main Road, Service Road for the Cable-Stayed Bridge, and Ramp Section



Pavement Structure of Service Roads and Vehicular Roads

Pavement Structure of Pedestrian Pathways and Sidewalks

Drawing 3. 38. Pavement Facility Design Scheme

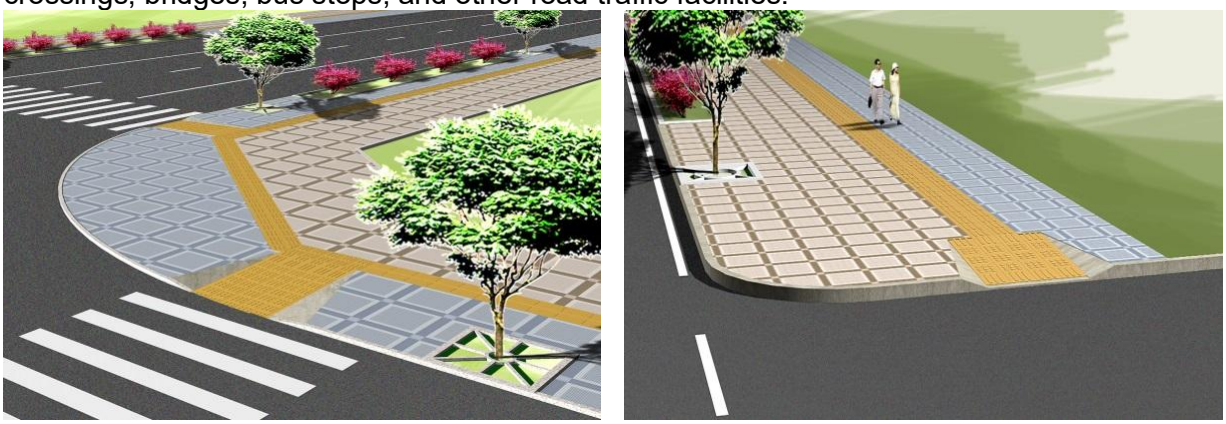
3.7. Road Auxiliary Works

3.7.1. Road curb

Within the scope of this project, barriers shall be installed along the median strip, carriageway, vehicle lanes, pedestrian walkway slabs, and boundary strips of tree pits beside roadside trees.

3.7.2. Accessible design for persons with disabilities

The accessible design for this project shall accommodate the needs of visually impaired persons, physically disabled individuals, vulnerable elderly persons, children, and others by ensuring accessibility at pedestrian sidewalks, access points along the route, road intersections, pedestrian crossings, bridges, bus stops, and other road traffic facilities.



Drawing 3. 39. 3D Drawing of Accessible Facilities

Pedestrian paths have been provided along the improved roads to facilitate navigation for visually

impaired individuals on foot. Pedestrian paths in road sections shall be constructed continuously. When unobstructed, their placement shall be at a minimum distance of 0.5 m from the roadside tree pits, with a pedestrian walkway width of 0.3 m. Tactile paving shall be installed at turning points of blind pathways. For obstacles or objects posing potential hazards to visually impaired persons, tactile paving shall be provided around them to alert and guide such persons to safely circumvent these obstacles. Simultaneously, to ensure accessibility for persons with disabilities using wheelchairs, no abrupt changes in elevation or horizontal steps shall be present on pedestrian pathways within the road sections. Where changes in elevation or horizontal steps occur, ramped transitions shall be employed, with the ramp slope not exceeding 8%.
The pedestrian walkway at the road intersection shall be fitted with sloped curbs corresponding to the horizontal alignment of the pedestrian path, and the lateral slope of the roadside shall not exceed 8%. The lower end of the sloped path shall be level with the road surface elevation. The warning tactile paving at the intersection shall be connected to the tactile paving of the pedestrian walkway. If necessary, audible devices may be installed to ensure that visually impaired persons can cross the intersections safely. The slope of the pedestrian walkway along the bridge shall not exceed 4% to facilitate wheelchair access. The pedestrian walkway on the bridge shall be continuous with the pedestrian walkway of the road, and the height difference slope between the bridge and the pedestrian walkway shall not exceed 8%.

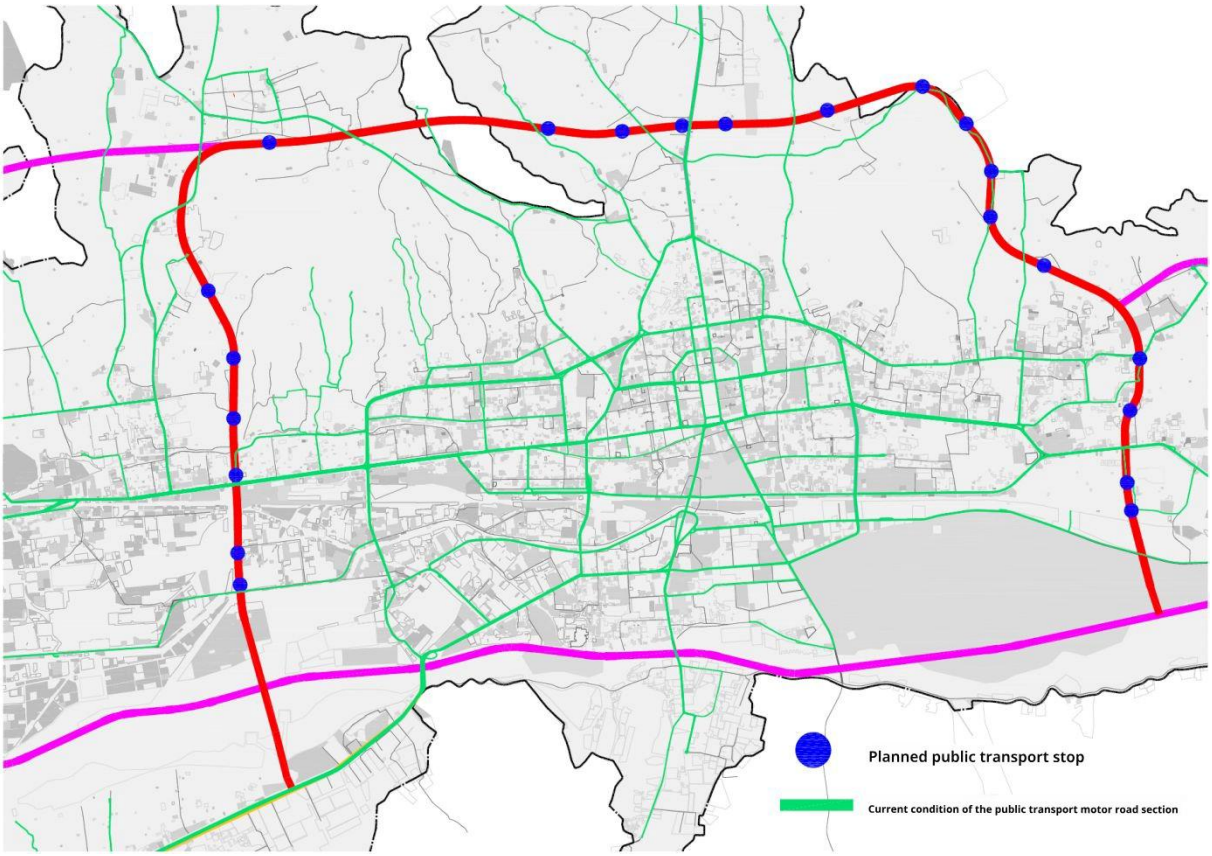
3.7.3. Public transport stop

Bus stops are provided along the entire route line and shall be either corner-shaped or linear bus stops. The length of the parking bay is 30 m, and the platform width is 2 m. This project includes 18 bus stops comprising 9 pairs, and 24 direct bus stops comprising 12 pairs. The allocation of bus stops is presented in Table 2.2.7-1. The allocation of existing bus routes and bus stops planned for the newly constructed ring road is shown in drawing 2.2.7-1.

Table 3. 19. Bus Stop Distribution List

No.	Location	Type of Parking
1	K0+480	Bus Bay
2	K0+930	Bus Bay
3	K1+970	Bus Bay
4	K2+740	Bus Bay
5	K3+540	Bus Bay
6	K4+450	Bus Bay
7	K7+470	Curbside
8	K11+300	Curbside
9	K12+330	Curbside
10	K13+120	Bus Bay
11	K13+720	Bus Bay
12	K15+120	Curbside
13	K16+500	Curbside
14	K17+300	Curbside
15	K18+000	Curbside
16	K18+630	Curbside
17	K19+680	Curbside
18	K21+600	Bus Bay

19	K22+350	Bus Bay
20	K23+350	Bus Bay
21	K23+720	Bus Bay



Drawing 3. 40. New ring road and the existing bus route, distribution locations of bus stops

3.8. Road traffic safety and management facilities

3.8.1. Fundamentals of the road traffic design

(1) Road classification: applicable international standard;
(2) Design speed: 100 km/h for the main road, 40–60 km/h for the auxiliary road;
(3) Importance coefficient for road sign structures: cantilever structure γ0 = 1.0; for other types of signs, γ0 = 0.95.

3.8.2. Design drawing

(1) The working drawing design and construction works shall comply with the Employer’s approval and conform to all relevant laws, documents, regulations, rules, and standards.
If the design drawings for the motor road, road facilities, and bridge pertain to freeway, highway, expressway, or other internationally standardized road types not existing in Mongolia or its motor road sector, the Contractor shall carry out the works in compliance with international or its national standards, norms, and regulations, suitably adapted to Mongolia’s climatic conditions to meet quality requirements. These standards shall be agreed upon and approved with the Employer prior to executing the construction works.

The working drawings, technical specifications, and information represent the Employer’s general understanding and objectives concerning the scope, purpose, and form of the works to be executed. While the Contractor shall base the design drawings on the information provided by the Employer, they shall not be limited by it and shall be responsible for the completeness and accuracy of the design.

(2) Road signal control system, traffic monitoring cameras, and traffic video surveillance system

Intersections shall be equipped with signal control systems where necessary, in accordance with traffic management requirements and professional traffic conditions. The tunnels are equipped with a traffic signal control system, a road traffic video surveillance system, and a vehicle flow detection system. This design drawing covers the electrical power supply and cabling of the field control devices for the tunnel traffic control system; the traffic police control center management console is excluded from the scope of this design drawing.

3.8.3. Road Traffic Signs

(1) Замын тэмдгийн төлөвлөлтийн зарчим

The **of Road Sign Planning**

The principle of installing road traffic signs is to regulate traffic, ensure traffic safety, provide comprehensive, accurate, and timely information to road users, facilitate speed and unobstructed movement, and enable drivers unfamiliar with the road and the surrounding motor road network to reach their destination efficiently and without deviation. Traffic signs shall be installed in accordance with the road alignment, traffic conditions, and adjacent structures, with various types of traffic signs deployed accordingly. Specifically:

- Prohibitory signs shall be installed in locations where vehicle movement restriction is required.
- Directional signs shall be installed at locations where the regulation of vehicle movement is required.
- Road signs conveying information such as direction, location, and distance shall be installed.
- Auxiliary signs shall be placed below the main signs, with additional explanations provided as required.
- The arrangement of road signs shall fully account for coordination with signage and marking at intersections, and sign placement shall be considered in a general context.
- Prohibitory signs: Signs that prohibit or restrict the movement of vehicles and pedestrians;
- Directional sign: a sign conveying information regarding road direction, location, and distance. The aforementioned signs may be installed individually or in combination.
- Commonly employed combined mounting methods include: vertical post, F-shaped post, R-shaped post, etc.

In accordance with the project’s signage design principles, the arrangement of road signs is executed to ensure that drivers recognize the signage content accurately and promptly at the designated speed, with the organization of road signs and markings being both aesthetically pleasing and attention-attracting. Within the scope of the drawing design, all types of signs and markings are uniformly positioned, with adjustments made to the front and rear sides. The configuration of signs and markings on adjoining roads is carefully coordinated to establish an integrated system.

- The types of road signs designed for this project are: prohibition signs, instructional signs, and directional signs.
- When it is necessary to install more than two types of road signs at a single location, they may be combined on one support post, provided that the total does not exceed three. When placing signs on a single support, they shall be arranged in the following order: first

upwards, then downwards; first to the left, then to the right; following the sequence of warning, instructive, prohibitive, and informational signs.

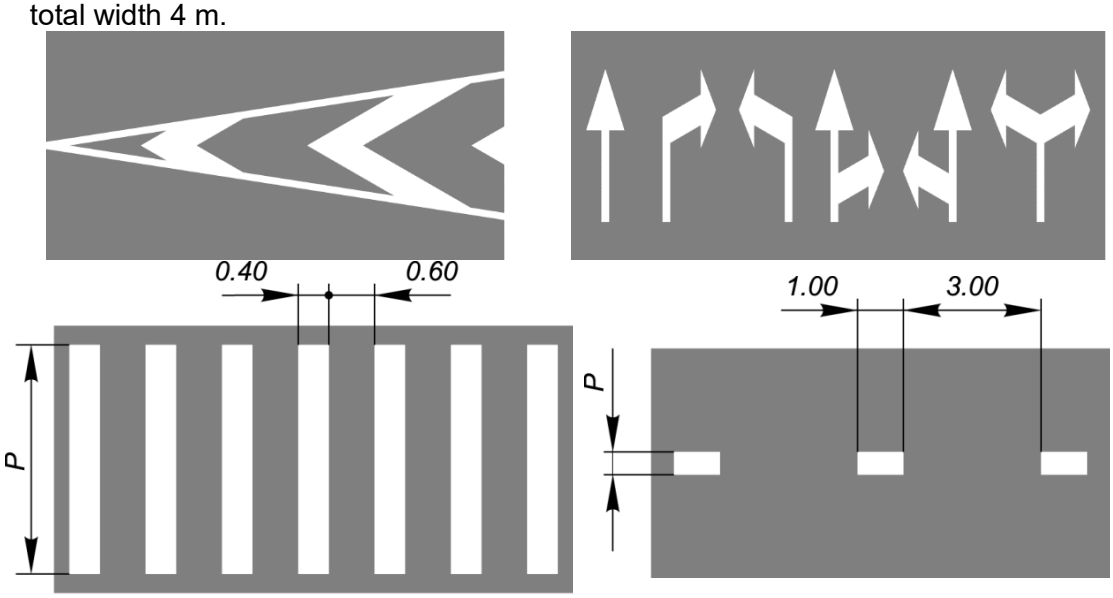
- When installing road signs beside the road, they must be positioned as perpendicular as possible, or at a defined angle, to the centerline of the road; Prohibitory and regulatory signs shall be angled between 0° and 45°, while directional and warning signs shall be angled between 0° and 10°.

3.8.4. Road traffic line markings

(1) Types of markings

Road traffic signs are utilized to control and guide traffic. They must ensure that vehicles travel in designated lanes, direct the flow of traffic, align vehicles correctly before merging or diverging, regulate driving discipline and order, and reduce the occurrence of accidents.
This provides a visual guidance function effective both day and night, with clearly defined lane boundaries, distinct lines, and contours, organically integrated with road signs to properly direct the flow of traffic.
The road markings designed for this project are classified into two categories: horizontal markings and vertical markings.

- Edge line of the traffic lane: a solid white line 15 cm in width.
- Separating line for a single-direction lane permitting crossing: a white dashed line is used, with line segment and interval lengths of 3 m and 9 m respectively, and a line width of 15 cm.
- Pedestrian crossing: white markings, line width of 40 cm, spacing between lines of 60 cm, total width 4 m.



Drawing 3. 41. Outline drawing of road traffic markings.

- Parking line: A 40 cm wide solid white line shall be used at a distance of 3 m from the pedestrian crossing. The length shall be determined according to the site conditions. Guide lane line: solid white line, 15 cm in width and 30 m in length.
- Crossing the lane separation line is prohibited: a 15 cm wide solid white line.
- Guide arrow: To more effectively indicate vehicle movement direction, when the design speed is ≥60 km/h, the ground guide arrow shall be 6.0 m in length and white in color. The guide arrow at the grade intersection shall be adjusted three times. The first group of guide arrows shall be positioned 3 m from the stop line, and the second group shall be placed at the beginning of the guide lane. The start and end points of the arrow coincide with the start and end points of the guide lane line. The third section is located 30 to 50 meters upstream of the arrow in the second section.

- Acceleration and deceleration lane markings: white dashed lines, with line segment and interval lengths of 1 m and 3 m respectively, and a line width of 40 cm, serving as separation boundaries between the main driving lanes.

Unified median markings for vehicles traveling in the same direction: line width 10 cm, fill line width 40 cm, interval 1.2 m.
Vertical markings: tunnel entrance, road edge, yellow and black diagonal lines at a 45° angle, line width 20 cm.

(2) Road Marking Materials
The road markings are variable markings. The product must be accompanied by a certified test report. The paint pre-mixes the glass fibers and applies them onto the surface during the hot-melt construction process. Coating density ≥ 1.8~2.3 (g/cm²), softening point 90℃~120℃; the finish must be free of wrinkles, blooming, foaming, cracking, tackiness, and adhesion; the color and appearance must not significantly differ from the standard panel. Non-adhesive wheel drying time ≤ 3 minutes; compressive strength ≥ 12 MPa; glass fiber content between 15% and 23%. Pre-mixed glass fiber strands and glass fibers sprayed on the surface shall comply with the applicable international standards.

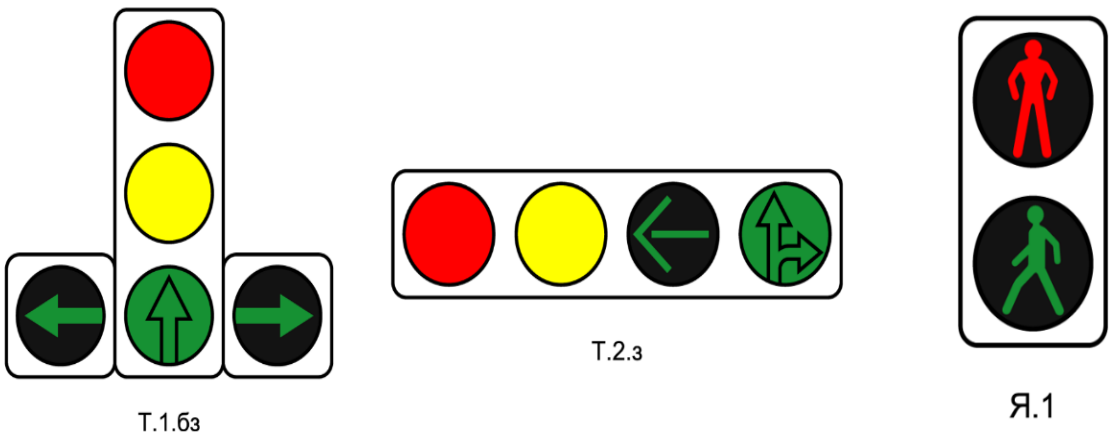
Except for markings, all other marking paints shall be hot-melt paints, and the product shall be accompanied by a certified test report. Paint density ranges from 1.8 to 2.3 g/cm³, with glass fiber strand application on the surface between 0.3 and 0.4 kg/m²; The softening point shall be between 90 ℃ and 125 ℃. The finish must be free from wrinkling, blooming, foaming, cracking, or tackiness, and its appearance shall not differ significantly from the standard plate. Non-adhesive tire drying time ≤ 3 minutes, compressive strength ≥ 12 MPa, and glass fiber content ranging from 18% to 25%. Glass fiber strands sprayed on the surface shall comply with the applicable standards. For continuous solid line markings, drainage connections shall be installed at intervals of 15 m. For other markings, drainage connections shall be provided along the drainage line where water blockage is possible, with the drainage connection width generally ranging from 3 cm to 5 cm.

3.8.5. Road Traffic Signal Installations

This project develops traffic signal installations at the interchange, including vehicle traffic signals, pedestrian signals, and lane indicators, adapted to traffic flow.

(1) Vehicle Traffic Signal

The traffic signal shall be clearly visible within its operational range at a minimum distance of 100 meters from any lane.



Зураг 3. 42. Гэрлэн дохионы диаграм

Technical requirements:
Diameter of the corresponding lamp: 300 mm

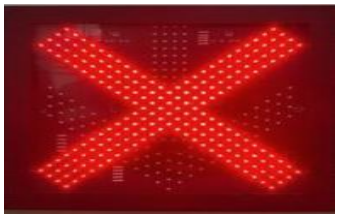
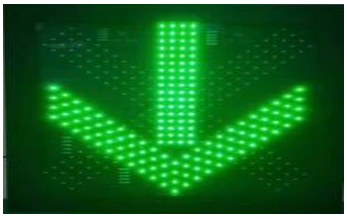
(2) Pedestrian signal light

1) Technical specifications of the signal light and applicable standards for the road type:
For one-way roads with four or more lanes:
It is appropriate to use Type I circular signal lights (diameter 300 mm).
For one-way roads with four or fewer lanes:
Type I circular signal lights (diameter 200 mm) shall be used.

(3) Lane indicator

Signal display: The lane indicator typically shows a red "X" and a green "↓"; the red "X" signifies prohibited passage, while the green "↓" denotes permitted passage.
Lighting and viewing angle: Lane indicators shall use energy-efficient LED light sources and must be sufficiently bright with an adequate viewing angle to ensure clear visibility of signals to drivers.

3.8.6. Туннелийн хяналтын байгууламжууд

Control facilities shall be specified in accordance with the 'Expressway Tunnel Design Specification, Volume 2: Road Traffic Engineering and Auxiliary Facilities.'

(1) Vehicle detector

1) To detect essential traffic parameters such as volume and speed for each lane;
2) To enable the determination of traffic flow directions;
3) It is capable of detecting all types of motor vehicles, ranging from two-wheeled motorcycles, and recognizes trailers as a single vehicle.
(2) Camera
1) Cameras shall be installed within the tunnel interior, exterior, and in auxiliary control buildings of the tunnel.
2) Cameras shall be installed at pedestrian crossings, emergency parking lanes within the tunnel, vehicle exits, and pedestrian exits.

3.8.7. Road Monitoring System

- **Information Exchange Infrastructure**

It shall be feasible to utilize 2G, GPRS, EDGE, EVDO, 3G, 4G mobile communication technologies, as well as high-speed wireless network technologies for data transmission. Depending on the network connection, the data of the respective registration post can be configured to be retrieved for each vehicle entry and on an hourly basis. If it is necessary to obtain camera data from the post, high-speed wireless network technology shall be employed.

(2) Road surveillance camera

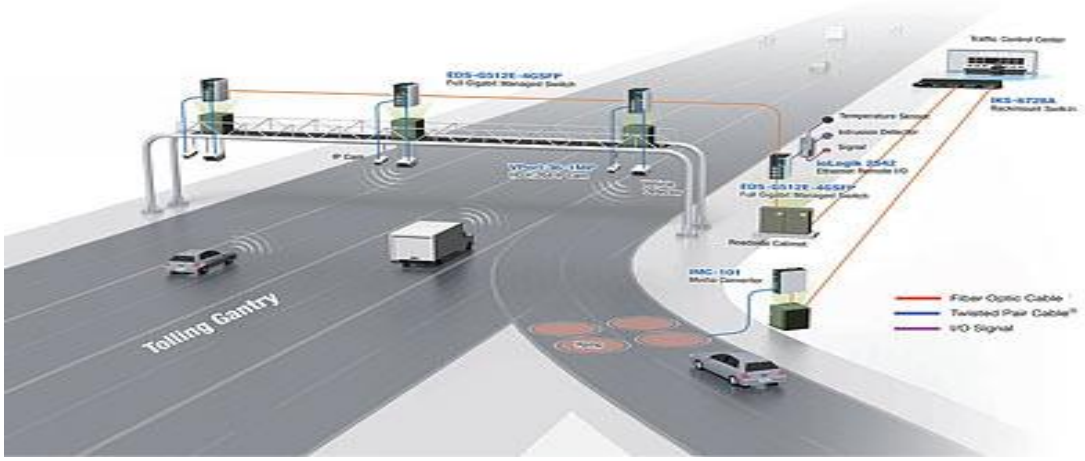
The Traffic Management Center has installed 45 cameras on the main streets of the motor roads in Ulaanbaatar City to collect quantitative data on vehicle speed, density, and congestion, which is used for traffic management.
Within the scope of the New Ring Road project, it is planned to install 16 cameras newly at 22 intersections.

	Package-1	Package-2	Package-3	Total
Road monitoring camera	7	4	5	**16**

(3) Payment system

The payment system shall be electronically planned within the working design drawings, and the Contractor shall deploy advanced technology by employing international highway standards as well as standards utilized in the Contractor’s own country for the camera monitoring system, road toll monitoring system, and emergency call system.

Drawing 21. Visibility of the electronic payment system



3.8.8. Other structures

(1) Accident- protected sign: installed at the main alignment point within the intersection;
(2) Barrier: A two-way separator shall be installed in the tunnel and positioned both on the tunnel sidewall and at the edge of the inspection walkway.

4. Bridge

4.1. Standards and Technical Requirements

(1) Road Gauge:
- **Railway gauge:** The 1,520 mm gauge railway must meet the ≥7010 mm loading gauge requirements approved by UBTZ. This condition references multiple railway gauge standards, including provisions for track safety clearance, cantilever height, and the height of protective shelters.
- **Urban road:** Width ≥4900 mm;
- **Underpass and drainage pipe:**Distance ≥2500 mm.

(3) Earthquake requirements:
The bridge is located in an earthquake intensity 8 zone, with a peak ground acceleration (PGA) of 0.20.

(4) Flood frequency for bridge design:
- Bridge: 1 flood per 100 years
- Drainage pipe: 1 flood per 100 years.

(7) Duration of Planning Services:
. The design service life shall be as follows.
- Main transmission pipeline and intersection: 100 years;
- Pedestrian bridge: 50 years;
- Water transmission pipeline and culvert: 30 years;
- Guardrail, widening, bearings, etc.: 15 years.

4.2. Bridge structure

The project comprises a total length of 9,034 meters and a width ranging from 19.5 to 45.5 meters, including 5 main bridges, encompassing structural types such as prefabricated concrete small box girders, and cast-in-place as well as prestressed concrete box girders. A total length of 4,730.8 meters of 7 overpass bridges at intersections is planned, involving prefabricated or cast-in-place concrete small box girders. Additionally, two auxiliary bridges, each with a total length of 60 meters, are planned using precast prestressed concrete small box girders. This project includes the construction of one overpass measuring 100 meters in length and 13.5 meters in width, utilizing precast prestressed concrete box girders. Based on the existing site conditions, it has been specified to construct eight drainage culverts and three pedestrian overpasses, respectively.

4.3. Principles for Bridge Planning

The design drawings of the bridge structures shall conform to detailed planning and water management plan requirements, adhering to operational, safety, durability, and architectural principles. The following technical principles shall be strictly observed.

(1) In accordance with the distinctive characteristics of this project, a detailed analysis was carried out based on domestic and international best practices for bridge structures, upon which the design drawings were developed. The primary technical objectives demand usability, structural safety, cost efficiency, durability, aesthetic appearance, environmental compatibility, technological advancement, and conformity with practical conditions. This solution integrates the latest concepts, materials, and technologies, embodying best practices; it promotes human-centered development and green growth by reducing greenhouse gas emissions,

conserving energy, ensuring environmental safety, and adhering to the principles of sustainable development.

(2) In the selection and design of the bridge type, comprehensive consideration was given to the project’s feasibility, construction process, and socio-economic benefits, while adapting the design to local conditions by accounting for terrain characteristics, transportation networks, and road intersections. In accordance with the general planning requirements, the bridge design is optimized to satisfy road traffic demands while minimizing negative impacts and ensuring compliance with the surrounding environment and the city master plan.

(3) The bridge type shall be selected based on operational usage, visual appearance, architectural planning criteria, and the specific characteristics of the site, grounded in a comprehensive evaluation of environmental and economic justifications; within the framework of this Feasibility Study, the proposed bridge variant is identified through the comparative analysis of multiple alternatives, considering technical, economic, environmental, and social factors.

(4) When designing bridge structures in urban areas, the flood frequency has been considered as once every 100 years. However, in urban areas with lower flood protection standards, applying a 100-year flood frequency complicates the actual usability of the bridge's carriageway. Therefore, the design may be based on the flood frequency at the river cross-section points. Nevertheless, it is appropriate to design the bridge structure for this project based on a flood frequency of 100 years.

(5) The arrangement of the bridge span shall be based on the approved plan to enhance the river basin as set forth in the urban and rural planning documents, taking into account the existing site conditions. In the absence of such a plan, spatial planning shall be developed based on the flood flow design drawing to satisfy flood flow or navigation requirements under current conditions. Furthermore, when designing bridge structures, significant alterations to the natural flow of the main river must be avoided, and the flood flow in the design shall be calculated in accordance with the current national standard.

(6) The bridge structure shall comply with planning requirements and possess sufficient load-bearing capacity; furthermore, the overall arrangement must be unobstructed, aesthetically pleasing, and harmonized with the surrounding environment and landscape.

(7) The landscape design drawing of the bridge shall be closely aligned with the local terrain and surroundings, intended to enhance the general visual appearance of the area and support the distinctive features of the regional landscape. The design of the superstructure of the bridge is similarly planned to be harmonious with the surrounding environment in appearance. Concurrently, throughout construction and maintenance activities, complete attention is dedicated to protecting the urban environment by incorporating a human-centered approach and minimizing adverse effects on the residents' quality of life.

(8) In the design of bridge structures, the adverse impacts resulting from natural disasters (earthquake, flooding, strong winds, etc.) and human activities (such as collisions) shall be thoroughly taken into account.

(9) The forms and materials of the structures employed in the bridge construction shall fully ensure the enhancement of structural durability and protection against corrosion.

(10) In accordance with the bridge structural type, it shall be equipped with auxiliary facilities including lighting, traffic signal signage, speed calming devices, lightning protection, grounding equipment, as well as waterproof drainage channels, monitoring, and safety systems. During the operational phase, to satisfy the requirements for vehicular and pedestrian stability, comfort, speed, and safety, an appropriate and optimized solution for structures such as extensions, temporary stopping sections, pedestrian pathways, and guardrails was developed.

4.4. Bridge Selection

4.4.1. Fundamental Principles of Selection

(1) Based on the construction conditions of Ulaanbaatar City and adapted to local characteristics, the appropriate type of bridge structure shall be selected. In addition to comparing the form and structure of the bridge, factors such as safety and reliability, durability, technological advancement, and economic justification shall be taken into account, as well as the visual appearance of the bridge and its compatibility with the surrounding environment.
(2) Bridge structures shall possess standardized configurations to facilitate prefabrication or mechanical assembly during construction activities.
(3) Urban bridges shall employ structural types that are comfortable, durable, and easy to maintain, and shall be designed as continuous structures with no joints in the mid-span wherever feasible.
(4) The superstructure of the bridge comprises the following types, including:

- prefabricated prestressed concrete small box girder
- prestressed concrete box girder
- steel box girder or composite steel-concrete girder, among others.

4.4.2. Bridge span and structural configuration

The spans of bridges conforming to the general technical requirements and suitable for the project environment typically range from 20 m to 70 m, representing medium to long spans. Cable-stayed and suspension bridges are generally appropriate for long spans; however, under the specific conditions of our project, such bridge structures are unsuitable and thus have been excluded from the comparison. Instead, when comparing structural schemes for planning, only bridge types with lengths ranging from 20m to 70m were selected.

4.4.3. Comparison of the upper structural configurations of the standard section along the bridge centerline

The 'New Ring Motor Road' (First Ring Motor Road) project in Ulaanbaatar City is situated within the city and classified as an urban road. Prefabricated concrete small box girders are suitable for medium spans (20 to 40 m); they offer high load capacity and resistance, efficient cross-sectional performance, good landscape compatibility, and structural integrity, making them particularly appropriate for standard sections of elevated urban roads. Thus, the assembled, pre-stressed concrete small box girder structure generally exhibits superior performance, is suitable for construction works, does not obstruct road traffic during construction, has minimal impact on the landscape, and offers the advantage of the lowest engineering costs. Therefore, it is recommended to use precast prestressed concrete small box girders, cast-in-place concrete box girders, reinforced concrete girders, and other structures (including overpasses, small-radius curved girders, variable-width sections, and long-span nodal bridges) in the standard sections of transmission pipelines.

4.4.4. Superstructure of non-standard bridge sections (main spans, railway, intersections, specially-shaped intersection segments, etc.)

Therefore, the variable-section cast-in-place concrete box girder is suitable for a wide range of spans, featuring excellent overall structural characteristics, enhanced earthquake resistance, ease of construction, optimal landscape impact, and minimal engineering costs. The option to utilize a precast concrete box girder with special nodes (including an overpass, curved girder with a small radius, section with reserve width, or span bridge) is provided.

4.4.5. Selection of the standard span

The bridge in this project is relatively long, and the bridge structure constitutes a significant portion of the total construction cost; therefore, an economic efficiency comparison is necessary. If the standard spacing is excessively short, the number of infrastructures increases, leading to a reduction in both aesthetics and economic efficiency. Conversely, if the standard spacing is excessively long, the number of infrastructures may be reduced; however, this results in a significant increase in the quantity and cost of the upper structural elements, especially the height of the cantilever beam, adversely affecting both aesthetics and economy.

The extensive coordination of precast structures for city bridges is shown in the following table.

Table 4. 1. Commonly used precast bridge types in city bridges

No.	Name	Structural form	Recommended span length (m)
1	Pre-stressed concrete small box girder	Precast box girder with wet joint	20~40
2	Prestressed concrete box girder	Segmental precast structure with epoxy adhesive joint or cast-in-place concrete joint	30~100
3	Steel box girder	Pre-assembly of large segments	30~150
4	Composite steel structure girder	Steel structure girder with concrete bridge deck	20~50

According to the preliminary survey report of this project, the topsoil layer in the area designated for the bridge structure is relatively thin, and the bearing layer is also limited. If longer spans are required to meet operational requirements, cast-in-place concrete, cantilever concrete box girders, or reinforced concrete composite girders may be employed for the crossing. Based on construction experience from similar nearby projects, and taking into account factors such as safety, efficiency, usability, and aesthetics, the recommended setback distance is 25 to 35 meters. However, a cost-benefit analysis was performed to establish the optimal distance. Within this context, an economic comparison of prefabricated reinforced concrete small box girder bridge elements measuring 25 m, 30 m, and 35 m in length was conducted for motor road sections with a bridge deck width of 26.5 meters. The construction and assembly method is, in all cases, suitable for on-site erection using lifting equipment; however, the structures are standardized in all variants and comprise a two-column support girder with bored cast-in-place pile foundations. Comparative analysis has demonstrated that a precast prestressed concrete small box girder with a length of 30 meters provides the optimal economic performance.

4.4.6. Selection

If the length of each continuous girder is excessively short, the number of expansion joints in the bridge will increase, compromising user comfort and necessitating additional expansion bearings, which detracts from the aesthetic quality of the bridge. If the length of continuous bridge spans is excessively long, the surface area of the bridge construction works decreases, and the overall construction period of the bridge becomes relatively longer. As the majority of these channels are situated in areas with high foot and vehicular traffic, it is advisable to minimize the construction duration to the greatest extent possible in order to reduce the load during the construction process. This planning corresponds to a medium length, with 3 to 5 joints per section, and the joint length shall be 90–150 meters; this approach enables work to be performed over a larger surface area, shortens the construction duration, and does not compromise comfort.

4.4.7. Selection of Support Type

The bridge support is a critical component of the bridge. They not only meet strength

requirements but also represent the most visually prominent elements beneath the bridge for pedestrians and vehicular traffic. Their shape and form greatly influence the bridge’s landscape and pose considerable challenges in the design of urban bridge environments. Therefore, the form of the bridge piers must be selected based on sound technical justification.

4.4.7.1. Selection of the support form for the cast box girder

For the cast box girder, three support form ratios were selected for comparison, and the results are as follows.

Table 4. 2. Comparison of cast box girder supports on the main alignment

Main line bridge support	Features
Support type plan (proposed option) 	Advantages: This type of support possesses defined strength, minimal reinforced concrete cross-section, relatively open visibility beneath the bridge, and an aesthetic appearance; The support structure is smooth and linear, suitable for roads with rigid or flexible bridges of substantial width that have a beneficial landscape impact.

In the third design phase, the load-bearing capacity is adequate, the view beneath is unobstructed, and the use of prefabricated components connected by assembly formwork is feasible; this approach reduces investment costs, minimizes waste, shortens construction time, and better satisfies landscape and other project requirements.

4.4.8. Selection of Cast-in-Place and Prefabricated Support Columns and Girders

With the advancement of fully prefabricated bridge construction technology, the prefabricated assembly method for bridge structures is progressively being introduced in bridge construction. Based on the actual conditions of the supports and girders in this project’s standard, the construction schemes for cast-in-place structures and prefabricated assembly have been compared as follows.

Table 4. 3. Comparison of Substructure Assembly Methods

Work	Planning 1: Cast Structure
Work Methodology	Formwork Assembly and On-Site Casting Activities
Structural Mechanical Properties	The structure demonstrates excellent static and earthquake performance, with optimal integrity and structural durability.
Construction complexity	The volume of construction and installation works is substantial, involving a large workforce and a complex construction process; however, the accumulated experience is well-developed, enabling the assurance of quality.
Sector status	International norms, regulations, and standards are well-established, with a unified understanding between the sector and the government.
Impact on society and the environment	Low environmental pollution and moderate energy consumption
Project Cost	Moderate
Construction period	Extended

The first design option (cast-in-place structure) is cost-effective, and the site conditions of

this project are suitable for cast-in-place construction. Meanwhile, prefabricated assembly works exhibit weak structural connections, and the associated factory-related technical conditions and standards are underdeveloped. Therefore, this model recommends employing a technologically advanced solution and a cost-effective precast construction scheme.

4.4.9. Selection of foundation type

According to the results of the geological survey, the soil geology is primarily stratified from top to bottom into topsoil, clay, gravel, and weathered sandstone. The weathered rock strata within the project scope have been excavated to significant depths. The surface soil geology mainly consists of clay, gravel, and soil layers with poor bearing capacity; therefore, shallow foundations are fundamentally unsuitable for this project. The foundation will employ bored cast-in-place piles, utilizing friction piles in areas where moderately weathered bedrock is situated at considerable depth from the ground surface, and bearing piles where the foundation rock is located near the surface.

4.4.10. Selection of Road Barriers

A comparison of three different materials was conducted for the protective barriers, with the results as follows.

Table 4. 4. Comparison of Main Line Protective Barriers

Main Line Protective Barrier	Features
Protective Barrier Plan 1 	Advantages: Visually appealing, transparent, and adaptable to all landscape requirements. High strength, impact resistant, suitable for high-grade urban bridges. Disadvantages: High cost; more expensive compared to concrete barriers. Installation requires stringent standards; for anchoring, installed components or high-strength bolts are used.
Protection railing Plan 2 	Advantages: Aesthetically acceptable, high-strength, impact-resistant, suitable for premium urban bridges. Disadvantages: Requires regular maintenance; more expensive and more complex to install compared to concrete railings.

Protection Barrier Plan 3 (Proposed Scheme)	Advantage: The exterior is irregular, featuring a distinct landscape. Highly durable, capable of withstanding impacts from heavy-duty vehicles, and suitable for elevated urban bridges. Durable, long-lasting, and virtually maintenance-free. Costs are moderate, materials are readily accessible, and construction technology is well-developed.

Comparing the above plans, the construction technology of the third schematic is advanced, with low production and maintenance costs, cost efficiency, and the utilization of high-capacity concrete barriers designed to prevent collisions. The formwork is reusable, which saves investment costs, reduces waste, and is advantageous for major construction projects. The protective barrier features convex and concave shapes, enabling it to better satisfy landscape and other related requirements. Therefore, it is recommended to adopt the 3rd design for the bridge impact protection barrier.

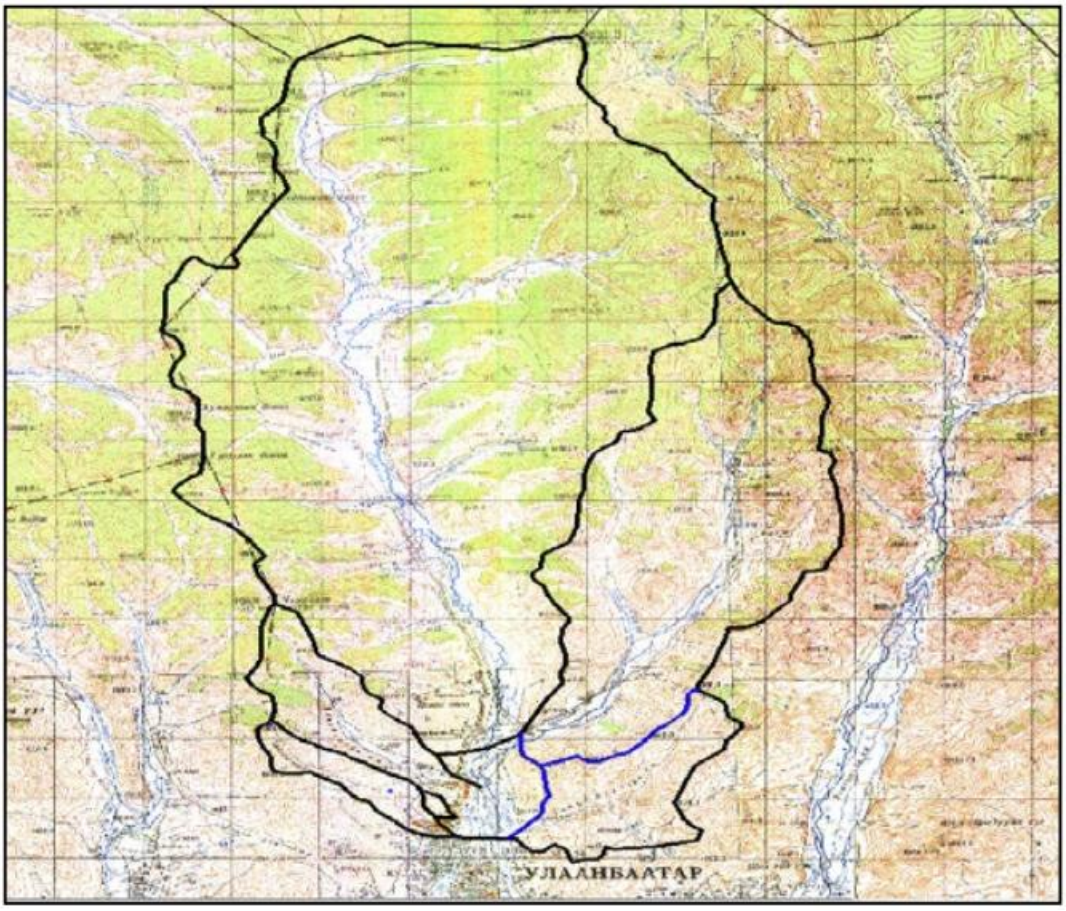
4.4.11. Hydrological calculations

This project crosses the midsection of the Selbe River at K14+250, passes beneath the Selbe River at K0+212, and traverses the Tuul River at its terminal section, featuring intersections A, B, and C of the Tuul intersection.

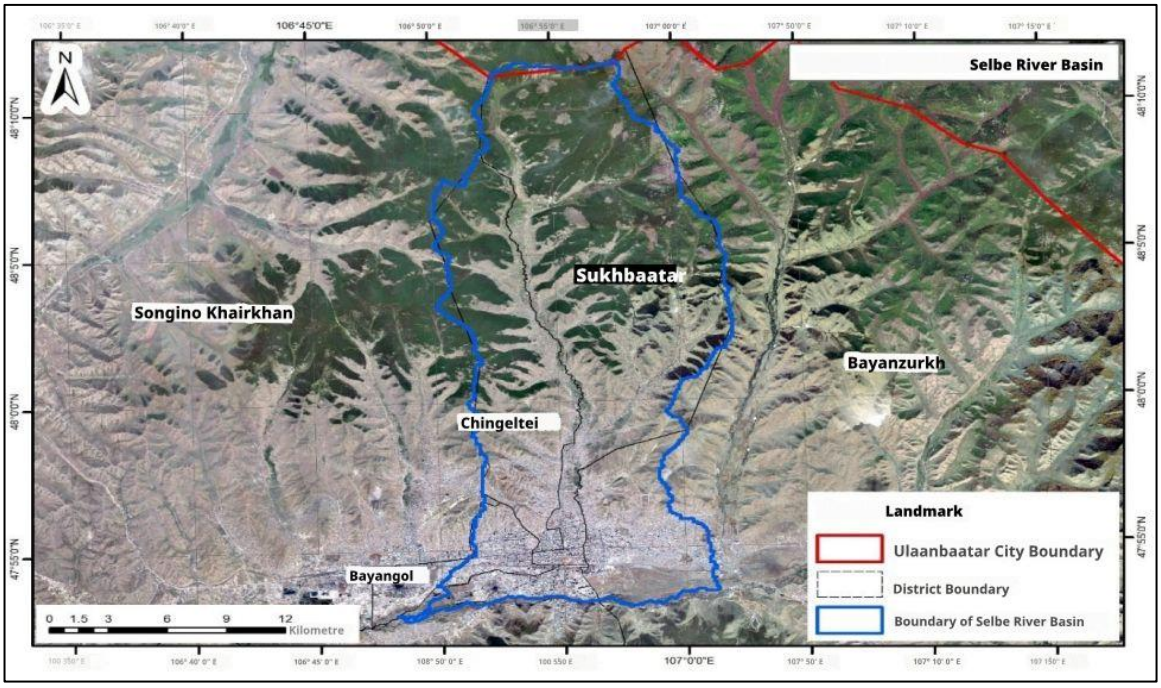
(1) Selbe River

4) Fundamental hydrographic characteristics of the river

The Selbe River originates at an elevation of 2000.0 m from the southern slope of Baga Mukhar Pass and its tributaries. The elevation at the confluence in the Tuul River valley is 1289.9 m. The difference in elevation between the source and the mouth is 710.0 m. The upper course of the river is termed the Bayan River, the middle course the Selbe River, and the lower course the Dund River. The valley of the Selbe River extends approximately 32 km and flows into the right bank of the Tuul River southeast of Ulaanbaatar City. The total area of the Selbe River basin is 498.0 km², including its tributaries, the Selbe and Damba rivers, which originate from the Baganuur branches. As a result of the flow from these tributaries, the river discharge substantially increases downstream of the main flow, causing the river channel to progressively widen and become more gradual. The average slope of the river is 3‰. The average width is 1.2 km, the narrowest section is 0.8 km, and the widest section is 2 km. More than ten tributaries converge on both banks of the Selbe River, forming the main flood channel. Among the major tributaries, the left bank includes the Ikh Bayan, Baga Bayan, Erenguu, Khangat, Baynbulag, Shargamorit, Godoi, Belkh, and Tömörzhuurkhudag rivers, while the right bank features the Harzan, Shar, Örgönt, Jigjid, Yargait, Shadivlan, Chingeltei, and Khailaas rivers, through various summer camp valleys crossed by the Selbe River.



Drawing 4. 1. Selbe River water accumulation area (K14+250)



Drawing 4. 2. Selbe River water accumulation area (K0+212)

The flow from the Selbe River’s spring snowmelt is not large but remains sustained for an extended period. Following the spring floods, the flow tends to stabilize, with water volume significantly increasing from July to September due to rainfall. Due to heavy rainfall, the flood event is brief, and the water recedes rapidly. In certain years, the daily rise of the river water level reaches 0.5 to 1.0 m. After September 20, the water level decreases sharply, entering the dry

winter season. Freezing begins at the end of October, with ice cover lasting approximately 150 days annually. During the winter season, the river channel freezes completely to the riverbed.

The historic maximum flow rates are as follows: in August 1959, the flow reached 45.0 m³/s; in August 1982, the water level rose to 250 cm and the flow reached 131.0 m³/s, which is nearly twice the multi-year average flow of the Tuul River.

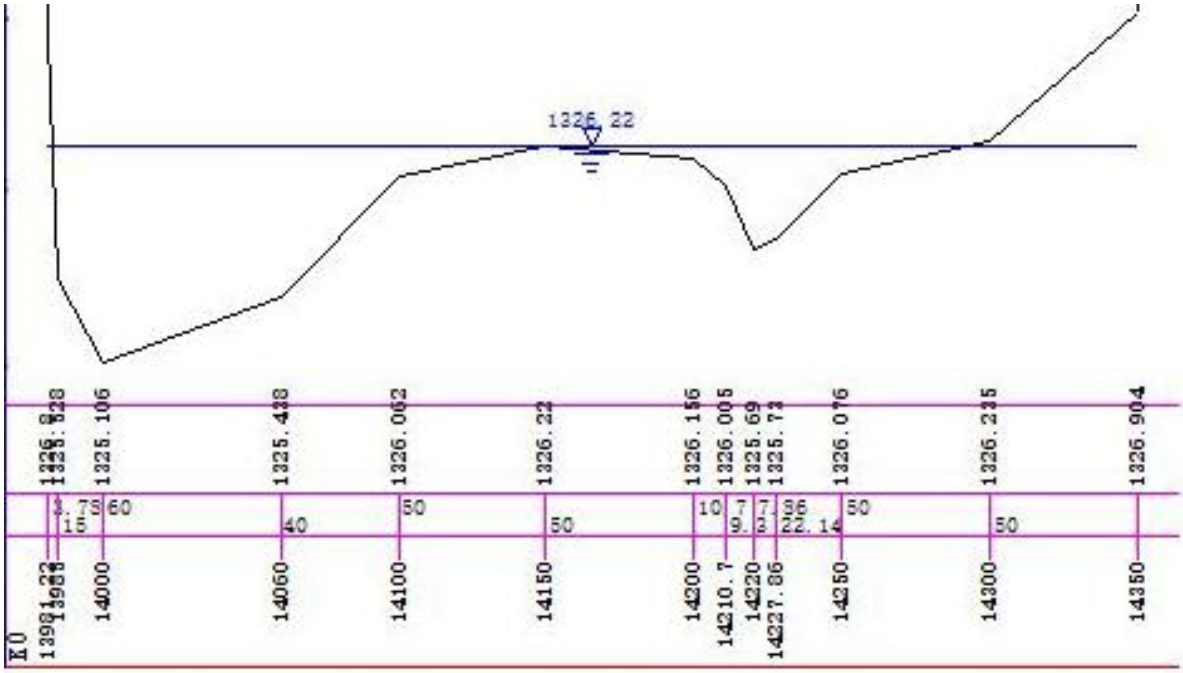
The annual distribution characteristics of the river flow are as follows: from November to March of the following year (dry winter season), it accounts for 9.5% of the annual flow; during the spring snowmelt period, it accounts for 25%; and during summer and autumn precipitation, it accounts for 65%.

The long-term average flow is 1.90 m³/s, with a flow module of 0.91 liters/second·km²; The maximum average flow rate is 12.1 m³/s, with the corresponding flow module of 43.8 liters per second per km².

According to the 'Hydrological Calculation Report,' this project bridges the Selbe River at the midstream section K14+250 and the downstream section K0+250. The catchment area and design peak flows are shown in the following table.

Table 4. 5. Basic Hydrological Parameters of the Selbe River

River	Road Crossing Mile	Drainage Basin Area (km²)	Design Flood Discharge (m³/s)			i (‰)
			1%	2%	5%	
Selbe River	K0+212	373	402	349.7	253.3	3
	K14+250	304.2	278.5	192.2	157.3	3



Drawing 4. 3Cross-Section of the River

The calculated 100-year flood level beneath the bridge is 1326.22 m. Pursuant to clause 1.21 of the "National Law on Road Traffic Safety" (NBRD 32-02-12), the scour bed elevation shall be no less than 0.5 m above the design flood level, specifically not less than 1326.22 + 0.5 = 1326.75 m. The minimum crown elevation in the design is 1335.385, which complies with the requirements.

(2) Determine the span length of the bridge.

Bridge length = 319 m. If the bridge span is designed as 11 spans of 30 meters each, the total length is 330 m. The bridge configuration of 11 × 30 m = 330 m > 319 m complies with the requirements.

(3) General calculation of the flow depth under the bridge

Following the calculation, the flow depth is 2.31 m. After the general scour of the main channel, the bed elevation of the main channel is established at 1326.22 - 2.31 = 1323.92 m.

(3) Calculation of flow depth in selected areas near the bridge piers

According to calculations, the flexural depth near certain sections of the bridge pier is 2.41 m, and the flexural height at certain sections is 1323.92 - 2.41 = 1321.51 m.

(4) Conclusion

The design flood elevation (BVT = 1326.22) of the Selbe River at the bridge construction site is 319 meters. At the 100-year flood level of 1326.22 m, the flow rate is 279 m^3 per second. The minimum bottom edge elevation of the girder in the design drawings is 1335.385, which complies with the requirements. The lowest elevation of the river channel is 1325.106 m, with the maximum water depth at the 100-year flood level being 1.114 m. The width of the water channel at the bottom elevation is 319 m. The bridge span design proposes an option with a length of 30 m and a width of 11 m, totaling 330 m in length. The local soil elevation near the foundation is 1321.51 m, and the pilastered level of the bridge foundation is planned to be 2.5 m below the soil elevation in some sections, i.e., at 1319.01 m.

(5) Others

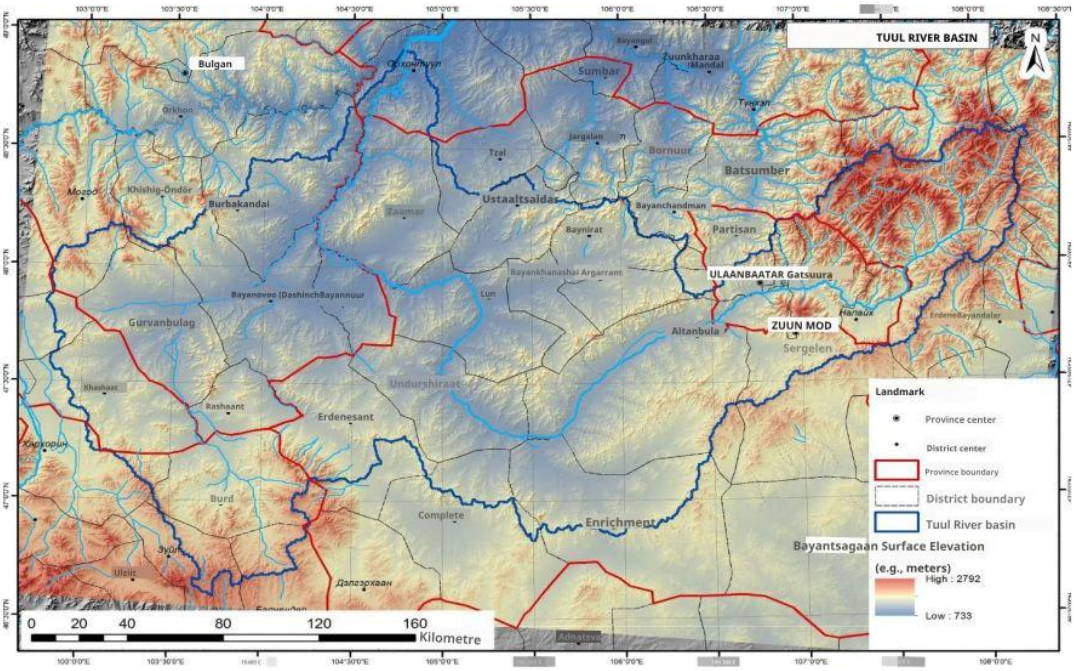
This project crosses the Selbe River downstream at chainage K0+212 using a continuous girder bridge with spans of (40+65+40) m, totaling 145 m to cross the river with a main span of 65 m. There is no support pier in the river, and since the culvert is higher than the existing bridge, hydrological calculations are not required.

(6) Tuul River

5) Fundamental hydrographic characteristics of the river

The Tuul River originates from the Nomin River, situated at an elevation exceeding 2200 meters in the Hangai-Khentii ridge, and from two source streams located on the southern slope of Shoroot Pass at an elevation of 2154 meters. The tributaries of the Tuul River include the Altai River, Saridag River, Khag River, Khongor River, Dunbalun River, Terelj River, Kherlen River, Uliastai River, and Selbe River within the Khentii mountain range.

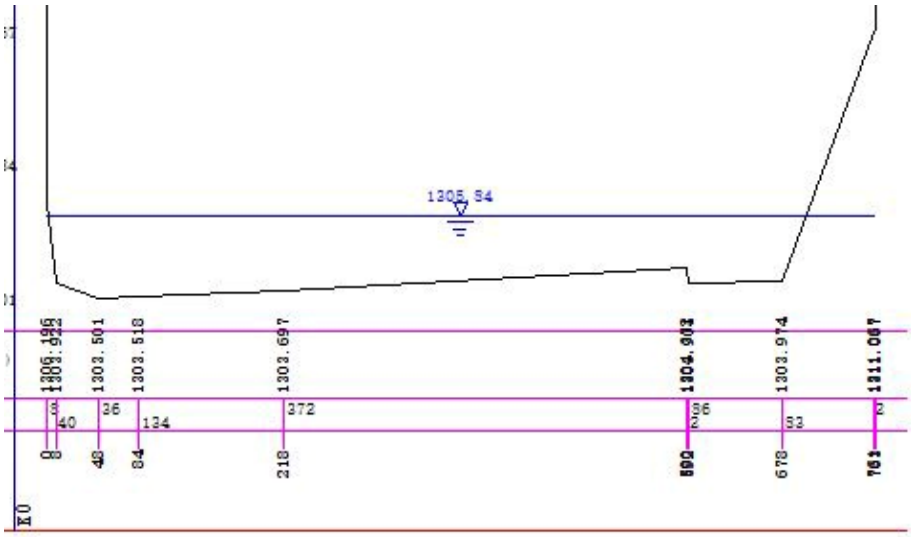
The Tuul River has a catchment area of 49,600 km², an overall length of 874 km, an average elevation of 1,474 m, an average gradient of 1.3‰, and constitutes 38 percent of the total area of the Orkhon River basin. It is the largest tributary on the right bank of the Orkhon River. Finally, it discharges into the right bank of the Orkhon River at 57°00′N, 104°47′40″E.



Drawing 4. 4Tuul River basin.

The average channel width of the Tuul River ranges from 35 to 75 m, with a depth of 0.8 to 3.5 m, a flow velocity of 0.50 to 1.50 m/s, and a riverbank height of 0.5 to 2.5 m. The average network density within the Tuul River basin is 0.39 km/km². Since 1945, long-term observation and research on water conditions have been conducted at the Tül River-Ulaanbaatar Observation Station; since 1985, at the Selbe River-Dambadarja; since 1994, at Serb-Sanzai; and since 1992, at the Uliastai River-Uliastai Observation Station. Based on the 2023 ULAANBAATAR CITY 'MASTER PLAN FOR URBAN ENGINEERING PREPARATION MEASURES,' the hundred-year flow rate of the Tuul River is 2994.3 m³/s.

(7) Determination of the flood level



Drawing 4. 5Cross-Section of the River

According to calculations, the flood level occurring once in 100 years under the bridge is 1325.84 m. According to Clause 1.21 of MNS 32-02-12 'Design of Motor Road Bridges and Culverts,' the bottom elevation of the deck girder shall be at least 0.5 m above the project flood level, i.e., no less than 1325.84 + 0.5 = 1326.34 m.

Conclusion

According to the project calculations, the bridge site at the Tuul River corresponds to a 100-year flood level of 1325.84 m and a 100-year discharge of 2994.3 m³/s. The final terminus of this project and the A, B, and C crossings at the Tulgyn intersection partially traverse the floodplain of the Tuul River, while the A, B, and C crossings connecting to the Tuul Expressway shall be subsequently adjusted in accordance with the design elevations of the Tuul Expressway.

4.4.12. Bridge Planning

(1) Standard and Technical Requirements

- **Road clearance:** Railway line ≥ 7010 mm; Urban road: ≥ 4900 mm; Conduit and water drainage pipe: ≥ 2500 mm
- Lane width: 3.75 / 3.5 m per lane
- Standard cross-sectional arrangement: For the steel truss bridge, the total width is 26.5 m, with the cross section constituted as follows: 0.5 m (protective barrier) + 12.25 m (vehicle lane) + 1.0 m (protective barrier) + 12.25 m (vehicle lane) + 0.5 m (protective barrier) = 26.5 m.
  The width of the steel cable-stayed bridge is 19.5 m; cross-section: 0.5 m (protective barrier) + 8.75 m (vehicle lane) + 1.0 m (protective barrier) + 8.75 m (vehicle lane) + 0.5 m (protective barrier) = 19.5 m.
- **Earthquake requirement:** The earthquake intensity is 7 to 8 on the scale, with peak ground acceleration of 0.15g to 0.20g.
- Flood frequency for bridge design: Bridge: 1/100; Stormwater drainage pipe: 1/50
- Warranty period: 100 years.
- Design safety classification: Grade 1;
- Environmental classification: Category I - The superstructure is designed for a Grade I environment (general conditions), while the substructure is designed for a Grade II environment (frost and thaw conditions).
- Estimated service life: The guaranteed service life of bridges on main roads and intersecting intersections is 100 years; overpasses: 50 years; Drainage pipes and culverts: 30 years; Guardrails, deformation indicator equipment, supports, and the like: 15 years.

(8) Design Drawing Technical Specifications

The technical specifications for the bridge works calculation in this project comply with the provisions of international regulations applicable to urban bridge design and utilize two limit state design methods: the load and resistance limit state, and the serviceability limit state.

Table 4. 6. List of Technical Specifications for Design Drawings

Work	Technical Description
Permanent Design Load	Refer to City Classification A for Lane Load
Temperature Load	-45°C ≤ T ≤ +45°C
Earthquake-Resistant Design	Time History Analysis or Response Spectrum Method
Superstructure	Main beam: Cast-in-place concrete box girder and precast prestressed concrete small box girder Intersection section: Cast-in-place concrete box girder and precast prestressed concrete small box girder
Type of bearing	Square bearing / rubber bearing for distributing horizontal forces
Substructure	Slab/Foundation: Prefabricated reinforced girder/frame support/direct support Foundation: φ1000 mm / φ1200 mm / φ1500 mm bored pile
Reinforcement	HRB400 or higher grade
Concrete	C50, C40, C35, C30, and others

Railway crossing section	Construction boundary: H = 7.0 m Distance between permanent structure and road centerline: L = 3.5 m
Road Intersection	Construction Boundary: H=5.2 m
Protective Barrier	Concrete Barrier

The materials used in this project planning must comply with the following standard.

Table 4. 7. Technical Specifications of Primary Materials for Bridge Design

Material	Area of Application	Standards and Technical Requirements
C50 Concrete	Cast-in-place concrete box girder Pre-stressed concrete small box girder Prestressed continuous girder	Modulus of elasticity 34,500 MPa Design axial compressive strength 22.4 MPa Design axial tensile strength 1.83 MPa
C40 Concrete	Frame support Rectangular support	Modulus of elasticity 32,500 MPa Design axial compressive strength 18.4 MPa Design value of axial tensile strength 1.65 MPa
C35 Concrete	Foundation slab Bridge abutment	Modulus of elasticity 31,500 MPa Design value of axial compressive strength 16.1 MPa Design value of axial tensile strength 1.52 MPa
C30 Concrete	Piled foundation	Modulus of elasticity 30,000 MPa Design axial compressive strength value 13.8 MPa Design axial tensile strength value 1.39 MPa
Hot-rolled ribbed reinforcing steel Reinforcement of grade HRB400	Total	Modulus of elasticity 210,000 MPa Design compressive strength value 330 MPa Design tensile strength value 330 MPa
Normative diameter φs15.2 mm Prestressed steel wire	Cast box girder spine Pre-stressed concrete small box girder Prestressed continuous girder	Standard compressive strength value 1860 MPa

Note: *The concrete strength grade is determined based on the standard compressive strength value of a 150 mm cube specimen.*

- Temperature load: According to climatic data for Ulaanbaatar City, the minimum and maximum temperatures are ±40℃. The Mongolian National Design Norms and Regulations (ВНбД32.02.03) employ identical technical specifications; therefore, the structural temperature load for this project is established at -40℃≤T≤40℃.
- Wind load: The maximum instantaneous wind speed in Ulaanbaatar City has been estimated at 30 m/s based on long-term data.

4.4.13. General Layout of the Bridge

The project includes the following **bridge structures**, namely:

- Five main directional bridges, with a total length of 9,034 meters and widths ranging from 19.5 to 45.5 meters; The structures comprise precast prestressed reinforced concrete box girders or cast-in-place prestressed box girders.
- 7 units of intersection ramp bridges, with a total length of 4730.8 meters, constructed with either precast or cast-in-place prestressed box girders.
- 2 units of at-grade auxiliary road bridges, with a total length of 60 meters, constructed with precast prestressed reinforced concrete box girders.
- 1 unit of line crossing bridge, 100 meters long and 13.5 meters wide, constructed with cast-in-place prestressed box girders.
- Furthermore, depending on the site conditions, 8 units of pipes and underpasses, and 3

units of pedestrian bridges are planned.

(1) Main Street Road Bridge Structure

1) Main Street Road Bridge No. 1

Main Street Road Bridge No. 1 is oriented in the north-south direction and intersects the existing bridges, main river, railway, and motor roads. When crossing the railway and existing bridges, continuous cantilever girders shall be employed, and for transverse road crossings, cast-in-place continuous girders without supporting columns shall be used. Standard sections for crossing main rivers and elevated bridges shall employ prefabricated prestressed concrete small box girder structures.

The starting point connects to the intersection of the Tuul Expressway and extends northward along the planned alignment. It passes over the existing bridge at chainage K0+212. The existing bridge is a reinforced concrete T-beam girder bridge with three spans of 18 meters each, crossing the mid-channel. (Lower section of the Selbe River) subsequently intersects with the existing motor roads. This design employs a cast-in-place continuous superstructure of (40+65+40)m for the existing bridge and motor road, and a continuous superstructure of (40+65+40)m for the planned motor road.

- The project crosses the Ulaanbaatar railway at stations K1+458 and K1+563.
- At point K1+458, a single-track railway with an internal combustion locomotive is located, where the railway embankment width is 4.5 meters and it intersects the project axis at an angle of 65 degrees.
- At point K1+563, a double-track railway with internal combustion locomotives is located, where the railway embankment width is 22 meters and the intersection angle is 88 degrees.
- The railway at these points is as follows:
- (30+45+30) meters,
- (30+50+30) meters will be crossed by a cast-in-place continuous reinforced concrete girder bridge of this length. Among these, the railway will be spanned by girders with main spans of 45 meters and 50 meters.

The first bridge extends backward and crosses Moscow Street at chainage K1+817. Moscow Street is a first-class main road, with plans to construct an underpass of meters in the future; it is not feasible to place bridge supports within the central median strip. This road comprises six lanes in two directions.

- Moscow Street will be traversed by a cast-in-place continuous box girder bridge spanning (45+70+45) meters.
- Subsequently, at station K2+275, a 12 m wide flood channel and the planned second-class, two-way, 4-lane road, measuring (45+65+45) m in length, will be crossed by a reinforced concrete bridge.
- Additionally, at station K3+021, Ard Ayush Street, a first-class, two-way, 6-lane road currently under construction, will be crossed by a (40+60+40) m reinforced concrete continuous girder bridge, and will subsequently connect to the road embankment as per the plan.

The first bridge crossing the existing road, bridge, and railway shall utilize prestressed reinforced concrete box girders. In other sections, precast prestressed box girders of 25 m and 30 m lengths shall be used. The total length of this bridge is 2951 meters, with a width varying between 19.5 and 45.5 meters.

2) Bridge 2 along the main street road

Bridge 2 along the main street road is located to the northeast of the project route. It intersects with the motor road under construction as well as with the existing roads. A continuous cast-in-place beam with few supports is employed for crossing the road. A continuous cast-in-place beam with few supports is utilized for curved sections with small radii and for bridge expansion segments. The bridge standard section shall utilize a prefabricated prestressed concrete small box girder structure. When crossing from the right side of the ring expressway, vehicles may pass unobstructed through the intersection on the right side of the ring expressway. The second bridge intersects the existing Bayankhoshuu Street road at sections K5+794 and K6+480. Bayankhoshuu Street is a two-way, four-lane, second-class main road. At the intersection, it employs (30+45+30) m and (27+40+27) m continuous cast-in-place concrete box

girders. The remaining section of the bridge utilizes 25 m ~30 m precast concrete small box girders. The bridge has a length of 1078 m and a width ranging from 26.5 to 37.9 m.

3) Bridge No. 3 along the main street

Bridge No. 3 along the main street is situated from west to east on the northern alignment of the road. The principal obstacles it spans are the main river and the road. A cast-in-place continuous beam with minimal supports is employed when crossing the road. A continuous cast-in-place girder with few supports is employed in the extension section of the high bridge. The standard section for crossing the main river and the elevated bridge utilizes a prefabricated prestressed concrete small box girder structure. A continuous cast-in-place girder measuring (35+50+35) m is utilized for crossing the existing Denjiin 1000 terminal road at chainage K12+620. The terminal road of Denjiin 1000 is a two-lane, second-class main road. Subsequently, at K12+720, it will traverse the tributary of the Selbe River. The tributary riverbed of the Selbe River intersects the planned route obliquely, with a width of 14 m and at an angle of 60 degrees.
Bridge No. 3 extends westward, employing a cast-in-place continuous box girder span of (30+40+30) m at section K13+232, crossing over Road No. 7. Road No. 7 is a first-class main road with four lanes in both directions. A (30+40+30) m cast-in-place continuous box girder is utilized to cross above the road at section K13+979 of the Sergelt project. The Sergelt project motor road is a two-way, two-lane, second-class main road. A (20+30+20) m cast-in-place continuous box girder is utilized to cross Dariekh Street at section K14+658. Dari Ekh Street is a two-way, second-class main road. Bridge No. 3 crosses the Selbe River between chainages K13+981 and K14+300. The Selbe River has a floodplain approximately 319 meters wide and is spanned by a 30-meter precast concrete small box culvert. Bridge No. 3 employs a prestressed reinforced concrete cast-in-place box girder with variable cross-sections where it intersects the existing road, and for the remaining span, utilizes precast concrete small box girders of 25 to 30 meters in length. The bridge is 2,315 m long and 26.5 to 42.9 m wide.

4) Four bridges along the main street road.

Bridge 2 along the main street road is oriented north-south and is positioned on the left side of the planned route. The principal intersecting obstacles are the railway and the motor road. A cantilever continuous main girder is utilized for crossing the railway, whereas a precast continuous main girder with small supports is employed for crossing the road. For sections of the high bridge with small-radius curves and widening segments, a pierless cast-in-place continuous box girder is used, whereas for standard sections spanning the main river and high bridge crossings, a prefabricated prestressed concrete small box girder structure is employed.
A (35+50+35) m cast-in-place continuous box girder is utilized to cross the road at K21+560, and a (35+50+35) m cast-in-place continuous box girder is employed to cross the road at K22+400. The forward extension employs a continuous (35+50+35) m cast-in-place reinforced concrete span to cross the Police College Boulevard at station K22+856. Police College Boulevard is a first-class arterial road comprising six lanes across two directions. Thereafter, it intersects several roads within the residential complex. At chainage K23+817, a continuous cast-in-place concrete box girder with spans of (30+40+30) m intersects the existing road, namely General 9th Street. General 9th Street is a second-class arterial road with two-way traffic and four lanes.
At section K23+874, the single-track diesel railway of Ulaanbaatar Railway, with an embankment width of 5.5 m, is crossed. The angle of intersection between the railway line and the alignment is 67 degrees. The planned 6.3 m wide road exceeds the existing one by embankment filling, ensuring an unobstructed connection. Bridge No. 4 crosses the existing motor road and the existing railway line, employing a prestressed concrete cast-in-place box girder with a variable section for the main span, while the remaining bridge girders use precast concrete small box girders with spans of 25 m and 30 m. The bridge is 2,570 m in length, with a width varying from 26.5 to 41 m.

5) Bridge No. 5 along the Main Street road

Bridge No. 5 along the Main Street road crosses the planned route at station K24+339. The planned road width is 23.75 m, with an intersection angle of 60 degrees to the planned road.

Bridge No. 5 employs a (35+50+35) m cast-in-place continuous main girder and is constructed using the post-tensioning method. The bridge is 120 m in length and 26.5 m in width.

Table 4. 8. Main Line Bridge Organizational List

Name	Structure	Support Span (m)	Extended (m)	Width (m)	Superstructure Construction Method
Main Line Bridge No. 1	Prestressed Concrete Cast-In-Place Girder + Prestressed Precast Concrete Small Box Girder	2×(40+65+40)+5×(3×30)+(40+65+40)+2×(3×30)+4×30+3×27+(30+45+30)+(30+50+30)+(3×30+31)+(45+70+45)+4×30+(2×30+25)+4×25+(45+70+45)+2×(4×30)+(3×30+28)+(2×28+2×30)+4×27.5+(40+60+40)	2951	19.5 ~ 45.5	Cantilever casting method + Casting method with small formwork + Installation of bridge erection machine
Mainline Bridge No. 2	Pre-stressed concrete cast girder + Prestressed Precast Concrete Small Box Girder	30+(30+45+30)+(3×25+30)+4×27+(27+3×26)+(2×26+25)+(2×25+2×30)+(30+2×27)+(27+40+27)+(2×25+30)+2×(3×30)	1078	26.5 ~ 37.9	Casting method with small formwork + Installation of bridge erection machine
Mainline Bridge No. 3	Prestressed Concrete Cast-In-Place Girder + Prestressed Precast Concrete Small Box Girder	2×(3×30)+(35+50+35)+(2×30+25+30)+4×30+3×(3×30)+(30+40+30+30)+2×30+3×26+2×26+3×30+2×(4×30)+3×30+(30+40+30)+4×(4×30)+4×30+(20+30+20)	2315	26.5 ~ 42.9	Casting method with small formwork + Installation of bridge erection machine
Mainline Bridge No. 4	Prestressed Concrete Cast-In-Place Girder + Prestressed Precast Concrete Small Box Girder	(5×30)+(35+50+35)+6×(4×30)+(35+50+35)+(4×30)+(3×30)+(4×30)+(35+50+35)+(3×25)+(4×30)+(5×30)+(3×30)+2×(4×30)+(5×30)+(1×25)+(30+40+30)+(2×30)	2570	26.5 ~ 41	Casting method with small formwork + Installation of bridge erection machine
Mainline Bridge No. 5	Prestressed Concrete Cast-In-Place Girder	35+50+35	120	26.5	Minimal support required for casting methods Casting method with small formwork

(2) Bridge with an intersecting intersection

For bridges with an intersecting intersection crossing transversely to the road, continuous cast-in-place girders with few supports are used. For small-radius curved sections and widening sections, continuous cast-in-place girders with few supports are employed. For large-radius curved sections, straight and equal-width sections, the structure of assembled precast concrete small box girders is utilized.

1) K1+090 PK upper and lower crossings

This bridge is planned to traverse the railway in Ulaanbaatar City. The traffic of the auxiliary road, planned at ground level, connects to the high bridge of the main line via a ramp (steep inclined road), crossing the railway entirely by bridge.

The bridge span (girder) structure comprises precast prestressed reinforced concrete box girders measuring 27 m and 30 m in length. The bilateral ramp bridges each have a length of 171 m and a width of 9 m.

2) Intersection of the New Ring Road and Ard Ayush Street

The intersection at point K3+054, connecting the under-construction Ard Ayush Street, is designed to link the high bridge on the main alignment of the New Ring Road with this street.

Vehicles traveling along Ard Ayush Street cross the ramp bridge to access the high bridge of the main line, while vehicles on the main line also utilize the ramp to exit to and enter this street. The bridge structure consists of precast prestressed concrete box girders measuring 27 m and 30 m in length; the ramp bridges on both sides are each 87.5 m long, and the bridge width is 9.0 m.

3) New intersection on the right side of the Second Ring Road

The intersection on the right side of the Ring Expressway is primarily established to connect the Second Ring Road (main line K6+366) and Bayankhoshuu Street (main line K5+794, K6+480) with a high bridge on the main line. Vehicles on the main line bridge proceed via exit A to exit C, then enter the route for the second lane change; vehicles on the second lane-change route enter exit C via exit B, subsequently accessing the main line bridge; The S crossing is configured to combine the A and B crossings; The vehicle performing a second lane change turns right at the D crossing towards the main line bridge, whereas the vehicle on the main line bridge turns directly to the E crossing and enters by switching to the second lane. The length of the bridge at Exit A is 370 m, with a width ranging from 6.25 to 10 m; it is constructed using prestressed cast-in-place concrete box girders and cast-in-place concrete box girders. The length of the bridge at Exit B is 257 m, with a width ranging from 7.05 to 10 m; it utilizes prestressed cast-in-place concrete box girders and cast-in-place concrete box girders. The bridge deck consists of precast prestressed concrete box girders, cast-in-place concrete box girders, and assembled precast prestressed concrete small box girders. The bridge is 303 m in length and 20.5 m in width. The D route bridge measures 130 m in length, with a width ranging from 6.25 m to 10.5 m, employing prestressed concrete small box girders. The length of the E-grade bridge is 225 m, with a width of 10 m, constructed of prestressed concrete small box girders.

4) New intersection on the left side of the Second Ring Road

This intersection is intended to connect the main line bridge with the Second Ring Road (station K20+835 on the main line). The Second Ring Road turns left and right via the A-grade road, leading to the main line overpass, where vehicles traveling on the main line turn right at the E-grade crossing to enter the Second Ring Road. The A ramp is a bridge 240 m in length and 20.5 m in width, constructed with prestressed concrete cast box girders and assembled prestressed concrete small box girders. The D ramp and the E ramp are single-span bridges with a width of 12 m.

5) Intersection with Highway No. 7

This bridge is primarily installed as a transmission conduit connecting to the main line of Highway 7 (K13+232 main line). The left side of the main line connects to Highway 7 by merging exit roads B and C into exit road A; The left side of the main line connects to Highway 7 by merging exit roads E and F into exit road D. Section A employs a cast-in-place concrete box girder, with a bridge length of 100 m and a width of 17.5 m. Section B features a bridge length of 155 m, a width of 9 m, and employs a cast-in-place concrete box girder. Section C employs a cast-in-place concrete box girder, with a bridge length of 243 m and a width ranging from 8.05 to 8.35 m. Section D uses a cast-in-place concrete box girder, with a bridge length of 120 m and a bridge width of 17.5 m. On slope road E, the bridge length is 180 m, and the bridge width is 9 m, utilizing a cast-in-place concrete box girder. On section F, the bridge length is 188 m, and the bridge width varies from 8.01 m to 8.3 m, employing a precast concrete cast-in-place box girder.

6) Intersection with Police Academy Avenue

This is designed to connect the main line bridge with Police College Avenue (K22+856 main line). Vehicles B and D access the service road via crossings at Police College Avenue, then proceed to the main line bridge. Vehicles on the main line enter the service road via entrances A and C, then proceed to Police Academy Boulevard. The bridge length employs assembled precast prestressed concrete small box girders, constructed by crane lifting. This includes interior entrance A, 240 m in length and 9 m in width; Exit B is 270 m long and 9 m wide; Exit C is 270 m long and 9 m wide; Exit D is 240 m long and 9 m wide.

7) Intersection with the Tuul Expressway

The primary objective is to connect the planned route to the Tuul Expressway. The Tuul Expressway merges exits B and C into exit A, which connects to the planned route. This includes Route A road, which is 358 m in length and 20 m in width, utilizing precast reinforced concrete box girders. Route B road is 194 m in length and 10 m in width, utilizing cast-in-place reinforced concrete box girders. Route C road is 241 m in length and 10 m in width, utilizing cast-in-place reinforced concrete box girders.

Table 4. 9. List of Bridges with Intersections

Bridge Name	Ramp	Structure Type	Span Arrangement (m)	Length (m)	Width (m)	Construction Method
Bridges Connecting the K1+090 Intersection	B Ramp	Prestressed Precast Reinforced Concrete Box Girder	3×30 + 3×27	171	9	Crane assembly
	C Ramp	Prestressed Precast Reinforced Concrete Box Girder	3×30 + 3×27	171	9	Crane assembly
Intersection of the New Ring Road and Ard Ayush Street	B Ramp	Prestressed Precast Reinforced Concrete Box Girder	2×30 + 27.5	87.5	9	Crane assembly
	C Ramp	Prestressed Precast Reinforced Concrete Box Girder	2×30 + 27.5	87.5	9	Crane assembly
New ring road and Second Ring Road (West) Intersection	A Ramp	Cast-in-place reinforced and plain concrete box girder	6×20 + 5×18 + (20+30+20) + (4×18 + 18.5)	370	6.25–10	Cantilevered casting
	B Ramp	Cast-in-place reinforced and plain concrete box girder	3×20 + (2×20 + 18) + (20+30+20) + (18 + 3×17)	257	7.05–10	Cantilevered casting
	C Ramp	Hybrid structure combining cast-in-place and precast elements	(2×19 + 20) + (20+30+20) + 4×25 + 3×25	303	20.5	Cantilevered casting with crane assembly
	D Ramp	Prestressed Precast Reinforced Concrete Box Girder	2×25 + 30 + 2×25	130	6.25–10.5	Crane assembly
	E Ramp	Prestressed Precast Reinforced Concrete Box Girder	3×(3×25)	225	10	Crane assembly
New Ring Road and Second Ring Road (East) Intersection	A Ramp	Reinforced Composite Prestressed Box Girder Constructed On-Site	(1×30) + (30+45+45+30) + (2×30)	240	20.5	Cantilevered casting
	D Ramp	Frame Bridge	1×12	12	12	Simply Supported Cast
	E Ramp	Frame Bridge	1×12	12	12	Simply Supported Cast
New Ring Road and Road No. 7 Intersection	A Ramp	Cast-in-Place Reinforced Concrete Box Girder	5×20	100	17.5	Cantilevered casting
	B Ramp	Cast-in-Place Reinforced Concrete Box Girder	(18.2+21) + (2×18 + 20) + 3×20	155	9	Cantilevered casting
	C Ramp	Cast-in-Place Reinforced Concrete Box Girder	(20 + 22.8) + 2×(5×20)	243	8.05–8.35	Cantilevered casting

	D Ramp	Cast-in-Place Reinforced Concrete Box Girder	2×(3×20)	120	17.5	Cantilevered casting
	E Ramp	Cast-in-Place Reinforced Concrete Box Girder	(19.7 + 20.5) + 4×20 + 3×20	180	9	Cantilevered casting
	F Ramp	Cast-in-Place Reinforced Concrete Box Girder	(21.6 + 22) + 4×21 + 3×20	188	8.01–8.3	Cantilevered casting
Intersection of the New Ring Road and Police Academy Avenue	A Ramp	Prestressed Precast Reinforced Concrete Box Girder	2×(4×30)	240	9	Crane assembly
	B Ramp	Prestressed Precast Reinforced Concrete Box Girder	3×(3×30)	270	9	Crane assembly
	C Ramp	Prestressed Precast Reinforced Concrete Box Girder	3×(3×30)	270	9	Crane assembly
	D Ramp	Prestressed Precast Reinforced Concrete Box Girder	2×(4×30)	240	9	Crane assembly
Intersection of the New Ring Road and Tula Expressway	A Ramp	Cast-in-Place Concrete and Reinforced Box Girder	3×20 + (30+45+30) + 2×(3×20) + (3×18 + 19.3)	358	20	Cantilevered casting
	B Ramp	Cast-in-Place Reinforced Concrete Box Girder	(3×18) + 3×20 + 4×20	194	10	Cantilevered casting
	C Ramp	Cast-in-Place Reinforced Concrete Box Girder	(2×20 + 20.7) + 3×(3×20)	241	10	Cantilevered casting

(3) Service Bridge

The service road crosses the Selbe River tributary at chainage K12+720; consequently, the tributary's width is 14 m, and the service road bridge is divided into left and right sections.

Table 4. 10. Planning List of the On-Ground Auxiliary Road Bridge

Name	Location	Structure Type	Support Span (m)	Extended (m)	Superstructure Construction Method
K12+720 On-Ground Auxiliary Bridge	Left Auxiliary Road	Precast Concrete Small Box Girder	1×30	30	Erected by Crane
	Right Auxiliary Road	Precast Concrete Small Box Girder	1×30	30	Erected by Crane

(4) Transverse Linear Bridge

An overpass has been installed at section K8+586.927 of the planned alignment. The existing road width is 13.2 m, with an intersection angle of 37 degrees relative to the planned road.

Table 4. 11. Schedule of Cross-Linear Bridge Arrangements

Name	Location	Structure	Support Offset (m)	Length (m)	Superstructure Methodology
Transverse Linear Bridge	Intersection point with the existing road at K8+586.927	Precast prestressed reinforced concrete	4×25m	100	Cast using the minimal formwork method

		box girder			

(5) Pedestrian bridge, underpass

Following the route implementation, pedestrian overpasses and underpasses shall be provided to ensure access for residents on both sides of the road.

Table 4. 12. List of Overpass and Underpass Planning

Overpass Underpass	Location	Structure Type and Function	Length (m)	Superstructure Construction Method
Pedestrian Bridge	K3+600 PK	2-32 m Precast Concrete Overpass	3.5	Cast in situ with Minimal Reinforcement
Pedestrian Bridge	K7+500 PK	2-32 m Precast Concrete Overpass	3.5	Cast in situ with Minimal Reinforcement
Pedestrian Bridge	K17+200 PK	2-32 m Precast Concrete Overpass	3.5	Cast in situ with Minimal Reinforcement

Table 4. 13. List of Trays and Underpass Sketches

Tray duct Underpass	Location	Structure Type and Function	Primary construction method
Water Drainage pipe	K2+303.3	2-5.0×5.0 m reinforced concrete box culvert	Concrete casting with bearing wall (abutment)
Intersection crossing	K4+600	1-4.0×3.0 m reinforced concrete box drainage channel	Casting by anchoring method
Intersection crossing	K11+124	2-5.0×5.0 m reinforced concrete box drainage pipe	Casting by anchoring method
Intersection Flood flow	K16+330	1-4.0×3.0 m reinforced concrete box culvert drainage pipe	Casting by anchoring method
Intersection crossing	K16+450	2-5.0×5.0 m reinforced concrete box drainage pipe	Casting by anchoring method
Intersection crossing	K18+750	2-5.0×5.0 m reinforced concrete box drainage pipe	Casting by anchoring method
Intersection crossing	K19+630	1-4.0×3.0 m reinforced concrete box culvert drainage pipe	Casting by anchoring method
Intersection Flood flow	K19+750	1-4.0×3.0 m reinforced concrete box culvert drainage pipe	Casting by anchoring method

A total of eight box culvert drainage pipes are provided as underpasses for channels. The main structure entirely employs cast-in-place reinforced concrete box culvert drainage pipe construction. The invert of the drainage pipe is generally designed with consideration of the natural ground level, minimizing excavation wherever feasible. Inlet and outlet passages for the water transmission pipes shall be selected from eight-shaped winged wall openings or straight wall openings, designed according to the characteristics of each water transmission pipe.

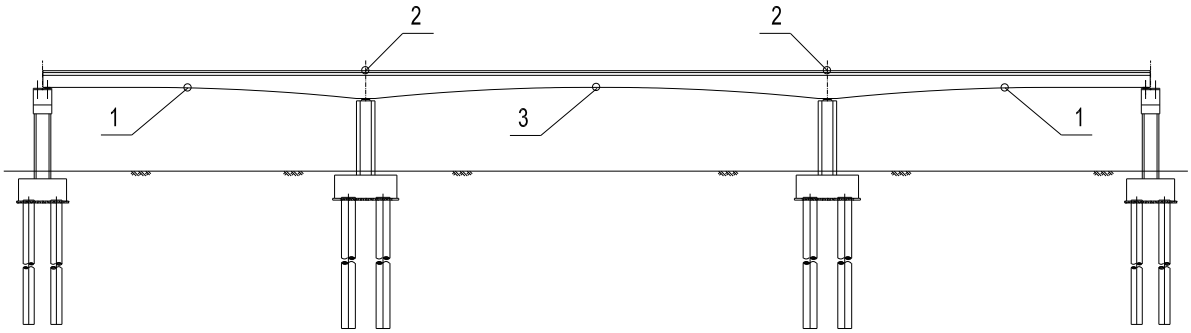
There are a total of three pedestrian bridges, utilizing precast concrete box girders for the superstructure. The bridge length is 2 × 32.0 m, amounting to 64 m in total, with a bridge width of 3.5 m. The stairs shall be constructed using reinforced concrete and be 2.5 m wide. Considering the distance between two persons using walkers, the slope shall be less than 8%. The slope is classified as 15.0 m for 4%-5%, 12.0 m for 5%-6%, and 9.0 m for 6%-8%, respectively. The platform length is 2.44 m, and the slope is constructed using anti-slip material. Handrails are installed on both sides of the staircase. The handrail consists of a double barrier with heights of 0.85 m and 0.65 m. Markings shall be applied at the beginning and end of the handrail to assist visually impaired persons.

4.4.14. Results of the superstructure design

The design of the bridge superstructure's permanent state shall calculate the load capacity of components in compliance with ultimate limit state requirements and verify the crack resistance of components according to serviceability limit state requirements.

For this project, the design of the pre-stressed box girder for cantilever casting assumes that the entire cross-section of the box girder remains under compression in the serviceability limit state, with no tensile stress permitted. The pre-cast concrete box girder and pre-stressed small box girder connected by anchorage are comprised of Class A components; that is, under serviceability limit conditions, tensile stresses in the cross-section are allowed provided they do not exceed the designed tensile stress value, and the formation of cracks is strictly prohibited.

For the variable cross-section box girder, classical control sections shall be selected for verification in the calculations. Specifically, 1 - the lower edge of the middle portion of the side span, 2 - the upper edge of the central support point, 3 - the lower edge of the middle portion of the intermediate span.



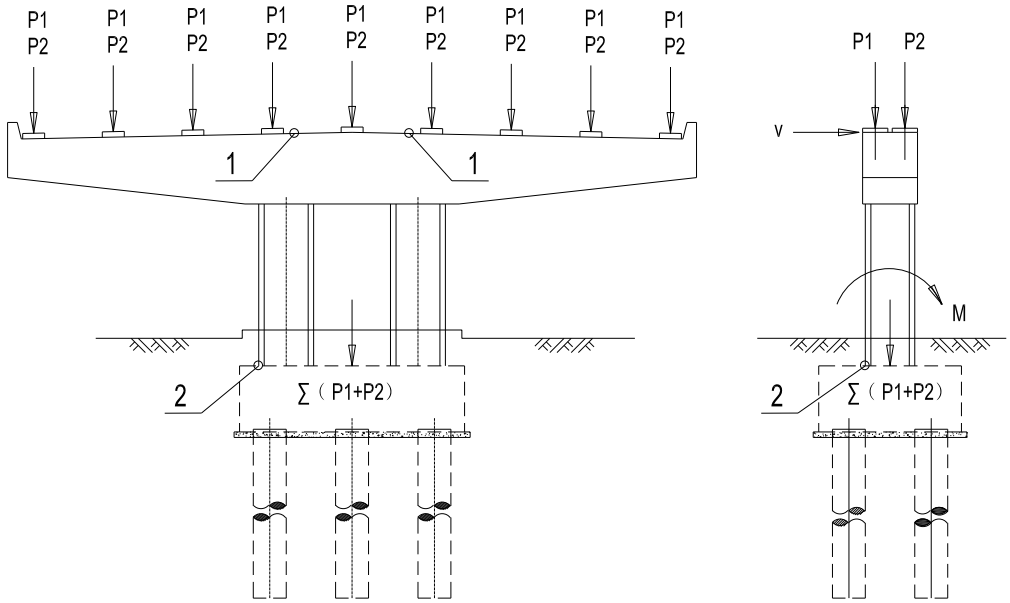
Drawing 4. 6. Schematic diagram of control points for the variable cross-section box girder.

4.4.15. Results of the Superstructure Calculations

The design of the bridge foundation structures shall calculate the component capacities in accordance with the ultimate limit state requirements and verify the component resistances in accordance with the serviceability limit state requirements. In this project, the precast stringer is designed as a Class A component, and in accordance with normal serviceability design, tensile stresses are permitted to develop in the stringer cross-section; however, these tensile stresses shall not exceed the calculated tensile stress values. The bridge pier is designed as reinforced concrete, and although the cross-section of the foundation permits hairline cracks to ensure proper operational performance, the crack width does not exceed the specified limit. For the precast girder and bridge piers, control sections were re-checked in the calculations, specifically: 1- the upper edge of the girder at the pier location, 2- the lower position of the rectangular pier, 3- the lower position of the frame pier.

(1) Calculation results of the precast crossbeam

The precast crossbeam contains 15.2 mm diameter prestressed steel strands. HRB400 reinforcement bars with a diameter of 28 mm, spaced at 120 mm intervals, are uniformly arranged at the top of the crossbeam; HRB400 reinforcement bars with a diameter of 25 mm, spaced at 120 mm intervals, are uniformly arranged at the bottom of the crossbeam. The clamp diameters are 20 mm, with a spacing of 100 mm.

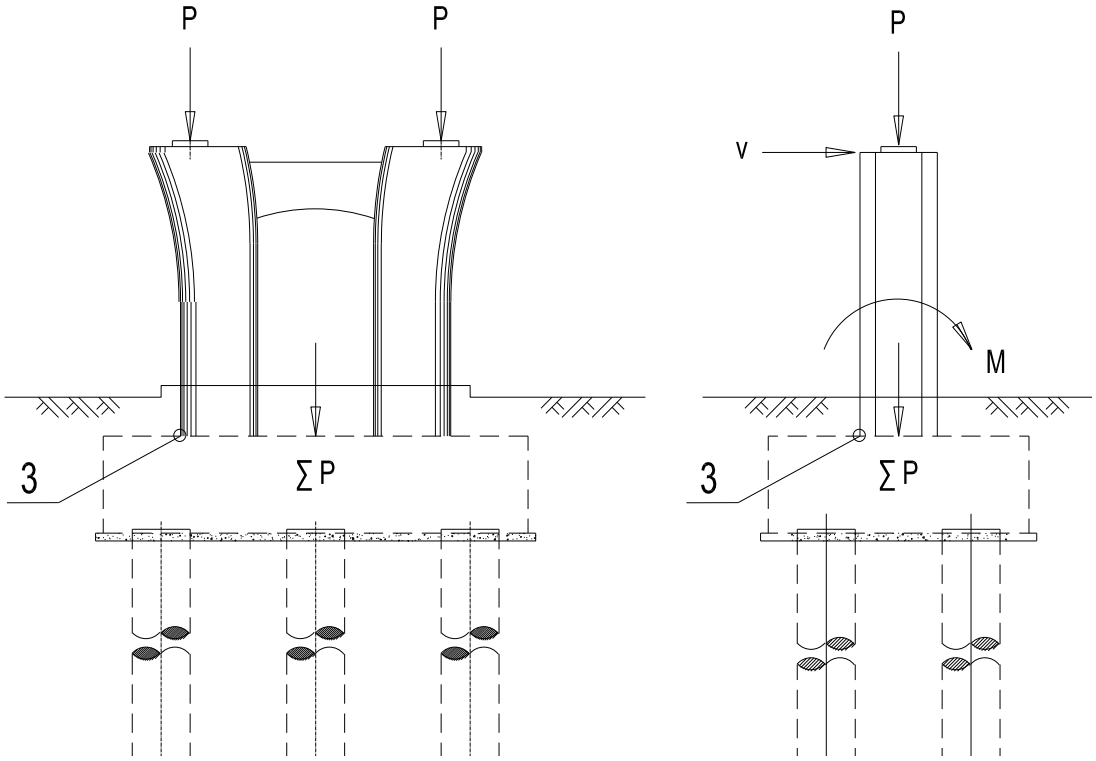


Drawing 4. 13. Load diagram of the prefabricated cross beam.

According to the calculation results, the ultimate load-bearing state of the prestressed cover cross beam, as well as the serviceability states necessary to ensure normal operational performance, comply with the technical requirements.

(2) Results of foundation calculations

HRB400 steel reinforcement with a diameter of 25 mm and spacing of 100 mm shall be uniformly arranged along the main body of the foundation, encompassing the rectangular footings and frame foundations; Stirrups with a diameter of 14 mm, spaced at 100 mm intervals.

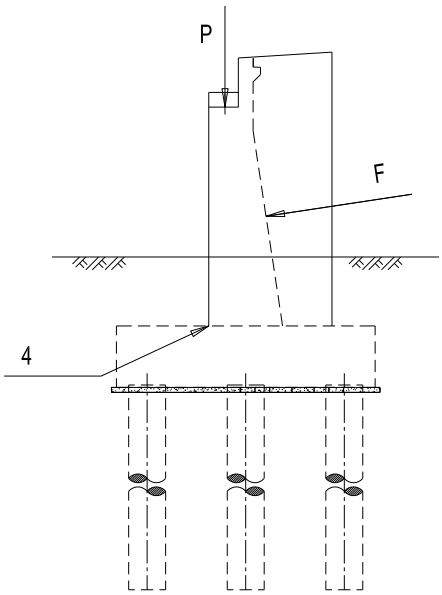


Drawing 4. 16. Stress diagram of the frame foundation

According to the calculation results, the bridge piers comply with the technical requirements for both the ultimate load-bearing state and the normal operational serviceability.

(3) Results of foundation calculations

Grade HRB400 structural reinforcement is uniformly arranged around the bridge pier body, with a diameter of 12 mm and a spacing of 150 mm; The clamp has a diameter of 10 mm and a spacing of 150 mm.



Drawing 4. 17. Load-bearing force diagram of the bridge support

The calculation results demonstrate that the support complies with the technical requirements for both the ultimate limit state and the serviceability limit state.

(4) Calculation of foundation bearing capacity

1) Determination of the physical and mechanical properties of the soil

According to geological survey data, the layers are as follows.
Ⅰ layer soil: Embankment fill, yellow-brown, thickness: 2.0 m, base settlement depth of the layer: 2.0 m;
Ⅱ layer soil: Water-saturated sandy gravel layer, yellow-brown, thickness: 11.0 m, base settlement depth of the layer: 13.0 m;
Soil of the III layer: Plastic gravel layer, yellow-brown, thickness: 2.0 m, foundation pit excavation depth at the layer bottom: 15.0 m;
Soil of the IV layer: Water-saturated sandy gravel layer, yellow-brown, thickness: 3.5 m, foundation pit excavation depth at the layer bottom: 18.5 m;
Soil of the V layer: Soft plastic silty gravel layer, light yellow, thickness: 8.7 m, foundation pit excavation depth at the layer bottom: 27.2 m;
Ⅵ soil layer: Hard silty gravel layer, light yellow, thickness: 3.3 m, embedment depth of the layer base: 30.5 m;
Ⅶ soil layer: Hard clayey gravel layer, yellowish brown, thickness: 5.5 m, embedment depth of the layer base: 36.0 m;
Ⅷ soil layer: Sandstone, grey-green, thickness: 6.0 m, embedment depth of the layer base: 42.0 m.

2) Calculation Results

The foundation diameter of the prefabricated spine standard section is 1200 mm, with the spine length of 40 m. Twenty-eight HRB400 reinforcement bars, each 25 mm in diameter, are uniformly arranged around the main body of the spine with a spacing of 115 mm between bars. The stirrups, 12 mm in diameter, are arranged as circular reinforcement with a spacing of 100 mm.

The diameter of the foundation of the cast girder support is 1500 mm, the length of the girder is 45 m, and 32 pcs. of HRB400 grade reinforcement with a diameter of 25 mm and spacing of 130 mm are uniformly arranged around the girder’s main body; the stirrups have a diameter of 12 mm and are arranged as circular reinforcement with spacing of 100 mm.

Calculation results indicate that the vertical compressive capacity of a single girder foundation, as well as the ultimate limit state and serviceability limit state capacities, comply with the technical requirements.

4.4.16. Planning Adapted to Frost Conditions

This project is located within a seasonally frozen soil zone with a frost depth ranging from 2.5 m to 3.5 m, pursuant to the 'Preliminary Geotechnical Investigation Report for the New Ring Motor Road Exploration Works in Ulaanbaatar City' (hereinafter referred to as the Preliminary Investigation Report). The superstructure is designed for a category I environment (general environment), while the substructure is designed for a category II environment (frost heave environment).

(1) Calculation Principles

- Control of Expansion and Settlement: This is primarily aimed at preventing or reducing settlements and differential settlements caused by frost heave that affect the building structure.
- Ensuring foundation stability: The foundation shall be capable of withstanding load variations caused by frost heave and thaw cycles, as well as ice loading when located near water.
- Ensuring structural integrity: The structural design shall accommodate or resist limited deformations to prevent cracking and operational damage.
- Enhance the strength and durability of materials and structures to resist severe environmental conditions such as freezing and thawing.

(2) Fundamental calculation parameters

- Primary selection and design drawings

Utilize the pile foundation with stepped base form, embedding the pile tip into a stable layer at a depth exceeding the maximum frost penetration. Position the pile tip within the bearing layer (e.g., bedrock or dense gravel layer) to prevent frost formation inside the pile and to mitigate the weakening effects of lateral frost. The increased frost heave force and the weight of the cap can also resist the typical frost force (uplift force). Furthermore, during the freezing process, the increased frost in the soil surrounding the peg generates an additional downward force (negative frictional resistance) on the peg; consequently, the negative frictional resistance has been duly accounted for in the design drawing.

- High-precision design drawing

This project is designed to accommodate uneven foundations by implementing simple supports followed by continuous simple supports, then continuous or continuous structural bridge decks; selecting bearings capable of accommodating large displacements; utilizing expansion devices that are resistant to large displacements, low temperatures, and provide excellent waterproofing; and reinforcing drainage channels and drainage structures to reduce the number of expansion joints and enhance adaptability.

- Material Selection

For this project's material selection, concrete resistant to freeze-thaw cycles was utilized, with strict control of the water-cement ratio, incorporation of high-quality air-entraining agents, and an increase in the thickness of the protective layer over reinforcement bars in accordance with the project's technical requirements.

- Design drawing of the drainage system

A well-organized and unobstructed drainage system for the bridge deck (including longitudinal slope, cross slope, and drainage pipes) is planned. The drainage system utilizes a combination of longitudinal and transverse drainage pipes. Rainwater is collected longitudinally along the bridge support and conveyed to the soil drainage system; drainage holes are provided every 5 meters longitudinally near the protective barrier to prevent collision. The drainage pipe uses Φ200 PVC pipe. Rainwater on the auxiliary bridge deck flows along the transverse slope of the deck, discharging into drainage channels intermittently located within the isolating zone railings, and then flows through drainage iron pipes into the river beneath the bridge.

- Backfill After the Platform

Strict control shall be exercised over backfill materials, and frost-resistant, impermeable materials (such as sand, gravel, etc.) shall be used for platform backfilling. The use of frost-susceptible soil (such as silt, clay, etc.) is strictly prohibited. Compaction and densification within each layer shall comply with the requirements specified in the technical specifications.

- Work Quality Control

1) Construction during extremely cold winter and spring thaw periods should be avoided; if unavoidable, the technical requirements for winter construction—including preheating of materials, thermal insulation, maintenance, and monitoring of formwork temperature—must be strictly adhered to, ensuring that concrete is protected from frost damage before achieving its essential strength.
2) Protection of foundation soil: If the foundation cannot be poured immediately after excavation, effective measures must be implemented to prevent the foundation from freezing, soaking, and softening (such as covering with thermal insulation materials).
3) Control of backfilling: When backfilling with frost-free materials, the materials must not be frozen, and the compaction process must meet the specified requirements.

4.4.17. Earthquake- resistant Design

(1) Selection of earthquake-resistant design standards

According to the earthquake design standard of Mongolia, BNbD22.01.01/2021, the MSK seismic intensity is classified into levels 7, 8, and 9, which defines the required seismic measures during the development of construction design drawings and establishes the energy level necessary. The probability of exceeding seismic vibrations within 50 years is as follows:
10% probability (corresponding to a 475-year return period) – basic design seismic intensity;
2% probability (corresponding to a 2475-year return period) – rare earthquake intensity.
The relationship between exceedance probabilities and return periods across different standards is presented in the following table.

Table 4. 14. Exceedance probabilities and return period provisions in various standards

Earthquake parameters	Seismic intensity	Rare seismic intensity		
	Probability of exceedance exceeded	Return duration	Probability of exceedance exceeded	Return duration
Earthquake parameters of Mongolia design standard	50 years, 10%	475 years	50 years, 2%	2475 years
International earthquake design standard	50 years, 10%	475 years	50 years, 2%	2450 years

Considering the legislation and more detailed provisions such as the flexibility of the lower sections, earthquake isolation model, and fall protection shielding model, the earthquake design for this bridge project has been prepared in accordance with relevant standards and regulations.

(2) Ground acceleration

Table 4. 15. Correlation between basic seismic intensity and peak acceleration at varying exceedance probabilities of earthquake motion (50-year design reference period)

I_0 Basic intensity/level	Peak ground acceleration at varying exceedance probabilities				
	63.2%	10%	3%	2.5%	2%
6	0.017g	0.050g	0.082g	0.088g	0.095g
7	0.034g	0.100g	0.161g	0.172g	0.186g
7.5	0.048g	0.143g	0.231g	0.246g	0.265g
8	0.068g	0.200g	0.316g	0.336g	0.361g
8.5	0.096g	0.288g	0.451g	0.478g	0.513g
9	0.136g	0.400g	0.612g	0.647g	0.691g

When using the response spectrum method for analysis, the fundamental calculation acceleration (corresponding to a 10% probability of exceedance in 50 years) is employed as the unit value, and the peak ground acceleration for earthquake motion at other exceedance probabilities within the 50-year reference period can be determined by proportional correlation. The adjustment coefficients for peak ground acceleration of different fundamental intense earthquake motions may be determined by the calculated ratios presented in the following table.

Table 4. 16. Ratio of peak ground motion acceleration at various exceedance probabilities (50-year design reference period)

I_0 Basic intensity/level	Peak ground acceleration at varying exceedance probabilities				
	63.2%	**10%**	**3%**	**2.5%**	**2%**
6	0.342	1.000	1.641	1.757	1.907
7	0.342	1.000	1.615	1.752	1.865
7.5	0.336	1.000	1.607	1.714	1.850
8	0.342	1.000	1.581	1.681	1.808
8.5	0.335	1.000	1.567	1.663	1.784
9	0.342	1.000	1.532	1.620	1.729
Average value	0340	1.000	1.591	1.693	1.824

(3) Structural stability analysis

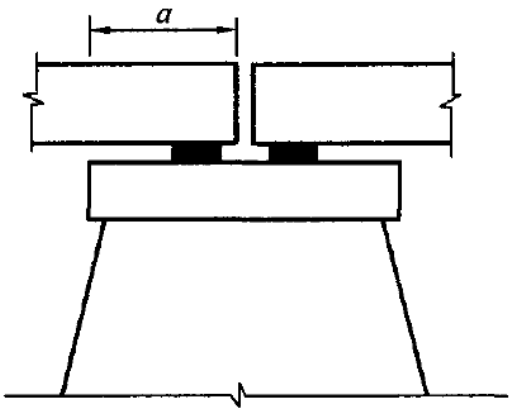
To ensure the seismic conceptual planning stability of bridges, the following three principal measures are primarily implemented.

- Symmetrically arranged along the bridge alignment;
- All directional restraint systems of the bridge exhibit symmetrical, precise, and balanced load transfer mechanisms;
- The cross-section of the bridge foundation is either rectangular or circular, with the earthquake impact force clearly defined.

(4) Measures to reinforce earthquake-resistant design

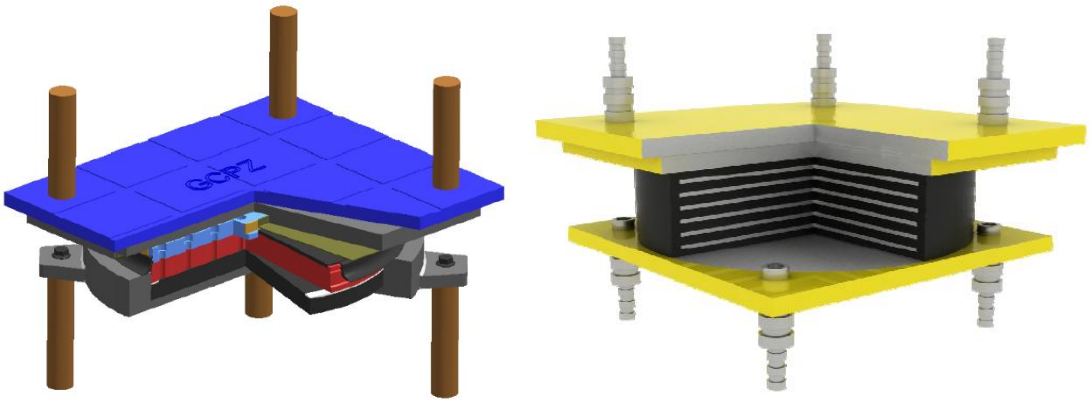
The following primary measures are implemented to strengthen earthquake design planning to ensure that the bridge structure maintains a defined capacity to resist earthquakes.

- The volumetric ratio of reinforcement in the outer clamp of the potential plastic hinge region of the support shall be no less than 50% of the volumetric reinforcement ratio in the dense stirrup area of the plastic hinge.
- To prevent excessive lateral displacement of the main girder, a transverse cover is applied to the transverse girder.
- The overlapping width of the main beam and the support body is the minimum distance from the end of the main beam to the edge. $a \geq 70 + 0.5L$ is reached.



Drawing 4. 7. Schematic diagram of the minimum overlapping width.

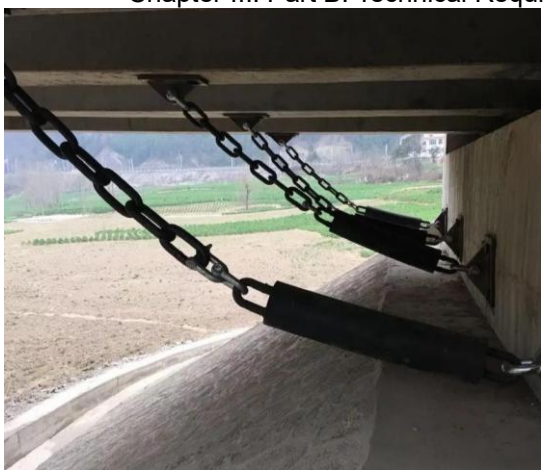
- To absorb shocks and limit the displacement of the main beam, rubber pads or other elastomeric mats are installed between the main beams and between the main beam and the support breast wall.
- The main transmission pipeline incorporates the design concept of a "seismic-resistant bridge" in the earthquake design drawings. To mitigate the seismic impact on the main transmission pipeline during an earthquake, this design employs shock-absorbing tank-type bearings installed on cast box cross girders, along with rubber bearings that dissipate horizontal forces on prefabricated prestressed reinforced concrete small box cross girders. This measure effectively reduces the forces on the support, controls the relative displacement between the main girder and the support’s apex, and enhances the overall durability of the bridge.



Bearing support Rubber horizontal bearing support

Drawing 4. 8. Earthquake-resistant bearing

- For bridges located within the anchorage strength zones of 7 degrees and above, limit devices have been installed along the bridge’s longitudinal axis to control the relative displacement between the support and the girder. Commonly used limiting devices are illustrated in the drawing below.



Limiting device of steel plate Equipment to render the connection limit flexible

Drawing 4. 9Limiting device

4.4.18. Work methodology

To expedite the project construction, reduce the construction duration, and enhance efficiency, the bridge construction works must commence simultaneously. The fundamental procedure for bridge construction is as follows: relocation of underground utilities, land clearance and demolition within the road planning boundary, construction of the road for the worksite, erection of bridge structures' abutments (foundations, lower sections, upper sections, bridge deck system, etc.), followed by embankment construction, landscaping, and installation of road signs and markings.

For each bridge structure within this project, please refer to the construction plan below according to the terrain and road conditions as presented in the following table.

Table 4. 17. Superstructure Construction Plan

Road Section	Work Methodology
Precast Concrete Small Box Girder	Method of crane lifting combined with bridge erection machine assembly
Cast bridge overpass on the main line requiring flow underneath during construction, section of the service road	Cantilever method and casting with limited supports
Simple section of cast continuous bridge on the main line; sections with low traffic beneath the bridge during construction works	Casting with full supports or with limited supports

4.4.19. Construction of the substructure

Within the project scope, the bridge structure is predominantly planned to be constructed in situ, employing traditional dry-land construction methods for the infrastructure. Based on the geological survey report and soil geology, various piling excavation technologies are utilized, and the pile caps are constructed by reducing the slope or excavating support pits. The pier is constructed using the classical cast-in-place method.

4.4.20. Design of auxiliary structures

Auxiliary bridge structures primarily include collision protection barriers, noise insulation screens, bridge deck surfacing, bridge deck drainage channels, piers, and temperature expansion joints.

4.4.20.1. Concrete Protective Barrier

The road classification of the bridges constructed within the project scope corresponds to urban main roads, primary transit routes, and sloped bridges utilizing concrete barriers.

4.4.20.2. Noise Barrier

According to noise insulation performance, noise barriers are classified as absorptive, reflective, or composite absorptive types. According to their form, they can be classified into two main types: arched and straight flat shapes.

Drawing 4. 10. Noise barrier schematic diagram

This project is situated on a main road with a high traffic load within the city; therefore, the design requirements for the noise barrier screen are stringent, necessitating due consideration of both noise reduction effectiveness and landscape requirements. The use of noise-absorbing sound insulation screens causes considerable damage to the landscape and is currently rare on urban roads. Although noise insulation-type screens are designed to be light and transparent, sound reflections significantly impact upper floors and they do not effectively reduce noise. Therefore, it is unsuitable for use in areas with multi-storey buildings. The hybrid noise-absorbing and noise-insulating screen is based on the two aforementioned primary types, combining their respective advantages, and is currently widely applied on urban roads. Therefore, this model recommends the use of hybrid noise-absorbing and noise-insulating screen solutions.

As stated in the Environmental Impact Report, noise barriers are employed at noise-sensitive locations along the road alignment. The noise barrier is installed on elevated external road barriers.

4.4.20.3. Bridge Deck Pavement

The total thickness of the prefabricated concrete small box girder bridge deck pavement for the main line and access roads is 20 cm, comprising from top to bottom: 4 cm of AC-13 fine asphalt concrete with pcs. (SBS modified) + 6 cm of AC-25 coarse asphalt concrete with pcs. + a waterproofing layer, beneath which is a 100 cm cast-in-place concrete layer. Prefabricated concrete small box girder surfacing layer.
The total thickness of the cast-in-place box girder bridge deck on the main alignment is 18 cm, from top to bottom: 4 cm of AC-13 fine asphalt concrete with pcs. (SBS modified) + 6 cm of AC-25 coarse asphalt concrete with pcs., plus a waterproofing layer, and an 8 cm layer of C40 grade cast-in-place concrete cast integrally as the cast-in-place concrete deck.
The total thickness of the wearing course of the auxiliary bridge deck is 20 cm from top to bottom: 4 cm AC-13 fine graded asphalt concrete (SBS modified) + 6 cm AC-25 coarse graded asphalt concrete + a waterproofing layer, and a 10 cm C40 cast-in-place concrete layer reinforced with a precast concrete layer. Concrete small box girder.

The total thickness of the transverse linear bridge pavement is 20 cm and is constructed from top to bottom as follows**:**

- **4 cm thick AC-13 fine graded PCS asphalt concrete (SBS modified)**
- **6 cm thick AC-25 coarse graded PCS asphalt concrete**

- **Waterproofing layer**

Beneath the asphalt concrete pavement of the precast prestressed reinforced concrete box girder **A 10 cm thick C40 grade concrete layer cast in situ is planned.**

4.4.20.4. Bridge Drainage Channel

The drainage system utilizes a combination of longitudinal and transverse drainage pipes. To collect longitudinal rainwater towards the bridge supports and direct it to the soil drainage system, drainage holes shall be provided longitudinally at 5 m intervals near the obstacle of the accident. The drainage system utilizes Φ200 PVC pipes.

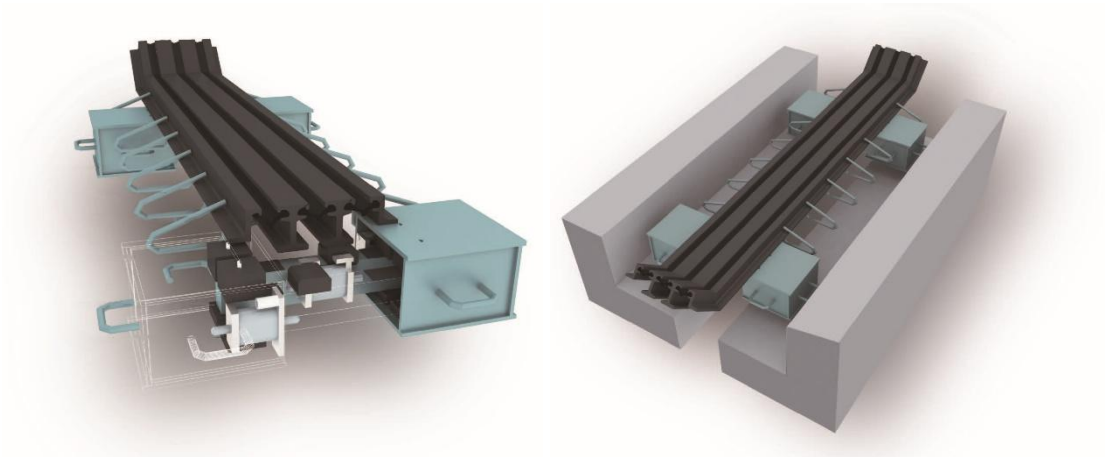
Rainwater on the auxiliary bridge deck flows along the transverse slope of the deck, intermittently passing through the drainage channel located within the median strip of the isolation zone, and subsequently discharges into the river beneath the bridge via a metal drainage pipe.

4.4.20.5. Bearing Support

The precast concrete small box girder utilizes rubber bearings to disperse horizontal forces, whereas the cast-in-place continuous main girder employs pot-type shock-absorbing bearings.

4.4.20.6. Temperature Indication

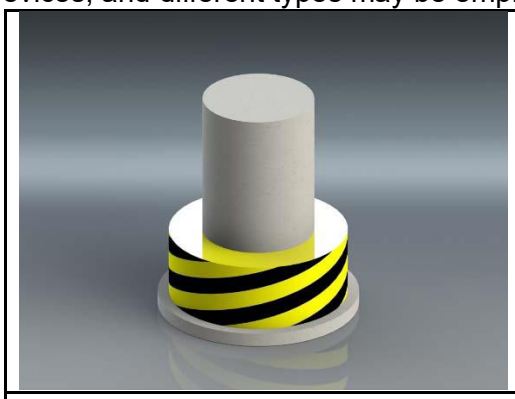
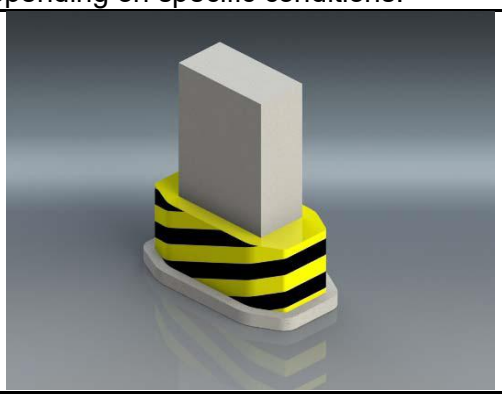
The bridge expansion joint is designed as a modular expansion joint, employing two models: D80 and D120.

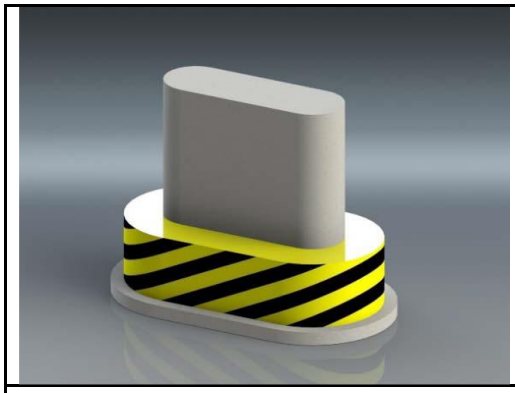
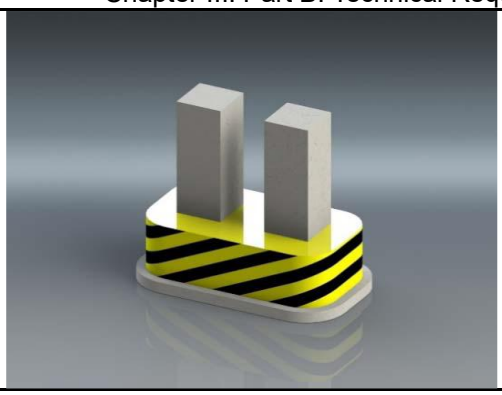


Drawing 4. 11. 3D drawing of the temperature indicator

4.4.20.7. Protective isolation measures

The supports located on the isolation strip shall be equipped with collision-resistant isolation devices, and different types may be employed depending on specific conditions.

	
Wheel stopper	**Rectangular barrier**

	
Elliptical barrier	**Double diaphragm barrier**

Drawing 4. 12. Multi-stage composite material energy dissipation and protective barrier equipment

4.4.21. Structural stability design of bridge structures

Located within a zone of seasonally frozen soil with a frost depth ranging from 2.5 m to 3.5 m. The superstructure is designed for a category I environment (general environment), while the substructure is designed for a category II environment (frost heave environment). The standard design service life of the structural drawings is 100 years. The main structure (principal duct spine, supports, slab) has a planned service life of 100 years. Protective barriers, pedestrian walkways, drainage facilities, temperature sensors, and expansion joints have a service life of 15 years and are replaceable components.

(1) Design of Concrete Structure Durability

In determining the corrosion resistance and durability of concrete structures, it is imperative to consider the operational conditions and environmental context, and to select corrosion-resistant, impermeable structures with suitable structural form, design, and high-quality concrete, supported by a well-founded construction plan and appropriate construction measures. This model outlines specific requirements for the selection of concrete raw materials, including fundamental proportional parameters such as the water-to-cement ratio, thereby ensuring that the concrete exhibits impermeability, volumetric stability, and resistance to cracking.

Cement: Portland cement or ordinary Portland cement shall be used, with the composite material consisting of slag or ash. Rapid-hardening cement shall not be used.

Aggregates: The fine aggregate shall have a suitable grading, be uniform and hard in texture, exhibit low water absorption, and possess low porosity; it shall consist of clean natural medium to coarse river sand particles. Artificial sand produced by a specialized unit may also be used. Sea sand is prohibited. Coarse aggregate shall be clean, crushed stone with an acceptable gradation, good particle shape, uniform and dense texture, and a low coefficient of linear expansion. Crushed stone containing sand shall not be used.

Moisture reducer: A suitable water-reducing agent significantly enhances concrete workability, reduces heat of hydration, lowers the internal temperature of the concrete, and delays the temperature peak.

Annex: The addition of a suitable concrete admixture prevents early shrinkage cracks, crawling, and excessive porosity in the concrete.

Structural measures are as follows:

1) The design must be simple and clearly visible, avoiding sharp edges and corners. The structural form, arrangement, and configuration shall be designed to prevent the accumulation of water, moisture, and harmful substances on the concrete surface. The structural form shall be suitable for the compaction and maintenance of concrete during the construction process and shall mitigate stress concentrations and limiting pressures arising under load.
2) Reliable drainage design
3) A durable waterproofing layer shall be established between the concrete bridge and

pavement structure layers.

4) To minimize construction defects, the minimum thickness of the protective layer for both ordinary reinforcing bars and prestressed reinforcement shall be increased.
5) The concrete grade shall be appropriately increased.
6) The calculated crack width on the concrete structure surface for this bridge shall be controlled at 0.2 mm.
7) The concrete structure surface has been coated. The concrete coating provides both protective and decorative functions. This bridge utilizes an anti-corrosion coating on the concrete surface in combination with the landscape design, with the finishing system specified based on the landscape design.

(2) Concrete Work Supervision

1) Prior to concrete casting, preliminary testing to select the concrete mix in accordance with the design drawings and construction process requirements shall be conducted. The characteristics of the concrete structure, construction environment, and service conditions must be taken into account to establish the quality control requirements for the entire construction process and for each construction joint, as well as the quality assurance measures. To inspect and enhance the concrete work process, the technology for concrete pouring in critical structures must be validated.
2) When casting concrete in hot weather, measures shall be taken before pouring to reduce the temperature of the formwork, reinforcement bars, and the adjacent air temperature. The temperature of the concrete entering the formwork shall not exceed the ambient air temperature and shall not surpass 30 °C.
3) During the curing period, the maximum temperature within the concrete shall not exceed 65°C, and the temperature difference between the curing water on the concrete surface and the concrete surface temperature shall not exceed 15°C. The difference between the maximum internal temperature and the surface temperature of the concrete structure or component at any hardening stage shall not exceed 20°C. During the concrete curing process, if the temperature difference between the ambient air and the surface exceeds 20°C, the concrete surface must be covered with an insulating layer.
4) At the time of formwork removal, the temperature difference between the base concrete and the surface concrete, as well as between the surface concrete and the ambient air, shall not exceed 20°C. Effective measures shall be implemented to prevent cracking during concrete placement in hot, windy, and dry conditions.
5) During the casting of large concrete volumes, such as foundation slabs, careful temperature control and crack monitoring must be ensured.

(3) Design of the structural integrity of steel elements

Steel structures constitute one of the principal construction materials utilized in engineering structures. The durability of steel, if not protected against corrosion, is highly susceptible to deterioration. Steel structures must be subjected to appropriate corrosion protection measures to ensure normal functionality throughout the design service life. Currently, measures for protecting steel structures against corrosion primarily involve mechanical isolation methods, that is, the use of specific materials to prevent corrosion by isolating the surface of the protective coating from aggressive substances such as water and oxygen. The other method involves artificially enhancing the protective capacity of the corrosion protection material based on the principle of a micro battery, thereby positioning it at a higher potential pole and ultimately achieving the intended protective effect.

1) Corrosion protection paint

The corrosion protection system applies a coating to the surface of the steel structure using materials that exhibit strong adhesion, corrosion resistance, and micropenetration, such as chlorinated rubber, acrylic acid, polyurethane, epoxy asphalt, and epoxy powder. The surface of the steel structure is isolated from the external environment, thereby eliminating the impact of external environmental factors and ensuring protection against corrosion.

2) Spray painting of steel

The metal spraying protection system typically comprises a sprayed metal layer and a sealed coating. The metallic coating generally consists of zinc, aluminum, or a zinc-aluminum alloy. This process involves applying molten zinc, aluminum, or their alloys onto the surface of fabricated steel structures by flame spraying or arc spraying methods. A dense, uniform thin layer forms on its surface. This metal coating functions both as a mechanical seal for the structure and as local sacrificial anode protection. Metal paint generally serves only as a primer in the protective coating system, and its surface requires a dense coating, an intermediate paint layer, and a topcoat. Therefore, the costs are relatively high.

The two aforementioned steel girder coating systems are widely used for domestic steel bridges. For this project, corrosion protection coatings represent a simple process with a flexible and user-friendly structure, low cost, ease of repair in case of damage, and excellent adaptability to the shapes of components. With recent advances in corrosion protection technology, the project employs coating protection systems designed to provide a service life of 20 years or more.

To reduce operational loads and comprehensively address economic factors, it is recommended to apply the following long-term corrosion protection system for the steel structures of this project: two layers of epoxy zinc-rich primer at 2 × 40 μm, two layers of epoxy intermediate iron oxide coating, and two layers of 240 flux coating at 2 × 35 μm.

5. Tunnel

5.1. Tunnel dimensions and requirements

This project features a single separate tunnel, which is a long tunnel.

(1) The detailed tunnel arrangement is presented in the following table.

Table 5. 1Tunnel table

No.	Name	Starting and ending chainage numbers	Extended (m)	Tunnel classification	Construction restrictions (m)	Type of pipeline Slope (%)	Lighting	Ventilation
1	New ring road tunnel	K8+730–K10+810	2080	Class I	14×5	0.95%，-0.99%	LED lighting	Mechanical ventilation

The tunnel of the New Ring Motor Road is approximately 1434.37 m in length, commencing at entrance marker K8+730; the exit manhole is numbered K10+810 with a design elevation of approximately 1423.29 m. The longitudinal slope within the tunnel extends over 2080 m with gradients of 0.95% and -0.99%, featuring an inverted slope profile. The maximum excavation depth is approximately 80 m.

5.2. Geological Description of Tunnel Works

(1) Geological Conditions

The project encircles Ulaanbaatar City from the west to the east, passing through the northern part of the city, forming a loop that crosses various geomorphological features of differing origins, including basins and elevated terrain.

In the northern section of the ring road area, specifically near Chingeltei, Sharkhad, and the Dar-Ekh mountains, linear erosion conditions develop within small ravines and hollows between the mountains. In contrast, the Tuul River basin, gradually extending toward the southwestern and northeastern edges of the region, features flat terrain with minimal surface deterioration and flood damage conditions.

In the vicinity of the surveyed area, the surface soil and thickness of surface deposits are limited, comprising modern Quaternary alluvial (pQ1) hard and flexible brown and gray clayey deposits, gravelly deposits dominated by sandy stones, and clayey gravel deposits. Furthermore, the modern Quaternary alluvial (pQ1) deposits with low moisture content and water saturation consist of brown, yellowish-brown, and gray gravel layers distributed stratigraphically. According to geomorphology, the karstified sandstone of carbonate rocks is distributed in the elevated sections of the ring zone.

1) **Surface soil:** Brown soil containing plant roots with a thickness of up to 0.2 m.
2) **Foundation clay:** Modern Quaternary alluvial (pQ1) deposits comprising firm, plastic brown and gray clays.
3) **Clay-dominated gravel deposits:** Modern Quaternary colluvial slope deposits (dpQ1), comprising brown and gray clays with dominant gravel and exhibiting hard, soft, and plastic properties.
4) **Sand-dominated gravel deposits:** Modern Quaternary slope deposits (pQ1), consisting of brown-gray sands with low to saturated moisture content, dominated by sand gravel deposits.
5) **Diagenetic Sandstone:** Greenish-gray diagenetic sandstone originating from carbonate/sodium carbonate/cicty deposits.

(2) Hydrological Conditions

It has been determined that the groundwater level in the pits of the Tuul River valley along the survey area ranges between 2.5 and 3.5 meters. As of March 11, 2025, the groundwater is hydraulically connected to the Tuul River, and the seasonal groundwater level may increase by 1.0 to 1.5 meters. The chemical composition of the groundwater indicates a neutral environment, characterised by soft water containing significant quantities of compounds indicative of contamination. The composition corresponds to type II magnesium calcium bicarbonate. The water from this supply point meets the requirements of the standard 'Technical Conditions for Water Used in Concrete and Construction Mortar UST 3821:85'.

(3) Climatic conditions

The study area falls within Mongolia's ⅡB climatic zone of the mountainous steppe subregion and, similarly to other regions, is characterized by a continental extreme climate. This region is characterized by an extremely dry, cold, and severe climate with substantial precipitation, and soil and rock subject to deep freezing. As this tunnel section is entirely located within the permafrost zone, it must have a frost-resistant and thermally insulated design.

5.3. Selection of the tunnel

(1) Selection of the tunneling method alternative

According to the route planning discussions and investigations, the tunnel in this project is a long tunnel with a maximum foundation depth of approximately 80 m. There are no controlled structures within the main body of the tunnel, and there are few locations sensitive to environmental risks. The tunnel predominantly passes through a metamorphosed rock formation. The open cut method is initially excluded by combining the characteristics of common construction methods with adaptability to form.

Based on analysis and research, a comprehensive engineering and economic evaluation will be conducted in accordance with the project overview and the hydrogeological conditions of the Tunnel site, and the Tunnel will be constructed using the drill and blast method.

5.4. Tunnel cross-section design

The tunnel cross-sectional drawing must primarily comply with vehicle clearance requirements, while simultaneously accommodating the planning needs of various tunnel operational equipment

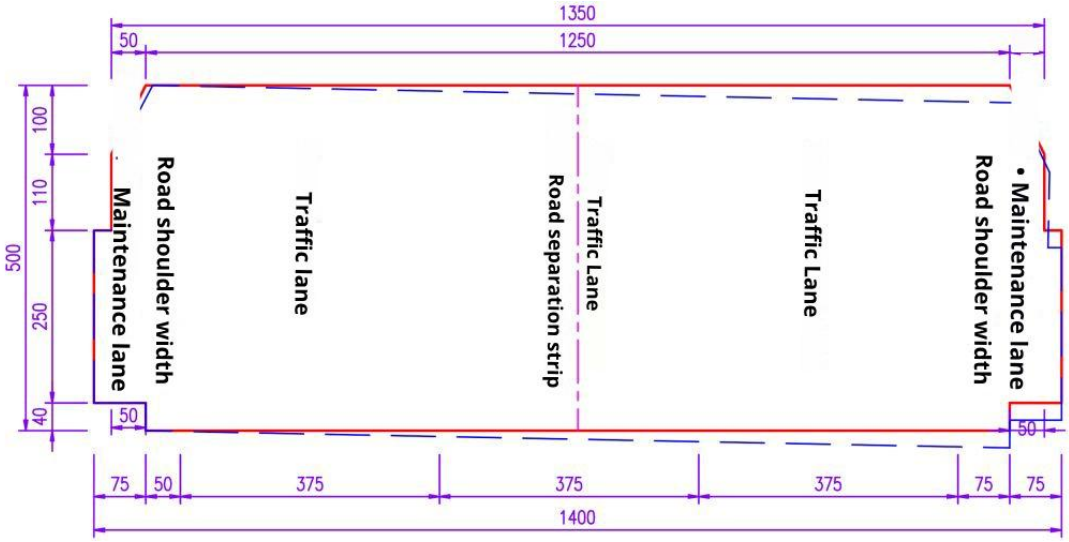
and accounting for construction tolerances. In accordance with the above principles, develop the schematic for the cleaning and operational equipment and define the Tunnel section. The arrangement of operational equipment shall not impede vehicle cleaning; to meet the process planning requirements of each piece of equipment; and also facilitate ease of maintenance.

(1) Construction restrictions

This Tunnel shall be designed in accordance with the first-class main motor road standard, allowing for a speed of 80-100 km/h.

The defined restriction width: 0.75 m (maintenance lane) + 0.5 m (side clearance) + 3 × 3.75 m (driving lanes) + 0.75 m (side clearance) + 0.75 m (maintenance lane) = 14.00 m;

Specified height limits: 5.0 m on the carriageway and 2.5 m on the maintenance road.

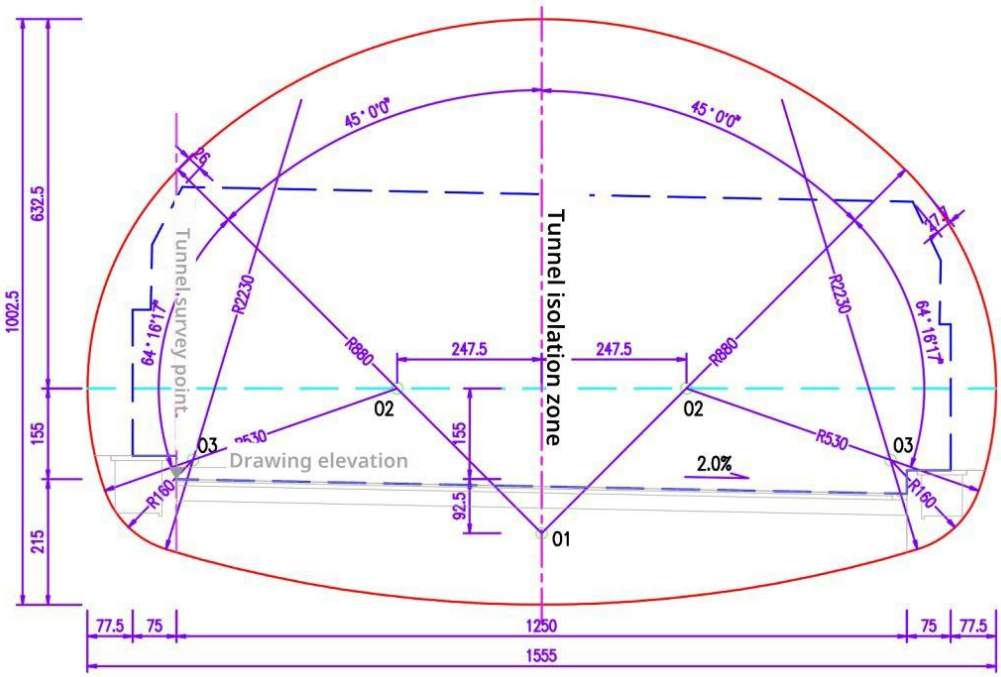


Drawing 5. 1. Cleaning of underpass construction for the new ring road of Ulaanbaatar City (unit: cm).

(2) Tunnel internal contour

The tunnel contour design drawing shall comply with the tunnel construction boundaries and accommodate the road surface, drainage facilities, and interior tunnel furnishing requirements. Furthermore, it shall provide space for installation of ventilation, lighting, fire protection, monitoring, and operational management systems, while taking into account surrounding rock deformation and construction methodology considerations.

This project adheres to the general conceptual design principles for the tunnel in accordance with the road conditions. The tunnel section comprises an invert arch door and a curved wall. The tunnel features a 'three concentric circles' section with a standard internal profile: the arch door and the side wall are connected by two arches; the side wall and the invert arch door are connected by a large-radius arch; and the invert arch door and the side wall are connected by a small-radius arch. The internal contour of the tunnel structure is as follows.



Drawing 5. 2. Internal profile of the tunnel on Ulaanbaatar City’s new ring road (unit: cm)

(3) Planning of a crossing

In compliance with the requirements of the “New Ring Motor Road Tunnel Design Drawing Volume 1: Building Engineering,” “Building Fire Protection Design,” and the “Regulations for Road, Railway, and Expressway Tunnels” (Tunnel Code for Expressways and Railways), as well as the “Railway Tunnel Regulations” (BND 32-07-10), the length of the motor road tunnel on Ulaanbaatar City’s new ring road is 2080 m, with 2 vehicular passages and 5 pedestrian passages.

Construction limits for vehicle crossings: 4.5 m clear width, 5.0 m clear height, vertical wall section.

Construction limits for pedestrian crossings: 2.0 m clear width, 2.5 m clear height, vertical wall section

5.5. Planning of tunnel construction works

5.5.1. Selection of Tunnel Type

(1) Type and Classification of Structure

A tunnel separated by a specific distance between two tunnels is classified into three types: small transparent tunnel with a narrow clearance, and continuous arched tunnel.

(1) Standards, , Rules, and Requirements

In accordance with the regulations for the design of tunnels on the new ring motor road, the specified distance between separated tunnels must be determined based on the principle that it does not adversely affect the structural integrity of the two tunnels, and must be established in conjunction with the tunnel cross-section, rock cross-section conditions, and rock cross-section parameters. Form dimensions, structural design drawings, construction methods, and requirements to be adhered to during the construction period. The clear distance between the two tunnels shall be 0.8 to 2.0 times the excavation width, with lower values applied under generally favorable surrounding rock conditions and higher values applied under generally unfavorable surrounding rock conditions.

The selection of the minimum separation distance for tunnels with standard spacing is closely related to geological conditions and tunnel spacing; however, factors such as excavation depth and ventilation during operation must also be comprehensively considered. When the excavation depth is substantial, the distance between two tunnels must consider the effects of ground stress, based on the principle that the two tunnels should not adversely affect each other. The minimum clearance distance between isolated tunnels in the as-built model is shown in the following table.

Table 5. 2. Reference Table for Double Tunnel Clearance Distance (m)

Tunnel Cross Section	Tunnel Length (m)	80% of the area is characterized by surrounding rock conditions		
		Ⅲ	Ⅳ	Ⅴ
Twin Carriageway Tunnel	≤200	5～10	8～12	10～20
	200～500	5～10	10～15	15～25
	500～1000	10～15	15～20	20～30
	≥1000	15～20	20～30	30～40
Three-Lane Tunnel	≤200	5～10	10～15	15～20
	200～500	10～15	15～20	20～30
	500～1000	15～20	20～30	30～40
	≥1000	20～30	30～40	40～50

If the tunnel length does not satisfy the aforementioned requirements, the use of small culverts or multiple arch tunnels is allowed.

When terrain conditions are relatively narrow, conventional isolated tunnel excavation is not feasible, or the installation of isolated tunnels substantially increases the scope of engineering works (including raised deck bridges and elevated bridge abutments). It is feasible to construct a challenging, small cleaning tunnel. The cleaning of the small cleaning tunnel must not be insufficient; otherwise, the structure between the two tunnels will significantly influence one another, resulting in construction difficulties and increased costs. The maximum feasible length and clearance of small-diameter tunnels may be referenced from the provisions in the following table.

Table 5. 3. Standard table of maximum feasible length and clearance for small-diameter tunnels

Tunnel Cross Section	Maximum feasible tunnel length (m)	Tunnel clearance (m)
Twin Carriageway Tunnel	750～1000	5～15
Three-Lane Tunnel	500～750	8～20

Note: *A lower value shall be adopted if geological conditions are favorable. High valuation will be granted under unfavorable geological conditions.*

An integrated roadbed may be employed at both ends of the arch tunnel, providing advantages such as land conservation, smooth connectivity, and reduced volume of connecting engineering structures; however, the construction of the arch tunnel is complex and incurs high costs. The primary factors of the arched tunnel are its horizontal alignment configuration and tunnel length. The arched tunnel length can be comprehensively determined based on geological conditions and the external project scope of the tunnel. The maximum permissible length may be referenced from the provisions of the following table.

Table 5. 4. Reference maximum lengths for multiple arched tunnels

Tunnel Cross Section	Maximum permissible tunnel length (m)	Tunnel Cross Section	Maximum feasible tunnel length (m)
Six-lane tunnel	400～750	Six-lane tunnel	300～500

Note: This table was developed considering economic efficiency and feasible construction timelines. If special requirements exist, the maximum values recommended in the table may be exceeded.

(2) Definition of structure type

If the experience of constructing mountainous tunnels domestically and internationally over the past several decades is consolidated and analyzed, generally, for long and extra-long tunnels, separated tunnels are preferable; For medium and short tunnels, smaller clear distances and continuous arched portals offer greater advantages.

Assuming suitable conditions for the three types of tunnels, the comparative list is as follows.

Table 5. 5. Comparative table of the three types of tunnel structures

Structural form	Simple isolated tunnel	Double-arched tunnel	Arched tunnel
3D			
Minimum spacing between two openings	（1.5～5.0）B	3m–1.5B	
Width	(2.5–7.0)B	2B + (3m–1.5B)	2B + 3m
Wire installation difficulty	Larger	Smaller	Smaller
Assembly difficulty	Smaller	Medium	Larger
Duration	t	1–1.5t	2–3t
Project Cost	M	1.1M	1.3–1.5M
Quality control difficulty	Easier	Medium	Difficult
Explosive vibration	Essentially no control	<10–20 Centimeters/s	<10 Centimeters/s
Environmental protection	Steep slopes may occur in narrow mountainous sections	Lower slope in narrow mountainous terrain	Lower slope in narrow mountainous terrain
Usage conditions	Various types of tunnels	Short or medium-length tunnels with favorable surrounding rock conditions	Short Tunnel
Note: B denotes the width of a single tunnel. T denotes the period required to construct a separate, independent tunnel of equal length, and M represents the cost of the isolated tunnel gate.			

The tunnel length of the new ring motor road in this project is approximately 2080 m. Based on current geological survey data and on-site observations of mountain orientation, and considering tunnel length, surrounding rock classification, tunnel environment, construction challenges, construction duration, cost, and other parameters, it is recommended to use isolated (partially short-span) tunnels for the new ring road tunnel.

5.5.2. Planning of Tunnel Entrances and Exits

The design of tunnel portals must comprehensively consider multiple factors, including

geographical location, topography, geological conditions, stability of excavation slopes, waterproofing, drainage facility requirements, portal illumination, and environmental protection landscaping. In accordance with the fundamental principle of 'Entering the tunnel early and exiting from the tunnel face,' it is necessary to minimize excavation at both the portal and rear slopes to ensure slope stability. Accordingly, the portal structure shall be simple, aesthetically pleasing, and spacious, and shall be consistent with the terrain of the tunnel entrance. The primary forms of portals are cut-and-cover, straight-cut, and end-wall types. The foundation of the tunnel portal must be structurally verified. Should this fail to satisfy the portal requirements, surface grout or void grout bonding shall be employed to reinforce the layer and enhance the foundation’s load-bearing capacity. During the construction and assembly phase, geological conditions shall be further defined, and various treatments shall be applied to the tunnel portal in accordance with the tunnel’s geological features. The portal shall be designed in accordance with principles of economy and practicality, considering the surface terrain, landform, and location; the entrance shall be arranged to integrate cable ingress and control facilities with the entrance finishing.

Drawing 5. 3. Existing condition of the tunnel entrance

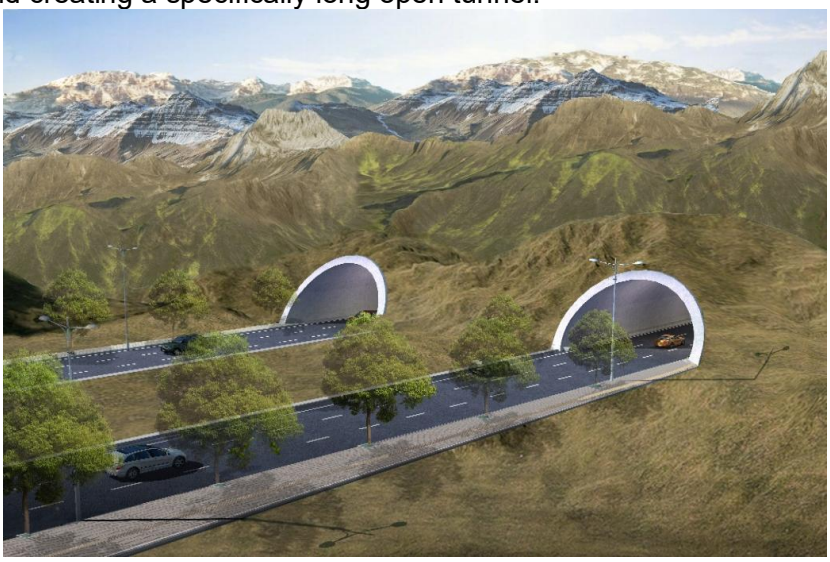
Drawing 5. 4. Existing condition of the tunnel exit

(1) Design principles for the tunnel entrance and exit

Following the principle of 'early entry and late exit,' excavation activities are reduced to ensure mountain stability; the excavation height of the tunnel portal slope is lowered to minimize damage to the natural landscape of the tunnel entrance and exit and to facilitate vegetation restoration. Design drawings of protection measures and green spaces necessary to enhance structural and environmental integration, ensure slope stability, and reduce slope erosion, thereby achieving the objective of "Safety, Environmental Protection, and Environmental Coordination."

The water drainage system at the tunnel entrances and exits shall be integrated with the road drainage system.

According to the Republic of Mongolia's "EARTHQUAKE ZONE" (BNbD 22-01-21) earthquake design standard for structures and historical seismic data, the seismic retention force at the section of the underground passage of the new ring road in Ulaanbaatar City corresponds to a basic earthquake value of 7 degrees, equivalent to 0.11g to 0.14g. The softness of the tunnel entrance and exit slopes, overall safety, cave entrance landscape, and economic efficiency have been designed in compliance with earthquake requirements by constructing a tunnel gate cut from bamboo and creating a specifically long open tunnel.



Drawing 5. 5. 3D diagram of the tunnel cross-section used in this project

(3) Special requirements for the design of tunnel entrances and exits

1) During earthquakes, an analysis of the forms and causes of tunnel damage must be conducted, requiring the implementation of earthquake-resistant measures at the portal sections. Specific measures are as follows: establishing a defined inclination on the saw-cut portal wall or constructing a retaining wall structure at the front of the portal; The portal material shall be high-grade precast reinforced concrete; The portal wall and the open excavation shall be entirely connected by circular connector steel bars to enhance earthquake resistance.
2) The portal structure of the tunnel located in the permafrost zone shall have sufficient resistance to withstand structural deformation and stress effects caused by increased frost and thaw settlements. The portal foundation shall be positioned 0.25 m away from the frost line to prevent frost heave and thaw settlement. If the foundation depth is excessive, replacement of the foundation is required.

5.5.3. Lining Design

(1) Principles for the Design of Lining Structures

1) The lining structure is designed as a composite support lining based on the surrounding rock level, terrain, burial depth, and tunnel formation conditions, in accordance with the principles of the New Austrian Tunnelling Method.

2) The type and dimensions of the lining structure shall be determined through a comprehensive engineering analysis of structural calculations, considering operational requirements, the surrounding rock level, arch lining thickness, structural stress characteristics, conditions of engineering structures, and environmental factors.

3) The tunnel design drawings and excavation shall adhere to the principle of 'minimal

damage, rapid reinforcement, frequent measurements, and early closure.'

4) The lining structure in sections with poor surrounding rock conditions extends 5 to 10 meters into adjacent well rock-conditioned areas.

(2) Parameters supporting the lining structure

In addition to the open tunnel adapted to the terrain and geological conditions at the tunnel portals of this project, the design drawings for the tunnel lining comply with the principles of the Austrian New Austrian Tunneling Method, employing composite lining comprising systematic anchors, wire mesh, shotcrete, reinforcement mesh, steel cages, and large flue supports. and other advanced support measures are applied according to various levels of the surrounding rock. The secondary lining comprises cast waterproof concrete or reinforced concrete, with a waterproof slab and non-woven geotextile fabric installed between the primary and secondary linings to serve as a waterproofing layer. The type of tunnel lining, the lining section type, and the dimensions of the lining structure are primarily designed using the engineering analogy method, and necessary theoretical calculations and validations are carried out on the tunnel structure. Structural requirements, combined with economic and technical comparisons, correspond to support parameters derived based on the surrounding rock strata level and cavity depth.

Table 5. 6. Support parameters for the lining section of the New Ring Road Tunnel

Type of lining	Detailed face	Primary face				Secondary lining	
		Anchor bar (ring transverse longitudinal)	Reinforcement mesh	Shotcrete	Reinforced arch frame	Arch ring Sidewall	Reverse arch support
Ⅴ	Large pipe canopy A108×6 mm Single control small pipe φ42×4 mm	A25 hollow concrete anchor (1.0×0.5 m, 4.0 m length)	A8 spacing 20×20 cm Double layer	28 centimeters	I22b I-beam spacing 0.5 m	60 cm reinforced concrete	60 cm reinforced concrete
Ⅳ	C22 concrete anchor	C22 concrete anchor (1.0×0.8 m, 3.5 m length)	A8 spacing 20×20 cm	24 centimeters	I18 I-beam spacing 0.8 m	55 cm reinforced concrete	55 cm reinforced concrete

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(3) Open trench design

The open tunnel is arranged based on the actual conditions of each culvert. The open tunnel structure employs cast reinforced concrete, and the foundation load-bearing capacity must be no less than 300 kPa; The temporary slope protection of the open tunnel employs sprayed anchorage protection, and the filled slope surface must be connected to the original terrain as closely as possible. The upper part of the open tunnel is generally protected by planting grass over a mesh, and steep slope locations can be continuously safeguarded with grass secured on anchor rod frames.

(4) Primary face

The initial segment comprises cast-in-place concrete reinforced with shear mesh, steel mesh, and an I-section double beam.
The steel frame must be fully welded with shear reinforcement and steel mesh, and firmly anchored to the surrounding rock.
The cast concrete shall be of C25 grade and require the use of wet spraying technology. The tension rods utilize A25 hollow tendons and C22 concrete anchors. The steel bearing plate is placed over the exposed tendon anchors. Tendon heads shall be threaded, and the bearing plate must be firmly secured to the surrounding rock with nuts. The tendon heads and bearing plates shall be coated with sprayed concrete. It is pertinent to note that, in cases of significant marginal

displacement of the surrounding rock, the primary support shall be secured in the circular direction by means of a bending joint.

(5) Secondary lining

The secondary lining shall employ C30 reinforced concrete structures, and during installation, a trolley with a full section shall be used to facilitate monolithic casting in a single operation. Concrete shall be conveyed by mechanical pumping to enhance the overall compaction of the secondary lining, minimize transverse joints, and avoid longitudinal construction joints. The allowable construction period for the secondary lining shall be determined from construction measurement data, and the initial bearing capacity shall be maximized without exceeding its specified limit.

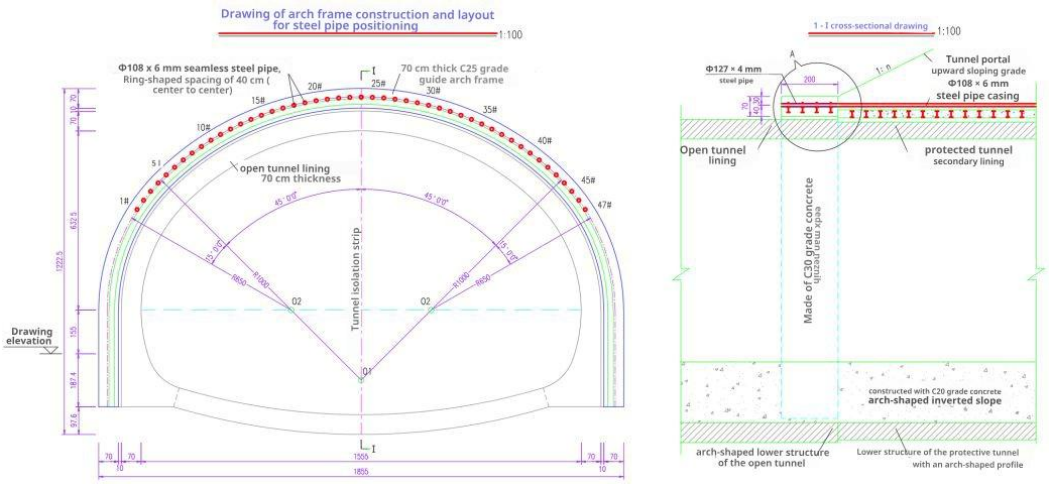
5.5.4. Auxiliary Facilities and Measures

Auxiliary facilities are temporary supports or temporary reinforcement measures intended to ensure workplace safety, whose bearing capacity may disregard the impact on the permanent safety of the structure. When the tunnel traverses shallow folded, bent, or fractured zones, as well as weak sections with poor self-stability, it is necessary to implement engineering auxiliary measures. The engineering auxiliary measures must be closely coordinated with the design drawings of the tunnel’s primary foundation structures and the selected excavation method. During the assembly process, it is essential to reinforce monitoring, measurement, and information requests to timely adjust auxiliary construction methods or drawing design parameters, ensuring better conformity with the conditions of the construction site. The engineering auxiliary measures implemented within the tunnel primarily include pipe shafts, small guide pipes, front anchor rods, and surface concrete reinforcement.

The advanced support measures approved in this tunnel design chiefly comprise advanced long pipe sheds, advanced short pipe sheds, and advanced anchor rods. Detailed long pipe shed: Installed at both ends of the tunnel to prevent collapse during excavation and deformation of the rear slope; Advanced Small Pipe Shelter: Suitable for rock sections surrounding Level V; Advanced Anchor Handle: Suitable for rock sections surrounding Level IV, primarily to prevent collapses during tunnel excavation.

(1) Detailed Long Pipe Canopy

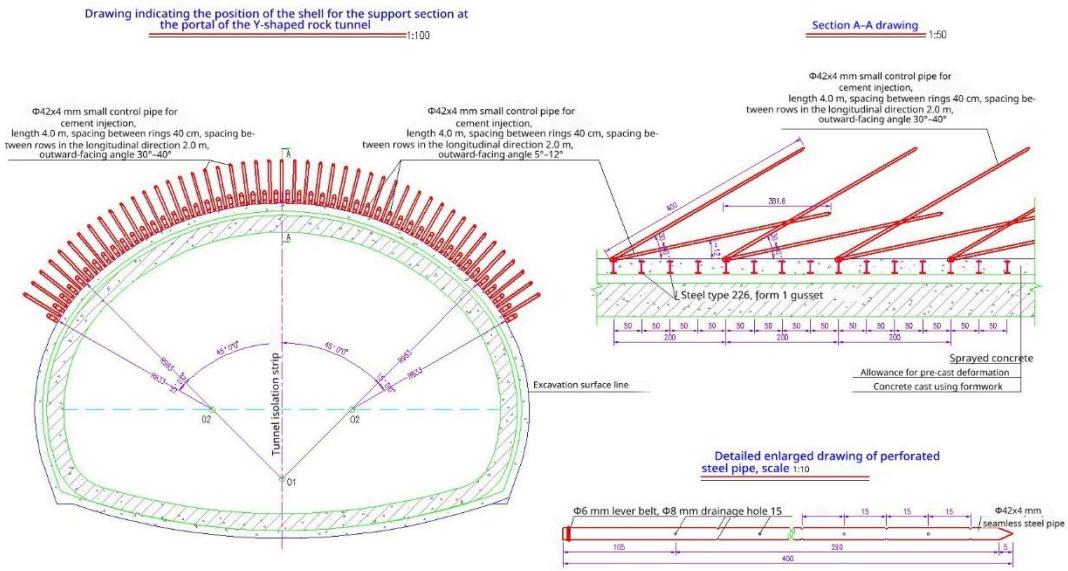
This is located at the main tunnel entrance. The depth of the pipe arch shall be determined by integrating the terrain and geological conditions. The pipe arch shall be constructed of A108 × 6 mm hot-rolled seamless steel pipe, spaced at intervals of 40 cm, with connection wires directly joined. The construction deviation of the inclined steel pipe from the design alignment shall not exceed 15 cm; the proportion of identical cross-sectional joints along the tunnel's longitudinal axis shall not exceed 50%, and the overlaps of the steel pipe joints shall be staggered by at least 1 meter. To ensure the drilling direction, a 70 cm thick C25 reinforced concrete arched sleeve door was installed on the exterior of the lining, with the length of the arched sleeve door measuring 2.0 m. Taking into account the sagging during drilling, the drilling direction shall be maintained within 1 to 3 degrees of the steel pipe design alignment. The drilling position and orientation must be measured using surveying instruments. An inclinometer shall also be employed to measure the deflection of the steel pipe during the drilling process. If the deflection exceeds the permissible limit, it must be rectified promptly to prevent any impact on the excavation or supports.



Drawing 5. 6. Detailed schematic diagram of the pipeline canopy length

(2) Small control pipe

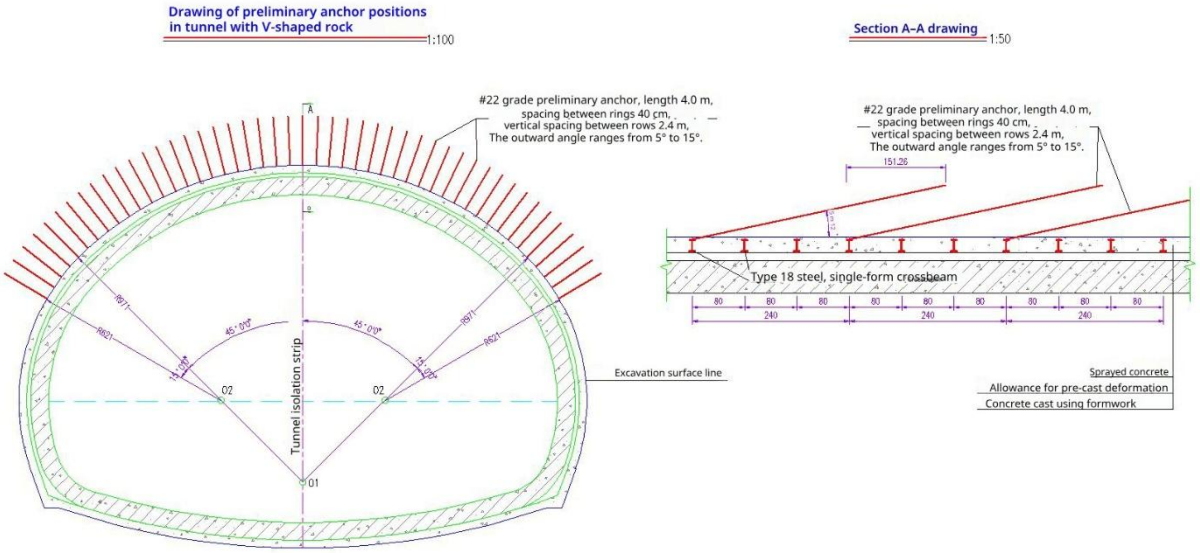
The small control pipe utilizes a 42 mm outer diameter hot-rolled seamless steel pipe. The circular spacing of the steel pipes is approximately 40 cm, with the outer insertion angle controlled between 10 and 15 degrees, and the tail end is fixed to a steel frame. Each small pipe row shall overlap longitudinally by at least 1.0 m.



Drawing 5. 7. Detailed diagram of the reinforcement casing

(3) Preliminary protection

Protection employing C22 early strength concrete slurry is utilized. The spacing around the anchor handle is approximately 40 cm, with the outward insertion angle adjusted to approximately 10° to 20°. The tail end is fixed outside the steel frame, and each row of hooks shall overlap longitudinally by no less than 1.0 m.



Drawing 5. 8. Detailed anchor bolt schematic diagram

(4) Auxiliary measures for the small-clearance tunnel

When organizing the construction regime of the small-scale underpass, it is necessary to consider the entire process of the two adjacent and parallel tunnels by relying on the New Austrian Tunneling Method, reinforcing micro-earthquake blasting, strengthening intermediate rock, establishing data and information mechanisms, enhancing vibration testing, and conducting precise monitoring and measurements. The various methods for excavating the surrounding rock shall be selected based on scientific principles; timely installation of anchor spray support shall be executed; the step distance for each operation in the right and left tunnels shall be optimally arranged; the construction works must minimize damage to the surrounding rock (particularly medium-hard rock) and tunnel structures, while ensuring construction safety and quality.

The A25 hollow cavity anchor bolt (at the rock portal section surrounding Level V) is employed as systematic support to reinforce the surrounding rock. The reinforcement measures for the lining rock column are shown in the table below.

Table 5. 7. Measures for reinforcing the rock column

Type of lining	A25 hollow concrete anchor	
Portal of the V-level rock tunnel section	Length (m)	Ring × vertical spacing (m)
	5.0	1.0×0.5

5.5.5. Earthquake resistance design

According to the Mongolian building earthquake design standard 'EARTHQUAKE ZONES' (BNbD 22-01-21) and historical seismic data, the seismic design intensity for the underpass section of the Ulaanbaatar City new ring road is 7 points, with a basic seismic value of 0.11g to 0.14g. Considering the requirements set for earthquake criteria, earthquake analysis and verification calculations may be omitted. The following fundamental measures shall be implemented to ensure the tunnel's resistance to earthquakes.

(1) The tunnel location has been selected in stable mountainous terrain with favorable geological conditions and earthquake resistance. The tunnel alignment prevents adverse geological conditions such as soil sliding and collapses.
(2) The lining structure of the tunnel’s open excavation and the surrounding sections of Grade V and IV rock consists of reinforced concrete curved walls with inverted arch gates, with the circular earthquake joint established at the boundary between the open and dark

sections.

(3) To enhance the overall earthquake resistance, steel bars are employed to effectively connect the tunnel excavation with the open excavation.

(4) The sides of the open excavation shall be backfilled and compacted with concrete-laid stone slabs, ensuring the fill height is no less than 7 meters. The upper section of the open excavation shall be compacted with crushed stone soil (with a compaction degree of not less than 90%) to effectively enhance the earthquake resistance of the structure.

(5) Strictly control the filling slope gradient to not exceed 1:1.5.

(6) Provide adequate protection for the mountain above the tunnel portal and the embankment slopes of the external road section of the tunnel; it is mandatory to thoroughly eliminate or mitigate all safety hazards, including collapse and rockfall, throughout the construction stages.

(7) The secondary lining is a cast reinforced concrete structure, within which circular earthquake joints are installed at intervals of 9 to 12 meters along the longitudinal direction, and may be positioned together with settlement and expansion joints.

(8) The protective extent of the crack fracture zone, the section with transitions between soft and hard layers, and the section with changes in structural form shall be extended to encompass better surrounding rock or the section of normal structure. The length of the protection shall include the length of the extensions at both ends. The protective length surrounding grade V rock shall be no less than 10 m, and surrounding grade IV rock no less than 5 m.

(9) Structural measures necessary to enhance the earthquake resistance of the connecting structure between the main tunnel and the auxiliary tunnel at the vehicular and pedestrian crossing locations shall be implemented.

(10) Voids behind the lining are strictly prohibited. In the presence of the aforementioned issues, it is mandatory to inject cement mortar behind the lining. The geological conditions within the fracture zone are poor; the surrounding rock strata are generally classified as V and IV, with groundwater frequently abundant. To ensure the structural safety of the lining during the construction phase, a more robust reinforcement method must be employed in conjunction with auxiliary protective construction measures. Considering the substantial loose load on the foundation structure within the fracture zone, the secondary lining shall be constructed of reinforced concrete to ensure structural safety; The tunnel face support employs a small concrete pipe to pre-support the rock mass at the tunnel heading, followed by a circular excavation method with reserved primary soil; In areas with abundant water, preliminary mud stabilization is required to prevent disasters such as sudden water inflows and mudslides.

5.5.6. Waterproofing and drainage design for tunnel interiors and exteriors

(4) Principles of drainage pipe design

1) The design of tunnel drainage structures must be conducted by integrating engineering characteristics, topographical conditions, engineering geology, hydrogeology, and survey data. An integrated, unobstructed drainage system that facilitates easy maintenance shall be established, ensuring proper interaction with surface and groundwater both inside and outside the tunnel.
2) The tunnel drainage channel shall be designed according to the principles of prevention, drainage, retardation, combined closure, adaptation to local conditions, and comprehensive management to ensure the normal operation of tunnel structures and operational facilities, as well as driving safety, by maintaining dryness following tunnel completion.
3) To prevent altering the general direction of groundwater flow, it is essential to adhere to the principle of excavation rather than closure for karst water in deep rivers and pipeline conduits;

4) Tunnel construction has a significant impact on the life and production activities of surface settlements and, in the event of geological hazards, requires countermeasures primarily focused on 'sealing and restricting' tunnel drainage operations.

(2) Tunnel Waterproofing

The secondary lining of the tunnel shall be constructed using concrete with permeability not exceeding class P8. A waterproofing layer consisting of a 1.5 mm EVA waterproof membrane and a 400 g/m² felt covering shall be installed between the primary support and the secondary lining. Tunnel construction joints and settlement connections shall utilize embedded rubber seals, whereas longitudinal construction joints shall employ iron plate-coated waterstops. To ensure that the geotextile material effectively fulfills its filtration and drainage functions, the geotextile and the waterproof membrane are installed separately; specifically, the geotextile is laid first, followed by the waterproof membrane.

Following tunnel excavation, when increased water volumes and surface water runoff severely impact the surface ecological environment, measures such as grouting rock joints in the vicinity to restrict or reduce water flow shall be implemented.

Drawing 5. 9. Tunnel waterproofing schematic drawing

(3) Tunnel drainage pipe

The tunnel lining drainage system entails the construction of comprehensive longitudinal and circular blind drainage gutters between the waterproofing layer and soil concrete, ensuring uniform flow of seepage from the surrounding rock behind the lining through the lateral drainage gutters. After excavation of the tunnel, Ω-shaped spring drainage pipes were installed vertically on the rock surface according to the development of groundwater in the surrounding rock mass, thereby draining seepage water from the surrounding rock and ensuring uniform flow in the drainage channel at the initial tunnel support. A50HDPE single-wall perforated corrugated pipe was installed as a circumferential drainage conduit between the first support and the waterproofing layer, while A100HDPE double-wall perforated corrugated pipe was placed longitudinally along the side footings; these were installed on both sides of the tunnel and connected by cross pipes within the drainage system. To discharge groundwater from the Tunnel; During operation, surface water and sewage from the road are discharged by installing side ditches and gutters on both sides of the Tunnel lining, thereby separately diverting contaminated water and water from the surrounding rock of the lining. In areas with abundant fracture water in primary rock formations, such as lithological contacts and fracture zones, the ring drainage pipes

and transverse drainage pipes are installed with greater density.

The tunnel lining is primarily equipped with drainage channels intended to discharge fire-fighting and cleaning water, thereby isolating groundwater behind the lining from contaminated water. Control ports have been installed on the longitudinal drainage pipes at the base of the sidewalls, enabling maintenance of the tunnel drainage system.

The excavation of the tunnel has altered the infiltration and flow conditions of the groundwater, resulting in groundwater accumulation within the tunnel. The tunnel presents a humid environment. To improve the operational environment of the tunnel road and given the increased difficulty of maintenance work on the culvert road, the design includes the installation of a blind pipe beneath the tunnel lining base to allow water infiltration and reduce water damage on the road surface.

(4) Waterproofing for temperature and deformation sensors

The tunnel deformation joint is equipped with two waterproofing strips: an external rubber waterproofing strip and an installed rubber waterproofing strip, both secured with iron bar clamps. The filler material is required to be impermeable to water. The construction phases of the ring may be adjusted according to the construction conditions. It is advisable to install a minimal number of construction phases. The ring assembly section is equipped with rubber seals installed at intervals of 10 meters. The arched covers of open, dark holes and the metal connection joints on both sides of the structure are equipped with iron plate renderings installed longitudinally along the Tunnel.

During construction, attention shall be paid to the overlap of waterproofing membranes, installation of pre-embedded drainage pipes, water stops, and nozzles of pre-embedded anchors. If the installation location is unsuitable, appropriate adjustments shall be made.

(5) Tunnel drainage channel

The external waterproofing layer of the open pit lining comprises a 'composite system with a single membrane' (400 g/m² felt lining + 1.5 mm EVA waterproof membrane + 400 g/m² geotextile material) and shall be installed above the soil filled with a 50 cm waterproof clay layer. It is essential that the membrane is properly sealed at the edges to prevent water ingress. Ensure proper overlap.
The tunnel entrance drainage pipeline was constructed in accordance with the terrain characteristics, designed to divert surface water 5 meters away from the excavation line of the tunnel’s rear slope, thereby preventing rainwater from entering the slope and tunnel. A drainage channel was installed to convey water directly into the natural valley and the roadbed drainage channel.

When located at the ascending section of the tunnel entrance, install a reverse drainage channel in the roadbed section of the culvert to prevent water from outside entering the tunnel. When located at the descending section of the tunnel entrance, connect the roadside drainage inside the tunnel to the drainage channel at the roadbed of the tunnel entrance.

(6) Protection of the aquatic environment

During construction, it is required to implement measures such as plastering and water blocking to prevent surface water loss and avoid impacts on the surrounding ecology and residents' lives.
шаардлагатай.

5.5.7. Tunnel lighting structure

When designing the tunnel lining, the type, number of layers, and thickness of the lining shall be comprehensively selected, taking into account factors such as the road classification, traffic volume, road subgrade bearing capacity, local environmental conditions, material supply, climatic conditions, and construction constraints. To ensure uniform support of the lining structure, the tunnel lining shall be stable, dense, and uniform. The tunnel lining shall be adequately strong, smooth, durable, slip-resistant, and wear-resistant.

Tunnel roadway surface: 4 cm thick AC-13C fine-graded asphalt concrete with pcs. (SBS modified) + 7 cm thick AC-25 coarse-graded asphalt concrete with pcs. + 26 cm thick C40 concrete base (The C40 concrete structure shall be monitored for flexural strength, which must exceed 5.0 MPa).

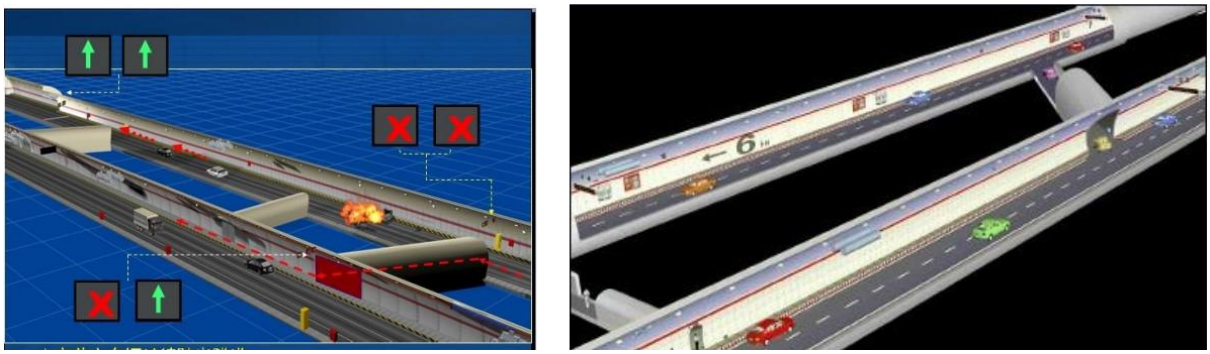
5.5.8. Design drawings for pedestrian crossings and emergency stopping lane strips

In the event of a fire within the tunnel, to evacuate vehicles inside the tunnel as rapidly as possible and to facilitate maintenance operations, two transverse passages for vehicles have been constructed between the left and right tunnels, spaced 750m apart. The cleaning of the horizontal crosswalk complies with the technical specifications and takes into consideration the factors of ditches and pedestrian crossings. The clear width is 4.5 m and the height is 5 m.

In the event of a fire in the tunnel, a total of five pedestrian passages have been installed between the western and eastern underground exits at intervals of 250 m to facilitate the urgent evacuation of personnel within the tunnel. The vehicle cross passage may also be used as a pedestrian passage. The pedestrian crossing is designed with a transverse clearance for vehicles, accommodating 1 vehicle and 2 pedestrians. The clearance of the pedestrian crossing area complies with technical requirements, with a specified width of 2 m and a height of 2.5 m.

The emergency stopping lane is located on the right side of the driving direction, with a spacing of 750 m between lanes, an effective length of 40 m, and a total length of 50 m. The public emergency parking area comprises four lanes, with a width at least 3 meters greater than the standard.

The central line of the pedestrian crossing is perpendicular to the tunnel axis, as is the central line of the vehicular crossing. Fire doors are installed at both vehicular and pedestrian crossings. Pedestrian crossings and emergency parking lanes should preferably be situated in areas with more favorable surrounding rock conditions and may be suitably adjusted in response to changes in geological circumstances. To minimize damage to the surrounding rock, an appropriate construction method must be selected during the construction of the intersection section.



Drawing 5. 10. Schematic drawing of the tunnel cross passage

5.5.9. Durable design

The measures to ensure the durability of the structure are as follows.

(1) Utilization of corrosion-resistant concrete, with a concrete abrasion resistance coefficient of not less than 0.8;
(2) To satisfy the waterproofing and crack resistance requirements of the project structures, it is recommended to use high-performance waterproof concrete for the tunnel secondary lining and other structures. The abrasion resistance grade of the secondary lining concrete shall not be less than P8.
(3) When casting large volumes of concrete in tunnel structures, the use of hot cement with high moisture content shall be avoided. Instead, double mixing technology (incorporating a high-efficiency water-reducing agent with high-quality fly ash or soil ash) shall be applied, and the optimal mix ratio shall be determined through testing.
(4) The water-cement ratio shall be strictly controlled, with an upper limit of 0.45.
(5) The maximum chloride ion content in concrete shall be 0.06%. The chloride ion content in various raw materials used for the production of reinforced concrete in chloride-free environments (including cement, mineral admixtures, aggregates, admixtures, and mixing water) shall not exceed 0.2% and 0.1% by weight of cementitious materials, respectively. Chloride ion diffusion coefficient (28 days) DRCANTIMETERS < 10×10^{-12} m²/s.
(6) Non-alkali reactive aggregate shall be used for concrete. When using alkali-reactive aggregate, the maximum alkali content in the concrete shall be 3.0 kg/m³.
(7) Aggregates used for concrete shall be uniform, hard, well-graded in particle shape and size, and possess minimal voids. The crushing index of aggregates with large pcs shall not exceed 7%, and water absorption shall be less than 2%.
(8) The chloride ion content in concrete additives shall not exceed 0.02% of the total weight of the gel material in the concrete, and the sodium sulfate content in high-efficiency water reducers shall not exceed 15% of the dry weight of the water reducer.
(9) Requirements for construction and installation works:
1) The assembly of durable concrete works shall integrate the characteristics of the project and its surrounding environment, proposing measures for quality control and assurance throughout all construction activities and construction joints, and shall have developed the relevant construction technical regulations.
2) Before commencement of construction and installation works, the concrete mix proportion and raw materials (commercial) shall be tested on the concrete; the workability, strength, and durability of the concrete shall be measured and determined by comparative crack resistance tests.
3) The designed thickness of the concrete protective layer shall be verified. The protective layer of the subgrade may be constructed using fine stone concrete, and the strength of this layer must exceed that of the constituent body concrete.
4) Large-scale concrete construction works shall be executed strictly in compliance with the applicable standards and regulations.
5) During the rainy season concrete pouring, the drainage systems of sand and gravel silos must remain unobstructed. The vehicle shall be equipped with rain protection and anti-slip devices. The surface of the cast silos shall have rain protection and shall be fitted with waterproof materials. Increase the number of moisture measurements for the aggregate and promptly adjust the water used for mixing. On days with moderate rainfall or heavier, the surface of the concrete pouring silos shall not be newly opened; on rainy days, concrete mixtures that meet plastering requirements and are resistant to impact and abrasion shall not be produced. On days with light rain, appropriate measures must be taken during construction: properly control the consumption of mixing water, suitably reduce concrete slump, and, if necessary, appropriately decrease the water-cement ratio of the concrete. Reinforce the drainage pipe and prevent rainwater from flowing into the casting silos; Thoroughly protect the surfaces of new and existing concrete, particularly at the joints. In the event of heavy rain or a downpour during casting, immediately stop the feeding, vibrate the concrete placed in the silos, and compact it prior to finishing. After rainfall, it is necessary to first remove the water from the silos and promptly clean the areas washed by the rain. If the concrete form can be modified, continue with the additional casting of joint concrete; otherwise, it shall be considered a construction joint. Continuously review the weather forecast, enhance meteorological

observations within the construction zone, and properly organize the construction works.

6) Quality Control

Concrete cover thickness: Determination of the actual concrete cover thickness on site using a non-destructive rebar cover thickness sensor;

Concrete protective layer density: Typically measured by the rebound test assessing the compressive strength of the concrete surface of the component, thereby indirectly indicating the density of the concrete cover. The measurement period shall be approximately 28 days, and the measured average strength must not be less than the predetermined value.

Quality control is conducted on-site in accordance with durability requirements, and a registration report is issued.

7) An additional waterproofing layer has been installed on the exterior of the tunnel structure to protect the interior lining concrete from exposure to corrosive environments.

Strict control of the thickness of the clean protective layer of the primary reinforcement in reinforced concrete structures

5.6. Tunnel insulation design and measures

The project site is located within the semi-arid sub-zone between mountains of Mongolia’s II B climate zone, characterized by a polar continental climate. The climatic conditions of this region are extremely dry, cold, and severe, with relatively abundant precipitation; the soil and rock freeze to significant depths. The proposed tunnel design elevation is approximately 1440 meters, with a minimum annual temperature of -45°C. Therefore, it is imperative to consider the operational safety of the tunnel and the long-term structural durability under the cold conditions prevalent in this region. Examples from cold region railway and motor road tunnels in countries including the People's Republic of China, Europe, America, and Japan demonstrate that frost damage to similar tunnels constitutes a very serious issue. In certain instances, frost damage has caused deterioration of main tunnel structures, resulting in decommissioning and severely affecting transportation safety. According to the latest statistical data from the Japan Road Association and the Comprehensive Railway Technical Institute, throughout Japan, of a total of 3,800 railway tunnels, 1,100 encounter operational difficulties during the winter season due to frost, thereby posing a threat to transportation safety. Among motor road tunnels, only in Hokkaido Prefecture, out of 302 large-scale motor road tunnels, 104 have exhibited severe frost damage. To remove the ice columns formed on the walls and arch sections, electric heating devices were installed, resulting in significant maintenance costs. Multiple recurrent failures have been observed in certain tunnels constructed under similarly extreme environmental conditions internationally. For instance, the Xinjiang Tianshan No. 2 tunnel suffers from excessive water leakage, and during winter, frozen water compromises the normal transportation conditions, causing the tunnel to be virtually out of operation at present. Additionally, the Chidaolian Tunnel in Gansu Province experiences freezing of the drainage channels during winter, causing disruption of drainage operations; frost behind the lining results in expansion, leading to cracking of the lining concrete, increased water leakage, icing on the road surface, and negatively impacting safety.

The primary cause of these severe consequences is that most of these tunnels were constructed prior to the 1990s, when adequate design measures against frost were not implemented. This constitutes a significant lesson.

Accordingly, it has become imperative to investigate the effects of seasonal freeze-thaw cycles on tunnels and to develop appropriate technical solutions for insulation and frost protection. Tunnel construction in high mountainous and cold zone conditions constitutes a globally complex and comprehensive engineering challenge. Both frost heave and freeze-thaw effects must be accounted for throughout the construction process. In addition to addressing water seepage and protection, it is essential to ensure the proper functioning of drainage channels. Matters such as

ensuring construction quality and organizing normal construction operations under cold climate conditions must be determined solely through practical testing and experience. Several countries have learned from prior unsuccessful attempts at constructing tunnels in similar conditions and have successfully addressed the following critical technologies based on extensive studies and tests. This includes: frost expansion prevention technology for liners in cold regions, thermal insulation technology for liners, water protection and drainage system technology in cold regions, liner protection technology under extreme overload conditions at high altitudes in cold regions, and methodologies against cracking and interlayer water seepage.

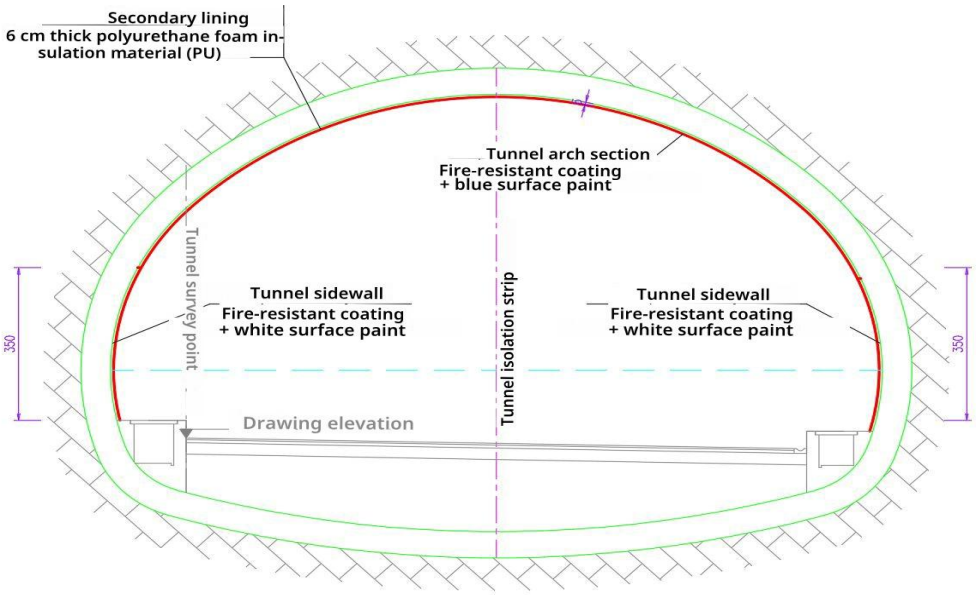
(5) Comprehensive measures for protecting a lengthy tunnel traversing a cold-region mountain slope from freezing.

1) Anti-freeze concrete shall be utilized at the tunnel portal section, with reinforcement and anchorage executed in accordance with the specifications.
2) Through the application of preliminary grout injection into the rock mass and secondary grout injection behind the lining, the potential water accumulation zones can be minimized, thereby achieving the objective of preventing water infiltration.
3) In sections susceptible to frost heave, a protective solution utilizing either a surface thermal insulation layer or a ground-source heat pump within the lining shall be employed to prevent water accumulation behind the rock from freezing and expanding.
4) A proper waterproofing and drainage system shall be designed and implemented. It is necessary to use deeply recessed drainage channels or frost-protected drainage channels, especially at the tunnel outlet section. This prevents water exiting the tunnel from stagnating at the outlet section and subsequently spreading and freezing on the road surface.
5) It is essential to improve construction quality and prevent issues such as lining cracks and water infiltration resulting from performance defects.

(6) Frost protection measures planned for the tunnel of this project

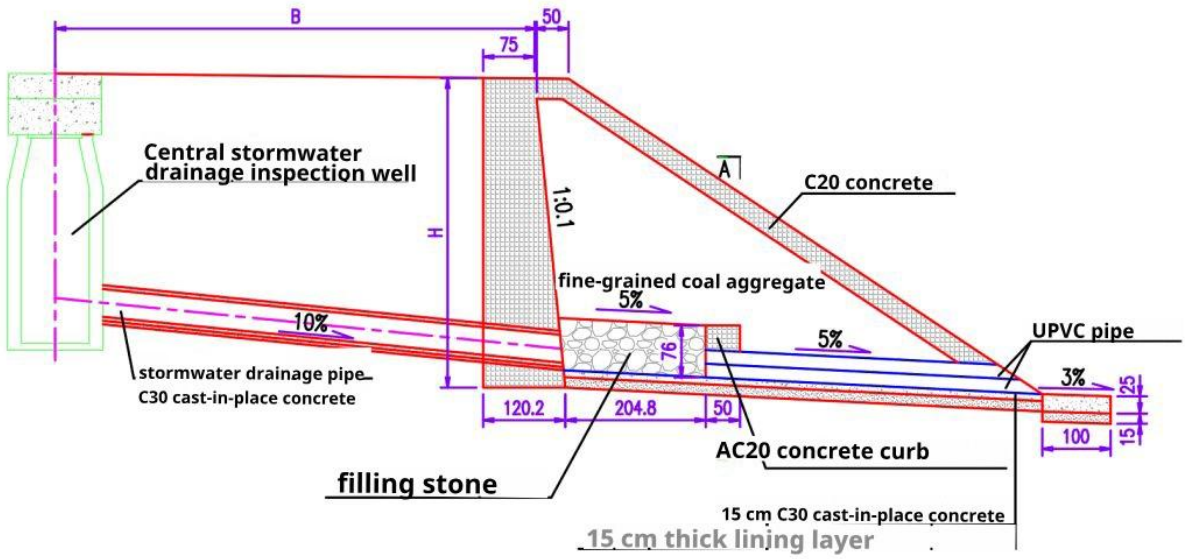
Geological surveys indicate that this road passes through the mountainous valley steppe subzone of Mongolia's II B climatic region. This zone is characterized by a polar continental climate with extremely dry, very cold, and harsh conditions, relatively high precipitation, and soils and rocks exhibiting deep freezing characteristics. After the tunnel is commissioned, due to the influence of hot-cold air exchange, a thermal transition zone may develop at a certain depth beginning from the tunnel entrance. This zone freezes during the winter and thaws during the summer.

1) To maintain the temperature behind the lining above 0℃ during the winter, thermal insulation lining is planned within a specified length of the tunnel entrance. The thermal insulation layer of the insulated lining shall be positioned on the inner edge of the secondary lining. This thermal insulation shall consist of 5–6 cm thick polyurethane foam (PU) material. Furthermore, based on the research, the feasibility of installing a ground-source heat pump within the tunnel lining is also being examined. Furthermore, all foundation structures of the portal section shall be installed below the frost line to ensure structural stability.



Drawing 5. 11. Drawing of the tunnel portal insulation layer.

2) A central drainage channel shall be installed beneath the arch at a specified distance from the tunnel portal. The central drainage channel shall be installed at a specified depth below the road surface, ensuring it is located beneath the maximum frost penetration depth. For other tunnel sections, a central drainage channel with a depth of up to 0.85 meters below the road surface is sufficient and maintains heat through geothermal energy.
3) The connected sections of the circular drainage pipe at the base of the wall, the longitudinal drainage pipe, and the transverse drainage pipe shall be wrapped and secured with geotextile material to prevent clogging by clay and sand. This measure prevents the formation of ice within the circular, horizontal, and transverse drainage pipes of the tunnel lining, avoids water blockage, ensures the proper operation of the tunnel drainage system, and protects the structural integrity of the surrounding rock and tunnel lining.
4) A central inspection shaft shall be constructed every 200 meters between the tunnel’s central drainage channels. The shaft opening shall be sealed with cast concrete, and a thermal insulation layer installed within the shaft to ensure the proper functioning of the central inspection shaft.
5) In the drainage channel section protected against tunnel frost, an insulated, buried drainage channel shall be designed to ensure the uninterrupted flow of the tunnel drainage system.



Drawing 5. 12. Insulation scheme drawing for the drainage culvert

6) The roadside drainage ditch of the main tunnel shall be positioned beneath the road surface and installed at a specified depth. A sand settling well shall be designed every 25 meters along the roadside drainage ditch. The sand settling well shall feature a double-layer cover, with asphalt fiberglass wool used as insulation in the gap between the covers. Additionally, thermal insulation with 5 cm thick polyurethane foam shall be applied beneath the cable duct cover.
7) The initial anchorage strength of the joint section shall be enhanced to reduce the pressure exerted on the secondary lining.
8) Water infiltration through rock fissures shall be sealed using fluid mortar, mitigating the effects of freeze-thaw cycles in the rock.
9) Enhancing the quality and uniformity of the initial sprayed concrete, protecting the waterproofing membrane, increasing the density of each layer, and extending the structural frost penetration depth. Furthermore, specialized ventilators and air temperature regulating devices shall be utilized on frozen soil. This device regulates the air temperature in accordance with the operational requirements. On one hand, it maintains a stable sub-zero temperature within the excavation area, thereby preventing landslides and freeze-thaw expansion caused by soil thawing, and protecting the rock surface from thawing; on the other hand, it facilitates the normal development of concrete strength under standard curing conditions.
10) The secondary lining of the tunnel section shall be designed using reinforced concrete structure to improve structural load-bearing capacity and prevent damage caused by frost.
11) Based on international experience and research on tunnels in cold mountainous regions, pertinent recommendations have been issued concerning the length of the tunnel’s insulated section and the selection of thermal insulation materials.

The air temperature within the tunnel is influenced by the external ambient temperature, gradually decreasing inward from the tunnel entrance. Beyond a specific depth within the tunnel, the air temperature is no longer impacted by the external ambient temperature and reaches a state of stability. The magnitude of this effect is closely associated with factors including the coldest monthly temperature of the region, the tunnel length, and the prevailing wind direction.

For tunnels exceeding 2000 meters in length, it is appropriate to determine the length of thermal protection at both ends based on estimates. If the land formation, climatic conditions, elevation differences, and prevailing wind direction at both ends vary significantly, the thermal protection at each end shall be designed asymmetrically. Subsequently, in accordance with geological and hydrogeological conditions, and based on verified meteorological data, it is necessary to establish foundational parameters and determine the tunnel lining length through detailed calculations.

The lining concrete shall be selected for frost resistance. Where necessary, concrete incorporating special additives such as basalt may be utilized to enhance frost resistance. Thermal protection of the tunnel structure can be achieved by using thermal insulation and frost protection materials. It is recommended to use polyurethane (PU) foam material as thermal insulation for the lining of the arch section.

5.7. Tunnel construction method

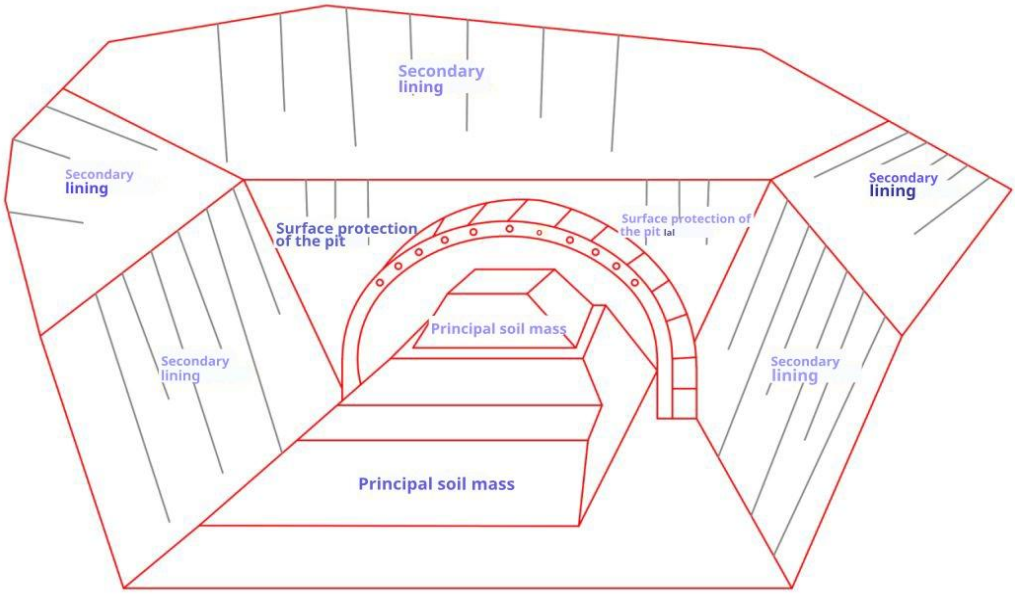
5.7.1. Tunnel excavation method

The exposed portion of the tunnel shall be excavated by the open method, while the underground section shall be planned and executed according to the principles of the New Austrian Tunneling Method (NATM). As the tunnel involves a large excavation opening, to ensure safety during excavation, it is recommended that mechanical excavation be primarily employed at the tunnel portal in rock category V, based on the geotechnical characteristics of the soil layers. In the shallow sections of rock category V and in sections of rock category IV, the ‘soft blasting’ or ‘pre-

split blasting’ method shall be employed to preserve the surrounding rock structure as completely as possible, control both over-excavation and under-excavation, and to remove soil without roadway excavation.

Before commencing excavation of the shaft section, it is necessary to provide a drainage channel at the upper part of the shaft to halt water flow within the excavation environment. This measure will prevent surface water from infiltrating the excavation site, thus preventing adverse impacts on the adjacent slopes and shaft supports. During excavation, it is necessary to concurrently protect the side slope while excavating the slope. When approaching the bottom of the shaft, the central main soil shall be preserved in advance, and after the support assembly at the shaft mouth is completed, excavation proceeding inward shall be performed.

Following excavation of the tunnel’s open section, if the height of the side and upper slopes (typically exceeding 15 m), the thickness of the shaft lining, or the geological conditions are adverse, it is recommended to perform earth filling in the open section to stabilize the side loads before beginning excavation of the underground section.



Drawing 5. 13. Scheme drawing of the tunnel portal excavation

The interior section of the tunnel shall be constructed using a concealed method. For the grade V rock section, the excavation method along the two side walls is recommended. For the grade IV rock section, the circular excavation method shall be employed, retaining the central soil during excavation. These methods may be adapted and modified based on the prevailing geological conditions. Excavation works shall be conducted in successive shifts, with each tunnel shift being at least 50 meters in length beyond the adjacent one. However, the length of the secondary lining concrete pour layer shall not exceed that of a single lining cycle.

During construction, neither the left nor the right wing shall be left with only the initial anchorage. During excavation, preliminary anchorage works shall be expedited, and the initial anchorage must be executed promptly. To prevent the semicircular lower leg of the initial anchorage from settling, a small pipe foot lock or locked anchor shall be installed on all arch anchorages.

During tunnel excavation, it is imperative to closely monitor the rock structure to minimize damage and prevent both over-excavation and under-excavation. The reinforcement mesh and steel supports must be tightly affixed to the rock surfaces, with supports firmly anchored; initial fixing shall be performed promptly and reliably using concrete sleepers and ‘shaant’. The secondary lining works shall be executed mechanically, employing concrete transport trucks, concrete pumps, and lining formwork machines for the assembly. This ensures the concrete quality remains dense on the

interior surface and smooth on the exterior surface

5.7.2. Duration of construction and installation works

Based on the tunnel construction scope, geological conditions, and technical specifications of the construction equipment, excavation works shall be conducted in two directions with two work sections designated as entry and exit, comprising a total of four work sites. Three months are allocated for construction preparation, and tunnel excavation and electrical installation works are scheduled to be completed within 18 months. The total construction duration is 21 months.

To ensure the safety of tunnel construction works and to minimize the mutual impact between excavation activities of the east and west tunnels, the following control requirements are proposed for the longitudinal distance between tunnel excavation areas, based on geological conditions: In sections with loose rock, the longitudinal difference between adjacent work areas shall not be less than 50 meters. In sections of hard rock, this spacing requirement may be reduced but shall be planned to be no less than 30 meters. During construction, the principle of 'Support First, Then Excavation' shall be strictly enforced; excavation on the opposite side of the tunnel may only commence once the initial tunnel support is confirmed stable in accordance with the design drawings. This is intended to prevent adverse effects arising from the combined influence of internal stresses within the rock. Based on construction organization and the consideration of relevant factors, a temporary restriction is imposed to commence excavation work for the east and west tunnels with a one-month separation.

5.7.3. Design drawing for the organization of tunnel construction works

(1) Construction work organization plan

Tunnel construction works shall be executed using a series of mechanical equipment, employing trackless transport methods for excavation spoil removal and flat wagons for secondary lining concrete casting.

During construction, a significant quantity of soil and rock will be excavated, with certain portions suitable for use as embankment fill for road slopes, slope protection, and as fill material for the road base and sub-base layers. However, the remaining material must be disposed of as waste; hence, it is required to plan a waste storage area and implement protective measures to prevent erosion caused by water runoff and to protect the environment from adverse effects. Additionally, construction activities may adversely affect the underground water system by causing redistribution of water resources, which could pose challenges to local communities reliant on groundwater for their subsistence. Therefore, it is required to minimize the adverse effects on the ecology and environment in the vicinity of the project during the tunnel construction process.

(2) Construction Site Allocation

The organization of the tunnel construction site defines the site size, location, and primary organizational layout based on the project scope, construction methodology, and environmental conditions.

The main facilities located in the tunnel's external area include the explosive storage warehouse, construction materials warehouse, power supply building, soil and rock transportation area, cement and aggregate storage warehouse, wastewater treatment facility, laboratory, workers' rest quarters, and office buildings.

The construction site is typically located near the tunnel entrances and exits. Taking into account transportation distances and safety, it is appropriate to position the reinforcement processing area and storage yards for gravel and sand adjacent to the entrances and exits. The office and workers’ rest areas offer greater flexibility but are generally positioned near access points. The air compression device shall be located as close as possible to the tunnel entrance

to minimize ventilation energy losses.

(3) Temporary construction road

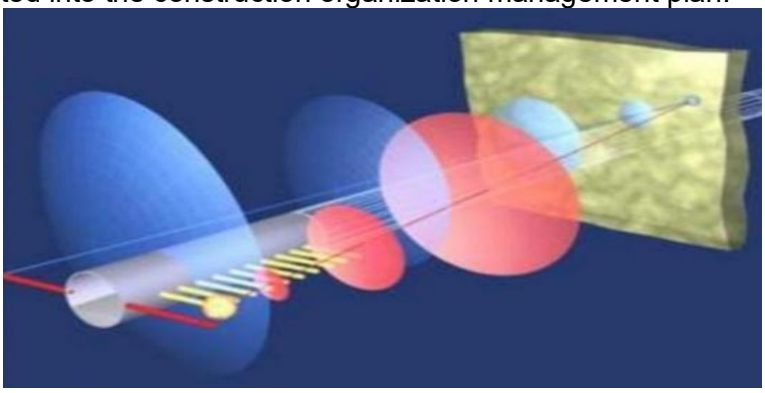
The arrangement of the temporary construction road shall adhere to the principle of reusing previously utilized roads wherever feasible. For large-scale temporary construction roads, a dedicated design must be developed, with optimal planning of the horizontal and vertical alignments, while prioritizing the protection of the surrounding environment. The temporary road planning for tunnel construction shall be coordinated integrally with the construction of general line bridges, culverts, and drainage structures.

(4) The waste soil generated during tunnel construction

In regulating this, emphasis shall be placed on preventing environmental pollution and soil erosion. Therefore, the waste must be reused to the greatest extent possible. Waste that cannot be reused shall be collected in a designated temporary waste storage area in accordance with applicable regulations, stabilized with a basal foundation, covered with soil, and rehabilitated by planting trees and grass to establish green landscaping.

5.7.4. Preliminary geological survey

To ensure the safety of tunnel construction and structures, preliminary geological reconnaissance surveys must be conducted during the construction phase. Using methods such as drilling and geophysical surveys, the engineering-geological and hydrogeological conditions of the rock mass surrounding the front area of the excavation site shall be identified in advance. In accordance with potential changes in geological conditions during excavation, the following risks shall be anticipated, analyzed, and appropriate measures planned. This includes the probability of rockslides in the surrounding area, potential locations of sudden water emergence, water quantity, groundwater, clay content, and their respective impacts on construction activities. Preliminary geological reconnaissance is an essential component of the works and must be explicitly incorporated into the construction organization management plan.



Drawing 5. 14. Preliminary Geological Drawing of the Tunnel

5.8. Risk management of Tunnel Construction Works

5.8.1. Summary

As a principal form of road structure, the tunnel entails relatively high risks during the construction phase. Under conditions of compressed construction schedules and stringent investment control, the concept of risk management has been progressively applied in recent years within urban engineering construction practices and development, particularly in the phased implementation of urban transport system projects. Therefore, it is essential to comprehensively apply the successful experience in this field to this project, as it plays a vital role in implementing risk management, reducing risks, and successfully delivering the project.

5.8.2. Classification and Stages of Work Risk Management Tasks

(1) Stages of Risk Management

Based on the project's operational characteristics and environmental conditions, as well as the general principles of risk management and the specific aspects of tunnel works, it is necessary to develop a detailed risk management plan. It is recommended that the project’s risk management be implemented in the following three stages: scheme development stage, design stage (generally encompassing preliminary design, detailed design, and construction design stages), and construction stage. The primary tasks at each stage are risk identification, risk assessment (divided into calculation and evaluation), and risk control. The key focus areas for each stage are presented in the following table.

Table 5. 8. Risk Management Classification and Main Task Consolidation Table

Stages of Risk Management	Risk Management Content		
	Risk Identification	Risk Assessment	Risk Control
Planning Stage	The foundation of the project risk management system shall be established by collecting baseline data and obtaining expert recommendations. Identify sources of risk consistent with the construction environment and the specific characteristics of the project, and utilize this information as reference material for planning and design works.	Primarily employ the risk assessment methodology when evaluating risks. This involves using methods such as comparison with similar projects, professional recommendations, and consultations, to determine the scope of the risk and establish an acceptable level should the risk materialize.	By employing methods such as experience from analogous projects and expert consultations, engineering measures shall be developed to mitigate the principal risks pertinent to the project, ensuring the feasibility of seamless execution of subsequent construction works.
Design Stage	The risk source database shall be refined by re-examining and reassessing existing risk sources, adding newly identified risk sources, and improving and correcting the foundational risk data.	In risk assessment, numerical modeling analysis shall be combined with analogous construction experience and expert recommendations. On this basis, risk levels shall be classified and defined, and risk control indicators established.	Comprehensive risk mitigation measures shall be developed. Risk alert levels, preliminary warning signals, and danger signal indicators shall be established.
Construction stage	To thoroughly review, verify, and rectify the sources of risk.	Additional assessments shall be conducted on newly identified risk points; typically, newly added sources of risk are not extensive.	Implement procedures to control, monitor, and record risks. Develop a pre-prepared construction contingency plan for execution in the event of risk occurrence. Additionally, implement engineering measures on-site to mitigate risks.

(2) Identify and analyze the project's risk factors.

Tunnel construction is classified as a high-risk project. The primary characteristics are as follows: the environmental conditions involving risks are highly complex; risk factors are diverse; structures designed to withstand risks are vulnerable; there is a strong interrelation among various risk factors; initial disasters have a high probability of triggering secondary disasters; and, in the event of risk occurrence, there is limited capacity to accept or mitigate the consequences. Therefore, all potential sources of risks that may give rise to possible hazards must be thoroughly examined, identified, classified, and controlled. As a result of detailed and comprehensive research and analysis, the principal sources of risk for this project have been classified into the following main categories. This includes: underground engineering networks, local roads, high-voltage electricity transmission poles, and adjacent buildings.

Note: In addition to the aforementioned environmental risk sources, the inherent structural complexity of the tunnel is also regarded as a risk source. This pertains to considerable variations in the surface topography at the project site, associated with weak geological conditions and significant soil and rock instability.
Therefore, it is necessary to incorporate not only external environmental risks but also risks related to the tunnel structure and engineering geological conditions within the scope of risk management and monitoring.

(3) Fundamental Plan for Risk Control during the Construction Phase

1) The project management platform shall be employed as the foundation to establish the risk management system. For optimal risk management, a dedicated organizational structure, human resource allocation, and workflow system shall be developed and implemented.
2) All information and documentation collected during the geological exploration and design phases shall be thoroughly reviewed, and comprehensive baseline survey work shall be fully organized. Within the scope of construction works, all relevant risk factors—such as urban utility networks, motor roads and bridges, buildings, and structures—shall be comprehensively incorporated and examined in detail within the project environment.
3) Preliminary risk management planning shall be conducted meticulously, establishing a closed and independent risk management system. Risk management shall encompass all the following stages: risk identification, risk assessment, and risk control.
4) A detailed risk management plan shall be developed for each risk source, setting risk management objectives for each of the three stages: identification, assessment, and control. Should the management objectives of the current phase not be fully achieved, advancement to the subsequent phase shall be prohibited. This approach enhances discipline and accountability in risk management implementation, thereby preventing the transfer of uncontrolled risk elements to the next phase.
5) Meticulously structured construction management is an essential measure for controlling risk occurrences. Perform a comprehensive analysis of geological exploration data and the integrity of construction design documentation, preliminarily develop the master plan based on finalized design documentation, and prepare a stable 'Construction Organization Plan for the Execution Stage.' The implementation plan for all major nodes, complex, and critical engineering works must be stable and reliable, and a specialized detailed organizational plan shall be prepared for each relevant stage and technological process. It is necessary to develop in advance an engineering plan for equipment that may impact the construction schedule, conduct design review, and prepare organizational documentation for the implementation phase.
6) Risks shall be appropriately categorized and assigned levels based on the characteristics of each risk source. A specific construction organization plan tailored to each distinct risk source shall be developed. For the highest risk sources, potential hazardous indicators and adverse conditions shall be anticipated, and at least one contingency plan shall be prepared in advance.
7) Integrate traditional quality management with the project’s risk management, ensuring that the project control objectives and evaluation criteria are implemented comprehensively, without

redundancy, and in a cohesive manner. At the management level, it is essential to organize work without duplication or omission.

8) Based on the requirements and needs of risk management information, the information platform shall be reintegrated and enhanced, upgrading the traditional information platform for underground engineering works to include 'caution,' 'early warning,' and 'alert' functions.
9) Throughout the risk management process, the experience of internal specialists within the sector shall be fully respected. A major expert review meeting shall be convened to address comprehensive planning matters, deliberate, and approve the plan. Periodic expert consultations will be held on critical phases and complex special issues to integrate experience. Furthermore, regular monthly expert consultation meetings shall be conducted to identify deficiencies based on expertise and implement necessary corrective actions.
10) Alongside the use of traditional methodologies, research and implementation of new technologies and materials shall be conducted, specifically adapted to the characteristics of risk sources.
11) According to the classification of risk sources, and considering the actual conditions of the relevant management departments and organizations, the project plan shall be presented in advance to all property units and contractual agreements shall be concluded, thereby ensuring the stability and integrity of the plan and preventing alterations to the project plan resulting from external factors.
12) For all sources of risk, an "Emergency Response Plan" shall be developed, and specialized drills and comprehensive training shall be conducted to ensure timely, effective, and systematic management of hazardous incidents.

5.8.3. Risks in Tunnel Construction and Their Mitigation Measures

(1) Fundamental Risks in Tunnel Construction Works

1) Soil Collapse and Subsidence

The causes of collapse during tunnel excavation are diverse and can generally be categorized into the following two factors: Natural factors, including geological conditions, loading conditions, changes in groundwater, and others; Human factors: inappropriate design or improper construction methodology. Technical measures: employing the “Preliminary Reinforcement” method, which involves installing supports, casting concrete, and stabilizing the surrounding rock to enhance rock quality. Alternatively, minimizing deformation of the surrounding rock by utilizing the rotary spraying arc method or pre-cut perforation techniques. Implement effective drainage measures before and during construction, ensuring that groundwater is discharged without entering the tunnel. Select the appropriate excavation method, utilizing techniques such as the staged excavation method, short-stage method, central wall partition method, and glass-shaped method. To enhance the initial anchorage, employ methods including increasing the thickness of sprayed concrete, compacting and extending anchor rods, adding reinforcement mesh or using fiber-reinforced concrete, and augmenting or densifying steel structures. Perform high-quality measurements of the surrounding rock and take immediate corrective measures if any deformation or abnormalities are detected. This includes constructing permanent concrete lining in accordance with the design drawings, employing reinforced concrete lining, increasing the thickness of the lining concrete, modifying the cross-sectional shape of the lining, and enhancing the concrete quality grade.

2) Sudden water inflow

One of the most common geological hazards during tunnel construction that causes flooding and soil instability is sudden water inflow. The primary causes of sudden water inflow are water sources such as fractures, large sinkholes and depressions (tar water), excavated voids within Carboniferous rock formations (areas storing water in old mine workings), as well as old water reservoirs in metal and non-metallic mines. Technical measure: Define the drainage direction of the main flow in gullies and hollows relative to the tunnel location by utilizing drainage pipes, drainage channels, drainage pits, and dewatering conduits. Use grout to cease water flow; in cases where the water flow in gullies and hollows is low or where alternative outlets or branch watercourses exist, apply the method of blocking the fluid entry. Water drainage using the counter

slope of the tunnel excavation, discharging water through suction pumps and pipes, establishing intermittent pump stations and water collection depressions in sections, situating temporary mobile pump stations near the excavation area, and transferring water to permanent pump stations via suction pumps.

(2) Risk mitigation measures during tunnel construction

1) Measures to mitigate risks during the construction phase of the tunnel portal and the shallow curved concealed excavation sections.

A. Prior to commencement of construction works, a thorough verification of the tunnel location, topography, geological conditions, all kilometer markers, and elevation data is required. All hazard-causing factors, such as collapse and rockfall, must be individually identified and eliminated. If loose soil or other adverse geological materials exist on the excavation crest and have already caused collapse, they shall be completely cleaned and removed. Loose rocks, boulders, and hazardous stones with the potential to fall must also be fully cleared; if removal is not feasible, reinforcement measures shall be applied.

B. Before commencing excavation works at the ingress point, it is mandatory to construct a water diversion channel above the pit to prevent surface water from penetrating into the excavation area. This measure will prevent detrimental impacts on the stability of the exposed tunnel slope and the excavated pit. During excavation, protective measures for the slope shall be implemented simultaneously with the slope cutting. Furthermore, prior to full penetration, it is required to reserve the soil of the central section of the excavation.

C. According to the geological data collected to date, given the poor geological conditions at the entrance sections of both tunnel portals, excavation will commence only after preliminary reinforcement of these sections with a long pipe lattice and small control pipes to ensure construction safety.

2) Measures to Prevent Risks during the Construction of Drainage Channels

A. Surface Treatment

Prior to Commencing Tunnel Excavation Works, the Site Must Be Inspected for the Presence of Water. If Water Is Found in the Drainage Channel, Appropriate Preliminary Drainage Measures Shall Be Implemented. If No Water Is Present on Site, Temporary Water-Stopping Ditches Shall Be Constructed to Prevent Flowing Water and Rainwater from Entering the Channel. Protective measures to prevent water infiltration must be strengthened.

B. For surface anchoring, cement shall be poured on the ground surface and anchor bolts installed for reinforcement.

3) Measures within the culvert

An appropriate excavation method shall be selected based on the surrounding rock conditions, and preliminary reinforcement within the culvert shall be thoroughly executed. Strictly monitor each stage of construction, precisely control the length of excavation repetition and advancement, intensify control and measurement activities, and ensure timely and proper direction of design drawings and construction works.

(3) Measures to mitigate the risks associated with fractured bedrock zones and underground water development areas

1) Based on the geographical conditions and the collected data, fracture zones have been identified in certain sections of the tunnel portal, which increase construction risks and pose a threat of collapse and other accidents. Therefore, it is imperative to rigorously implement support measures throughout the construction process.
2) Enhance the preliminary geological data, identify soil fracture zones and groundwater development, and implement the prescribed technical measures.
3) During penetration of fracture zones by drilling methods in mining operations, protect the intermediate pipeline and install preliminary small drainage channels to reinforce the soil.

Additionally, taking into account the conditions of underground water rise, a suitable method for cement grouting shall be selected.

4) For drilling and permeation in the fracture zone by the mining method, it is appropriate to select and employ the three-stage seven-step method and the CD method; throughout construction, the sequence of hole permeation shall be strictly monitored and the progress of permeation controlled.
5) Enhance site supervision and surveying, perform regression analysis on survey data, and oversee the design drawings and construction works.

(4) **Risk control measures for water-permeable sections of construction**

Based on tunnel construction experience and considering the specific characteristics of the tunnel in this project, the following engineering measures will be primarily implemented in sections with water-bearing soil.

1) Using a scientific management methodology, the preliminary estimation and notification of sudden large inflows of water in underground engineering works shall be prioritized and enhanced.
2) Measures to stop water infiltration shall be carried out by surface casting. When stopping water infiltration by casting, the surrounding weakened rock areas must be included. The length of the casting section shall be determined based on geographical conditions, water volume, water pressure, and other pertinent factors. The spacing between the centers of the casting holes shall be established in accordance with the thickness of the compression curtain, the radius of compression distribution, and the overlap of distribution areas for each hole.
3) Preliminary drilling and water drainage measures
When implementing dewatering measures through preliminary drilling, conditions must be ensured to allow the drilling water to flow rapidly away from the underground section. The bottom of the preliminary drilling hole shall be excavated 1 to 2 spiral lengths in advance of the face excavation section of the hole.

(5) Measures Against Landslides and Surface Soil Instability
Based on experience, the following measures shall be implemented to mitigate landslides or unstable surface soil conditions:

1) When selecting the tunnel alignment, it is essential to avoid, as far as possible, sections prone to landslides or surface instability.
2) To satisfy the requirements of directional operations, where circumventing the earthquake slip zone is not feasible, the crossing should be carried out in the shortest possible direction along the slip boundary, and the tunnel foundation must be established on stable rock formations.

(6) Technical safety measures for tunnel excavation, drilling, and blasting works

1) Excavation constitutes the most critical stage in ensuring tunnel safety. Due to the large tunnel cross-section, it is essential to strictly comply with the design drawings and construction organization plans, select the optimal excavation method, carefully monitor cycle progression, and determine the most suitable blasting parameters to guarantee the safety of the construction works.
2) Excavation of the tunnel through topsoil and disturbed zones shall be executed using mechanical excavation or shallow borehole blasting methods. After blasting, thorough inspections shall be performed, and in accordance with geological conditions, blasting parameters shall be timely adjusted to ensure blasting safety. During construction, the principle of 'pre-installation of the pipeline, short advance, strong support, strict water control, early closure, and frequent measurement' shall be strictly adhered to, ensuring that all stages of work are conducted in close coordination and consistently progressed.
3) When drilling equipment or a drilling machine is used for tunnel excavation, the wet drilling method must be employed, and re-drilling in residual sections is strictly prohibited.
4) Underground blasting operations shall be conducted in accordance with the 'Blasting Safety Regulations'. Blasting within the tunnel shall be executed under unified supervision, with all personnel relocated to a safe zone—protected from toxic gases, vibrations, and rock

fragments—at a distance of no less than 200 meters.

5) Following the blasting, ventilation must be performed to expel smoke and gases. Subsequently, the safety inspector shall permit entry to the worksite only after a minimum of 15 minutes. After verifying and confirming that the area is safe, other workers shall be permitted to enter the site.
6) In the event of an unexploded cartridge (blast failure), a safety zone must be established, and it shall be dealt with safely in accordance with regulations exclusively by the blaster who executed the blast. Depending on the circumstances, the following methods shall be employed: reconnecting burning or electric wires and conducting a re-blast; detonating residual sections is prohibited. A parallel blasting tunnel shall be drilled at a distance of 0.6 meters from the unexploded charge for conducting a detonator blast; however, attention must be paid to fractures in the rock to ensure no cracks connected to the unexploded charge are present. If the blasting material is obstructed, it must be safely removed prior to re-blasting.
7) Processing of explosive materials shall be carried out at a designated processing site located at least 100 meters from the tunnel portal.
8) Measurement of the surrounding rock during underground excavation constitutes a critical stage of construction works management. Appropriate technical safety measures shall be implemented in accordance with varying geological conditions.
9) Immediately following tunnel excavation, the installation of the structural support shall be carried out without delay. Any changes in the surrounding rock measurement data, cracking of the sprayed concrete surface, or the appearance of fissures on the ground surface shall be regarded as a warning of potential danger. Under such circumstances, personnel shall be immediately evacuated from the site, and construction shall resume only after appropriate stabilization measures have been implemented.

5.9. Design Drawing for Tunnel Environment Protection

(1) Principles for Design Drawing Development

The implementation of the tunnel road project is essential for conserving land resources, minimizing the destruction of surface vegetation, and protecting the environment. The tunnel road design drawing consistently adheres to environmental protection principles and emphasizes the application of advanced environmental technologies and innovative methods. A combined policy of prevention and protection shall be implemented, adhering to the principles of comprehensive planning and optimal organization. Engineering construction and environmental protection shall proceed concurrently, with the imperative to minimize the occurrence of new mountain-related diseases resulting from human activities.

(2) Environmental protection measures at the design drawing stage

1) During the placement of the tunnel portal, the natural state of the mountain shall be preserved to the greatest extent possible, ensuring maximum harmony with the surrounding environment.
2) Landscaping the tunnel portal area with greenery not only facilitates light protection works but also contributes to environmental preservation by reducing smoke and dust and enhancing air purification.
3) The tunnel cross-section design shall be refined to optimally balance excavation and filling, thereby minimizing the volume of waste material. Soil excavated from the tunnel shall be suitably regulated in the vertical axis and utilized for the road foundation fill. Hard, high-quality rock shall be consolidated and stored at a specialized stone processing facility for use in retaining structures and as concrete aggregate; should disposal be necessary, waste shall be stored at designated waste sites according to the conditions of each respective work section.
4) When designing the tunnel drainage system, the method of 'prioritizing prevention, combining blocking and sealing, and subsequently draining infiltrated water' must be applied. This approach will effectively optimize the tunnel drainage process and positively impact water resource conservation.

5) Water inside the tunnel and at the tunnel portals must be discharged in a manner compatible with environmental requirements.

(3) Environmental protection measures during the construction phase

1) The wet spraying technique shall be employed in the concrete spraying process. This constitutes a critical measure that, on one hand, mitigates dust generation caused by dry spraying and, on the other hand, ensures the quality of the concrete.
2) Utilize construction methods and equipment that minimize noise and vibration.
3) Strive to reuse site waste by employing excavated sand and gravel as materials for road subbase construction.
4) Choose an appropriately designated area for disposal of unusable waste, such as semi-barren land or depressions.
5) Following construction activities on the construction site, thorough cleaning, establishment of green landscaping, and restoration works shall be performed to ensure environmental protection.
6) During construction, wastewater and chemically contaminated muddy liquids potentially harmful to the environment must be treated before discharge.

(4) Protection of Earthworks

1) Measures for Protecting Earthworks from Erosion and Damage During Construction

A. Prior to the commencement of construction activities, drainage facilities shall be fully completed; before tunnel excavation, protection of the tunnel portal and side slopes, along with the installation of drainage pipes, shall be carried out. Water discharged from inside the tunnel shall be treated and disposed of in accordance with applicable standards, ensuring no contamination of river and stream waters.
B. Unauthorized excavation and trenching during the construction of temporary roads are prohibited; measures shall be implemented to prevent contamination and erosion of water and soil.

2) Protective measures for water and soil at the waste disposal site for excavated soil.

A. The selection of the waste disposal site shall be based on the design drawings and planning documentation. In general, a site with a gentle slope within a mountainous ravine is selected, avoiding valleys that accumulate significant amounts of water and environmentally sensitive areas. The stone masonry wall includes drainage holes, and a drainage pipe is installed at the bottom of the site. Upon the completion of the project, the site shall be leveled, the soil restored, trees planted, and turfed.
B. Unauthorized accumulation of waste is prohibited; all waste must be received, managed, and disposed of at the designated waste disposal site.

5.10. Tunnel ventilation system

5.10.1. Design Principles

(1) The engineering design for the tunnel ventilation system shall comply with currently valid standards and regulations, incorporate successful international best practices from comparable projects, and be adapted to the actual project conditions, ensuring safety, economic efficiency, advancement, optimization, and environmental sustainability.
(2) During normal road traffic conditions, harmful exhaust gases emitted from vehicles inside the tunnel (such as CO) and odors in the air are diluted by fully utilizing natural ventilation, airflow induced by traffic movement, and mechanical ventilation, thereby complying with hygiene standards and environmental assessment requirements and providing a suitable environment for drivers and maintenance personnel. Moreover, to ensure safe driving, air quality and environmental visibility will be enhanced.
(3) In the event of a fire within the tunnel, the ventilation system shall deliver airflow into the tunnel

at a specified velocity to control the dispersion of smoke and hot gases, while supplying a suitable amount of fresh air to passengers and firefighters inside the tunnel. This ensures safe evacuation from the hazardous tunnel during human evacuation, permits fire-fighting vehicles to approach safely downwind during fire suppression, and establishes the necessary conditions for firefighters to carry out rescue operations.

(4) The tunnel ventilation shall be designed to operate simultaneously in the event of a fire.

(5) The capacity of the ventilation equipment shall be planned to accommodate future requirements. Subject to compliance with the project design standards, investments in project implementation and operational power consumption shall be minimized to the greatest extent possible, while maintenance and management shall be facilitated.

(6) When selecting ventilation equipment, priority shall be given to safety and reliability, considering technological advancements. Equipment shall be sourced locally whenever feasible.

The noise and vibration levels of all operational equipment within the ventilation system must comply with applicable standards and the requirements of the relevant impact assessment reports, both externally and internally.

5.10.2. Meteorological data

Average sea level elevation: 1350 meters Average air pressure: 850 hectopascals Average temperature: -0.4℃ to 1.3℃

5.10.3. Drawing design standard

Ventilation hygiene standard:

(1) Permissible CO concentration inside the tunnel δ:

1) During normal operations, the design concentration of CO inside the tunnel δ shall not exceed 150 ppm.
2) In the event of traffic congestion, all lanes inside the tunnel shall have stationary vehicles with no movement between them, and the average speed Vt ≤ 30 km/h, with the congestion duration not exceeding 20 minutes; the design concentration of CO inside the tunnel shall be δ = 150 ppm.
3) In tunnels with mixed pedestrian and vehicle traffic, the design concentration of CO inside shall not exceed 70 ppm.

(2) Permissible dust concentration inside the tunnel K: All tunnel lighting shall employ LED light sources. The values of the permissible dust concentration K inside the tunnel, using LED light sources as specified in the "Road Underpass Ventilation Design Regulations" document, are presented in the table below.

The fan layout plan is as follows.
Two fans constitute one set, with approximately 250 m spacing between each set;
Located 160 m from the tunnel portal.

When installing substations at both ends of the tunnel, fans shall be positioned as evenly as possible at both tunnel portals; The substation fan shall be installed near the tunnel substation side only when the substation is situated at a single end.

Based on ventilation calculation results, the required air volume in the new ring road tunnel shall be regulated according to the operating conditions of diluted CO under normal traffic, monitored under the operating conditions of diluted CO during congestion, and, in the event of

fire, it shall serve to prevent tunnel fire smoke from transferring into the chimney system.
This project requires a total of 8 sets of fans for the left and right lines, with two units per set, totaling 16 units.

5.10.4. Tunnel ventilation control

(1) Number of fans operating in the underground road

If the piston wind generated by natural airflow and traffic flow fails to achieve CO and VI values in compliance with technical requirements, it is necessary to activate a specified number of fans for forced ventilation. The ventilation system shall serve as the primary energy-consuming equipment for the operation of the underground section of the expressway. To achieve energy savings, the number of operational fans shall be regulated in accordance with the required parameters under varying working conditions, based on CO concentrations and VI values. The air volume in the underground tunnel is controlled by the number of activated fans and can be adjusted incrementally from 0 to 100% of the nominal volume.

According to the ventilation calculation results, the required airflow for normal driving conditions in a single-bore tunnel is regulated based on the diluted CO concentration. In this case, a total of four sets of fans are required, two per set, amounting to eight fans in total; In single-bore tunnel congestion conditions, the required air volume is regulated based on the diluted CO concentration. In this case, a total of eight sets of fans are required, two per set, amounting to sixteen fans in total; In the event of a fire in a single-bore tunnel, this system prevents the ingress of tunnel smoke and switches to the chimney system. In this case, a total of four fan sets are required, including one set of two fans, totaling eight fans.

Table 5. 9. Number of operational axial fans under all working conditions

Classification of working conditions	Number of recommended jet fans per tunnel
Normal conditions	4 sets (2 pcs./set)
During road traffic congestion	All 8 sets of fans shall operate
In case of fire	4 sets (2 pcs./set)

The operational conditions and control indicators specified in the table constitute the fundamental requirements; additional operational conditions may be introduced based on actual operational needs. The fan within a tunnel may operate independently or two fans may operate concurrently as a single unit arranged in parallel. It shall be possible to adjust the number of operating fans at any time during actual operations. As it is not possible to repair a fan while in operation under any condition, all fans within the tunnel must be capable of operating in rotation. In the event of a fire in the underground road, vehicles located ahead of the fire shall evacuate rapidly from the underground road at normal speed. The tunnel airflow shall be regulated by axial fans installed to operate at velocities of 2 to 3 m/s, extracting smoke and dust from the underground road to the outside, thereby ensuring the safety of vehicles located behind the fire.

(2) Ventilation Control Method

The ventilation control system shall be integrated with the lighting control system, fire alarm system, fire-fighting system, traffic control system, and centralized management system.
There are two primary types of tunnel ventilation control: automatic control and manual control.
The automatic control method regulates the airflow volume through the network using signals from sensors installed in tunnel detection devices (e.g., CO/VI sensors, vehicle detectors, wind speed, and direction sensors).
The manual control regulates the airflow volume by manually operating the equipment. This shall be divided into connection control and individual control. The manual control device shall be installed in a safe and easily accessible location, with clear signage and protective measures. The height of the operating button shall not exceed 1.5 m above the ground.
The primary methods of automatic control are direct control, indirect control, and program control.

The direct control method directly detects smoke concentration and CO content within the

tunnel via smoke transmission sensors and carbon monoxide concentration sensors installed at various points throughout the tunnel. Following calculation and processing, a control signal is issued to monitor the operation of the fan.

Indirect control method: Utilizing traffic flow energy data from the tunnel's approach section and detection data from vehicle detectors within the tunnel, the traffic volume, driving speed, vehicle type, and configuration inside the tunnel are continuously assessed. This enables the analysis and calculation of vehicle emissions, including CO emissions, thereby facilitating effective air volume control.

Program control method: Does not take into account the actual variations in VI, CO concentration, or traffic volume; rather, based on empirical data, it calculates traffic volume and the corresponding emissions of smoke and CO for each time segment, controlling the fan operation according to a predetermined program.

The fan in the tunnel must satisfy the following requirements during operation.

1) The motor must not be started and stopped frequently, as this causes voltage fluctuations and adversely affects the fan's service life to some extent;
2) The control cycle of the fan shall be no less than 10 minutes;
3) When starting the fan individually or in a group, the fan with the shortest accumulated operating time shall be started first;
4) The fans shall be started individually or in groups with a time interval not less than 30 seconds. In actual operations, different control schemes may be utilized depending on the circumstances.

5.10.5. Tunnel fire prevention and smoke extraction duct

The tunnel shall implement manual ventilation mode under fire conditions. If the ventilation control mode was initially set to automatic control, the system shall automatically switch to manual control. The system shall alert the operator with auditory and visual signals and recommend appropriate actions. The proposed measure shall reduce the wind speed in the fire tunnel to 2–3 m/s, with the wind direction optimally oriented to facilitate the safe evacuation of personnel. The operator may disregard the proposed action and perform the operation manually in its entirety.

In the event of a fire, two underpasses shall be closed to prohibit vehicle access. To organize evacuation, rescue, and fire-fighting operations, tunnel management personnel shall immediately enter the tunnel. In general, the principles of traffic management are as follows.

If in proximity to a fire source (for example, in a tunnel lane directly above the fire source), leave the vehicle and evacuate.

At a safe distance from the fire source (for example, the section of a single-lane tunnel upstream from the fire source), after confirming the complete cessation of traffic in the fire-free tunnel section distant from the fire source, traffic in the tunnel section near the fire source shall be redirected to the fire-free zone via a transversal route, following the procedure below: vehicles in the lane closest to the fire source shall first be evacuated, relocating the vehicles nearest to the fire source in the adjacent tunnel; then, vehicles in the second closest adjacent tunnel to the fire source shall be evacuated; following this principle, all vehicles within the fire-affected tunnel shall be relocated.

In general, the organization of road traffic must be systematic, that is, directed and supervised on site.

In the event of a fire, the fire tunnel shall be ventilated at the fire rescue airflow velocity, while the main fan of the adjacent tunnel shall operate under normal conditions. The jet fan shall be employed in the fire tunnel to maintain the air pressure in the open communication duct at a lower level than the air pressure in the normally operating tunnel, thereby preventing smoke and high-temperature gases from the fire tunnel from spreading into the adjacent tunnel. If the axial fan can ensure uniform airflow, the traffic in the closed section behind the fire source will remain

smoke-free and in a safe environment.

The smoke and high-temperature gases at the fire source flow back towards the rear; to ensure the safety of vehicles and pedestrians behind, it is necessary, in the event of a fire in the tunnel, to regulate the wind speed along the tunnel length within prescribed limits. According to the technical specifications, the velocity of fire smoke exhaust in the chimney shall be assumed to be 2–3 m/s, taking into account the temperature of the lower fire smoke flow and the velocity of convective displacement of the constituents. In general, the transition from normal operational ventilation to fire ventilation shall not occur instantaneously; the required time depends on the complexity of the tunnel ventilation system. In the event of a fire, first adjust the operational status of the fan, then regulate the wind speed for the rescue operation to control the fire level and the direction of smoke flow. After all personnel have been completely and safely evacuated from the tunnel, the ventilation system of the smoke shaft must be activated. The mechanical ventilation system of the smoke chimney must select different ventilation methods depending on the location of the fire origin. The primary function of the smoke chimney is to expel smoke along the adjacent tunnel.

Special principle for controlling post-fire ventilation:

In the event of a fire hazard, ventilation shall be divided into at least two stages: evacuation and rescue stage, and fire suppression stage. During the evacuation and rescue stages, ventilation is primarily intended to control the distribution of air volume; During the fire suppression stage, ventilation is primarily intended to control the distribution of temperature.

Table 5. 10. Outcome drawing for the installation of fans in the tunnel

5.12.13. Main electrical distribution station and fire-fighting pump room of the tunnel

(1) Ventilation system

1) The low-voltage electrical distribution room is equipped with a mechanical ventilation system, mechanical chimney, natural air supply, and temperature sensors. The fan removes excess heat inside the room by operating at variable frequency in response to temperature fluctuations, thereby maintaining the temperature of the low-voltage electrical distribution room at no less than 40 °C. The normal ventilation volume of the low-voltage distribution room is calculated based on the heat generation of the transformer, low-voltage distribution panels, and other equipment, as well as the ventilation frequency; the emergency exhaust duct ventilation rate is set at 12 air changes per hour, with the calculated ventilation volume being 5627.95 m³/hour. The fan employs a single-stage design based on the volume required for emergency ventilation, thereby fulfilling the requirements for both normal and emergency ventilation simultaneously. The fan is equipped with a frequency converter and operates at variable frequency in accordance with indoor temperature variations during normal ventilation. The accident control switch

is installed on the low-voltage distribution board and the exterior wall; in the event of a fire, the system is shut down manually or automatically to mitigate smoke.

2) The high-voltage distribution room is equipped with mechanical ventilation, a mechanical chimney, and natural air supply. The normal ventilation volume for the high-voltage distribution room shall be determined as the greater of the heat generated by the transformer, high-voltage distribution cabinet, and other equipment, or the calculated ventilation frequency. The emergency chimney ventilation frequency is 12 times per hour, with a calculated ventilation volume of 3813.98 m³ per hour. The fan employed for emergency ventilation is a single-stage fan that concurrently satisfies the requirements for both normal and emergency ventilation. The fan is equipped with a frequency converter, and the regular ventilation operates at a variable frequency according to the changes in indoor temperature. The accident control switch is installed on the low-voltage distribution board and the exterior wall; in the event of a fire, the system is shut down manually or automatically to mitigate smoke.
3) The power supply room for the electrical system without interruption is equipped with a mechanical ventilation system, a mechanical chimney, and natural air supply. The volume of regular ventilation for the power supply room without interruption shall be calculated based on whichever is greater: the heat generated by the equipment or the ventilation frequency. The ventilation frequency for emergency exhaust ducts is 12 air changes per hour, with a calculated ventilation volume of 2517.91 m³/hour. The fan employs a single-stage design based on the volume required for emergency ventilation, thereby fulfilling the requirements for both normal and emergency ventilation simultaneously. The fan is equipped with a frequency converter, and the regular ventilation operates at a variable frequency according to the changes in indoor temperature. The accident control switch is installed on the low-voltage distribution board and the exterior wall; in the event of a fire, the system is shut down manually or automatically to mitigate smoke.
4) The stray current electrical room is equipped with a mechanical ventilation system, mechanical exhaust ducts, and natural air supply. The standard ventilation volume of the stray current electrical room shall be calculated based on whichever is greater: the heat generated by equipment or the required ventilation frequency. The ventilation frequency of the emergency chimney is 12 air changes per hour, with a calculated ventilation volume of 2910.67 m³/hour. The fan employs a single-stage design based on the volume required for emergency ventilation, thereby fulfilling the requirements for both normal and emergency ventilation simultaneously. The fan is equipped with a frequency converter, and the regular ventilation operates at a variable frequency according to the changes in indoor temperature. The accident control switch is installed on the low-voltage distribution board and the exterior wall; in the event of a fire, the system is shut down manually or automatically to mitigate smoke.
5) The control center is equipped with a mechanical ventilation system, a mechanical chimney, and a natural air supply. The standard ventilation volume of the control center is calculated according to whichever is greater: the heat output of the equipment or the ventilation frequency. The emergency chimney ventilation frequency is 12 cycles per hour, with a calculated ventilation volume of 5405.79 m³/hour. The fan is a single-stage unit designed to simultaneously satisfy the requirements of both regular and emergency ventilation, based on the emergency ventilation volume. The fan is equipped with a frequency converter, allowing regular ventilation to operate at a variable frequency according to the indoor temperature. The accident control switch is installed on the low-voltage distribution board and the exterior wall; in the event of a fire, the system is shut down manually or automatically to mitigate smoke.
6) A mechanical ventilation device has been installed in the fire pump room. Air exchange is calculated at 5 times per hour, with a calculated air exchange volume of 1221.8 m³ per hour. The method of regulating airflow utilizes both upward supply and upward return techniques. Due to the humid working environment in the pump room, all fan motors shall be moisture-resistant motors.

(2) Ventilation system

The control room is equipped with a comfortable ventilation system, with a cooling load of 11.48 kW, a cooling index of 130 W/m2 per unit area, a ventilation heating load of 7.51 kW, and a heating index of 85 W/m2 per unit area. The spare parts room is equipped with a comfortable ventilation system, having a ventilation cooling load of 4.05 kW and a cooling index of 130 W/m2 per unit area, as well as a ventilation heating load of 2.65 kW and a heating index of 85 W/m2 per unit area. A split air conditioning system with one indoor and one outdoor unit has been selected. The external unit is installed on the external concrete slab. The air conditioner condensate is discharged through a pipe to an external storage tank, which is regularly emptied. The air conditioner cooling pipe is made of copper, with rubber and plastic materials used for insulation.

5.11. Tunnel water supply, drainage, and fire protection facilities

5.11.1. Design principles

(1) To ensure the regular operation and operational safety of the tunnel structure and its equipment, the tunnel drainage system shall comply with the principle of 'prevention, drainage, isolation, locking, adaptation to local conditions, and integrated management.'
(2) Accurately classify tunnel traffic projects, implement the fundamental principles of “safety, efficiency, and practicality,” and reasonably establish the scope of fire protection.
(3) The tunnel water supply shall be safe and reliable, complying with the specific requirements for water quantity, water quality, and water pressure at each water point.
(4) When planning fire protection and water supply systems, it is essential to integrate long-term and short-term plans based on the law governing road traffic growth, with priority given to the short-term horizon.
(5) A comprehensive approach must be adopted from the outset to rationally define the fire protection and water supply system planning scheme in accordance with tunnel management and maintenance systems, scope, level, project characteristics, and water source studies.
(6) The tunnel fire protection system’s pipeline network is configured in a ring shape and assumes a single concurrent fire incident; the fire protection water supply system employs a wet fire protection water supply system.
(7) The water source for extinguishing tunnel fires shall be the city’s nearest water supply. For tunnels lacking a surrounding water supply network, it is advisable to first consider utilizing groundwater sources such as well water. If conditions allow, natural water sources such as rivers, lakes, seas, and reservoirs may be utilized, provided that the technical requirements are fulfilled.
(8) The water source for tunnel fire extinguishing shall be located separately from domestic and industrial water sources, and the firefighting water supply shall be regarded as a dual water source.
(9) When selecting various equipment, priority shall be given to advanced technology, energy efficiency, environmental protection, excellent performance, high reliability, uniform technical specifications wherever possible, and ease of maintenance.
(10) In Ulaanbaatar, winters are extremely cold (down to -40°C), summers are short (up to 30°C), with frequent freeze-thaw cycles. Water supply, drainage, and fire water supply pipes require frost protection measures.

5.11.2. Scope of design drawings

The water supply, drainage, and fire protection design drawings for this project primarily include: tunnel fire hydrant systems, water spray foam fire suppression devices, fire extinguisher configurations, and fire alarm system designs.

5.11.3. Selection of the primary design parameters

(1) Fire hydrant

1) Water consumption for fire suppression in the tunnel: 20l/s;
2) Water consumption for fire suppression outside the tunnel: 30l/s;
3) Water guns shall be installed at adverse points to fill the water column: ≥10m;
4) If the outlet water pressure of the fire hydrant exceeds 0.5 MPa, a fire hydrant equipped with a pressure-reducing and stabilizing dual valve, a 25 m water pipe, and two 19 mm fire extinguishing water guns shall be used.
5) The duration of fire in the I tunnel shall be at least 3 hours
6) Spray flow rate: ≥5l/s

(2) Water film-forming foam fire hydrant

1) Freeze-resistant foam liquid mixing ratio: 3%
2) Mixed liquid flow rate: ≥30l/min
3) Foam liquid reserve 30L
4) Spraying distance ≥6m
5) Injection time ≥30min
6) Water supply pressure ≥0.35 MPa

(3) Fire extinguisher configuration

A minimum of four portable dry powder fire extinguishers (MF/ABC6) shall be installed indoors.

5.11.4. Fire extinguishing capacity

When planning and designing city road tunnels in accordance with the applicable standards, the fire water supply system shall be designed concurrently. It is not required to design a fire water supply system for IV category tunnels, nor for III category tunnels intended for pedestrian and non-motorized vehicle traffic. This is a I category tunnel, and its fire water supply system will utilize a temporary high-pressure water supply system.

5.11.5. Quantity of Firefighting Water

The quantity of firefighting water in the tunnel shall be determined based on the number of fires that occurred during the period and the volume of water consumed to extinguish those fires (including both the interior and exterior of the tunnel). The quantity of firefighting water used for each tunnel in this project is presented in the table below.

Table 5. 11. Table for Calculation of Tunnel Fire Water Consumption

Tunnel Name	Starting Point	End Point	Tunnel Length (m)	Tunnel Type	External Fire Hydrant Water Consumption (l/s)	Internal Fire Hydrant Water Consumption (l/s)	Total Fire Water Consumption (l/s)	Fire Water Supply Duration (hours)	Tunnel Fire Water Consumption (m^3)
1	K8+730	K10+810	2080	Type 1	30	20	50	3	540

5.11.6. Fire Protection System Design Drawing

(1) Fire Water Supply Source

This tunnel is located within the city and utilizes the municipal water supply as its water source.

(2) Fire Hydrant Water Supply System

The tunnel in this project is classified as a Class I tunnel. The tunnel's fire water supply system comprises a temporary high-pressure water supply system. The water consumption for tunnel fire suppression is calculated at 20 l/s per fire within the tunnel, and 30 l/s for extinguishing fires outside the tunnel. The fire duration is three hours. The water consumption for tunnel fire suppression per fire incident is 540 m³. A 600 m³ fire water tank and fire pump room are located in small external chambers at the tunnel portals to store the water reserves used for extinguishing fires both outside and inside the tunnel.

The main fire water supply pipeline within the tunnel shall consist of DN300 cast iron galvanized welded steel pipe, 6.0 mm in thickness, with a pressure resistance capacity of ≥1.0 MPa, and equipped with bell-and-spigot joints. The fire line pipeline within the tunnel shall be installed into wells located on the right and left sides; by connecting to the main fire water supply trunk pipeline, an external ring network surrounding the tunnel is established to ensure the reliability of the water supply. The fire hydrant branch pipe is constructed from DN65 hot-dip galvanized welded steel pipe, having a wall thickness of 4.0 mm and a pressure rating of ≥1.0 MPa.

The main pipe within the tunnel consists of DN300 hot-dip galvanized seamless steel pipe, featuring internal and external walls, connected by grooved couplings (clamps). The DN300 pipe connects the main fire water supply pipe with two nozzles located outside the tunnel openings at both ends of the tunnel, forming a circular fire pipe network to ensure reliable water supply on both sides. Fire hydrants are installed at 50-meter intervals, and the fire hose cabinets are mounted on the external wall. The duct extension connection shall be adjusted to accommodate the fire water supply pipe requirements within the tunnel. A pressure gauge shall be installed at the tunnel's ingress and egress sections. When the dynamic pressure at the fire hydrant water outlet exceeds 0.5 MPa, or the static water pressure exceeds 1.0 MPa, pressure shall be reduced using a pressure-reducing and stabilizing fire valve, and in the event of fire, the fire alarm button shall be activated.

The main fire water pipe in the tunnel is connected to the vertical fire hydrant pipe by a mechanical (flow) joint, and the main pipe is generally equipped with an electric solenoid valve to remain dry. The main fire water supply pipe is divided into multiple independent sections. In the event of damage to a section, no more than five fire hydrants shall be rendered inoperative. Install the damper valve at the highest point of the main fire pipeline within the tunnel. Install the drainage valve at the lowest point of the pipeline network.

Reliably weld the fire extinguishing pipes in the tunnel to the grounding network every 50 meters.

(3) This tunnel shall be equipped with foam fire extinguishing devices generating a water spray cover capable of rapidly and effectively suppressing fires, in addition to the standard fire extinguishing functions.

All fire hydrants in the tunnel are equipped with water film-forming foam fire extinguishing devices, which primarily comprise fire-extinguishing foam fluid cartridges, rubber hoses, proportional mixers, intermittent sprinklers, and hose guide frames, among other fittings. Content of water-based foam fire extinguisher: 3%.

(4) Fire extinguisher installation

The fire extinguisher configuration for this project is classified as highly hazardous, and the fire classification is Class Bx. The fire extinguisher type is a 6 kg ammonium phosphate dry powder extinguisher. The fire hydrant, water cover generator, and fire extinguisher are all housed within a single box, with 4 pcs. installed in each box. The fire is detected early and is suitable for timely on-site use.

(5) Water pump connector and Y-strainer

The tunnel fire extinguishing system is equipped with a water pump connector located approximately 3 meters to the right side of the tunnel entrance access direction. This is used for filling the pipe network of fire truckswithwater. Subsurface types shall be employed. Concurrently, to prevent contamination in the water of the foam fire extinguishing device generating the water covering, a Y-shaped filter equipped with a telescopic device has been installed.

(6) External fire hydrant of the tunnel

The external fire extinguisher hydrant is installed underground approximately 5 meters outside each tunnel.

(7) Fire water tank, fire pump room, and similar facilities.

The fire water tank and fire pump room for this project are located in the central zone of the tunnel's small portal.

The structure comprises an aboveground structure and an underground reinforced concrete structure, with fire resistance class II, roof waterproofing class II, basement waterproofing class I, and waterproof concrete rated at permeability class P6.

The fire resistance rating for this project is Level 2. The fire pump room in this project functions as a fire compartment.

The planned fire water consumption for this Tunnel is 540 m³. To ensure the safety of the fire water supply, a 600 m³ reinforced concrete fire water tank has been installed. The fire water tank is equipped with a water inlet pipe, water outlet pipe, ventilation pipe, and drainage pipe. The water tank, inspection hole, iron ladder, wall-passing pipes, pipe fittings embedded in the wall, pipe hangers for water pipes, and ventilation holes are detailed in the drawing titled “Rectangular Reinforced Concrete Water Tank” (05S804). A grille has been installed at the inlet and outlet sections of the fire water tank to prevent clogging of the conveyance pipe by floating objects. The water in the tank is pumped by the fire pump to maintain a dynamic pressure of no less than 0.35 MPa at the outlet of the fire hydrant at the most unfavorable point within the tunnel's fire pipeline network.

1) The control box located in the fire pump room operates the fire pump and pressure regulating pump, and features both remote control and manual operation on site. Equipped with a digital display for local management to directly indicate the water level of the reservoir.
2) In the event of a fire in the tunnel, the fire hydrant water supply fire pump shall be capable of delivering water to the main fire suppression pipeline, thereby ensuring continuous fire extinguishing operation.
3) Under normal conditions, when the pressure in the fire hose network decreases, the pressure stabilizing pump shall be automatically started to supply pressure to the hose network and ensure compliance with the dynamic pressure requirements at the fire hydrant outlet.
4) The water pump control cabinet shall include a low-frequency automatic cycle test function to operate the water pump continuously at low speed, preventing corrosion and shaft seal wear.
5) A remote pressure gauge is installed on the outlet pipe of each water pump to monitor the water supply pressure during pump operation. All collected data shall be transmitted to the water pump control panel.
6) A remote water level display is installed on the fire water tank, and a float valve is installed to trigger alarms for excessively high or low water levels.
7) The deep sewage pump is installed utilizing an automatic connection system, with its opening and closing controlled automatically by the water level in the reservoir. The control device shall be supplied by the manufacturer.
8) The fire water reservoir shall be covered with soil of a thickness not less than that of the local permafrost layer.
9) The fire water reservoir is rectangular in shape, and since the tunnel fire extinguishing systems are relatively autonomous, the water in the reservoir remains stagnant throughout the year in the absence of a fire incident, leading to water quality deterioration and a tendency for algae growth. The solution is to install a self-cleaning sterilizer in the fire water reservoir, perform regular cleaning, add bleaching powder and other disinfectants, and to maintain the water quality, regularly clean the reservoir’s water drains.
10) Fire extinguishers shall be installed in the fire pump room and transformer room.
11) This design drawing stipulates the installation of two sets of portable ammonium phosphate dry powder fire extinguishers (MF/ABC5) in the tunnel fire pump room. The tunnel box shall be reclassified as a Class A moderately hazardous area, and two sets of

portable ammonium phosphate dry powder fire extinguishers (MF/ABC3) shall be installed.

12) Corrosion protection of the fire protection pipe

The iron pipe for the tunnel’s interior and exterior fire protection water supply shall be coated twice with anti-corrosion paint, followed by one application of fire-resistant paint.

(13) Insulation to protect the fire extinguishing pipe from freezing

The fire extinguishing pipes specified in this design drawings for the tunnel employ multiple insulation methods, including electric heaters, external insulation, and thermal insulation coatings, thereby enabling the project to withstand the high-altitude and cold climate of the site. The insulation method primarily involves electric heating with external thermal insulation.

(8) Electric Heating

Electric heat insulation is an insulating technology that continuously heats pipes, tanks, and equipment by converting electrical energy into thermal energy. Compared to traditional steam heating, electric heaters offer advantages including energy savings, precise and stable temperature control, and simplified maintenance. Furthermore, it is easy to assemble, space-efficient, flexible during installation, safe, and durable, and is extensively used in petrochemical plants, fire protection pipelines, municipal water supply systems, sewage pipes, and other sectors. Electric heating technology operates on the Joule heating effect (electric current passing through a resistor generates heat), transferring thermal energy via the heating cable to the target object, compensating for heat loss to the surrounding environment, and thus maintaining the desired temperature. The electric heating unit consists of an electric heating cable.

In this design drawing, the main fire pipe (D325x5) located within the tunnel’s fire pipe duct is each equipped with three electric heaters. The parameters of the electric heating magnetic film are 10 W/m. To maintain the required temperature for the pipeline water supply and to facilitate heat transfer upwards, the heaters are evenly arranged on both sides and along the bottom of the pipe. Electric heating magnetic films operate under constant pressure.

1) **External insulation**

Aluminum foil is a highly efficient thermal insulating material. It exhibits excellent reflective properties, is lightweight, corrosion-resistant, easy to install in construction works, and is widely employed in building, HVAC (heating, ventilation, and air conditioning), industrial pipeline insulation, and cold chain applications. Simultaneously, aluminum foil is flexible and can be directly wrapped around pipes and equipment. Aluminum foil, owing to its excellent reflective properties and flexible composite applications, has become an indispensable material in modern insulation projects. In the electric heating system, the heating magnetic film can be repaired, thereby reducing heat loss.

Polyurethane foam is a widely used, high-performance plastic with closed or open-cell structure, applied in construction, cold chain, industrial equipment, and other sectors. This material features low thermal conductivity, high strength, waterproofing, and moisture resistance, making it currently one of the best thermal insulation materials. Polyurethane foam adheres directly to substrates such as metal and concrete without additional reinforcement and demonstrates excellent adhesion.

The rubber-plastic thermal insulation material is a flexible closed-cell thermal insulation produced by foaming nitrile rubber (NBR) or polyvinyl chloride (PVC). It features low thermal conductivity, fire resistance, moisture resistance, flexibility, ease of installation, earthquake resistance, and sound absorption properties. Simultaneously balanced and cost-effective, it is widely used in construction assembly, heating, ventilation, petrochemical, and other industries.

For this project, the thermal insulation layer of the planned tunnel's main fire pipeline is a passive insulator. The insulation material comprises 0.5mm thick aluminum foil, 5cm thick polyurethane foam, and 8cm thick rubber-plastic insulation, which is installed inside the fire pipeline trench surrounding the pipe.

2) **Each insulation layer**

In this tunnel design drawing, the cover over the fire duct channel is insulated using multiple insulation layers to enhance thermal insulation.

Automatic fire alarm system

This tunnel is equipped with an automatic fire alarm system comprising a fire alarm controller, graphic monitoring workstation, fire detectors, manual alarm buttons (with fire telephone jacks), fire hydrant button, fire-designated wiring, fire transmission system, control and management modules, and other equipment.

A fire alarm controller has been installed in the tunnel central control room, which is connected to the local fire suppression service to monitor tunnel fire hazards. A professional fire telephone host has been installed in the tunnel central control room to establish communication with the local fire suppression service in the event of a surface fire. The fire alarm controller is equipped with a printer for printing system operation information. Simultaneously, it monitors the operational status of the deep sewage pump, fan, and other equipment to prevent fire exposure and to interrupt the fire during an incident. The fire alarmwarningtransmitter is used for evacuation and rescue operations.

The fire alarm system module box is installed in the tunnel central control room, drainage pump room, and at the entrance and exit sections to monitor the equipment. The fire alarm controller is equipped with a communication interface to the tunnel central control room.

In the event of a fire, the automatic fire alarm system transmits signals via sensors to the tunnel central control room server, activating the fire alarm, automatic fire extinguishing equipment, fire pumps, deep well pumps, fans, and other connected control devices, isolating non-fire circuits, indicating the fire location, and executing extinguishing commands.

5.12. Tunnel Electrical Power Supply and Distribution

5.12.1. Summary of the Drawing Project

The left alignment of the tunnel project commences from stake number LK8+730 to LK10+810, with a total length of 2080 m. The right alignment of the tunnel begins at stake number K8+730 and extends to K10+810, with a total length of 2080 m. This tunnel is designed for a maximum speed of 80 km/h, comprising six lanes with two-way traffic. The total number of tunnels comprises 5 pedestrian crossings and 2 vehicular crossings.

5.12.2. Design Principles

a. The fundamental basis of the drawing design consists of technical specifications and the applicable industry standards.
b. The electrical supply ensures safe, reliable, and normal operation, complying with the power supply requirements for various load levels as specified in the drawing design.
c. The grounding type for the 220/380 V electrical distribution system in this project is the TN-S system. The N conductor and PE conductor are rigidly separated from the low-voltage distribution center and connected by equipotential bonding.
d. Reactive power compensation of the 220/380 V electrical distribution system utilizes a combination of on-site compensation for large capacity inductive loads in the low-voltage distribution cabinet of the substation and centralized compensation.
e. Equipment Selection: Select advanced, mature, and reliable equipment that has been proven to operate continuously for extended periods in similar working environments, ensuring stable performance at a reasonable cost.

5.12.3. Scope of design drawings

(1) Drawing Content: Tunnel 10/0.4 kV electrical power supply and distribution system; tunnel lighting system; power system; lightning protection and grounding systems; tunnel substation; electrical power supply, distribution, lighting, lightning protection, and grounding systems for

the fire pump room; and other related systems.

(2) The boundary of the electrical supply design: the upper end of the switch cabinet of the 10kV high-voltage incoming line constitutes the boundary of the drawing. The section below the interface falls within the scope of this drawing, whereas the section above the interface (e.g., the external power supply line) pertains to the local power supply department. The pre-embedded protective conduits for the incoming 10kV line have been reserved in accordance with this project design.

5.12.4. Load level

The load levels for this project include electrical signals, traffic signals, and similar. Control facilities constitute a critical load of the 1st level. Primary lighting and other loads are classified as 1st level loads, whereas maintenance sockets and road lighting, as other supply loads, are classified as 3rd level loads. Table A shows the detailed classification of load.

Table 5. 12. Load level table

№	Name	Classification
1	Emergency lighting Light signal Road traffic control installations Ventilation and lighting control installations Emergency call device Fire Detection, Alarm, and Monitoring Installations Central Monitoring Installations	Category 1a
2	Fire Water Pump Electrical Heating of Fire Water Supply Pipes Solenoid Valve Primary Lighting Smoke Exhaust Fan	Grade 1
3	Air Conditioner	Grade 2
4	Other Tunnel Electrical Loads	Category 3

Note: a. This first-level load is an exceptionally critical load.
b Ventilation other than that used as the primary load.

5.12.5. Tunnel power supply and distribution design drawings

(1) Power upply source

This project plans to construct a substation with small-sized piles and an equipment room outside the tunnel. This substation implements a dual-circuit power supply by introducing two 10 kV main feeder lines from the city's electrical network to the two 10 kV sections of the substation. Both 10 kV power supplies operate simultaneously to ensure 100% normal operation. The cubicle-type substation with dual-circuit power supply is situated outside the tunnel, adjacent to a large embankment. The 10kV power lines are connected to the substation via two 10kV feeder circuits.

According to load calculations, the substation is equipped with two 1600kV dry-type transformers, and the cubicle-type substation likewise contains two 1600kV dry-type transformers. Both transformers operate simultaneously, performing the function of mutual backup. If one transformer is not operational, the other transformer is capable of bearing the entire load.Two 10 kV input circuit breakers and the busbar circuit breaker are electrically interlocked and operated manually.

For first-class critical loads, in addition to the two aforementioned power supply sources, an uninterruptible power supply (UPS) and an emergency power supply system (EPS) shall be installed as supplementary power sources to ensure that the lighting outage duration does not

exceed 0.3 seconds and the power supply maintenance time is not less than 90 minutes.

(2) 10kV/0.4kV electrical distribution system

1) Two 1600kV transformers are installed at the central substation, and two 1600kV transformers are installed at the box-type substation. Both transformers are dry-type, equipped with temperature controllers and communication interfaces. For monitoring the control system cables, remote control interface terminals shall be redundantly installed in each circuit of the switchgearboxes.
2) Power distribution mode for each system

A. **Lighting electric distribution**

The tunnel lighting electric distribution employs the main body type. The lighting main line, powered by the low voltage from the substation, is routed through the cable bridge duct within the tunnel, and conveyed to the cable bridge via a pre-buried conduit incorporating a distribution box. Use insulated wire clips to connect wires to each lamp.

B. **Control electrical distribution**

The tunnel control electrical distribution line is routed via the communication cable bridge to the control box. After distributing the control box to the branches, route the cables through pre-buried metal conduits to the cable bridge, and subsequently from the cable bridge to the electrical facility. The radial power supply is taken from the control box to the control device.

C. **Fan electric distribution**

The thrust fan capacity in the tunnel is relatively large, and the system utilizes radial cables. The fan is a flue gas fan, primarily used for ventilation and dependent on fire load. For ventilation implementation, a control box was installed on the fan at the site. Each package fan is powered by two low-voltage feeders from the substation, divided into two sections (one primary and one backup); this power supply is delivered through an electrical cable bridge in the tunnel to the control box on the site-installed fan. The control box for operating the above-ground fan shall be connected to the fan via a pre-embedded metal conduit, and the independent circuit shall be operated and controlled from the control box, supplying power to two fans per group.

D. **Fire power distribution**

The tunnel fire extinguishing system shall be powered from two electrical power sources distributed from the substation (one primary and one standby). A box fitted with a dual electric switch for terminal transfer is installed in the fire pump room. From the substation supply cabinet to the dual supply switch in the fire pump room, cables are routed through pre-embedded conduits, then drawn along a pre-embedded metal conduit from the dual electric switch box to the water pump.

E. The low-voltage electrical distribution system utilizes a two-level distribution method comprising main distribution (substation) and terminal distribution (field equipment). Switching operations between the two-level distribution systems are either selective or partially selective.

3) Reactive power compensation

This substation employs a low-voltage centralized automatic reactive power compensation device and is equipped with an automatic low-voltage reactive power compensation cabinet on the 0.4 kV low-voltage line. Following compensation, the capacity factor on the 10 kV side shall exceed 0.90.

4) Signalling, Protection, and Measurement

The 10kV input line of the main substation in this project is equipped with time-limited overcurrent protection, instantaneous tripping, zero-sequence protection, and overload protection. The 10kV output line of the main substation, along with the 10kV input and output lines of the kiosk-type substation, are equipped with inverse time-limited overcurrent protection, instantaneous tripping, zero-sequence protection, and overload protection devices. The signal from the electrical meter is transmitted through the main line and connected to the electrical control computer at the monitoring center. The 0.4 kV side of the substation employs a main line circuit breaker of the low-voltage system with two-stage protection against long-delay overcurrent and short-delay

short-circuit faults. The low-voltage distribution circuit utilizes a circuit breaker or fuse to protect against overloads, short circuits, and ground fault failures. The incoming feeder at the substation’s 0.4kV side, the status of the main feeder circuit breaker, as well as the electric meter and other signals, are integrated into the control system.

5) Measurement

For this project, meter cabinets have been installed at substations designated for local meter measurements. Internal control meters and submodule meters collect data via low-voltage smart meters and are centrally managed through the energy monitoring system.

(3) Quality Requirements for Tunnel Power Supply

During normal operation, the permissible voltage deviation from the secondary output of the 10kV line supply transformer to the primary input of the line terminal transformer shall be within ±5% of the nominal line voltage. The permissible voltage deviation for the clamps of roadTunnel electrical equipment shall meet the following requirements: for motors, ±5%; where multiple motor operating locations are distant from the substation and compliance with the above is challenging, the voltage may be below 95%, but not less than 90%; for other electrical equipment, ±5% in the absence of specific regulations. An active filtering device is installed to ensure power quality.
Power factor: low voltage (Employer’s input) COSΦ ≥ 0.85, high voltage COSΦ ≥ 0.9.

(4) Tunnel power monitoring

A communication control unit is installed in the box-type substation, whereby each tunnel forms an industrial ring network to transmit tunnel power control signals via the tunnel communication system's optical cable to the tunnel control room.

1) Scope of system control

Control of the 10 kV supply circuit of the high-voltage switchgear cabinet;
Control of the emergency lighting UPS;
Control of the emergency power supply EPS;
Control of the 0.4 kV input circuit of the low-voltage switchgear cabinet;
Control of the 0.4 kV fire protection output circuit of the low-voltage switchgear cabinet;
Control of the capacitor compensation cabinet;
Control of other electrical equipment.

2) System functional requirements

Information acquisition function: collection and monitoring of line voltage, current, active power, reactive power, frequency, and transformer temperature, etc. Collection and monitoring of circuit breaker and switch status signals
Control and operational functions: For implementation of the system's remote control function, the opening and closing operations of circuit breakers, switches, and contactors can be managed via the LCD display. The upper and lower setpoints of the telemeters can be adjusted via the LCD display.

Screen functionality: aesthetically pleasing, bright, and smooth images; unified window interface design; and the capability to display multiple windows simultaneously; Main connection diagram; table of telemeter parameters (including limit values); curves (such as load and voltage curves) capable of displaying real-time operating conditions; and the functionality to display historical data graphs;
Report printing function: This system includes a simple, convenient, and flexible subprogram for generating reports, enabling the printing of various daily, monthly, and annual reports. Daily reports can be stored for one month, monthly reports for one year, and annual reports for ten years.

Event logging and recall function: The system records switch openings and closures, allows printing of these events, and the corresponding screen color changes, blinks, issues an alert, and displays event information. Should the analog measurement exceed the threshold, the system is capable of recording, signaling an alarm, and printing. The system includes a function to recall

events. The system automatically records various events, enabling operators to comprehend the historical status of the electrical supply and distribution system. The system includes a table for power flow analysis.

Human-computer interaction function: the operational interface is highly user-friendly; menu operations and critical functions require a password. The operational interface is fully in Mongolian, with audible alarms.

The systemsoftware incorporates a self-diagnostic function.

(5) Selection and Installation of Electrical Equipment

All products must be capable of adapting to low-temperature climatic conditions. When selecting box-type substation equipment, the transformer and distribution devices shall be specified based on the operating environment and installation site. The electrical equipment installed outside the tunnel shall be selected based on advanced technology, ensuring safety, reliability, energy efficiency, environmental protection capability, and reasonable cost. The electrical equipment installed within the tunnel, considering the operational environment and constraints on maintenance, shall not only comply with the aforementioned requirements but also be compact, have low losses, produce minimal noise, be air-cooled, explosion-proof, moisture-resistant, corrosion-resistant, vibration-resistant, and meet fire safety standards.

The 10kV high-voltage box employs an SF6 constant ring network switch box. The transformer utilizes an SCB13 series high-efficiency, energy-saving dry-type transformer (with protective coating). The low-voltage switchgear box employs a GGD low-voltage fixed switchgear cabinet; the cabinet body is constructed from high-quality iron plate and finished with electrostatic powder coating.

The distribution cabinets, control boxes, socket boxes, insulation piercing wire clamps, and intersection box protection level shall be IP55 within the tunnel.

Electrical distribution cabinet material: The distribution cabinet inside the tunnel shall be constructed of stainless steel. Other boxes shall be made of high-quality electrolytic plate with an electrostatic spray coating applied to the surface for corrosion protection. The foundation plate of the auxiliary installation shall be made of galvanized steel plate, with the plate thickness as follows: for box height ≤400mm, the box body thickness is 1.2mm; For box height >400mm, the main body thickness of the box is 1.5mm, and the auxiliary foundation plate thickness is 2.0mm.

5.13. Tunnel lighting

5.13.1. Design principles

(1) The fundamental principle of the tunnel lighting system drawing design is to ensure driving safety and comfort, facilitate the operation of the lighting circuit, consider maintenance convenience during tunnel operation, and maximize energy efficiency.
(2) Based on the "General Technical Requirements for Lighting of Motor Roads, Streets, and Squares in Cities, Towns, and Other Settlements" MNS 6846:2020, and relevant conditions, the lighting data were obtained as follows.

5.13.2. Design drawing standard

Design Drawing Standard

To ensure pedestrian safety, the lighting at tunnel entrances and exits shall comply with the following requirements.

When the length of the transmission section is ≤40 meters, the average illumination on the horizontal surface shall be ≥30 lx.

If the length exceeds 40 meters, the illumination shall be maintained at 50 lx during both day and

night.

5.13.3. Calculation Conditions

Tunnel length: L = 2080 m;
Road width: W = 12.5 m;
Tunnel height: H = 7.875 m;
Lighting installation height: H=5.7 m;
Design drawing speed: 80 km/h;
Hourly traffic volume in the design drawing = 860 veh/(h.ln);
Illuminated parking distance: 100 m;
Road type: Tunnel asphalt concrete pavement
Tunnel reflection: Tunnel walls (light-colored fire-resistant coating, height 4.0 m) 70%, arch gate (dark-colored fire-resistant coating) 10%.
Illumination uniformity UO ≥ 0.4, longitudinal uniformity UL ≥ 0.7.
Coefficient of lighting variation: Asphalt concrete pavement surface 15 lx/cd·m^{-2}.
Light maintenance coefficient M = 0.7.
Tunnel exterior lighting L20(s) = 3000 cd/m².
Decay coefficient at tunnel entrance k = 0.026.
The lighting utilization factor is 0.6, and the lamp maintenance factor is 0.7.
LED lamps are employed, with the rated luminous flux of the light source specified as follows.

Table 5. 13. Reference table for the rated luminous flux of lighting

Lighting power (W)	Nominal luminous flux of the lamp (lm)
100 W	11000
250 W	27500
400 W	48000

5.13.4. General requirements for LED luminaires

The tunnel entrances and exits shall be equipped with conventional enclosed lighting systems. Lighting fixtures with an IP65 protection rating and glare control function shall be used in tunnels for motor vehicles. It is advisable to employ lighting fixtures with a radiation dispersion angle of less than 10° in vehicular tunnels.

LED lamps use semiconductor materials that emit light. Compared to other light-emitting materials, they are green in color, energy-efficient, reliable, and long-lasting. Their principal characteristics include extended service life, high luminous efficiency, robust solid-state packaging, strong impact resistance, and low heat dissipation. Accordingly, the design for this project incorporates LED lighting solutions; namely, LED lighting is employed for the tunnel entry section, the transition section, and the main section.

The lighting assembly comprises lamp posts, lamp covers, LED light modules, and power supply (including cables up to the lighting intersection box).

Lighting structure: flat-profile design, fabricated from a single extrusion of aluminum alloy, durable and long-lasting, constructed from materials capable of withstanding specified mechanical loads, electrical stress, and thermal stress. Electrical components shall be moisture-resistant, intrinsically safe, fireproof, and flame-retardant.

Grounding continuity: The light non-charged metal shall be continuous and connected to the main grounding conductor via the residential grounding bolt.

The primary structural components and electrical power supply of the lighting device shall be replaceable.

The light switch-off time shall not exceed 1 second, and the power factor shall be greater than 0.95.

The light protection level: the dust and water resistance rating of the light enclosure shall be no less than IP65. If the front part of the light is equipped with an acrylic panel, the panel cannot be

sealed with adhesive, and disassembly and installation of the panel do not reduce the protection level.

5.13.5. Selection, installation, and fire protection of cables

For high-voltage cables, WDZ-YJY-8.7/10kV fire-resistant cross-linked polyethylene insulated, PVC sheathed copper conductor power cables shall be used.
A fire-resistant electrical cable WDZ-YJY-0.6/1kV shall be used for low-voltage cabling. Electrical cables for primary and secondary load circuits, emergency lighting, and other lighting circuits shall not be installed on the same cable tray. When installed on a single rack, the cables shall be separated by fire-resistant partitions, and the interior of the rack shall be coated with fire-resistant paint. Cables installed outside the rack shall be routed within hot-dip galvanized steel conduits along the wall panels.

The tunnel outlet employs WDZ-BYJ-450/750V fire-resistant cables, which shall be installed in hot-dip galvanized steel conduits.
The control line consists of WDZ-KVVP fire-resistant cables, and the fire-protected control line consists of WDZN-KVVP fire-resistant cables.
Standard electrical cables and fire electrical cables shall be installed on separate cable trays or on fire-resistant segregated trays. High-voltage electrical cables and low-level signal cables shall be installed on separate cable trays.
The electrical supply for tunnel emergency lighting, evacuation lighting, and similar installations utilizes WDZN cables and wires. All other electrical equipment utilizes WDZ cables and wires.

The lighting power distribution method employs a combination of main and radial circuits. The electrical cable shall be installed from the fastening of the cable duct within the trench to the tunnel cable tray through a prefabricated conduit embedded in the sidewall. The lighting branch circuit shall be arranged along the cable tray. At each lighting fixture location, its associated connection line shall be insulated with a piercing wire clamp and routed through a metallic conduit to the luminaire position.
The primary and enhanced lighting distribution cables are fire-resistant; the emergency lighting cables are also fire-resistant. The lighting and electrical equipment are connected to the grounding wires installed on the bridge using perforated wire clamps.
The steel cable duct shall conform to the dimensions of 200 mm × 150 mm × 1.5 mm (width × height × thickness). The metal cable duct and its accessories must be hot-dip galvanized products that satisfy quality requirements and comply with the applicable standards. The interior and exterior surfaces of the cable duct shall be smooth, flat, and free of burrs, with no bending, warping, or other deformations. The tunnel cable bridge employs a hot-dip galvanized steel bridge, with a galvanization coating of 600 g/m².

5.13.6. Design drawing of the tunnel lighting protection and grounding system

The tunnel lightning protection grounding, operational grounding, and protective grounding are part of the grounding system, and the grounding resistance shall not exceed 1 ohm. The repeated grounding is executed at both ends of the tunnel entrance, with the grounding resistance not exceeding 4 Ohms. A galvanized flat steel strip 40x4 mm is installed as the grounding branch line of the grounding cable on the tunnel lighting bridge, serving as the conduit for strong and weak current cables within the tunnel. All PE terminals of electrical equipment within the tunnel are reliably connected to the grounding branch conductor or the main equipotential bonding conductor. All electrical distribution equipment at every level within the tunnel is equipped with dedicated lightning arresters and surge protection devices.

The high-voltage lateral input line is equipped with lightning surge protection devices. A parallel surge arrester with first-level protection (Class III test category, current capacity ≥60 kA, voltage protection level 6 kV) is installed on the low-voltage distribution cabinet's electrical input line. A secondary-level surge arrester with secondary protection is installed in parallel on the electrical input line of each low-voltage secondary distribution box (Test Class III, current capacity

≥ 40 kA, voltage protection level 4 kV); A tertiary-level surge arrester with tertiary protection is installed in parallel on the electrical input line of each low-voltage tertiary distribution box (Test Class II, current capacity ≥ 7 kA, voltage protection level 2.5 kV); Separate series voltage suppressors (Category 1 test classification, current capacity ≥ 3 kA, voltage protection level 1.5 kV) shall be installed on the electrical input lines of electronic equipment, including automatic fire alarm devices, control alarm devices, and communication apparatus.

5.13.7. Electricity energy saving and environmental protection

Used to reduce operational losses of dry-type transformers and enhance the technical and economic efficiency of the transformer.
The low-voltage side of the transformer is equipped with automatic centralized reactive power compensation to reduce energy distribution losses.
To reduce electrical line losses, the cable cross-section must be optimally selected.
Power components constitute energy-saving products.

5.14. Tunnel monitoring system

5.14.1. Scope of design drawings

The tunnel monitoring system model mainly encompasses various control systems depending on the level of tunnel monitoring.

In addition to the tunnel, the scope of the tunnel control system design drawing shall include the lighting of adjacent roads outside the tunnel (generally within 300 meters from the tunnel portal) and other facilities, which must be appropriately adjusted according to their function and incorporated into the tunnel control system design drawing.

5.14.2. Design principles

It is essential to actively and diligently apply new theories, new technologies, new materials, and new equipment under conditions of safety, practicality, reliability, economic efficiency, energy conservation, environmental protection, and advanced technologies, ensuring coordination and integration with other facilities.

Depending on the tunnel control level, different monitoring facilities shall be installed, and the tunnel monitoring facilities must be planned according to the principle of 'one-time planning and design drawing with phased implementation,' taking into account the anticipated increase in road traffic. Reserved and pre-installed equipment and transmission pipelines within the tunnel must be implemented concurrently.

Control facilities inside the tunnel must not encroach upon the tunnel’s construction limits.

The operational safety of the tunnel must be ensured, and tunnel accidents must be prevented. In the event of a tunnel incident (including fire), it is imperative to detect it promptly, activate communication functions, guide individuals appropriately, and facilitate timely rescue operations to prevent secondary accidents.

The tunnel shall not be planned in isolation but must be coordinated with the road network and associated infrastructure equipment to ensure the integration of rescue operations.

5.14.3. Tunnel Control System Configuration

(1) Central Control Management System,

6) System Structure:

The equipment in the control room comprises workstations, PLCs, database servers, web servers, video servers, IP SAN, control memory hard drives, UPS for equipment control, power control system communication management units, main switches, and control software.
Refer to the diagram“Control Room Equipment Layout”for detailed information on the organization of the control room.

(2) System Capacity:

A)

- The central control systemhas the following functions: Capable of receiving various data transmitted from different facilities, including data information, video information, and audio information;
- Capable of comprehensively processing various information transmitted from multiple facilities and coordinating the monitoring of these facilities;
- Capable of executing a pre-configured control scheme on a computer, either automatically or manually;
- Capable of flexibly displaying traffic conditions inside and outside the tunnel, as well as equipment operational status, in forms such as data, graphics, and drawings;
- Capable of automatically performing information backup and document storage;
- Capable of appropriate querying, counting, and report generation;
- Capable of continuous monitoring of the operational status of each device;
- The control room computer network shall have an interface for information exchange with other management systems of the respective highway.

B)

- The workstation shall perform the following functions.
- Traffic control functions:
- It shall be capable of collecting and processing basic traffic data;
- It shall be capable of collecting operational status information of traffic control installations;
- It shall be capable of supplying control information for traffic management installations, including control signals, traffic control schemes, traffic lights, and lane delineators.

B)

- Lighting control functions:
- Must be capable of collecting status information from the lighting control facility;
- Must be capable of providing display information to the control room’s display device;
- Must be capable of supplying control information to the lighting control unit, including lighting control signals.

C)

- Management Functions:
- Must be capable of performing computer network management functions;
- Must be capable of executing daily maintenance and management of the system.

D)

- The fire alarm and fire control computer shall have the following functions.

- Must be capable of collecting and processing data from the fire alarm system;
- Capable of collecting information on the status of fire alarm and fire protection systems and issuing control signals;
- The status of the installation, alarm addresses, and timing information shall be displayed on the display device in the central control room, indicating the status of the respective installation, with the capability to automatically switch video images.

(3) Control Method:

The Tunnel in this project is a long tunnel utilizing a centralized control system. Data is transmitted via an external terminal device in real time directly to the control room. The computer located in the control center performs centralized analysis and processing of the collected data, and subsequently sends commands directly to the control devices located within the tunnel.

(4) System network communication

1) Network type

The tunnel project is equipped with two distinct networks: an automated control network and a video surveillance network. The automatic fire alarm and fire connection system employ a bus-type centralized alarm system.

Road traffic control network: including the road traffic control system;

Video surveillance network: including the video surveillance system;

The road traffic control network and the video surveillance network share a single-mode external optical cable with 8 chips, of which 2 chips are allocated to the road traffic control system, 2 chips to the video surveillance system, and the remainder are reserved as spares.

The video surveillance system primarily comprises video monitoring devices. The bandwidth for a single 2-megapixel camera is considered 6M. A 100M optical fiber ring network, under normal operation, provides a bandwidth of 70M, which supports approximately 11 cameras.

2) Network structure

Both the traffic control network and the video surveillance network utilize a 100M bandwidth network.

The network architecture utilizes a two-layer network structure composed of a core layer and an access layer.

This comprises: the access layer of the core layer forming a 100M optical fiber ring network.

Switch configuration for the two-layer network architecture:

Main switch: installed in the tunnel control room;

Access level switch: installed in the tunnel, responsible for accessing network devices within the tunnel.

(5) Road traffic control system

1) System structure

The traffic control system collects traffic data from tunnel sections in real time, performs analysis and processing, and manages traffic flow through various control measures to ensure traffic safety, maintain smooth traffic, reduce congestion, and improve transportation efficiency.

This system comprises the Tunnel Management Computer, PLC, and communication network,

together with tunnel site equipment. All testing equipment results shall be located in the control room for statistical data processing and to assess road traffic and meteorological conditions. In accordance with the specific conditions of the road section, the relevant control plan shall be developed, and control tasks assigned to the control installations and data transmission devices for each section.

2) Equipment arrangement

The selection and arrangement of equipment shall be determined by traffic engineering specialists. This project incorporates traffic control devices installed within the tunnel, including signal lights and lane markers. A PLC is installed in the control room.

3) System capacity

A) Traffic data collection function

Traffic parameters, especially traffic volume, represent the principal data for assessing the service level of the highway. The collection and accumulation of traffic data constitute the fundamental basis for key decision-making in road traffic management. Concurrently, changes in traffic flow, vehicle speed, and population facilitate the evaluation of the traffic flow's operational status. Therefore, the control system shall accurately and dynamically detect the traffic parameters of each section along the expressway, perform the analysis, processing, and storage of the data.

B) Tunnel Traffic Control Function

Tunnel traffic control primarily monitors the traffic flow within the tunnel zone, limits speed, modifies road traffic under abnormal conditions, provides information to drivers, and ensures traffic safety and regulation. The measures for regulating traffic within the tunnel are primarily aimed at controlling road traffic through traffic signals and lane markings.

C) Traffic Accident Detection Function

To minimize loss of life and property damage, it is essential to promptly and accurately detect abnormal traffic operations, enhance the response speed of the system, and allocate crucial time for emergency actions and rescue operations. Relying exclusively on patrol personnel, manual procedures, alarms, and video monitoring is inadequate; therefore, measures for the automatic detection of road traffic accidents must be implemented. The method for automatic detection of video events entails the utilization of video surveillance from cameras installed within the tunnel, with corresponding function updates based on this data. Analysis of the camera footage activates event signals based on the image processing algorithm. The algorithmic software requires minimal specifications regarding image brightness and color saturation, allowing operation under diverse weather conditions including day and night, rain, snow, fog, and other atmospheric phenomena. This system is capable of detecting parking, traffic congestion, queue overload, pedestrian access onto the expressway, wrong-way vehicles, low-speed vehicles, insufficient following distance below the permitted threshold, road traffic accidents, vehicle displacement, as well as accompanying audible and visual signal indicators on the expressway. Automatic detection of video events provides effective control tools that enhance real-time traffic monitoring and visibility, which are critically important for improving response speed during emergencies, reducing the occurrence of secondary accidents, minimizing accident losses, and elevating the level of operational management. Therefore, this project employs this method as an automatic event detection system.

(6) Video Surveillance System

1) System Structure

The video surveillance system consists of remotely controlled cameras outside the tunnel, fixed cameras inside the tunnel, remotely controlled cameras at pedestrian crossings, video transmitters, video storage servers, IPSAN, and a fiber optic ring network.

The tunnel images are transmitted to the control room using a video encoder. The video images displayed in the control room are received by a decoding and display system, and recorded onto a storage disk for archival purposes. The storage period is 60 days. It is strictly prohibited for the system to automatically overwrite video images triggered by the alarm signal.

The control decoder at the tunnel control room workstation transmits the output image to the primary LCD display. Simultaneously, the compressed video footage is deployed at the upper-level control center.

2) Equipment Arrangement

The locations for camera installation at the tunnel and tunnel entrances are designated by traffic

engineering specialists. One fixed camera shall be installed in the control room and the fire pump room, and two fixed cameras shall be installed in the substation.
3) Principal capacities
① The tunnel control office shall have the capability to remotely operate the cameras, including electrical switching, panning, tilting, zooming, and focusing.
② The tunnel control office shall have the capability to record all camera footage.
③This system includes a programming function that switches cameras and monitors in groups and displays them in patrol mode.
④Based on various alarm signals within the system (such as fire, traffic accident, or video processor alarms), the camera image of the relevant location is automatically switched to the main display. If a remote camera is located near the alarm point, the camera operation can be automatically controlled (using the camera’s preset position), thereby allowing the control station to view real-time images of the alarm point directly.
(6) Lighting Control System
The tunnel lighting control system for this project fully utilizes the lighting equipment and dimming control system. This system primarily comprises an external lighting sensor, an internal lighting sensor, a controller for the intelligent tunnel lighting system, an on-site digital display with manual/automatic converter, a dimming control cabinet, highway tunnel LED lighting fixtures with controllable illumination, communication systems, and computer-based monitoring control software.
The external tunnel lighting sensor of the system converts the detected external tunnel lighting signal into a 4-20mA standard signal and transmits it to the dimming control cabinet. The internal tunnel lighting control device of the system converts the detected lighting signals of the tunnel entrance and intermediate sections into 4-20mA standard signals and transmits them to the dimming control cabinet. This system is adjustable according to road traffic volume and can be dimmed based on the configured traffic volume parameters. The controller of the intelligent tunnel lighting system, located within the dimming control cabinet, calculates the dimming intensity corresponding to the primary lighting for each entry and exit section’s enhanced lighting, based on internal and external tunnel illumination and specified traffic volume data, then converts these values into a DC 0-5 V constant current analog output signal to regulate the output power of the enhanced lighting fixtures. The variation in luminous output power results in a change in the luminous flux emitted by the lamp, thereby fulfilling the objective of controlling the illumination within the lit area.
The control room management computer is connected to the tunnel intelligent lighting system controller through an Ethernet switch. The control computer employs control management software to configure relevant parameters, issue instructions, read real-time signals, and store data with incremental dimming. If the communication between the control computer and the dimming control cabinet is interrupted, the control cabinet shall automatically dim in accordance with parameters such as external tunnel lighting and the prescribed traffic volume.
(7) Tunnel fire automatic alarm and fire connection system
1)System summary
The fire alarm system is designed to send alarm signals automatically or manually in the event of a fire within the tunnel, promptly notify the higher-level control center, and facilitate requests for fire suppression, rescue, and other necessary actions.
The fire alarm system shall have the capability to promptly and accurately indicate the location of the fire within the tunnel. The alarm signal shall be transmitted via the fire alarm controller to the tunnel management office, and the corresponding location alarm information shall be displayed on the fire alarm computer. The computer system of the tunnel management office shall develop a traffic control plan for underpass road traffic signs, ventilation, fire protection, lighting equipment, and related control devices to promptly and efficiently direct vehicles and personnel within the tunnel and ensure tunnel safety.
The fire alarm system installations of this project employ fiber optic cable trays with temperature-sensitive fire detectors, manual call points, and acoustic and visual alarms.
2)System Architecture
Centralized fire alarm controller, graphic display device, direct control panel, bus fire wire host,

fire wiring, temperature and smoke detectors, fiber optic temperature cable system, manual fire alarm call points, acoustic and visual alarms, input-output modules, and fire hydrant call points;
Fire alarm device protection rating: IP65.
3) Equipment Arrangement
①Centralized Fire Alarm Controller
The fire alarm controller shall be installed in the control room.
Fire alarm control box installed.
The fire alarm controller capacity, total number of address codes for fire detectors, manual call points, control modules, or connected signal modules shall have a tolerance of ±20%.
The fire alarm controller shall provide an alarm information output interface to facilitate coordination of the relevant remedial measures.
②Graphic display device, direct control panel, fire wire host
To be installed in the control room.
Utilize the government installation.
③Manual call point (with telephone socket)
Installed approximately every 50 meters near a fire hydrant, positioned in a clearly visible location.
Install driving direction indicators, 1.5 m in height, on the right side of the tunnel.
Installed in the control room, substation, and fire pump room.
Ceiling installation.
④Sound and light alarms
The alarms are installed approximately 50 meters apart, at one location with a fire hydrant, and positioned in a visible area.
These are located on the right side of the tunnel driving lane, with a height fixed at 2.5 m.
They are installed in the control room, substation, and fire pump room.
Thisis installed on the ceiling.
⑤Temperature sensor
The control scope must encompass the entire tunnel.
Two units of temperature sensors are installed in each tunnel.
⑥Heat and smoke sensor
Installed in the control room, substation, and fire pump room.
Ceiling installationwill be carried out.
4)Main capacity
①The system shall be capable of continuously monitoring fire conditions within the tunnel without any gaps or interruptions. It shall be highly reliable, safe, sensitive, accurate, and durable. The service life of the primary equipment materials shall not be less than 10 years. This system is capable of self-diagnosing faults, continuously detecting the operational status of the equipment, and reporting the damage location to the highest-level control center.
②In the event of fire, the system issues audible and visual alarms, and automatically records, stores, displays, and prints the fire section and location. Audible and visual alarms can be manually disabled.
③In the event of fire, the tunnel's internal controller automatically performs the following functions.
Closing the tunnel,
Operating the relevant fans,
Opening the solenoid valve,
Switching on all tunnel lights.
④Workstation:
Fire alarm signal sounds;
The fire alarm panel shall be displayed on the fire alarm automatic signaling and fire connection control computer (indicating fire zone, illumination level, fan forward and reverse operation, and traffic signal mode alerts);
The video surveillance system monitor shall automatically switch to the fire zone screen and initiate automatic recording;
It provides information on feedback concerning the operation of the various aforementioned equipment (fire alarm section, tunnel lighting levels, fan reverse rotation status, traffic modes).
The fire alarm system equipment shall be corrosion-resistant, moisture-proof, waterproof,

dustproof, lightning protected, and possess other functions appropriate for the tunnel environment; The detector must not be affected by the high-velocity airflow from the turbine fan or the hot air emitted by the machinery, and it must neither lose its signal nor produce false alarms.
⑤Connection to the smoke duct fan:
The coordinated control mode of the smoke duct system shall comply with the following regulations.
To initiate the chimney fan, the alarm signals from two independent fire detectors, each with one smoke protection, shall be used as an interlocking signal, and the activation of the chimney fan shall be controlled by the fire interlock controller.
The manual control mode of the chimney system entails manually operating the chimney fan and other equipment from the fire interlock controller situated in the control room to start or stop them. The fire damper controller’s start and stop switches for the flue fan are directly connected via a dedicated circuit to the direct control panel installed in the control room, enabling manual direct control of the flue fan’s start and stop operations.
The flue fan start and stop operation signals can be fed back to the fire damper controller.
⑥Fire pump connection:
The connection control mode and the low-pressure switch signal installed on the water outlet pipe of the fire hydrant system are used as direct control signals to operate the fire hydrant pump. The fire connection controller being in automatic or manual mode does not affect the control of the connection. The activation signal of the fire hydrant button shall serve as both the alarm signal and the connection bell signal to initiate the fire hydrant pump, and the fire connection controller shall be used to operate the fire hydrant pump.
In manual control mode, the start and stop buttons of the fire hydrant pump control cabinet shall be connected via a designated line to the direct control panel of the fire connection coordinator installed in the control room, enabling direct manual operation for starting and stopping the fire water pump.
The operational signal of the fire hydrant pump is returned to the fire connection controller.
⑦Connection to the pressure stabilizing pump: The pressure stabilizing pump is controlled by the automatic start and stop pressure switches of the pressure stabilizing pump installed within the fire water supply network.
5) Fire Control Room
Fire control room arrangement: The fire control room is shared with the control room. Fire alarm and fire connection control cabinets are positioned at a distance of 800 mm from other control boxes. Fire alarm and fire connection control computers are situated at a specified distance from the control workstations.
The fire control room shall feature the following control and display functions.
The control panel shall be equipped with a manual direct pump start button connected via a dedicated circuit;
The control panel shall be capable of displaying the operational status of the fire pump and the pressure regulating pump.
The control panel is capable of displaying alarm signals for high and low water levels of water sources such as the fire water tank and elevated fire water reservoir, as well as indicating the normal water level.
(8) Emergency Telephone and Notification Transmission System
This project integrates the emergency telephone system and the tunnel notification transmission system, implementing a comprehensive operational system that shares the main controller, network management, and system software. The emergency telephone transmission and tunnelalertbroadcast systems utilize the same optical fiber. The emergency telephones installed in the tunnel’s right and left tunnels, as well as those at the tunnel entrances, are all fully equipped. The transmission of the emergency telephone system, control area equipment signals, and image transmission are conducted via a single optical cable.
(9) Ventilation Control System
In tunnels, smoke emitted from vehicles, along with smoke and dust on the road surface, does not disperse easily, which is highly detrimental to human health and adversely affects driving safety. Therefore, maintaining good air quality in tunnels is an essential prerequisite for driving

safety. The ventilation control system is capable of monitoring the number of fans, wind direction, and operating duration based on pertinent environmental data and detected motion energy information; it ensures energy-efficient operation and control to maintain the fans' optimal service life. In the event of fire, fire smoke extraction shafts designed for specific locations are implemented to ensure tunnel safety and operational environment comfort.

（10）Wireless Communication System

The tunnel wireless communication system utilizes wireless AP coverage. Wireless AP units are installed in the tunnel at intervals of 100 meters, and a wireless communication system management cabinet is located in the tunnel control office.

(11) Principles for selecting equipment

The equipment and materials utilized in the tunnel monitoring project shall comply with requirements for adaptation to low-temperature climatic conditions, conform to the provisions of the current applicable standards, and be accompanied by documents certifying product quality.

When selecting devices related to the fire alarm system for the tunnel control project, it is required to select devices exceeding 3C certification and possessing an IP65 protection rating.

5.14.4. System power supply

(1) Power supply of the control facility

The power supply for the centralized management system of this project, including the road traffic control system, video surveillance system, lighting control system, and power monitoring system, utilizes the UPS located at the control center. Furthermore, it shall comply with the following requirements.

Each system shares an uninterruptible power supply device, and the power supply for each system from the shared uninterruptible power supply device shall be provided through a dedicated circuit.

The uninterruptible power supply shall be equipped with automatic and manual control devices.

The capacity of the uninterrupted power supply shall be no less than 1.3 times the total calculated load of the connected devices, and the backup battery shall provide continuous power for more than 60 minutes.

(2) Power supply for the automatic fire alarm and fire signal control system.

The load level of the fire protection system is classified as Level 2. The alternating current supply for the fire alarm and automatic fire connection control system utilizes the fire power supply and includes a dedicated battery as a backup power source. The optical fiber temperature-sensing fire detector is powered by a UPS, with a battery or UPS backup duration of not less than 3 hours. The tunnel, building structure audio and visual alarms, input-output modules, and similar equipment shall be powered by UPS, equipped with its own battery and a 24 VDC power supply module, with a backup duration of no less than 30 minutes.

2.8.1.6 Cable Selection and Installation

(2) Grounding

1) All metallic lines entering and exiting the protected zone (such as power lines, control lines, etc.) connected to protective devices shall be equipped with SPD voltage protection, and all protectors must have reliable grounding.

2) Electrical meter ducts, covers, control cabinets, protective conduits, etc., which are generally not energized but must be grounded to protect metallic components from insulation failure.

3) The grounding point of the signal cable shall be located on one side of the control box and the control room.

4) The protective grounding in the control cabinet, the grounding of the alarm panel, and the protective grounding shall each be connected to their respective grounding buses, which shall then be connected by insulated copper conductors to the main equipotential bonding busbar.

5) The lightning protection grounding of the residual current system and the protective grounding

of the low voltage distribution system shall share grounding devices, with the grounding resistance not exceeding 1 ohm.

5.15. Tunnel structure

5.15.1. Construction

(1) Work summary

The total construction area of this project amounts to 495.54 ㎡, comprising two independent buildings: the fire pump room and the electrical distribution room. The building area of the fire pump room is 102.95 ㎡, while the building area of the electrical distribution room is 392.59 ㎡. The fire pump room is a single-story underground structure with a relocation staircase installed on the lower floor. The total length of the basement facility is 11.8 m, the total width is 7.4 m, the height is 4.85 m, and the thickness of the top slab is 3.35 m; The relocation staircase is a single-story frame structure, 7.1 m wide, 3.05 m long, and 3.6 m high. The electrical distribution room is a single-story building located on the first floor, with an overall width of 12.9 m, a length of 37.6 m, and a cornice height of 5.1 m.

(2) Overall site design drawing

1) Work summary

The new ring motor road tunnel is a long tunnel, with the portal collar number K8+730 at approximately 1434.37 m elevation; The chainage of the outlet is K10+810, the design elevation is approximately 1423.29m, with longitudinal gradients within the tunnel of 0.95% and -0.99%, and a total rock slope length of 2080m. The maximum excavation depth is approximately 80m.
In compliance with the operational requirements of the tunnel, a fire water reservoir, two auxiliary buildings, a fire water pumping station, and an electrical distribution room have been installed at the tunnel portal.

2) General Organization

When selecting the site, the fundamental principles must comply with the rational use of land, conservation of land resources, and implementation of land use policies, fully taking into account the production functions and based on the topographical survey conducted on-site.
The planned site is a relatively typical corridor area. To meet functional requirements, each unit is arranged in accordance with site territorial conditions to comply with fire protection regulatory requirements.

The main structures consist of a distribution room, fire water tank, and fire pump room. The fire water tank and the fire pump room are located 30 meters from the tunnel's minor mile end entrance, while the distribution room is situated 12 meters from the fire water tank and fire pump room. The two construction sections are located along the expressway. The required clearance between fire protection models shall be maintained.

3) Vertical design drawing

This site exhibits variations in natural elevation. The area measures approximately 130 meters in length and 18 meters in width. The planned slope is 1%. The terrain is level and suitable for construction.

(3) Design drawings for buildings and structures

1) Design drawing data:

1.1) The design service life of the construction drawings is 50 years.
1.2) Fire resistance is Level 2.
1.3) Earthquake resistance: The structure is designed to withstand an earthquake of intensity 7.
1.4) Roof waterproofing protection: The waterproofing level of the roof is executed in accordance with Level II standards.

1.5) Fire hazard: Class D.
1.6) Masonry work quality control is Level B.

2) Standard for the decoration of large-scale buildings.

Exterior wall: cement mortar exterior wall with 40 mm thick inorganic thermal insulating mortar, Type I thermal insulation material.
Interior wall: mixed mortar interior wall with imitation glazed paint.
Ceiling: cement mortar imitation glazed tile ceiling (intended for the underside of outdoor cantilever); Mixed mortar imitation glazed tile ceiling (applicable to all ceilings except the outdoor cantilever underside).

Floor: cement mortar floor; Waterproof paint is temporarily applied to the inner walls and bottom of the cable duct.
Roof: 20mm thick cement mortar protective layer, 4mm thick polymer asphalt waterproof layer, one layer of base treatment, 25mm thick cement mortar leveling layer, 20mm thick crushed stone slope, 50mm thick roof waterproof crushed stone wool board installed by dry method, and a 15mm thick cement mortar leveling layer.

Doors and windows: Fire-resistant Category B steel solid panels; energy-efficient wall windows fabricated from 70 series aluminum alloy with thermal insulation (single-frame double glass, double glazing comprising 6mm thick hollow glass, 6+12A+6mm, with an external window air infiltration rating of level 6).
Staircase: Cement mortar stair.
Drainage: 900 mm wide concrete drainage.
Sloped road: Cement tooth-edged slope, concrete mortar.

3) Energy-saving construction design drawing.

3.1) Construction organization is reasonable, providing sufficient sunlight and ventilation.
3.2) The exterior wall of the fire water tank is constructed with 400 mm thick ventilated concrete blocks; the interior and exterior walls of other buildings are constructed with 200 mm thick ventilated concrete blocks, with the exterior coated in 40 mm thick inorganic Type I thermal insulation mortar; Exterior windows: Series 70 broken bridge aluminum alloy energy-saving wall windows/fixed windows, single frame with double glazing, where the double glazing consists of 6 mm thick hollow glass, and the exterior window air infiltration level is 6 (6+12A+6 mm).

4) Construction unit design drawing

The construction design drawing of this project is based on the principles of practicality, economy, and aesthetics. Situated in accordance with their operational capacity and availability. A simple and consistent finishing method is employed for the road surface design.

Table 5. 14. List of Equipment Building Structures Located at the Tunnel's Short Distance End

№	Building Name	Area	Structure	Unit	Quantity	Remark
1	Fire Extinguishing Water Tank and Fire Pump Room	102.95 ㎡	Structure	Pcs.	1	One-Storey Building Above Ground and One-Storey Building Underground
2	Electricity Distribution Room	392.59 ㎡	Structure		1	One-Storey Building Above Ground

4.1) Fire water tank, fire pump room

The fire water tank and fire pump room constitute a single-story framed structure with a construction area of 102.95 m² and a total floor height of 3.9 m (measured from the external ground level to the roof). The fire water tank and fire pump room are designated as specified.

4.2) Electrical Distribution Room

The electrical distribution room is a single-story framed structure and will provide for the tunnel’s electrical needs upon completion. The floor area of a single building is 392.59 m², with a primary height of 5.40 m (measured from the exterior floor to the building roof). The layout is designed for high and low voltage distribution rooms, residual current device rooms,

residual current power supply rooms, control centers, and spare parts rooms, among others.

5) Building Fire Protection Design Drawing

In accordance with the “Fire Protection Regulations for Building Design”, the fire protection design for this project assigns a building classification level of 2 and a fire resistance rating of 2. The distance from adjacent buildings complies with the requirements for fire escape routes and fire separation distances.

5.1) The fire resistance rating of this building is Class 2.
5.2) Each room in this building has a direct exit door to the outside to ensure safe evacuation. The construction site area shall not exceed 2500m², with each unit constituting a fire protection zone.
5.3) The exterior finishing shall be constructed from non-combustible, fire-resistant materials.

6) Selection of Primary Construction Materials

6.1) Requirements for Construction Finishing: Exterior Finishing: The combustibility rating of the exterior insulation material shall be no less than B1, and the combustibility rating of the soil insulation material shall be no less than B2.
6.2) Construction materials: The internal environment pollution reduction classification for this project is Class I. The primary finishing materials used in the construction are non-toxic, free from radioactive substances, and are neither gaseous nor hazardous flammable materials. Furthermore, the additives for concrete products comply with the national standard.

Table 5. 15. Table of Construction Materials

№	Name	Selected Material	Applicable Section
1	Surface	Waterproof roofing with a self-protection layer, impermeable, Grade II waterproofing	Surface
	Ceiling 1	Ceiling with cement mortar and faience coating	Rain Ceiling
	Ceiling 2	Ceiling with mixed mortar and coating （Attention：The ceiling decoration of the substation has not been completed. Clean and polish the foundation, then apply putty, smooth with sandpaper, and finish with white latex paint.）	Interior ceiling
2	Exterior wall	Exterior wall of cement mortar, externally covered with 40mm thick inorganic thermal insulation Type I material	Exterior wall
3	Interior wall	Composite mortar imitation ceramic coating for interior walls	Interior wall surface
5	Floor	Cement mortar floor, interior wall, and lower slab of cable duct coated with waterproof paint	All floors
6	Sloped road	Cement toothed sloped road	All sloped roads
7	Foundation footing	Cement mortar foundation footing	All foundation piles with a height of 150
8	Drainage	Cast-in-place concrete drainage	All drainage with a width of 900

5.15.2. Structure

(1) Work summary

The total construction area of this project is 495.54m2, comprising two separate buildings: a fire

pump room and an electrical distribution room. The building area of the fire pump room is 102.95m2, and the building area of the electrical distribution room is 392.59m2. The fire pump room is a single-story underground structure with a relocation staircase installed on the lower floor. The total length of the basement facility is 11.8 m, the total width is 7.4 m, the height is 4.85 m, and the thickness of the top slab is 3.35 m; The relocation staircase is a single-storey framed structure measuring 7.1 m in width, 3.05 m in length, and 3.6 m in height, with cornice detailing. The electrical distribution room is a single-story building located on the first floor, with an overall width of 12.9 m, a length of 37.6 m, and a cornice height of 5.1 m.

(2) Principles of Structural Design Drawings

1) The safety level of the concrete structure and the design service life shall comply with the “BUILDING STRUCTURE AND FOUNDATION RELIABILITY. GENERAL REQUIREMENTS” /BNbD 20-01-11/.
2) When designing concrete structures, it is necessary to consider the construction technology level and the actual engineering conditions.
3) The concrete structural design drawings shall comply with the following requirements.

   3.1) Selection of feasible structural systems, component shapes, and configurations.
   3.2) The building layout and elevation drawings shall be consistent, with uniform and continuous mass and strength across all sections.
   3.3) The load-transferring path of the structure shall be simple and clear, with vertical sections continuous and uniform;
   3.4) A stable structure is recommended; critical components and primary load-transferring elements must incorporate redundant restraints or multiple load transfer paths.
4) Structural design drawings and calculations shall be based on geological survey data, as well as relevant national technical conditions, standards, and regulations.
5) The extent of construction tolerances shall satisfy process design requirements and shall also consider construction errors, measurement inaccuracies, equipment installation, structural deformations, and construction process demands. Its value shall be determined based on geological conditions, burial depth, load, type of structure, construction progress, and other circumstances, as well as measurements from analogous projects;
6) The structural design shall be carried out according to the type of structure, intended use, load characteristics, construction technology, and other relevant conditions. The structure or component shall satisfy the requirements for durability, rigidity, stability, and strength, as well as technical specifications such as waterproofing and fire protection;
7) The strength of the concrete structure shall be designed in accordance with the service life calculation period of the relevant facility, the nature of its surrounding environment, and the level of operational activity.

(3) Standards for Structural Design

1) Design reference period: /BNbD 20-01-11/; based on this, the standard service life for the structural design drawings of this project is 50 years.
2) Design service life: 50 years.
3) Construction responsibility level: Pursuant to clause 9.1 of /BNbD 20-01-11/, the construction responsibility level for the structural works of this project is Level 3, with a structural reliability index $\gamma n = 1.0$.
4) Construction earthquake protection classification: Pursuant to /BNSD 22-01-21/, the structural reinforcement classification for this project is Category 3.
5) Earthquake resistance: Magnitude 7 (0.1g)
6) Site type：Class Ⅰ（Confirmation required following completion of the geotechnical survey）
7) Foundation water protection level: Level II, drainage resistance level P8.

(4) Basic loads and their values.

1) Permanent load (Pd): structural self-weight of reinforced concrete, $\gamma = 25$ kN/m³.

Foundation cap load: pavement weight, γ = 18 kN/m³.
Foundation water pressure: the groundwater level corresponds to the buoy protection model water level and is calculated based on hydrostatic pressure.
Lateral soil pressure at the foundation: Calculated according to the static soil pressure during the operational phase.

2) Long-term load (Pl)
   Equipment weight: Calculated based on the actual weight of the equipment.

Effects resulting from frost heave, settlement, and foundation deformation.

3) Short-term load (Pt)

Basic wind pressure $\omega 0$ = 0.85 KN/m² (once every 50 years), snow ground pressure Sg = 0.50 KN/m² (once every 50 years).
Ground load in the fire pump room: 20 KN/m².
The standard value of variable load on an inaccessible roof is 0.5 KN/m².

4) Special load: Earthquake effect calculated at intensity 7 (0.1g).

(5) Foundation design drawing

This project does not include an engineering geological survey report. The bearing capacity of all construction unit foundations shall be no less than 300 kPa. The foundation design level is Grade 3.
The fire pump room has a cast reinforced concrete foundation slab, and the distribution room is supported by an independent foundation beneath the reinforced concrete, founded below the permanent frost line.

(6) Structural scheme

Taking into account the purpose, functions, load characteristics, and construction technology of the structures in this project, a single-storey, single-span box structure was approved for the basement of the tunnel fire pump room. The basement box structure has a clearance of 6.95 m, a total length of 11.8 m, a total height of 5 m, and the soil cover above the top slab is approximately 3.35 m. According to preliminary calculations, the thickness of the basement floor slab, the top slab, and the side walls is 450 mm each. The relocation staircase for the fire pump room employs a single-storey frame structure with spans of 2.7 m and 6.8 m and a roof height of 3.6 m. The electrical distribution room utilizes a single-storey frame structure with spans of 7.8 m and 8.4 m and a roof height of 5.1 m.

6. Infrastructure and Green Facilities

6.1. Engineering Preparatory Activities

6.1.1. Water Transmission Pipeline Works

(1) Design principles

During the engineering design process, the integrated pipeline drawing performs a comprehensive management function for various related pipeline disciplines and is responsible for coordinating and resolving various conflicts in the horizontal and vertical alignments of different pipelines; It serves as the fundamental basis for organizing the sequence of utility pipeline construction works during the construction phase, coordinating construction activities, managing construction operations, and verifying the accuracy of various specialized utility pipeline construction drawings; It constitutes the principal basis for the management, maintenance, and extension of engineering utility pipelines throughout production and operational phases. It is critically important that the planning of underground utility pipelines beneath the road be conducted in a scientific, reasonable, and systematic manner. This design drawing complies with the following principles.

(1) The scope of pipelines within this area is based on the major city utility pipelines.

(2) The technical requirements of various specialized transmission pipelines must be met to the greatest extent possible. The minimum requirements for the depth of various specialized pipeline coverings shall be complied with as far as practicable.

(3) Under normal conditions, the following principles shall be observed when crossing pipelines: smaller pipelines shall be placed beneath larger pipelines, branch pipelines beneath main pipelines, non-gravity flow pipelines beneath gravity flow pipelines, bending pipelines beneath non-bending pipelines, and designed pipelines shall provide passage over existing pipelines.

(4) Adequate clearance between various utility pipelines and roadside trees shall be ensured.

(5) The horizontal and vertical alignment of transmission pipelines shall be designed considering the necessity for phased project implementation.

(6) The subterranean spatial resources beneath the urban motor road shall be fully developed, efficiently utilized, systematically organized, and commissioned.

(7) Ensure a proper connection between existing pipelines and newly constructed pipelines, and organize the facilities systematically.

(8) Ensure safety, feasibility, cost-effectiveness, and provide room for long-term development.

Comprehensive design drawing of pipeline cross-sections: Along the planned route, seven types of utility networks have been installed, including electrical cables, communication cables, sewage lines, stormwater drains, water pipes, heating pipelines, and street lighting cables.

Complete layout of transmission pipelines: The comprehensive design drawing of the transmission pipelines comprises stormwater drainage pipes within the road red line, sewage pipes, water supply pipes, communication cables, electrical cables, heating pipelines, and the flat and vertical routing designs of street lighting cables, as well as the reserved conduit pipes on site and the planning drawings for pipeline locations at road intersections.

6.1.2. Stormwater Drainage System

6.1.2.1.Drawing general requirements of the city’s stormwater and floodwater drainage master plan, reduces the need for stormwater pumping stations, and fully utilizes existing pipelines, channels, canals, and other infrastructure.

(2) Implement a drainage system for conveying stormwater and sewage trunk mains, incorporating both short- and long-term planning.

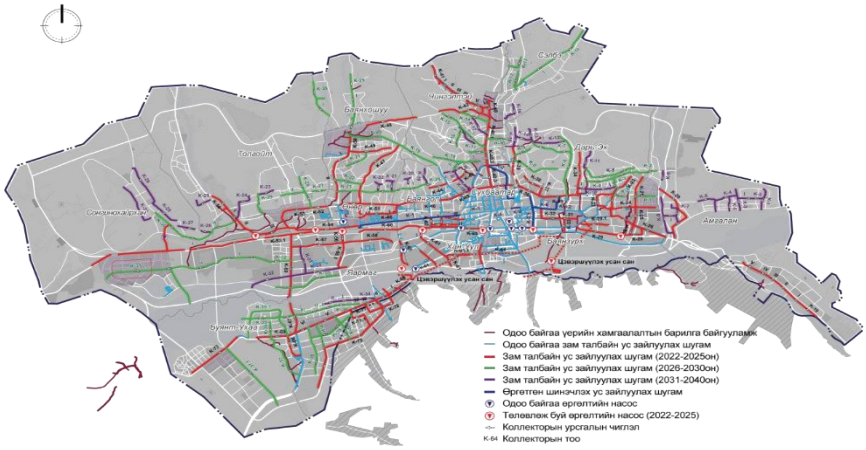
(3) Following the organization of rainwater in accordance with the vertical alignment of the planned motor road network and the existing land conditions, the flow proceeds to the lower section, thereby reducing the length of the transmission pipeline.
(4) The planning and vertical axis of the rainwater pipeline network shall be closely coordinated with the motor road and sewage design, reserving adequate space for water transmission pipelines, electrical, and communication ducts; optimally utilizing the road gradient; minimizing the cross-sectional dimensions of pipes and ducts; reducing construction costs; and ensuring uniform pipeline connections.
(5) Integrate the planned land allocation, land conditions, and planning parameters on both sides of the road and within the existing settlements, and reasonably delineate the water catchment areas.
(6) Fully address the drainage pipe issues of the existing settlements following road construction and ensure proper integration of the village drainage system with the urban stormwater system.
(7) To ensure consistent flow of rainwater over both short and long terms, the issue regarding the short-term and long-term connections of the rainwater drainage system shall be fully addressed.

6.1.2.2. Planning of rainwater conditions

Population growth, air conditioning units, heat emissions from vehicles and industry, reduction in vegetation, decreased water-absorbent surfaces, and the construction of high-density buildings have collectively increased energy consumption, causing water accumulation on roads and sites. At the city scale, of the total 1,065 kilometers of hardened motor roads, stormwater drainage pipes have been installed along 209 kilometers, with 22 kilometers subjected to expansion and renovation. Furthermore, 81.5 kilometers of stormwater drainage lines have been laid to protect the existing main and auxiliary roads totaling 161.6 kilometers.
According to the general development plan for Ulaanbaatar City through 2040, construction of 267 kilometers of principal roads, 23.2 kilometers of auxiliary roads, and 332 kilometers of stormwater drainage trunk lines is planned.
Within the jurisdiction of Ulaanbaatar City:

- Extension and upgrading of 22 kilometers of stormwater drainage pipelines;
- Construction of 7 new expressway bridges and culverts to mitigate flood risks;
- Total length of stormwater drainage pipelines for new expressway sections: 413.5 kilometers;
- Construction of 2 new lift pumping stations;
- Construction of two new rainwater purification facilities;
- Installation of eight lift pumps;

In recent years, technology for the collection and utilization of rainwater has been rapidly advancing in many countries worldwide. For countries with limited territory such as Mongolia, where groundwater and surface water resources are scarce, it has become imperative to collect and reuse rainwater. The following measures will be implemented between 2025 and 2040, including:
Rainwater shall be collected via a centralized system, treated, and utilized for domestic purposes. Pedestrian pathways enabling rainwater infiltration and the reuse of infiltrated water shall be constructed in phases, with collaboration between the public and private sectors to implement the Smart City technology.



Drawing 6. 1. Schematic drawing of the rainwater drainage system

6.1.2.3. Design drawing of the rainwater drainage pipe system

(1) Scope of the design drawing

The scope of the rainwater engineering design corresponds to the professional motor road design, encompassing the rainwater drainage pipes along all sections of the Grand Circle. The design includes rainwater drainage pipelines along the road, rainwater drainage pipelines at road intersections, temporary drainage ditches, and transverse pipes intended to connect the drainage pipeline networks on both sides of the road.

(2) drawings and design calculations

Road rainwater drainage pipes are primarily designed to drain rainwater from the road and its surrounding areas. The appropriate rainfall formula is selected based on the actual precipitation conditions in Ulaanbaatar City. This method determines the maximum flood runoff without adjustments, using the catchment area, rainfall intensity, and rainfall coefficient for areas smaller than 15 km². This method is widely adopted internationally.

Flow velocity :

Table 6. 1. Minimum flow velocity at maximum filling stage of the pipe in the road stormwater drainage network

Diameters(mm)	**H/DMinimum velocity during filling(m/s)**			
	0.6	0.7	0.75	0.8
150-250	0.7			0.65
300 - 400		0.8		
450 - 500			0.9	
600 - 800			1.0	
900			1.1	
1000 - 1200				1.2
1500				1.3
Greater than 1000				1.5

- For a stormwater conveyance pipe with a return period of 0.33 years, the minimum velocity shall be 0.6 m/s. Stormwater drainage pipes are typically installed parallel to the ground to ensure the design flow velocity.

(3) Special engineering model for stormwater

A. Method for dividing the water catchment area

The subdivision of the water catchment area in this project must not only adhere to the plan but also take into account the current conditions. The water fraction used in the calculation of the stormwater drainage pipeline shall incorporate the limits defined for both the current conditions and the long-term plan, and both shall be assessed jointly.

(4) Stormwater conveyance pipe and pipe foundation

①Requirements for the pipe

The material of the drainage pipe must comply with specified requirements to ensure the normal operation of the drainage system.

The drainage pipe must have sufficient strength to resist external loads and internal water

pressure. External loads include the weight of the soil and dynamic loads resulting from vehicular traffic. The self-flowing pipe is designed to facilitate sludge removal and to generate internal water pressure during dewatering. To prevent pipe breakage during transportation and construction processes, they must have adequate strength;
The drainage pipe must be capable of removing wastewater contaminants and resist abrasion. They must also be corrosion-resistant, especially for certain aggressive industrial wastewater. The drainage pipes shall be impermeable to prevent wastewater leakage and infiltration, contamination of groundwater, and corrosion of other pipelines and building foundations.
The internal surface of the drainage pipes shall be clean and smooth to minimize hydraulic resistance. Drainage pipes shall preferably be constructed from domestic materials, and the use of prefabricated pipes with suitable diameters and rapid manufacturing can reduce transportation and construction costs.
②Selection of Pipe Materials
This model compares and selects pipe materials appropriate for drainage systems. There are four commonly used pipe materials for drainage systems.

The principle for selecting drainage pipes is to consider technological aspects, quality reliability, advancements, and economic efficiency. Therefore, within this engineering technology, considering the geological characteristics of the foundation, reinforced concrete pipes, reinforced concrete pipes with bell and spigot joints, HDPE pipes, and plastic sand-filled pipes reinforced with fiberglass are compared; following a technical and economic evaluation, the pipe that is technically feasible and economically justified is selected.
For small-diameter drainage pipes, reinforced concrete pipes exhibit high energy consumption, limited service life, poor energy efficiency, and inadequate environmental protection capabilities, resulting in a total cost that is not advantageous compared to plastic pipes. They were gradually replaced by plastic pipes. The cost of plastic pipes increases with the increase in diameter. The unit price of plastic pipes is significantly higher than that of reinforced concrete pipes; thus, the overall cost of plastic pipes is considerably less favorable in comparison to reinforced concrete pipes. Therefore, plastic pipes with large diameters do not experience a significant price reduction, despite extensive promotion efforts, and are challenging to use. Small and medium diameter plastic pipes are newly developed in recent years. They are promoted by the Ministry of Construction for their advanced technology, flexibility, resistance to installation damage, economic efficiency, energy savings, and environmental protection capabilities, and are now widely utilized. The roughness coefficient of the HDPE pipe is only 64–71% that of the reinforced concrete pipe, indicating that at the same hydraulic gradient, the permissible flow velocity in the HDPE pipe corresponds to that of a reinforced concrete pipe with one nominally larger diameter.
In summary, for the construction of the drainage pipeline network, HDPE pipes and stormwater pipes are predominantly used. Considering the actual conditions of laying the drainage network and the cost-efficiency of the respective pipes, the drainage pipes developed on this occasion were selected as follows: reinforced HDPE pipes are employed for coil pipes (D505); reinforced concrete pipes (Grade II or III) are utilized for pipes with diameters DN500 and above.
In this model, HDPE pipes with diameters of ≤500 mm are used for rainwater drainage. The quality shall comply with the technical requirements of the applicable standard, and the mechanical properties shall satisfy the requirements of the relevant regulations. For burial depths of ≤6.0 m, the modulus of rigidity strength is 8 KN/m², corresponding to a minimum level of S2; for burial depths exceeding 6.0 m, the modulus of rigidity strength is 12 KN/m². The interface employs a rubber ring socket connection.
Rainwater gravity pipes with diameters exceeding 500 mm shall utilize Class II reinforced concrete pipes, with the interface employing a flexible rubber sealing ring and elastic coupling interface. The primary factory-supplied materials consist of acid-alkali resistant, corrosion-resistant rubber rings, whose physical properties comply with the applicable technical regulatory standards.

(5) Pipefoundation

When the bottom of the HDPE spiral reinforced pipe is located within the original soil layer, it shall be replaced by a 15 cm layer of medium coarse sand bedding; When the bottom of the pipe is

located within the newly filled soil layer, it shall be replaced by a 20 cm layer of medium coarse sand bedding; ② When the base of a level II reinforced concrete pipe foundation rests on the original soil layer, the pipe base shall be replaced with a 10–20 cm layer of medium-coarse sand bedding; When the pipe base is situated within a recently backfilled soil layer, it shall be replaced with a 20 cm layer of medium-large particle sand bedding. The trench for connecting the rainwater drainage pipes shall be directly excavated, and medium-sized pcs. sand shall be placed and compacted from 15 cm below the pipe invert up to the road trench, achieving a compaction level of not less than 95%.
The pipe bedding shall be placed on the original soil layer of good quality or on a treated soil layer. The preparation of the inlet branch pipe and the base of the inspection well shall be identical to that of the corresponding main pipe. The bearing capacity of the transmission pipeline foundation must comply with the standard road load requirements and shall be no less than 100 kPa.

(6) Rainwater Facility

Inspection wells: For flow pipes with diameters d ≤ 600 mm, a Φ1000 mm circular rainwater inspection well shall be used; For transmission pipelines with a diameter d > 700 mm, the inspection chamber shall be circular or rectangular in shape, with a channel length of 1000 mm and a width equal to the maximum diameter of the pipeline. When the diameter of the drainage pipeline is between 700 and 1400 mm, the height of its working section shall be equal to the maximum pipeline diameter. For water supply pipelines with diameters ≥1500 mm, it is not required to adjust the elevation of the work section. For inspection wells connected to water transmission pipelines (where the pipeline diameter is ≤900 mm), the width of the cleaning platform shall be equal to half of the maximum pipeline diameter.
A flow channel shall be installed at the bottom of the inspection well.
Stormwater inlet: The stormwater inlet may be a flat-grate stormwater inlet (suitable for asphalt or concrete pavement) or a vertical-grate stormwater inlet (suitable for low-lying areas or roadside edges). It may be selected or combined according to the specific road profile. The grating is constructed from flexible steel (load capacity ≥ D400 grade).

6.1.3. Flood protection

6.1.3.1. Flood protection plan

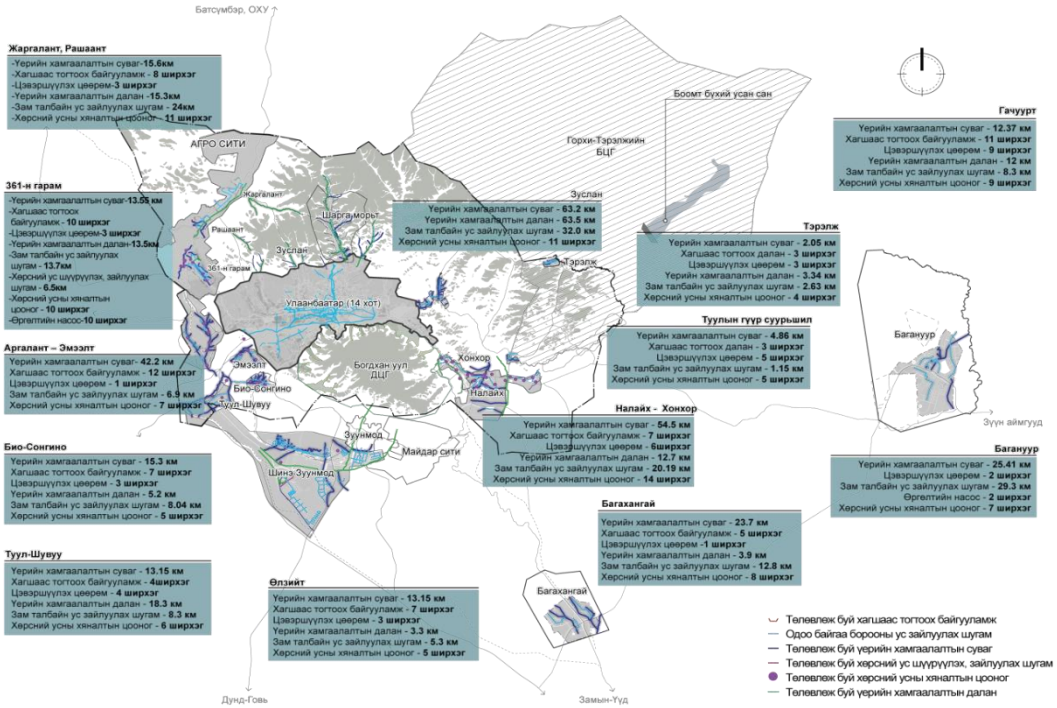
(1) Construction of flood protection embankments and reservoirs

It is appropriate to establish the central urban settlement areas near major rivers with a flood protection level 1-5% higher than the floodwater flow. However, most settlements in Ulaanbaatar City are located in the valleys of the Tuul, Selbe, Uliastai, Terelj, Bayangol, and Belkh rivers, resulting in a very high flood risk. The 2040 Master Plan proposes the construction of 106.75 kilometers of new flood embankments, the repair of 118.9 kilometers of existing flood embankments, the improvement of flow in small rivers, and the assurance of continuous water flow in eight locations to protect against flood risks arising from major river flows.
Based on research and calculations, it is planned to establish reservoirs covering a total area of 1402.96 ha at 14 locations along the main rivers, with the aim of creating a slightly humid climatic environment. These include:

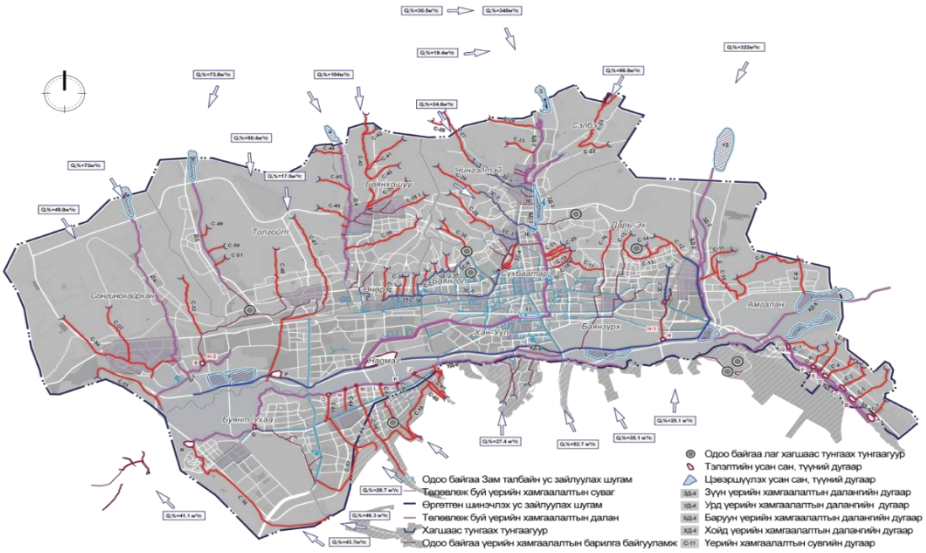
①The protective embankment of the Tuul River -37.8 km, at 7 lake locations, covering1116.5 ha
②Selbe, protective embankment of the Middle River -21.6 km, floating pond-3 locations with 32.16 ha
③Protective embankment of the Uliastai River-11 km, lake -1 location, 132.5 ha
④Protective embankment of the Terelj River -8.1 km, reservoir-1 location, area 24.4 ha
⑤Protective embankment of Bayangol -6.1 km, lake -1 location, 48.7 ha
⑥Protective embankment of Takhir River-9.7km, Lake at Location No. 1-48.7ha
⑦Protective embankment of Songin River-5.7km
⑧Protective embankment of Kheel River-17.2km

Flood protection channels: Ulaanbaatar City is susceptible to flood hazards due to short-term intense rainfall in the surrounding areas. During the flood of the Shariin Us River, the floodwaters

flow along the river, transporting a substantial amount of mud, sand, and stones, damaging the residential complexes along the road and the surrounding environment, compromising and destroying bridges and overpasses, thereby causing significant damage. Due to the effects of wind, precipitation, and human activities, settlement areas within urban residential zones experience erosion and collapse, posing a risk of complete ground subsidence. To mitigate land degradation in these areas, clay and stones deposited by floodwaters have been removed at 83 locations, and vegetation has been naturally cultivated; flood drainage channels totaling 202.2 kilometers have been constructed at 65 locations, along with 2-3 level flood purification reservoirs at 19 locations, which discharge into the river to safeguard the drinking water source from contamination and reduce the risk of infectious disease transmission. To mitigate flood risks, artificial lakes and reservoirs will be established to collect rainwater and spring meltwater; additionally, urban green spaces will be enhanced, domestic tourism promoted, and a humid, comfortable environment for leisure activities created.



Drawing 6.2. Schematic drawing of floodwater protection embankment



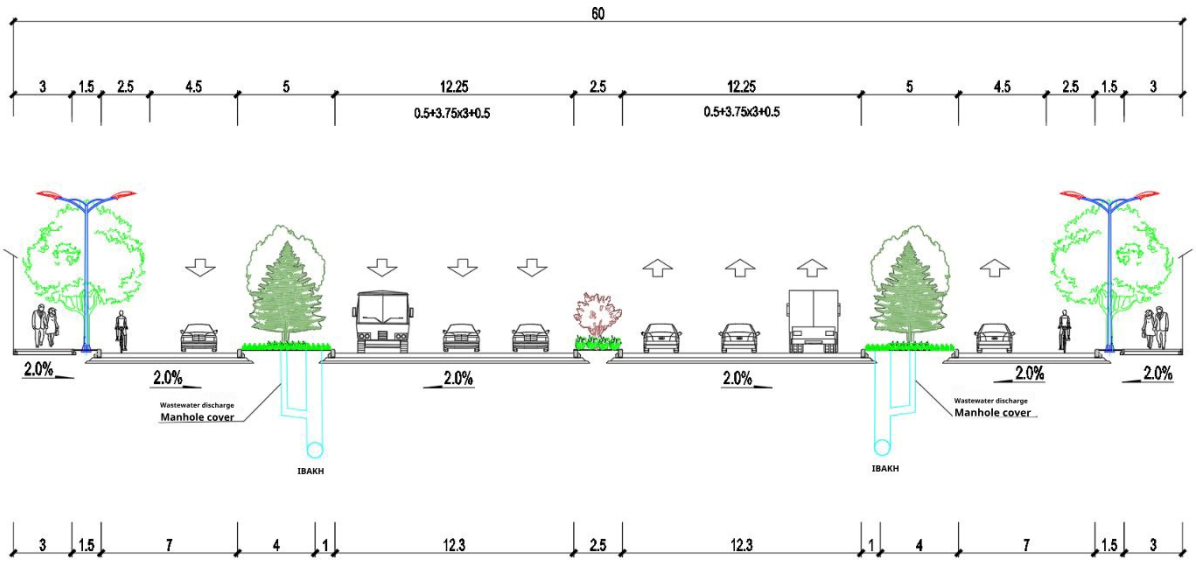
Drawing 6. 2. Schematic drawing of floodwater protection structure

(2) Riverbank and flood protection zone

The reduction of river flow and significant pollution in urban settlements, along with the loss of natural self-purification capacity, are associated with activities such as mineral extraction, tree felling, and vegetation removal within the river protection zone. The implementation of the 'Water Source Protection Zone and Sanitary Facilities for Water Supply Sources,' which aims to protect water sources, reservoirs, and resources from pollution and to prevent flood disasters affecting the population, is inadequate. The type and scope of water source protection zones and sanitary facilities shall be determined in accordance with the following provisions. According to clause 4.6 of Resolution No. 25 dated March 30, 2023, of the Ulaanbaatar City Citizens’ Representative Khural, the protective zone for flood protection structures shall be established at 10 meters from the outer edge of buildings, 5 meters from the outer edge of dikes and canals, and 5 meters from the outer edge of stormwater and groundwater drainage pipelines.

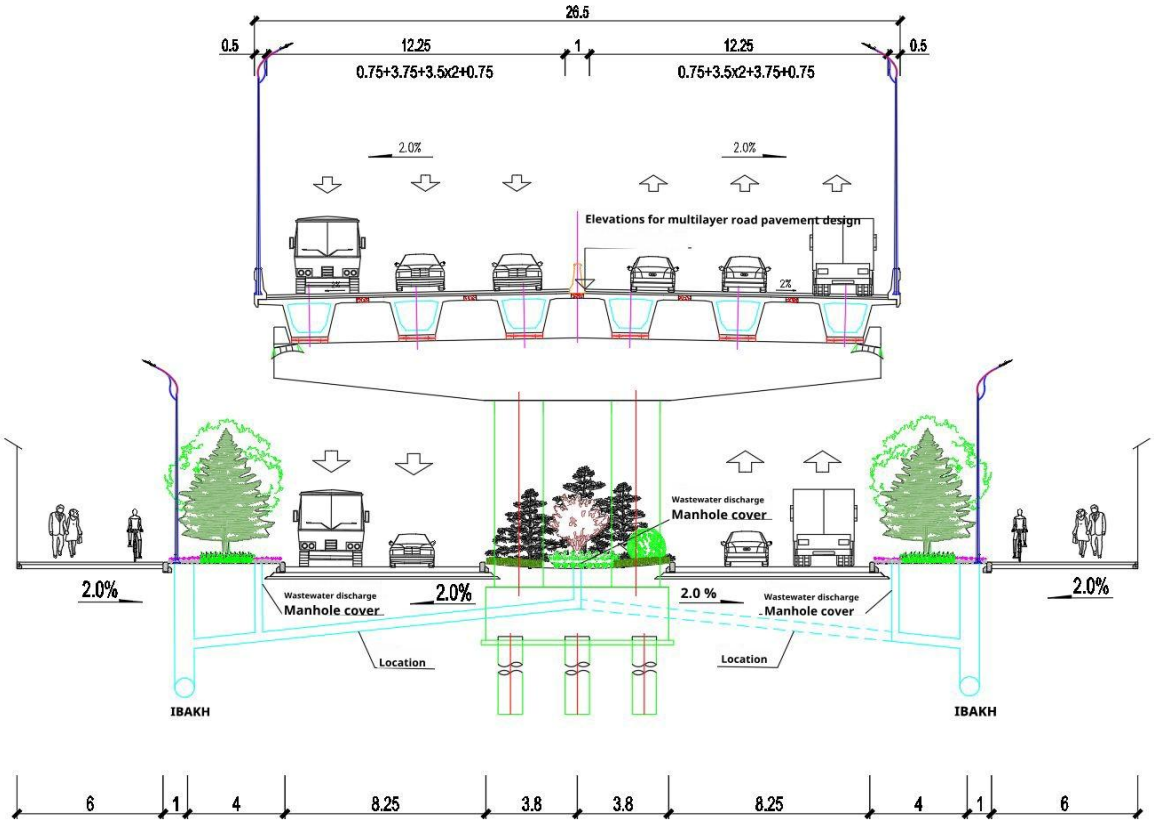
6.1.4.10. Comprehensive design drawing of the stormwater culvert cross-section

(1) 60m road: 60m = 3m (pedestrian path) + 1.5m (tree water reservoir) + 2.5m (non-motorized vehicle lane) + 4.5m (service road) + 5m (depressed green belt) + 12.25m (motor vehicle lane) + 2.5m (median) + 2.5m (median) + 5m (depressed green belt) + 4.5m (service road) + 2.5m (non-motorized vehicle lane) + 1.5m (tree water reservoir) + 3m (pedestrian path); The stormwater drainage pipes designed according to this model shall be installed on both sides of the adjoining shoulder as shown in the drawing below.



Drawing 6. 3Standard cross-sectional drawing of a 60 m road embankment structure.

(2) 45 m road: 45 m = 3.5 m (pedestrian walkway) + 2.5 m (non-motorized vehicle lane) + 5 m (grassed green belt) + 7.5 m (earth shoulder) + 8 m (central median strip) + 7.5 m (earth shoulder) + 5.5 m (earth shoulder) + 5 m (non-motorized vehicle lane) + 3.5 m (pedestrian walkway). The rainwater runoff drainage pipe designed in this model is distributed along the side strips on both sides. For details, refer to the drawing below.



Drawing 6. 4Standard cross-sectional drawing of a 45 m road embankment structure

6.2. Heat supply

6.2.1. General section

Calculations and planning for the relocation, transfer, and reinforcement of the heat supply pipeline network and facilities situated transversely and longitudinally along the motor road

alignment have been developed.

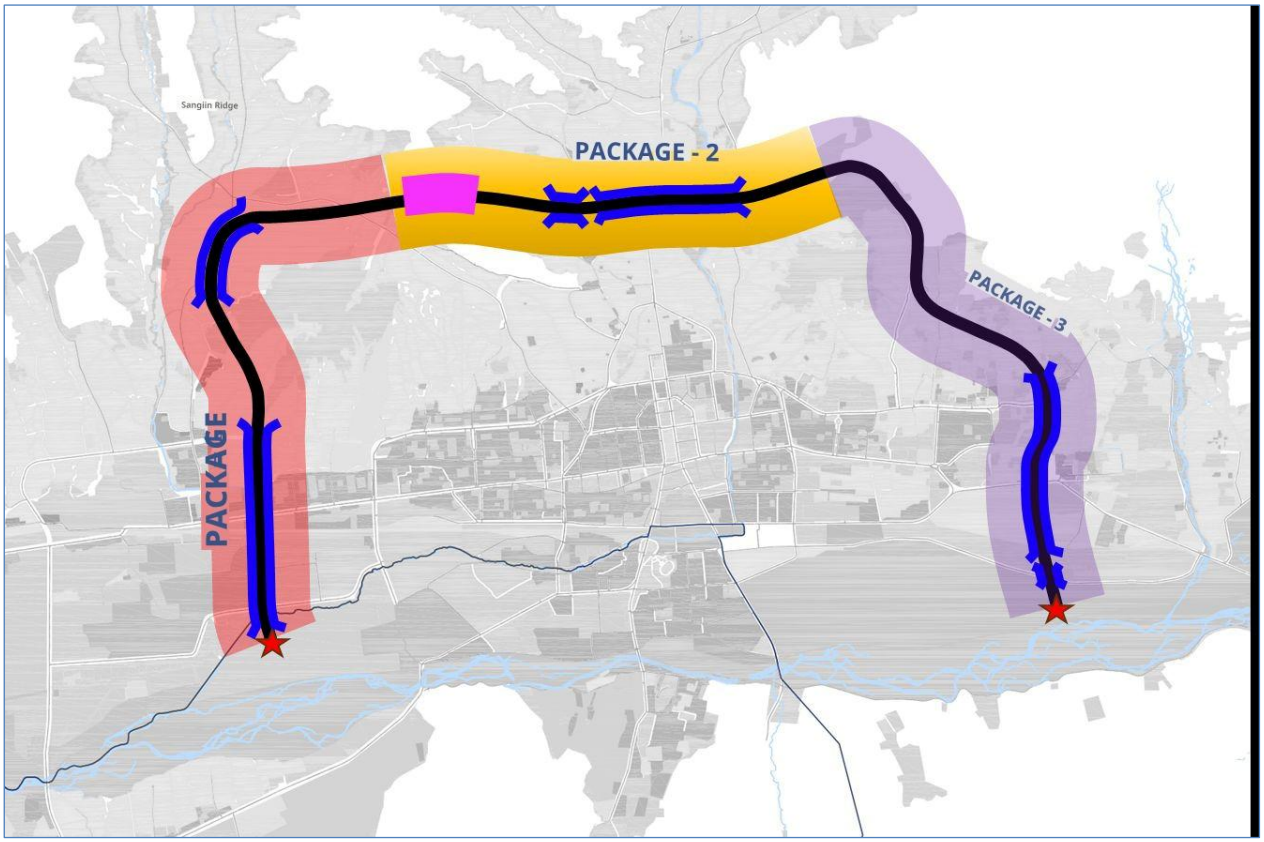
6.2.2. Planning of the heating supply pipeline network

6.2.2.1 Scope

The alignment of the First Ring Motor Road project passes through the territories of Khaan-Uul District’s 3rd and 4th Khoroos; Bayangol District’s 20th and 29th Khoroos; Songinokhairkhan District’s 6th, 7th, 8th, 9th, 10th, 16th, 23rd, 28th, 30th, 39th, and 40th Khoroos; Chingeltei District’s 15th, 16th, 18th, and 22nd Khoroos; Sukhbaatar District’s 14th and 16th Khoroos; and Bayanzurkh District’s 2nd, 5th, 13th, 21st, 26th, 27th, 29th, 31st, 32nd, and 36th Khoroos within Ulaanbaatar City. The impact scope within 31 khoroos of six districts in Ulaanbaatar City is calculated as 150 meters on each side from the road axis, totaling 300 meters, covering an area of 8.4 hectares along the entire route. The water supply system planning solution shall develop preliminary plans for relocating, transferring, and reinforcing the pipeline network and facilities situated within the motor road planning corridor.

6.2.2.2 Planning for the reinforcement and relocation of the external heat pipeline network

In accordance with the plan to implement the new ring motor road route design in three phases, the water supply and sanitation sections of the feasibility study were also planned in three phases.



PACKAGE 1: Motor road from the TPP-4 road to the planned beginning of the tunnel – 8.6 km

PACKAGE 2: Motor road from the beginning of the tunnel to Bayanzurkh District, 21st khoroo – 6.2 km

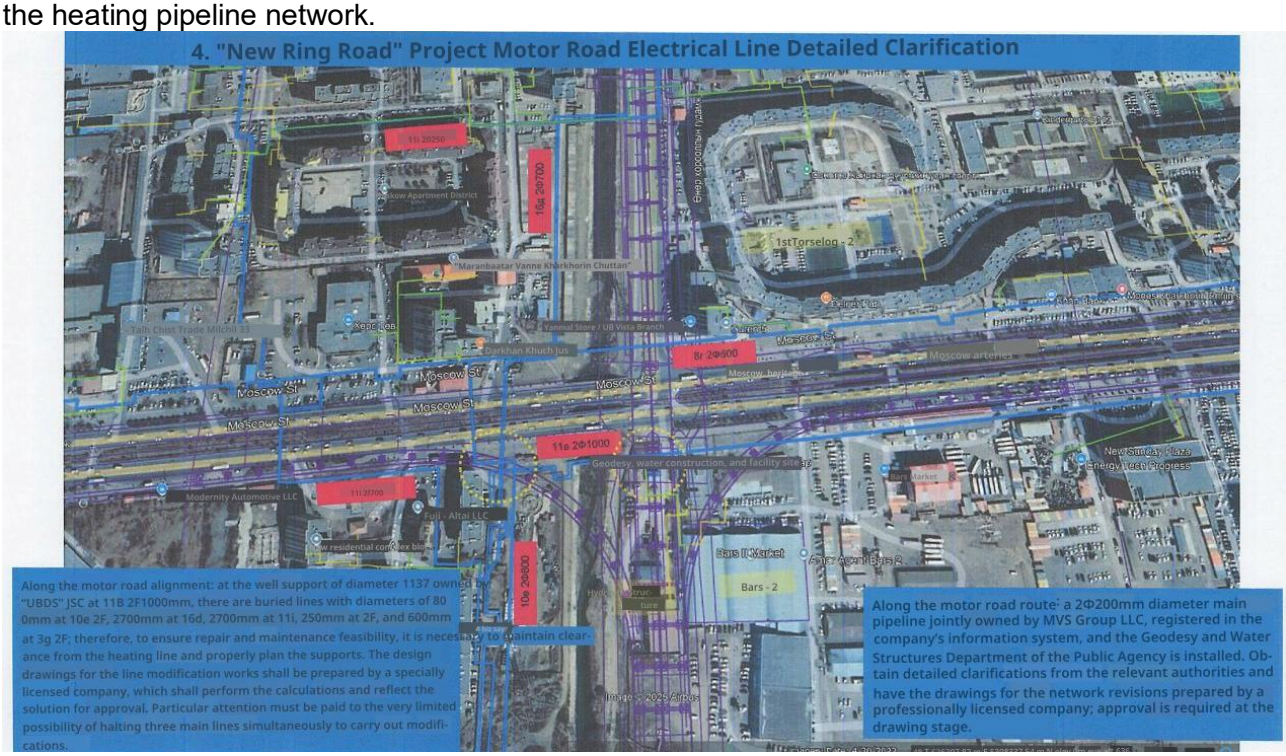
PACKAGE 3: From Bayanzurkh District, 21st khoroo to the Dunjingarav intersection

At the initial section of the New Ring Road-2 planning route, where it intersects with the TPP-4 road, overhead heating supply mains of 10b diameter comprising twin 2Φ800 and 2Φ1000 pipes are located. The motor road planned within the section containing the overhead network is designed as a bridge structure, and during the installation phase, it is necessary to protect the overhead network and perform the assembly.

Хүснэгт 1. Heating supply pipeline intersecting the motor road route of Package-1

Data concerning the heating supply pipeline						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-1	11k mainline	2x250 mm	2x60	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	11k mainline	2x500 mm	2x50	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	11k mainline	2x400 mm	2x170	Steel pipe	In operation	Relocate in coordination with the motor road working drawing
	Line of OSNAUG HUT-16	2x250 mm	2x110	Steel pipe	In operation	Relocate in coordination with the motor road working drawing

Along the alignment of Package 1, it is planned to relocate and reinforce heating pipelines positioned transversely and longitudinally at a total of four points, in coordination with the motor road and bridge foundations. A total of 800 meters of heating supply pipeline network is located. It is recommended to install a protective conduit in the trench when relocating and transferring the heating pipeline network.



Source: Clarification No. 01/1326 from UBDT LLC

According to the clarification document from UBDT LLC, the existing major heating supply pipelines are designed as bridge structures within the motor road planning route, and it is planned to maintain the existing heating pipelines safe and operational during the motor road construction phase.

In coordination with the motor road working design, it is necessary to obtain additional clarifications and prepare the drawings for strengthening and rerouting the heating supply pipeline from “UBDS” JSC and “OSNAAUG” SUE.

Since the route of Package 2 predominantly passes through ger districts, there is no centralized heating pipeline network.

Хүснэгт 2. Heat supply lines intersecting the Motor Road alignment of Package 3

Data concerning the heating supply pipeline						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-3	OSNAUG HT-17 line	2x150 mm	2x75 mm	Steel pipe	In operation	Relocate in coordination with the motor road working drawing
	OSNAUG HT-18 line / Trench containing 5 lines /	2x150 mm	2x50	Steel pipe	In operation	Relocate in coordination with the motor road working drawing
	Jointly owned line of OSNAUG HT-17 and private consumers	2x400 mm	2x80	Steel pipe	In operation	Relocate in coordination with the motor road working drawing
	Jointly owned line of OSNAUG HT-17 and private consumers	2x80 mm	2x80	Steel pipe	In operation	Relocate in coordination with the motor road working drawing
	Jointly owned line of Nutgiin Buyan and other consumers	2x500 mm	2x150	Steel pipe	In operation	Relocate in coordination with the motor road working drawing

Within Package 3, it is planned to relocate and reinforce the thermal pipelines, positioned transversely and longitudinally at a total of five points along the route, in coordination with the foundations of the motor road and bridge structures. A total of 800 meters of heating supply pipeline network is located. It is recommended to install a protective conduit in the trench when relocating and transferring the heating pipeline network.

The existing major thermal supply pipeline network, as detailed in the clarification letter from 'UBDS' LLC, is planned to be integrated into the motor road route planning as bridge structures, with the existing thermal pipelines maintained in safe operation throughout the motor road construction phase.

In coordination with the motor road working design, it is necessary to obtain additional clarifications and prepare the drawings for strengthening and rerouting the heating supply pipeline from “UBDS” JSC and “OSNAAUG” SUE.

In accordance with the requirements of the master plan, the heating pipeline network planning is optimized in alignment with the existing motor road alignment, geographic location, natural factors, socio-economic conditions, and the current urban environment, ensuring that the heating system is safe and reliable while incorporating a modern, advanced, environmentally protective, and energy-efficient concept. Simultaneously, to optimize investment and reduce project costs, the initial heating facility is utilized to the greatest extent possible.

6.2.3. Conduct thermal calculations

There are three appropriate methods for installing the heat pipeline network: overhead installation, underground trench installation, and direct burial.

The three installation methods each possess distinct advantages and disadvantages. Based on the specific characteristics of this project and the particular requirements outlined in the Urban Planning Brief, a comprehensive technical and economic comparison of the methods for laying the heating network has been conducted. A brief overview of the three methods for laying the heating network is presented below.

(1) Installation from the top

Floor installation provides a short construction period, a relatively simple insulation structure, and is suitable for maintenance and management. However, the thermal performance of the roof layer is inadequate, and the external protective structure is prone to damage. Consequently, annual

maintenance and management costs are high, and heat loss is considerable. The erection of embankments on both sides of the road affects the city's visual appearance and is not sufficiently compatible with urban planning, construction, and development.
(2) Installation of underground channels and gutters
Although the installation method of channels and gutters meets environmental protection planning requirements, it exhibits poor corrosion resistance and thermal insulation properties, relatively high heat loss, significant network maintenance, high operational costs, prolonged construction periods, and substantial impact on urban traffic and the daily lives of residents.
(3) Direct Burial
When laying hot water pipelines underground, the direct burial method is primarily specified in the factory technical conditions. Compared to duct installation, direct burial entails lower costs, longer service life, shorter construction duration, reduced heat loss, decreased maintenance workload, and more economical operation. Although the investment exceeds that of embankment construction, it does not affect the urban landscape and exerts relatively minimal impact on city traffic, which is advantageous for urban planning. In recent years, the direct landing method has been actively implemented and promoted both domestically and internationally.
Following the comprehensive technical and economic comparison, it is preferable to install the heat pipeline for this project by direct burial.

6.2.4. Selection of pipe material

During the manufacture of the heat pipeline, it is essential to consider various factors including the surrounding environmental conditions, whether the pipeline is underground or above ground, the presence of corrosive gases in the vicinity, the ambient temperature and humidity at the location, as well as the method of installation. These are critical considerations in the manufacture of heat transfer pipes.
Iron pipes are predominantly used in heating pipeline systems. The primary advantage of iron pipes is their capability to withstand high internal pressure and dynamic loads; connections for transmission pipes are straightforward, whereas a disadvantage is that both the interior and exterior surfaces of iron pipes are prone to corrosion. The steel content used shall comply with the requirements of the national standard.
Seamless steel pipes are made from a single piece of metal and have no seams on the surface. According to the manufacturing method, seamless pipes are classified into hot-rolled pipes, cold-rolled pipes, cold-drawn pipes, compressed pipes, and jack pipes; seamless steel pipes are extensively utilized. General purpose seamless steel pipes are manufactured from plain carbon structural steel, low alloy structural steel, or alloy structural steel, designed for maximum output; they are primarily utilized as transmission pipes or structural components for fluid conveyance.
Spiral submerged arc welded steel pipes can be produced from fine billets with large diameters, enabling the manufacture of welded pipes with varying diameters but identical billet widths. The production cost is low, the process is straightforward, and manufacturing large-diameter pipes is facilitated. Large-diameter welded pipes are predominantly fabricated using spiral submerged arc welding. These are typically employed for purposes including welding in liquid transportation pipelines, metal structures, and external foundations.
Table 6. 2. Table Comparing the Properties of Pipe Materials

Pipe Material	Pipeline Characteristics	Scope of Application
20#Iron	The strength of 20# steel is slightly higher than that of 15# steel, and it seldom fractures. This iron exhibits excellent welding performance and can be heated up to 880-900℃ for cutting, which can be improved by quenching with water. The arc welding and spot welding performance of 20# steel is relatively good, and the thickness is smaller during gas welding.	Used in various mechanical components that are not subjected to heavy loads but require high hardness.

Q235B	Q235B steel contains carbon ranging from 0.12% to 0.20%, exhibiting defined tensile strength, durability, hardness, good castability, and ease of stamping and welding. Features medium carbon content with well-balanced overall performance, good strength, ductility, and favorable welding properties.	General mechanical components, as well as structural elements such as buildings and bridges, are intended for welding.
Q355B	The yield strength is 355 MPa, representing high tensile strength suitable for applications requiring enhanced durability, as it can withstand greater pressure and external forces, making it appropriate for pipelines necessitating high strength. This exhibits adequate hardness at room temperature and can withstand a specific degree of deformation without failure, thereby improving the safety and reliability of the transmission pipeline.	This is suitable for transmission pipeline systems transporting water, petroleum, gas, and other conveyables. This also applies to structural steel frames, including bridge truss structures, as well as primary load-bearing structures and bridge constructions.
L290	A minimum compressive strength of 290 MPa effectively withstands internal high pressure, ensuring safe and stable transportation, while the tensile strength adequately resists complex external environmental loads. This exhibits excellent welding performance and effectively fuses the weld and base materials during the welding process. The strength and durability of the welded joint meet the operational requirements.	The L290 transmission pipeline is suitable for transporting crude oil, refined oil, and other petroleum products, as well as natural gas, and is also appropriate for material transportation in chemical, metallurgical, and other industrial sectors.

In summary, based on the comparative analysis of the aforementioned materials, for this project, a double-sided spiral welded deep submerged arc-welded steel pipe with DN ≥ 250 was selected for the transmission pipeline. These pipes are fabricated from rolled steel plates, and the pipe material is Q235B carbon steel. For transmission pipelines with DN < 250, seamless steel pipes are utilized, with material specified as No. 20 steel. The wall thickness deviation of the steel pipe ranges from 0 to 0.5 mm. A directly buried pipeline accounts for internal pressure as well as soil pressure, ground loads, the pipeline's dead weight, internal pressure, minimum wall thickness requirements due to temperature fluctuations, minimum wall thickness resulting from local pipe wall depressions, and the effects of pipe stiffness.

6.2.5. Selection of Insulation Materials

3.4.1. Due Selection of Insulation Materials

Due to environmental conditions, pipes installed outdoors typically require insulation and measures to protect against freezing, necessitating the use of insulating materials. The objective is to reduce heat loss, maintain the thermal environment at specified temperatures and pressures adequate for production and living requirements, conserve fuel, and safeguard heat pipelines from external impacts. Commonly used pipe insulation materials include glass wool, composite silicate, polyurethane, rock wool, rubber, and plastic wool.

Directly buried insulated pipes are referred to as prefabricated insulated pipes and are generally classified into two types: plastic-coated steel prefabricated insulated pipes (high-density polyethylene directly buried insulated pipes) and steel-coated steel insulated pipes (high-temperature steam insulation pipes). The high-density polyethylene directly extruded insulated pipe comprises a conductor, a working metal pipe, a foam insulation layer, and an outer protective polyethylene plastic pipe, all sequentially supplied outward by the equipment.

The main technical performance shall conform to the following requirements.
The thermal conductivity coefficient at the average operating temperature shall not exceed 0.12 W/(m·K);
②The density shall not be less than 60 kg/m³;
③Except for soft and loose materials, the compressive strength of rigid prefabricated products shall be at least 0.3 MPa, and the compressive strength of semi-rigid insulation materials under 10% compression shall be at least 0.2 MPa.
The pipeline for this project employs polyurethane insulation material.
The first layer is a polyurethane insulation layer created by simultaneously injecting a rigid polyurethane foam compound into the cavity between the steel pipe and the outer casing using a high-pressure foaming machine. This phenomenon is commonly referred to as "foam within the pipe." Its purpose is to provide waterproofing, retain thermal energy, and support the weight of the thermal network. For transmission medium temperatures ranging from -50℃ to 120℃, rigid polyurethane foam is employed as the insulation layer. Subsequently, a high-density polyethylene protective layer is installed within a specified wall thickness of black (yellow) plastic pipe. Its purpose is to protect the polyurethane insulation layer from mechanical damage, corrosion, and water ingress. It is characterized by low engineering cost, minimal thermal loss, energy efficiency, corrosion resistance, excellent insulation properties, long service life, compact footprint, rapid construction, environmental protection, and safety. The prefabricated straight-wound sprinkler coil thermal insulation pipe comprises iron pipes/sections for environmental transmission works, a polyurethane rigid foam plastic insulation layer of the sprinkler, and a polyethylene outer protective pipe of the coil. The product structure is illustrated in the drawing below.

Drawing 6. 5. Composition of the Prefabricated Straight-Wound Sprinkler Coil Insulation Pipe

The Prefabricated Sprinkler Thermal Insulation Pipe has the following advantages:
①The mechanical properties of the outer protective pipe are enhanced, enabling effective protection of the insulation layer;
②The wall thickness of the outer protective pipe is reduced;
③The water absorption capacity of the insulation layer is decreased. The insulating layer functions with stability and reliability;
④The sealing rate of perforations in the insulating layer has improved;
⑤The axial misalignment of the insulating pipe has been reduced;
⑥The uniformity of density throughout the insulating layer of the transmission pipe has been enhanced;
⑦The compressive strength of the insulating layer has increased;
⑧The thermal conductivity coefficient of the insulating layer has decreased, thereby reducing energy loss.
In addition to the aforementioned advantages, the spray coil process determines the appropriate insulation layer thickness based on the transmission environment temperature of each project, thereby reducing unnecessary excess mass. Under low-stress conditions, the outer coating thickness is determined solely by the requirements for corrosion protection, handling, transportation, and installation. This thickness can be substantially reduced compared to the outer coating thickness within the pipe, resulting in cost savings. The sprayer coil production line

possesses a compact structure with minimal connections, effectively reducing manufacturing costs during production. By actively promoting national policies for environmental protection and energy conservation, the advantages of products employing sprayer-applied directly buried insulating pipes were emphasized. Therefore, this project employs pre-insulated, directly buried pipes with sprayed assembly.

6.2.6. Pipe Fittings and Valves

Valves are devices used to open, close, and regulate the flow of the transported medium within the pipeline. Common types of valves for heating pipelines include stop valves, gate valves, butterfly valves, check valves, control valves, and ball valves.

The stop valve can be classified into three types according to the ambient flow direction: straight-through type, right-angle type, and direct flow type (inclined stem type). The stop valve ensures tight sealing; however, the valve body is long, exhibits high average flow resistance, and the nominal diameter does not exceed 200 mm.
The gate valve is available in two forms: open stem and concealed stem. Furthermore, according to the shape and number of gate discs, there are wedge and parallel types, as well as single-disc and double-disc varieties. The advantages and disadvantages of gate valves are identified in comparison with stop valves. These are typically used in pipes with a nominal diameter exceeding 200 mm. Stop valves and gate valves primarily function to open and close the transmission pipeline. They exhibit poor adjustability and are thus unsuitable for flow regulation.
The butterfly valve body is very short, presents low flow resistance, and its adjustment performance is somewhat superior to that of stop valves and gate valves, albeit at a higher cost. Butterfly valves are widely utilized in domestic direct-buried district heating network projects.
The connection methods for stop valves, gate valves, and butterfly valves may be flange, threaded, or welded. Their actuation methods include manual operation (for small diameters), gear, electric, hydraulic, and pneumatic actuation (for large diameters). The 'Technical Specifications for the Heat Network' stipulate that for shut-off valves with a nominal diameter of 500 mm or greater, an electric actuator shall be utilized.
A check valve is a valve designed to prevent backflow of the medium within the pipeline or equipment. This valve operates by utilizing the kinetic energy of the fluid to open. Check valves in heating systems are customarily installed at the pump discharge, drainage device outlet pipes, and other locations where reverse fluid flow is prohibited. The widely used check valves are mainly of the swing and lift types. Lift check valves provide good sealing performance but may only be installed in horizontal pipelines and are generally used for horizontal pipelines with a nominal diameter of less than 20 m. Cage check valves have poor sealing performance and are primarily used in vertical upward flows or in pipelines with large diameters.
When it is necessary to regulate the flow of the heating carrier, a manual adjusting valve or an automatic flow control device shall be installed on the transmission pipe. The valve disc of the manual regulating valve is conical. By turning the handwheel to adjust the position of the valve disc, the gap between the bottom of the valve disc and the diameter within the valve body can be altered, thereby regulating the average flow. For a highly controllable regulating valve, the valve disc lift height and flow velocity should be approximately linear.
Ball valves can be classified by function into shut-off ball valves and extinguishing control ball valves. Shut-off ball valves are used as branch valves for transmission pipelines and as bypass valves for main pipelines of large diameter. Shut-off regulator ball valves combine the shut-off and control functions into a single unit. The flow rate is determined by the pressure differential and can be intuitively observed through the switch on the handle. This is suitable for water supply demands in accordance with various requirements. Simultaneously, the ball valve controlling the shut-off is also a simple shut-off valve. In cases requiring urgent maintenance, when turned off and subsequently reopened, the locking device on the plug can maintain the original water supply. According to installation requirements, ball valves are categorized as either straight-through ball valves or tee ball valves. The direct-buried ball valve can be adjusted to suit the burial depth of

the valve stem passing through the pipeline and can operate without the need for valve chamber construction. The direct-buried ball valve is easy to install, shortens the construction period, and reduces infrastructure investment costs.

6.3. Water supply and sanitation

6.3.1. General section

6.3.1.1. Basis, document

The calculations and planning for the relocation and reinforcement of water supply and sanitation pipeline networks and structures located transversely and longitudinally within the motor road alignment have been developed based on the following documents, which include:

- Law on Urban Development of Mongolia; Resolution No. 52 of 2020 Approving Mongolia's Long-Term Development Document 'Vision 2050'
- Law on the Operation of Urban and Settlement Water Supply and Sanitation Systems
- General Development Master Plan for Ulaanbaatar City until 2020; 2030 Conceptual Framework, 2013
- Conceptual Framework of the General Development Plan of Ulaanbaatar City Until 2040, 2021
- Government Resolution No. 204 of 2009 on the Regulation for the Preparation, Approval, and Certification of Building Design Drawings
- 'Urban and Rural Planning and Construction' Building Norms and Regulations BNbD 30-01-04
- Water Supply. External Network and Facilities” BNbD 40-02-16
- Sewerage. External Network and Facilities” BNbD 40-01-14

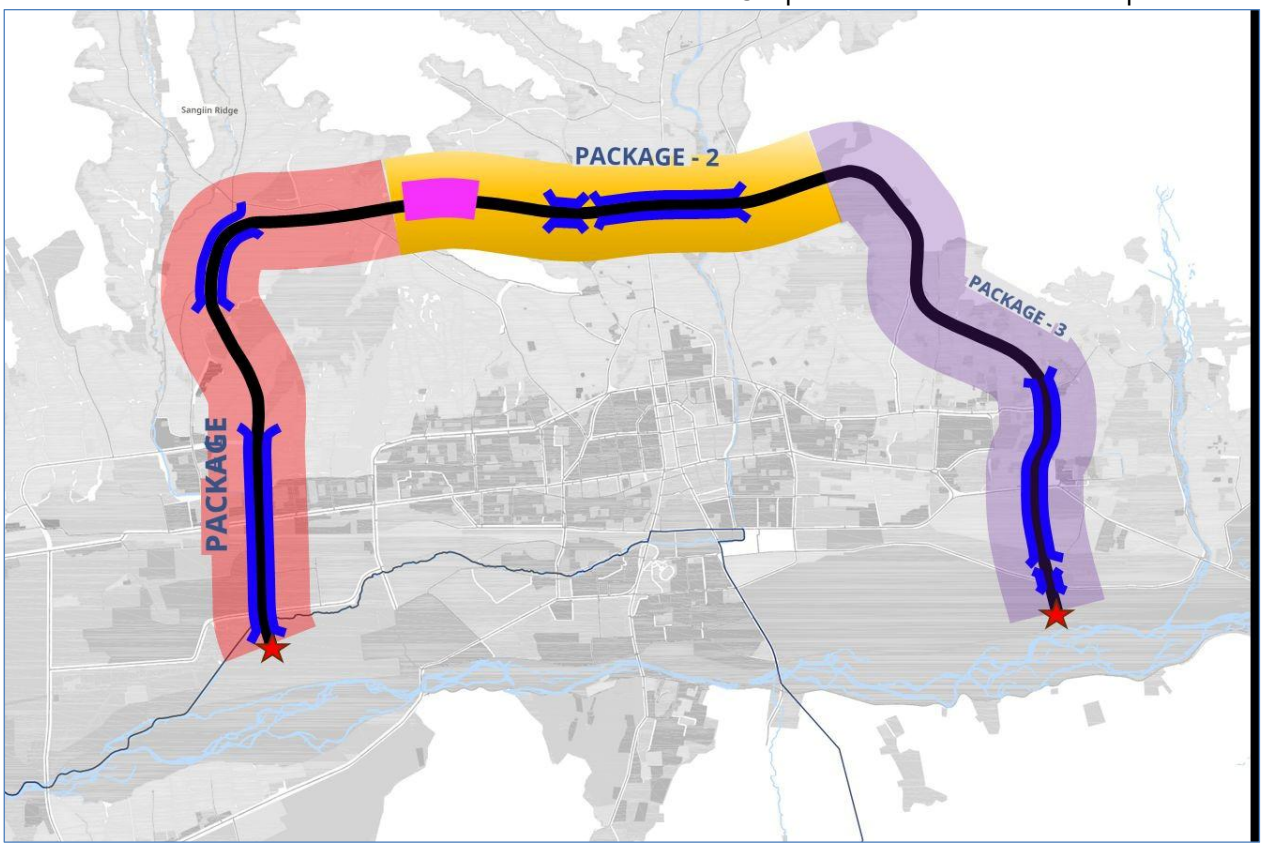
6.3.2. Water Supply System Planning

6.3.2.1 Scope

The alignment of the First Ring Motor Road project passes through the territories of Khaan-Uul District’s 3rd and 4th Khoroos; Bayangol District’s 20th and 29th Khoroos; Songinokhairkhan District’s 6th, 7th, 8th, 9th, 10th, 16th, 23rd, 28th, 30th, 39th, and 40th Khoroos; Chingeltei District’s 15th, 16th, 18th, and 22nd Khoroos; Sukhbaatar District’s 14th and 16th Khoroos; and Bayanzurkh District’s 2nd, 5th, 13th, 21st, 26th, 27th, 29th, 31st, 32nd, and 36th Khoroos within Ulaanbaatar City. The impact scope within 31 khoroos of six districts in Ulaanbaatar City is calculated as 150 meters on each side from the road axis, totaling 300 meters, covering an area of 8.4 hectares along the entire route. The water supply system planning solution shall develop preliminary plans for relocating, transferring, and reinforcing the pipeline network and facilities situated within the motor road planning corridor.

6.3.2.2 Planning for the Relocation, Transfer, and Reinforcement of Water Supply Pipeline Networks

Aligned with the plan to implement the new ring motor road route in three packages, the technical and economic feasibility study divided the water supply and sewerage section planning correspondingly into three packages.



PACKAGE 1: Motor road from the TPP-4 road to the planned beginning of the tunnel – 8.6 km

PACKAGE 2: Motor road from the beginning of the tunnel to Bayanzurkh District, 21st khoroo – 6.2 km

PACKAGE 3: From Bayanzurkh District, 21st khoroo to the Dunjingarav intersection

Table 3. Water supply pipeline intersecting the Package-1 motor road alignment

Water supply pipeline data						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
	BUK-2 potable water pipeline	200 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Potable water pipeline from station B VK3 to BUK-2	200 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Khar Khory potable water pipeline	400 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Southern 700 pipeline	700 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Bayangol Am potable water pipeline	600 mm	70	HDPE plastic	In operation	Reinforce in coordination with the motor road working drawing

Package-1	First Khoroo potable water pipeline	600 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Ring Line of First Residential District	600 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road design drawings, and relocate sections aligned with the road carriageway accordingly.
	Upper and Lower Reservoir Pipelines of Bayankhoshuu	2x350 mm	80	HDPE Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Upper and Lower Reservoir Pipelines of Bayankhoshuu	280 mm	80	HDPE Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Upper and Lower Reservoir Pipelines of Bayankhoshuu	280 mm	110	HDPE Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Upper and Lower Reservoir Pipelines of Bayankhoshuu	2x350 mm	110	HDPE Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Bayankhoshuu Ring Line	Φ225 mm	110	Plastic, Φ225 mm, X10-X11	In operation	Reinforce in coordination with the motor road working drawing
	Pipeline of Distribution Station No. 270	Φ63/25	272	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Service center line	Φ100 mm	153	Iron	In operation	Reinforce in coordination with the motor road working drawing

Within the route of Package 1, a total of 14 points feature potable water pipeline networks arranged transversely and longitudinally. The potable water pipeline network arranged transversely is planned to be reinforced with an iron casing. The firefighting pipeline of the 1st residential area, located either transversely or longitudinally along the motor road route, is planned for relocation. Within the alignment of Package-1, there is a total of 1395 meters of potable water pipeline network. Additionally, along the motor road alignment, there are 4 units of ger district water distribution stations. The possibility of relocating the water distribution stations in accordance with site planning and the road alignment must be investigated and assessed.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

Table 4. Water supply line intersecting the Motor Road route in Package 2

Water supply pipeline data						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal

Package-2	Haylaast water reservoir supply line	300 mm	85	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Haylaast water reservoir discharge line (left side)	200 mm	85	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Haylaast water reservoir discharge line (right side)	200 mm	85	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Dari Ekh clean water line	300 mm	80	Cast iron pipe	In operation	Reinforce in coordination with the motor road working drawing
	Dari Ekh clean water line	110 mm	80	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	First Khoroo potable water pipeline	600 mm	70	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Service center line	Φ100 mm	153	Iron	In operation	Reinforce in coordination with the motor road working drawing

Within the Package 2 route, there are a total of seven points where the clean water pipeline network is located both transversely and longitudinally. The potable water pipeline network arranged transversely is planned to be reinforced with an iron casing. A total of 650 m of potable water pipeline network is located along the alignment of Package 2. Additionally, 4 units of residential area water distribution stations are situated along the motor road alignment. The possibility of relocating the water distribution stations in accordance with site planning and the road alignment must be investigated and assessed.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

Table 5. Water supply pipeline intersecting the motor road alignment within Package 3.

Water supply pipeline data						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-3	Gachuurt source pipeline.	700 mm	85	Wall	In operation	Reinforce in coordination with the motor road working drawing
	Pipeline of the No. 5 water distribution station.	Φ50/63 mm	140	Plastic	In operation	To be relocated in coordination with the motor road working drawings.
	Main source line	600 mm	550	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Sharhad ring pipeline	110 mm	300	Plastic	In operation	Reinforce in coordination with the motor road working drawing

	Yalaltin potable water pipeline	500 mm	85	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Janjang potable water pipeline	200 mm	140	Plastic	In operation	Reinforce in coordination with the motor road working drawing
	Main source line	Φ2 x 400 mm	160	Tin	In operation	Reinforce in coordination with the motor road working drawing

The potable water pipeline network is located at a total of seven cross and longitudinal points along the Package 3 route. The potable water pipeline network arranged transversely is planned to be reinforced with an iron casing. A total of 1460 m of potable water pipeline network is located along the Package 3 route. There are also five water distribution stations for residential areas located along the motor road route. The possibility of relocating the water distribution stations in accordance with site planning and the road alignment must be investigated and assessed.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

6.3.3. Sewerage System Planning

6.3.3.1. Scope

The alignment of the First Ring Motor Road project passes through the territories of Khaan-Uul District's 3rd and 4th Khoroos; Bayangol District's 20th and 29th Khoroos; Songinokhairkhan District's 6th, 7th, 8th, 9th, 10th, 16th, 23rd, 28th, 30th, 39th, and 40th Khoroos; Chingeltei District's 15th, 16th, 18th, and 22nd Khoroos; Sukhbaatar District's 14th and 16th Khoroos; and Bayanzurkh District's 2nd, 5th, 13th, 21st, 26th, 27th, 29th, 31st, 32nd, and 36th Khoroos within Ulaanbaatar City. The impact scope within 31 khoroos of six districts in Ulaanbaatar City is calculated as 150 meters on each side from the road axis, totaling 300 meters, covering an area of 8.4 hectares along the entire route. The water supply system planning solution shall develop preliminary plans for relocating, transferring, and reinforcing the pipeline network and facilities situated within the motor road planning corridor.

6.3.3.2. Planning of Sewerage Network, Reinforcement, Transfer, and Relocation

The scope of the sewerage engineering design is identical to that of the motor road engineering and encompasses the relocation of the entire sewer line along the ring road.

Table 6. Sewer pipeline intersecting the motor road alignment of Package-1

Information on the sewer pipeline						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-1	Pressure pipeline for the Future Residential Area	2x400 mm	1450	HDPE Plastic	In operation	Strengthening, relocation, and transfer in coordination with the motor road working drawings
	Southern collector	1400 mm	220	Reinforced concrete	In operation	Strengthening in coordination with the motor road working drawings (in areas of high traffic congestion)

	Pressurized sewage pipeline	800 mm	85	Steel pipe	In operation	Reinforce in coordination with the motor road working drawing
	Tuul-1 Collector Section 4	1500 mm	180	Steel pipe	In operation	Strengthening in coordination with the motor road working drawings (in areas of high traffic congestion)
	Central Collector	1400 mm	85	HDPE plastic	In operation	Strengthening in coordination with the motor road working drawings (in areas of high traffic congestion)

Along the route of Package 1, clean water pipelines are located transversely and longitudinally at a total of five points. Major city centralized sewage collector pipelines are situated at the intersection with Enkhtaivny Avenue in the planned road section. Therefore, measures shall be implemented to reinforce the pavement within the road carriageway along the route, ensuring no disruption to the operational regime of the sewage pipeline network. A total of 2020 meters of pressurized and non-pressurized sewage pipeline network is located along the route of Package-1.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

Table 7. Sanitation drainage pipeline intersecting the route of Package-2 motor road

Information on the sewer pipeline						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-2	Chingeltei Collector	400 mm	90	Soft insulation	In operation	Strengthening, relocation, and transfer in coordination with the motor road working drawings
	Khaylaast Collector	300 mm	110	Soft insulation	In operation	Reinforce in coordination with the motor road design drawing

Along the route of Package 2, there are a total of two points with potable water pipeline networks located both transversely and longitudinally. The sewer pipeline network along the motor road route planned in the ger district area is relatively limited. There is a total of 200 m of pressurized and non-pressurized wastewater pipeline network along the alignment of Package-2.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

Table 8. Sewerage pipeline intersecting the alignment of the Package-3 motor road

Information on the sewer pipeline						
Package number	Pipeline name	Pipe diameter	Length, m	Material, service life	Operational status	Planning solution proposal
Package-3	Employer's branch pipeline	200 mm	100	Plastic	In operation	Reinforce in coordination with the motor road working drawing

	Employer’s branch pipeline	150 mm	110	Cast iron pipeline	In operation	Reinforce in coordination with the motor road design drawing
	Collector No. 3	300 mm	110	Cast iron pipeline	In operation	Reinforce in coordination with the motor road design drawing
	General collector	300 mm	150	HDPE plastic	In operation	Reinforce in coordination with the motor road design drawing
	Second section of the Tuul-1 collector	1500 mm	180	HDPE Plastic	In operation	Strengthening in coordination with the motor road working drawings (in areas of high traffic congestion)

There are a total of five locations with cross and longitudinal potable water pipeline networks along the alignment of Package-3. The sewer pipeline network along the motor road route planned in the ger district area is relatively limited. A total of 650 m of pressurized and non-pressurized sewage pipeline networks are located along the route of Package-3.

In coordination with the motor road working design drawings, it is required to obtain additional clarifications from USUG and prepare the strengthening works drawings for the potable water pipeline.

6.3.4. Material and Technological Study

With the continuous emergence of new materials, technologies, and processes, water supply pipeline materials have rapidly developed from the initial few types to over ten distinct types. The representative types of pipes currently used in the water distribution pipeline system are grey cast iron pipes, steel pipes, and malleable iron pipes. In terms of operational performance, the material of grey cast iron pipes is grey pig iron, which has low strength and hardness and cannot withstand high external loads. Furthermore, due to the rigid interface of the pipeline connections, frequent occurrences of pipe breaks and leaks are observed in the water supply network. Examining the international context, industrially developed countries have replaced gray cast iron pipes since the 1960s, generally transitioning to the use of ductile iron pipes. The steel pipe is suitable for assembly and installation, exhibits high strength, and provides advantages such as ease of processing pipes and connectors during operation; however, its disadvantages include low rigidity, deformation, susceptibility to corrosion, stringent requirements for internal lining, protection against external corrosion, and the occasional need for cathodic protection, thereby causing relatively high overall costs. PE pipes have gradually been introduced for urban water supply as a new type of pipe, primarily used for medium and small diameter pipes.

A. Flexible Steel Pipe

Flexible steel pipes, also referred to as flexible ductile iron pipes, are pipe materials that gradually developed in Western industrialized countries during the 1950s. Before casting molten iron, magnesium or a rare earth element magnesium spheroidizer is added to the molten iron, which converts needle-shaped graphite into spheroidal graphite; therefore, it is known as ductile iron. Needle-shaped graphite facilitates the fracture of the iron matrix, making it prone to cracking, whereas spheroidal graphite eliminates this damage and increases hardness. Therefore, from the perspective of the mechanical properties of flexible steel pipe materials, they offer advantages such as high strength, high tensile capacity, and corrosion resistance. Its operational lifespan can reach 30 to 50 years, and the wall thickness of pipes with the same diameter is only half that of gray cast iron pipes.

B.FRP Pipe

The FRP pipe consists of fiberglass reinforced thermostatic resin plastic. This type of pipe first appeared globally in the 1970s. Based on the manufacturing process, it is classified into centrifugal casting and fiberglass winding types. The fiberglass winding method is further subdivided into continuous winding and filament winding. The manufacturing process of the above three pipes is performed during production by mixing with quartz sand to increase structural rigidity, as required. The wall structure of the FRP pipe generally consists of two components.

Structural layer: composed of orthophthalic non-gelled polyester resin or modified orthophthalic non-gelled polyester resin.

Surface strengthening: The inner and outer surfaces of the pipe walls shall consist of alkali-free chopped strand glass fiber mat combined with corrosion-resistant, high-strength resin.

Although FRP pipes may employ different resins and fibers to fulfill structural design requirements under various operational conditions, the associated pipe costs can vary substantially.

FRP pipes are corrosion-resistant, lightweight, easy to transport and install, have a low friction coefficient, and exhibit high conveyance capacity.

Based on actual usage conditions, FRP pipes are primarily employed in wastewater conveyance and water intake projects.

C.Steel Pipe

Steel pipes exhibit excellent mechanical strength, can withstand substantial external loads and high internal pressure, adapt effectively to complex terrain, and are easy to fabricate. However, owing to their properties, they are prone to corrosion and thus require protection of both internal and external surfaces against corrosion; cathodic protection is necessitated when appropriate. Therefore, except in exceptional circumstances such as river crossings, railway and motor road intersections, and highly complex terrain, reinforced culverts are required.

D. Plastic Pipes

At present, Mongolia manufactures the most extensive range of polyvinyl chloride pipes (PVC pipes). The advantages of this type of pipe include ease of fabrication and installation, resistance to scaling, light weight, and a smooth surface; however, most pipes are brittle, not resistant to external pressure or impact, and possess a high coefficient of thermal expansion, which is a drawback. Therefore, PE pipes are primarily used for industrial process piping and internal water supply systems.

In recent years, this sector has advocated the use of polyethylene pipes (PE pipes) known as high molecular weight polyethylene pipes. These pipes possess very high molecular weight, high tensile strength, light weight, abrasion resistance, low temperature tolerance, corrosion resistance, smooth internal surfaces, high elongation at break, and do not require bedding during pipeline installation. The construction is appropriate, and the total cost is slightly lower than that of ductile iron pipes. The service life is significantly longer than that of iron and ductile iron pipes, exceeding 50 years. The assembly and installation are appropriate. Currently, pipes with diameters exceeding DN1000 can be manufactured, exhibiting high durability.

Considering the circumstances, the pipeline for this project shall be polyethylene (PE) piping, and the pipes and fittings must comply with the applicable standards. The pipeline interfaces shall be welded, and the pipes shall be installed on a roadbed prepared with a 20 cm thick sand cushion base. At the shaft, valves and hooks shall be supported by C20 concrete bases, and to prevent damage to the pipes, a rubber gasket shall be installed between the support and the pipe. The foundation and inspection well of the water supply pipeline shall be situated on the natural soil layer with favorable soil quality or on the treated soil layer, with a foundation bearing capacity of no less than 100 KN/m².

(4) Water supply facilities

Chimney valve well: This design employs a reinforced concrete rectangular valve well measuring 1200 x 200 mm.

Valve: For water transmission pipelines with a DN300 diameter, use gate valves; for gate valves of DN200 diameter and below, use valve sleeves; for gate valves with a DN300 diameter, use valve wells; for water transmission pipelines exceeding DN300 diameter, use butterfly valves and butterfly valve wells.

6.3.5. Pipeline Works

(1) Standard for water supply pipeline design

The "Water Supply, External Networks, and Facilities" (BNbD 40-02-16) and the "General Development Plan of Ulaanbaatar City until 2040" stipulate that the nominal diameter of the water transmission pipeline design shall be DN150. Fire hydrants and fire-fighting pipe connections shall be installed at intervals of 150 meters on both sides of the road, with a fire water flow rate of 15 L/s.

(2) Sewer Pipeline Design Standards

The "Sanitation Pipelines, External Networks, and Facilities" (BDB 40-01-14) and the "Ulaanbaatar City Development Master Plan until 2040" specify that no new sewer pipelines shall be constructed for this project; the relocated sewer pipelines are planned within the existing extent.

(3) Design standards for stormwater and snowmelt drainage pipeline systems

The “Working drawings and calculation norms for the drainage of stormwater and snowmelt from urban and settlement territories and roadway areas” (BD 40-302-13) and the "Ulaanbaatar City General Development Plan until 2040" specify that stormwater conveyance pipelines are designed based on a 10-year return period and are equipped with cotton materials.

(4) Standard for design drawings of flood protection structures

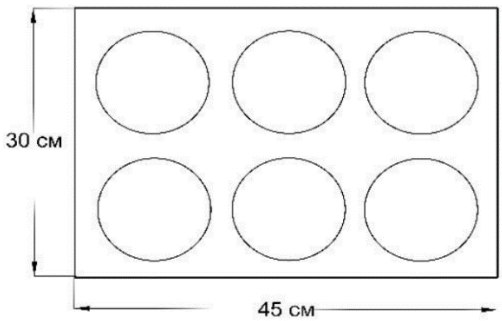
The “Mongolian National Building Codes and Regulations for the Design of Water Structures” (BHbD 33-01-03), “River Hydrotechnical Structures” (BHbD 33-01-05), and the “General Development Plan of Ulaanbaatar City until 2040” provide for flood protection design drawings based on a 100-year flood event.

(5) Standards and Technical Requirements for Road Lighting

The standards for road lighting design drawings comply with the 'General Technical Requirements for Lighting of Motor Roads, Streets, and Squares in Cities, Towns, and Other Settlements,' MNS 6846:2020, Table 1 – Standard for Grade I main road asphalt pavement lighting indicators, in accordance with the design.

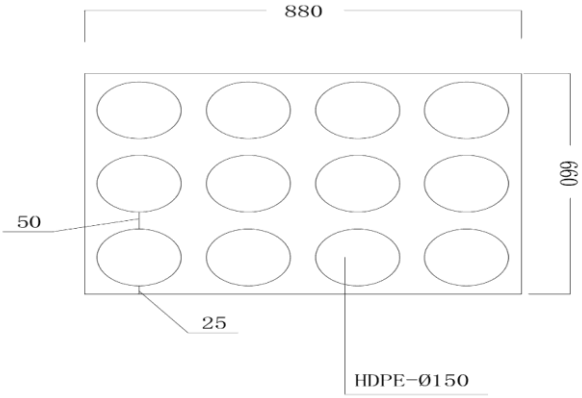
(6) Standard for Telecommunication Pipeline Design

“Electrical Installation Regulations” BD-43-101-03, the “Ulaanbaatar City 2040 Development Master Plan,” and the capacity of the communication and signaling network duct facilities are planned according to the (6+0) configuration, employing 6 units of Φ110mm HDPE pipeline system.



(7) Design drawings and standards for electrical transmission pipelines

Technical specifications and installation requirements for telecommunications manhole and duct facilities” MNS 6668:2017, the “General Development Plan of Ulaanbaatar City until 2040,” and the capacity of communication and signaling network duct facilities are planned according to the (6+0) configuration, utilizing a system of twelve Φ150 mm HDPE pipes.



(8) Heat Transmission Pipeline Standard

“Heat Network” (BNbD 41-05-18), “Heat Network” (BNbD 41-02-13), design and installation of metal and polymer pipes for heating systems (BD 41-101-08), and in accordance with the “General Development Plan of Ulaanbaatar City until 2040”, this project will not install new heat pipelines but will plan the relocated heat pipeline network within the existing scope.

② Selection of Pipe Materials

This model compares and selects pipe materials appropriate for drainage systems. There are four commonly used pipe materials for drainage systems.

The principle for selecting drainage pipes is to consider technological aspects, quality reliability, advancements, and economic efficiency. Therefore, within this engineering technology, considering the geological characteristics of the foundation, reinforced concrete pipes, reinforced concrete pipes with bell and spigot joints, HDPE pipes, and plastic sand-filled pipes reinforced with fiberglass are compared; following a technical and economic evaluation, the pipe that is technically feasible and economically justified is selected.

For small-diameter drainage pipes, reinforced concrete pipes exhibit high energy consumption, limited service life, poor energy efficiency, and inadequate environmental protection capabilities, resulting in a total cost that is not advantageous compared to plastic pipes. They were gradually replaced by plastic pipes. The cost of plastic pipes increases with the increase in diameter. The unit price of plastic pipes is significantly higher than that of reinforced concrete pipes; thus, the overall cost of plastic pipes is considerably less favorable in comparison to reinforced concrete pipes. Therefore, plastic pipes with large diameters do not experience a significant price reduction, despite extensive promotion efforts, and are challenging to use. Small and medium diameter plastic pipes are newly developed in recent years. They are promoted by the Ministry of Construction for their advanced technology, flexibility, resistance to installation damage, economic efficiency, energy savings, and environmental protection capabilities, and are now widely utilized.

Among these, the roughness coefficient of HDPE pipes ranges from only 64% to 71% of that of reinforced concrete pipes; consequently, under the same hydraulic gradient, the permissible flow velocity in an HDPE pipe can be equivalent to that of a reinforced concrete pipe with a nominally larger diameter. In summary, HDPE pipes are widely used in the current construction of sewer pipeline networks. Considering the actual conditions for pipeline installation and related cost efficiency, the sewer pipe designed for this project utilizes HDPE reinforced coil pipe. The quality shall comply with the technical requirements of the applicable standard, and the mechanical properties shall satisfy the requirements of the relevant regulations. For burial depths of ≤6.0 m, the modulus of rigidity strength is 8 KN/m², corresponding to a minimum level of S2; for burial depths exceeding 6.0 m, the modulus of rigidity strength is 12 KN/m². The interface employs a rubber ring socket connection.

Pipeline bedding: When the HDPE spirally reinforced pipe invert is situated in the natural soil layer, it shall be replaced by a 15 cm layer of medium-grained sand cushion. When the pipe invert is located within the newly backfilled soil layer, it shall be replaced by a 25 cm layer of medium-grained sand cushion. The foundation of the transmission pipeline shall be established on the natural soil layer of adequate quality or on the treated soil layer, with a foundation bearing capacity

of not less than 100 KN/㎡.

(4) Sewage Facilities

Inspection Well: For pipes with a maximum diameter of 600 mm, the length and width shall be 1000 x 1000 mm. For pipes with diameters of 700 mm and above, the length shall be diameter plus 400 mm, and the width shall be diameter plus 500 mm. The diameter of the manhole depends on the pipe diameter: for pipes with a diameter of ≤ 600 mm, the manhole diameter is 1000 mm; for pipes with a diameter of 700 mm, it is 1250 mm; for pipes with diameters between 800 and 1000 mm, it is 1500 mm; and for pipes with a diameter of 200 mm, it corresponds to 200 mm. For pipes with diameters not exceeding 150 mm and depths not exceeding 1.2 meters, the manhole diameter is 600 mm. When installing the shaft at a depth exceeding 3 m, the well diameters shall not be less than 1500 mm.

The height of the well working section shall be based on the principle of 1800 mm from the working platform to the road surface. If the height of the well working section is less than 1200 mm, the well width shall be D+300 mm, but not less than 1000 mm. The inspection well channel shall be positioned at the upper level of the pipe with the largest diameter. If the diameter of the well pipe is 700 mm or greater, a working platform shall be installed on one side of the trench, and on the opposite side, a debris-clearing platform with a minimum width of 100 mm is required. If the pipe diameter exceeds 2000 mm, the work section shall be housed within a trench box, and the trench well opening shall measure 2000 x 2000 mm.

A flow channel must be installed at the bottom of the inspection and control manhole.

6.4. Electric power supply and information communication network

6.4.1. Lighting line network

(1) Basis of the design drawing

1) 《Technical General Requirements for the Lighting of Motor Roads, Streets, and Squares in Cities, Towns, and Other Settlements》 MNS 6846 2020

2) 《Design of Street and Road Lighting for Cities, Towns, and Settlements》BD30-102-11

3) 《General Requirements for Lighting Equipment》UCS 1901B

4) 《Technical Manual for the Installation and Construction of Lighting Equipment》 (UCS 1902A:2022 Implementation Document)

5) 《Electrical Facilities Regulation》 BD-43-101-03

Additionally, the brief project information and technical requirements provided by road specialists.

(2) DrawingProject Principles and Objectives

1)Project Principles

①Primarily, safety: compliance with standards for lighting, uniformity, and glare control. Ensuring road traffic safety and reducing the risk of road traffic accidents during night hours; Preventing and suppressing criminal conduct; Protecting buildings, structures, and public property; Enhancing the safety environment of residential complexes; Preventing harmful activities.

②Economic Feasibility: Optimized Total Life Cycle Cost.

③Energy Conservation and Environmental Protection: Implementation of Technologies with Low Energy Consumption and Low Carbon Emissions, Incorporating Advanced Control Technologies.

④Advanced Technology: Compliant with the Requirements of Future Smart Innovations (e.g., Internet of Things Control).

⑤Avoid light pollution: during the design process, emphasize the reduction of light pollution, including glare.

⑥Environmental coordination: street lighting shall adhere to the architectural aesthetic principles as a vital element of urban and residential landscapes, ensuring coherence and harmony with the surrounding environment.

⑦Facilitation of maintenance and major repairs: The design takes into account post-maintenance activities to ensure suitability, safety, and efficiency objectives are met.

2)Objectives of the drawing design

①To establish a scientifically based road lighting technological solution that complies with functional requirements while considering economy and energy efficiency.

②Feasibility assessment for project implementation.

③Propose the optimal implementation plan alongside risk prevention and control strategies.

(3) Summary and scope of the design drawings.

The road classification for this project is Class I for the main carriageway and Class II for pedestrian paths, with a total central road length of 24,793 m, comprising 12,779 m of motor road, 9,034 m of overpasses, 950 m of culverts, 2,030 m of underpasses, and road slopes up to 4%. The road surface shall be asphalt pavement, designed for a speed of 80 km/h, consisting of six lanes with two-way traffic and two cross sections. This road lighting design comprises the lighting model for the road section and the lighting design for the bridge section. The lighting design for the tunnel section is detailed in the tunnel section documentation.

(4) Content of the drawing design

1) Road lighting system;

2) Road lighting electrical distribution system;

3) Road lighting control system;

4) Grounding system.

(5) Design drawings of the road lighting system

1) Lighting standard

The road category of this project is Category I main road, with an asphalt pavement surface. The design standard is 'MNS 6846 2020: General Technical Requirements for Lighting of Motor Roads, Streets, and Squares in Cities, Towns, and Other Settlements.' The project lighting standards are defined as follows.

Table 6. 3. Motor Road Lighting Specifications

Road Classification	Road Rating	Average Luminance, $\bar{L}$ (cd/m²), not less than	Luminance Uniformity		Average Illuminance $\bar{E}$h (lx), not less than	Threshold Increment TI (%), Not less than	Illumination Uniformity, Uh, somewhat
			General uniformity of illumination U0, Not less than	Uniformity according to illumination Ul, somewhat			
Highway	1A	2,0	0,4	0,7	30	10	0,35
	1B	1,5	0,4	0,7	20	10	
Main road	1C	1,0	0,4	0,7	15	15	
	1D	1,0	0,4	0,6	15	15	
Accumulator Road	2A	0,8	0,4	0,6	10	15	
	2B	0,8	0,4	0,5	10	15	
Rural local road	3A	0,6	0,35	0,4	6	15	0,25
	3B	0,4	0,35	0,4	6	15	

NOTE: 1. This requirement applies when the road surface is asphalt. If the road consists of concrete pavement, its average illumination level shall be calculated as reduced by approximately 30%. 2. All numerical values in the table correspond to measurements under dry road conditions. 3. Main roads with significant structures, city centers, commercial streets, the capital's broad avenues, and ring roads shall be provided with first-class lighting. 4. Public areas and road sections with a higher risk of criminal activity shall maintain lighting levels adequate for facial recognition.

Table 6. 4. Illumination requirements for pedestrian walkways

Pedestrian walkway classification	Illumination [$\bar{E}h$], lx, minimum	Illumination uniformity Uniformity ratio [Uh], not less than
Tender Document-1	20	0.3
Tender Document-2	10	0.3

Tender Document-3	6	0.2
Tender Document-4	4	0.2
Tender Document-5	2	0.1
Tender Document-6	1	0.1

The lighting level $\overline{Eh}$ of the road and street pedestrian surfaces shall be not less than 50% of the lighting level of the adjacent roadway. The lighting uniformity ratio Uh on pedestrian surfaces shall be not less than 0.3.
The ratio of illumination between the carriageway surface and the roadside (SR) shall not be less than 0.5.
Note: This parameter may be exempted for rural motor roads.

2) Selection of lighting and light sources

①Lighting
The lighting fixture must be airtight, suitable for outdoor use, with an IP65 ingress protection rating, and the electrical cavity protection level of the lamp shall be no less than IP53. The lighting protection classification is Class I, which shall comply with the nationally mandatory product certification requirements. The lighting is corrosion-resistant, with a contemporary design, smooth lines, an attractive appearance, and a lightweight yet durable structure, providing efficient light distribution and glare reduction capabilities. Various types of electrical circuits corresponding to the selected luminaires are installed at each lighting fixture. The lighting production process shall comply with the relevant standards.
②Light source
At present, the light sources commonly employed for road lighting are high-pressure sodium lamps and LED lamps. Two types of lamps are used to varying degrees for road lighting, with LED lamps being increasingly adopted in recent years.

In conjunction with the specific conditions of this project, this model employs highly efficient LED lamps as the light source. The luminous efficacy of the LED street lamp shall be no less than 130 lm/W, the surface temperature of the light source shall not exceed 100℃, the color temperature shall range from 3000K to 5000K, and the light distribution curve shall be allocated according to the butterfly light intensity pattern. Each branch circuit of the LED street lighting shall be equipped with a protective circuit breaker; specifically, the phase conductor of each lamp must be protected by a circuit breaker, which shall be installed on the incoming supply line side of the LED lamp.

3) Lighting Pole

The lighting pole has dimensions of Φ50×133×219, with a wall thickness of ≥3.5 mm; its structure consists of a conical flange shaft, and the base measures 150×80×60. The materials for the light pole may be chosen from aged iron (painting not required), hot-dip galvanized iron (in accordance with ISO 1461 standard), hot-dip galvanized iron (in accordance with BS EN ISO 1461 international standard), or plain iron (which must be coated with corrosion protection as per the standard). If plain iron is used, it shall be sprayed with a corrosion-protective agent. Mixing different colors is prohibited. This project utilizes light gray, RAL 7035, RGB 197, 199, 196.

4) Road lighting organization plan

In accordance with the standard two-road cross-section, all elements such as surface illumination, lighting, and uniformity comply with the requirements of the 《General Technical Requirements for Lighting of Motor Roads, Streets, and Squares in Cities, Towns, and Other Settlements》 MNS 6846:2020 standard. Refer to the DIAlux simulation results diagram for the exact value.

Based on the modeling outcomes and the street lighting planning scheme, the following summary is provided.

①Section 1 of the Road (60m Wide Road Lighting Cross-Section): Street lighting planning scheme specifies a single-pole, two-bracket, 10m long structure installed at the center of the central median strip of the highway, with the pole center positioned 1.75m from the road curb. The light source comprises a 100W+100W LED lamp with a 15° tilt angle, a 1.5 m arm length, an installation height of 10 m for the light source, and an approximate installation spacing of 30 m.

Street lighting consists of single and double poles symmetrically placed on both sides of the structure's enclosure along the auxiliary road, non-motorized lane, and pedestrian path, with the pole centers located 0.75 m from the road curb and poles measuring 8 m in length. The light source comprises a 65W+20W LED lamp with a 10° inclined angle, a 1.5 m arm length, a mounting height of 8 m for the light source, and an installation spacing of 30 m.

②Section 2 of the road (road lighting cross-section with a width of 45 m): Street lighting design: the vehicular lane on the overpass is protected by a collision barrier (the base and bridge section are cast monolithically). Single-pole streetlights, each 10 m in length, are symmetrically installed on both sides at the location. The light source is as specified. The lamp arm is 1.5 m long, the mounting height of the light source is 10 m, and the installation spacing is 30 m. Along the auxiliary road on site, the non-vehicular lane, and the pedestrian walkway, street lighting with single 8 m poles was installed symmetrically on both sides of the roadside strip. The center of each lamp post is positioned 0.5 m from the railing. The luminaire’s light source is a 70 W LED lamp, with a mounting height angle of 15 degrees, a luminaire length of 15.8 m, and an installation spacing of 4 m.

③Typical scheme for installing crossbars on the sloped road: the sloped section utilizes lighting installed at a low position, symmetrically placed on both sides of the 1.2-meter-high collision protection barriers. The light source of the lantern is a 5W LED lamp, with a lamp height angle of 0°.

④Enhancement of intersection lighting: Install 15-meter-high pole lights at the intersections of this road and the main roads, utilizing 3×300 W LED lamps as the light sources; Install 13-meter-high pole lights at other grade-separated intersections, utilizing 2×300 W LED lamps as the light sources.

(6) Electric power supply and distribution system for illumination

The lighting electrical load for this project has been calculated as a three-tier load. Voltage drops shall be considered due to long-distance electrical transmission, low temperatures of low-voltage supply cables, sensitivity verification of fire protection devices, efficiency of the power supply and distribution system, and reserve electrical loads (landscape lighting, traffic control devices, bus stops, toll collection points, etc.). Taking into account reliability, investment, and other factors, the maximum radius for the electric supply in this project is 650 meters; that is, an 80 kVA box-type substation is installed every 1,300 meters, with a total of 18 box-type substations along the entire line.

The box transformer is installed outside the pedestrian walkway or at the road intersection, ensuring that it does not interfere with road traffic. The incoming voltage of the high-voltage line is 10 kV; the 10 kV power supply is sourced from the nearest city’s electrical distribution network. The box-type substation comprises the incoming high-voltage line and distribution equipment, transformer, low-voltage distribution devices, lighting controller, and electricity meter. The load capacity of the box transformer is 5 kW for landscape lighting within the power supply network, 5 kW for traffic control, 5 kW for the toll station, and 5 kW for festivities at bus stops. The transformer load factor is approximately 70%.

①The protection level of the outdoor box-type substation shall not be lower than IP54.
②Reactive power compensation: The power factor of LED lamps shall be no less than 0.85.
③Electric energy meters: Active and reactive power meters shall be installed on the main incoming low-voltage feeders of the box-type substation to separately measure the electricity consumption of landscape lighting, traffic control, toll booths, bus stops, and similar facilities.

2)Installation of electrical supply conduits for lighting

①Method for selecting and laying cables

Taking into account street lighting load, long-distance power transmission, voltage drop, and low-temperature effects, the main electrical supply for road lighting uses YJV-0.6/1kV-5x25mm² and YJV-0.6/1kV-5x16mm² cables installed within PVCSC10 protective cable conduits.

②The cable shall be buried at a depth of no less than 1.2 meters below ground level in pedestrian pathways and isolation strips, and at no less than 1.2 meters within the carriageway, protected by SC100 hot-dip galvanized steel conduit.

③The cable shall be protected by SC100 hot-dip galvanized steel conduit at street intersections, junctions, and transformer entry and exit points, and the steel conduit shall be provided with corrosion protection.

④The branch line from the main power supply to the upper lamp uses BVV- (3×2.5) insulated cables. To balance the three-phase load, the lamp connection sequence shall follow the wiring order of the three-phase wires: L1, L2, L3.

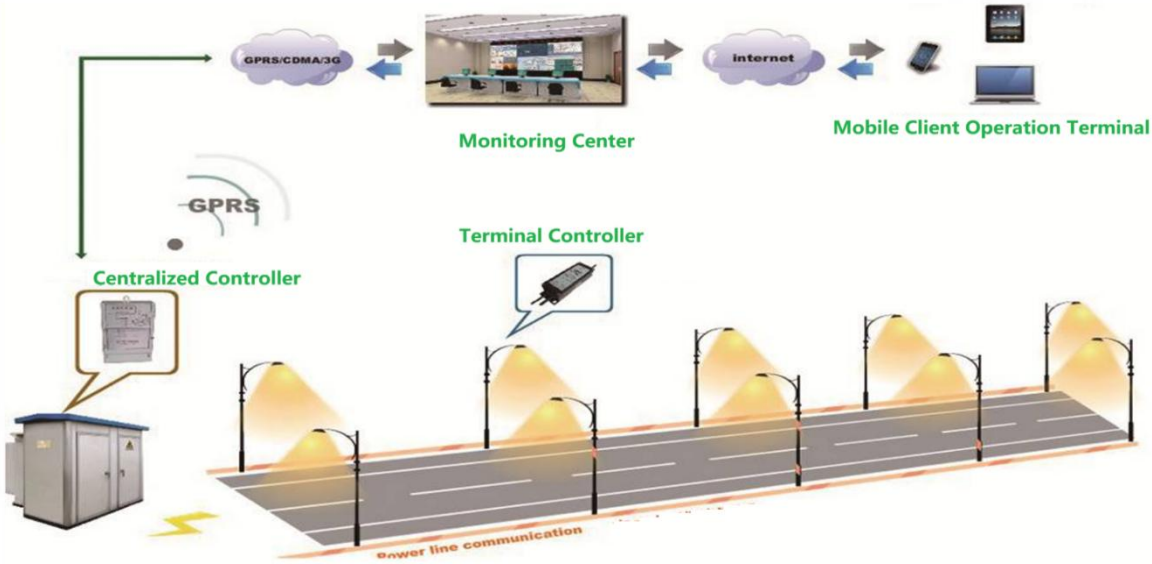
⑤The connection of the street lighting fixtures has been carried out inside the anti-theft gate designed to protect the street lighting system, and an additional 0.5 meters of cable must be left at each anti-theft gate.

(7) Lighting Control System

Urban road lighting constitutes a vital component of the city’s public infrastructure. The increase in the number of urban road lighting fixtures has resulted in higher energy consumption, while the energy supply remains limited. Furthermore, maintenance activities and the high costs associated with urban lighting (including manual management and street lighting inspections) have presented challenges to urban management. Scientific management of urban lighting and green energy conservation necessitates more efficient oversight and energy-saving solutions within the management departments.

At present, street lighting management utilizes both traditional manual and automatic control methods. The automatic control system employs a timer and a light control switch. This control method lacks flexibility and cannot acquire the real-time status of each streetlight. Moreover, it is unable to individually monitor each streetlight under actual conditions, adjust the illumination levels accordingly, or effectively achieve energy savings. This method of urban lighting control and management is relatively simple and broad in scope, exhibiting low service quality and limited energy savings, and is no longer capable of meeting the requirements of modern urban lighting.

The street lighting in this project incorporates PLC (Power Line Communication) technology to implement intelligent control of individual luminaires. The control system comprises the main computer control software, centralized controller, and terminal controllers (single-light controller, dual-light controller), among others. The centralized controller is installed in the low-voltage distribution cabinet of the power supply transformer, while the terminal controller is installed at the lighting terminal. Refer to the detailed system structure diagram in the drawing below.



Drawing 6. 6. Schematic diagram of the electrical conductor street lighting control system.

The centralized controller connects to the control center via wireless communication networks including GPRS, CDMA, WCDMA, and 4G; and connects to the terminal controller via Power Line Communication (PLC). The centralized control system manages each terminal controller by receiving, executing, and transmitting commands from the upper-level computer control software, controlling the switches and illumination of each streetlight, implementing intelligent streetlight control and advanced management, thereby maximizing energy savings. The network control terminal controller monitors the operational status of the luminaires and is capable of

implementing fault alarm functions. Furthermore, the system may incorporate additional functions, such as road environment monitoring and alarm assistance, to conform to functional requirements. The control of the street lighting circuit switch is based on an intelligent control terminal installed in the low-voltage distribution room of the box transformer, operating under main control mode, photoelectric control, and manual standby.

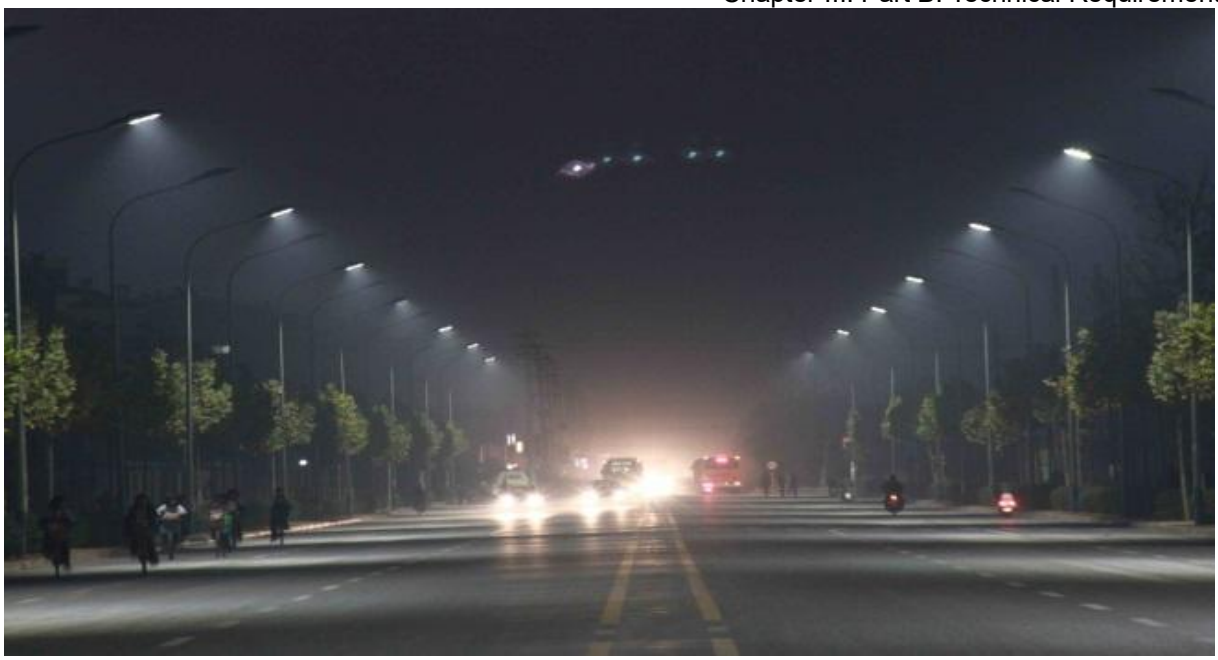
The intelligent control terminal is capable of automatic operation after configuring the latitude, longitude, and date of the respective region. The control output supported by the database can automatically manage the switching on and off of street lighting according to the daily sunrise and sunset times and the configured advance or delay settings. The street lamp is equipped with a driver power supply, which is connected to a single lamp controller via the driver power supply. It utilizes a PWM signal to regulate the output of the driver power supply, thereby enabling remote switching and dimming control.

The centralized controller of the entire street lighting system is integrated into the cloud monitoring center management (including the street lighting control server, computer, mobile devices, etc.) under unified management; where conditions permit, control workstations may be established within the street lighting control department. The street lighting control center and the intelligent control terminal employ wireless communication methods such as GPRS, CDMA, or 4G, while the intelligent control terminal and the managed streetlights may utilize electric transmission line connections. Installation of communication control lines is not required; the street lighting system can be intelligently controlled through an APP and system authorization installed on the control center’s or management personnel’s mobile device.

The lighting control terminal employs Digital Signal Processing (DSP) technology to sample alternating current, thereby collecting, calculating, processing, storing, and displaying data such as current, voltage, active power, and power factor on-site; it fully performs data transmission and lighting facility control in accordance with instructions from the control center. In the event of errors, theft, or data exceeding prescribed limits, active alarms are triggered to ensure the safe and reliable operation of the road lighting system. In case of communication failure, the lighting system can operate automatically according to the preset time limits for switching on and off. The principal functions are as follows.

1) Automatic and manual remote control function

This system categorizes all control terminals into several groups in accordance with different road lighting control requirements and can manage sectors and individual lights through time control or a combination of time control and light control. It is also possible to manually open and close branches, switch a single light or a group of lights on and off, dim them, and perform other operations. The control center, in addition to automatically conducting scheduled inspections according to a predetermined time cycle, can manually query and select the voltage, current, power, status of branch circuit breakers, individual light brightness, and switch status of the control terminal at any time. To conserve energy, when the peak traffic flow decreases to one-fifth, the street lighting intensity shall be reduced by 30%. When the peak traffic flow decreases to one-third, the street lighting intensity shall be reduced by 50%. Street lighting shall be intermittently switched off during nighttime to maintain uniformity.



Drawing 6. 76 Result drawings for each lamp controller

2) If the control terminal issues an active alarm signal or the control center detects abnormal data during inspection, the control center shall automatically emit an audible alarm, store the data automatically, display the corresponding location and type of fault on the map, and be capable of transmitting information to the mobile phones of the relevant personnel.

3) Equipment Theft Alarm

In the event of unauthorized operation and theft of the surveillance terminal equipment, the control center computer shall immediately emit an audible alarm, automatically record and display the corresponding location on the map along with the equipment type, and transmit the information to the mobile phones of the relevant personnel.

Alarm content: active during daytime and inactive at night; lamp failure; stabilizer malfunction; controller failure; distribution box door open; voltage and current exceedance; terminal power outage; line fault; cable theft; personal injury.

4) Moreover, the control system automatically calculates the lighting rate, allows for query and report printing, and permits remote real-time querying and monitoring.

(8) Grounding system

1) This project employs the TN-S grounding system, requiring the neutral point of the distribution transformer to be directly grounded.

2) The main grounding conductor (PE conductor) integrated into the street lighting system must be re-grounded repeatedly. The re-grounding device shall be fabricated from hot-dip galvanized angle steel L50×50×5, 2.5 m in length; its upper end is buried at a depth of 1.1 meters and welded to hot-dip galvanized flat steel measuring 40×4 mm. It shall be welded to no fewer than two main bars beneath the street lighting foundation and to the pole mounting bolts. The grounding resistance shall not exceed 4 ohms. If the measured grounding resistance exceeds 10 ohms, the installation of an additional artificial grounding electrode is required.

3) The box-type substation shall be grounded using a circular grounding system. The grounding device comprises a hot-dip galvanized angle iron grounding electrode L50×5 with a length of 2.5 m; the upper end is buried at a depth of 1.1 meters. The horizontal spacing is 5 m. The grounding electrode is connected to a hot-dip galvanized flat iron 40×4, with a measured grounding resistance of less than 4 ohms.

(9) Energy Saving

In planning the technical equipment of the road lighting system, full consideration is given to the requirements for energy management and operational optimization to develop an energy-efficient design and establish favorable conditions for controlling the energy-saving system. The lighting power distribution and control system utilizes a combination of centralized and decentralized management. The centralized controller can automatically dim the user program according to pre-

configured settings or the real-time dimming strategy of the control center. To achieve management and energy-saving objectives, the street lighting across the entire urban area has been integrated into the unified control system of the street lighting control center. The following technical measures are primarily employed in the lighting design to optimize energy conservation.
1) Choose highly efficient, energy-saving, and durable LED light sources and associated accessories. The total luminous efficacy of the luminaire shall be greater than 130 lm/W, with an efficiency not less than 70%.
2) After maintenance and restoration, the power factor of each LED light source unit shall be no less than 0.9.
3) The choice of design standard must be scientific, well-founded, adapted to local actual conditions, and comply with the national norms and standards of road design to achieve an energy-efficient design.
4) To reduce initial capital investment, minimize line losses, and decrease operational and management costs, the cable cross-section shall be optimally selected.
5) By selecting a highly efficient and energy-saving distribution transformer, transformer process losses and load losses are significantly reduced, effectively addressing issues related to outdated technology and the high losses of aging transformers.
6) To scientifically manage street lighting and conserve green energy, select an advanced and cost-effective smart lighting system.

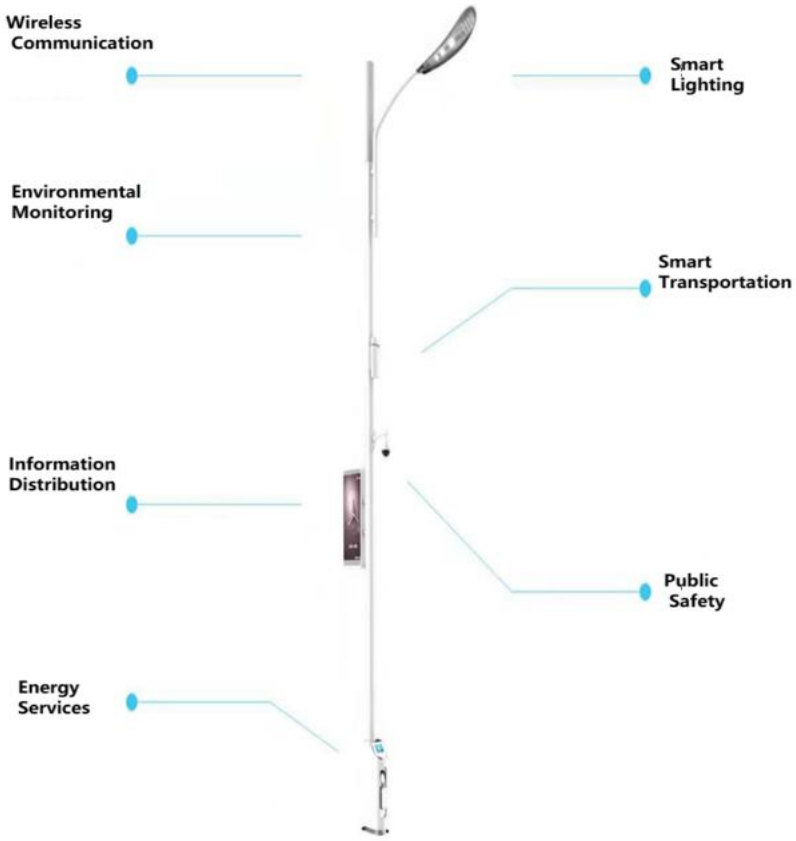
(10) Application of new technologies in smart street lighting

1) Smart street lighting

Smart street lighting represents the most effective input and service interface for smart cities. Urban areas contain numerous streetlights, representing the densest infrastructure and facilitating data collection and dissemination. Smart street lighting will serve as a crucial source for Internet of Things data collection in the future. Urban smart street lighting is a fundamental component of a smart city, capable of improving the capacities of urban and municipal services. These constitute a key solution for smart cities and have the potential to support smart city governance and the implementation of smart city initiatives in the urban lighting sector.

The smart street lighting collects information about the city through integrated sensors, generating all types of big data necessary for future smart cities. The data is hosted on the cloud, constituting big data. These data interact with the government’s internal road traffic system, police management system, financial management system, and procurement management system, thereby providing diverse informational support for big data applications in smart cities. Upon analysis and processing, it is feasible to display news on the electronic screens of street traffic lights to provide services to citizens.

The intelligent streetlight system relies on LED street lighting and a smart management platform, integrating data from WIFI base stations, cameras, infrared sensors, radar, electronic display screens, charging piles, and other electronics, serving as an information conduit for implementing data monitoring, environmental monitoring, vehicle monitoring, security monitoring, pole displays, underground pipeline monitoring, urban hazard surveillance, urban hazard alarms, and urban emergency alarms.



Drawing 6. 86 Smart Street Lighting Circuit Drawing

2) Current Issues

In revisiting the primary functions of street lighting, it is necessary to consider road illumination and smart lighting capabilities—that is, through intelligent control to collect and manage various data, adjust lighting, and save energy—thereby ensuring traffic safety and the proper operation of road lighting, and subsequently to consider various functional carriers beyond street lighting.

① Issue of configuring the function

Charging mounds shall not be installed on roads with severe urban congestion, and no streetlight pole shall be equipped with functions such as traffic control, pollutant monitoring, air quality surveillance, weather observation, medical assistance, or other related functions. Each function must be adapted in accordance with its characteristics, application environment, scope, and other actual conditions, and subsequently modified to suit the conditions of the respective locality. We must not blindly promote large, complex functions that are flashy yet possess little practical value.

② Interdepartmental coordination issues: At present, the city lighting management is overseen by a dedicated management organization with explicit managerial responsibility. However, the multifunctional roles of light poles span multiple sectors, including public safety, transportation, communications, and medical services, involving the interests of various departments as well as their daily operations, maintenance, and managerial obligations. Operators encounter difficulties in reaching consensus on business communications and coordination among the related departments. A comprehensive solution is required.

③ Further maintenance issues: As the street lighting work is unique, the maintenance team is only capable of performing standard street lighting maintenance and lacks experience in the maintenance and management of the new smart street lamps. Additionally, street lighting serves as an ancillary facility for the road and requires daily maintenance. Smart street lamps incorporate multiple functions and span several professional disciplines, which complicates the rapid response of maintenance teams in the event of unexpected failures, thereby creating a significant safety hazard. These issues have significantly increased the daily management and maintenance difficulties of street lighting. At a later stage, a dedicated intelligent team for street lighting maintenance is required, or, to reduce costs, maintenance duties are delegated to a specialized

unit or a third-party company responsible for integrated maintenance services.
3)Proposals
Due to the substantial investment, complexity of functions, involvement of multiple departments, and subsequent challenges in maintaining the smart street lighting, it is recommended that implementation be carried out in phases.
Firstly, to establish a smart lighting system based on the primary lighting (this project has been developed);
Secondly, this project includes reserved load capacity and permits the future integration of wireless WiFi and video surveillance systems without the need to remove the light poles.
Finally, once conditions are fully developed, it will be possible to comprehensively upgrade the smart street lighting functions.

(11) Others

All electrical equipment shall employ the most advanced products presently available in Mongolia, and products explicitly prohibited by the state shall not be used. All products shall be capable of operating within ambient temperatures of -40℃ to 60℃ and shall possess certification for climatic adaptability.

6.4.2. Design drawing of the electrical transmission pipeline

(1) Basis of the design drawing

1) 《Electrical Installations Regulation》 BD-43-101-03
2) 《Ulaanbaatar City General Plan to 2040》

Additionally, the brief project information and technical requirements provided by road specialists.

(2) Principles and Objectives of the Design Drawing

1)Project Principles
①Primary Safety Principle
The national standard 《Electrical Installations Regulation》 BD-43-101-03 and all applicable safety standards shall be complied with concerning safety measures, including line insulation, lightning protection, and grounding. Avoid flammable and explosive hazard zones by maintaining a safe distance from gas, heating, and other pipelines; use materials resistant to pressure and corrosion, and proactively prevent risks such as short circuits and leakage.
②Principle of reliability in electrical power supply
Optimize cable capacity and the number of circuits in conjunction with regional load forecasts to ensure long-term energy demand is met. Reserve the interface of critical node connections to enhance the switching capacity for fault incidents. Coordinate with the city power network planning to ensure efficient connections between substations and distribution stations.
③Principle of Intensification and Standardization
To mitigate the direct burial impact on road structures, the method of pipe installation is preferred. Thereafter, to facilitate maintenance, the technical specifications of the pipes, the dimensions of manhole chambers, and the marking system are consolidated. Optimize the utilization of the road cross-sectional space and appropriately arrange water supply, drainage conduits, communication lines, and other pipelines.
④Principles of environmental regulation: Avoid crossing ecologically sensitive areas and minimize damages to green spaces and groundwater caused by construction.
2)Objective of the drawing
①To establish a safe and flexible electrical power supply network
Ensure high reliability of the power supply, reduce fault repair response times, and guarantee stable electricity consumption for residents and industrial facilities.
②To support the efficient integration of urban infrastructure
To reduce the overlapping excavation works of power transmission pipelines and main road projects, and to improve overall execution, these are developed and constructed concurrently.
③To support the sustainable development of the city
Surplus capacity is reserved to accommodate future load growth requirements and to ensure regional development and the availability of new energy along the main pipelines.

④Green and low-carbon implementation

The utilization of environmentally friendly pipe materials significantly reduces carbon emissions throughout the entire lifecycle compared to conventional designs.

(3) Project design summary and scope

The motor road classification for this project comprises a primary structure of Grade I and pedestrian paths of Grade II, with a total central road length of 24,793 m, including 12,779 m of motor road, 9,034 m of overpasses, 950 m of transmission pipes, 2,030 m of underpasses, and road gradients of 3-4%. The road surface shall be asphalt pavement, designed for a speed of 80 km/h, consisting of six lanes with two-way traffic and two cross sections. This power transmission duct design comprises road sections, bridge sections, and tunnel sections.

(4) Content of the drawing design

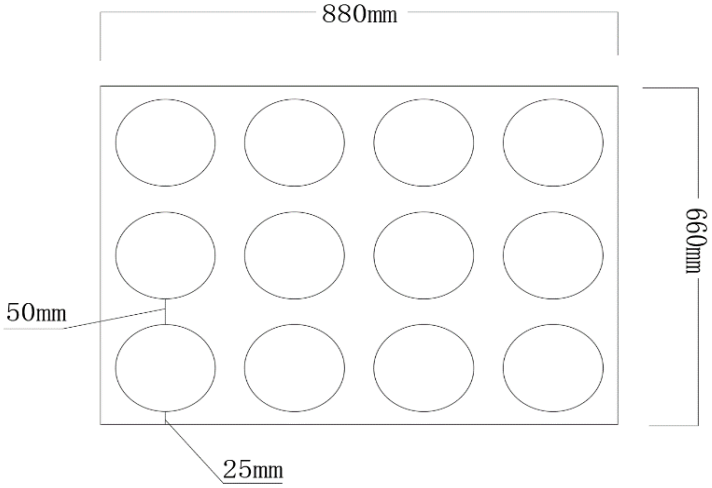
1) Power transmission duct;

2) High strength.

(5) Power Transmission Duct Design

1) Number of power transmission ducts

In accordance with the "General Plan of Ulaanbaatar City until 2040" and the "Electrical Installations Regulations" BD-43-101-03, the capacity of the energy network duct facility is arranged with 12 shafts, that is, a 4x3 configuration of twelve Ø150 mm ducts, utilized in the preliminary routing of the power transmission line. 0.4 kV electrical cables for all lines and certain adjacent consumers.



Drawing 6. 9. Drawing of electrical conduit

2) Analysis of electrical conduit materials

In conclusion, PVC pipes demonstrate poor temperature adaptability, low resistance to cold temperatures, limited pressure capacity, and a tendency to deteriorate and leak due to adhesive or slip-type joints. HDPE pipes are suitable for use at temperatures ranging from -50 °C to 60 °C, resistant to high pressure, do not drip during heat fusion, have greater durability than PVC pipes, and offer a comparable total cost to PVC pipes. Considering factors such as the minimum winter temperature of -40 °C in Ulaanbaatar City, the use of HDPE pipes (high-density polyethylene pipes) for energy transmission pipelines is recommended for this project.

The flexural rigidity of the HDPE pipe shall be ≥10.5 kN/m² (road load), and the remaining performance parameters must be selected from pipes approved by the relevant technical authorities of Mongolia, suitable for use in energy protection. Hot melt joints shall be used for pipe connections, with the spacing between pipe bedding set at 2.0 meters along pedestrian walkways and 1.5 meters when crossing streets, to ensure compliance with pressure and pressure resistance requirements. The pipe cushion is supplied by the manufacturer.

3)Installation of electrical transmission conduit

This project comprises three components: motor roads, bridges, and tunnels.

①Electrical transmission conduit in the motor road section and overpass section

In accordance with the planning and pipeline integration, a 60-meter-wide motor road section and a 45-meter-wide motor road (overpass) section are designed with an electrical network containing

12 ducts installed along the pedestrian pathway on the left (front) side of the designated section. The upper section of the pipeline is covered with soil at a minimum thickness of 1.0m, and the power transmission pipeline consists of HDPE high-density polyethylene pipe with an internal diameter of Ø150 mm and a wall thickness of 10 mm.
The pipeline installation layout employs a 3x4 configuration. For detailed information on the lifting method, please refer to the 'Detailed Cross-Section Drawing of Power Transmission Pipeline Installation' drawing and the bending technique of the main power transmission pipeline route (Type A).
A.Electric power transmission duct crossing the road transversely
For transverse crossing of the road, 12 units of Ø150 HDPE duct pipes, C20 concrete, Ø10 steel reinforcement bars, and a soil cover of at least 1.0 m are used to provide full protection. For detailed information regarding the lifting method, refer to the "Electric Power Transmission Duct Crossing Drawing"; the primary method for burying the concrete cover of the transverse duct pipe is the embedding method (Type B).
B.Electrical power horizontal street crossing pipe
There are two types of electrical power crossing pipes.
One type utilizes 12xØ150 HDPE pipes, C20 concrete, Ø10 reinforcing bars, complete protection, and a soil cover of no less than 1.0 m. Installed at intersections, with one section every 1000 m within urban areas and one section every 2000 m internally.
For detailed information regarding the lifting method, refer to the "Cross-sectional drawing for electrical power conduit installation" and the buried method (Type B) for electrical communication line conduits.
The alternative type employs 6xØ110 HDPE pipes, C20 concrete, Ø10 reinforcing bars, full protection, and a soil cover of at least 1.0 m. One unit has been installed every 250 m along the entire road. For detailed information regarding the lifting method, refer to the "Detailed Drawing of Electrical Conduit Cross-Section Installation" and the street cross-section for the method of burying line conduits (C-shaped).
For detailed information on the exact location of the aforementioned electrical transmission conduits, refer to the drawing titled "Typical Scheme of Electrical Communication Line Conduits."
②Installation of an electric transmission pipeline in the transmission pipeline section
This project comprises two transmission pipelines along the railway and includes a service road; a river crossing with a single transmission pipeline, lacking a service road and pedestrian pathway, with insufficient space for installing an electric transmission pipeline. To cross the railway on the auxiliary road at the site, the use of pipe jacking is expensive, challenging to construct, and unsuitable for subsequent maintenance. The electrical transmission pipeline shall be installed beneath the flange of the box girder using an angular steel clamp. The angle iron guard is suspended at a distance of 1 m, and the electrical conduit employs a Ø150 hot-dip galvanized iron pipe. If the union line pipe is longer than 80 m, it shall be segmented by 1 m to facilitate subsequent connection. The fire-resistant sealing is performed upon disconnection of the conduit.
③Installation of electrical transmission conduit in the tunnel section
As the fire line pipes are installed in the duct outside the tunnel, the communication line pipes are placed within the cable duct inside the right tunnel (front side), fitted with an openable cover. The transmission conduit consists of 12×Ø150 HDPE pipes, fastened with pipe clamps spaced at 2 m intervals. When the length of the power transmission pipeline exceeds 80 m, it shall be separated by 1 m to facilitate subsequent connections. The fire-resistant plug shall be installed when disconnecting the transmission pipeline.
④For cables operating at 10 kV and below, the bending radius of a 3-core cable shall be no less than 15 times the cable’s outer diameter. Subsequently, to facilitate the easy pulling of cables, a cable-pulling wire (iron) shall be retained in each conduit.
⑤The specified clearance between the electrical transmission conduit and other adjacent pipelines shall comply with the requirements stipulated in clauses 2.3.35 to 2.3.45 of the "BD-43-101-03 Electrical Installations Regulations." When relocating pipelines that fail to meet clearance requirements, priority shall be given to adopting the method for coordinating the installation of communication pipelines. Refer to the specific methods outlined in the 'Method for Coordinating the Intersection of Communication Pipelines and Other Conduits.'

⑥The longitudinal slope of the electric transmission pipeline planned on this occasion essentially corresponds with the slope along the road. The longitudinal drainage slope of the electrical transmission pipeline shall be no less than 0.2%, and the longitudinal drainage slope of the branch pipeline between power streets shall also be no less than 0.2%.
(6) Design of Electrical Manholes
1) Power manholes shall be configured according to project specifications as straight, three-way, four-way, well-type, or similar forms. Manholes of the TBUH-3 type with 12 boreholes and a depth of 100 cm to 120 cm, suitable for the installation of the transmission pipeline system, shall be utilized. Considering frictional forces, straight sections shall have power manholes installed at intervals of 80 meters; corner power manholes shall be constructed at rotation angles exceeding 45°. For rotation angles less than 45°, manholes with appropriate angles may be used, but the spacing between working manholes must be increased. Three-way power manholes shall be installed on horizontal branch pipelines intersecting streets transversely, while four-way manholes shall be installed at intersections.
2) The drainage slope adjacent to the electrical well shall not be less than 0.5%, with a water collection pit measuring 0.5 m x 0.5 m x 0.5 m. When rainwater accumulates in the water collection pit, it shall be manually pumped out using a water pump.
3) The materials for the electrical well shall comply with the specified load and environmental requirements.
(7) Grounding
1) Along the electrical transmission pipeline, install two pieces of galvanized flat steel sized 40x4 as the main body of the horizontal grounding, and place vertical grounding rods (φ50, L=2500 mm angle iron) every 100 meters, welding them to the horizontal grounding main body.
2) The grounding device of the electrical well creates a common main grounding body by welding the natural grounding electrode and the artificial grounding electrode using the main reinforcement within the well. The grounding resistance shall not exceed 10 Ohms. After completion of the electrical well, the grounding resistance shall be measured. If the requirement is not met, weld hot-dip galvanized pipes sized 50×5 at both ends of the installed cable fastening sections, bury the top part at a depth of 0.8 meters, and ensure compliance. Simultaneously, install galvanized flat steel sized 40x4 around the well wall on the upper installed sections of the fastening reinforcing bars, perform equipotential bonding for exposed electrical conductive metal parts such as the cable support column, ladder, U-shaped tension rings, thereby ensuring the grounding resistance does not exceed 10 Ohms.

6.4.3. Planning of Information and Communication Network Lines

6.2.3.1 General Section, Rationale

Within the scope of the Feasibility Study Project for New Ring Road-1, the planning for relocation and reinforcement calculations of information and communication network ducts, cable line networks, and structures situated transversely and longitudinally along the motor road alignment was developed based on the following documents. These include:
1. Technical Specifications and Installation Requirements for Communication Well and Conduit Facilities, MNS 6668:2017
2. Technical Requirements for Plastic Pipes for Communication Network Conduits, MNS 5017:2023
3. Ulaanbaatar City General Plan up to 2040
4. Proposal Submitted by Information and Communication Network LLC in Official Letter No. 03/602 dated 9 June 2025

6.2.3.2 Principles and Objectives of the Design Drawings
1) Principles of the Design Drawings
①Standardization and Compliance Principles
The relevant Mongolian standards shall be strictly enforced, adhering to the requirements for general urban motor road planning and the special planning for underground utility lines. At the working drawing stage, the alignment and depth design of communication utility lines must be planned in accordance with standards, ensuring appropriate spatial separation or intersection

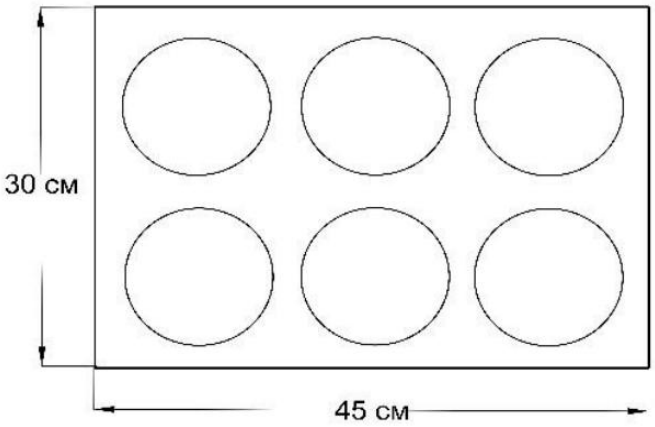
clearance with existing and planned other infrastructure utility lines.
② Principle of Extendability
The next-generation 5G network, following mobile communications, is predicated on the concept that it will serve as the fundamental infrastructure for advanced technologies such as the Internet of Things (IoT), autonomous vehicles, and remote-control devices; accordingly, an additional 20% to 30% of conduit hole capacity is reserved to meet future demands, including 5G base stations, IoT devices, and smart light poles. The modular design was approved to facilitate subsequent extensions and upgrades, as well as to adapt to technological advancements in fiber-optic networks (FTTx).
③ Principle of general regulation
Concurrent with the new ring road project, design and construction works shall be conducted to coordinate the spatial planning of electrical power, water supply, drainage, gas, and other pipeline networks, thereby avoiding conflicts and reducing secondary excavation costs.
④Principle of Economy and Electrification
Select high-cost pipes based on comparison, selection, safety, and operational viability.
⑤Principle of Safety and Reliability
Verify that the requirements for environmental impact, motor road load, pressure, and weather resistance are satisfied, and ensure the adequacy of drainage system protection and supports. Steel pipes, and even concrete, are utilized to seal and reinforce the main joints. For the pipeline interface, verify the absence of water infiltration and compliance with other requirements.

6.3.2.3 Drawing Design Objective

Requirements
To establish modern communication infrastructure, including the development of a communication network spanning the entire road segment, thereby enabling service provision to users along the road, and through the implementation of smart city networks such as surveillance cameras and RFID, facilitate the advancement of the digital economy.
Efficient utilization of the city's resources
By integrating the general planning of Ulaanbaatar City's communications, the partial master plan for construction along the routes, and motor road and infrastructure repair works under the strategy of 'Unified Planning, One-time Construction,' overlapping activities such as motor road excavation and cutting are minimized, thereby saving time and costs.
p. To meet the service demands that ensure the livelihood of the citizens
Within the framework of the ring road project, the establishment of a telecommunications network enables users in the ger district to access high-speed fiber optic cable services, facilitates the construction of new residential complexes, and, with increased service coverage, reduces the digital divide.
(3) Project design summary and scope
The motor road of this project is classified as Class I, and the pedestrian path as Class II, with a total length of the main drainage system of 24,793 meters, including a road length of 12,779 meters, overpasses totaling 9,034 meters, culverts totaling 950 meters, and tunnels totaling 2,030 meters. The road surface shall be asphalt pavement, designed for a speed of 80 km/h, consisting of two carriageways with six lanes in total. The telecommunication duct infrastructure comprises three sections: the road section, the bridge section, and the tunnel section.

6.4.4. Capacity of the duct infratructure

The capacity of the information communication duct infrastructure is planned as (6+0), consisting of six Φ110 mm pipes, based on MNS 6668:2017 Technical Specifications and Installation Requirements for Communication Wells and Duct Infrastructure Standard and the General Plan of Ulaanbaatar City until 2040.



Drawing 6. 10. Schematic drawing of communication line piping

6.2.4.1 Analysis and comparison of communication duct materials

The technical requirements for plastic pipes used in communication network ducting are specified in the MNS 5017:2023 standard, which mandates that plastic pipes for communication network ducting shall be manufactured from either polyvinyl chloride (PVC) or high-density polyethylene (HDPE); however, PVC pipes are predominantly utilized.

Table 6. 5. Comparative table of PVC and HDPE pipes

No.	Indicator		PVC pipe	HDPE pipe
1	Material properties		Hardness: Rigid and prone to fracture. Ultraviolet resistance: Suitable for outdoor use after addition of stabilizers, although prolonged exposure may cause degradation. Chemical resistance: Resistant to weak acids and alkalis, but sensitive to certain solvents.	Flexibility: Flexible, not prone to fracture. Impact Resistance: Durable at low temperatures and resistant to brittle fracture. Corrosion Resistance: Resistant to acids, alkalis, and organic solvents; suitable for chemical environments.
2	Physical Properties	Temperature Adaptability	From 0 °C to 45 °C (high temperature softens material, low temperature induces brittleness)	From -50 °C to 60 °C (resistant to short-term high temperatures up to 80 °C)
		Pressure resistance	Medium (PN6–PN16)	Medium (PN6–PN16)
3	Installation and maintenance	Connection method	Adhesive compression (simple, but may leak due to aging)	Heat fusion connection (leak-proof, requires specialized equipment)
		Ease of Assembly	Easy	Requires Welding Technique
4	Service Life and Environmental Protection	Lifespan	20–40 years (exposure to ultraviolet radiation or chemicals may reduce lifespan)	50–100 years (subject to ground movement, soil settlement, etc.)
		Environmental protection	Contains chlorine; combustion may generate dioxins, rendering restoration more complex.	Recyclable, with low industrial pollution

5	Cost Comparison	Material cost	PVC is generally inferior to HDPE
		Total cost	HDPE is durable and requires minimal maintenance, making it potentially more cost-effective

In summary, PVC pipes exhibit poor temperature adaptability, limited resistance to low temperatures, low pressure capacity, are inexpensive, easy to install, and suitable for low-pressure systems. HDPE pipes are suitable for use within the temperature range of -50°C to 60°C, are more appropriate for high-pressure and severe conditions, do not leak at hot melt joints, exhibit a longer service life compared to PVC pipes, and incur higher costs relative to PVC pipes.

The ring stiffness of HDPE pipes is ≥10.5 kN/m², making them suitable for road loading conditions. Hot melt joints shall be used for pipe connections, with the spacing between pipe bedding set at 2.0 meters along pedestrian walkways and 1.5 meters when crossing streets, to ensure compliance with pressure and pressure resistance requirements. The pipe cushion is supplied by the manufacturer.

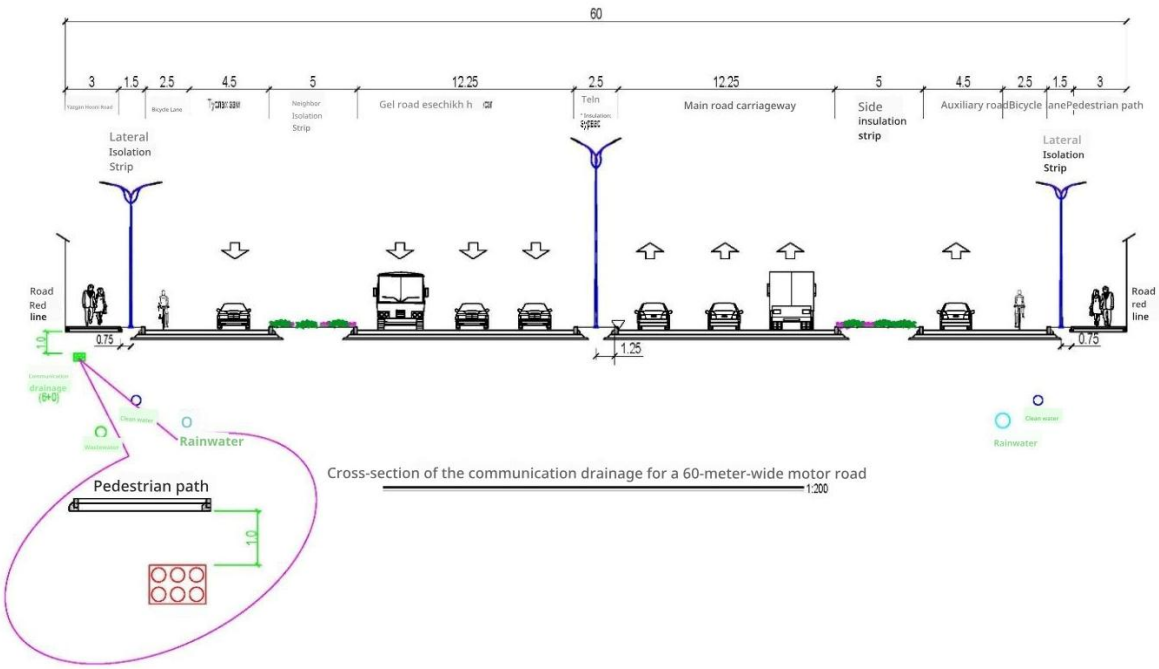
The communication ducting planned along the ring road consists of three types: beneath pedestrian walkways, within tunnel sections, and alongside bridge structures. Considering that air temperatures in Ulaanbaatar City can reach as low as -40°C during the winter season, it is recommended to use HDPE pipes (high-density polyethylene pipes) for the communication ducting.

6.2.4.2 Installation of Communication Line Conduits

The communication ducting system for this project comprises three sections: beneath the pedestrian walkway, tunnel segments, and bridge structures.

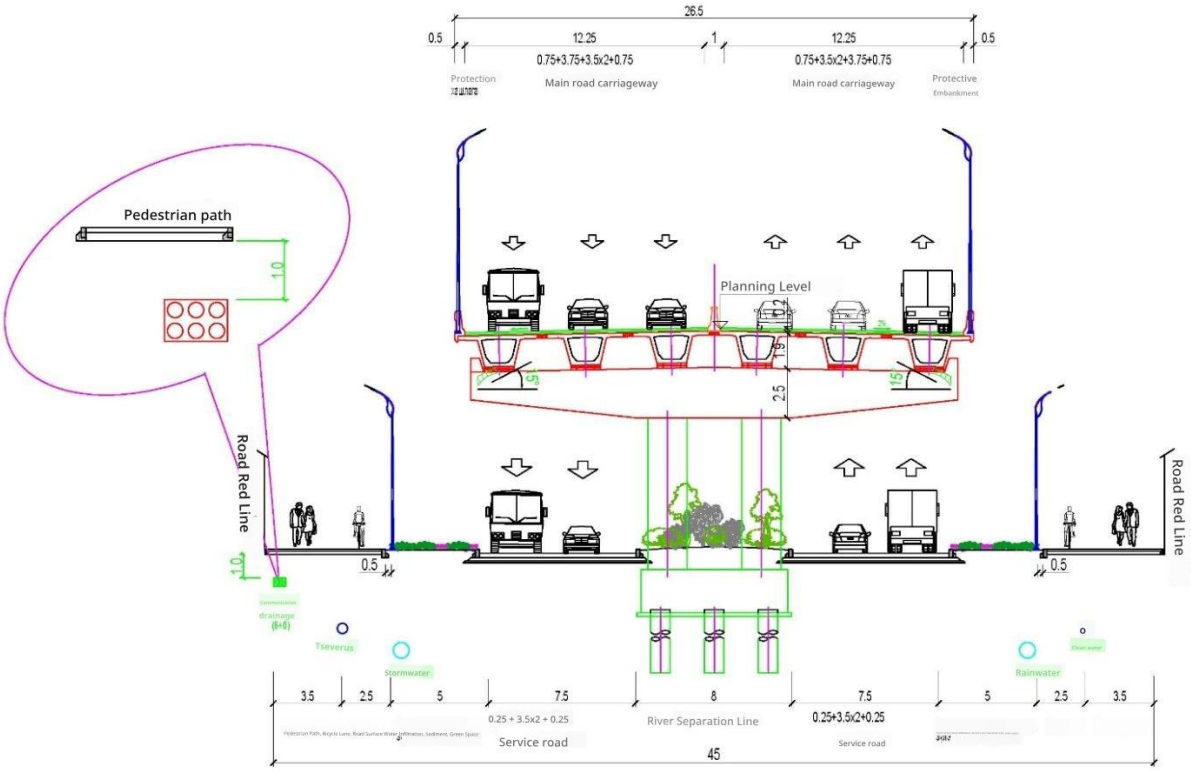
For the planned 60-meter-wide motor road section, a communication ducting system with a (6+0) capacity under the pedestrian walkway is designed. Furthermore, crossings along and across the motor road, as well as intersections, shall be planned at intervals of 500 meters within the urban motor road section and 1000 meters within the ger district area.

Drawing 1. Cross-section of a 60-meter-wide road



For the section of the multi-level motor road, an underpass structure with (6+0) capacity communication conduit is planned beneath the pedestrian walkway adjacent to the lower motor road. It is required to plan motor road crossings every 500 meters within the urban area and every 1000 meters in the ger district, including three types: along the motor road, transverse crossings, and at intersections.

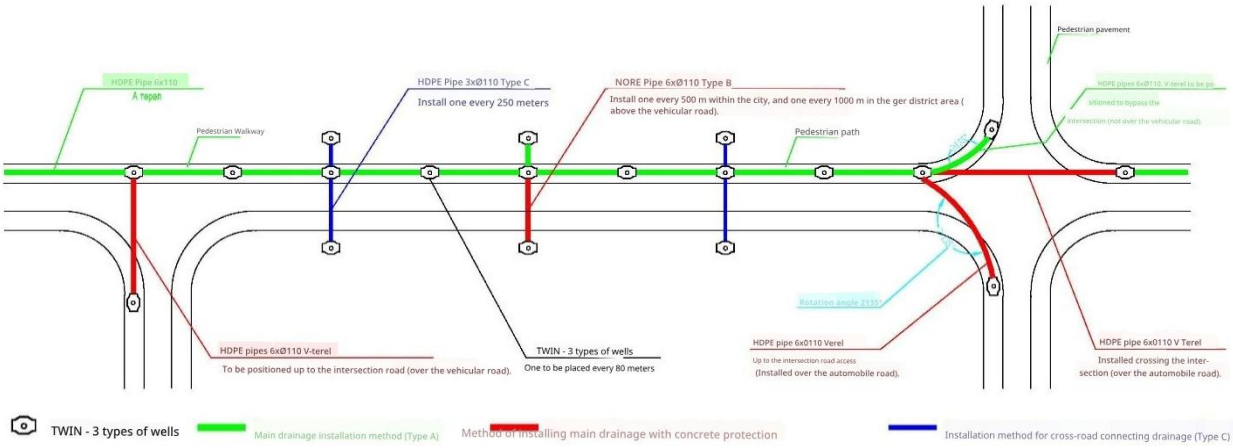
Drawing 2 Cross-Section of the Multilevel Road



A 2 km-long tunnel system is planned within the section of the new ring motor road. Given the commencement of sales of autonomous vehicles in the Mongolian market and the growing demand for such vehicles, it is necessary to design an autonomous driving network within the tunnel section.

Since there are no norms or standards of this kind in Mongolia, it is essential to adapt international standards and regulations to Mongolia’s conditions and to have the corresponding documentation approved.

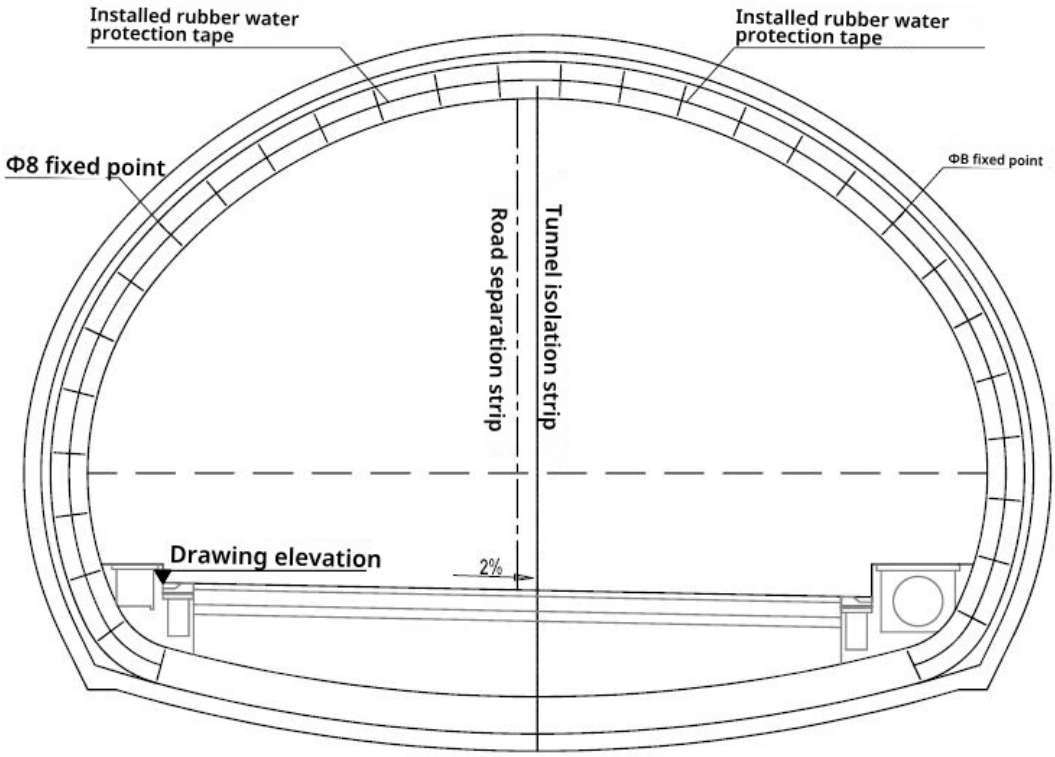
The federal drainage system is designed in three types: along the motor road, at crossings, and at intersection accesses. For urban motor roads, cross drainage is planned every 500 meters, and in ger districts, every 1000 meters.



Since GPS and other types of positioning system signals do not operate inside tunnels, alternative technologies are required. In environments where positioning systems are inoperative, systems such as LiDAR or 3D mapping, radar, and cameras are employed. The next-generation 5G mobile network constitutes the fundamental infrastructure for advanced technologies such as the Internet of Things (IoT), autonomous vehicles, and remotely operated devices. In our country, 5G network trial stations commenced operation in 2022, and currently, Unitel Group's 5G network is available in the capital city. Therefore, the use of 5G network within the tunnel system

constitutes a technologically and economically suitable solution.

Drawing 3. Tunnel Cross-Section



In the tunnel section, a duct located beneath the pedestrian walkway adjacent to the carriageway shall be constructed and designed to feature covered access points every 120 meters for cable installation.

6.5. Road lighting, protection and relocation of cables within the motor road alignment,

6.5.1. Lighting

1. **Safety:** comply with standards including lighting, uniformity, and glare control. Ensure road traffic safety and reduce the risk of road traffic accidents during nighttime hours.
2. **Energy saving and environmental protection:** implementation of technologies with low energy consumption and low carbon emissions, employing advanced control systems.
3. **Advanced technology:** compliant with future smart modernization requirements (e.g., control via the Internet of Things).
4. **Avoid light pollution:** Attention shall be given to reducing light pollution, such as glare, during the design process.
5. **Environmental regulation:** Street lighting shall comply with architectural aesthetic principles as an essential element of the urban and residential landscape, ensuring harmony and integration with the surrounding environment.
6. **Ease of maintenance and major repairs:** The design shall ensure ease of maintenance works to achieve objectives of suitability, safety, and efficiency.
7. **Implement the optimal plan:** Propose a strategy for risk prevention and control.
8. Road lighting system
9. Road lighting electrical distribution system
10. Road lighting control system
11. Earthing system

6.5.2. Electrical power transmission network

Fully oordinated and connected with the National Electricity Transmission Grid LLC and Ulaanbaatar Electricity Distribution Network LLC, the overhead high-voltage lines along the road have been comprehensively identified. This includes high-voltage poles and overhead lines with voltage levels of 220 kV, 110 kV, 35 kV, 10 kV, and 6 kV. The number and detailed information of these lines are specified in the annexes of the official letters from National Power Transmission Network LLC and Ulaanbaatar Power Distribution Network LLC.

The relocation of high-voltage overhead lines within this project includes poles and lines at 110kV, 35kV, 10kV, and 6kV voltage levels, while 220kV lines and poles are excluded from the scope of the relocation.

A preliminary relocation option has been determined, and the budget for the estimated costs has been established. In coordination with the National Electricity Transmission Grid LLC and Ulaanbaatar Electricity Distribution Network LLC, the following four types of transfer options have been approved:

(1) Relocation of high-voltage steel towers

This applies when a high-voltage overhead line support pole (steel pole) is located within the road boundary, including steel poles of 110kV, 35kV, 10kV, and 6kV voltage levels.

The overhead high-voltage line that does not comply with the applicable technical requirements is relocated to a different location to ensure safety clearance.

The advantages and disadvantages of its design, construction, and economics are as follows.

Advantages: By optimizing the road alignment, it is possible to avoid the road expansion zone; when replanning the tower locations, to combine land parcels and thereby enhance transmission efficiency; The technology is fully developed, and the construction schedule is comparatively controlled. The cost of relocating a single tower is low, rendering it suitable for local adjustments.

Drawback: The line alignment requires replanning, which may entail issues such as land acquisition and coordination with other urban infrastructure; the design drawing is highly complex. The demolition of the old tower and the construction of a new tower, as well as the temporary interruption of electrical power or the erection of temporary support structures during the construction works, significantly impact the traffic on adjacent roads and the local residents; If associated with large-scale relocation, the total cost may be comparable to the cost of the new line.

Figure 2. Relocation of High Voltage Tower

(2) Elevation of High Voltage Overhead Line

This applies when an overhead line is installed above a newly constructed bridge and the required clearance height is not maintained; this includes high voltage steel poles with voltage ratings of 110 kV, 35 kV, 10 kV, and 6 kV.

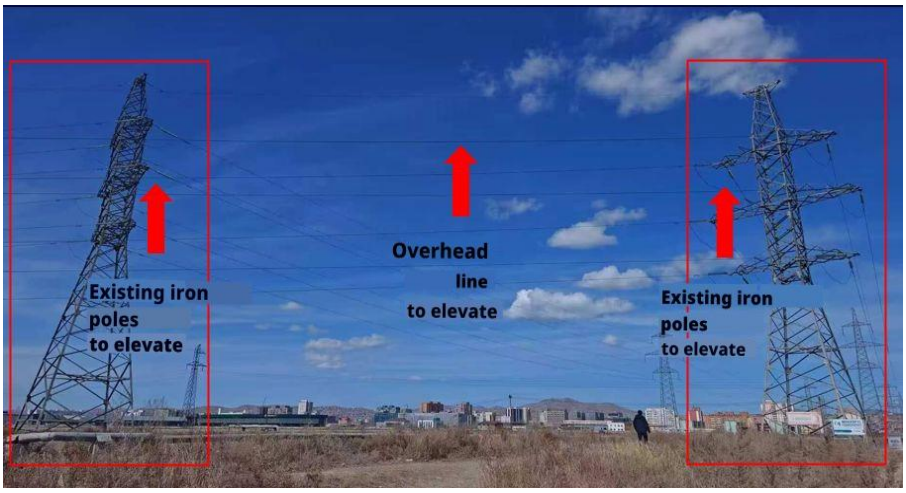
The vertical clearance from the high-voltage overhead line to the motor road must comply with the relevant technical conditions. For high-voltage overhead lines, high-voltage steel poles elevate the line to maintain the required safety clearance.

The advantages and disadvantages of its design, construction, and economics are as follows.

Advantage: Reduction of the occupied area by increasing the height of the steel tower or adjusting the conductor sag; No requirement to alter the line route, thereby minimizing the construction scope; Modification costs are lower than those associated with relocation or underground solutions.

Weaknesses: The mechanical specifications of the conductor require reassessment, and substitution with more durable materials is necessary, thereby increasing the complexity of the design; High mountain operations involve significant risks, require support from specialized equipment, and may be influenced by weather conditions; Long-term continuous settlement adjustments may be required, resulting in increased operation and maintenance costs.

Figure 3. Erection of high-voltage overhead power lines.



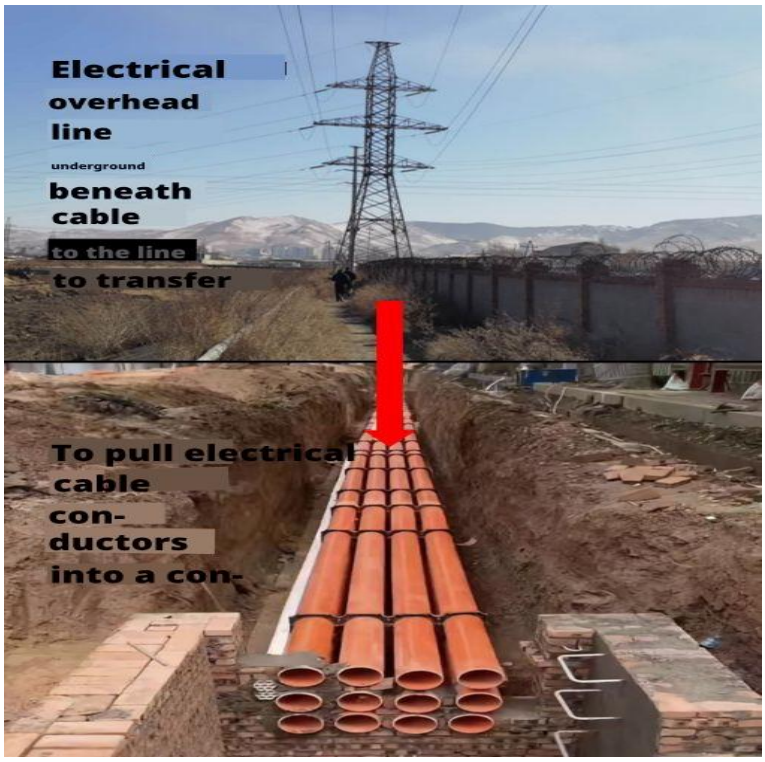
(3) Construction of new towers paired with adjacent overhead lines.

Applicable where securing sufficient space is not feasible due to geographical location constraints;

this includes high-voltage steel poles of 110 kV, 35 kV, 10 kV, and 6 kV voltage levels.
The overhead high-voltage line that does not comply with the applicable technical road clearance requirements shall be connected to the adjacent overhead line to ensure safety clearance.
The advantages and disadvantages of its design, construction, and economics are as follows.
Advantages: Reducing spatial congestion, minimizing the number of poles and towers, optimizing urban spatial planning, alleviating spatial load after road realignment, ensuring integrated planning of the line route, and preventing conflicts with new roads, underground utilities, and other structures. to shorten the construction and installation period, complete the laying of new lines in a single operation, avoid repeated earthworks, reduce electrical interruptions, and prevent multiple disruptions to road traffic caused by phased construction; to centralize resource utilization, consolidate construction machinery and equipment (such as heavy cable-laying devices, cranes, etc.), thereby reducing unit engineering costs; Initial investment savings, reduction in quantities of materials such as poles, foundations, and grounding devices, reduction of land acquisition and leasing costs, optimization of long-term operation and maintenance expenses, a 50% reduction in inspection routes, improved efficiency in error detection and repair, and the implementation of unified maintenance standards collectively enable the reduction of personnel training and management costs.
Disadvantage: The surplus reduces the risk. A single line fault may cause simultaneous power outages in the sections covered by the two primary lines. An automatic sectional switch or a redundant power supply must be additionally configured. The construction window is limited. A prolonged power outage is required to replace the line, which may impact the reliability of electricity supply to the Employer's consumers. Coordination of the multi-departmental electric power supply plan is required. The technical connection is complex. The removal of old lines may cause accidental damage due to deterioration. Preliminary detection and reinforcement of corrosion must be undertaken. Loss of reasonable costs. The advantage of the original dual-line reserve capacity has been lost. Future expansion requires identifying alternative routes to enhance long-term investments.
(4) Relocation of high-voltage overhead power lines underground.
This applies in cases where the road width is restricted and the required pavement height is not achieved, and covers only high-voltage overhead power lines with voltage levels of 10kV and 6kV. High-voltage overhead power lines with inadequate clearance from the road and in the vertical direction shall be relocated underground at their respective locations in the form of electrical tunnels to satisfy the relevant regulatory requirements. The advantages and disadvantages of the conceptual design, construction works, and economic aspects are as follows:

Advantages:
The capacity to accommodate multiple electrical cables simultaneously, enabling pre-planning for future expansion;
The capability to satisfy long-term requirements with a single construction, thereby eliminating the need for repeated excavation;
Long-term economic efficiency is maximized.
Disadvantages:
Strict quality requirements are imposed on the construction work; inadequate performance may lead to latent risks.
Maintenance, fault diagnosis, and resolution during operation are relatively complex.

Figure 4. Planning of high-voltage overhead lines underground



6.5.3. Costs for information and communication planning (communication ducting, cable relocation, new construction, CCTV installation, equipment, software)

a) Communication ducting and cable relocation
b) Communication ducting and cable (new camera)
c) CCTV installation
d) Equipment
e) Software
f) Plan the alignment of the new ring road-1 to minimize crossings with existing utility networks as much as possible
g) During the planning stage, when transferring the heating supply network into the tunnel system, the water supply, electrical supply, and telecommunications network cables shall be transferred simultaneously into the tunnel system.
h) The alignment of the motor road planning intersects with Peace Avenue, where major sanitation sewage collectors are located; it is necessary to consider this and ensure the safety of the pipeline networks.
i) At the electrical supply planning stage, the existing safety of the Power Distribution Network (PDN) shall be given the highest priority, and the road alignment must be coordinated accordingly; furthermore, cable wiring must be planned in accordance with regulatory standards.
j) When relocating the 0.4 and 10 kW cable lines of the Power Transmission and Distribution Network (PTDN), cable blocks were designed in compliance with the supplier organization's requirements.
k) The transmission of the specified line network shall be considered to be situated within the green belt and red line along the planned motor road.

l) When reinforcing, relocating, or transmitting information and communication cable ducting facilities, proposals shall consider the capacity of existing ducting as well as the feasibility of planning new ducting.

m) At the next stage of this project, it is necessary to coordinate the working drawings of the motor road with additional clarifications from the relevant supply organizations regarding the relocation and reinforcement of heating supply, water supply, sanitation, electrical supply, and communication cables, and to develop the corresponding working drawings.

6.6. Landscape and green space planning

6.6.1. Green landscaping works

(1) Specifications or green landscaping

1) Green strip separating vehicle lanes

Trees may be planted if the width is ≥1.5 meters. If the width is less than 1.5 meters, shrubs or soil-covered plants may be used.

When planting trees, the trunk must be situated at a minimum distance of 0.75 meters from the barrier.

2) Roadside Trees

The spacing between roadside trees along the main road shall be 5 to 8 meters, with trunk diameters ≥ 8 cm and planting sizes ≥ 1.5 meters.

The size of the tree pit shall be at least 1.5 m x 1.5 m, or a continuous tree strip with a width of at least 1.2 m shall be used.

(2) Technical Specifications for Tree Planting

1) Tree Planting Requirements

Table 6. 6. Requirements for the distance between green spaces and buildings, roads, and public utilities

No.	Building, road, and public utilities	Building, road, and engineering networks	
		Coniferous and deciduous trees, distance to trunk and trunk axis (m)	Shrubs and fungi towards the riverbank (m)
1	From the exterior side of the building	5.0	2.0
2	From the edge of pedestrian walkways and park roads	1.0	0.7
3	From the roadside	1.5	0.6
4	From the street edge and curb	2.0	1.0
5	From the inner edge of the wall or foundation	1.5	0.6
6	From the center of the tower and slab column	2.0	1.0
7	At a distance of 2 meters or more from the fence	4.0	1.0
8	From overhead and underground electrical lines a. From the heat transfer pipeline b. From the potable and wastewater pipelines c. From the electric power transmission cables year From the trolleybus and lighting pole foundations	3.0 3.0 2.5 5.0	3.0 3.0 2.5 2.0

9	Planting of trees and vegetation: a. Distance between plants b. Distance between rows c. Distance between loosely planted rows	 3.0-4.0 3.0-4.0 2.5-4.0	 0.7-1.5 1.0-1.5 1.0-1.5

requirement

2) Soil requirement
Planting soil depth: tree ≥ 1.2 meters, shrub ≥ 0.8 meters, plant ≥ 0.3 meters;
The soil pH shall range from 6.5 to 7.5, with a salt content not exceeding 0.3%.

(3) Greening of the unit length

When vehicles travel at varying speeds, the visual appearance of the landscape on both sides of the road will differ. Controlling the frequency of alterations in the plant landscape units ensures the stability of the driver's line of sight and facilitates the greening of the landscape road area. If the length of the green area and the driving speed are coordinated as presented in the table, the vegetation within the road green zone can exert a positive influence from a landscape perspective.

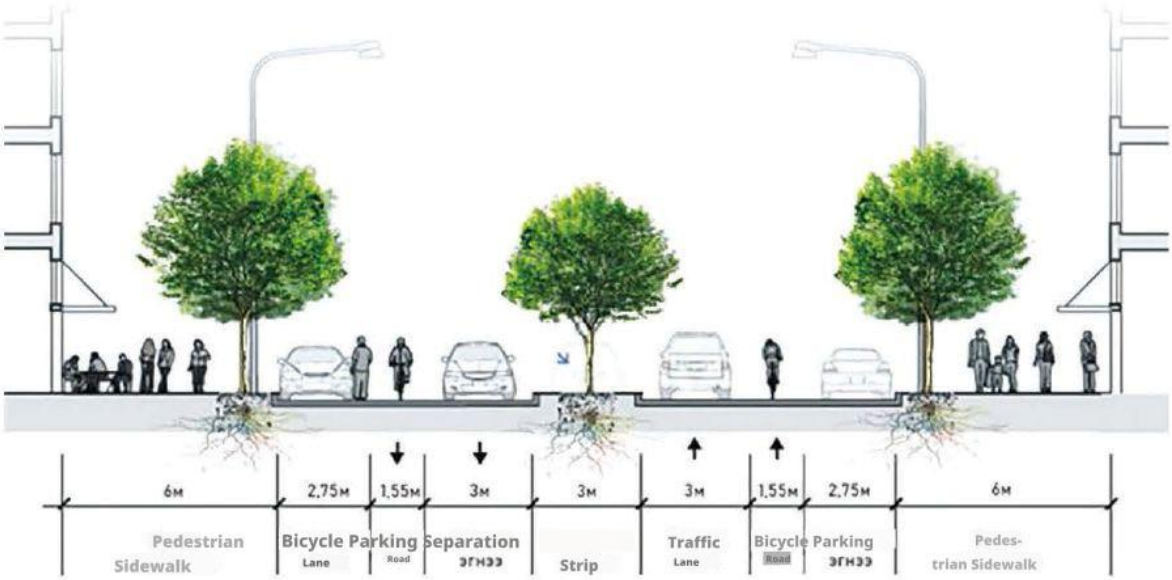
Table 6. 7. Relationship between the length of the greening unit and the driving speed

Speed v (km/h)	v ≤ 40	40 < v ≤ 60	60 < v ≤ 80
Green unit length L (m)	20 < L ≤ 50	50 < L ≤ 80	80 L ≤ 110

6.6.2. Selection of trees and grasses for road landscaping

It is recommended to select trees and grasses for road landscaping that are adaptable to environmental conditions, resistant to various adverse effects, provide a stable greening effect, exhibit ornamental qualities, and are environmentally friendly.

(1) Key factors to consider in roadside landscaping:



Drawing 6. 11. Design drawings for landscaping along highways (example drawing)

1) The severity of the natural environment. For example: iron rust, poor soil, bricks, gravel, and other construction debris.
2) Wastewater and chemical substances. For example: saline wastewater, motor oil, gasoline, etc.;
3) Effects of climatic seasons. For example: dry winds during summer, cold winters, strong local winds, and protective measures associated with construction;
4) Air pollution factors. Such as ozone, sulfides, dust, and particulates that inhibit normal plant growth;
5) Infrastructure and human involvement. Construction covers, risks of road traffic accidents, pedestrian activities causing damage to vegetation, etc.

(2) Principles for tree selection

1) Stress resistance requirements. Select deciduous trees suitable for cold and snowy conditions, road intersections, and green spaces along main city roads;
2) Consideration of ecological functions. Deciduous trees must possess the capacity to obstruct sunlight, regulate surface temperature, purify the air, and attenuate noise;
3) Restriction on evergreen trees. Evergreen trees grow slowly, have low crowns, provide minimal shading during summer, and obstruct sunlight in winter, adversely affecting traffic safety.

(3) When selecting green spaces for pedestrian pathways, the following factors shall be taken into account.

1) Root system and wind resistance requirements. To prevent tree fall caused by shallow root systems that may endanger pedestrian safety, select tree species with deep roots, thick major trunks, large crowns, and strong anchorage resistance.
2) Resistance to strong winds and heavy rainfall. Prioritise tree species with deep root systems to withstand strong winds and heavy rainfall;
3) Avoid damage to the road surface foundation. Select tree species whose roots neither protrude nor damage pedestrian pavement or underground utilities;
4) Crown and shading requirements. Tree species with large crowns, dense branches, and foliage can reduce temperatures of roads and pedestrian pathways during the summer season; however, excessive obstruction of road signs and markings must be avoided.
5) Enhancement of ecological functions. Tree species with large crowns, dense branches, and foliage provide environmental benefits such as dust suppression, noise reduction, and wind protection.
6) Adaptability requirements. Select tree species suitable for narrow pedestrian paths and poor soil conditions that are infertile and iron-deficient, resistant to intense light and extreme temperatures, and whose branches and leaves do not easily fall.
7) Ornamental design. Prioritize tree species bearing attractive flowers and fruits to enhance the street’s aesthetic appeal and attract pedestrian attention.
8) Environmental friendliness. Avoid selecting trees that emit strong odors, produce allergenic pollen, or contaminate pedestrian clothing;
9) Safety and maintenance requirements. Regular tree pruning shall be carried out to ensure the visibility of road signs, maintain safe clearance distances, guarantee pedestrian safety, and preserve natural scenic beauty;
10) Comprehensive Selection Criteria

The following ten requirements must be met for trees and herbaceous plants.
Phenological characteristics: early spring leaves, dark green foliage in summer, attractive leaves in autumn, pruning-resistant;
Form of healthy trees: straight main trunk, evenly distributed branches, full crown;
Ornamental value: attractive leaves, flowers, fruits, and berries.
Morphological characteristics: main trunk height ≥1.8 meters, branch angle >30°, moderate density of branches and leaves.
Transplantation adaptability: ease of transplantation, high survival rate.
Durability: resistant to urban pollution, iron deficiency, and adaptable to extreme climates;
Disaster resistance: deep root system, capable of withstanding wind and snow pressure, with branches and leaves that are difficult to break;
Low maintenance: highly resistant to diseases and pests, resulting in minimal repair and maintenance costs;
Longevity: long-term service life.

(4) Criteria for selecting turf grasses

Select turf grasses characterized by a short growth cycle, rapid coverage, and ease of maintenance. The specific requirements are as follows.
1) To prevent any impact on pedestrian and vehicular traffic, avoid selecting plants with strong odors;

2) Resistant to cutting, with strong regenerative capabilities;
3) Able to withstand high surface temperatures, dust, and road spray, exhibiting resistance to adverse conditions;
4) Displaying stable phenological traits, with ornamental flowers and fruits of value;
5) Giving preference to low-growing herbaceous plants;
6) Select shrubs with multiple branches, resistant to pruning, tolerant to shade, and resistant to diseases and pests;
7) Small, dense leaves;
8) Small, dense flowers;
9) Small fruits with high yield;
10) High survival rate after transplantation and appropriate characteristics;
11) Strong coverage force with uniform expansion.

(5) Selection criteria for ground cover plants.
Morphological requirements: low, creeping growth habit; dense branching; foliage.
Growth characteristics: rapid expansion rate, establishing a stable coverage area within a short timeframe (5–10 years).
Resistance to adversity: infertile conditions, iron deficiency, pests, diseases, trampling resistance, and maintenance of ornamental value throughout the year;
Safety: non-toxic, non-irritating odor; flowers, fruits, and leaves shall not pollute the surrounding environment.

(6) Selection criteria for turf vegetation
Scope: coverage of creeping growth, low, dense, uniform, and visually attractive surfaces;
Leaf characteristics: thin, flexible, and long growth duration;
Adaptability: corrosion resistant, high temperature resistant, and can be trimmed;
Stress resistance: well-developed root system, resistant to foot traffic, with strong regenerative capacity;
Safety: non-thorny, non-toxic, non-allergenic, and harmless to humans and animals.

6.6.3. Selection of woody plants for green space design elements

(1) Selection plant composition according to the landscape function.
The following elements are predominantly used in green space design: solitary trees, groups of trees, street trees, dense forests, plant hedges, and ornamental boundary trees. Specifically:
Single tree/isolated shrub: a tree or shrub planted individually in lawn or open space to define an independent form;
Group of trees: a partial planting comprising two or more plants of the same or different species within the green area;
Street tree: a tree planted in a single row along both sides of the road or adjacent to the building;
Dense forest: a forest belt formed by planting hundreds of identical and diverse tree species over a large area (such as a park);
Plant hedge: low-density shrubbery used to protect flower beds from trampling or to separate internal sections of a garden;
Planted at the edge of flower borders: plants up to ≤0.5 meters in height or low shrubs planted outside the road curb or along the edge of flower beds.
(2) Vegetation screening, raw maintenance, and planning
Vegetation screening shall function to protect flower beds and demarcate landscape areas. For single-row planting, only one tree species shall be selected; for multiple-row planting, various species may be combined and coordinated.
(3) Proposed species for vegetative hedging
Natural hedges requiring no pruning: it is recommended to plant low shrubs such as saxifrage, stipa, grasses, rose, and spirea;
Hedges requiring pruning for shaping: pruning-resistant tree species such as birch, dogwood,

cotinus, multiflora rose, and light-fruited rose are recommended.

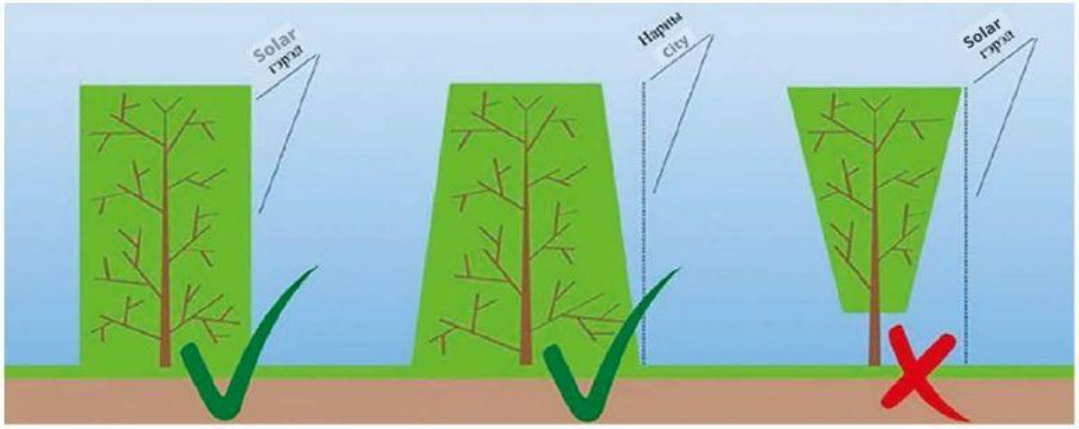
(4) Classification of Vegetative Barriers by Height

They are categorized into three types based on height.

Tall vegetative barrier (2–3 meters): used for spatial separation;

Medium-height vegetative barrier (1–2 meters): used for functional zoning;

Short vegetative barrier (0.5–1 meter): used for decorative edging.



Drawing 6. 12. Plant morphology and the amount of light affecting the lower branches (example drawing)

6.6.8. Analysis of the natural conditions of Ulaanbaatar City

Climate: Annual average precipitation is approximately 200-300 mm, concentrated in the summer season; Winter is long and cold; spring is windy with abundant sand.

Soil: Predominantly gray-brown soil; sandy soil is poor and highly saline.

Challenges: Severe wind erosion, water resource scarcity, and frozen soil adversely affect root growth.

6.6.9. Source for the selection of plant species

Mongolia Green Facility UCS 0802C:2022 "Selection of Tree and Crop Species"

Table 6. 8. Analysis of the primary selection of perennial plants

№	Plant Name	Height (m)	Application	Resistance					Soil Condition	
	Mongolian Name, Latin Name			Light-Loving	Shade-Tolerant	Resistant to Air Pollution	Cold-Resistant	Strong Wind Resistance	Soil Moisture	Soil Type
1	Pine Pinus sylvestris	20-40	o	o		●	o	o	Dry, Wet	Excluding salt
2	Siberian pine Pinus sibirica	35	oo	o	o	●	o	o	Dry, Wet	Excluding salt
3	Moyle Padus racemosa	17		o	o	o	o	o	Dry, Wet	Fertile soil
4	Toshloy Berberis sibirica	1.0-1.5	o	o		o	o	o	Dry, Wet	Fertile soil
5	Peach Amygdalus mongolica	1.0-2.0		o		o	o	o	Dry, Wet	Excluding salt
6	Elm Ulmus pumila	5.0-10	o	o	o		o	●	Dry, Wet	In all soil types

7	Doloono Cornus sanguinea	4.0	o	o		o	o	o	Moist	Excluding salt
8	Mongolian oakQuercus mongolica	20-30	oo	o		o	o	o	Dry, Wet	All types
9	Pinned flowerSyringa villosa	4.0		o		o	o	o	Dry, Wet	Fertile soil
10	Fragrant cedar Juniperus sibirica	0.5	oo	o		●	o	o	Dry,	Sandy
11	Dike bark Lonicera microphylla	0.3-1.5		o		o	o	o	Moist	Fertile
12	Ornamental Juniperus pseudosabin a	0.5	oo	o		o	o	o	Dry	Sandy
13	Dianthus Dianthus deltoides	0.3-0.4		o		o	o		Dry, moist	Sandy
14	Mountain rose Rosa davurica	1.0-2.0		o		o	o	o	Dry	In all soil types

"o" - Denotes specific growth conditions and resistance; "so" - Denotes potential adaptive capacity; "●" - Indicates the absence of resistance capacity (See Table 2 of the parameters related to woody plants’ resistance in Mongolian National Standard BNBd 30.01.03. Note: Please refer to the National Standards of Mongolia for detailed information regarding the resistance of woody plants.)

6.6.4. Design of trees and shrub vegetation

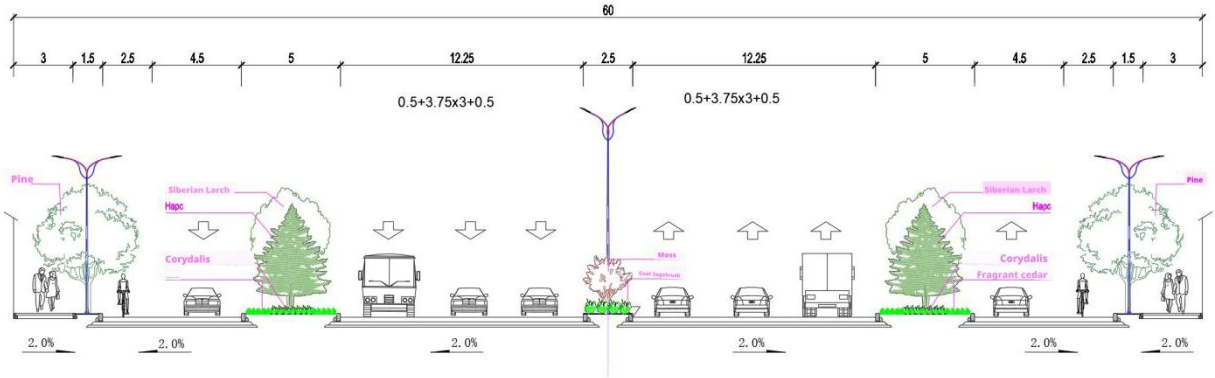
As vehicles travel at varying speeds, the visual perception of the landscape on both sides of the road will differ. Regulating the frequency of changes in vegetation landscape units ensures the stability of the driver's visual rhythm and fulfills the purpose of guiding roadside green spaces. When the length of the green area and the driving speed are correlated as specified in table 9.4.10.10-1, the roadside green zone vegetation will effectively demonstrate landscape visibility.

Table 6. 9. Correlation between the length of the greening unit and the driving speed

Speed v (km/h)	**v ≤ 40**	**40 < v ≤ 60**	**60 < v ≤ 80**
Length of the greening unit L (m)	20 < L ≤ 50	50 < L ≤ 80	80 < L ≤ 110

(1) 60 m Road section: wind protection and forest belt for sand prevention
Function: to block wind and sand, reduce snow accumulation on the road, and isolate external sand sources.
Vegetation:
Trees: Poplar, Siberian Larch, Scots Pine – cold resistant, iron tolerant, deep-rooted, and wind resistant.
Shrubs: Prunus chinensis, European Red Pine – nitrogen fixation improves soil quality and attracts fruit-bearing birds.
Shrubs: field juniper, hawthorn, wild rose, ground cypress, dianthus

Land: Hard grass maintenance – the surface shall be covered; sand application is prohibited.
Structure: Trees, shrubs, and grasses shall be planted and cultivated in multiple layers; dense bushes shall be located on the windward side; the slope of tree height shall be increased on the leeward side; the proportion of evergreen tree species shall be regulated in accordance with the requirements of the technical specifications.

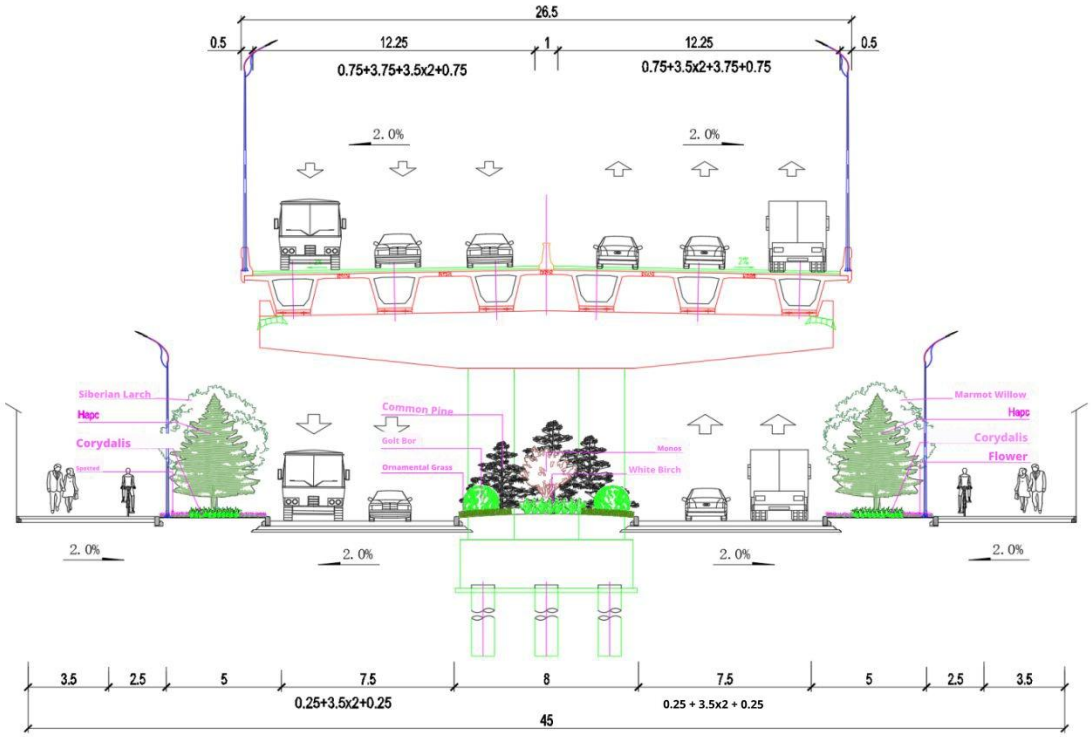


Drawing 6. 13Cross-section adjustment of green landscaping in a 60m standard section.

(2) 45m road section: ecological buffer and landscape screening zone.
Function: Enhance the urban interface, purify the air, and reduce noise.

Vegetation:

Trees: Mongolian larch, Siberian fir, Scotch pine – native species with deciduous autumnal foliage.
Small trees: Aspen, Willow - nitrogen-fixing and soil-improving; their fruits attract birds.
Shrubs: Red-yellow, Mountain rose, Siberian fir, Gobi ganga, Ground cypress, Dianthus - cold-resistant flowering plants that enhance seasonal dynamics.
Ground cover: Hard herbaceous species - low maintenance and highly adaptable.



Drawing 6. 14. 45 m standard section transverse profile of green landscaping configuration

(3) Intersection node: resilient green landscaping
Function: to prevent glare, segregate traffic flows, and adapt to narrow road widths.

Vegetation:

Trees: Siberian larch, Scots pine – cold-resistant, iron-resistant, deeply rooted, and wind-resistant.

Shrub: Lonicera microphylla – resistant to pruning and pollution.

Ground cover: Gobi sandwort (Thymus mongolicus) and Carex duriuscula – resistant to trampling and emitting a fragrant aroma.

Structure: Wave-shaped planting beds, combined with water-permeable gravel layers, enhance rainwater infiltration.

HAVING REVIEWED THE DOCUMENT SPECIFIED IN ANNEX 1 TO THE CONTRACT, THE AUTHORIZED REPRESENTATIVES OF THE APPROVED PARTIES:

EMPLOYER “..... REPRESENTING “..”: DIRECTOR	CONTRACTOR “..... REPRESENTING “..” LLC: EXECUTIVE DIRECTOR