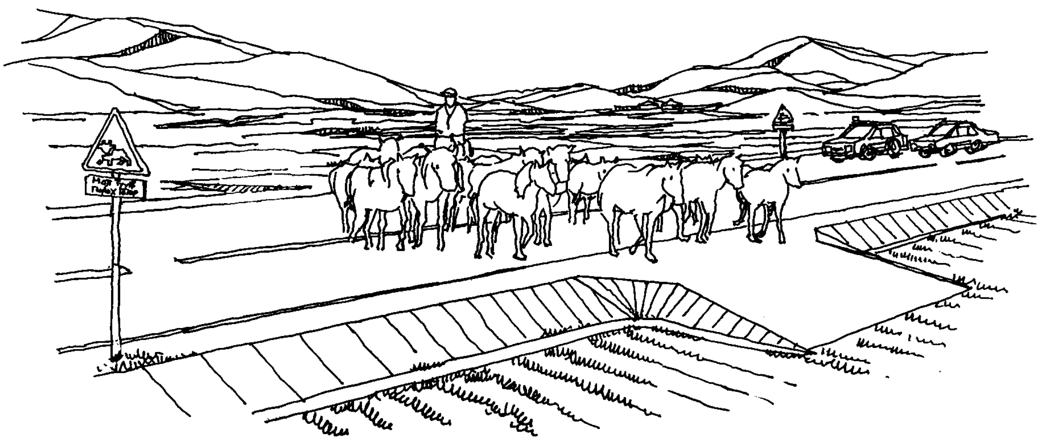
CHAPTER 7 ESTABLISHMENT OF DESIGN CRITERIA



CHAPTER 7 ESTABLISHMENT OF DESIGN CRITERIA

7.1 Road Design Standard

7.1.1 Review of Existing Design Standard

(1) Mongolian Standards

Highway Design Standards in Mongolia were substantially revised by the ADB project of Technical Assistance Grant in 1998. The standards in Mongolian version were published in 2000.

1) Road Function

Road function is classified into four types, and conventional highways have four categories; hence, the total is seven categories for purposes of selecting effective design and assuring performance of road network functions as shown in Table 7-1-1. Level of service is shown in Appendix B.

Table 7-1-1 Functional and Technical Classifications of Highways and Corresponding Operational Traffic Characteristics and Traffic Volumes

Road Type	Road Category	Number of Lanes	Functional Classification	AADT, equivalent passenger cars per day or level of service[2]	Divided/ Undivided	Access Control
Freeways		Multi-lane Highways[1]	Arterials	B	Divided	Restricted
Expressways			Arterials and regional	B	Divided	Partially Restricted
Conventional Highways	I			C	Divided or Undivided	Can be partially restricted
	II			C	Undivided	Unrestricted
	III	Two-lanes Roads	Arterials, regional and local roads	C	Undivided	Unrestricted
	IV		Regional and local	400-2000	Undivided	Unrestricted
Low Volume Roads		One-two Lane	Local	< 200 Mixed Traffic	Undivided	Unrestricted

Note: 1): Number of lanes is more than 2. 2): Average Annual Daily Traffic (vehicles per day; vpd)

2) Typical Cross Sections

Typical cross sections except for bridge section are shown in Table 7-1-2. Freeways and Expressways are applicable to divided 4-lane road, Conventional Highway category I is desirable to be divided 4-lane road and others are for 2 or 1 lane road. Shoulder width depends on surface type and number of lanes. Right-turn and left-turn lanes, climbing lanes, passing lanes and turnouts are prepared as auxiliary lanes.

Table 7-1-2 Basic Dimensions of Cross Section Elements

Road Type	Road Category	Number of Lanes	Traffic Lanes		Shoulder Dimensions (m)			Median Width (m)	
			Number of Lanes	Lane Width (m)	Usable	Surfaced[1]	Paved Strip	Minimum	Desirable
					Left/Right[2]	Left/Right[2]	Left/Right[2]		
Freeways		Multi-lane Highways[1]	≧4	3.75	2-3.75/3.75	1-3/3	1-3/0.75	3.5	20
Expressways			≧4	3.75	2-3.75/3.75	1-3/3	1-3/0.75	3.5	20
Conventional Highways	I		≧4	3.5	3.5	3.0	0.5/0.5	0	5
	II		2-3	3.5	3.0	2.0	0.5		
	III	Two-lanes Roads	2	3.5	1.5-2.5	2.0	0.3		
	IV		2	3	1.5-2.0	0.5	0.3		
Low Volume Roads		One-two Lane	1-2	4.5-5 Roadway Width[1]	1				

Note:

1: Shoulders surfacing: Bituminous mixes, Concrete for Freeways and Expressways; Aggregate for other roads.

2: First value for two lanes in one direction, second in other cases

3) Geometric Design Criteria

Design speeds are shown in Table 7-1-3. They are applied from criteria of each road category. Freeways are applicable to 140 km/h at flat area, while road with low traffic volume is applicable from 30 km/h at Mountainous area.

Minimum parameters for horizontal and vertical alignment are shown in Table 7-1-4. Vertical curve on sag points is applied by the basis of economical aspect. The minimum sight distance for stopping points should ensure for visibility of any object of the height of 0.2m, assuming the height of 1.2 m of driver's eyes from roadway surface.

Other major parameters are shown in Appendix B.

Table 7-1-3 Design Speeds

Road Type	Road Category	Number of Lanes	Design Speed (km/h)		
			Flat	Rolling	Mountainous
Freeways		Multi-lane Highways	140	120	80
Expressways			120	100	80
Conventional Highways	I		120	100	60
	II		120	100	60
	III	Two-lanes Roads	100	80	50
	IV		80	60	40
Low Volume Roads		One-two Lane	60	40	30

Table 7-1-4 Minimum Parameters for Horizontal and Vertical Alignment

Design Speed (km/h)	Maximum Grades (%)	Minimum Sight Distance (m)		Minimum Curve Radii (m)				
				Horizontal Alignment All Sections		Vertical Alignment		
		For Stopping	For Passing	Required Super Elevation (%)		Crest	Sag	
				6.0	4.0	All Sections	Basic Section	Mountain Terrain
140	3.0	280	-	1250	1500	17000	7200	3600
120	4.0	250	800	750	900	14000	6200	3100
100	5.0	200	680	450	550	9000	4800	2400
80	6.0	140	560	250	300	4500	3200	1600
60	7.0	85	420	150	150	1600	1800	900
50	8.0	70	340	100	100	1100	1400	700
40	9.0	55	290	60	60	700	1000	500
30	10.0	45	230	30	30	500	800	400

4) Pavement Structure

Pavement structural types are mainly divided into three types of quality in Mongolian Standards such as high, intermediate and low quality. Three types are defined as follows:

High Types: This pavement structure consists of asphalt or cement concrete surface pavement and asphalt or cement stabilized base coarse.

Intermediate Types: This pavement structure consists of asphalt or cement concrete surface pavement and binder-stabilized base coarse by aggregate or soils.

Low Types: This pavement structure consists of binder-stabilized surface by aggregate and soil or aggregate or gravel base coarse.

5) Climatic Zone

Climatic zone in the study area is shown in Appendix B. Pavement cross-fall and minimum pavement elevations are designed based on climatic zone. The section between Erdene and Baganuur is located at Zone III, and the section between Baganuur and Undurkhaan is located at Zone IV.

(2) Comparison of Typical Cross Section

Comparison of typical cross section of rural arterial road in Mongolia, AASHTO, Japan and Asia Highway is shown in Appendix B. Lane width ranges almost between 3.0 and 3.5 m. Shoulder width ranges between 1.5 and 2.5 m.

Comparison of typical cross section in case of major arterial road projects in Mongolia is shown in Appendix B. The type of Highway class was applied to III of the Mongolian Standards in recent projects. 3.5 meter of lane and 1.5 meter of shoulder width were respectively applied by the Mongolian Standard.

(3) Comparison of Geometric Design Criteria

Comparison of geometric design criteria in case of rural arterial road in the Mongolian, AASHTO, Japan and Asia Highway is shown in Appendix B. Value of maximum vertical grade of the Mongolian Standards on the same design speed is higher than others.

Comparison of geometric design criteria in case of major arterial road projects in Mongolia is shown in Appendix B. In the World Bank Projects, geometric criteria for the purpose of rehabilitation were not established. Minimum horizontal curve radius and maximum vertical curve radius respectively are applied by the Mongolian Standard in recent projects

7.1.2 Establishment of Design Criteria

(1) Background

Since the geometric design standard of National Highway must reflect the desired goals of the Government of Mongolia, it is preferable to apply uniform standards through the country if these are available.

The study road of Eastern Arterial Road is a part of the “Millennium Road” which is strategically important for socio-economic and regional development and improving the foreign relationship with neighboring countries. The “Millennium Road” is expected to fulfill an international standard such as loading specifications, geometric criteria and so forth. Therefore, it is imperative to establish the geometric design standard for the Study taking into consideration the above viewpoints.

A Policy on Geometric Design of Highways and Streets published by AASHTO has been widely referred to make framework of geometric design standard in many other countries, even though each criteria of design control may be discussed within such framework to reflect characteristics of traffic as well as physical and natural conditions in each country or region.

The Highway Design Standards in Mongolia (hereinafter called “HDSM”) was prepared in 1998 under a Technical Assistance Grant from the Asian Development Bank, and it is successfully prepared by reflecting such characteristics in Mongolia. On the other hand, Japan also has made efforts to revise its own standard for the sake of warranting public investment and to develop several criteria from experiences.

It is a matter of fact that amenity or good performance brought by a new road is recognized not in the design stage but in the operation after opening to the public. On the contrary, good performance could be expected not only by good engineering practice itself but also both education to drivers and enforcement against illegal users may be required.

(2) Definition of Terms

The following technical terms as defined are commonly used (refer to Fig. 7-1-1).

Roadway : the portion of a highway, including shoulder, for vehicular use.

Traveled Way : the portion of the roadway for the movement of vehicles, exclusive of shoulders.

Shoulder : the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and lateral support of subbase, base and surface courses. Hard Shoulder is the portion to be paved or surface treated. Soft Shoulder is the portion to be covered by sub-base material and so forth.

Marginal Strip : the portion of the shoulder and the same pavement structure of the traveled way extended, usually 0.25 m - 0.5 m. This is also the space for road marking at both ends of traveled way.

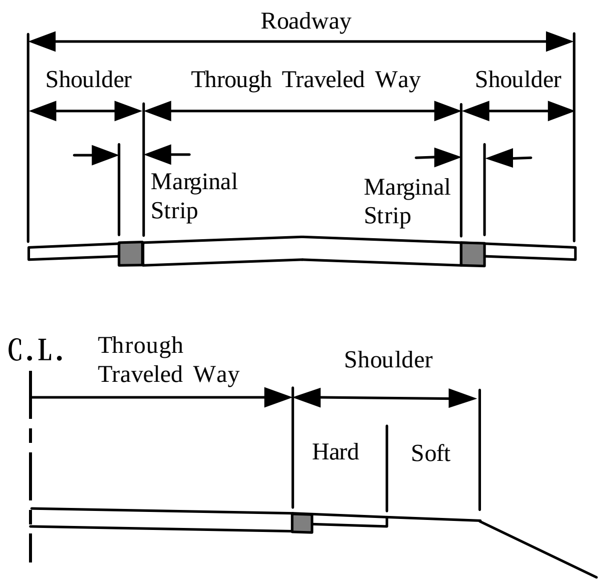


Figure 7-1-1 Configuration of Road Structure

(3) Geometric Design Criteria for the Eastern Arterial Road (EAR)

1) Functional Classification as a Design Type

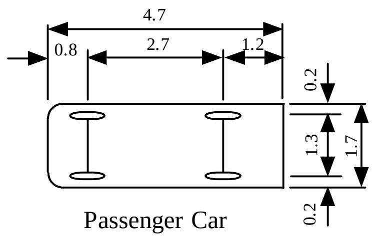
The Eastern Arterial Road, as a part of the "Millennium Road", is planned to improve a part of existing National Highway No. A0501. The road is designated as a Rural Arterial Road with the primary road function of mobility and the priority given to motorized vehicles.

2) Design Vehicle

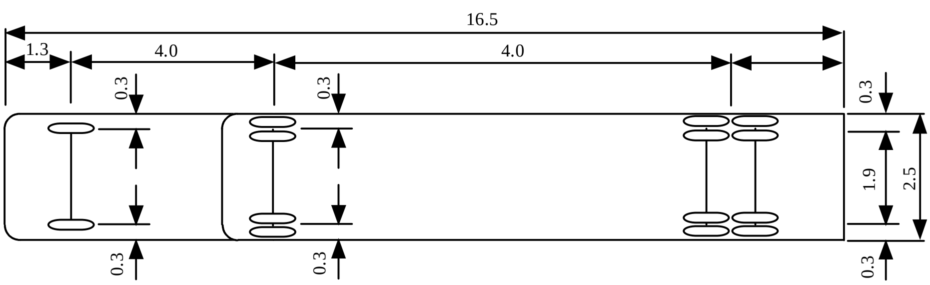
The physical characteristics of vehicles and proportion of variously sized vehicles using arterial road are positive controls in geometric design. For purpose of geometric design, each design vehicle has larger physical dimensions and lager minimum turning radius than those of almost all vehicles in its class.

Three general classes of vehicles have been selected, namely Passenger Car, Truck and Semitrailer. The Passenger Car class includes sedan, wagon van and pick-up, while the Truck class includes bus, single-unit truck and so forth. The Semitrailer class represents truck tractor-semitrailer combination, especially for targeting 40 ft container transport.

Taking into consideration similar vehicular size composition to Japan, the same design vehicles are as shown in Figure. 7-1-2 is applied to the Study, and the Semitrailer class is to apply to "Through Traveled Way" and the Passenger Car to "Sight Distance", standing on the structural yet practical viewpoint.



Passenger Car



Semitrailer Combination

Figure 7-1-2 Design Vehicles

3) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of road when conditions are so favorable that design features of road govern. The design speed is to be determined logically with respect to the terrain, adjacent land use, type of road and the design speed of adjoining section.

The design speed selected will directly affect many geometric elements, namely horizontal and vertical alignments, sight distance, provision of superelevation, etc.

Other features such as traveled way width and roadside clearance are also influenced by design speed but to a lesser degree.

The followings may warrant the design speed of 100 km/h at flat terrain, 80 km/h at rolling terrain and 60 km/h at mountainous terrain applied to the Eastern Arterial Road.

- The road is expected high mobility as international road.
- The road is located on rural area and planned to avoid urbanized area.
- The terrain in the Study Area is variable. Depending on the terrain, change of the design speeds is preferable from the economical viewpoint.
- The gap of design speeds of adjoining section, which is over 20 km/h, disturbs safety drive due to change of geometric design standard suddenly.

Note: Flat Terrain : the lateral slop is over 0.0 % and under 10.0 %.

Rolling Terrain : the lateral slop is over 10.0 % and under 25.0 %.

Mountainous Terrain : the lateral slop is over 25.0 %.

Source: Definition of Terrain from Asia Highway Standard

4) Cross Section Elements

Lane Width

Lane widths of 2.7 m to 3.75 m are generally used in highway through the world.

3.75 m lane width is internationally accepted as the widest possible lane width because wider than this width would result in two-lane use for one lane, which should be avoided for safety reasons.

The standard lane width in Asian Highway was 3.50 m for Class-I and II. In other countries, the regulated maximum standard lane width in the Japanese standard regulates that the widest lane width is 3.50 m, and some expressways in France and Sweden apply a 3.50 m lane width.

In Mongolia, 3.50 m lane is regulated as Conventional Highway Class-I, II and III. The “Millennium Road” is designated as Conventional Highway Class-III.

The lane width of 3.50 m is applied to the Study, and it is sure this width accords with that of regulated lane width for the “Millennium Road”.

Shoulder Width on Embankment

Shoulder widths of 1.0 m to 3.6 m are generally used in highway through the world.

The regulated standard lane width in Asian Highway Standard was 3.0 m (Class-II, flat and rolling terrain), and 2.0 m (Class-II, mountainous and steep). In other countries, the regulated standard lane width in the Japanese standard was 2.50 m to 1.75 m, and rural arterial road in U.S.A apply a 2.4 m width to 1.2m.

In Mongolia, shoulder width ranging from 1.5 m to 2.5 m is regulated as Conventional Highway Class-III, and shoulder width in recent projects shows a tendency to apply 1.5 m as shown in Figure. 7-1-3.

Considering the functions of the shoulder together with economical, service level and functions as the “Millennium Road”, 1.5 m is recommended in the Study.

Marginal Strip Width

This portion is also the space for road marking at both ends of traveled way. 0.3 m marginal strips are recommended in the Study.

Climbing Lane

This lane is provided for passing cars against heavily loaded vehicles, which result in speeds that could impede following vehicles on grades. It is not necessary in the Study. Because traffic volume is not exceed the capacity on grades as shown in Appendix B.

5) Crossfall of Traveled Way and Shoulder

A crossfall of 2.0 percent is adopted as a standard on the rural road, considering the advantage in the rapid draining the pavement during rainstorms as well as comfort of drivers.

A crossfall of 4.0 percent is adopted for the unpaved shoulders in order to use them effectively for surface rainwater flow.

Normal crown arrangement is applied to the roads except at sections with superelevation.

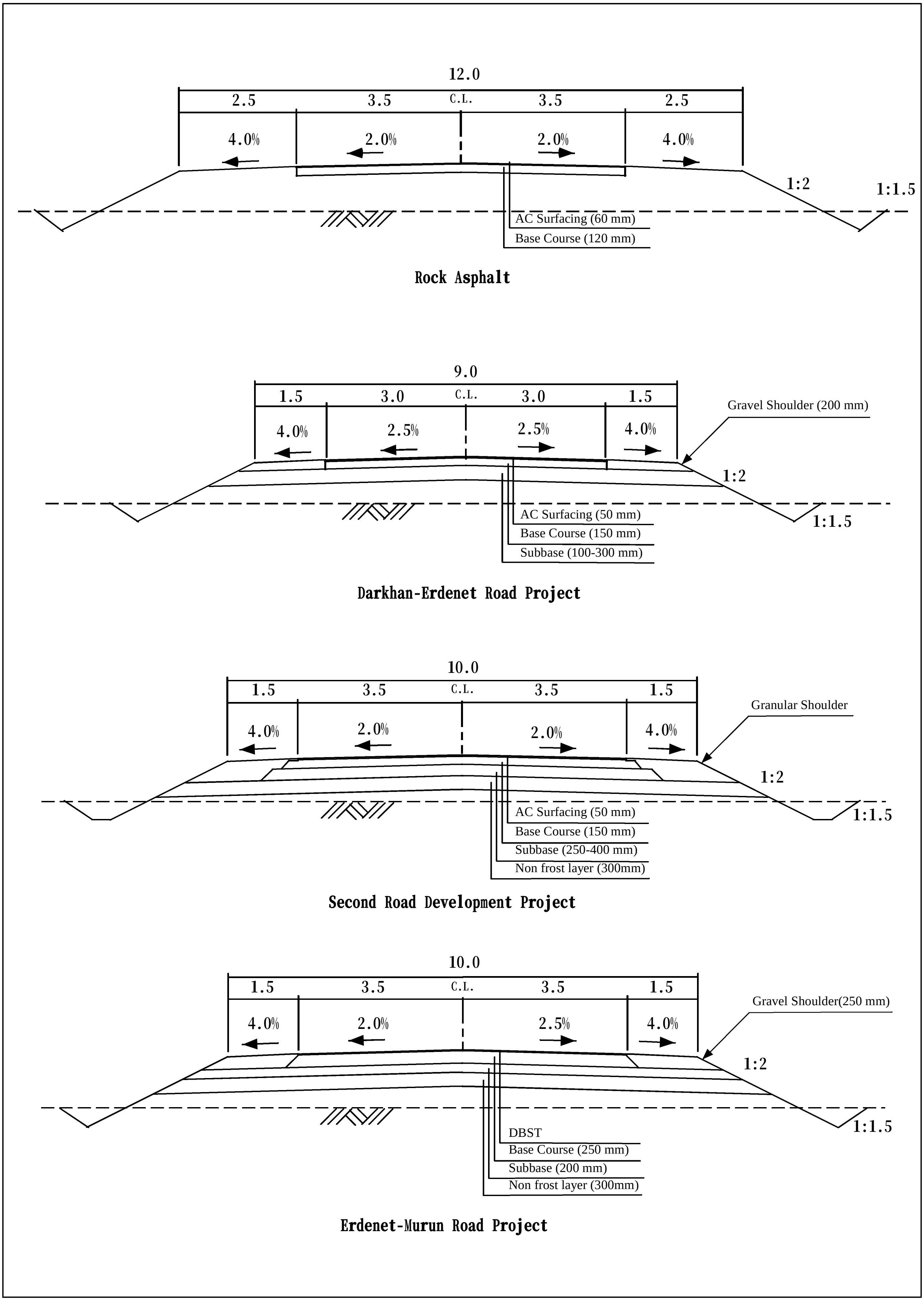


Figure 7-1-3 Typical Cross Section in Recent Projects

6) Type of Pavement

Considering the ease of construction and maintenance, the economical and functional viewpoints, flexible type pavement is selected generally for the arterial road. The flexible type pavement agrees with the “Millennium Road” plan.

7) Horizontal and Vertical Clearances

A. Horizontal Clearance

Horizontal clearance limit illustrated in Figure 7-1-4 indicates outer edge of the shoulder.

B. Vertical Clearance

Height of design vehicle applied in the HDSM is 4.0 m. 4.3 m vertical clearance limit is recommended for the Study in consideration of headroom and overlaid thickness.

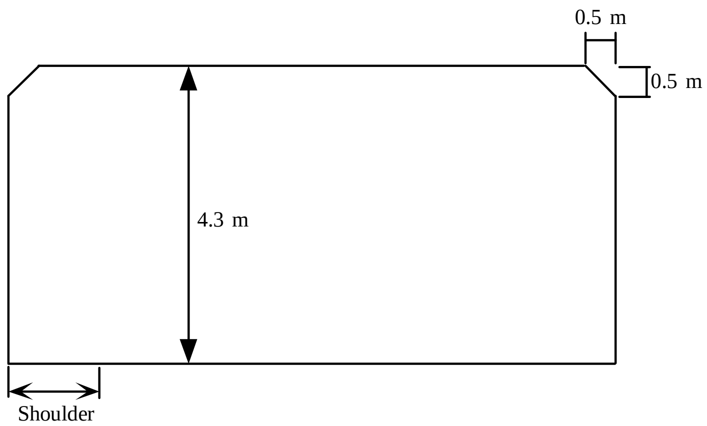


Figure 7-1-4 Horizontal and Vertical Clearance

8) Other Design Elements

Design criteria of other design elements are determined according to discussions described in the Appendix B.

9) Summary of Geometric Design Criteria

Table 7-1-5 summarizes the geometric design criteria for the Eastern Arterial Road.

Table 7-1-5 Summary of Geometric Criteria for the Eastern Arterial Road

	Item	Unit	Design Criteria		
0.	Terrain	-	Flat	Rolling	Mountainous
1.	Design Speed	km/h	100	80	60
2.	Traveled Land Width	m	3.5		
3.	Shoulder Width	m	1.5		
4.	Marginal Strip Width	m	0.3		
5.	Crossfall of Traveled Way	%	2.0		
6.	Crossfall of Shoulder	%	4.0		
7.	Type of Pavement	-	Flexible Type Pavement		
8.	Stopping Sight Distance	m	205	140	85
9.	Maximum Superelevation	%	6.0		
10.	Minimum Horizontal Curve Radius	m	450	250	150
11.	Minimum Horizontal Curve Length	m	170* or 1,200/ θ	140* or 1,000/ θ	100* or 700/ θ
12.	Minimum Transition Curve Length	m	85	70	50
13.	Sharpest Curve without Transition Curve	m	1,500	1,000	500
14.	Sharpest Curve without Superelevation	m	5,000	3,500	2,000
15.	Max. Relative Slope for Superelevation Runoff	-	1:175	1:150	1:125
16.	Maximum Grade	%	4.0	6.0	7.0
17.	Minimum Vertical Curve Length	-	Refer to Appendix B		
18.	Horizontal Clearance	-	Roadway Width		
19.	Vertical Clearance	m	4.3		
20.	Space between Safety Rest Area	m	40 to 60 km / Max. 100km		

Notes: θ shows intersection angle in degree for horizontal curve (min. 2 degrees).

The figure with * shows absolute value in case that θ is more than 7 degrees.

The figure in parentheses shows value for bridge.

7.2 Design Criteria for Bridge

7.2.1 Application of Design Criteria

Mongolian Design Criteria have been applied for the design, construction, improvement and maintenance of National Roads for Ulaanbaatar City and Department of Roads, Ministry of Infrastructure.

The design criteria for the Project bridges and Culverts construction shall apply in the following Specifications for this Millennium International Road.

Design Standards, Mongolian Officials

Highway Design Standards, Republic of Mongolia, 1998

Road Bridge and pipe Culverts, BNbD 2.05.03-97, Road Department, Ulaanbaatar, 1997

Construction Norms and Regulations, BNbD 2.05.02-97, Road Department,

Ulaanbaatar, 1997

Specifications for Highway Bridges, Japan Road Association, 1994-1996

Part 1: Common Specification
Part 2: Steel Bridge
Part 3: Concrete Bridge
Part 3: Substructure & Foundation

Standard Specifications for Highway Bridges, AASHTO of American, 1995

7.2.2 Design Condition

(1) Scale of Bridge

a) Proposed Width of Bridge

The defined width in Mongolia Standard is 4.5m for one lane, 6.5m and 8m for two lanes.

To keep the over geometric design standard and design speed for the Project, the carriage way width of bridges including shoulders will be proposed 8m corresponding to the Millennium Arterial Road as shown in Figure-7-2-1.

Design criteria for the Project, Millennium Arterial Road is defined HWY- Ⅲ of road category. The carriage way width is 3.5m wide for one lane.

Design Speed: 100, 80, 60 km/h

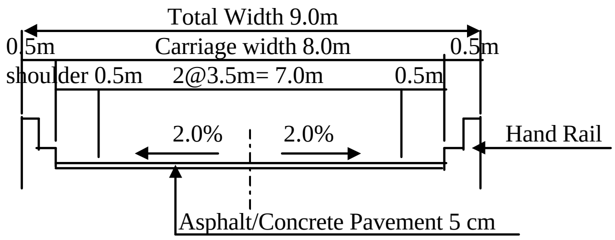


Figure 7-2-1 Proposed Standard Cross Section of Bridge

b) Scale of Bridge

The scale and type of planning bridges shall be determined taking into account of topographic, geological conditions and characteristics of existing river or water way.

Based on the results of Hydrology Study, each bridge length and scale on the Project route shall be planned considering design flood water level, flood flow (design discharge Q m^3/s), free board under girder and approach embankment as shown in below Figure 7-2-2.

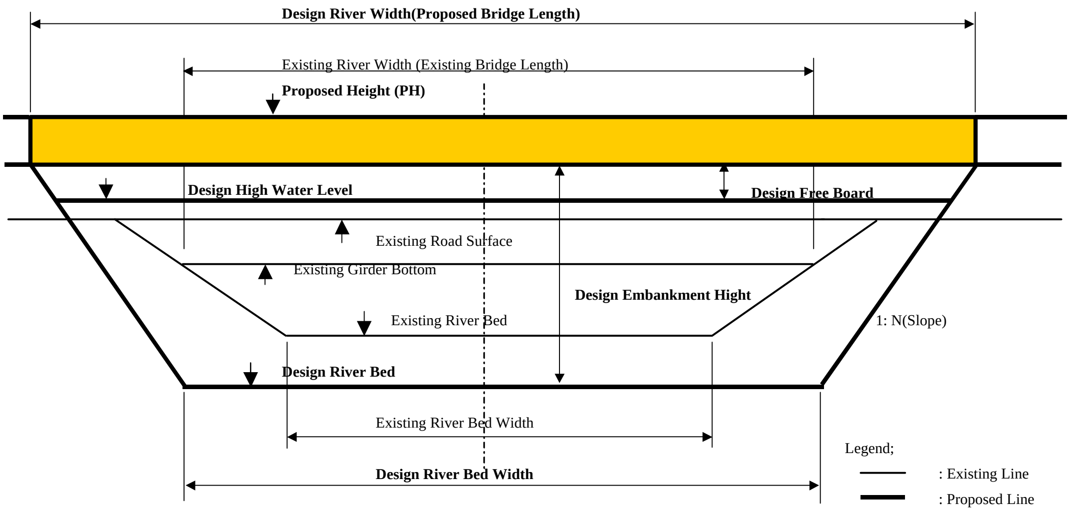


Figure 7-2-2 Design River Section

Proposed Types are basically as follows;

- Superstructure: RC / PC T-shape girder
- Substructure: RC Reversed T-shape (abutment), RC s (pier)
- Foundation: Spread Footing, RC pile
- Protection for Bridge: Concrete, Rubble, Gabion, etc

(2) Design Load

a) Dead Load and Material Strength

The Following unit weights of materials shall be applied in computing the dead load as below Table 7-2-1.

Table 7-2-1 Unit Weight of Materials

Types of Dead Load	Unit Weight (kgf/m^3)	Types of Dead Load	Unit Weight (kgf/m^3)
Steel or cast steel	7850	Asphalt pavement	2300
Cast iron	7250	Bituminous material	1100
Aluminum alloys	2800	Compacted sand, earth/gravel	1900
Timber(treated/untreated)	800	Loose sand, earth, and gravel	1800
Concrete(plain)	2350	Under ground water	1000
Concrete(reinforced/prestressed)	2500		
Cement mortar	2150		

The strengths of material for concrete, reinforcing steel bar and the others are to be determined in consideration of the Mongolian useful materials and laboratory testing. Especially, cement and reinforcing bar are produced in Darkhan factory in Mongolia referred to hearing records in Appendix.

Gathering the data, examination, record of materials, strengths for concrete, and reinforcing steel bar from many executed Projects as ADB, WB and JICA Grant Aid of Japan in Mongolia, the materials and basic strength of standard shall be adopted taking into account of these data as shown in Table 7-2-2.

Table 7-2-2 Materials and Basic Strength

PC girder	$\sigma ck = 400kgf/cm^2$	Abutment, Pier	$\sigma ck = 210kgf/cm^2$
RC girder	$\sigma ck = 240kgf/cm^2$	Approach Wall	$\sigma ck = 210kgf/cm^2$
RC Slab, Cross Beam	$\sigma ck = 240kgf/cm^2$	RC Pile (Precast)	$\sigma ck = 240kgf/cm^2$
Concrete Pavement	$\sigma ck = 240kgf/cm^2$	RC Box Culvert (Precast)	$\sigma ck = 210kgf/cm^2$
RC Hand Rail	$\sigma ck = 210kgf/cm^2$	RC Pipe Culvert (Precast)	$\sigma ck = 210kgf/cm^2$

* Concrete Compressive Strength σck (28 days)
Cement Factory (Darkhan, EREL Cement & other one factory in Mongolia)

(Darkhan Metallurgical Plant)

Steel Grade (deformed Bar)	Length (Dia mm)	Chemical Composition %					Strength(N/mm2)	
		C	Si	Mn	P	S	Yield	Tensile
SD295	Length 6000-12000mm	0.16-0.18	0.15-0.37	0.60-0.90	0.04 max	0.04 max	295 min	440-600
SD345		0.18-0.20	0.15-0.37	0.80-1.00	0.04 max	0.04 max	345-440	490 min
SD390	Diameter 10- 32mm	0.18-0.26	0.15-0.37	0.95-1.25	0.04 max	0.04 max	390-510	560 min

* Steel Reinforcing Steel SD295, SD345 , SD390 (Yield strength $\sigma py > 30 kgf/mm^2$)
Prestressing Steel T-12.7mm (Yield strength $\sigma py = 160kgf/mm^2$)

b) Live Load

The various loading capacity expected to increase along with future development of economy. For the Project bridges, the live loading system shall be applied corresponding to the Millennium Arterial Road, especially.

A comparison of the live loading systems in use around the world expressed as Bending Moment of Girder is given in Figure 7-2-3.

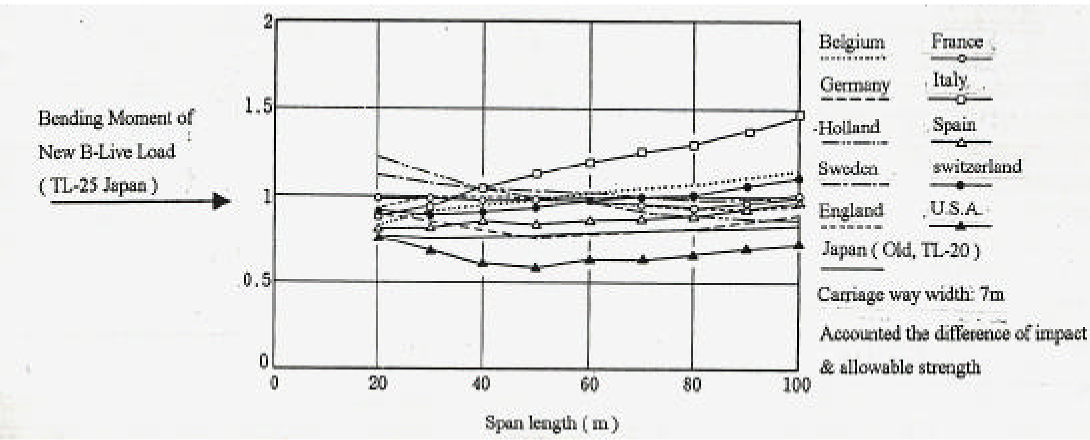


Figure 7-2-3 Comparison of Bending Moment for Live-Load in the World

The live-loading method of Japanese Specification (A, B-Live Loading Method) is shown in Figure 7-2-4.

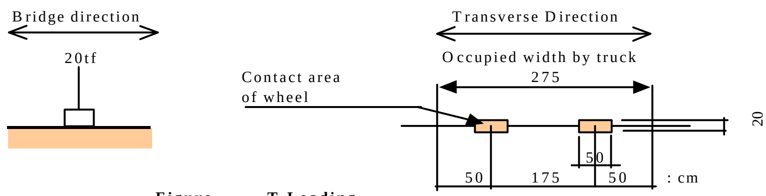


Figure T-Loading

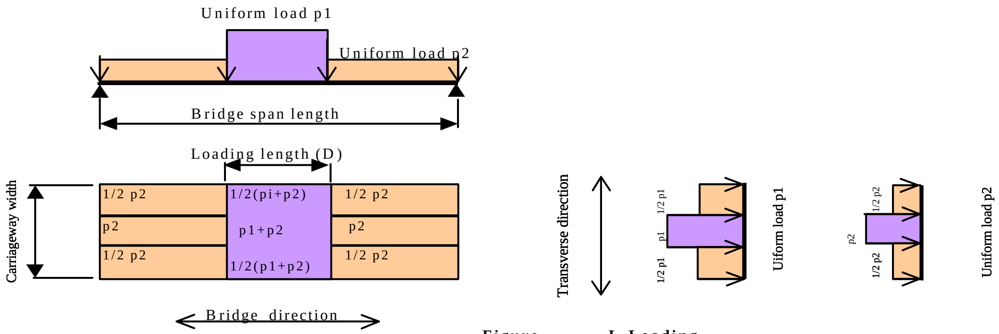


Figure L-Loading

Table L- Loading (A,B-Live Load, Japan)

(L: Span)

Main loads (width 5.5m)						Sub loads (width-5.5m)
	Uniform loads p1		Uniform loads p2			
Loading length D (m)	Load (kgf/m2)		Load (kgf/m2)			
	for Bending Moment	for Shearing Force	L<80	80<L<130	L>130	50% of
A-Load 6, B-Load 10	1,000	1,200	350	430-L	300	Main load

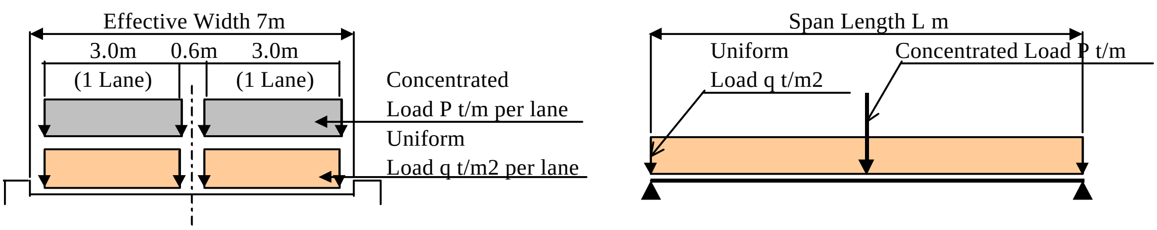
Table Uniform Loading for Sidewalk

	For Slab	For Main Girder		
Span Length (m)	-	L≦80	80< L≦130	130< L
Uniform Load (kgf/m2)	500	350	430− L	300

Figure 7-2-4 Live Loading Method of Japanese Specification

The American standard live load is illustrated below Figure 7-2-5.

ASSHTO American Standard HS20-44

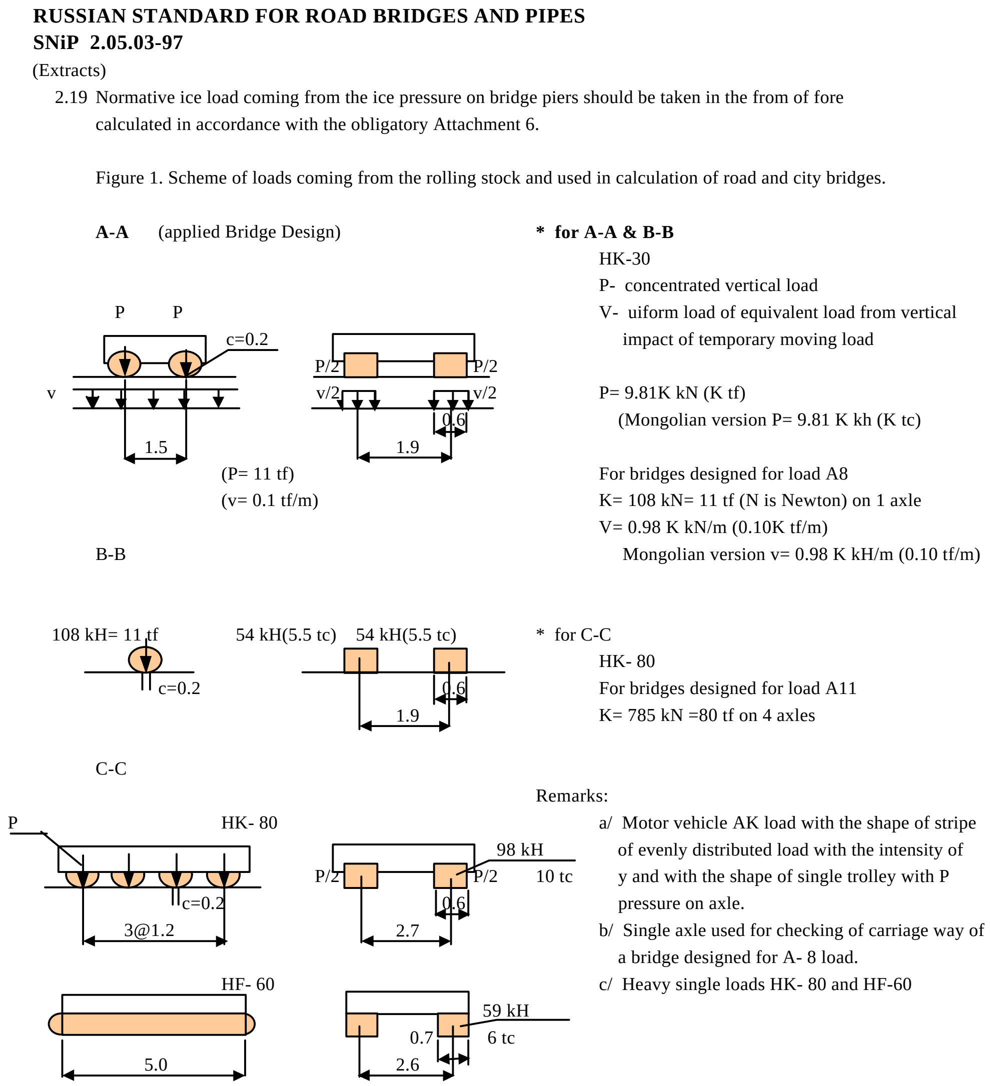


Load	In case of 2 lane load	Increased 25%
Concentrated Load	2* 8.16= 16.32 ton (P=2.72 t/m)	P= 3.40 t/m
Uniform Load	2*0.96= 1.92 t/m (q=0.32 t/m2)	q= 0.40 t/m2

Impact Fraction
I= 15/ (L+38)

Figure 7-2-5 Live Loading Method of American Standard

On the other hand, Mongolian live loading standard as SniP 2.05.03-97 of Russian Standard for Road Bridges and Pipes is shown in below Figure 7-2-6.



RUSSIAN STANDARD FOR ROAD BRIDGES AND PIPES
SNiP 2.05.03-97
(Extracts)

2.19 Normative ice load coming from the ice pressure on bridge piers should be taken in the from of fore calculated in accordance with the obligatory Attachment 6.

Figure 1. Scheme of loads coming from the rolling stock and used in calculation of road and city bridges.

A-A (applied Bridge Design)

*** for A-A & B-B**
HK-30
P- concentrated vertical load
V- uiform load of equivalent load from vertical impact of temporary moving load

P= 9.81K kN (K tf)
(Mongolian version P= 9.81 K kh (K tc)

For bridges designed for load A8
K= 108 kN= 11 tf (N is Newton) on 1 axle
V= 0.98 K kN/m (0.10K tf/m)
Mongolian version v= 0.98 K kH/m (0.10 tf/m)

B-B

* for C-C
HK- 80
For bridges designed for load A11
K= 785 kN =80 tf on 4 axles

C-C

Remarks:
a/ Motor vehicle AK load with the shape of stripe of evenly distributed load with the intensity of y and with the shape of single trolley with P pressure on axle.
b/ Single axle used for checking of carriage way of a bridge designed for A- 8 load.
c/ Heavy single loads HK- 80 and HF-60

Figure 7-2-6 Mongolian Live Loading Standard

As a further example, a comparison of Mongolian, Japanese and American standards are shown in Figure 7-2-7 below for bending moments for different span lengths. It can be seen that the Japanese live loading system is the heaviest for each span length considered (15, 20,30 and 40m).

To produce robust structures on the Project Road, as Millennium Arterial Road, it is recommended that either the Japanese and/or American AASHTO live load system shall be applied.

From viewpoints of smaller traffic volume 1,420 vehicles/ day and 6.6% ratio of heavy vehicle (large truck) of total traffic volume forecasting in year 2015, the standard of live loading system in case of Japanese Specification shall apply type A- live load (classified major regional road).

Comparison of Bending Moment (Carriageway width = 7m)

Bridge Span Length (m)	15	20	30	40
Mongolian (tfm)	154.13	213.50	336.00	463.50
Japanese B-Live (tfm)	217.79	343.78	636.78	984.48
Japanese A-Live (tfm)	174.04	268.78	499.28	784.48
AASHTO (tfm)	184.75	279.41	516.31	815.54

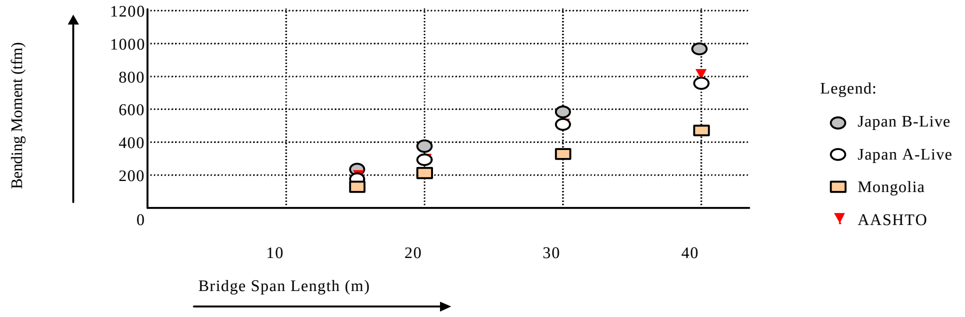


Figure 7-2-7 Comparison of Live-Load using Mongolia, Japan and American Standards

Applied Live Loading System

*** Japanese A-Live Load**

Specifications for Highway Bridges, Japan Road Association, 1994-1996

Part 1: Common Specification
Part 2: Steel Bridge
Part 3: Concrete Bridge
Part 3: Substructure & Foundation

*** AASHTO of American HS20-44 Live Load**

Standard Specifications for Highway Bridges, AASHTO of American, 1995

c) Other Main Loads

- Impact Fraction (I): as Table 7-2-3

Table 7-2-3 Impact Fraction

Standard	Kind of Bridge	Impact Fraction (I)
Japan	RC Girder PC Girder	7/ 20+L 10/ 25+L
AASHTO	RC/ PC	15/ L+38

Note: L= Span length

- Earthquake:

  Seismic horizontal coefficient Kh=0.10
  (Construction Norms and Regulations, Design Norms, SNIP II -7-81,M-87)
  Seismic Regions and Value (Class or Range in Mongolia: 1 to 12)
  Ulaanbaatar City: 6,7,8 Undurkhaan: 6 Baganuur: 6 Erdene: 7

- Influence of creep, shrinkage of concrete

  Coefficient of creep (ϕ): 2.8 (4-7 day), 2.5 (14 day), 2.2 (28 day), 1.9 (90 day)
  1.4 (365 day)
  Shrinkage of concrete: 20*10-5 (4-7 day), 18*10-5 (28 day), 16*10-5 (90), $12*10^{-5}$ (365 day)

- Earth Pressure:

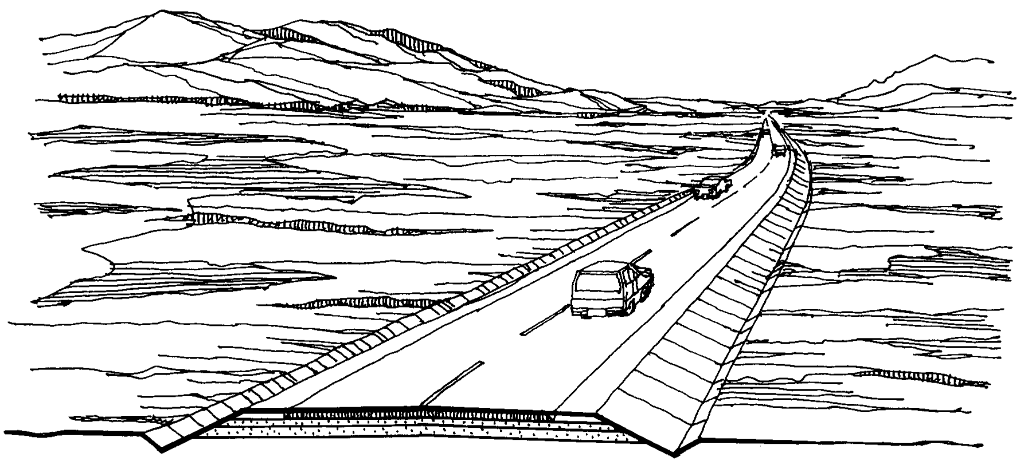
  Coulomb's Active/ Passive Earth Pressure Coefficient
  Ordinal Time and Earthquake Time

- Hydraulic Pressure

  Hydrostatic Pressure, Flowing Water Pressure, Hydrodynamic Pressure

- Buoyancy or Uplift
- Wind load
- Others

CHAPTER 8 SELECTION OF OPTIMUM PAVEMENT STRUCTURES



CHAPTER 8 SELECTION OF OPTIMUM PAVEMENT STRUCTURES

8.1 Review of Pavement Materials in Each Project

The review was made based on the technical specifications for the project funded by Kuwait Fund. According to DOR, the specified material requirements for the ADB First Road Project is very similar to the Kuwait Fund Project.

(1) Subbase

Table 8-1-1 shows the gradation requirements. As shown in the figure, material passing the 75 μm sieve is low.

Other requirements are as follows:

- Uniformity coefficient : min. 5%
- Liquid limit : max. 35%
- Plasticity index : max. 6%
- Linear shrinkage : max. 3%
- Maximum size : max. 45 mm
- Soaked CBR-value : min. 30%

The specified CBR-values are the value at compacted to 100% of the maximum dry density determined by the Modified Proctor test. As the specified minimum compaction is 98%, the design CBR-Value of the subbase is less than 30%.

Table 8-1-1 Gradation Requirements for Subbase Material

Sieve Size	Percentage passing (by mass)
37.5 mm	80 - 100%
25.0 mm	70 - 100%
19.0 mm	60 - 100%
9.5 mm	45 - 100%
4.75 mm	30 - 90%
2.00 mm	20 - 80%
475 μm	10 - 50%
75 μm	2 - 8%

(2) Base course

Crushed stone base is specified. Specified requirements are as follow:

- Grading : Table 8-1-2
- Maximum size : max. 45 mm
- Plasticity index : max. 6%
- Soundness by sodium sulphate : max. 12%
- Los Angeles abrasion value : max. 30%

- Flakiness index : max. 35%
- 10% fine : min. 110 KN
- Average dry density : min. 87% of the solid density of the stone

Table 8-1-2 Gradation Requirements for Graded Crushed Stone Base Material

Sieve Size	Percentage passing (by mass)
37.5 mm	90 - 100%
25.0 mm	80 - 95%
19.0 mm	60 - 80%
9.5 mm	40 - 60%
4.75 mm	25 - 40%
2.00 mm	15 - 30%
475 μm	7 - 19%
75 μm	5 - 12%

This project specified the average dry density compacted at the site instead of minimum CBR-value of the material which is usually used for the road project.

The specified degree of compaction is min. 100% of the maximum dry density determined by the Modified Proctor text.

(3) Bitumen

The requirements of the bitumen are determined based on AASHTO. However the range of the penetration grade 90/130 does not coincide with the AASHTO's grade. The grade follows GOST. This may be decided in consideration with sources of bitumen.

In addition above, Frass breaking point, not higher than -23^{o}C, is specified. This condition might be added the very cold weather condition in Mongolia.

(4) Coarse Aggregates for Bituminous Mixture

The specified physical characteristics of the coarse aggregate as follows:

- Los Angeles abrasion : max. 25%
- Soundness by sodium sulphate : max. 12%
- Aggregate crushing value : max. 25%
- Water absorption : max. 20%
- Flakiness index : max. 20%
- Percent passing 75 μm sieve : max. 0.5%

(5) Coarse Aggregate for Surface Dressing

The specified requirements to the coarse aggregate, chippings, are same to the bituminous mixture except the flakiness index and water absorption. Higher value, max. 25% is specified.

The water absorption is not specified.

8.2 Review of Pavement Cost in Each Project

To review the pavement cost, we have reviewed the following completed projects.

- ADB First Road Development Project
- Kuwait Fund Road Project

8.2.1 ADB First Road Development Project

The background and outline of the project are described previously. The project started in 1997 and was completed in 2000. Therefore, the cost estimated was at the time of 1996. Table 8-2-1 shows the engineering estimated cost for the pavement materials of Nalaikh - Maanti Road estimated by Intercontinental Consultants and Technocrats.

Ulaanbaatar - Altanbrag Road is mostly rehabilitation of existing road, so there is no appropriate engineering cost estimate available.

At the time, the surface type was Double Bituminous Surface Treatment (DBST) as described in Section 4.8.2 and was later changed to Asphalt Concrete Surface.

Table 8-2-1 Construction of Nalaikh-Maanti Road: Quantities and Costs

Description	Unit	Quantity	Unit Cost (US$)
Ordinary fill using borrow area materialist	m^3	319,846	2.00
Selected fill	m^3	159,923	3.50
Non-frost fill	m^3	219,254	4.50
Graded granular subbase	m^3	132,837	9.00
Graded crushed aggregate base	m^3	115,277	16.00
Double bituminous surface treatment	m^2	427,160	4.00

Table 8-2-2 shows contracted unit prices on the Ulaanbaatar - Altanbulag Road. It is also 1996 prices.

Table 8-2-2 Bill of Quantities for Periodic Maintenance of Ulaanbaatar - Darkhan Road Section

Description	Unit	Estimated quantity	Unit rate (US$)
Embankment construction (including refilling excavations where needed) using compacted suitable fill involving re-use of suitable fill materials obtained from road excavations	m^3	64,250	2.13
Embankment construction using compacted suitable fill obtained from borrow areas (including refilling excavations where needed)	m^3	130,350	2.13
Providing **subgrad**e for pavement using compacted **selected fill**	m^3	64,900	3.19
Providing improved **subgrade** for pavement using compacted selected **non-frost** fill	m^3	108,000	3.19
Providing **graded granular subbase**	m^3	92,200	7.33
Providing **graded crushed aggregate base**	m^3	116,600	13.49
Providing **prime coat on non-bituminous surface**	m^2	641,200	0.36
Providing **asphalt concrete surfacing course**	m^3	27,080	87.85

The comparison of engineering estimate and contract prices is shown in Table 8-2-3.

Table 8-2-3 Unit Price Difference

Description	Unit	Engineering Estimate in US$	Contracted Price in US$
Ordinary fill using borrow area materials	m^3	2.00	2.13
Selected fill	m^3	3.50	3.19
Non-frost fill	m^3	4.50	3.19
Graded granular subbase	m^3	9.00	7.33
Graded crushed aggregate base	m^3	16.00	13.49
Double bituminous surface treatment	m^3	4.00	-
Asphalt concrete surface course	m^3	-	87.85

The project had specified materials as shown in Table 8-2-4 and from the table, it was recognized that the price of bitumen and reinforcing steel were high, even comparing with Japanese market price of US$180-210 and US$200-250 respectively in the year 2000 (US$=¥120). This is because those materials were mostly imported from Russia, with resulting high transport costs.

Table 8-2-4 Specified Materials in ADB First Road Development Project

Material	Unit	Price (US$) and Location		Transport	Price Delivered to Site (US$)	Remarks
Bitumen	Ton	187.00	Ulaanbaatar	Train	200/ton	China, Russia
Diesel	Liter	0.18	Ulaanbaatar, Darkhan	Tank truck	0.19/litre	Local oil station
Petrol	Liter	0.20	Ulaanbaatar, Darkhan	Darkhan	0.21/litre	Local oil station
Lubricants	Liter	0.63	Ulaanbaatar, Darkhan	Darkhan	0.65/litre	Local oil station
Cement	Ton	51.00	Darkhan, Ex-factory	Cargo Truck	60/ton	Bag cement
Reinforcing Steel	Ton	235.00	Ulaanbaatar, Market	Trailer	355/ton	Local Factory, China, Russia

8.2.2 Kuwait Fund Road Construction Project

Table 8-2-5 is a rough engineering estimate of the cost for improvement and reconstruction of Darkhan - Erdenet Road by Intercontinental Consultants and Technocrats. Also, Table 8-2-6 shows the contract unit prices. The surface course in the estimate was double bituminous surface treatment and later it was changed to asphalt concrete.

Table 8-2-5 Darkhan-Erdenet Road Project Rough Estimate of the Cost in US$

	Works required to be done			
	Embankment (m^3)	**Subbase** (m^3) 230 mm	Base **(m^3)** 150 mm	**Pavement Surfacing** (m^2)
Total Quantity	318,814.52	187,547.75	130,113.75	1,080,000.00
Unit Rate	**3.50**	**8.00**	**15.00**	**5.00**

Table 8-2-6 Construction of Darkhan-Erdenet Road: Quantities and Costs

Description	Unit	Estimated Quantity	Unit Rate (US $)
Fill	m^3		
Soft material	m^3	487,031	3.54
Hard material	m^3	19.386	6.95
Subbase and Base			
Natural material for **subbase** in accordance with Sub-clause 1209 (a) of the Specifications	m^3	288,427	**6.35**
Natural material for base in accordance with Sub-clause 1209 (a) of the Specifications	m^3	27,567	**5.05**
Graded crushed stone base in accordance with Sub-clause 1209 (c) of the Specifications	m^3	117,404	**10.35**
Surfacing and Pavement Works			
Prime coat in accordance with Sub-Clause 1317	m^2	645,272	**0.40**
Asphalt concrete surfacing using 16 mm nominal sized aggregate	m^3	46,156	**92.06**

Table 8-2-7 Unit Price Comparison

Description	Unit	Engineering Estimate in US$	Contracted Price in US$
Embankment	m^3	3.50	3.54-6.95
Subbase	m^3	8.00	5.05-6.35
Base	m^3	15.00	10.35
Double bituminous surface treatment	m^2	5.00	-
Asphalt concrete surface course	m^3	-	92.06

8.3 Evaluation of Existing Pavement

The following recently completed project roads were investigated. However, ADB First Development Project between Ulaanbaatar and Altanbulag and Kuwait Fund Project between Darkhan and Erdenet were omitted since they were recently completed and wear is not yet anticipated.

8.3.1 Nalaikh - Bayan Pass Road Construction Project

This was completed in September1997. The pavement structure was 7 cm asphaltic concrete surface and 15 to 20 cm base course on embankment.

The embankment had been left for a long period so there is no settlement due to embankment consolidation. However, compared with JICA's project section, which is adjacent to the project road, some asphaltic concrete surface was already deteriorated for the following reasons.

- Poor mixing by an old asphalt mixing plant having only two hot bins, which could not mix graded aggregates.

- Use of pebbles, which do not have angular faces and a consequent lack of interlock between the pebbles.
- Low compaction and low temperature of asphaltic concrete mixing

8.3.2 Ulaanbaatar - Arvaikheer Road

The road was constructed between 10 and 26 years ago. Mostly it is simplified pavement structure based on SNIP, Russian Standard, for which cutback asphalt was used for admixing at site.

Some sections of the road are still in good condition but most sections were deteriorated as shown in Table 8-3-1. All kinds of pavement defects are present, and some are illustrated in photographs.

According to the design drawings and the construction at site, little consideration was given to the base course and proper drainage. In addition, construction was done by mostly military corps without quality control. This has resulted in more severe damage, especially at almost all cut sections where the road was completely damaged down to the subgrade. The Department of Roads has started some repair work at this section but after one winter season it is damaged again.

Table 8-3-1 Pavement Defects and Causes

No.	Type of Defects			Causes	Repairs
	Classifications	Forms	Features		
1.	Cracks	Alligator Cracks	Interconnected cracks forming a series of small blocks resembling an alligator’s skin or chicken wire.	Associated with a granular untreated base that has failed or with soft subgrade caused by moisture saturation.	Replaced the wet material by hot-mix asphalt concrete or new granular material and possibly installing drainage.
		Edge Cracks	Longitudinal cracks near the edge of the pavement, with or without transverse cracks branching towards the shoulder.	Lack of lateral or shoulder support for the asphalt pavement caused by settlement or yielding of the base material underlying the cracked area.	Filled with asphalt emulsion slurry or cutback asphalt mixed with sand.
		Joint Cracks	Edge-joint crack that occurs between the pavement and the shoulder and lane-joint crack which occurs between two adjoining paving lanes.	Alternate wetting and drying or freezing and thawing for edge-joint crack and a weak seam or poor bond between adjoining spreads for lane-joint crack.	Filled with an asphalt-emulsion slurry, asphalt compounds or heavier-bodied asphalts.
		Reflection Cracks	Found in asphalt overlays over portland cement concrete and cement-treated bases.	Vertical or horizontal movements beneath the overlay resulting from traffic loads, temperature, and earth movements.	Filled with an asphalt-emulsion slurry or a light grade of cutback asphalt and fine sand.
		Shrinkage Cracks	Interconnected cracks forming a series of large blocks, usually with sharp corners or angles.	Volume change in the asphalt mix or in the base or subgrade.	Sealed with an emulsion asphalt slurry followed by a surface treatment, a slurry seal, or an overlay on the entire surface.
		Slippage cracks	Crescent-shaped cracks resulting from horizontal forces induced by traffic.	Lack of bond between the surface layer and the course beneath due to dust, dirt, oil, or the absence of a tack coat.	Removing the surface layer from around the crack and patched with a hot-mix asphalt.
2.	Distortions	Channeling/Grooving /Rutting	Channelized depressions that develop in the wheel tracks of asphalt pavements.	Consolidation or lateral movement under traffic in one or more of the underlying courses or by displacement in the asphalt surface	Milled to a level plane or simply filled with hot-mix asphalt to be followed by an overlay across the entire pavement.
		Corrugations/Shoving	Plastic movement typified by ripples across the pavement surface or localized bulging of the pavement surface.	Lack of stability in the asphalt pavement mixtures.	Scarified, mixed with the base, and recompacted before resurfacing.
		Depressions	Depressed in localized areas of limited size that may or may not be accompanied by cracking.	Traffic heavier than that for which the pavement was designed and by consolidation or movement within the subgrade.	Filled with hot-mix asphalt and compacted to restore the area to the same grade as the surrounding pavement.
		Upheaval	Localized upward displacement of a pavement due to swelling of the subgrade or some portion of the pavement structure.	Ice expansion in the granular courses beneath the pavement or in the subgrade.	Water source to be isolated from freezing temperatures or to be drained from beneath the pavement.
3.	Disintegration	Pot Holes	Bowl-shaped holes of various sizes in the pavement resulting from localized disintegration under traffic.	Weakness in the pavement resulting from a weak subgrade or base course, too little asphalt, too thin an asphalt surface, too many fines, too few fines, or poor drainage.	Cleaning out the hole and filling it with a premixed asphalt patching material.
		Raveling	Progressive loss of surface material by weathering and/or traffic abrasion.	Poor construction methods, inferior aggregates or poor mix design.	Surface treatments include slurry seal, sand seal, or asphalt-aggregate treatment to retard progressive deterioration.
4.	Slippery Surfaces	Bleeding/Flushing	Presence of excess asphalt or a film of asphalt on the pavement surface.	Rich asphalt mixes, improperly constructed seal coats, or too heavy a prime or tack coat.	Repeated applications of hot sand, rock screenings or coarse aggregate to blot up the excess asphalt.
		Polished Aggregate	Aggregate particles worn smooth under the abrasive action of traffic.	Naturally smooth uncrushed gravels and crushed rock that wears quickly under the action of traffic.	Covered by the surface with a skid-resistant treatment.
5.	Surface Treatment Problems	Loss of Cover Aggregate	Whipping-off of aggregate under traffic -from a surface-treated pavement, leaving the asphalt film exposed.	Aggregate spread after asphalt has cooled too much, too dusty or wet when spread, not rolled or seated immediately after spreading, etc.	Hot, coarse sand spread over the affected area to replace lost aggregate.
		Longitudinal Streaking	Alternating lean and heavy lines of asphalt running parallel to the center line of the road.	Providing inadequate coverage of spray pattern at the time of asphalt spraying.	Planing off the streaked surface and applying a new surface treatment.
		Transverse Streaking	Alternating lean and heavy lines of asphalt running across the road.	Spurts in the asphalt spray from the distributor spray bar.	Planing off the streaked surface and applying a new surface treatment.

Photograph 8-3-1 Alligator Cracks **Photograph 8-3-2 Rutting**

During the site visit, the most widespread pavement defect in the hilly areas was alligator cracking based on poor drainage and unsuitable material used in the base course, as shown in Photograph 8-3-1.

The most common defect on embankment areas was rutting and corrugation, and severe corrugation has resulted in very uncomfortable riding conditions.

Photograph 8-3-3 Depression/Upheaval

Photograph 8-3-3 shows typical defects in cut on the pass. Because of poor drainage and insufficient base course material, depression and upheaval were observed.

Photograph 8-3-4 Raveling **Photograph 8-3-5 Maintenance Work**

Photograph 8-3-4 has shown raveling caused by lack of tack coating on existing layer and poor mixing and laying. Photograph 8-3-5 has shown typical maintenance work on the road. It was generally patching work, no matter how the pavement was damaged.

8.4 Evaluation of Maintenance Methods

Since the independence from the Council for Mutual Economic Assistance (COMECON) in the early 1990's the economy in Mongolia was severely damaged. In 1995, the Department of Roads had a maintenance unit but there was only one engineer employed and no budget allocated. In addition, equipment for maintenance work was aged and hard to use.

Between 1990 and 2000, there was little road maintenance work done by the Department of Roads. So most of the road constructed more than 10 to 30 years ago were severely damaged.

The Project Completion Report for the ADB First Road Development Project reported that most roads were had exceeded their life expectancies and were without proper maintenance.

In recent years, the Department of Roads has started maintenance work, which is mostly patching work. The equipment used for patching work is generally only one steel roller.

From observation of the patching work, the following are recognized.

- There is no engineer to evaluate pavement conditions at site, so even if pavement was broken due to base course or subgrade defects, only patching work was applied. This kind of patching work can last only one winter season.
- There is no quality control of asphalt mixture, especially laying temperature.
- There is not enough equipment for patching work, especially small compactors.
- There is no skilled labor at site so improper maintenance work was done, i.e., no cleaning up in patching area (removing dust) or no tack coating on existing pavement.

8.5 Proposal for Traffic Load for Designing Pavement

The Axle load survey was conducted between May 7th and 12th at Erdene Sum, Kherlen River, Tsenkher River, Murun River and Undurkhaan City.

Because the small quantity of data collected, in order to evaluate the ESAL, all locations and directions were combined and statistically analyzed.

8.5.1 ESAL Conversion

For ESAL conversion, a few methods exist such as AASHTO method, TRL method and Japanese method. In this study, we have adopted AASHTO method.

The following are conversion tables for ESAL based on the AASHTO method.

Table 8-5-1 AASHTO Asphalt Pavement Equivalent Conversion Factor (1)

Single Axle Load, Pt = 2.0

$n : \left(\frac{W}{18}\right)^n$

Pavement Structure Number (SN): 1,2,3,4,5,6

Axle Load (kips)	1	n	2	n	**3**	**n**	4	n	5	n	6	n
2	0.0002	3.87	0.0002	3.87	**0.0002**	**3.87**	0.0002	3.87	0.0002	3.87	0.0002	3.87
4	0.002	4.11	0.003	3.85	**0.002**	**4.11**	0.002	4.11	0.002	4.11	0.002	4.11
6	0.009	4.28	0.012	4.02	**0.011**	**4.08**	0.010	4.20	0.009	4.28	0.009	4.28
8	0.030	4.32	0.035	4.14	**0.036**	**4.10**	0.033	4.21	0.031	4.28	0.031	4.28
10	0.075	4.40	0.085	4.19	**0.090**	**4.10**	0.085	4.19	0.079	4.32	0.076	4.38
12	0.165	4.44	0.177	4.27	**0.189**	**4.11**	0.183	4.19	0.174	4.32	0.168	4.39
14	0.325	4.47	0.338	4.32	**0.354**	**4.13**	0.350	4.18	0.338	4.32	0.331	4.40
16	0.589	4.49	0.598	4.36	**0.613**	**4.16**	0.612	4.17	0.603	4.29	0.596	4.39
18	1.00	-	1.00	-	**1.00**	-	1.00	-	1.00	-	1.00	-
20	1.61	4.52	1.59	4.39	**1.56**	**4.22**	1.55	4.16	1.57	4.28	1.59	4.39
22	2.49	4.55	2.44	4.45	**2.35**	**4.26**	2.31	4.18	2.35	4.26	2.41	4.38
24	3.71	4.56	3.62	4.47	**3.43**	**4.28**	3.33	4.18	3.40	4.26	3.51	4.36
26	5.36	4.57	5.21	4.49	**4.88**	**4.31**	4.68	4.20	4.77	4.25	4.96	4.36

This table shows the case of a single axle load and a Terminal Serviceability Index (Pt) of 2.0. The structure number is variable, however most projects in Mongolia have adopted 5 cm (2 in) AC surface, approximately 20 cm (8 in) base course and 30 cm (12 in) subbase shown in Section 4.8.7. This structure gets the following structure number.

$$SN = 2 \times 0.42 + 0.14 \times 8 + 0.08 \times 12 = 2.92$$

From this calculation, we have selected SN = 3 in the table for computation of ESAL. In addition, for the tandem axles, the following table is adopted.

Table 8-5-2 AASHTO Asphalt Pavement Equivalent Conversion Factor (2)

Tandem Axle Loads, Pt=2.0 $n : \left(\frac{W}{18 \times 2}\right)^n$

Pavement Structure Number (SN) : 1,2,3,4,5,6

Axle Load (kips)	1	n	2	n	**3**	**n**	4	n	5	n	**6**	n
2	0.0000	-	0.0000	-	**0.0000**	-	0.0000	-	0.0000	-	0.0000	-
4	0.0003	3.70	0.0003	3.70	**0.0003**	**3.70**	0.0002	3.86	0.0002	3.86	0.0002	3.86
6	0.001	3.85	0.001	3.85	**0.001**	**3.85**	0.001	3.85	0.001	3.85	0.001	3.85
8	0.003	3.87	0.003	3.87	**0.003**	**3.87**	0.003	3.87	0.003	3.87	0.002	4.15
10	0.007	3.88	0.008	3.88	**0.008**	**3.88**	0.007	4.12	0.006	4.25	0.006	4.25
12	0.013	3.95	0.016	3.76	**0.016**	**3.76**	0.014	3.88	0.013	3.95	0.012	4.02
14	0.024	4.23	0.029	4.02	**0.029**	**4.02**	0.029	4.02	0.024	4.23	0.023	4.28
16	0.041	3.94	0.048	3.75	**0.050**	**3.70**	0.046	3.79	0.042	3.92	0.040	3.96
18	0.066	3.92	0.077	3.70	**0.081**	**3.62**	0.075	3.73	0.069	3.86	0.066	3.92
20	0.103	3.86	0.117	3.65	**0.124**	**3.55**	0.117	3.65	0.109	3.77	0.105	3.83
22	0.156	3.77	0.171	3.58	**0.183**	**3.45**	0.174	3.55	0.164	3.66	0.158	3.74
24	0.227	3.65	0.244	3.48	**0.260**	**3.32**	0.252	3.38	0.239	3.54	0.231	3.60
26	0.322	3.48	0.340	3.32	**0.360**	**3.14**	0.353	3.20	0.338	3.33	0.329	3.42

8.5.2 Representative ESAL for the Vehicles on the Project Road

Based on the axle load survey, types of vehicles are divided into four categories such as Ordinary Truck, Heavy Truck, Trailer and Bus.

ESAL for each category is shown in Tables 8-5-3- to 8-5-6 respectively.

Table 8-5-3 Representative ESAL for Ordinary Truck

No.	Axle Load 1 (t)	ESAL 1	Axle Load 2 (t)	ESAL 2	Axle Load 3 (t)	ESAL 3	Axle Load 4 (t)	ESAL 4	Axle Load 5 (t)	ESAL 5	Axle Load 6 (t)	ESAL 6	Total Load	ESAL Total
1	1.975	0.003	2.300	0.006	-	-	-	-	-	-	-	-	4.275	0.009
2	2.350	0.006	1.900	0.002	-	-	-	-	-	-	-	-	4.250	0.009
3	1.500	0.001	2.550	0.009	-	-	-	-	-	-	-	-	4.050	0.010
4	1.550	0.001	2.750	0.012	-	-	-	-	-	-	-	-	4.300	0.013
5	2.350	0.006	2.600	0.009	-	-	-	-	-	-	-	-	4.950	0.016
6	2.450	0.007	2.850	0.014	-	-	-	-	-	-	-	-	5.300	0.021
7	2.175	0.004	3.000	0.017	-	-	-	-	-	-	-	-	5.175	0.021
8	2.400	0.007	2.900	0.015	-	-	-	-	-	-	-	-	5.300	0.021
9	1.550	0.001	3.200	0.021	-	-	-	-	-	-	-	-	4.750	0.022
10	2.550	0.009	2.950	0.016	1.300	0.001	1.300	0.001	-	-	-	-	5.500	0.026
11	2.450	0.007	3.050	0.018	1.300	0.001	1.400	0.001	-	-	-	-	5.500	0.026
12	2.500	0.008	3.100	0.019	1.300	0.001	1.300	0.001	-	-	-	-	5.600	0.028
13	2.500	0.008	3.150	0.020	-	-	-	-	-	-	-	-	5.650	0.028
14	2.650	0.010	3.200	0.021	1.300	0.001	1.200	0.001	-	-	-	-	5.850	0.033
15	2.550	0.009	3.300	0.024	1.400	0.001	1.250	0.001	-	-	-	-	5.850	0.035
16	2.700	0.011	3.400	0.027	-	-	-	-	-	-	-	-	6.100	0.038
17	2.600	0.009	3.300	0.024	2.300	0.006	-	-	-	-	-	-	5.900	0.039
18	2.650	0.010	3.500	0.031	-	-	-	-	-	-	-	-	6.150	0.042
19	2.750	0.012	3.500	0.031	-	-	-	-	-	-	-	-	6.250	0.043
20	2.800	0.013	3.450	0.029	1.600	0.001	1.350	0.001	-	-	-	-	6.250	0.044
21	2.550	0.009	3.500	0.031	2.100	0.004	1.700	0.002	-	-	-	-	6.050	0.045
22	2.750	0.012	3.800	0.043	-	-	-	-	-	-	-	-	6.550	0.055
23	2.500	0.008	3.950	0.051	-	-	-	-	-	-	-	-	6.450	0.059
24	2.550	0.009	4.000	0.053	-	-	-	-	-	-	-	-	6.550	0.062
25	0.010	3.600	0.035	2.800	0.013	2.350	0.006	-	-	-	-	-	0.045	0.064

26	2.700	0.011	4.000	0.053	-	-	-	-	-	-	-	-	6.700	0.064
27	2.800	0.013	4.100	0.059	-	-	-	-	-	-	-	-	6.900	0.072
28	2.600	0.009	3.900	0.048	2.900	0.014	2.300	0.006	-	-	-	-	6.500	0.077
29	2.400	0.007	4.300	0.072	-	-	-	-	-	-	-	-	6.700	0.079
30	1.500	0.001	4.450	0.083	-	-	-	-	-	-	-	-	5.950	0.084
31	2.750	0.012	4.600	0.095	-	-	-	-	-	-	-	-	7.350	0.107
32	2.550	0.009	4.650	0.099	2.000	0.003	1.300	0.001	-	-	-	-	7.200	0.111
33	2.500	0.008	4.800	0.113	-	-	-	-	-	-	-	-	7.300	0.121
34	2.650	0.010	5.000	0.133	1.400	0.001	1.400	0.001	-	-	-	-	7.650	0.144
35	2.700	0.011	5.300	0.169	-	-	-	-	-	-	-	-	8.000	0.180
36	2.600	0.009	5.450	0.189	-	-	-	-	-	-	-	-	8.050	0.199
37	2.600	0.009	5.500	0.196	-	-	-	-	-	-	-	-	8.100	0.206
38	2.750	0.012	4.800	0.113	4.100	0.059	3.750	0.041	-	-	-	-	7.550	0.225
39	2.750	0.012	5.650	0.219	2.800	0.013	3.050	0.018	-	-	-	-	8.400	0.261
40	2.750	0.012	5.900	0.262	-	-	-	-	-	-	-	-	8.650	0.274
41	2.800	0.013	5.050	0.138	3.650	0.037	4.550	0.091	-	-	-	-	7.850	0.279
42	2.750	0.012	6.000	0.279	-	-	-	-	-	-	-	-	8.750	0.291
43	2.850	0.014	5.000	0.133	4.150	0.062	4.500	0.087	-	-	-	-	7.850	0.295
44	2.750	0.012	6.050	0.289	-	-	-	-	-	-	-	-	8.800	0.301
45	2.450	0.007	6.100	0.299	-	-	-	-	-	-	-	-	8.550	0.306
46	2.600	0.009	5.950	0.271	3.200	0.021	3.300	0.024	-	-	-	-	8.550	0.326
47	2.600	0.009	5.050	0.138	4.400	0.079	4.700	0.104	-	-	-	-	7.650	0.330
48	2.650	0.010	5.050	0.138	4.400	0.079	4.900	0.123	-	-	-	-	7.700	0.350
49	2.400	0.007	6.350	0.353	-	-	-	-	-	-	-	-	8.750	0.360
50	2.700	0.011	6.350	0.353	-	-	-	-	-	-	-	-	9.050	0.364
51	2.750	0.012	6.350	0.353	2.500	0.008	3.050	0.018	-	-	-	-	9.100	0.390
52	2.950	0.016	6.450	0.376	-	-	-	-	-	-	-	-	9.400	0.392
53	2.650	0.010	5.900	0.261	4.450	0.083	3.950	0.051	-	-	-	-	8.550	0.405
54	2.550	0.009	6.150	0.309	3.700	0.039	4.000	0.053	-	-	-	-	8.700	0.410
55	2.650	0.010	6.650	0.427	4.100	0.059	4.200	0.065	-	-	-	-	9.300	0.561
56	2.600	0.009	6.750	0.454	4.500	0.087	4.700	0.104	-	-	-	-	9.350	0.654
57	3.350	0.026	7.550	0.719	3.600	0.035	3.200	0.022	-	-	-	-	10.900	0.802
58	2.350	0.006	6.950	0.415	5.400	0.000	6.500	0.389	-	-	-	-	21.200	0.810
59	3.850	0.046	7.750	0.802	2.600	0.009	2.600	0.009	-	-	-	-	11.600	0.866
60	3.850	0.046	6.550	0.401	6.700	0.440	-	-	-	-			10.400	0.887
61	2.550	0.009	8.500	1.000	-	-	-	-	-	-	-	-	11.050	1.009
62	2.700	0.011	8.300	1.000	-	-	-	-	-	-	-	-	11.000	1.011
63	3.150	0.020	6.900	0.497	6.000	0.279	7.100	0.557	-	-	-	-	10.050	1.354
64	2.700	0.011	8.950	1.468	-	-	-	-	-	-			11.650	1.479
65	2.800	0.013	9.050	1.538	-	-	-	-	-	-	-	-	11.850	1.551
66	2.900	0.015	9.700	2.061	-	-	-	-	-	-	-	-	12.600	2.076
67	2.850	0.014	10.350	2.736	4.200	0.065	3.700	0.039	-	-	-	-	13.200	2.854
68	2.750	0.012	9.800	2.168	8.400	1.000	8.850	1.400	-	-	-			4.580
													Simple average	**0.416**

Within the above 68 data, data has some variation so statistical analysis is required to get a representative ESAL for ordinary trucks. According to Thomson's reject method, three largest data (2.076, 2.854 and 4.580) were rejected by 1% significant level.

After rejecting those three data, average value is 0.289 and 75 percentile value 0.362. As a representative ESAL for ordinary trucks, take 0.362.

Table 8-5-4 Representative ESAL for Heavy Truck

No.	Axle Load 1 (t)	ESAL 1	Axle Load 2 (t)	ESAL 2	Axle Load 3 (t)	ESAL 3	Axle Load 4 (t)	ESAL 4	Axle Load 5 (t)	ESAL 5	Axle Load 6 (t)	ESAL 6	Total Load	ESAL Total
1	3.20	0.022	**2.05**	0.004	**1.80**	0.000	-	-				2	7.050	0.026
2	3.70	0.039	**2.10**	0.007	**2.40**	0.000	1.60	0.001	1.85	0.002	-	-	8.200	0.049
3	3.40	0.028	3.80	0.043	-	-	-	-					7.200	0.071
4	3.80	0.043	3.55	0.033	-	-	-	-	-	-	-	-	7.350	0.076
5	4.15	0.062	7.25	0.049	-	-	-	-					11.400	0.112
6	3.10	0.019	6.30	0.341	-	-	-	-					9.400	0.361
7	3.10	0.019	6.30	0.341	-	-	-	-					9.400	0.361
8	2.80	0.013	**6.30**	0.415	**6.05**	0.000	-	-	-	-			15.150	0.427
9	4.80	0.113	**6.25**	0.374	**5.70**	0.000	-	-	-	-	-	-	16.750	0.487
10	3.95	0.051	**6.20**	0.442	**6.40**	0.000	-	-	-	-	-	-	16.550	0.493
11	3.65	0.037	**6.05**	0.588	**7.75**	0.000	-	-					17.450	0.625
12	3.75	0.042	8.45	1.000	-	-	-	-	-	-			12.200	1.042
13	4.60	0.095	**8.20**	0.954	**7.90**	0.000	-	-					20.700	1.049
14	3.55	0.033	**8.05**	0.622	**6.00**	0.000	7.70	0.781	**1.40**	0.001	**1.25**	0.000	17.600	1.437
15	2.45	0.007	**7.40**	0.935	**8.60**	0.000	7.35	0.643					18.450	1.586
16	3.70	0.039	**9.75**	1.797	**9.40**	0.000	-	-					22.850	1.837
17	4.15	0.062	**9.10**	1.142	**7.95**	0.000	7.05	0.541	6.90	0.495			21.200	2.240
18	4.10	0.060	**10.00**	1.915	**10.10**	0.000	8.80	1.353	9.60	1.929			24.200	5.256
19	4.65	0.099	15.80	17.143	-	-	-	-					20.450	17.242
20	4.65	0.100	15.80	17.143	-	-	-	-					20.450	17.243

Note: Bold letter shows tandem load, ESAL is represented by first axle. Simple Average 2.601

Among the above 20 data, a similar method to the ordinary truck data was applied. According to Thomson's reject method, the largest three data (5.256, 17.242 and 17.243) were rejected by 1% significant level.

As a representative ESAL for heavy truck, 1.047 is used.

Table 8-5-5 Representative ESAL for Trailer

No.	Axle Load 1 (t)	ESAL 1	Axle Load 2 (t)	ESAL 2	Axle Load 3 (t)	ESAL 3	Axle Load 4 (t)	ESAL 4	Axle Load 5 (t)	ESAL 5	Axle Load 6 (t)	ESAL 6	Total Load	ESAL Total
1	3.65	0.037	**3.65**	0.057	**3.90**	0.000	-	-	-	-	-	-	11.20	0.094
2	4.40	0.079	**5.90**	0.090	**2.50**	0.000	2.70	0.011	-	-	-	-	12.80	0.180
3	2.80	0.013	**7.75**	1.284	**9.95**	0.000	-	-					20.50	1.297
4	5.10	0.145	**9.10**	1.578	**9.80**	0.000	6.30	0.341	6.50	0.389	-	-	24.00	2.453
5	3.35	0.026	**7.90**	1.001	**8.45**	0.000	7.60	0.739	7.75	0.802			19.70	2.568
6	3.40	0.028	**6.60**	0.694	**7.95**	0.000	7.85	1.000	8.40	1.000			17.95	2.722
7	4.80	0.113	**9.30**	1.769	**10.30**	0.000	6.70	0.440	6.80	0.468	-	-	24.40	2.790
8	3.70	0.039	**7.85**	0.881	**7.85**	0.000	7.95	1.000	8.50	1.000			19.40	2.921
9	5.90	0.260	**10.10**	1.476	**8.40**	0.000	9.90	2.264					24.40	4.000
10	5.90	0.265	**10.35**	1.729	**8.60**	0.000	9.90	2.264					24.85	4.258
11	3.30	0.025	**8.40**	1.132	**8.60**	0.000	8.80	1.353	9.90	2.187			20.30	4.696
12	5.10	0.146	**8.30**	1.111	**8.60**	0.000	10.50	2.781	10.90	3.239			22.00	7.276
13	4.95	0.129	**10.50**	2.230	**10.60**	0.000	11.50	4.030	12.10	4.960			26.05	11.350
14	4.45	0.083	**9.10**	1.645	**10.05**	0.000	11.85	4.961	12.05	5.332			23.60	12.021
15	4.90	0.124	**10.20**	2.116	**10.55**	0.000	11.75	4.400	12.70	6.043			25.65	12.683
16	4.55	0.092	**10.20**	2.100	**10.50**	0.000	14.55	10.524	13.55	7.871			25.25	20.586
17	5.00	0.133	**11.70**	3.276	**12.15**	0.000	15.00	11.917	**15.45**	7.577	**15.70**	0.000	28.85	22.903
18	4.90	0.123	**11.70**	3.255	**12.10**	0.000	14.70	12.560	**15.10**	7.092	**15.40**	0.000	28.70	23.030

Note: Bold letter shows tandem load, ESAL is represented by first axle. Simple average 7.657

For Trailers, the same analysis method was applied for 18 data and one datum was rejected. Then the average value is 7.657, which is adopted.

Table 8-5-6 Representative ESAL for Bus

No.	Axle Load 1 (t)	ESAL 1	Axle Load 2 (t)	ESAL 2	Axle Load 3 (t)	ESAL 3	Axle Load 4 (t)	ESAL 4	Axle Load 5 (t)	ESAL 5	Axle Load 6 (t)	ESAL 6	Total Load	ESAL Total
1	2.000	0.003	3.600	0.035	-	-	-	-	-	-	-	-	5.600	0.038
2	2.600	0.009	3.600	0.035	-	-	-	-	-	-	-	-	6.200	0.045
3	1.800	0.002	4.050	0.056	-	-	-	-	-	-	-	-	5.850	0.058

Simple average **0.047**

Since the number of data is limited to three, it is not reliable to use this value for future ESALs. Therefore 0.426 was selected as an ESAL for Buses. This value has come from the ADB First Road Development Project, Detailed Engineering for Nalaikh - Maanti Road Final Report, in February 1999.

ESAL for vehicle composition is as shown in Table 8-5-7.

Table 8-5-7 ESAL for Vehicle Composition

Vehicle Composition	Representative ESAL/Vehicle
Ordinary Truck	**0.362**
Heavy Truck	**1.047**
Trailer	**7.657**
Bus	**0.426**

8.5.3 Estimated ESAL's on the Project Road

From Chapter 3: Socio-economic Study, Framework and Forecast of Traffic Demand, sectional traffic demands are estimated for years 2005, 2010 and 2015 respectively based on traffic in year 2000. Results are shown in Table 8-5-8.

Table 8-5-8 Future Traffic Demand for Five-Vehicle Composition

Year	ALL	Growth Rates (%)	Car	Growth Rates (%)	Bus	Growth Rates (%)	S-Truck	Growth Rates (%)	M-Truck	Growth Rates (%)	L-Truck	Growth Rates (%)
Erdene - Baganuur												
2000	689	-	357	-	155	-	14	-	123	-	40	-
2005	835	1.04	430	1.04	187	1.04	18	1.05	150	1.04	50	1.05
2010	1063	1.05	548	1.05	237	1.05	25	1.07	188	1.05	65	1.05
2015	1417	1.06	716	1.05	325	1.07	33	1.06	250	1.06	93	1.07
Baganuur - Jargaltkhaan												
2000	426	-	216	-	72	-	11	-	95	-	32	-
2005	630	1.08	308	1.07	113	1.09	20	1.13	140	1.08	49	1.09
2010	907	1.08	437	1.07	168	1.08	30	1.08	214	1.08	68	1.07
2015	1352	1.08	640	1.08	256	1.09	41	1.06	317	1.09	98	1.08
Jargaltkhaan - Murun												
2000	316	-	144	-	57	-	9	-	82	-	24	-
2005	453	1.07	201	1.07	84	1.08	14	1.09	119	1.08	35	1.08
2010	656	1.08	286	1.07	127	1.09	21	1.08	174	1.08	48	1.07
2015	994	1.09	428	1.08	192	1.09	30	1.07	275	1.10	69	1.08
Murun - Undurkhaan												
2000	330	-	156	-	57	-	9	-	86	-	24	-
2005	478	1.08	222	1.07	84	1.08	14	1.09	125	1.08	35	1.08
2010	702	1.08	324	1.08	127	1.09	21	1.08	184	1.08	48	1.07
2015	994	1.09	496	1.09	192	1.09	30	1.07	289	1.10	69	1.08

In Section 8.5.1: data was classified into four-vehicle composition: ordinary truck, heavy truck, trailer and bus. To convert the vehicle composition into ESAL composition, calculation was as follows.

Using the ratio of Heavy Truck and Trailer on the data mentioned in the Table 8-5-9, future traffic demand for each vehicle categories is obtained. The results are shown in Table 8-5-10. The ratio of Heavy Truck and Trailer is assuming 49% and 51%.

Table 8-5-9 Vehicle Compositions for ESAL's

	S-Truck	MR-Truck	MA-Truck	Tractor	LR-Truck	LA-Truck
ESAL Classification	**Ordinary Truck**				**Heavy Truck**	**Trailer**
Erdene Sum	14	23	12	1	12	5
	-	-	-	-	(70.6 %)	(29.4 %)
Kherlen River	3	13	5	1	7	3
	-	-	-	-	(70.0 %)	(30.0 %)
Tsenkher River	2	10	12	0	2	8
	-	-	-	-	(20.0 %)	(80.0 %)
Murun River	6	8	6	0	1	4
					(20.0 %)	(80.0 %)
Undurkhaan City	1	2	2	1	1	4
	-	-	-	-	(20.0 %)	(80.0 %)
Total	26	56	37	3	**23**	**24**
	-	-	-	-	**(48.9 %)**	**(51.1 %)**

Table 8-5-10 Future Traffic Demand for Four-Vehicle Composition

Erdene - Baganuur

Year	**Bus**	Growth Rates	**Ordinary Truck**	Growth Rates	**Heavy Truck**	Growth Rates	**Trailer**	Growth Rates
2000	155	-	137	-	20	-	20	-
2005	187	1.04	168	1.04	25	1.05	26	1.05
2010	237	1.05	213	1.05	32	1.05	33	1.05
2015	325	1.07	283	1.06	46	1.07	47	1.07
Baganuur - Jargaltkhaan								
2000	72	-	106	-	16	-	16	-
2005	113	1.09	160	1.09	24	1.09	25	1.09
2010	168	1.08	234	1.08	33	1.07	35	1.07
2015	256	1.09	358	1.09	48	1.08	50	1.08
Jargaltkhaan - Murun								
2000	57	-	91	-	12	-	12	-
2005	84	1.08	133	1.08	17	1.08	18	1.08
2010	127	1.09	195	1.08	24	1.07	24	1.07
2015	192	1.09	305	1.09	34	1.08	35	1.08
Murun - Undurkhaan								
2000	57	-	95	-	12	-	12	-
2005	84	1.08	139	1.08	17	1.08	18	1.08
2010	127	1.09	205	1.08	24	1.07	24	1.07
2015	192	1.09	319	1.09	34	1.08	35	1.08

From Table 8-5-10, cumulative ESAL is as shown in Table 8-5-11.

Table 8-5-11 Cumulative ESAL for Four Vehicle Categories

Erdene - Baganuur

Year	**Bus**	Cumulative ESAL	**Ordinary Truck**	Cumulative ESAL	**Heavy Truck**	Cumulative ESAL	**Trailer**	Cumulative ESAL	ESAL for the section
2000	155	-	137	-	20	-	20	-	-
2005	187	132,944	168	100,749	25	42,572	26	321,333	**298,700**
2010	237	164,819	213	125,854	32	54,252	33	410,592	**676,000**
2015	325	218,463	283	163,841	46	74,315	47	560,463	**1,184,900**

Baganuur - Jargaltkhaan

2000	72	-	106	-	16	-	16	-	-
2005	113	71,914	160	87,866	24	38,216	25	286,468	**242,200**
2010	168	109,232	234	130,148	33	54,457	35	419,221	**598,700**
2015	256	164,819	358	195,552	48	77,386	50	593,896	**1,14,500**

Jargaltkhaan - Murun

2000	57	-	91	-	12	-	12	-	-
2005	84	54,810	133	73,993	17	27,564	18	210,651	**183,500**
2010	127	82,021	195	108,347	23	38,776	24	292,651	**444,300**
2015	192	124,0.	305	165,163	34	54,661	35	414,043	**823,200**

Murun - Undurkhaan

2000	57	-	95	-	12	-	12	-	**-**
2005	84	54,810	139	77,296	17	27,564	18	210,651	**185,100**
2010	127	82,021	205	113,632	23	38,776	24	292,651	**448,600**
2015	192	124,003	319	173,090	34	54,661	35	414,043	**831,400**

The cumulative ESALs for 10 years are 0.44 x 10^6~ 0.68 x 10^6 ranges and these ranges are similar to those of other major arterial roads such as Ulaanbaatar ~ Darkhan Road estimated by ICT for ADB First Road Development Project (0.40 x 10^6), Darkhan ~ Erdenet Road estimated by ICT for Kuwait Fund Road Project (0.5 x 10^6).

8.6 Classification of the Pavement

To identify the optimum pavement structure for the project route, selection must consider a number of factors, as shown in Table 8-6-1.

Asphalt pavement is the most suitable pavement structure for the project route because of the strength, durability, riding comfort and low maintenance cost. However, to identify the optimum pavement structure, further study of the pavement structures are required.

Table 8-6-1 Comparison of Pavement Structure Options

	Type of the Pavement	Surface Material	How to use material	Strength	Durability	Riding Comfort	Initial Cost	Maintenance Cost	Characteristics
Road Structure	Non-paved road	Natural Earth Road	-	*minimum Depending on bearing capacity of existing ground	*Nil	*Bad	*Not Necessary	*Not Necessary If existing route was damaged then passes through next route anywhere.	1) Easily ruts 2) Angular stone damages tires 3) Dust problem by traffic
		Gravel Road	Gravel Only laid	*Low to Medium For only light traffic	*Low	*Bad	*Very Little	*Low maintenance cost but frequent maintenance required.	1) Easy to lay down 2) Angular stone damages tires 3) Dust problem by traffic
	Paved Road	Asphalt Pavement	Asphalt Surface Treatment	*Medium Similar design method with HMA. Strength of surface is not considered. For light to medium traffic.	*Medium Same durability with HMA below Base course. Surface is 2 to 3 years durability.	*Fair	*Low to Medium	*Low maintenance cost but more frequent maintenance required than HMA.	Basic characteristic of the asphalt is same as HMA
			Hot Mixed Hot Laid Asphalt (HMA)	*Large Design of pavement structure based on subgrade bearing capacity. Not strong for static load.	*Large Generally 10 years Life expectancy. But less life expectancy in severe climate condition In addition, strong ultraviolet ray area.	*Excellent	*Large Installation of asphalt mixing plant and crushing plant. Paving equipment such as Paver, road roller and tire roller	*Low maintenance cost in general but very large maintenance required when reached the life end. Clack repair required in cold weather country. Surface treatment required in strong ultraviolet ray area.	1) Generally not strong for temperature change (Rutting in high temperature and embrittlement destruction in low temperature) 2) Weak for static load 3) Weal for Ultraviolet ray
		Cement Concrete Pavement	Portland Cement Concrete Pavement	*Maximum	*Maximum Generally more than 20 years.	Good Disadvantage in Joint	*Very large	*No maintenance cost required in general but maximum maintenance cost required when reached life end.	1) Needs more preparation work such as forming 2) Paving speed is very low
			Pre-cast Concrete Pavement	*Maximum	*Maximum Generally more than 20 years.	Good Disadvantage in Joint	*Very large	*No maintenance cost required in general but maximum maintenance cost required when reached life end.	1) Prefabricate in the factory 2) Shorter construction time than ordinary cement concrete pavement

8.7 Selection of Optimum Type of Pavement Surface

8.7.1 Introduction

Since the Eastern Arterial Road (EAR) is designated as a part of Millennium Road to accommodate incremental vehicular traffic, the pavement structure should be bearable and durable enough for all-weather use.

The pavement is to be designed to fulfill functions such as:

1) sufficient total thickness and internal strength to carry expected traffic loads;
2) adequate compaction to prevent the penetration or internal accumulation of moisture; and
3) a top surface that is smooth, skid resistant, and resistant to wear, distortion, and deterioration by weather and deicing chemicals.

Asphalt concrete pavement that is designed strong enough will require bigger initial investment but less maintenance cost. Moreover, an excessive investment to pavement might result in shortage of fund to build a necessary road in anticipated length.

On the other hand, bituminous surface treatment that has similar pavement thickness will require comparatively small initial investment but bigger maintenance cost to keep the same serviceability. Furthermore, it will incur additional investment to execute intensive rehabilitation works unless appropriate repair works are undertaken timely at damaged portion.

"Life Cycle Cost (LCC)" analysis that compares totaling costs of initial investment, maintenance and repair costs with total benefits at present value enables to examine whether an initial investment is optimum or not to select a type of pavement.

8.7.2 Cost Comparison by Embankment Height and by Type of Pavement

Generally, cost estimates are carried out using unit price analysis of certain project. Such quoted unit prices are deemed to represent a prevailing market price in current business circles. However, particular attention should be paid to reality of unit prices, considering the characteristics of civil work such as material availability, hauling distance and volume of work.

The EAR has a typical cross section of which the road comprises structures as shown in Figure 8-7-1.

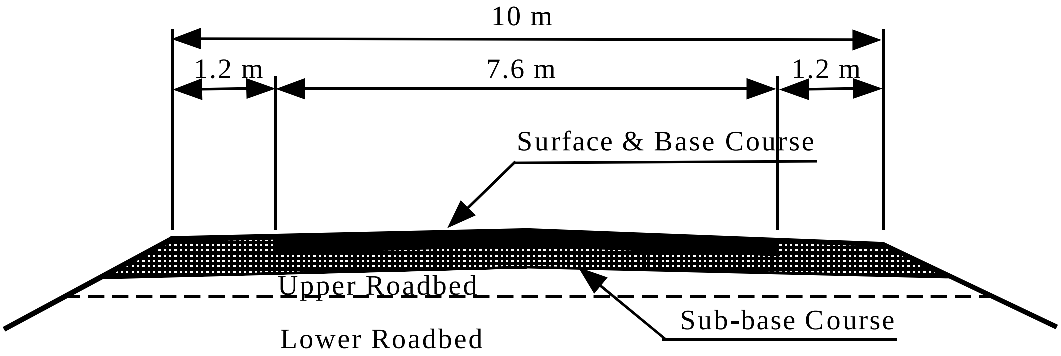
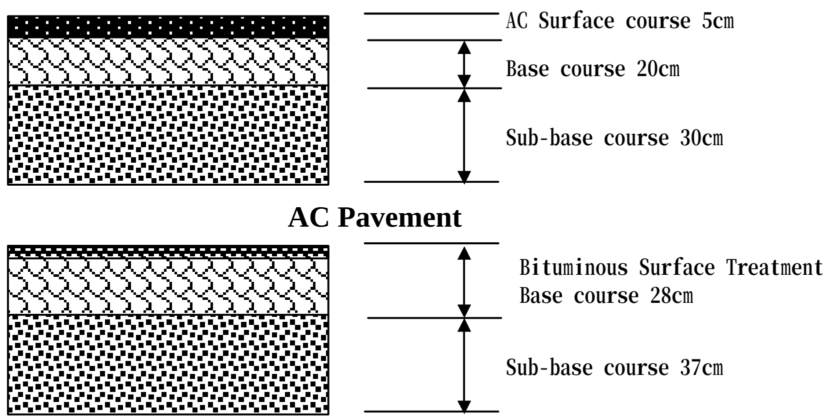


Figure 8-7-1 Typical Cross Section and Road Structure

For the purpose of comparison, following two types of pavement are selected as the representatives of actual practice in Mongolia, namely Asphalt Concrete (AC) Pavement and Bituminous Surface Treated (BST) Pavement.



BST Pavement

Figure 8-7-2 Selected Types of Pavement Structure for Comparison Study

The following unit prices are referred for the purpose of cost comparison.

Table 8-7-1 Unit Prices of Pavement Structures

Work Items	5cm thick AC surfacing including prime coat	BST surfacing including base material for repair	Graded crushed stone base	Natural material for subbase	Non-frost fill for Upper Roadbed	Ordinary fill for Lower Roadbed
Unit	$/m^2	$/m^2	$/m^3	$/m^3	$/m^3	$/m^3
Unit Price	5.00	0.70	10.35	6.35	4.50	3.54

Figure 8-7-3 shows cost difference between two types of pavement after direct construction cost of pavement per 1 km is calculated at each embankment height. It reveals that the cost difference depends on type of pavement and such difference is less significant according to the increase of embankment height. It may point out the fact that the type of pavement is not significant to cost-wise matter as far as the material is available in case that the embankment height is enough high.

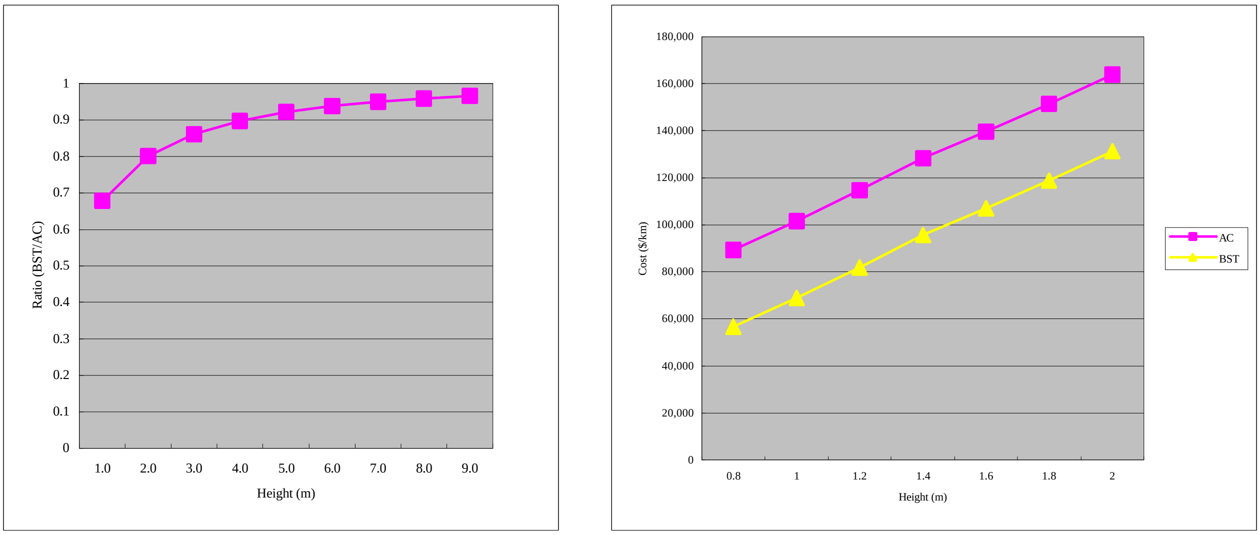


Figure 8-7-3 Cost Difference Between Two Types of Pavement, AC and BST

8.7.3 Advantages of Asphalt Concrete Pavement

Both flexible pavements of Asphalt Concrete (AC) pavement and BST pavement theoretically have the same function on the basis of similar pavement structure. The pavement spreads the wheel load to the subgrade so that the maximum pressure on the subgrade is small enough to be easily supported by the subgrade in case of proper selection of pavement materials and with adequate pavement thickness. Simultaneously, the surface of a flexible pavement exposed to vehicular traffic should be tough to resist distortion and provide a smooth, skid resistant riding surface. It should be waterproof and sloped to shed surface water to the roadside to protect the entire flexible pavement structure and the subgrade from the weakening effects of moisture. It should resist wear and retain necessary anti-skid properties. It should also be bonded to the layer or course beneath it.

However, AC pavement has many advantages except cost-wise matter compared with BST pavement from technical viewpoints, provided that plant-mix asphalt concrete and construction equipment are available. Many forms of pavement defect that might be found after opening to public are summarized in Table 8-3-1. AC pavement is superior to BST pavement that badly requires in-situ technique in the aspects of resisting distortions and disintegrations as well as no risk of problems caused by surface treatment. Accordingly, AC pavement may be recommended technically to the place where the embankment height is enough high and plant-mix asphalt concrete and construction equipment are available.

8.7.4 Life Cycle Cost (LCC) Analysis on Type of Pavement

The EAR has salient features from engineering aspects such as relatively low traffic, extreme climatic conditions and freeze-thaw cycle where empiricism still plays an important role even up to the present day. One of such features is inevitable thermal cracking that is induced by low-temperature and thermal fatigue on the flexible pavement. For the purpose of LCC analysis, the following assumptions are taken even though the pavement design procedure is adopted to perform averting failure criteria during design life:

(1) Routine maintenance including thermal cracks filled with asphalt emulsion slurry for both AC pavement and BST pavement.
(2) Design life of 20 years for AC pavement with overlay at 10 years interval.
(3) Surface dressing at 2 years interval on BST pavement due to keeping similar roughness of AC pavement and avoiding particular surface treatment problems.

LCC analyses are conducted at two sections of the EAR, namely Erdene to Baganuur and Murun to Undurkhaan. The former section is a representative for relatively heavy traffic volume and high embankment, and the latter is for low embankment with small traffic.

The principal economic benefits are savings in vehicle operating costs. With the new paved road the average IRI is expected to be about 3.0, compared with 14.0 for the without case. With good standard routine maintenance and surface dressing every two years, it is considered that an IRI of about 3.0 could be sustained throughout the period 2004 to 2025. The traffic details used in the economic analysis are based on the analyses in Chapter 3. In addition to benefits attributable to normal traffic, it is considered that the paved road would lead to a modest amount of generated traffic. Travel time savings have not been included in the preliminary economic analysis. This conservative approach reflects the inherent difficulty of putting a value on travel time.

Vehicle operating costs in 2001 economic prices are shown below, based on the RED (roads economic decision) VOC model developed by the World Bank.

Table 8-7-2 Vehicle Operating Costs in $ per Vehicle km

Vehicle Type	IRI 14 without project	IRI 3 WITH PROJECT	VOC saving
Car	0.234	0.100	0.134
Bus (medium)	0.189	0.126	0.063
Small Truck	0.160	0.088	0.072
Medium Truck	0.251	0.159	0.092
Large Truck	0.415	0.258	0.157

Table 8-7-3 Results of LCC Analysis

Section		Type	Initial Investment* (M. $)	NPV (Thousand $)	EIRR
Erdene - Baganuur	L= 33 km	AC	10,399	1,420	13.9%
		BST	9,639	1,792	14.5%
Murun - Undurkhaan	L= 67 km	AC	9,811	736	13.2%
		BST	7,508	6,243	20.8%

Note: * shows estimated costs of pavement and embankment only on the assumption that the former is 4m high on average and the latter is 2 m. Costs of bridges and structures are excluded for the sake of analysis.

8.7.5 Selection of Pavement Surface

The LCC analysis shows that BST pavement is superior to AC pavement in the section of Murun to Undurkhaan, while it can be seen that both are almost equal in the section of Erdene to Baganuur.

The existing Asphalt Plant that was procured by Japan's grant aid is located at Erdene and it can supply asphalt concrete to a construction site along National Highway No.A0501. In Mongolia, asphalt concrete can deliver 100 km at most, provided that a dump truck can haul it on paved road. It is also pointed out that some maintenance and repair works require asphalt concrete after the road is open to public.

On the contrary, AC pavement is not practical in Murun to Undurkhaan, because the existing Asphalt Plant at Erdene is enough far and hot-mixed asphalt concrete is not available. BST pavement requires in-situ techniques at the stage of both construction and maintenance, using the same construction equipment.

The following type of pavement is proposed to each section, considering results of LCC analysis, equipment availability and ease of maintenance.

Section	Type of Pavement
Erdene - Tsenkhermandal West :	AC Pavement
Tsenkhermandal West - Undurkhaan :	BST Pavement

CHAPTER 9 PROPOSITION OF ALTERNATIVE SOLUTIONS

CHAPTER 9 PROPOSITION OF ALTERNATIVE SOLUTIONS

9.1 Consideration for Crossing Point of Kherlen River

(1) Description

The Kherlen River is the third longest river in Mongolia, 1,090 km long. The Kherlen River flows on the border of Tuv and Khentii Provinces and it is natural river, namely without any structures such as guide bank, revetment and so on.

The waterway of the river crossing point is classified into three sections in the Study: namely, flooding and meandering area in the north, transition area in the middle and converging area in the south. These salient features are brought by geographical features in the surroundings of the Kherlen River.

The Khentii Nuruu Mountain is close to the river and a range of mountains guide the river flow, while the Nuga steppe spreads in the west. The flooding and meandering area extends in the Nuga steppe due to the flat terrain. The Kherlen River lodged between Mt. Tumur Ulgii and the tip of Khentii Nuruu mountain range diverges and meanders widely in flood prone area, and the flood prone area spreads up to 5 km from the confluence point where the Kherlen River converges and the existing Kherlen Bridge is located. Figure 9-1-1 shows the conditions of Kherlen River in the study area.

The width of Kherlen River is 4.5 km wide in northern area, and the waterway is so unstable that erosion and sediment take place repeatedly. The land use at the eastern bank is pastureland around Khongor valley, while at the western bank the water sources for Baganuur spread along Kherlen River. The DOR proposed route passes through the water sources. There are many watercourses in this flood prone area. According to the designed drawings, six watercourses are filled. However, once flooding happens, it is estimated that the water level will rise, innumerable watercourses will appear, and the whole width of waterway will be filled with floodwater.

The width of river varies from 2 km to 500 m in the middle area. At the northern part of middle area, streams of Jargalant valley flow into the Kherlen River and many watercourses get together to converge its flow. Accordingly, the width of river is rather wide and the river flow is still unstable. The northern foot of Mt. Tumur Ulgii is eroded and approximately 10 m sheer precipices appear. At the southern part of middle area, there are mountain ranges on the both sides of river. The land use at the eastern bank is pastureland together with sheer precipices around Jargalant valley, and there are many wadis toward the Kherlen River.

The width of river becomes narrow to about 300 m in the south area. The Kherlen River is surrounded by mountains and meets the Khutsaa River and streams from the Ust valley. The land use on the eastern bank is pastureland in the Ust valley. Marshy land exists along the Khutsaa River.

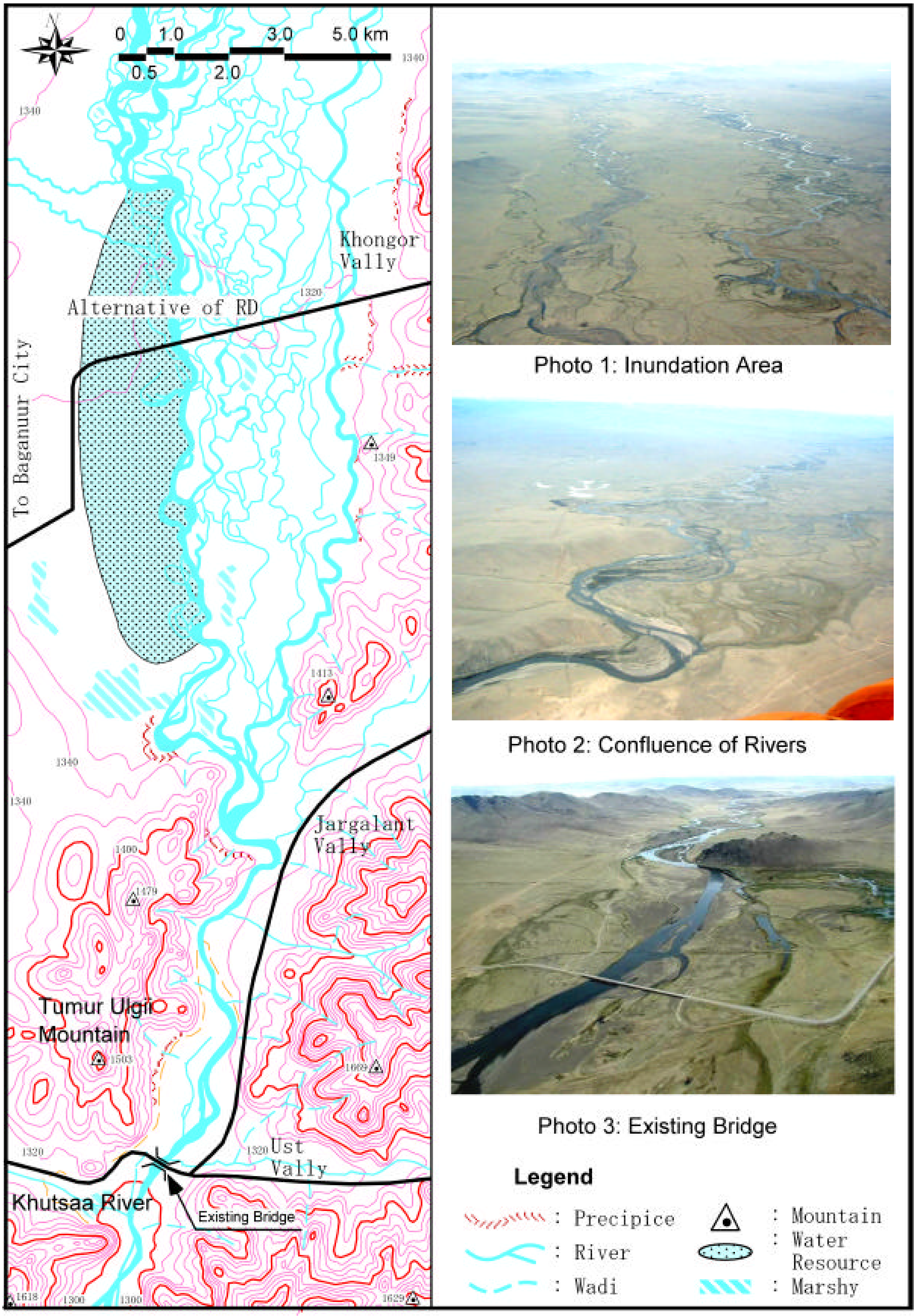


Figure 9-1-1 Condition of Kherlen River

(2) Comparison of Kherlen River Crossing

The project road will cross the Kherlen river within 20 km in east of Baganuur. The alternatives are in the north, in the south and the middle.

For the purpose of qualitative comparison of the crossing points of the Kherlen river, the following aspects are taken into account:

(a) River Morphology
(b) Scale of Bridge Structures and Length of River Training
(c) Environmental Impact
(d) Ease of Maintenance

At the north where the river is located in the flooding and meandering area in, it is subject to official consent that the route is planned to pass the water sources area for Baganuur District, notwithstanding outstanding issues of flood prone area in the crossing point.

A long span bridge is desirable to cross over the river because consideration of river morphology, river training, scouring and so forth. However, it is obvious that bridge becomes longer than others, even if bridges are planned to be limited to major watercourses. Furthermore, new guide banks are required and they may be considerable volume of works because the length of guide bank is generally equal or more a half of bridge length and they are installed at both sides. These facilities of bridges and guide banks will necessitate high costs of maintenance.

On the contrary, at the south where the river is well guided by mountain ranges and the waterway is located in relatively narrow strip. Accordingly, the scale of bridge works will be rather small and the river training may be shorter. Moreover, it is anticipated that adverse environmental impacts will be able to minimize due to no significant change of existing bridge conditions.

At the middle area, there is no salient feature on river morphology except the transition between the north and the south mentioned above. However, the foot of Mt. Tumur Ulgii is close to the river and it may cause to make it difficult that the approach road will require considerable volume of earthwork of cut and fill. It will bring adverse environmental impacts to the surroundings.

Table 9-1-1 shows the qualitative comparisons with salient feature regarding the Kheren river crossing. It is obvious that south area is suitable for crossing of Kherlen River.

Table 9-1-1 Comparison of Salient Features on Three Routes and Evaluation

Items	South Route	Middle Route	North Route
Outline of Bridge and Approach Road			
Route Location and Road Length	54 km Between Baganuur T shape Intesection and Jargalant Crosssrods through existing Kherlen Bridge	54 km (including 16.7km paved road) Between Baganuur T shape Intesection and Jargalant Crosssrods through Transition Area of the Kherlen River	55.8km (including paved road 22.5km) Between Baganuur T shape Intesection and Jargarant Crosssrods based on the DOR Detailed Design
Bridge Length	350m	1,300m	3,800m
General Conditions of Land Use	1) Pastureland spread widely in both banks and marshy area esist in the western bank 2) The route is planned to avert the southern end of Baganuur Coal Mine and the Ikh Gun Lake.	1) Pastureland spread in the eastern bank and mountain ranges exist in the western bank. 2) The route is matched with Baganuur Landuse Plan.	1) Pastureland spread in both banks. 2) The route is planned to pass water sources existed along the Kherlen River in the western bank.
1. River Morphology	1) **Sound** because the Kherlen River is stable because mountain ranges guide river flow at both sides. 2) Additional river training works are required.	1) **Uncertain** because the Kherlen River is stable along mountain ranges but unstable along pastureland. 2) Intensive river training is required.	1) **Changeable** because the Kherlen River is so unstable that erosion and sediment take place repeatedly. 2) Intensive river training is required.
2. Construction Cost	1) **Low** because of totaling 350 m long bridge and some additional revetment works.	1) **High** because of totaling 1,300 m long bridge and considerable river training works.	1) **Very High** because of totaling 3,800 m long bridge and large-scale river training works..
3. Matching of Development Plan	1) **Good** because the route is planned to avert any developemnt plans.	1) **Good** because the route is planned to match the landuse plan.	1) **Poor** because the route is planned to pass in the water souce area in Baganuur thah is envienmentally protected.
4. Adverse Emvironmental Impacts	1) **Lesser Degree** because the route is planned to follow the existing route. 2) River training works are limited to the smallest.	1) **Considerable** because the western approach road requires 10 m deep cut in the slope of Mt. Tumur Ulugii. 2) Intensive river training works take place to some extent.	1) **Considerable** because the drinkin water supply in Baganuur is affected to some extend. 2) Intensive river training works take place to some extent.
Evaluation	**Acceptable**	**Not Acceptable**	**Not Acceptable**

Note : Lengths of road and bridge are estimated on the assumptions that the grade is 6% and the maximum per height is 10 m high.

9.2 Selection of Alternative Routes and Evaluation

9.2.1 Alternative Route Study

There are several existing routes in between Erdene and Undurkhaan and each route comprises a large number of shifting tracks. For the selection of the best route, alternative route study is conducted where some parallel routes exist. If there is no alternative or parallel route, the route selection was to identify one alignment among multiple shifting tracks.

9.2.2 Definition of Terms

The term "Corridor" is perceived as a concept that it has a wide strip and reveals effects or influences brought by the project road in the study area. The corridor of the Eastern Arterial Road is fixed between Erdene and Undurkhaan.

The term "Route" is defined that is has concrete design controls such as type of road, design speed, road width together with number of lanes and location of safety rest areas.

A route study will be able to envisage location of road by averting physical constrains such as villages, public facilities, coal mining and so forth. However, it still remains ambiguous to identify exact mining concession and properties affected by the project road because the location of road is neither calculated nor marked up at site.

The term "Alignment" is defined so as to have coordinates horizontally and vertically based on the outputs of detailed design such as finished grade, curvature, distance from centerline and so forth.

Accordingly, affected mining concession and properties will be identified topographically.

9.2.3 Methodology for Alternative Route Study

Considering the designated roles and functions of the Eastern Arterial Road based on the corridor study which was defined in Millennium Road Planning, a route study is conducted to set alternative route for route selection, and a alignment study will be conducted to the next step.

Figure 9-2-1 shows the methodology of route study, which consists of the four (4) major work items;

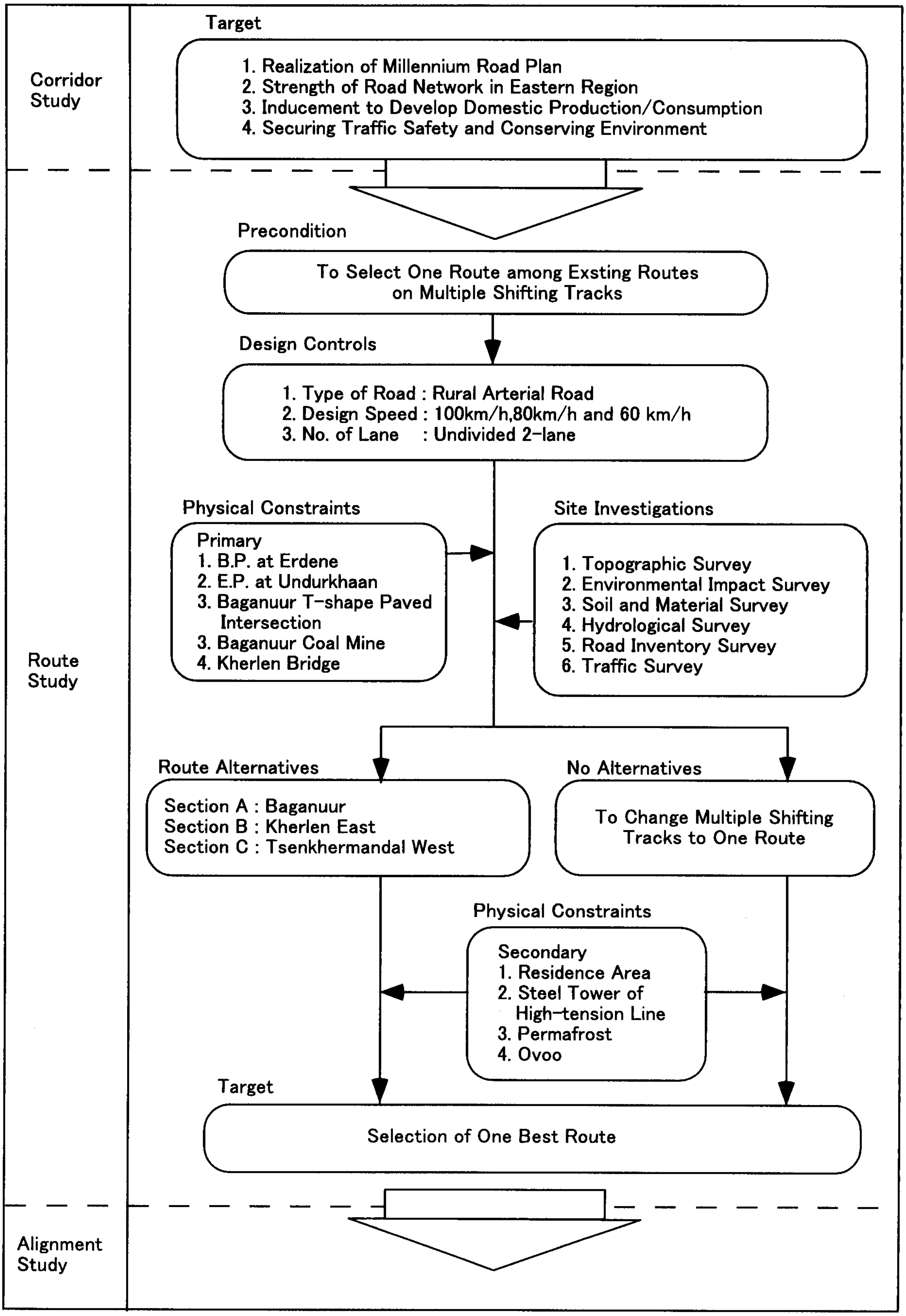


Fig. 9-2-1 Methodology of Route Alternative Study

(1) Design Controls

To realize the designated roles and functions of the Eastern Arterial Road, it is necessary to determine major design controls of which those elements have relation horizontally and longitudinally to select a route.

It is necessary to consider accessibility among major cities from the point of view preventing traffic accidents and making sound development of village.

The Eastern Arterial Road is planned to pass through Undurkhaan, which is an important point of inter-modal city connecting to three east provinces.

(2) Physical Constrains

A route selection should be controlled to keep distance to a certain point in order to avert adverse social impacts or to avoid considerable compensation costs, which is called “Primary Controlling Point” On the contrary, established connecting points on A0501 which was confirmed as the beginning point and ending point of the Eastern Arterial Road and Baganuur T-shape paved Intersection is also primary controlling points.

Few public properties are affected by the road improvement in the study route. However, Baganuur Coal Mine and public facilities are so important that they are classified as primary controlling points. The crossing point of Kherlen River selected by Paragraph 9.3 is also identified as primary controlling points.

It is desirable to keep distance to a certain point if a project road can be averted it or such points as inevitable to affect points will be replaced or removed with compensation, which is called “Secondary Controlling Point”.

Exploring mining concession, residence area, steel tower of high-tension line, preying spot “Ovoo” and existence of permafrost are regarded as secondary controlling points.

No permafrost is found in principle under the existing road due to disturbance by car passing. It is likely possible to construct roads on permafrost by the mitigated countermeasures such as high embankment, replacement of subsurface soil and so forth, wherever the existence is confirmed. These countermeasures is expected to support road structure and minimize the environmental impact.

Ovoo, which is piled high with stone conically and is thrust into its center a branch which is tied texture written a sutra, is located at mountain passes, junctions, springs. It is likely possible to replace Ovoo to roadside because it was done in the past road development projects. And, Ovoo has been identified to be not objective items for Environmental impact assessment within project site.

(3) Site Investigation / Data Collection

Site investigations, such as topographic survey, environmental impact survey, soil and geological survey, hydrological survey and traffic survey collecting data concerning mining concessions and aerial photos, are carried out to reveal natural and physical conditions of the project area.

These basic data are referred to for technical and financial evaluation of each alternative.

(4) Route Alternatives

Referring to the topographic maps at a scale 1:25,000, alternative routes were selected to find the best route among existing tracks. However, these maps are so old that additional information and investigation are required to update maps and integrate information for the study. Baganuur Area is especially necessary to be updated because Baganuur Coal Mine and approach road are not on the latest map.

The following points are taken into account;

1) The alternative route refers to the existing routes.
2) The crossing point of the Kherlen River is determined to be nearby the existing bridge.
3) The ecosystem in Mongolia is sensitive and high priority is given.

Three road sections have been selected to conduct the alternative route study, according to identification of physical constraints and site investigations. They are as follows;

1) Section A: Baganuur (Baganuur 3-leg intersection - Kherlen River)
2) Section B: Kherlen East (Kherlen River - Jargalant Crossroads)
3) Section C: Tsenkhermandal West (Jargalant Crossroads - Ogzam Valley)

The location of each section is shown in Figure 9-2-2.

The best route in Section A may go across Baganuur Coal Mine and run straightly eastward to the Kherlen River Bridge. It is shortest and suits to the same concept of the Millennium Road. However, there is no reality due to the existence of Baganuur coal mine, which is the biggest energy supplier of Ulaanbaatar and is planned to continue to operate for 60 years or more.