2-2-2 Design Plan

(1) Overall Scheme for the Project Works

Content of Project Work

i) Replacement of Abay Bridge (303 m):

- Construction of a new bridge approximately 145 m upstream from the old bridge
- Adoption of a concrete (extra-dozed) bridge for the superstructure
- Realignment of the road on the left bank of the river

ii) Road rehabilitation between Goha Tsiyon and Dejen (approximately 40.6 km)

- The Project road starts from the end of the first and second phase works and goes to the outskirts of Dejen
- The basic cross section consists of 2 lanes (each 3.5 in width) and a shoulder on either side 1.5 m in width
- Asphalt pavement (with an asphalt stabilization layer for high priority trouble spots)
- Shoulder will be widened to 2.5 m at sections in the urban area of Dejen in order to provide parking

The scope and content of Japanese cooperation were determined based on the following flow and on the basic concepts described in 2-2-1 (Design Policy).

Contents of Request from Ethiopia

i) Replacement of Abay Bridge (207 m)

ii) Road rehabilitation between Goha Tsiyon and Dejen (approximately 39 km)

iii) Road rehabilitation between Dejen and Debre Markos (approximately 67 km)

Proposed Contents of Request Based on Preliminary Survey Findings

i) Replacement of Abay Bridge (207 m)

ii) Road rehabilitation between Goha Tsiyon and Dejen (approximately 39 km)

iii) Road rehabilitation between Dejen and Debre Markos (approximately 67 km) as follows:

- Improvement of trouble spots (approximately 4 km) affected by flooding (around Ieda River) and loose subgrade materials (black cotton soil), etc.
- Replacement of 8 small bridges (22.6 m on average) suffering from extreme deterioration
- Procurement of construction materials necessary for maintenance of the remaining sections

Revised Project Scope Based on Discussions, etc. during the Site Survey

i) Replacement of Abay Bridge (303 m)

ii) Road rehabilitation between Goha Tsiyon and Dejen (approximately 40.6 km)

Examination Results for Basic Concept

<Roads>

- **i) Realignment:** Utilizing the existing road carry out improvements based on R<20 and gradient of 10% or more.
- **ii) Width:** Apply a basic cross section of 3.5 m for lanes and a 1.5 m shoulder without implementing major changes to the existing road.
- **iii)Pavement structure**: Add an asphalt stabilization layer for sharp curves (R<50 m or less) and gradients of 8% or more, etc.

<Bridge>

- **i) Width:** In order to retain old bridges, sidewalks will not be adopted. Moreover, in consideration of economy, shoulder width will be reduced to 1.0 m and a bridge width of 9 m will be adopted.
- **ii) Bridge location:** Taking into consideration the location of the approach roads, bridge length and appropriate span balance, etc., the new Abay Bridge will be constructed 145 m upstream from the old Abay Bridge.
- **iii)Bridge type:** Taking into consideration economy, harmonization with the old bridge, symbolism, etc., an extra-dozed type bridge has been selected for the new Abay Bridge.

(2) Road Rehabilitation

1) Outline of Road Plan

As indicated in Figure 2.2.4, Project road rehabilitation stretches for a total of 40.6 km from Goha Tsiyon (the end of the second arterial road rehabilitation project) through Abay gorge to Dejen. The gorge section has an average gradient of around 7.5% (L = 39.0 km), while the section that passes through Dejen is flatland (L = 2.3 km). Note that sheer cliffs surround the gorge section on both the mountain and gorge side of the road. Therefore, since realignment and major changes cannot be executed here, the existing road shall be fully utilized to minimize realignment to keep costs down. However, in order to strengthen the road structure (including the pavement) against erosion caused by rainwater flows on steep slopes and vehicle braking loads, a pavement structure that includes an asphalt stabilization layer shall be adopted on escarpments and sharp curves. In addition, adequate drainage facilities shall be adopted over the all sections in the gorge. Furthermore, in order to prevent falling rock from slopes from landing on the road, loose rocks shall be removed and retaining walls installed. Moreover, around points No. 28 and 31 between Abay Bridge and Dejen where landslides have previously occurred, horizontal boring holes shall be adopted to drain off groundwater.

Note that since vehicles traveling from Debre Markos to Addis Ababa frequently stop off and spend the night at Dejen, parking space shall be provided in Dejen. Furthermore, shoulder space shall be secured to provide sidewalks for the large numbers of pedestrians using the market in town. A bus terminal shall also be provided at the village of Filklik (No. 9 + 250), which is situated midway between Goha Tsiyon and Abay Bridge.

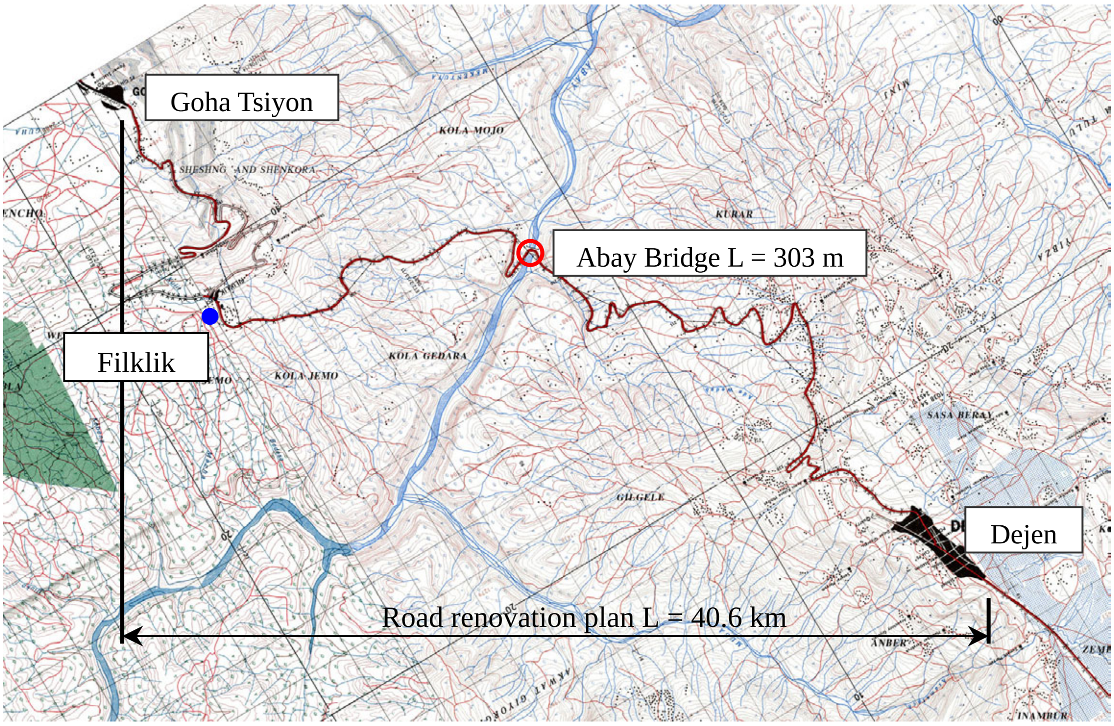


Figure 2.2.4 Section Targeted for Rehabilitation

2) Facilities Plan

a) Realignment plan

I. Review of existing detailed design

In the detailed design that the ERA implemented in 1996 (which was consigned to the British firm Parkman Ltd.), it was proposed that a plane curve radius of at least 50 m be adopted. Commensurate with this, it was proposed that tail armor be adopted as reinforcement for banked sections and that rock bolts be used to prevent falling rocks. However, not only are these measures very expensive, doubts remain over their long-term structural stability.

II. Road realignment concept

Based on the review findings of the detailed design described in **I**. and the results of the site survey conducted by the Study Team, the concept regarding vertical and plane alignment in this road design shall be based on the following concept, which proposes to utilize the existing road and enhance functions by implementing partial improvements:

- Do not implement major realignment (since it is structurally difficult and expensive).
- Carry out alignment improvements only for the most unstable sections (with a design velocity 20 km/h).

Tables 2.2.13 and 14 show the detailed results of the examination based on the above concept. The largest realignment occurs around point No. 0+200 where the vertical slope (gradient) increases to 15%. In addition, horizontal and vertical improvements not requiring major earthworks are planned. These include widening on the continuous curves between points No. 0+300 to No. 0+800, between No. 2+200 to 700 and around No. 34+200, as well as minor improvement to the sharp curve around No. 7+900.

Table 2.2.12 shows the length of road by design velocity that can be secured as a result of the above improvements. Figure 2.2.5 gives an illustration of this.

Table 2.2.12 Possible Travel Velocity and Section Length

Design Speed (km/hr)	Distance (km)	Percentage of Total (%)
20	0.5	1.2
30	13.1	32.2
40	2.8	7.0
50	6.9	16.9
60	17.3	42.6
Total	40.6	100

Table 2.2.13 Road Realignment Plan (1/2)

	Current Alignment									Improvement Alignment									
	Plane Alignment					Vergitcal Alignment				Plane Alignment					Vertical Alignment				
	No. of Radius <30m (20km/h)	No. of Radius <50m (30km/h)	No. of Radius <85m (40km/h)	No. of Radius <125m (50km/h)	No. of Radius >125m (60km/h)	Length of Vertical Gradient >12% (20km/h)	Length of Vertical Gradient >9% (30km/h)	Length of Vertical Gradient= 8-9% (40-50km/h)	Length of Vertical Gradient <8% (60km/h)	No. of Radius <30m (20km/h)	No. of Radius <50m (30km/h)	No. of Radius <85m (40km/h)	No. of Radius <125m (50km/h)	No. of Radius >_125m (60km/h)	Length of Vertical Gradient >12% (20km/h)	Length of Vertical Gradient >9% (30km/h)	Length of Vertical Gradient =8-9%(40-50km/h)	Length of Vertical Gradient <8% (60km/h)	Design Speed to be considered
Goha Tsion																			
No.0+300	1	1			1				200		2			1				200	30
No.0+500	2	1	1	1			100	400			3	1	1			100	400		30
No.1+000	2		1	1	3		200		300		2	1	1	3		200		300	30
No.1+500					5				500					5				500	60
No.2+000		1	1		5				500		1	1		5				500	30
No.2+500				1	4	250			250				1	4		500			30
No.3+000		1	2		3				500			2		3				500	40
No.3+500				1	5		300		200				1	5		300		200	30
No.4+000		2		1	3	200			300		2		1	3		400		100	30
No.4+500		1	1		3		300		200		1	1		3		300		200	30
No.5+000	1				5	200			300	1				5		200		300	20km/h
No.5+500					4				500					4				500	60
No.6+000		1			4		300		200		1			4		500			30
No.6+500			1		4		300		200			1		4		300		200	30
No.7+000				1	3				500				1	3				500	50
No.7+500	1				4				500		1			4				500	30
No.8+000					4				500					4				500	60
No.8+500					4				500					4				500	60
No.9+000			1		4				500			1		4				500	40
Filiklik																			
No.9+500					5				500					5				500	60
No.10+00			1	1	2				500			1	1	2				500	40
No.10+500				1	4		500						1	4		500			30
No.11+00					3				500					3				500	60
No.11+500				1	4		200		300				1	4		200		300	30
No.12+00				1	4		500						1	4		500			30
No.12+500		2	2				200		300		2	2				200		300	30
No.13+00		1	1		3				500		1	1		3				500	30
No.13+500		1	2	1					500		1	2	1					500	30
No14+000					5			500						5			500		50
No.14+500					3		200	300						3		200	300		30
No.15+000					2				500					2				500	60
No.15+500					3		200		300					3		200		300	30
No16+000					3				500					3				500	60
No.16+500				1	3			500					1	3			500		50
No.17+000					4		200	300						4		200	300		30
No17+500		1			4		500				1			4		500			30
No18+000					3				500					3				500	60
No.18+500					4			500						4			500		50
No.19+000		1		1	3				500		1		1	3				500	30
No19+500			1		3				500			1		3				500	40
Abay Bridge																			

Table 2.2.14 Road Realignment Plan (2/2)

	Current Alignment									Improvement Alignment									
	Plane Alignment					Vergitcal Alignment				Plane Alignment					Vertical Alignment				
	No. of Radius <30m (20km/h)	No. of Radius <50m (30km/h)	No. of Radius <85m (40km/h)	No. of Radius <125m (50km/h)	No. of Radius >125m (60km/h)	Length of Vertical Gradient >12% (20km/h)	Length of Vertical Gradient >9% (30km/h)	Length of Vertical Gradient= 8-9% (40-50km/h)	Length of Vertical Gradient <8% (60km/h)	No. of Radius <30m (20km/h)	No. of Radius <50m (30km/h)	No. of Radius <85m (40km/h)	No. of Radius <125m (50km/h)	No. of Radius >_125m (60km/h)	Length of Vertical Gradient >12% (20km/h)	Length of Vertical Gradient >9% (30km/h)	Length of Vertical Gradient =8-9%(40-50km/h)	Length of Vertical Gradient <8% (60km/h)	Design Speed to be considered
No.20+00			1	1	3				500			1	1	3				500	40
No.20+500		1		1	4		200		300		1		1	4		200		300	30
No.21+00					7		500							7		500			30
No.21+500					4		500							4		500			30
No.22+00		1	1		4		500				1	1		4		500			30
No.22+500			1	1	2				500			1	1	2				500	40
No.23+00		1			3				500		1			3				500	30
No.23+500			1	1	2		300	200				1	1	2		300	200		30
No24+000				1	7			500					1	7			500		50
No.24+500			1		2			200	300			1		2			200	300	40
No.25+000			2		2		200	300				2		2		200	300		30
No.25+500			1		2			500				1		2			500		40
No26+000				1	3		200	300					1	3		200	300		30
No.26+500			1		4		200	300				1		4		200	300		30
No.27+000			1	1	3		200	300				1	1	3		200	300		30
No27+500			3		2		100	400				3		2		100	400		30
No28+000					4				500					4				500	60
No.28+500				1	2				500				1	2				500	50
Kurar																			
No.29+000					3				500					3				500	60
No29+500			1		2				500			1		2				500	40
No.30+000			1		2				500			1		2				500	40
No.30+500					4				500					4				500	60
No.31+00					3				500					3				500	60
No.31+500					5				500					5				500	60
No.32+00			1		3				500			1		3				500	40
No.32+500					4				500					4				500	60
No.33+00					4				500					4				500	60
No.33+500					2				500					2				500	60
No34+000		1			3		300		200		1			3		300		200	30
No.34+500		1		1	1			500			1		1	1			500		30
No.35+000		2			4		300	200			2			4		300	200		30
No.35+500		1			1		300	200			1			1		300	200		30
No36+000					4				500					4				500	60
No.36+500					3				500					3				500	60
No.37+000					5				500					5				500	60
No37+500					3				500					3				500	60
No38+000					4				500					4				500	60
No.38+500					—				500					—				500	60
No.39+000					1				500					1				500	60
No39+500					—				500					—				500	60
No.40+00					—				500					—				500	60
No.40+500					—				100					—				100	60
No.40+600									End										

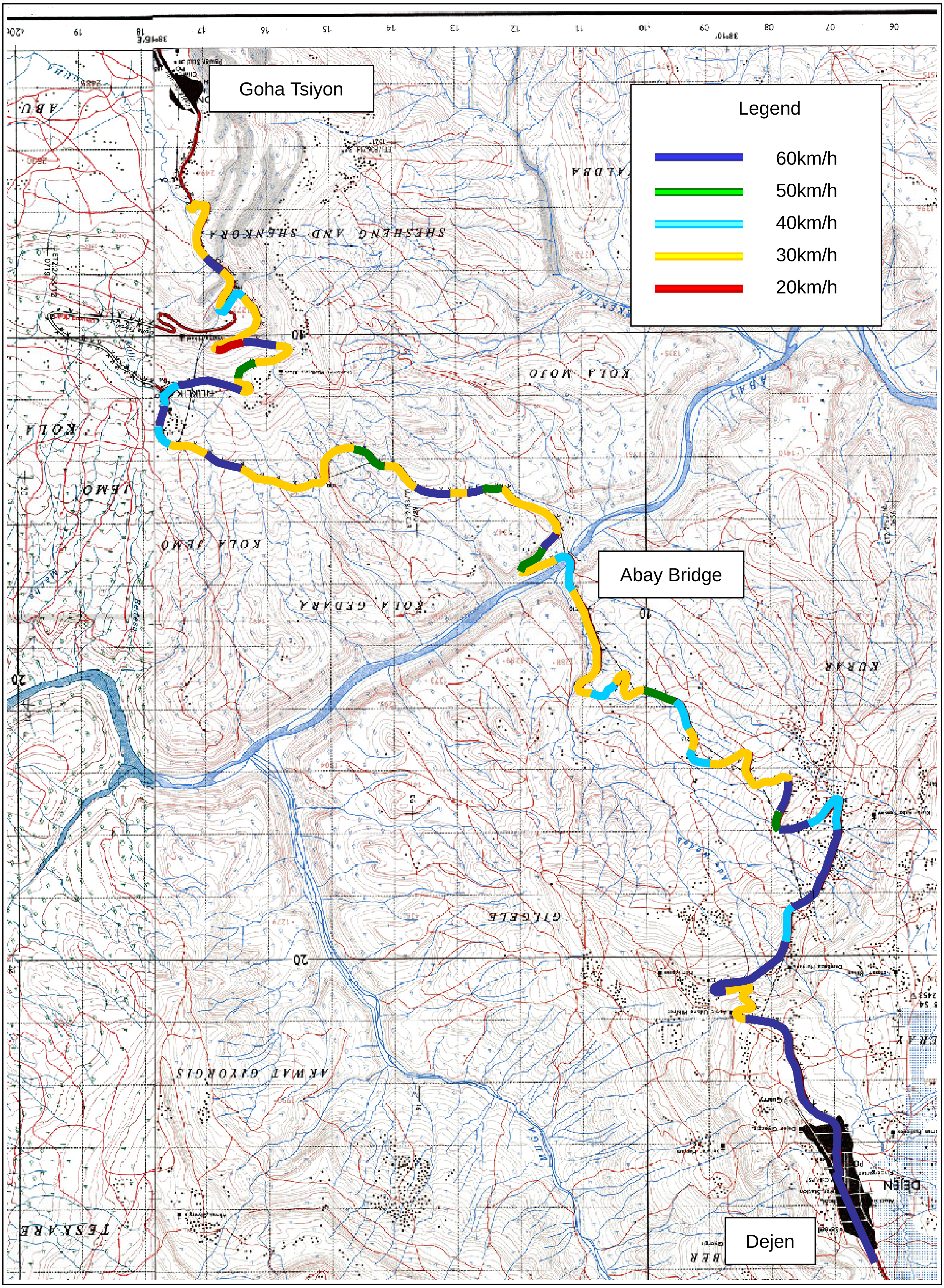


Figure 2.2.5 Map of Travel Speed on the Renovated

b) Road width composition for the gorge section

Site surveys determined that the existing road was too narrow to execute banking on the gorge side or cutting on the mountain side. Given this, 3 types of road width composition (including basic width composition) shall be applied when executing actual work on the road (see Table 2.2.15). Details of each composition type are indicated in Table 2.2.16.

The basic conditions for actual road width composition are as follows:

- Width of side ditches: a width of 1.0 m shall be secured taking into account an inner width of 0.6 m for maintenance and the appropriate side wall thickness.
- Cutting a protection shoulder: a width of 0.5 m shall be secured in order to ensure sufficient sight distance and protection against falling rock.
- Banking gradient: A gradient of 1:1.5 shall be adopted as a standard with a 1.5 m berm provided every 5 m on a bank.
- Cutting gradient: A gradient of 1:0.6-0.7 shall be adopted (for semi-hard rock with many cracks) and a 1.5 m berm provided every 7 m on a bank.

Table 2.2.15 Width Composition for Gorge Sections
(revise cutting gradient and applicable length)

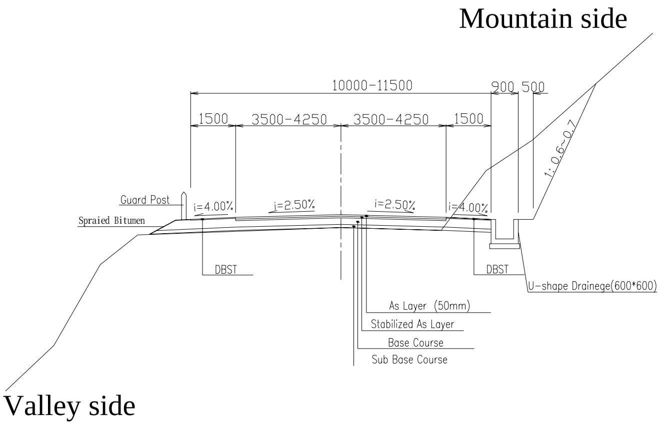
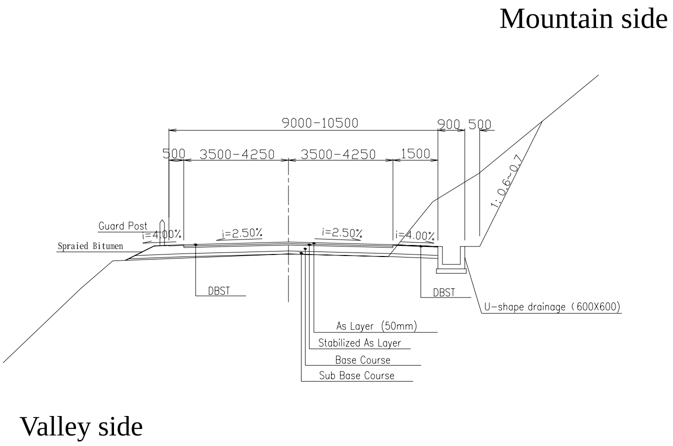
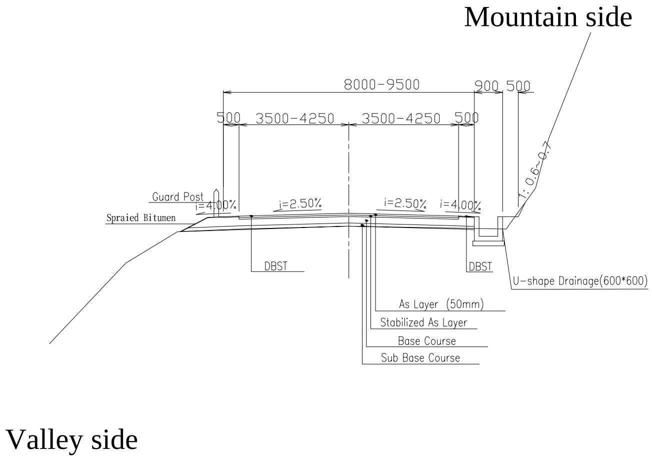
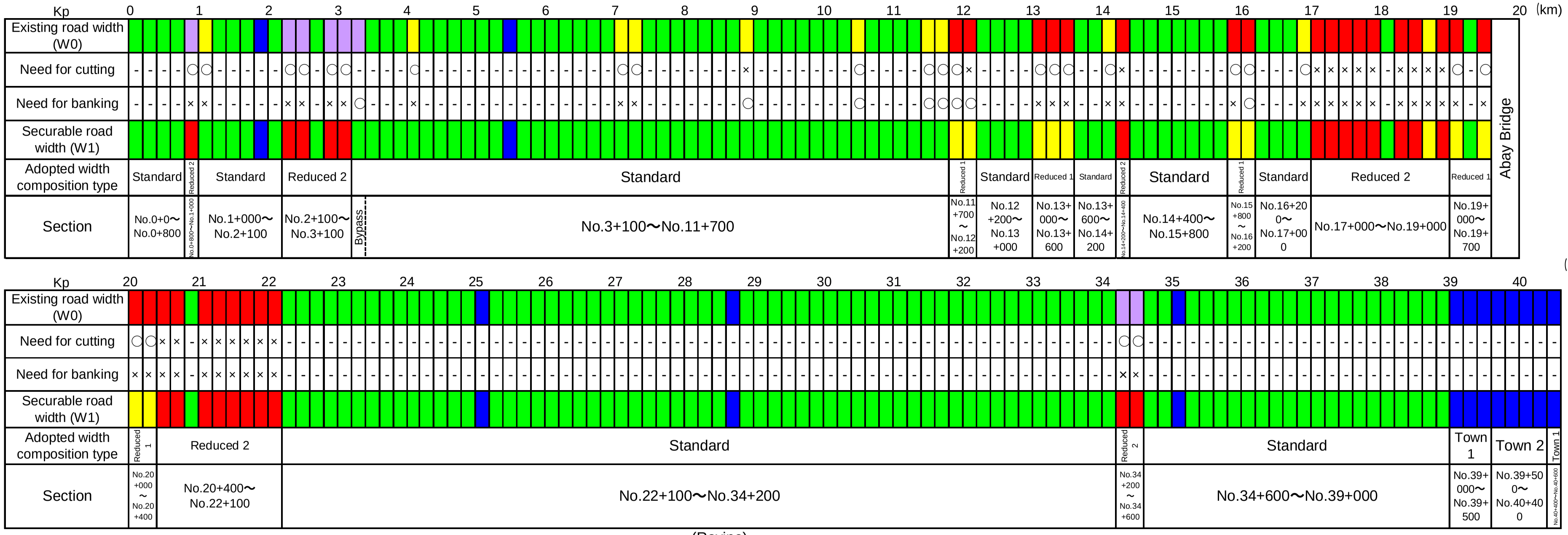
	Applicable Road Width	Outline
① Basic section		- Apply this width composition as much as possible where the existing road is sufficiently wide. - Secure a 1.5 m shoulder on the mountain side in order to secure sight distance, protection against falling rock and room for a side ditch. - Applicable length: 31.3km(80%) - Applicable area: around Filkrick Village, etc.
② Reduced Section (1)		- Apply this width composition where the existing road is too narrow to execute banking on the gorge side or cutting on the mountain side. - Reduced shoulder width on the gorge side (1.5 m → 0.5 m) - Secure a 1.5 m shoulder on the mountain side in order to secure sight distance, protection against falling rock, and room for a side ditch. - Applicable length: 2.6km (7%)
② Reduced Section (2)		- Apply this width composition where the existing road is even narrower and it is too difficult to execute banking on the gorge side or cutting on the mountain side. - Reduced shoulder width on the gorge side (1.5 m → 0.5 m) - Shoulder width on the mountain side (1.5 m → 0.5 m) - Applicable length: 5.10 km (13%)

Table 2.2.16 Road Width Composition Map



Adopted width composition type	Section
Standard	No.0+0〜No.0+800
Reduced 2	No.0+800〜No.1+000
Standard	No.1+000〜No.2+100
Reduced 2	No.2+100〜No.3+100
Standard	Bypass No.3+100〜No.11+700
Reduced 1	No.11+700〜No.12+200
Standard	No.12+200〜No.13+000
Reduced 1	No.13+000〜No.13+600
Standard	No.13+600〜No.14+200
Reduced 2	No.14+200〜No.14+400
Standard	No.14+400〜No.15+800
Reduced 1	No.15+800〜No.16+200
Standard	No.16+200〜No.17+000
Reduced 2	No.17+000〜No.19+000
Reduced 1	No.19+000〜No.19+700
Abay Bridge	
Reduced 1	No.20+000〜No.20+400
Reduced 2	No.20+400〜No.22+100
Standard	No.22+100〜No.34+200
Reduced 2	No.34+200〜No.34+600
Standard	No.34+600〜No.39+000
Town 1	No.39+000〜No.39+500
Town 2	No.39+500〜No.40+400
Town 1	No.40+400〜No.40+600

◇Road width legend

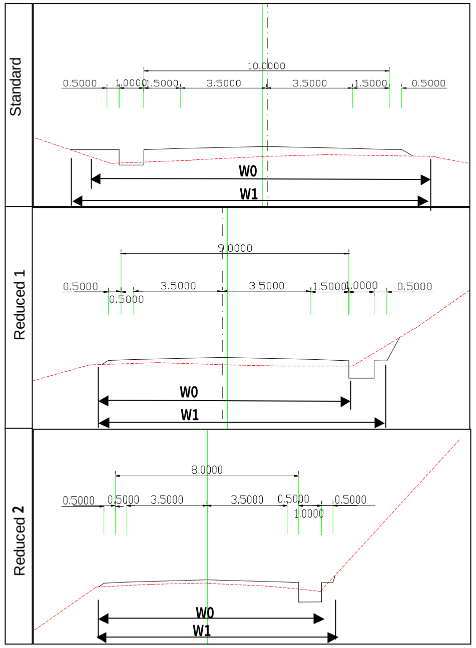
🟦 :W0,W1≧20m
🟩 :12m≦W0,W1≦20m
🟨 :11m≦W0,W1≦12m
🟥 :10m≦W0,W1≦11m
🟪 :W0,W1≦10m

Selection of certain width type

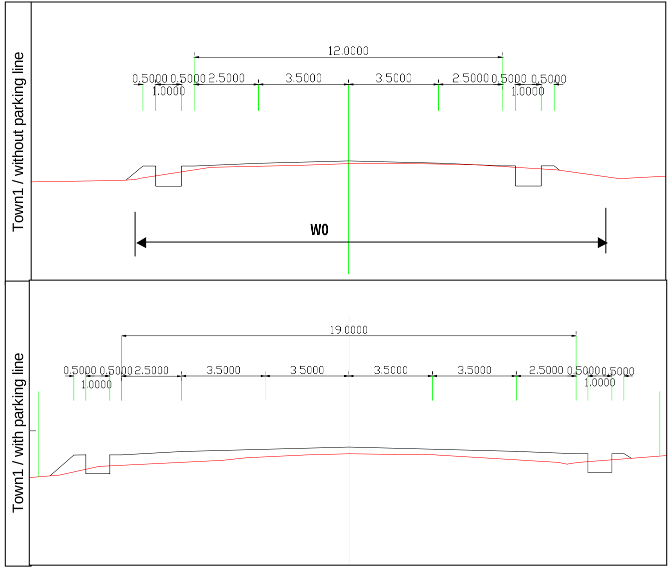
(Ravine)
1.Basically, if securable road width is W1≧12m, adopt the standard type.
2.Basically, if securable road width is 11m≦W1<12m, adopt the Reduced type 1.
3.Basically, if securable road width is 10m≦W1<11m, adopt the Reduced type 2.
But;
4.If cutting (up to 7 m) and banking (up to 5 m) is possible, adopt width composition 1 rank higher.
5.Minimum section length for adopting a certain width type shall be 200 m for Reduced type 2 and 400 m for the other types.

(Dejen urban area)
1.On the 900 m section in the town center, adopt urban type 2 (with parking strip).
2.For other sections, adopt urban type 1 (without parking strip).

(Ravine)



(Dejen urban area)



c) Pavement Design

I. Design technique

Pavement design will be carried out in accordance with the Ethiopian pavement design manual, which is based on British standards. Pavement strength and composition is based on the strength (CBR) of the existing subgrade soil and projected traffic volume of large vehicles. Note that the SN method will be employed in examining pavement composition (thickness). This thinking is the same as that contained in the Pavement Design Manual in Japan. In this approach, equivalent coefficients of thickness and materials in each layer are inserted into the formula indicated on page 2-42 and the result is acceptable if it satisfies the required SN.

II. Design conditions

i) Design life

As mentioned in 2-2-1 (1) 6) e) pavement design life shall be 20 years, which was also applied in the first and second phase arterial road rehabilitation works and in arterial road rehabilitation projects by other donors. Note adequate maintenance work shall also be implemented after the construction.

ii) Design traffic volume

In the basic design, pavement design will be carried out based on current traffic volume figures obtained from the ERA (see 2-2-1 (1) 6) a)) and projected future growth in traffic volumes.

iii) Design wheel load (8.2 t conversion factor)

Concerning wheel load, the following values (note standard axle load equivalent to 8.2t) were measured by the ERA in 2002 and 2003 and shall be adopted for the design of the Project road.

Table 2.2.17 Adopted Wheel Loads

Type of Vehicle	First, Second and Third Phase Plans	Third Phase Plan (considering overloading)	Debre-Gonder (reference)
Cars	Nil	Nil	Nil
Buses	1.0	1.8	1.8
Trucks	3.2	8.8	3.2
T-Trailer	5.7	11.9	5.7

iv) Road class according to cumulative wheel load

Road class based on wheel load in accordance with the ERA pavement manual is given below for three traffic volume growth and two axle load scenarios.

Table 2.2.18 Road Class by Case

		Low Growth	Middle Growth	High Growth
Phase I, II Axle Load	Y10	T5	T5	T5
	Y20	T6	T6	T7
Phase III Axle Load	Y10	T6	T6	T6
	Y20	T8	T8	T8

In the Project, a middling growth rate and a service life of 10 years is assumed. Given this, a road class of T6 is taken up for the Project road. Assuming the wheel loads adopted in Phases 1 and 2, this road class will have a service life of 20 years. Furthermore, the construction phase shall be planned for completion in 2008.

v) Subgrade strength (CBR)

A revised CBR survey was implemented at 10 points on the Project road and the results are shown in the table below.

Table 2.2.19 CBR Survey Results

Pit No.	TP- 1	TP- 2	TP- 3	TP- 4	TP- 5	TP- 6	TP- 7	TP- 8	TP- 9	TP- 10
Sta. No	0.2	3.2	13.8	21.6	22.5	25.0	25.7	26.5	27.7	29.2
CBR1	5	1	33	7	8	4	2	15	20	20
SOIL	Selected	Blackcotton	Selected	Selected	Selected	Blackcotton	Blackcotton	Selected	Selected	Selected

The above survey findings are divided into those before the Abay River (TP-1~3) and those after the Abay River (PTTP-4~10). PTTP-1~3 can be further divided into PTTP-1~2 and PTTP-3, while PTTP-4~10 can be divided into PTTP-4~7 and PTTP-8~10. The design CBR on each section is calculated using the following method. When doing this, TPTP-2, 6 and 7, which consist of loose ground (black cotton soil), are excluded from the data and replaced with the calculated design CBR.

Plotting the CBR findings in ascending order, the value corresponding to d below is adopted as the design CBR.

D = 0.1 x (n – 1)
D: X coordinate assuming the lowest value to be the first
N: number of data samples

Table 2.2.20 Adopted Design CBR

Section	n	D	Design CBR
TP-1〜2 : 11km	1	0	5
TP-3 : 8.5km	1	0	33
TP-4〜7 : 6.5km	2	0.1	7
TP-8〜10 : 14.0km	3	0.2	15

III. Examination of pavement composition

The SN method is used to determine pavement composition (thickness). Of the figures shown in Table 2.2.21, the shaded figures are the target SN values and the conversion factors for each applicable material are given in Table 2.2.22.

SN =(a1 x t1 + a2 x t2 + a3 x t3 + ・・ + an x tn)/25.4
SN: Structure Number
A: equivalent conversion factor
T: layer thickness (mm)

Table 2.2.21 Required SN Value Based on CBR and Design Wheel Load

	Required Structure Number. SN$_{Required}$						
Sub-grade CBR	Traffic Load Classes						
					T5,T6	T7	T8
≧30	1.10	1.25	1.60	1.90	2.35	3.00	3.50
15－20	1.35	1.50	1.80	2.20	2.75	3.80	4.20
10－14	1.60	1.80	2.10	2.50	3.00	4.10	4.50
7－9	1.90	2.00	2.30	2.75	3.30	4.30	4.70
5－6	2.10	2.20	2.50	2.90	3.50	4.50	5.00
3－4	2.40	2.80	3.10	3.40	4.00	5.00	5.50

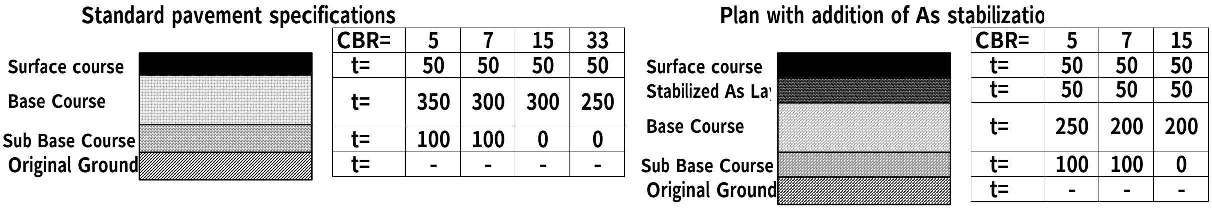
Table 2.2.22 Equivalent Conversion Factor of Materials

Type of Material	Existing Material Coefficients
Surfacing	
Asphalt Concrete (AC)	0.40
Base Course	
Asphalt Stabilized Materials:	0.30
Cement or Lime Stabilized Materials: C2	0.20
Cement or Lime Stabilized Materials: C1	0.15
Cement or Lime Modified Materials: CM	0.11
Granular, Crushed Base Materials: CRR	0.15
Granular, Crushed Base Materials: CRS	0.14
Base Course	
Granular, Crushed Materials Used for Subbase CBR>45	0.11
Natural Gravel Subbase, G45	0.11
Natural Gravel Subbase, G25	0.10

Note that minimum asphalt thickness in the case of a single layer pavement shall be 50 mm according to the ERA Pavement Design Standards.

IV. Pavement specifications and applicable conditions

Figure 2.2.6 shows pavement composition by subgrade strength.



CBR=	5	7	15	33
t=	50	50	50	50
t=	350	300	300	250
t=	100	100	0	0
t=	-	-	-	-

CBR=	5	7	15
t=	50	50	50
t=	50	50	50
t=	250	200	200
t=	100	100	0
t=	-	-	-

Figure 2.2.6 Pavement Composition by Subgrade Strength

As mentioned in 2-2-1 (1) 6) e), an asphalt stabilization layer will be added when necessary in order to improve resistance against rainwater flows and vehicle braking loads. Pavement structure specifications shall therefore be divided into the two types below.

- Asphalt Stabilized Sections: For sections with a steep gradient (8% or more) and sharp curves (R < 50 m).
- Standard Paved Sections: For sections other than those described above that run continuously for 500 m or more.

V. Results of pavement specification distinguishing

Table 2.2.24 and 25 show the results of applying the above criteria, while Table 2.2.23 shows the total findings.

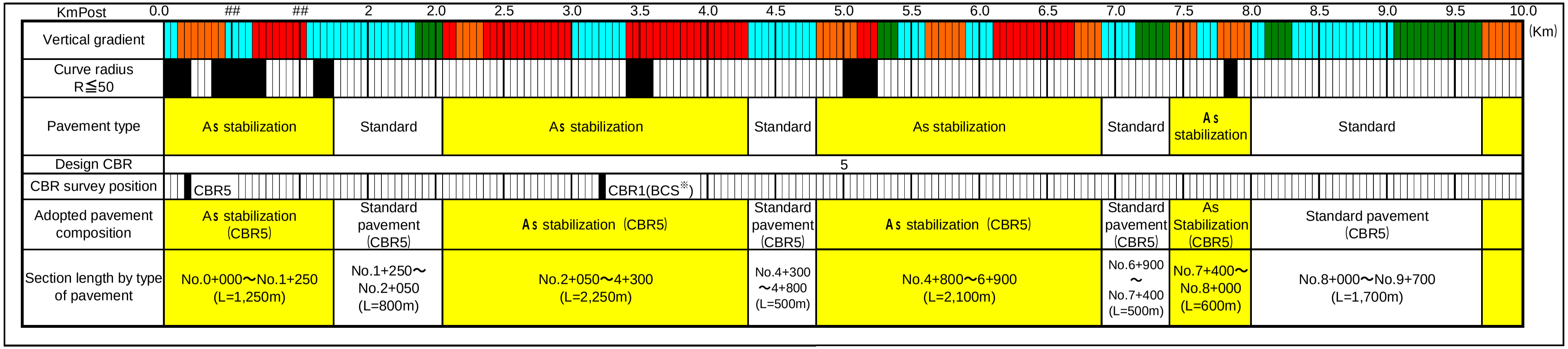
Table 2.2.23 Total Length by Pavement Specification

Pavement Specification	Road Section	Length (km)	Remarks
Standard Pavement Specification	Goha Tsiyon ~ Abay Bridge	3.50	
	Abay Bridge ~ Dejen	8.60	
	Subtotal	12.10	
Asphalt Stabilized Pavement Specification	Goha Tsiyon ~ Abay Bridge	16.15	Excluding Abay Bridge 0.3 km
	Abay Bridge ~ Dejen	12.05	
	Subtotal	28.20	
Total		40.30	Excluding Abay Bridge 0.3 km

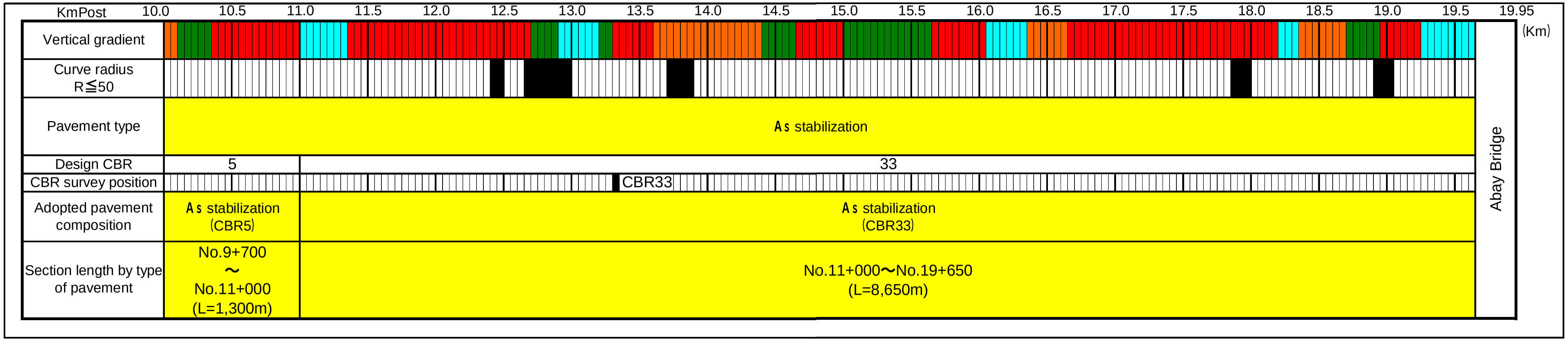
VI. Shoulder pavement

If shoulders are left unpaved, fast flowing rainwater on steep slopes will lead to serious erosion of the road and shoulders. Accordingly, in order to prevent this, road shoulders shall be given simple pavement protection (DBST) and surface water shall be shunted off the road and shoulders into side ditches.

Table 2.2.24 Classification of Pavement Structure Specifications



KmPost (Km)	0.0 – 1.25	1.25 – 2.05	2.05 – 4.3	4.3 – 4.8	4.8 – 6.9	6.9 – 7.4	7.4 – 8.0	8.0 – 9.7	9.7 – 10.0
Pavement type	As stabilization	Standard	As stabilization	Standard	As stabilization	Standard	As stabilization	Standard	
Design CBR	5								
CBR survey position	CBR5		CBR1(BCS※)						
Adopted pavement composition	As stabilization (CBR5)	Standard pavement (CBR5)	As stabilization (CBR5)	Standard pavement (CBR5)	As stabilization (CBR5)	Standard pavement (CBR5)	As Stabilization (CBR5)	Standard pavement (CBR5)	
Section length by type of pavement	No.0+000〜No.1+250 (L=1,250m)	No.1+250〜 No.2+050 (L=800m)	No.2+050〜4+300 (L=2,250m)	No.4+300 〜4+800 (L=500m)	No.4+800〜6+900 (L=2,100m)	No.6+900 〜 No.7+400 (L=500m)	No.7+400〜 No.8+000 (L=600m)	No.8+000〜No.9+700 (L=1,700m)	



KmPost (Km)	10.0 – 11.0	11.0 – 19.65	19.65 – 19.95
Pavement type	As stabilization		Abay Bridge
Design CBR	5	33	
CBR survey position		CBR33	
Adopted pavement composition	As stabilization (CBR5)	As stabilization (CBR33)	
Section length by type of pavement	No.9+700 〜 No.11+000 (L=1,300m)	No.11+000〜No.19+650 (L=8,650m)	

※ BCS：Black Cotton Soil

Subtotal	Standard specifications	3,500m
	With As stabilization	16,150m

Criteria for determining pavement specifications classification

① The asphalt stabilization layer shall be added on sections of steep gradient (8% or more) and sharp curves (R < 50 m).

②The standard pavement specifications shall be adopted in cases where sections other than those described above run continuously for 500 m or more.

◇Vertical slope legend

- 🟦 ：i＜6%
- 🟩 ：6%≦i＜8%
- 🟧 ：8%≦i＜9%
- 🟥 ：9%≦i≦10%

◇Pavement composition by type

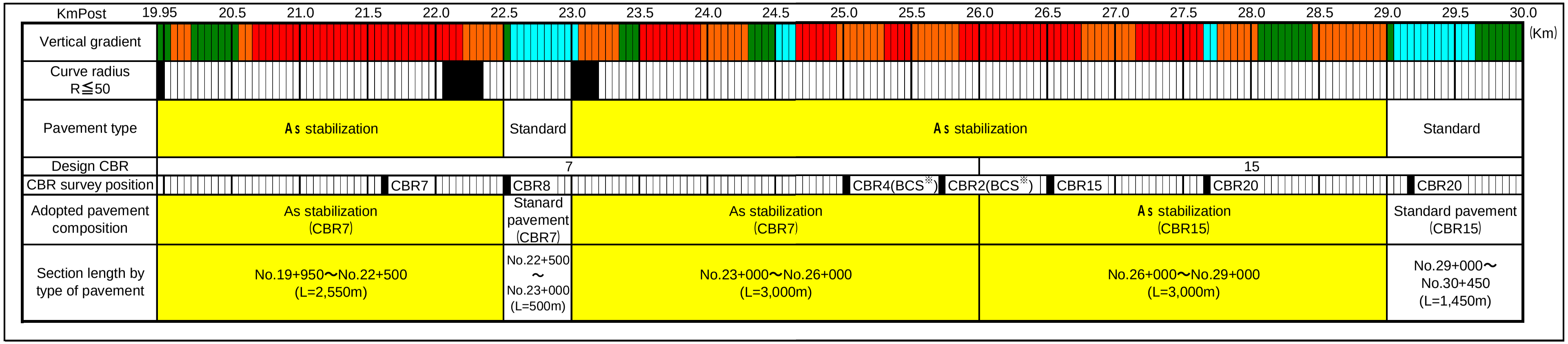
Standard pavement specifications

	CBR=	5	7	15	33
Surface course	t=	50	50	50	50
Upper subbase course	t=	350	300	300	250
Lower subbase course	t=	100	100	0	0
Original ground	t=	-	-	-	-

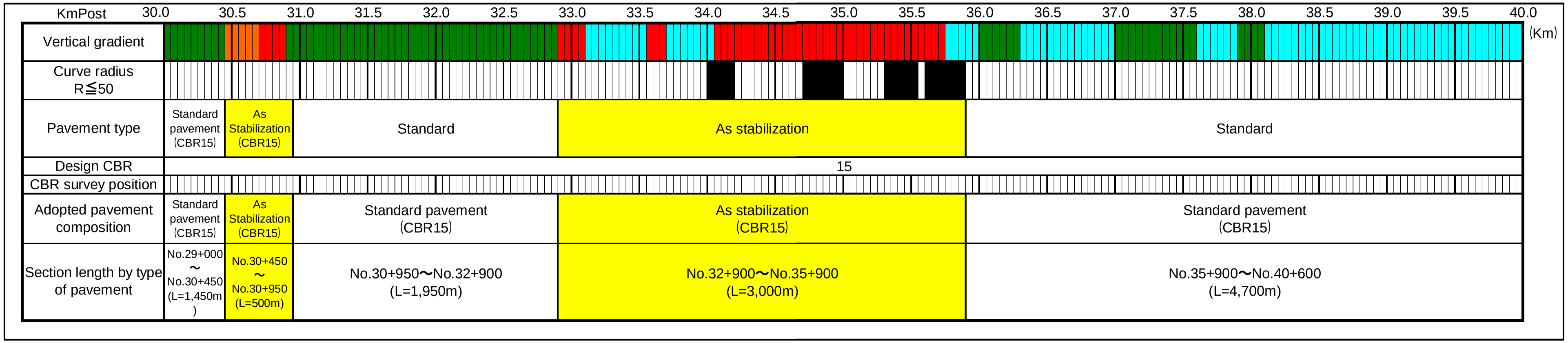
Plan with addition of As stabilization

	CBR=	5	7	15
Surface course	t=	50	50	50
As stabilization layer	t=	50	50	50
Upper subbase course	t=	250	200	200
Lower subbase course	t=	100	100	0
Original ground	t=	-	-	-

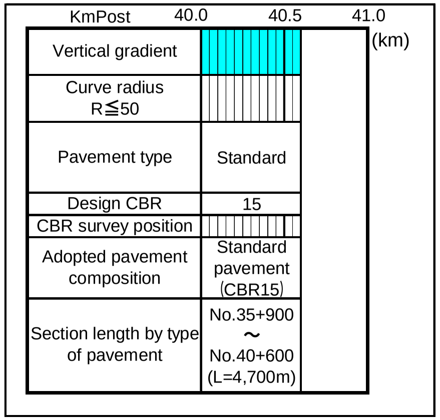
Table 2.2.25 Classification of Pavement Structure Specifications



KmPost	19.95 20.5 21.0 21.5 22.0	22.5	23.0 23.5 24.0 24.5 25.0 25.5	26.0 26.5 27.0 27.5 28.0 28.5	29.0 29.5 30.0 (Km)
Vertical gradient					
Curve radius R≦50					
Pavement type	As stabilization	Standard	As stabilization		Standard
Design CBR	7			15	
CBR survey position	CBR7	CBR8	CBR4(BCS※) CBR2(BCS※)	CBR15 CBR20	CBR20
Adopted pavement composition	As stabilization (CBR7)	Stanard pavement (CBR7)	As stabilization (CBR7)	As stabilization (CBR15)	Standard pavement (CBR15)
Section length by type of pavement	No.19+950〜No.22+500 (L=2,550m)	No.22+500 〜 No.23+000 (L=500m)	No.23+000〜No.26+000 (L=3,000m)	No.26+000〜No.29+000 (L=3,000m)	No.29+000〜 No.30+450 (L=1,450m)



KmPost	30.0	30.5	31.0 31.5 32.0 32.5	33.0 33.5 34.0 34.5 35.0 35.5	36.0 36.5 37.0 37.5 38.0 38.5 39.0 39.5 40.0 (Km)
Vertical gradient					
Curve radius R≦50					
Pavement type	Standard pavement (CBR15)	As Stabilization (CBR15)	Standard	As stabilization	Standard
Design CBR	15				
CBR survey position					
Adopted pavement composition	Standard pavement (CBR15)	As Stabilization (CBR15)	Standard pavement (CBR15)	As stabilization (CBR15)	Standard pavement (CBR15)
Section length by type of pavement	No.29+000 〜 No.30+450 (L=1,450m)	No.30+450 〜 No.30+950 (L=500m)	No.30+950〜No.32+900 (L=1,950m)	No.32+900〜No.35+900 (L=3,000m)	No.35+900〜No.40+600 (L=4,700m)



KmPost	40.0 40.5 41.0 (km)
Vertical gradient	
Curve radius R≦50	
Pavement type	Standard
Design CBR	15
CBR survey position	
Adopted pavement composition	Standard pavement (CBR15)
Section length by type of pavement	No.35+900 〜 No.40+600 (L=4,700m)

※ BCS：Black Cotton Soil

Subtotal	Standard specifications	8,600 m
	With As stabilization	12,050 m

Grant total	Standard specifications	12,100 m	30%
	With As stabilization	28,200 m	70%

Criteria for determining pavement specifications classification

① The asphalt stabilization layer shall be added on sections of steep gradient (8% or more) and sharp curves (R < 50 m).

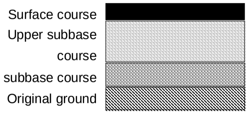
②The standard pavement specifications shall be adopted in cases where sections other than those described above run continuously for 500 m or more.

◇Vertical slope legend

- 🟦 : i < 6%
- 🟩 : 6% ≦ i < 8%
- 🟧 : 8% ≦ i < 9%
- 🟥 : 9% ≦ i ≦ 10%

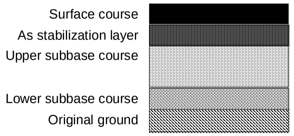
◇Pavement composition by type

Standard pavement specifications



CBR=	5	7	15	33
t=	50	50	50	50
t=	350	300	300	250
t=	100	100	0	0
t=	-	-	-	-

Plan with addition of As stabilization



CBR=	5	7	15
t=	50	50	50
t=	50	50	50
t=	250	200	200
t=	100	100	0
t=	-	-	-

d) Drainage Facilities Planning and Design

I. Lateral drainage facilities

Table 2.2.26 shows the results of the planning and designing of drainage facilities based on site survey findings and the concepts described in 2-1-1. Table 2.2.27, 28 and 29 shows a list of the different drainage facilities.

Table 2.2.26 Summary of Quantities for Drainage Facilities

Type of Renovation	Quantity	Contents of Renovation
New installation	18	Added to places where the capacity of lateral drainage structures is insufficient.
Replacement (P ⇒ P)	60	- Replacement of damaged pipes of ϕ900 or less with pipe culverts of ϕ900 or more (45 sites). - Replacement of damaged pipes of ϕ900 or more with new pipes of the same diameter (10 sites) - Damaged pipes of ϕ900 or more: expansion of pipe diameter to increase capacity (3 sites)
Replacement (B ⇒ P)	3	Replacement of damaged box culverts with pipes (ϕ1200 mm)
Bridge widening (insufficient width)	2	Bridges that are no problem in terms of drainage capacity but require widening or a separate bridge due to lack of width.
Repair	22	Existing drainage facilities requiring only repairs

Table 2.2.27 List of Different Types of Drainage Facilities (1/3)

Curvert No.	Station (Km)	Type	Existing Assignment			New Assignment			Capacity	Total Capacity	Catchment Area No.	Discharge	Existing Condition	Recommendation
			Pipe	Culvert		Pipe	Culvert							
			(ϕ) m	h (m)	b (m)	(ϕ) m	h (m)	b (m)	m3/sec	m3/sec		m3/sec		
1	184.80	Pipe	0.90			0.90			0.68	- (二次)	G1	-	Fair	
2	185.30	Pipe	1.00			1.00			1.66	- (内)	G2	-	Fair	
3	185.50	Slab		1.00	2.00		1.00	2.00	6.85	6.85	G2	1.27	Fair	
B-020	185.90	Girder		10.00	14.00		10.00	14.00	254.32	254.32	G1-2	87.15	small acsess curve	Bridge Widening
4	186.05	Slab		1.80	2.40		1.80	2.40	18.88	326.55	G3	7.72	Fair	
5	186.35	Slab		2.20	2.40		2.20	2.40	24.26				Fair	
6	186.55	Slab		2.10	2.20		2.10	2.20	20.22				Fair	
7	186.65	Slab		1.00	1.30		1.00	1.30	3.80				Fair	
B-021	186.85	Arch		10.00	14.20		10.00	14.20	259.39				small acsess curve	Bridge Widening
8	186.95	Arch		2.40	2.00		2.40	2.00	2.69	8.54	G4	2.42	Fair	
9	187.20	Arch		2.60	3.20		2.60	3.20	5.85				Fair	
10	188.20	Pipe	1.00			1.00			1.66	6.66	G5	2.58	Fair	
11	188.25	Pipe	0.65			0.90			2.50				Half Blocked	Replacement (P⇒P)
12	188.40	Pipe	0.65			0.90			2.50				Half Blocked	Replacement (P⇒P)
13	188.60	Pipe	1.00			1.00			1.66	3.31	G12-1	1.73	End Wall missed	Repair
14	188.90	Pipe	1.00			1.00			1.66				Fair	
15	189.00	Pipe	1.20			1.20			2.69	174.66	G9-1	0.69	Fair	
16	189.10	Slab		5.20	4.50		5.20	4.50	171.97				Fair	
17	189.70	Pipe	1.20			1.20			2.69	75.26	G9-2	1.38	Fair	
18	190.05	Box		2.80	4.10		2.80	4.10	69.87				Fair	
19	190.10	Pipe	1.20			1.20			2.69				End Wall missed	Repair
20	190.20	Pipe	0.65			0.90			2.50	10.27	G12-2	4.26	Blocked	Replacement (P⇒P)
21	190.30	Slab		1.00	1.60		1.00	1.60	5.07				Fair	
22	190.60	Pipe	1.20			1.20			2.69				Blocked and Broken	Replacement (P⇒P)
23	190.90	Pipe	0.90			0.90			1.25	18.10	G12-3	8.71	End Wall missed	Repair
24	191.30	Slab		1.10	1.50		1.10	1.50	5.24				Head Wall missed	Repair
25	191.55	Slab		1.50	2.00		1.50	2.00	11.61				Head Wall missed	Repair
26	192.00	Pipe	1.00			1.00			1.66	2.57	G9-3	1.45	Fair	
27	192.10	Pipe	0.80			0.80			0.91				Head Wall missed	Repair
28	192.80	Slab		3.00	3.00		3.00	3.00	48.95	48.95	G9-4	7.51	Wing Wall broken	Repair
29	192.95	Pipe	1.00			1.00			1.66	4.16	G7-4	2.60	Fair	
30	193.20	Pipe	0.90			0.90			2.50				Fair	

Table 2.2.28 List of Different Types of Drainage Facilities (2/3)

Curvert No.	Station (Km)	Type	Existing Assignment			New Assignment			Capacity	Total Capacity	Catchment Area No.	Discharge	Existing Condition	Recommendation
			Pipe	Culvert		Pipe	Culvert							
			(φ) m	h (m)	b (m)	(φ) m	h (m)	b (m)	m3/sec	m3/sec		m3/sec		
31	193.45	Slab		2.00	3.00		2.00	3.00	29.45	29.45	G7-3	10.94	Wing Wall broken	Repair
32	193.55	Pipe	1.20			1.20			2.69	32.14	G7-2	9.28	Wing Wall broken	Repair
33	193.80	Pipe	1.20			1.20			5.39				Fair	
34	193.95	D. Slab		3.60	3.00		3.60	3.00	122.05				Fair	
35	194.70	Pipe	1.20			1.20			2.69	130.14	G7-1	60.31	Fair	
36	195.00	Pipe	0.90			0.90			1.25				Head Wall missed	Repair
37	195.10	Slab		1.50	2.50		1.50	2.50	15.80				End Wall missed	Repair
38	195.35	Pipe	1.20			1.20			2.69	19.75	G6	5.76	Blocked	Replacement (P⇒P)
39	195.55	D. Box		3.50	2.50		3.50	2.50	90.11				Wing Wall broken	Repair
40	195.80	Box		2.50	3.00		2.50	3.00	39.08	129.19	G7-5	97.65	Fair	
41	195.90	Pipe	0.80			0.80			0.91				Head Wall missed	Repair
42	196.05	Pipe	0.80			0.90			1.25				Blocked	Replacement (P⇒P)
43	196.20	Slab		2.50	3.00		2.50	3.00	39.08	80.32	G8	11.82	Head Wall missed	Repair
44	196.55	Slab		2.00	2.30		2.00	2.30	20.29				Fair	
45	196.70	Pipe	0.60			0.90			2.50				Blocked	Replacement (P⇒P)
46	196.80	Slab		3.40	3.00		3.40	3.00	56.98	79.77	G9-5	17.83	Fair	
47	196.90	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
48	197.05	Slab		2.50	3.00		2.50	3.00	39.08				Fair	
49	197.30	Slab		3.00	3.00		3.00	3.00	48.95	90.53	G10	9.79	Fair	
50	197.50	Slab		3.00	3.00		3.00	3.00	48.95				Fair	
51	197.60	Pipe	1.00			1.00			1.66				Fair	
52	197.80	Pipe	1.00			1.00			1.66				Fair	
53	198.00	Pipe	0.60			0.90			1.25	53.52	G11	18.43	Blocked	Replacement (P⇒P)
54	198.10	Slab		3.50	2.00		3.50	2.00	32.20				Fair	
55	198.15	Pipe	1.20			1.20			2.69				Fair	
56	198.30	Slab		4.00	5.00		4.00	5.00	144.98	179.87	G12-4	32.73	Fair	
57	198.35	Pipe	2.00			2.00			10.52				Fair	
58	198.45	Pipe	1.00			1.00			1.66				Fair	
59	198.60	Pipe	1.00			1.00			1.66	13.84	G13	3.87	Blocken	Replacement (P⇒P)
60	198.80	Slab		1.50	2.50		1.50	2.50	15.80				Fair	
61	199.10	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
62	199.40	D. Pipe	1.00			1.00			3.31	21.62	G14	5.37	Fair	
63	199.55	Pipe	0.90			0.90			1.25				Fair	
64	199.65	Pipe	0.60			0.90			2.50				Blocked	Replacement (P⇒P)
65	199.80	Pipe	1.00			1.00			1.66				Fair	
66	199.95	Pipe	1.00			1.00			1.66				Check Dam broken	Repair
67	200.10	Pipe	1.00			1.00			1.66				Head Wall missed	Repair
68	200.20	Pipe	1.00			1.00			1.66				Fair	
69	200.40	Pipe	1.00			1.00			1.66				Fair	
70	200.60	Pipe	1.50			1.50			4.89				Fair	
71	201.00	Slab		3.00	2.00		3.00	2.00	26.94	43.87	G15	8.25	Fair	
72	201.40	Slab		4.40	3.10		4.40	3.10	81.26	81.26	G16	2.42	Fair	
73	201.45	Pipe	1.00			1.00			1.66				End Wall missed	Repair
74	201.60	Pipe	0.90			0.90			1.25				End Wall missed	Repair
75	201.70	Pipe	1.00			1.00			1.66				End Wall missed	Repair
76	201.95	Pipe	1.00			1.00			1.66				Fair	
77	202.50	Pipe	0.80			0.90			2.50				Broken	Replacement (P⇒P)
78	202.70	Pipe	0.80			0.90			2.50	11.23	G17	8.29	Broken	Replacement (P⇒P)
79	202.80	Slab		1.20	1.60		1.20	1.60	6.40				Fair	
80	203.30	Pipe	0.80			0.90			2.50	8.90	G18-1	4.49	Blocked	Replacement (P⇒P)
81	203.60	Pipe	1.00			1.00			1.66				Blocked	Replacement (P⇒P)
82	203.70	Pipe	1.00			1.00			1.66				Fair	
83	203.90	Pipe	1.00			1.00			1.66				Head Wall missed	Repair
84	203.95	Pipe	0.60			0.90			2.50				Blocked	Replacement (P⇒P)
85	204.10	Pipe	0.60			0.90			2.50	9.98	G18-2	7.10	Blocked	Replacement (P⇒P)
Blue Nile Bridge	204.40													
86	204.60	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
87	204.80	Slab		1.00	1.00		1.00	1.00	2.61				Fair	
88	205.05	Pipe	1.00			1.00			1.66	6.77	D21	3.23	Fair	
89	205.35	Box		3.50	2.50		3.50	2.50	90.11	90.11	D20	85.60	Fair	
90	205.40	Pipe	1.00			1.00			0.90	0.90	D19	0.53	Fair	
91	205.80	Pipe	1.20			1.20			2.69				Fair	
92	206.10	Slab		4.00	3.00		4.00	3.00	69.17				Fair	
93	206.20	Pipe	1.50			1.50			2.65	74.51	D17-2	13.55	Fair	
94	206.30	Slab		3.00	4.00		3.00	4.00	73.71				Fair	
95	206.60	Slab		3.00	4.00		3.00	4.00	73.71				Fair	
96	206.80	Pipe	1.00			1.00			1.66	149.07	D18	2.37	Fair	
97	207.20	Slab		1.70	4.00		1.70	4.00	34.96				Fair	
98	207.30	Pipe	1.00			1.00			1.66				Fair	
99	207.45	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
100	207.60	Pipe	1.00			1.00			1.66				Fair	
101	207.70	Pipe	0.80			0.90			2.50	43.28	D17-1	0.99	Blocked	Replacement (P⇒P)
102	208.10	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
103	208.50	Pipe	1.00			1.00			1.66				Fair	
104	208.70	Pipe	0.90			0.90			0.68	4.84	D16	3.06	Fair	
		Pipe				1.20			10.78					New Installation
105	209.20	Pipe	2.00			2.00			5.70				Fair	
		Pipe				1.20			10.78					New Installation
		Pipe				1.20			5.39	32.65	D11-7	29.97		New Installation

Table 2.2.29 List of Different Types of Drainage Facilities (3/3)

Curvert No.	Station (Km)	Type	Existing Assignment			New Assignment			Capacity	Total Capacity	Catchment Area No.	Discharge	Existing Condition	Recommendation
			Pipe	Culvert		Pipe	Culvert							
			(ϕ) m	h (m)	b (m)	(ϕ) m	h (m)	b (m)	m3/sec	m3/sec		m3/sec		
106	209.90	Pipe	0.80			0.90			2.50	- (逆)			Blocked	Replacement (P⇒P)
107	210.10	Pipe	0.70			1.00			3.31	3.31	D15	2.49	Blocked	Replacement (P⇒P)
108	210.80	Pipe	1.00			1.00			1.66				Fair	
109	210.90	Pipe	0.70			1.20			5.39				Blocked	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
110	211.05	Pipe	0.70			1.20			5.39				Broken	Replacement (P⇒P)
		Pipe				1.20			5.39	23.21	D11-6	21.26		New Installation
111	211.20	Pipe	0.80			1.20			5.39				Blocked	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
112	211.30	Pipe	0.70			1.20			5.39				Blocked	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
113	211.50	Pipe	1.20			1.20			2.69	24.25	D11-5	20.11	Fair	
114	211.60	Pipe	1.00			1.00			0.90				End Wall missed	Repair
115	211.80	Pipe	1.00			1.00			3.31	4.21	D14	0.76	Broken	Replacement (P⇒P)
116	212.00	Pipe	0.70			1.20			5.39				Broken	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
117	212.20	Pipe	1.00			1.00			1.66				Fair	
118	212.40	Pipe	0.70			1.20			5.39	17.83	D11-4	17.46	Broken	Replacement (P⇒P)
119	212.60	Pipe	0.60			1.20			5.39				Broken	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
120	212.70	Pipe	1.00			1.20			5.39	16.17	D11-3	15.16	Broken	Replacement (P⇒P)
121	212.90	Pipe	0.70			0.90			2.50				Broken	Replacement (P⇒P)
122	213.05	Pipe	0.70			0.90			2.50				Broken	Replacement (P⇒P)
123	213.25	Pipe	0.70			0.90			2.50	7.51	D13	2.03	Broken	Replacement (P⇒P)
124	213.40	Pipe	0.70			0.90			2.50				Broken	Replacement (P⇒P)
125	213.55	Pipe	1.00			1.00			1.66	4.16	D12	1.15	Fair	
126	214.20	Pipe	0.80			0.90			2.50				Blocked	Replacement (P⇒P)
127	214.30	Pipe	0.70			0.90			2.50				Blocked	Replacement (P⇒P)
128	214.40	Pipe	0.80			0.90			2.50	7.51	D11-2	7.79	Blocked	Replacement (P⇒P)
129	214.75	Slab		2.00	2.00		2.00	2.00	16.60				Fair	
130	215.05	Box		2.10	1.80	0.90			2.50	19.11	D11-1	5.71	Flooded over	Replacement (B⇒P)
131	215.30	Pipe	0.80			1.20			5.39				Broken	Replacement (P⇒P)
		Pipe				1.20			5.39					New Installation
132	215.40	Pipe	0.80			1.20			5.39	16.17	D10	13.55	Broken	Replacement (P⇒P)
133	215.60	Pipe	0.80			0.90			2.50				Broken	Replacement (P⇒P)
134	215.70	Pipe	0.80			0.90			2.50				Broken	Replacement (P⇒P)
135	215.90	Slab		1.20	3.50		1.20	3.50	18.21	23.22	D9	7.83	Fair	
136	216.05	Pipe	-			1.20			5.39				Broken	New Installation
		Pipe	-			1.20			5.39					New Installation
137	216.10	Pipe	-			1.20			5.39				Broken	New Installation
		Pipe	-			1.20			5.39	21.56	D8	20.16		New Installation
138	216.30	Pipe	1.00			1.00			3.31				Broken	Replacement (P⇒P)
		Pipe				1.20			5.39	8.70	D7	7.72		New Installation
139	216.45	Slab		3.00	2.00		3.00	2.00	26.94				Fair	
140	216.75	Pipe	0.80			0.90			2.50	29.44	D6	10.78	Broken	Replacement (P⇒P)
141	216.90	Pipe	1.00			1.00			3.31				Broken	Replacement (P⇒P)
142	217.10	Pipe	1.00			1.00			3.31				Broken	Replacement (P⇒P)
143	217.30	Pipe				0.90			2.50	9.13	D5	5.60	waterway	New Installation
144	217.45	D. Slab		6.00	4.00		6.00	4.00	342.12	342.12	D1-2	138.35	scoured	Repair
145	217.65	Pipe	1.20			1.20			2.69				Fair	
		Pipe				0.90			2.50	5.20	D4	3.23		New Installation
146	217.80	Box		1.50	1.50		1.50	1.50	7.71				Fair	
		Pipe				0.90			2.50	10.21	D2-2	12.05		New Installation
147	218.15	Pipe	0.90			1.20			5.39				Blocked	Replacement (P⇒P)
148	218.50	Pipe	1.00			1.00			1.66	7.05	D3-6	6.08	Fair	
149	218.80	Pipe	0.70			0.90			2.50				Half Blocked	Replacement (P⇒P)
150	219.00	Pipe	1.00			1.00			3.31				Broken	Replacement (P⇒P)
151	219.10	Pipe	1.00			1.00			3.31	9.13	D3-5	2.03	Broken	Replacement (P⇒P)
152	219.20	Pipe	0.90			1.00			3.31	3.31	D3-4	2.60	Fair	Replacement (P⇒P)
153	219.90	Pipe	0.90			0.90			2.50	2.50	D3-3	1.96	Fair	Replacement (P⇒P)
154	220.20	Pipe	1.00			1.00			3.31				Broken	Replacement (P⇒P)
155	220.40	Pipe	1.10			1.10			1.16	4.47	D3-2	0.74	Fair	
156	220.50	Pipe	0.60			0.90			2.50	2.50	D3-1	0.21	Blocked	Replacement (P⇒P)
157	220.90	Pipe	1.40			1.40			2.20				Fair	
158	221.00	Pipe	0.70			0.90			2.50				Blocked	Replacement (P⇒P)
159	221.10	Pipe	0.70			0.90			2.50				Blocked	Replacement (P⇒P)
160	221.30	Pipe	0.70			0.90			2.50				Blocked	Replacement (P⇒P)
161	221.40	Pipe	0.90			0.90			0.68	10.39	D2-1	4.10	Fair	
162	221.50	Pipe	0.60			0.90			2.50				Blocked	Replacement (P⇒P)
163	221.60	Box		1.00	1.70	1.20			5.39				Broken	Replacement (B⇒P)
164	221.90	Pipe	0.90			0.90			0.68				Fair	
165	221.95	Pipe	1.50			1.50			2.65				Fair	
166	222.05	Pipe	1.50			1.50			2.65				Fair	
167	222.40	Pipe	0.90			0.90			0.68				Fair	
168	222.50	Pipe	1.00			1.00			0.90				Fair	
169	222.60	Pipe	1.00			1.00			0.90				Fair	
170	222.70	Box		1.10	1.20	1.20			5.39				Broken	Replacement (B⇒P)
171	222.90	Pipe	1.00			1.00			0.90	22.62	D1-1	9.79	Fair	

Renovation Quantities

New Installation	n=	18
Replacement (P⇒P)	n=	60
Replacement (B⇒P)	n=	3
Bridge Widening	n=	2
Repair	n=	22

II. Road side ditches

Roadside ditches shall be installed in the following places and appropriately lead into terminal lateral drains located nearby. Ditches shall be open channels (with stone lining) and shall be appropriately designed based on flow rate and lateral width.

- Sites where the bottoms of slopes meet with roads.
- Sections where the downstream side of lateral slopes is on the gorge side on curves and there is the risk of erosion being caused by water accumulation.
- In villages and urban areas ditches shall as a rule be installed on both sides of the road.
- Concerning longitudinal pipes, ditch size shall be ɸ600 mm in order to stop the ditch cross section from becoming too big.

The resulting quantities of side ditches based on the above are as follows.

Table 2.2.30 Calculation Sheet for Roadside Ditch Quantities

Name	Section	Length (m)	Remarks
U-shaped side ditch	Goha Tsiyon ~ Abay Bridge	22,110	
	Abay Bridge ~ Dejen	21,010	
	Total	43,120	
Stone-lined side ditch	Dejen	4,600	Applicable to built-up parts of Dejen

e) Traffic Safety Facilities Planning and Design

Traffic safety facilities comprising vehicle fall prevention facilities, road traffic signs and demarcation lines shall be installed based on the basis described in 2-2-1 (1) 6) g). The thinking regarding the installation of each facility type is described below.

I. Vehicle fall prevention facilities

In the basic design, concrete guide posts of the same type adopted in the first and second phase works shall be installed to prevent vehicles from falling off the side of the road. Posts shall be installed in accordance with the Installation Standards and Commentary on Safety Fences (Japan Road Association) on the following sections, which are deemed to be especially dangerous:

- Sections where the curve radius is 150 m or less, longitudinal slope is more than 6.0%, height and slope gradient on the road side are 4.0 m or more and 1.0 m or less respectively;

- Before and after bridges for the purpose of preventing collisions with bridge structures.

II. Road traffic signs

The following road traffic signs shall be considered for introduction in the Project:

- Restriction signs (overtaking prohibition, speed restrictions)
- Hazard warning signs (sharp curve warnings, steep slope warnings)

Of these, curve warning signs shall be installed on curves considered too sharp to allow the passing of trailers.

III. Demarcation lines

Demarcation lines, centerlines and roadside lines shall be installed. Centerlines are particularly effective for promoting safety. Also, consideration shall be given to installing pedestrian crossings at necessary points in built-up areas in Filcrik, Crula and Dejen.

Table 2.2.31 Calculation Sheet for Traffic Safety Facilities

Visibility guide posts	RC, painted	m	16,579	
Road signs	Type A	nos	7	Place name signs
	Type B	nos	575	Traffic safety signs
Road Marking	Continuous line w = 15 cm	m	123,900	
	Broken line w = 15 cm	m	1,910	Bus stops, parking strips
	Continuous line	m	284	Pedestrian crossings

f) Slope Protection Facilities Planning and Design

Slope protection facilities were planned based on site survey findings and the concept described in 2-2-1 (1) 6) h). Table 2.2.32 shows the total quantities for each type of work.

Table 2.2.32 Calculation Sheet for Slope Protection Facilities

Simple dam	RC	m	98	H=5m
Gravity retaining walls	RC	m	655	H=2m
Groundwater drains		m	1,400	
Loose rock removal		m3	266	
Slope shoulder ditches	U-600*600	m	185	

(2) New Abay Bridge

1) Overall Bridge Plan

a) Outline of the New Abay Bridge Plan

The reconstruction plan for the New Abay Bridge was drawn up based on the concepts described on 2-2-1 (2). The main factors for the planning of the new Abay Bridge are as follows:

I. The location of the new Abay Bridge shall be kept a minimum distance of 120 m from the existing bridge, which is equivalent to the center span of the existing bridge.
II. The substructure of the new Abay Bridge shall be constructed outside of the river stream during the dry season onsite.
III. Span length shall be balanced against bridge length.
IV. The vertical alignment of the new bridge will take into consideration the drainage of the carriageway surface.
V. Bridge structure shall be planned so as to be economical.
VI. Bridge type shall be planned so as to be simple and easily maintainable.
VII. Bridge type shall be selected based on aesthetics and environmental preservation.

Table 2.2.33 shows the outline of the new bridge plan and Figure 2.2.7 indicates the Project scope, which includes permanent bridge and revetment work around piers.

Table 2.2.33 Outline of Bridge Plan

Item		Single span	Main bridge
Bridge length		18m	70m+145m+70m=285m
Road width (Shoulder＋Carriageway)		1.0m+3.5m+3.5m+1.0m	1.0m+3.5m+3.5m+1.0m
Vertical grade		2.0% ←	→ 2.0%
Cross grade		2.5% ←	→ 2.5%
Railing (wall＋handrail piping)		18×2=36m	285m×2=570m
Revetment work		—	around piers
Superstructure		RC single span box girder	PC 3 span continuous box girder with extra-dosed type
Substructure	Abutment	Rigid framed type 1set	Reserved T type 1set
	Pier	Wall typed 1piers	V shaped 2piers
Foundation		Spread foundation	Spread foundation

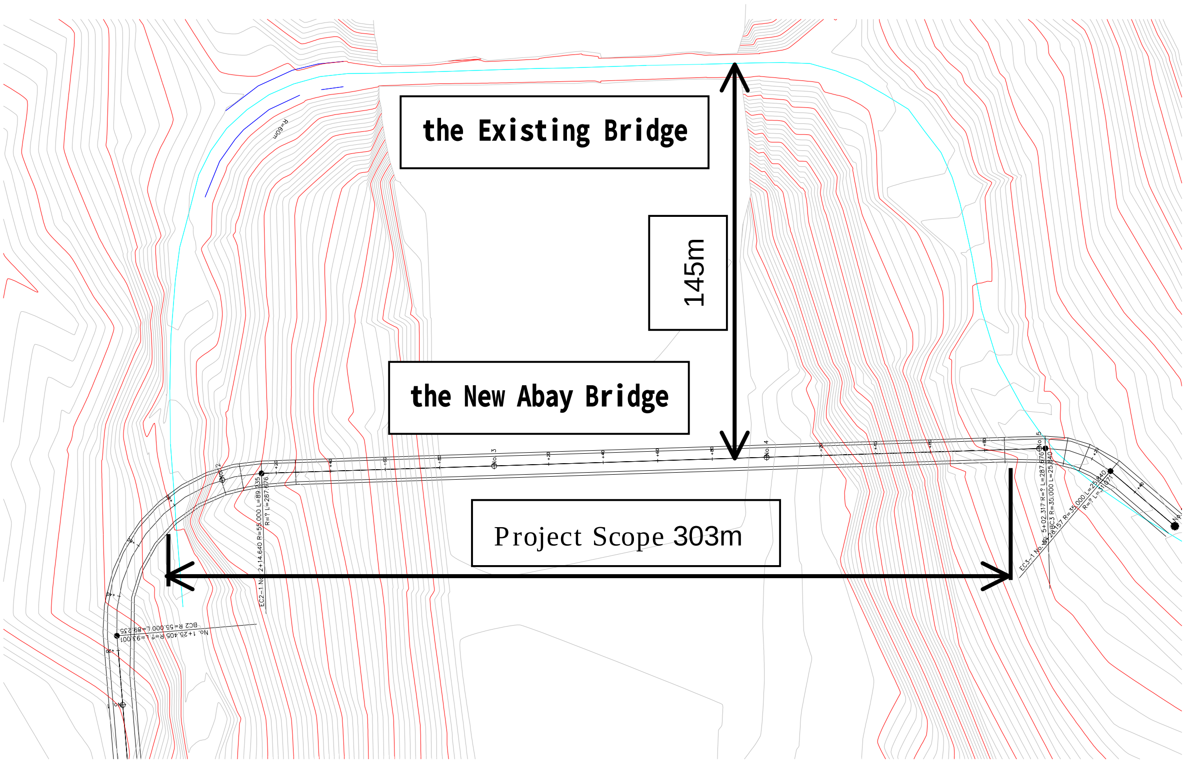


Figure 2.2.7 Project Scope

b) Design Standard

I. Applied design standard

The following design standards shall be applied in the Project.

- Bridge Design Manual: 2001 (Ethiopian code)
- Standard Specifications for Concrete
- Specifications for Highway Bridges (Japanese code)
- Road Structure Ordinance (Japanese code)
- River Engineering Ordinance (Japanese code)

The Ethiopian code “Bridge Design Manual: 2001”, which is based on ASSHTO, shall be applied in examining load conditions on bridges. As for examining bridge members, the Japanese allowable stress design method shall be applied.

II. Bridge cross sections

The Ethiopian standard for trunk roads on escarpments shall be applied to the cross sections, and is composed of a carriageway with two lanes and shoulders (no sidewalk) as indicated in Figure 2.2.8.

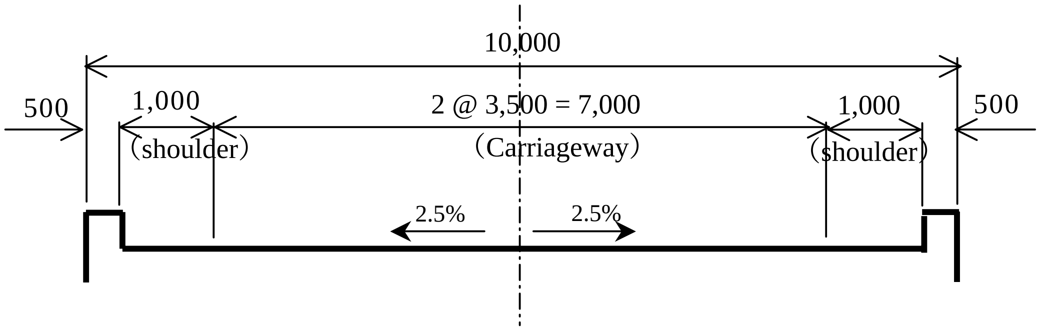


Figure 2.2.8 Bridge Cross Section for Escarpments

III. Design load criteria

Design load shall be based on Ethiopian standards and is described below.

i) Primary Load

＜Dead Load＞

Dead load is the total sum of the bridge materials shown in Table 2.2.34.

Table 2.2.34 Unit Weight by Material Type

Material	Unit weight (N/mm^2)	Material	Unit weight (N/mm^2)
Structural steel	77.0	Mortar	21.0
Reinforced concrete	24.5	Asphalt concrete	22.5
Prestressed concrete	24.5	Timber	8.0
Plain concrete	23.0		

＜Live Load and Impact Coefficient＞

A 25% incremental factor shall be applied to the following loads:

- HS Load: 319.7kN
- Uniform Load: 3.06kN/m2
- Concentrated Load: 26.7kN (for moment)
  38.5kN/m (for shearing force)

- Impact Coefficient:

for HS load I=20/(50+L)
for Uniform load I=10/(25+L)

Of the HS Load and Uniform Load, the more dominant one shall be applied for design. It is common knowledge that the Uniform Load is dominant in a longitudinal direction and therefore will be used for the superstructure design load, while the HS Load is dominant in a transversal direction and will therefore be used for slab decks.

＜Prestress force＞ To be considered
＜Influence by concrete creep＞ To be considered
＜Concrete shrinkage＞ To be considered
＜Earth pressure＞ To be considered
＜Water pressure＞ To be considered
＜Buoyancy or Uplift＞ To be considered

ii) Secondary load

＜Wind load＞

Wind load shall be based on the Ethiopian standard and monthly maximum wind velocity shall be deduced from survey data (see Table 2.2.35).

Table 2.2.35 Maximum Wind Velocity (Debre Markos Meteorological Observatory)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.
14	16	14	18	12	10	12	14	14	20	12	20	20

Note: max. monthly ratings 1993～2002 (unit: m/s)

＜Temperature variation＞

Actual surveyed temperature at the Abay Bridge perimeter is as follows:

Concrete surface: 10℃～40℃

＜Seismic design load＞

Abay Bridge is located in an Area"①" Zone according to the "Bridge Design Manual: 2001". Therefore, the corresponding seismic zoning coefficient from the Manual will be applied (see Figure 2.2.9).

$Cm = 1.2AS/(Tm^{2/3}) \leqq 2.5A$

Cm: horizontal seismic coefficient
A: response acceleration coefficient =0.03
S: seismic zoning coefficient =1.0
T: natural frequency

A safety buffer input using a horizontal seismic coefficient shall be applied and have a maximum rating of 2.5×0.03 = 0.075.

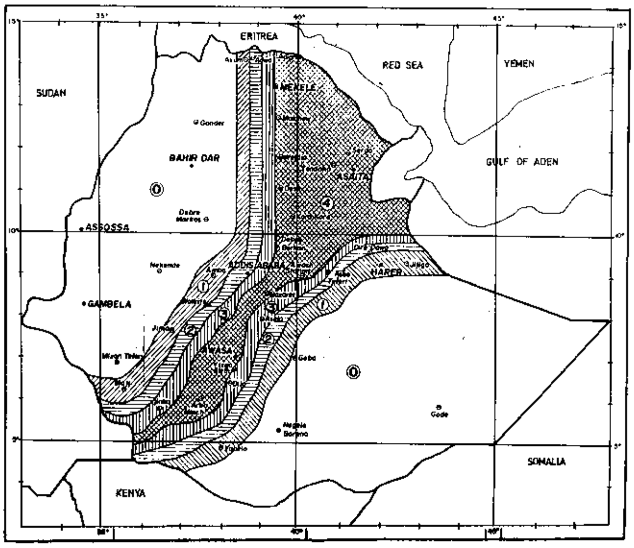


Figure 2.2.9 Seismic Zone

iii) Special load

- The following section forces shall also be input as part of erection load, which is dependent on bridge and structure type.
  Shearing force: 700kN
  Moment: 1050kNm
- Thermal load
  Temperature variation of the superstructure between the surface and bottom shall be determined using the Japanese standard “ Specifications for Highway Bridges”.
  T = +5℃

IV. Material and design strength

＜Design strength and Young’s modulus for concrete＞

- Main girder and main tower : 40N/mm^2 (Ec=3.11×10^4 N/mm^2)
- Piers : 30N/ mm^2 (Ec=2.80×10^4 N/mm^2)
- Pier Foundation and Abutment : 24N/ mm^2 (Ec=2.50×10^4 N/mm^2)

＜Re-bar＞

- sy=412N/mm2 (ASTM basis)

＜Prestressing steel＞

- Diagonal member : 19s15.2B
- Main cable : 12s15.2B
- Transverse cable : 4s15.2B
- Vertical steel member : SBPR930/1180 ф32

V. Incremental factors for allowable unit stress per load combination

Table 2.2.36 indicates the incremental factors per load combination that shall be applied in the Project.

Table 2.2.36 Incremental Factors by Load Combination

Load combination	Incremental Factor
Primary load	1.0
Primary load + wind load	1.15
Primary load + thermal load	1.15
Primary load + braking load	1.25
Primary load + vehicle impact load	1.50
Primary load + seismic load	1.50
Construction stage	1.50
Primary load + seismic load + thermal load	1.65

VI. Design criteria for superstructure

＜Bridge type＞	: concrete bridge for easy maintenance
＜Width＞	: refer to Figure 2.2.8
＜Live load＞	: Ethiopian standard
＜Cross grade＞	: 2.5%
＜Bridge deck pavement＞	: asphalt concrete pavement
＜Sidewalk＞	: not installed

VII. Design criteria for the substructure

＜Abutment＞ : concrete structure for easy maintenance
＜Pier＞ : concrete structure for easy maintenance
＜Embedded depth＞ : up to bearing stratum

VIII. Accessory facilities

The following accessory facilities shall be contemplated for the bridge.

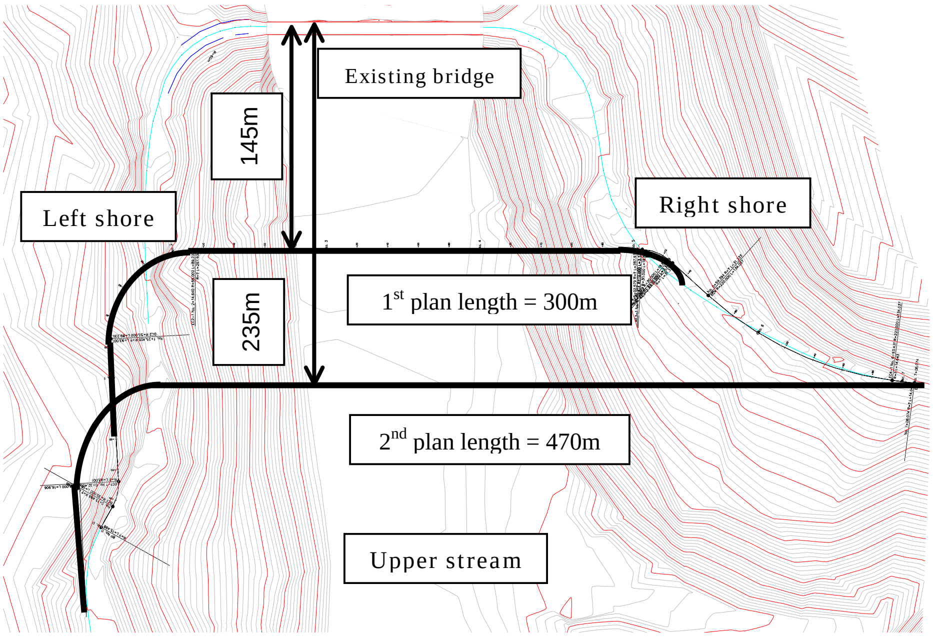
＜Expansion joint＞ : selected for high dewatering efficiency and simple maintenance
＜Bearings＞ : selected under easy maintenance concept
＜Safety fence＞ : concrete wall type and steel pipes for handrail

2) Bridge Planning

a) Bridge Location and Length

Two different routes were originally proposed for the new bridge. The evaluation sheet in Table 2.2.37 indicates the results of each alternative. Note that the 1st plan is selected because of its high cost efficiency.

Table 2.2.37 Bridge Location and Length

Bridges location		
New bridge location	1st Plan (145m away from the existing bridge on the upstream side. Minimum distance required is more than 120m (or the span length of the existing bridge).	2nd Plan (235m away from the existing bridge on the upstream side. Minimum distance required is more than 120m (or the span length of the existing bridge).
Road alignment	*On the right riverbank, the access road shall approach the existing road in a S-curve. *On the left riverbank, the actual curvature shall be re-applied.	*On the right riverbank, the access road shall make a straight approach to the existing road. *On the left riverbank, the actual curvature shall be re-applied.
Span length	145m	165m
Bridge length	Aprox.300m	Aprox.470m
Adaptability	*A bridge position with shorter bridge length shall favor in cost efficiency	*A straight alignment for the access road is favorable from a safety viewpoint.
Environmental preservation	*Short slope will minimize environmental impacts on flora.	*Long slope required on the right riverbank will affect flora.
Evaluation Results	It is confirmed that the 1st plan shall be feasible under high cost efficiency, smaller environmental impact favored from short bridge length and short slope in spite of marking demerit on road safety for vehicles.	

b) Span Arrangement

On the left riverbank, the access road will inevitably be aligned over the existing road. It shall therefore be necessary for the span arrangement for the new bridge to be further examined in regards to the longitudinal profile during temporary works throughout the construction period.

No piers are to be constructed in the river stream during the dry season and the number of piers shall be limited to the greatest extent possible. On the other hand, the superstructure load balance must also be considered. Accordingly, the span arrangement shown in Figure 2.2.10 shall be applied.

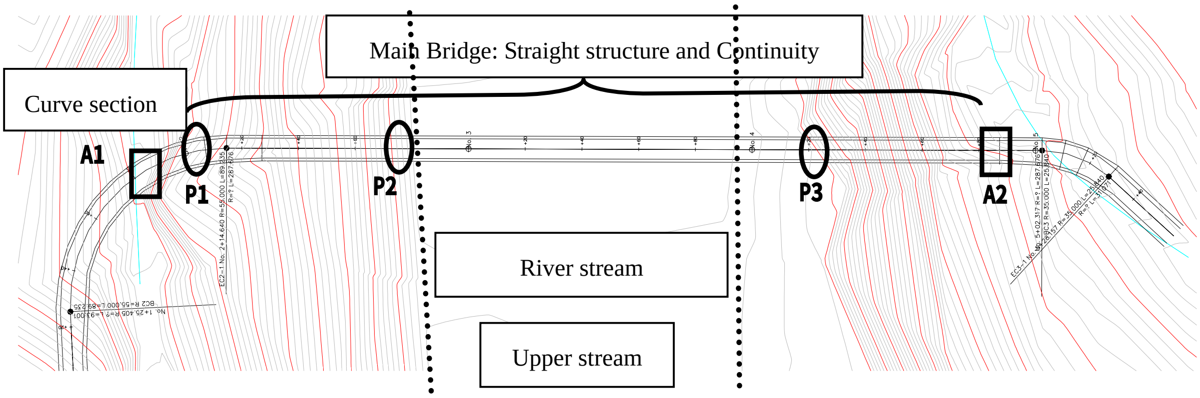


Figure 2.2.10 Proposed Span Arrangement

The above figure indicates that the center span will be located above the main river channel and shall be 145m in length. Note that piers shall not block the flow of the river. On the other hand, in order to ensure a straight structure with a continuous span, which will help realize high cost efficiency, additional piers shall be installed on the left riverbank and side spans shall be 70m in length. The main bridge, i.e. the straight section, shall be 285m in total length and contain 3 continuous-type spans.

A different bridge type shall be applied for curved sections on the left riverbank. The existing road and planned abutment makes it necessary that a single span bridge 18m in length be selected.

c) Design Flood Stage

According to the site surveys, there is much small driftwood piled around the arch abutment on the left riverbank 1.0 to 1.5m high. Meanwhile, records indicate that in August 1996 a record flood went more than 50cm over the top of the arch abutment. Based on the Ethiopian Bridge Design Manual, large-scale bridges need to be designed in consideration of the largest flood in a 100-year return period. Therefore, the design flood level shall be determined applying this concept. As shown in Table 2.2.11, the design flood level possible in a 100-year return period is 1031.664m (or1031.7m).

d) Bridge type selection

I. Superstructure type for the main bridge

The following concepts shall be strictly adhered to in selecting the bridge type for the main bridge.

- High cost efficiency
- Easy and simple maintenance
- Aesthetically in harmony with the existing bridge
- Symbolically meaningful
- Technological transfer
- A span length 145m or longer
- Consideration of the requests of the Ethiopian Government

An arch bridge, which is the bridge type for the existing bridge and which evidently has no superiority to a conventional concrete bridge in terms of cost efficiency, can be a benchmark for comparing alternatives. As for a steel bridge, it is rejected because of logistic problems in transporting materials and difficult maintenance, which requires periodic maintenance that includes reapplication of an anticorrosive layer. Here, the following two bridge types are taken up as alternatives and screened.

- PC 3 span continuous box girder bridge
- PC 3 span continuous box girder extra-dosed type bridge

As Figure 2.2.11 indicates, it is widely known from both domestic and overseas projects that an extra-dosed bridge is more advantageous in terms of cost efficiency when span length is about 110m long as compared to the continuous girder bridge. Table 2.2.38 and Figure 2.2.11 provide specific information for each bridge type alternative.

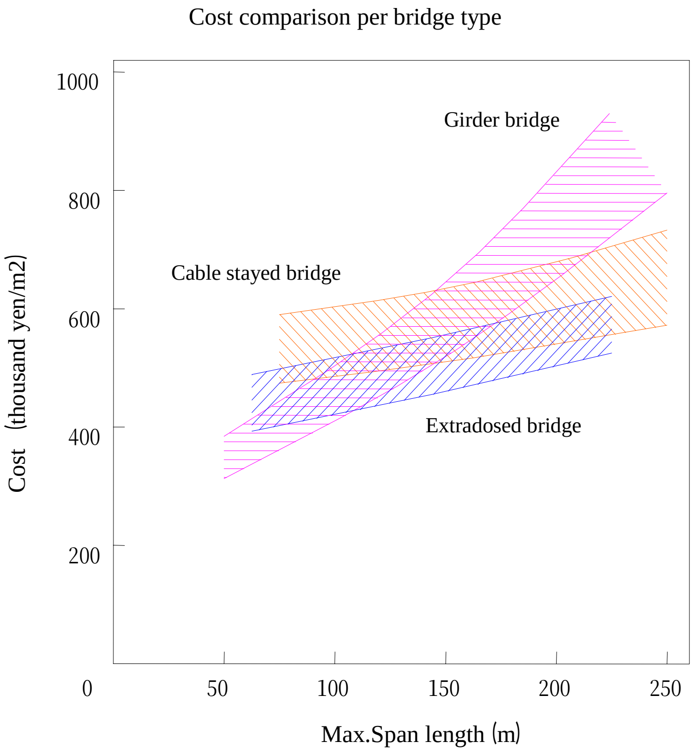
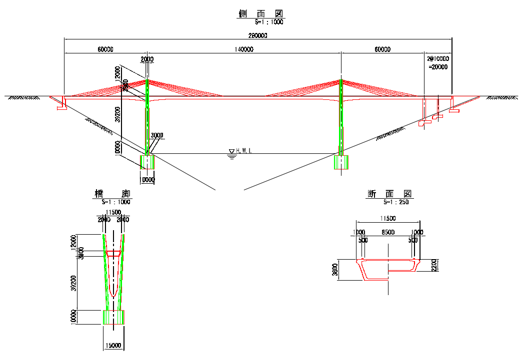
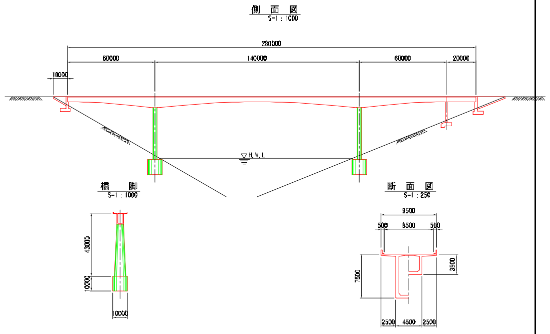
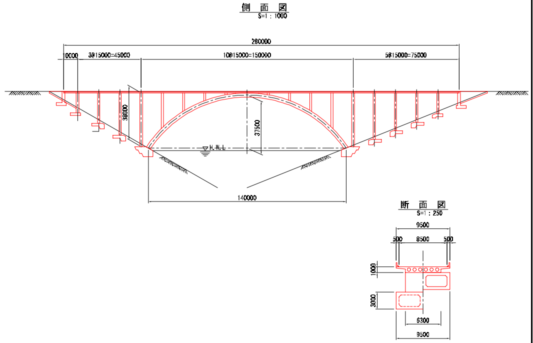


Figure 2.2.11 Cost / Span Length Comparison per Bridge Type

Table 2.2.38 Comparison Table on Bridge Type Selection

Bridge Type	Plan A: PC 3span continuous box girder Extradosed type bidge	Plan B : PC 3span continuous box girder bridge	Plan C : RC arch deck concrete bridge
Conceptual Drawing			
Stractural features	• It is a racional structure type with PCcable (diagonal member) installed out of the girders. • Strongly requested by the Ethiopian government and it shall be first intoroduced. • Box type section shall favor both concrete volume reduction and girder hight reduction at piers supporting. • V type pier shall favor concrete volume reduction. • Transferable in terms of technical knowledge and skills. • Lowest concrete volume required. ◎	• It is a functional structure type with continuous girders. • Experienced in Ethiopia. Same typed bridge is located at down stream side. • Box type section shall favor concrete volume • Girders Section shall remarkably be much higher than Plan A for installation of the prestressing bar. • Transferable in terms of technical knowledge and slills. • Increased superstructureself weight shall require larger substructures than Plan A. ○	• It is an arch type structurewhcich takes advantage of the concrete property（high compressive strength）. • Same structure type in basic as the existing bridge. • Hollow section shall be applied for the slab deck to reduce concrete volume. • Hollow slab deck structure can be applied for the approching streach as well as arched sterach. • Transferable in terms of technical knowledge and slills. • Highest concrete volume required. ○
Aesthetic features	• Excellent harmonization with the exiting bridge. • Symbolic appearance. ◎	• Harmonization with the exiting bridge can be obtained. • Girder size at support point gives massive appearance. ○	• Good harmonization with the exiting bridge. • Good aesthetic with the ravine. ◎
Construction featunes	• Site-casting & Cantilever method shall be employed for superstructure construction • After the main tower erected, PCmaterial and box girders shall be installed consequently to progress. • Longer construction preiod shall be required than Plan B (estimated 38months). ◎	• Site-casting & Cantilever method shall be employed for superstructure construction • Shortes construction period shall be requiredamong the alternatives (estimated 36months). ◎	• Cable erection shall be employed for the Arch section. • It is a struture type which requires large-scaled machinery and cranes. • Longest construction period shall be required among the alternatives (estimated 40months). △
Cost efficiency	◎（1.00）	○（1.05）	△（1.15）
Maintenace efficiency	• Almost free of maintenance including diagonal members. No major issues expected for future maintenance ◎	• Almost free of maintenance. No major issues expected for future maintenance ◎	• Almost free of maintenance. No major issues expected for future maintenance. ◎
Evaluation Results	• Plan C possesses advantage in terms of aesthetic features and disadvantage in cost efficiency. Beside longest construction period shall bereuqired. • Plan B gives massive appearance slightly due to high girder size at support point with piers. In terms of cost efficiency, no remarkable advantage against Plan A. • Plan A favors highest cost efficency and possesses advantages on overall features such as structure and maintenance efficiency. Plan A shall be selected in conclusion.		

◎：High ranked adaptability　　○：Moderate　　△：Low

II. Type of superstructure for the curved section

Bridge length at the curved section shall be 18m in length and the structure shall be beveled at 60 ° against the bridge center as indicated in Figure 2.2.12, resulting in torsion on the girders. Alternatives are specified and examined in Table 2.2.39 in order to determine the best superstructure for the estimated torsion. It was concluded that a RC box girder type of bridge is most appropriate in consideration of structural continuity with the main bridge, cost efficiency, construction workability, etc. for the curved alignment.

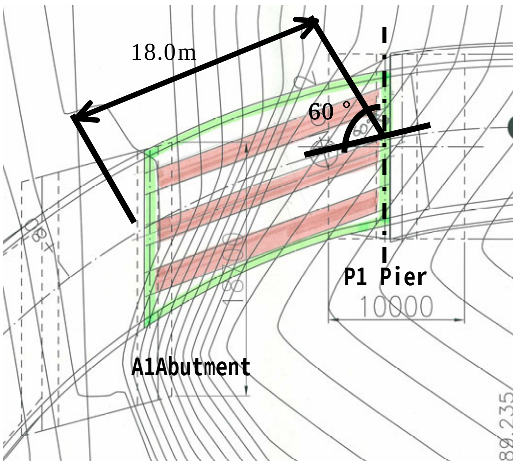


Figure 2.2.12 Superstructure at Curved Section

III. Substructure type

i) Piers for the main bridge (P1, P2, P3)

Piers shall be planned with a substructure that minimizes self-weight.

- Two different criteria shall be applied for P2 and P3, which are located at the upper and lower sides of the bridge (Figure2.2.13). The pier on the lower side will have a 10cm layer of protective concrete to prevent damage and/or erosion to the pier from debris flows.
- P1 shall have the same criteria as the structures for P2 and P3 and will support the superstructure with a wall.

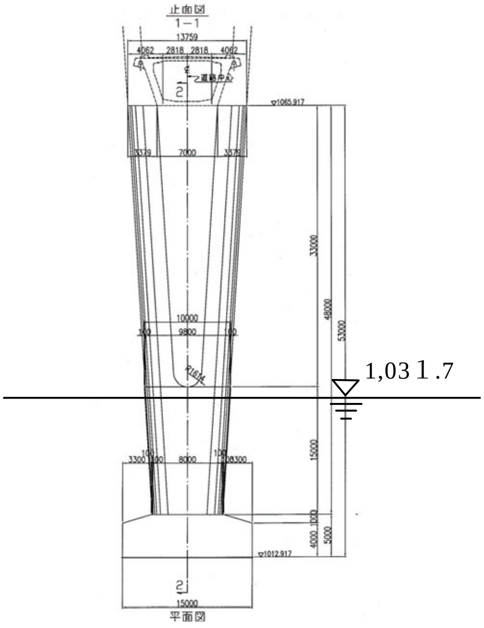
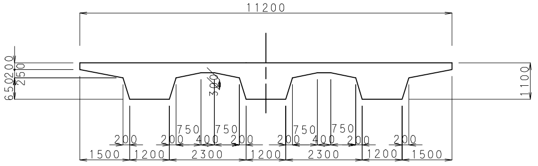
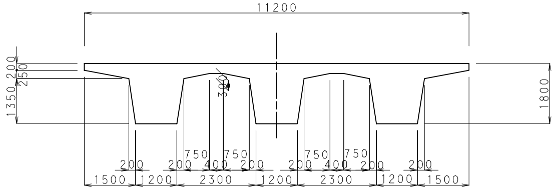
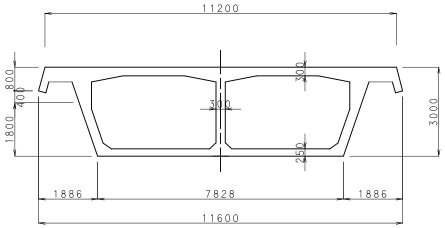


Figure 2.2.13 Pier Type

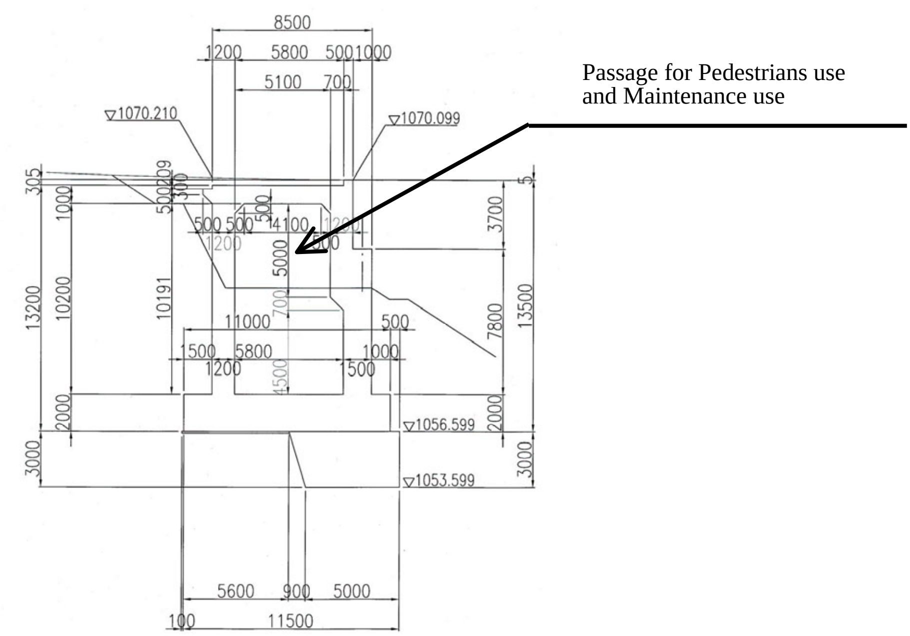
Table 2.2.39 Comparison Table on Superstructure Type for the Curve Section

Bridge Type	1st Plan : Simple PC 3 girders bridge	2nd Plan : Simple RC 3 girders bridge	3rd Plan : Simple RC 2 room box girder bridge
Conceptual Drawing	 Cross sectional area：7.100m2 Post tensioning system	 Cross sectional area：10.040m2	 Cross sectional area：9.072m2
Structural features	• Originally categorized with pre-tensioning method. • It is a structural type that enables to minimize girder hight. • Cross sectional area shall be smallest. • Low trosional regidity caused by the bevel（60°） and the open section chronically shall arise torsion load at the maingirder. • Accordingly, addtitional reinforcement shall be required. (intermid. cross beam , re-bar resisting against tosion stress) △	• 3 main girders bridge is specified because 2 main girder type shall require larger size of slab deck due to wider girder arrangement. • Low trosional regidity caused by both the bevel（60°）and the open section chronically shall arise torsion load at the maingirder. • Accordingly, addtitional reinforcement shall be required. (intermid. cross beam , re-bar resisting against tosion stress) • Girder self weight shall be heaviest △	• Box section structure shall possess high torsional rigidity. • Cross sectional area shall be smaller than 2nd Plan. • It is the structure which shall be adaptable to the bevel and curved alingment. ◎
Aesthetic features	• Slender apperance obtained • Unbalanced appearance given with hight of the Extradosed type girder at side span ○	• Slender apperance obtained as well as 1st plan. • Slightly unbalanced appearance given with hight of the Extradosed type girder at side span ○	• The hight of girders, which is shall give aesthetic accordance and continuity with the existing bridge. ◎
Construction features	• Large scale crane shall be required due to big selfweight（estimated 100t）when girder erection method employed. • Staging method on existing grade shall be applicable. • Torsional stress shall arise on main girders when prestressing wire tensioned . It shall carefully be monitored for prestressing execution. • Construction period shall be longest due to prestressing . △	• Staging method on existing grade shall be applicable. • Heaviest girder selfweight shall require larger-scale staging. △	• Staging method on existing grade shall be applicable. • Parts of the Forms shall be reusable due to the same structure type employed as the mainbridge. ◎
Cost Efficiency	○	△	◎
Maintenance efficiency	• No major issues for the concrete bridge	• No major issues for the concrete bridge	• No major issues for the concrete bridge
Evaluation Results	• 3rd Plan possesses remarkable advantages on high adaptability with bevel and curved alignment, resistance anti- torsional stress. • 1st Plan favors the lowest concrete volume, however suffers from longest construction period due to prestressing work included installation and tensioning of the prestressing materials. • 1st Plan and 3rd Plan render alomost same cost efficiency. • 3rd Plan shall be selected due to advantages on overall features such as structural merit, aesthetic harmonaization with the main bridge and cost effiency.		

◎：High ranked adaptability　　○：Moderate　　△：Low

ii) Abutment for the curved section (A1, A2)

The existing bridge shall be converted to pedestrian use after the new Abay Bridge opens to traffic. Note that a grade-separated crossing shall be employed at the A1 abutment, which will allow the planned route to overpass the existing road, and a rigid-framed structure for the abutment (see Figure 2.2.14) is employed to enable smooth traffic flows. A reversed T type structure shall be employed for the A2 abutment.



Passage for Pedestrians use
and Maintenance use

Figure 2.2.14 A1 Abutment Structure Type

IV. Foundation type

Geological survey data indicate that the bearing stratum shall consist of a sandstone layer with soft rock 3.0 to 6.0m below the ground surface. The survey also indicates that on the left riverbank there is an upper layer of stratum consisting of gravel with boulders, while on the right riverbank there is sand runoff from the upstream side of the river.

A spread type of foundation shall be applicable for all foundation work. Structural features are specified below.

A1 abutment: the bearing stratum consists of a mixture of soft rock and boulders in the upper layer. The stratum has a topographic break, which is 3.0 m off the grade level, and replacement concrete shall enable the spread type of foundation to be employed at the break.

P1 pier: Same ground composition observed at A1 abutment. The spread type foundation is therefore applicable.

P2 pier: The spread type foundation is applicable and will be directly placed on the bearing stratum, which is 6.0m below the ground surface. A cofferdam with sheet piles is required for earthwork. A vibro-hammer and water-jet equipment shall also be required to cut the massive rock layer.

P3 pier: The spread type foundation is applicable and will be directly placed on the bearing stratum, which consists of soft rock and has 2.0 to 3.0m of a thick silty sand layer piled on top. As in the case of the P2 pier, a cofferdam with sheet piles is required for earthwork. A vibro-hammer and water-jet equipment shall also be required to cut the massive rock layer.

A2 abutment: The spread type foundation is applicable and will be directly placed on the bearing stratum, which is 2.0 to 3.0m below the ground surface.

V. Revetment work

Revetment work shall be required for the P2 and P3 piers, which are located inside the river, in order that backfilled materials are not washed away by flooding in the rainy season. A 10m long revetment both on the upstream side and downstream side of the piers shall be considered. Based on the examination below, it is recommended that a stone revetment be employed.

＜Mat gabion type＞

- It would be necessary to prevent joint filling material from running off via suction pressure.
- Disadvantageous in terms of maintenance efficiency. Also, the wire netting is easily damaged by river flows.
- Disadvantageous in terms of cost efficiency. Also, wire netting would be

required for periodic maintenance and replacement.

＜Stone revetment＞

- Widely used in Ethiopia for conventional revetment work.
- Advantageous in terms of maintenance efficiency, since it would not be severely damage by river flows.
- Extremely advantageous in terms of cost efficiency, since low-cost local materials can be employed. This would help minimize construction costs.