2-2-6 Overall plan

(1) Applicable design standards and conditions

1) Road design conditions

The standards established in Ethiopia will be followed in the road design. The donor country's standards will be followed where the Ethiopian standards have no provision. Table 2-2-8 shows the road design conditions.

Table 2-2-8 Road design conditions

Bridge name	Unit	Gogecha Bridge	Modjo Bridge
Design elements		Urban/peri-urban area	Urban/peri-urban area
Road standards		DS2	DS1
Design velocity	km/h	50	50
Minimum stopping sight distance	m	55	55
Minimum passing sight distance	m	175	175
Minimum horizontal curve radius	m	85	85
Need for transition (clothoid) curves		Yes	yes
Maximum longitudinal slope (recommended)	%	6	6
Maximum longitudinal slope (absolute value)	%	8	8
Minimum longitudinal slope	%	0.5	0.5
Maximum superelevation	%	4	4
Minimum vertical curve radius (convex)	k	10	10
Minimum vertical curve radius (concave)	k	12	12
Standard cross slope	%	2.5	2.5
Shoulder cross slope	%	4	4
Right of way (ROW)	m	50	50

2) Bridge design conditions

i) Hydraulic conditions

a) Probability scale

In accordance with the road standards of Ethiopia, 100-year design flood discharges will be used in the design of the bridge.

b) Design flood discharges

The 100-year design flood discharges of Gogecha River and Modjo Rive are respectively 112 m^3/s and 1,144 m^3/s.

c) Design flood levels

The 100-year design flood levels of Gogecha River and Modjo Rive are respectively 1,957.522m and 1,747.163m.

d) Vertical clearances

The table below shows the vertical clearances stipulated in Bridge Design Manual (2002) of Ethiopia.

Discharge Q (m^3/s)	Vertical clearance (m)
0 - 3.0	0.3
3.0 - 30.0	0.6
30 to 300	0.9
> 300	1.2

Table 2-3 Vertical Clearance at Design Flood Level (DFL)

The table below shows the vertical clearance required for the two bridges derived from the table above.

Table 2-2-9 Design flood discharges and vertical clearances

	Gogecha Bridge	Modjo Bridge
Design flood discharge (m^3/s)	112	1,144
Vertical clearance (m)	0.9	1.2

e) Scour depth

The designs of Gogecha and Modjo Bridges include abutments and piers, respectively, in the river channels. However, since bedrock is exposed on the banks of both the Gogecha and Modjo Rivers, floods will pose no possibility of scour in future. Nonetheless, the scour depth of 2 m will be included in the bridge designs as a standard.

f) Revetment

The river which the planned bridge is to be built is natural river. The river channel has not been altered artificially and there is no embankment along the river. There is no revetment or bed protection work near the abutments or piers of the existing bridge or on the river banks upstream or downstream of the bridge. Bedrock is exposed on the river banks where the bridge exists. There are limited amounts of earth and stone sediment transported from the upper reaches of the river and tributaries upstream and downstream of the current bridge sites. Therefore, there is no possibility of river-bed variation caused by scour at the time of flood. In order to ensure safe and smooth flow of flood water as has been seen up to now after the bridge construction, the revetment work focused on restoration of the original conditions will be considered.

ii) Design live loads

As described in 2-1-5, Policies on Design Live Load, the figure 25 % larger than HS20 stipulated in the Ethiopian standards (Bridge Design Manual: 2002) based on AASHTO will be used as the design live load on the bridges.

iii) Seismic load

Ethiopia has Bridge Design Manual: 2002, which stipulated the seismic loads as follows:

a) Earthquake zones

The entire country is classified into five earthquake zones, ⓪ to ④, and the two bridges concerned are located in Zone ④.

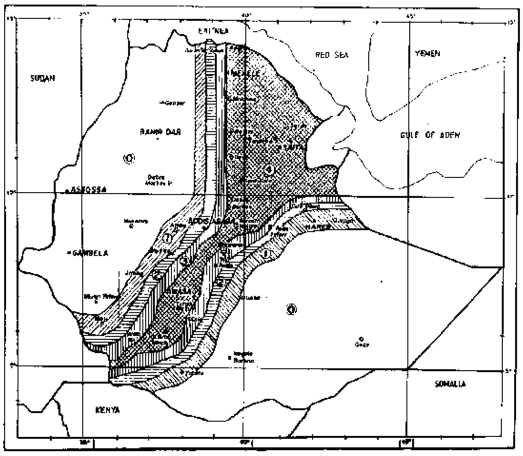


Figure 3-9 Earthquake Zones (Note: In zone 1-3 A≤0.07 and in zone 4 A≤0.10)

b) Response acceleration coefficient

Among the five earthquake zones, a response acceleration coefficient has been provided for each of the Zones 1 to 4, as shown in the table below. The coefficient for the three bridges concerned was set at A = 0.10 with safety allowance.

EBCS zone from Figure 3-9	Acceleration Coefficient
1	$A \leq 0.03$
2	$0.03 < A \leq 0.05$
3	$0.05 < A \leq 0.07$
4	$0.07 < A \leq 0.10$

c) Horizontal seismic vibration

Horizontal seismic vibration is obtained from the following equation:

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

where:

Cm: Horizontal seismic vibration,

A: Response acceleration coefficient = 0.10,

S: Site coefficient = 1.0 (in accordance with the table below) and

Site Coefficient	Soil Profile Type			
	I	II	III	IV
S	1.0	1.2	1.5	2.0

Tm: Natural period of structure.

The maximum vibration of Cm = 2.5A = 2.5 x 0.1 = 0.25 obtained from the equation above with safety allowance will be used in the design.

iv) Material strengths

Table below shows the strengths of various materials to be used in this project.

Table 2-2-10 Materials to be used

	Gogecha Bridge	Modjo Bridge
1) PC concrete	・Main girder σ_{ck}=35N/mm^2 ・Cross beam and filling concrete σ_{ck}=30N/mm^2	・Main girder σ_{ck}=35N/mm^2
2) RC concrete	・Sleepers and substructure work σ_{ck}=24N/mm^2	・Sleepers and substructure work σ_{ck}=24N/mm^2 ・Cast-in-place piles (underwater) σ_{ck}=30N/mm^2
3) Plain concrete	・Sidewalks leveling concrete σ_{ck}=18N/mm^2	・Sidewalks leveling concrete σ_{ck}=18N/mm^2
4) Reinforcing bars	SD345	SD345
5) PC steel materials	・Main cable 12S12.7 (SWPR7BL) ・Transverse prestressing cable 1S19.3 (SWPR19L)	・Main cable 12S12.7 (SWPR7BL) ・Transverse prestressing cable 1S28.6 (SWPR19L)

v) The specification process for span length

The specification process for the bridge span length is shown in Figure 2-2-6.

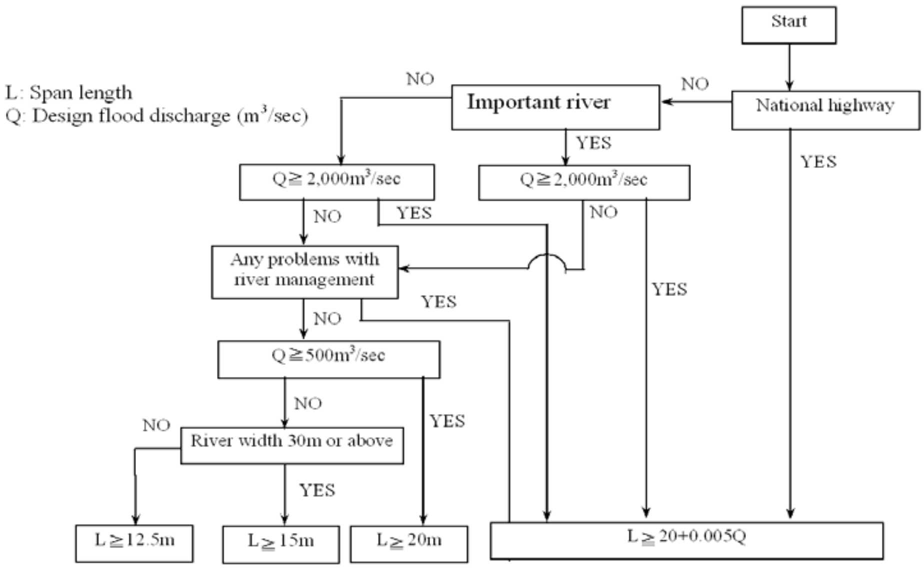


Figure 2-2-6 Specification Process for the Bridge Span Length

The table below shows the span lengths of the bridges concerned calculated in accordance with the procedures for the establishment of span lengths.

Table 2-2-11 Span lengths

Bridge name	Design flood discharge $Q(m^3/sec)$	Span length $L \geqq 20+0.005Q(m)$
Gogecha Bridge	112	L ≧ 12.5m (Application of a relaxed standard)
Modjo Bridge	1,144	L≧20m (Application of a relaxed standard)

(2) Road width plan

The widths of the bridges and the access roads are as described in 2-1-4Policies on Bridge and Road Widths.

(3) Examination of bridge length

1) Gogecha River

The length of Gogecha Bridge was decided using the following two criteria.

① Abutments will be constructed where they will not reduce the cross sectional area of flow at the design flood discharge derived from the hydraulic analysis.

② As a new bridge is to be reconstructed at the current position, it should be longer than the existing one.

Figure 2-2-7 shows the design cross section (required cross section) derived from the hydraulic analysis. In order to satisfy the criterion ① mentioned above, the abutments will have to be installed behind the planned revetments.

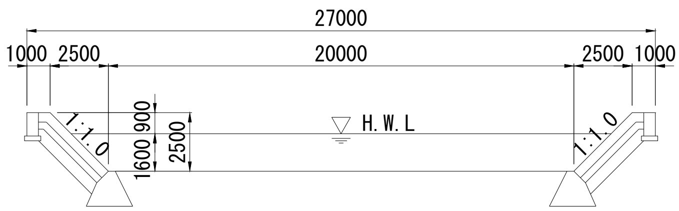


Figure 2-2-7 Design river cross section (Gogecha Bridge)

The survey team conducted on-site surveying and confirmed that the length of the existing bridge was L = 37.9 m. Therefore, the locations shown below which satisfy the conditions of being behind the revetments and a bridge length of 37.9 m or more were selected as the locations of the abutments of Gogecha Bridge.

Abutment A1: No.2+9.000m (Front of the parapet)
Abutment A2: No.4+7.000m (Front of the parapet)
Bridge length: L=38.000m

As the centerlines of the road and the river intersect at an angle θ=66°, a skew bridge (installing the abutments parallel to the revetments) is a possible alternative for the design of the new bridge. However, 1) it is not possible to shorten the length by intersecting the bridge and the river at an oblique angle since the length of the existing bridge is used as a criterion. 2) The required cross section area will be guaranteed even if a right bridge has been constructed. 3) A right bridge is structurally better and has better workability than a skew bridge. For these reasons, a right bridge was selected as the design of the new bridge.

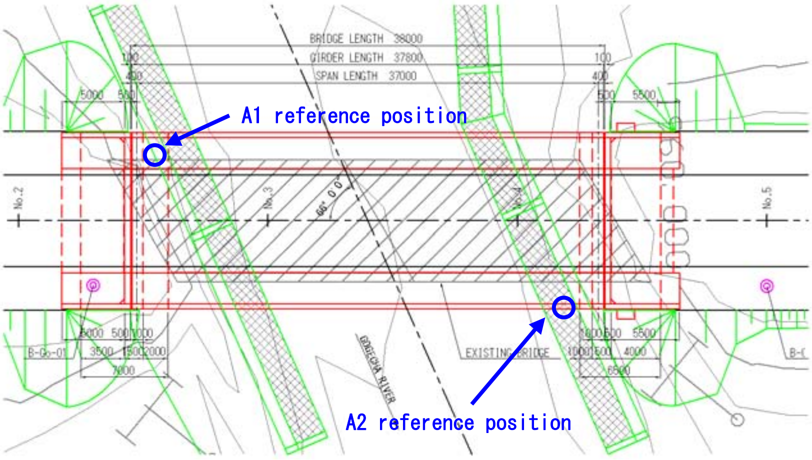


Figure 2-2-8 Reference points for the design of the new bridge (Gogecha Bridge)

2) Modjo Bridge

The length of the new Modjo Bridge was decided using the following three criteria.

① Abutments will be constructed where they will not reduce the cross sectional area of flow at the design flood discharge derived from the hydraulic analysis.

② Span lengths will be selected so that the impediment ratio of river flow and span lengths comply with the provisions of the Ordinance on Structures Including River Control Facilities.

③ As a new bridge is to be reconstructed at the current position, it should be longer than the existing one.

A PC continuous rigid-frame box-girder bridge with three spans connected was selected as the best alternative for the structure of Modjo Bridge (see below). The design high water level (H.W.L) at the position of the bridge derived from the hydraulic analysis is H.W.L = 1747.163 m and the width of the river at this H.W.L. is 62.510 m. If the impediment ratio is used as a criterion, the total width of piers which can be constructed in the river channel will be 3.75 m (the impediment ratio of 6 %) or less. However, the total width of the piers of the new bridge of 5.0 m (2.5 m x 2 piers) exceeds the upper limit of the impediment ratio. Therefore, in the design, Pier P2 (which is closer to the center of the flow than Pier P1) is to be located outside the cross sectional area of flow to make the impediment ratio, 4.0 % (= 2.5 m / 62.510 m), below the upper limit.

(Impediment ratio of river flow) = (a total width of bridge piers) / (river width) ≦ (5 %, in principle: 6 % if structurally necessary)

The span lengths of Modjo Bridge have to be 20 m or more because of the conditions such as the design flood discharge (as mentioned above). Therefore, the location of the Abutment A2 was established at 20 m (the distance from the center of P2 to the front of the parapet of A2) from the location of the Pier P2 established as mentioned above.

The location of the Abutment A1 was established with the conditions that 1) there should be appropriate clearances in front of the footing as it is to be constructed on a slope and 2) the length of the new bridge should be longer than the existing one. The clearance in front of the footing was set at B/2 (B: width of the footing) or more because the bridge has spread foundation with soft rock as a bearing stratum (mentioned below). The on-site surveying revealed that the length of the existing bridge was 90.7 m.

The Pier P1 is located where the selection of span lengths becomes horizontally symmetrical (20 m from the location of A1) with structural balance and workability taken into consideration

With the above-mentioned procedures, the length and the selection of span lengths of the new bridge were established as follows.

Abutment A1: No.3+7.000m (Front of the parapet)
Pier P1: No.4+7.000m (Center of the pier)
Pier P2: No.7+2.000m (Center of the pier)
Abutment A2: No.8+2.000m (Front of the parapet)
Bridge length: L=95.000m（20.0＋55.0＋20.0）

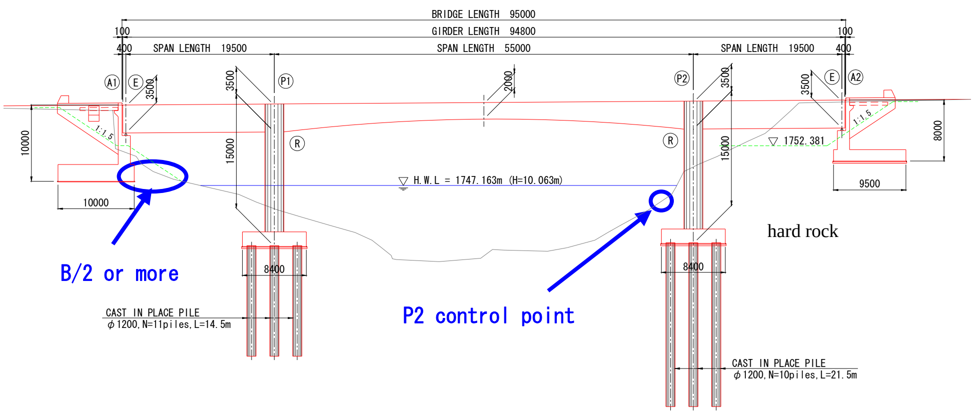
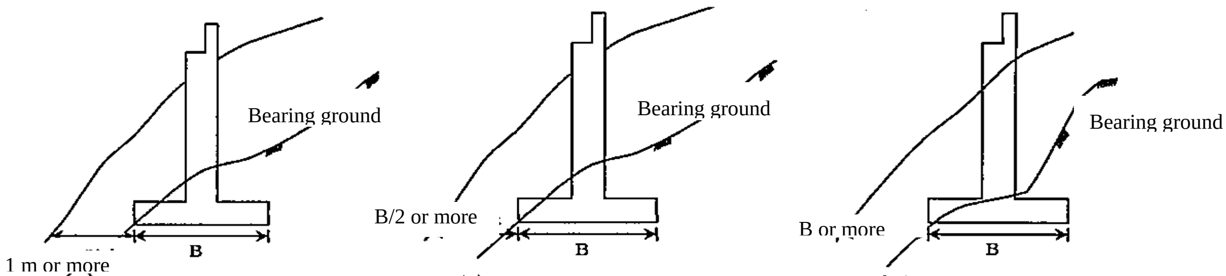


Figure 2-2-9 Criteria for the design of the new bridge (Modjo Bridge)



(a) When the support stratum is of hard rock

b) When the support stratum is of soft rock

(c) When the support stratum is of earth

Figure 2-2-10 Clearances in front of footing

(4) Comparison of bridge structure

1) Gogecha Bridge

As alternative bridge structures, superior ones in terms of structure, workability, economic efficiency and ease of maintenance were identified using the numbers of spans obtained from the standard span length defined by the design flood discharge as references and taking the standard bridge structures, applicable span lengths and the past use in Ethiopia into account. Since the required length and standard span length of this bridge were 38.0 m and 21.0 m, respectively, the following two alternative span lengths were considered.

- Single-span alternative (girder bridge): L = 38.0 m
- Two-span alternative (girder bridge): L = 2@19.0 m

Applicable superstructures were identified for the two alternatives mentioned above using the "standard applicable spans," shown in Table 2-2-12, as references.

Table 2-2-12 Standard applicable spans

Superstructure type		Recommended span	Curve applicable		Girder height
		50 m 100 m 150 m	Main structure	Bridge deck	Span ratio
Steel bridge	Simple composite plate girder		○	○	1/18
	Simple plate girder		○	○	1/17
	Continuous plate girder		○	○	1/18
	Simple box girder		○	○	1/22
	Continuous box girder		○	○	1/23
	Simple truss		×	○	1/ 9
	Continuous truss		×	○	1/10
	Reverse Langer girder		×	○	1/6,5
	Reverse Lohse girder		×	○	1/6,5
	Arch		×	○	1/6,5
PC bridge	Pretentioned girder		×	○	1/15
	Hollow slab		○	○	1/22
	Simple T girder		×	○	1/17,5
	Simple composite girder		×	○	1/15
	Continuous T girder, composite girder		×	○	1/15
	Continuous composite girder		×	○	1/16
	Simple box girder		○	○	1/20
	Continuous box girder (cantilever method)		○	○	1/18
	Continuous box girder (Push-out or support method)		○	○	1/18
	π shaped rigid frame ridge		×	○	1/32
RC Bridge	Hollow slab		○	○	1/20
	Continuous spandrel-filled arch		○	○	1/ 2

On the basis of the table above, the following three alternatives were selected for the comparison.

Table 2-2-13 Alternative bridge structures compared (Gogecha Bridge)

Alternative	Bridge type	Bridge structure	Number of spans	Bridge length
Alternative 1	PC bridge	PC simple post-tensioned T-girder bridge	1	L = 38.0m
Alternative 2	PC bridge	PC post-tensioned T-girder bridge with two spans connected	2	L = 2 @ 19.0 = 38.0 m
Alternative 3	Steel bridge	Steel simple non-composite I-girder bridge	1	L = 38.0m

Since the comparison of the three alternatives had revealed that the Alternative 1 was the best alternative, it was selected as the structure of Gogecha Bridge. (See Table 2-2-15)

2) Modjo Bridge

Since the required length and standard span length of this bridge were 95.0 m and 26.0 m, respectively, the following two alternative span lengths were considered.

- Three equal-length span alternative (girder bridge): L = 3 @ 31.667 = 95.0 m
- Three unequal-length span alternative (box-girder and arch bridges): L = 20.0 + 55.0 + 20.0 = 95.0 m

Applicable superstructures were identified for the two alternatives mentioned above using the "standard applicable spans," shown in , as references and the following three alternatives were selected for the comparison.

Table 2-2-14 Alternative bridge structures compared (Modjo Bridge)

Alternative	Bridge type	Bridge structure	Number of spans	Bridge length
Alternative 1	PC bridge	PC post-tensioned T-girder bridge with three spans connected	3	L=3@31.667=95.0m
Alternative 2	PC bridge	PC continuous rigid-frame box-girder bridge with three spans connected	3	L=20.0+55.0+20.0=95.0m
Alternative 3	RC bridge	Concrete arch bridge	3	L=20.0+55.0+20.0=95.0m

Since the comparison of the three alternatives had revealed that the Alternative 2 was the best alternative, it was selected as the structure of Modjo Bridge. (See Table 2-2-16)

Table 2-2-15 Comparison of bridge structures (Gogecha Bridge)

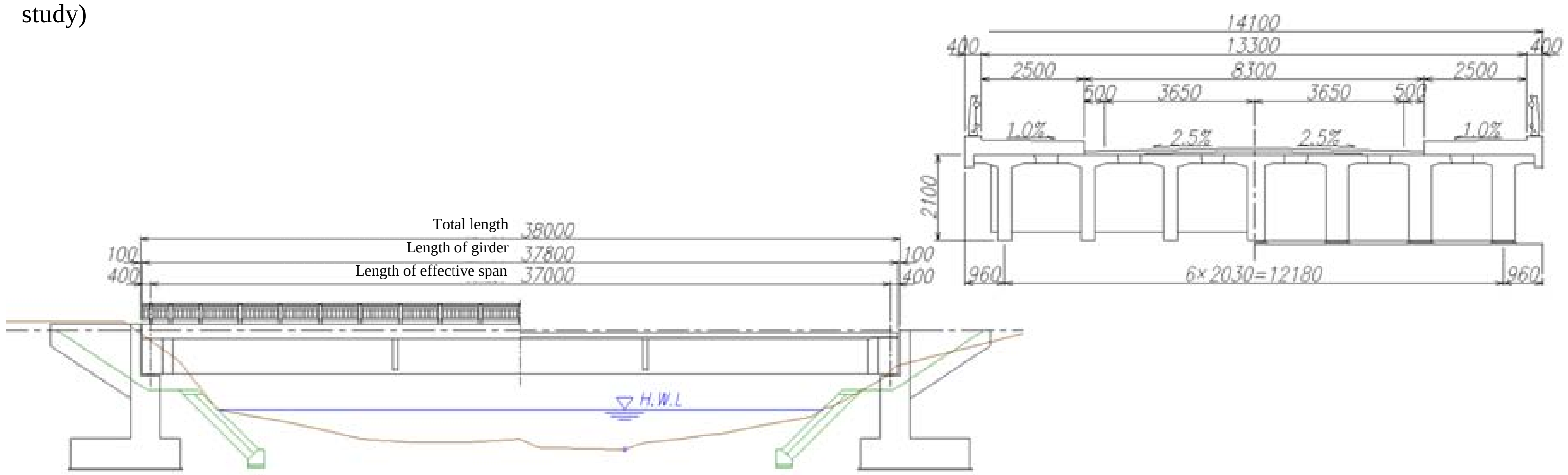
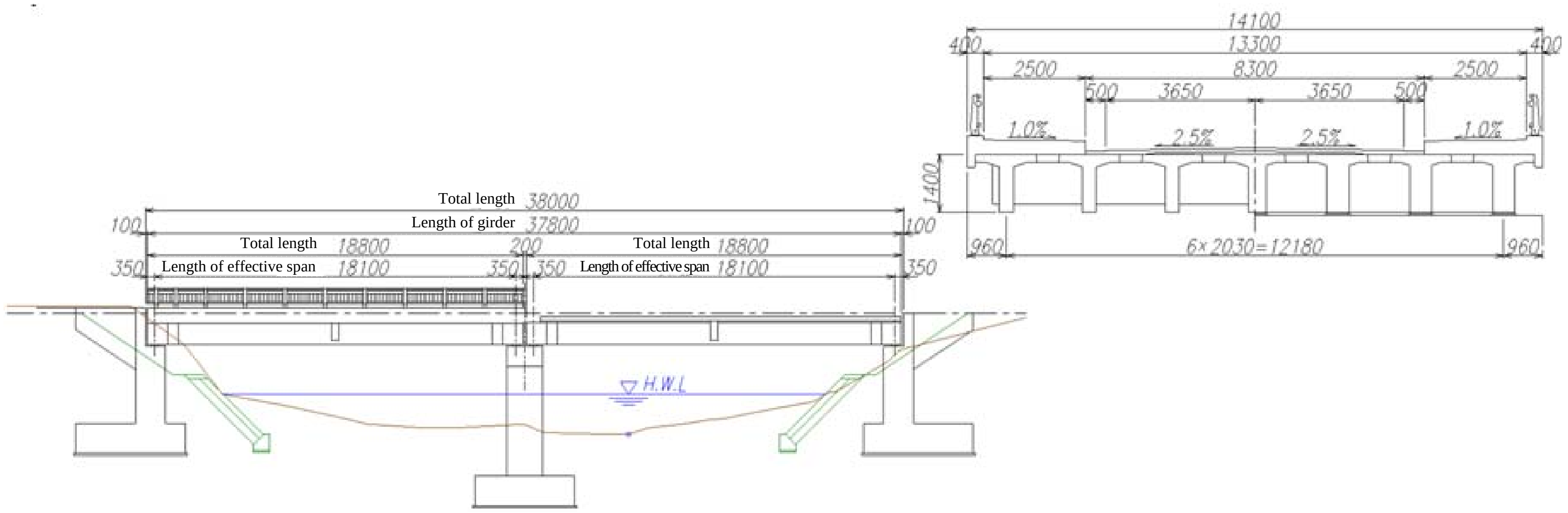
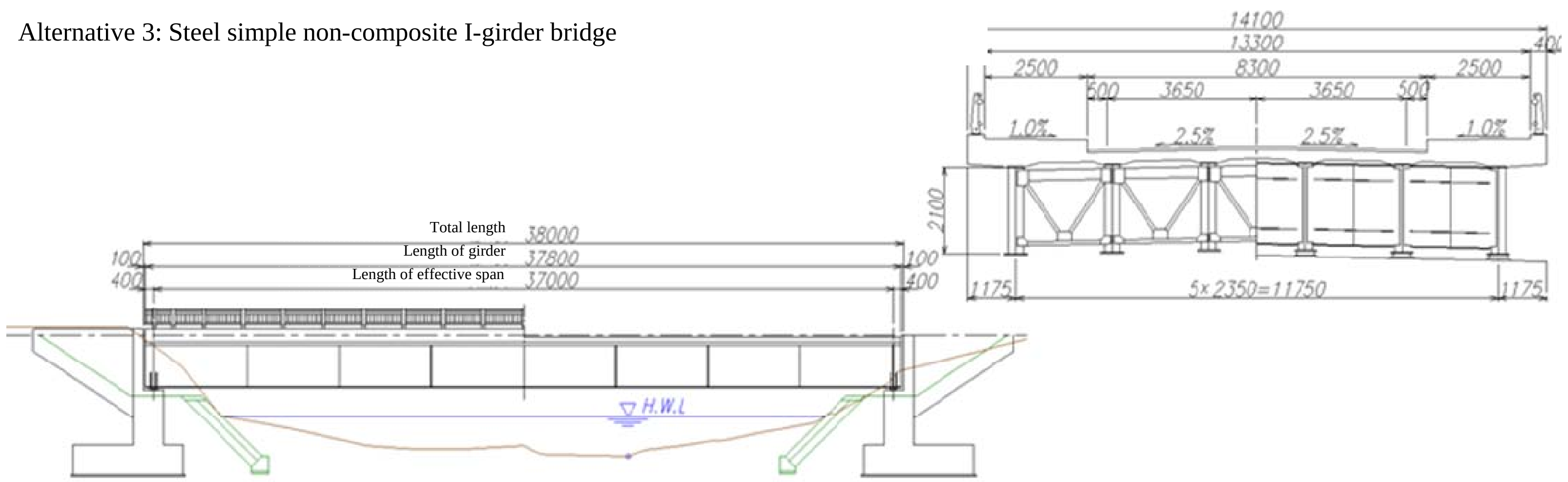
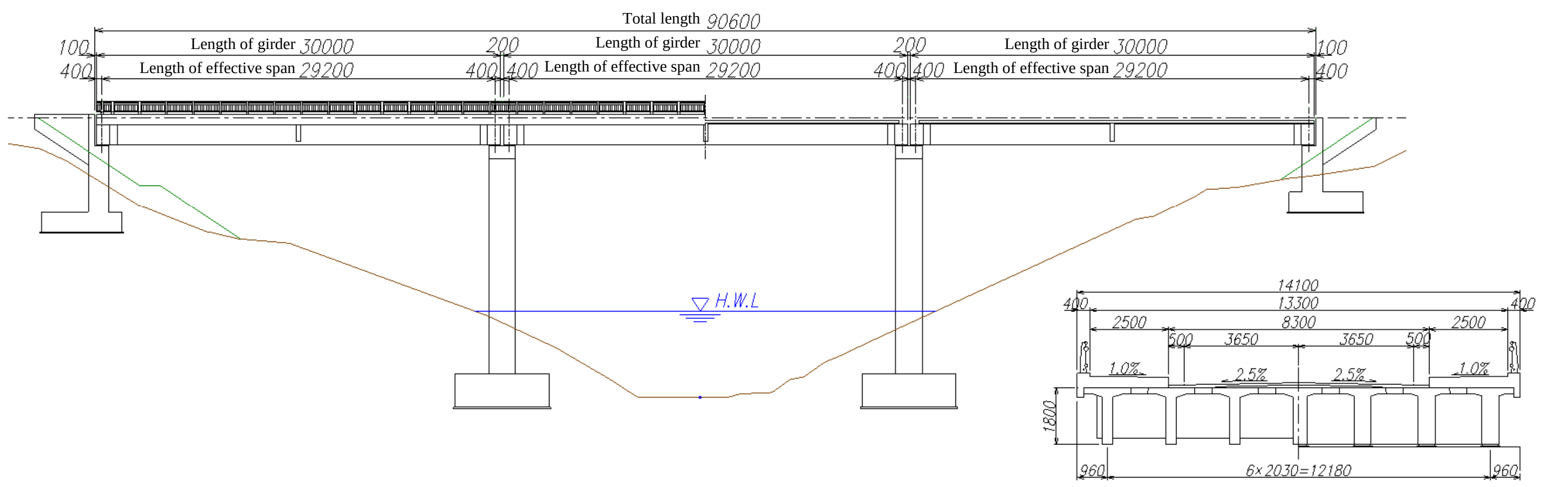
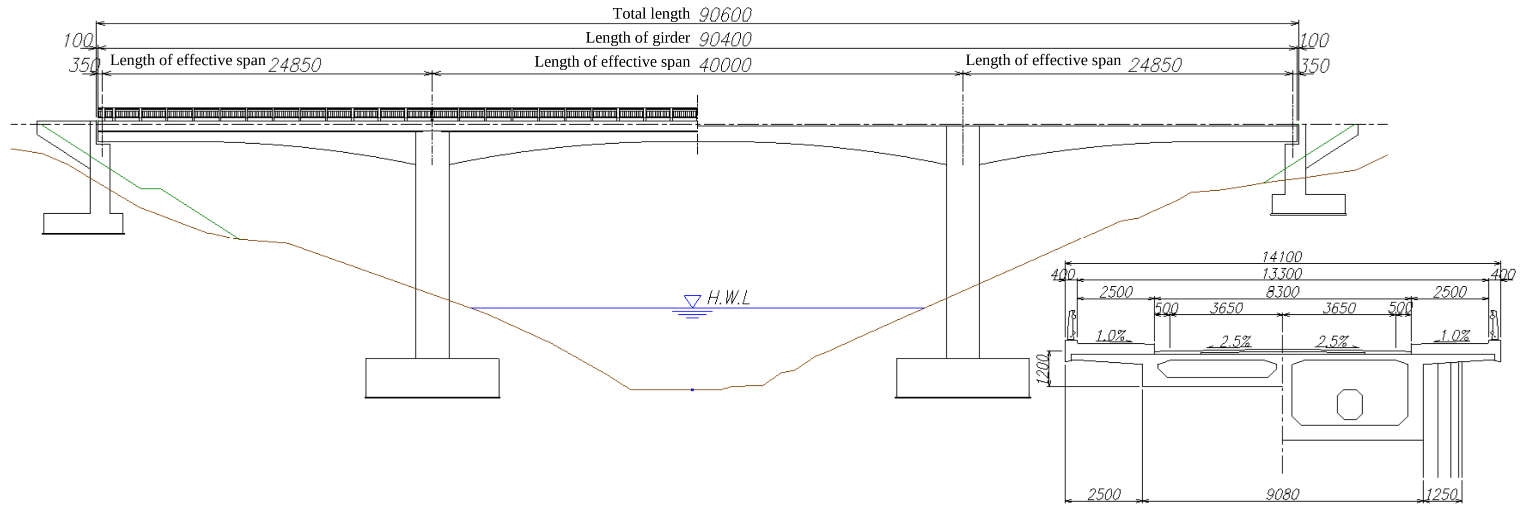
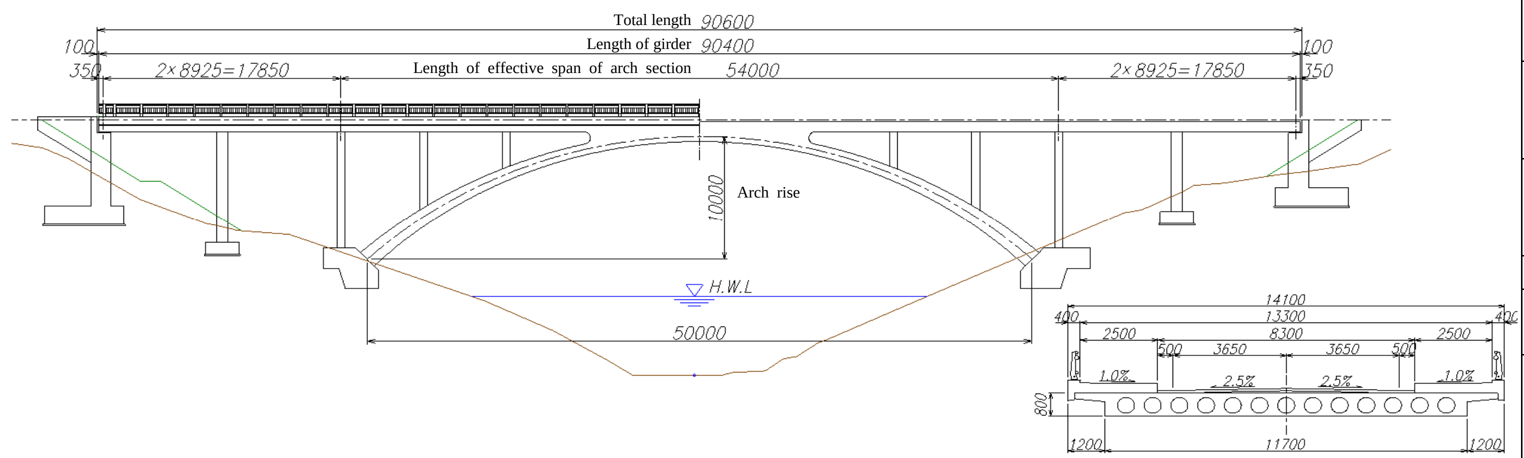
Bridge Structure	Characteristics		
Alternative 1: PC simple post-tensioned T-girder bridge (proposed by the preliminary study) 	Structure	- A common PC girder bridge structure, adopted in many grant-aid projects.	
	Workability	- The erection beam method enables the erection of the upper structure without works in the river; the construction involves no impact of the river.	
	Maintenance	- No maintenance work is needed, in principle, since it is a concrete bridge. - To sustain durability, it is essential to perform maintenance work on ancillary parts of the bridge, such as pavement, supports, expansion joints, and drainage facility.	
	River Characteristics	- No pier will be constructed in the river; the impediment ratio of river flow is 0 %, better than the status quo.	
	Economic efficiency	- This is the best solution in terms of economic efficiency. - Ratio to the estimated cost is 【1.00】	
	Overall evaluation	- This is the best solution with high economic efficiency and maintainability.	
Alternative 2: PC post-tensioned T-girder bridge with two spans connected 	Structure	- A common PC girder bridge structure, adopted in many grant-aid projects. - Simple girders are erected and connected at the support in the middle as a continuous girder bridge, providing excellent driving comfort and seismic resistance.	
	Workability	- The erection beam method, which enables the installation of the upper structure without works in the river, or the truck crane method, during the dry season, can be used. - The erection of the pier in the river will require a longer construction period than Alternative 1.	
	Maintenance	- No maintenance work is needed, in principle, since it is a concrete bridge. - To sustain durability, it is essential to perform maintenance work on ancillary parts of the bridge, such as pavement, supports, expansion joints, and drainage facility.	
	River Characteristics	- A pier will be constructed near the center of the river flow; the impediment ratio of river flow will be greater than the other options. - The standard span distance may not be sufficient, depending on the river conditions; in this regard, it is risky to adopt this structure.	
	Economic efficiency	- The construction of the upper structure alone is more cost effective than the other options, but the cost for constructing the substructure, accompanied by a pier, is higher; the economic efficiency is about the same as that of Alternative 1. - Ratio to the estimated cost is 【1.00】	
	Overall evaluation	- While the economic efficiency is as good as that of Alternative 1, the erection of the pier results in a lower workability than the other options. - The impediment ratio of river flow is the highest among the three plans.	○
Alternative 3: Steel simple non-composite I-girder bridge 	Structure	- A common plate girder structure with an I-shaped cross section (Steel I-girder), frequently used in Donor country. - The upper structure weighs less than a concrete bridge, cutting back the load to the substructure and the foundation.	
	Workability	- The main girder will be constructed by the truck crane belt method or the launching method. - As the slab is cast-in-place reinforced concrete, the erection of the upper structure will require a longer construction period.	
	Maintenance	- The steel material requires repainting as an anti-corrosion measure; if a weather-durable steel is used, however, repainting will not be needed.	
	River Characteristics	- No pier will be erected in the river; the impediment ratio of river flow will be 0 %, better than the status quo.	
	Economic efficiency	- The steel material lowers the economic efficiency compared with the concrete bridge options and also requires maintenance (repainting, etc.) costs. - Ratio to the estimated cost is 【1.09】	
	Overall evaluation	- The economic efficiency is the worst and maintenance costs will be incurred.	△

Table 2-2-16 Comparison of bridge structures (Modjo Bridge)

Bridge Structure	Characteristics		
Alternative 1: PC post-tensioned T-girder bridge with three spans connected (proposed by the preliminary study) 	Structure	- A common PC girder bridge structure, adopted in many grant-aid projects. - Simple girders are erected and connected at the supports in the middle as a continuous girder bridge, providing excellent driving comfort and seismic resistance. - The bridge is situated in steep terrains, needing high piers.	
	Workability	- The erection beam method enables the erection of the upper structure without works in the river; the construction involves no impact of the river. - The high piers will require a longer construction period.	
	Maintenance	- No maintenance work is needed, in principle, since it is a concrete bridge. - To sustain durability, it is essential to perform maintenance work on ancillary parts of the bridge, such as pavement, supports, expansion joints, and drainage facility.	
	River Characteristics	- Impact on the river is larger than the other alternatives, since the piers will be erected within the cross-section area of river flow. - The impediment ratio of river flow to the high water level (HWL) will likely exceed 10%, whereas the standard ratio is below 5 %.	
	Economic efficiency	- This is the best solution in terms of economic efficiency. - Ratio to the estimated cost is 【1.00】	
	Overall evaluation	- This is the best solution in terms of economic efficiency and maintainability, but due to the river characteristics issues, a hydrological analysis may find this structure infeasible. - The construction of high piers in the river requires a longer construction period and thus countermeasures against swollen streams will be needed.	△
Alternative 2: PC continuous rigid-frame box-girder bridge with three spans connected (alternative proposal) 	Structure	- The PC box-girder structure is suitable for long spans and has been adopted in many grant-aid projects. - The high piers allow the continuous rigid-frame structure, providing excellent driving comfort, seismic resistance and maintainability.	
	Workability	- The adoption of the cantilever erection method for the upper structure will involve no impact of the river. - As the upper structure is cast in place, it will require a longer construction period than the precast method in Alternative1.	
	Maintenance	- No maintenance work is needed, in principle, since it is a concrete bridge. - To sustain durability, it is essential to perform maintenance work on ancillary parts of the bridge. The maintenance work for this structure is, however, less labor-consuming than Alternative 1, which involves many supports, as the piers will have a rigid connection structure instead of supports.	
	River Characteristics	- Minimum impact on the river since the piers can be erected avoiding the cross section of flow.	
	Economic efficiency	- This alternative ranks in the middle in terms of economic efficiency. - Ratio to the estimated cost is 【1.05】	
	Overall evaluation	- Although the economic efficiency is lower than that of Alternative1, the river cross-section impediment issue is cleared and the structure, workability and maintainability are all excellent; thus, this is the best solution on the whole.	
Alternative 3: Concrete arch bridge 	Structure	- The main cross-sectional force is compression. This is a rational structure which effectively utilizes the compression-resistance of concrete. - Often used in valleys and other steep terrains.	
	Workability	- The adoption of the pylon method (cantilever erection) for arch ribs enables the construction without impact of the river. - The longest construction period among the three plans.	
	Maintenance	- No maintenance work is needed, in principle, since it is a concrete bridge. - To sustain durability, it is essential to perform maintenance work on ancillary parts of the bridge, such as pavement, supports, expansion joints, and drainage facility.	
	River Characteristics	- No pier will be erected in the river; the construction will involve no impact on the river.	
	Economic efficiency	- Lower than the other options. - Ratio to the estimated cost is 【1.65】	
	Overall evaluation	- Though the economic efficiency is poor, the impact of swollen river on the construction schedule is minimal as it involves no works in the river. - Because there is no impact on the river, this is a favorable alternative as well as Alternative 2, in terms of river characteristics. - The structure is suitable for steep terrains in terms of landscape.	○

(5) Examination on structures of substructure and foundation works

1) Gogecha Bridge

i) Selection of bearing stratum

The geological survey revealed the existence of a hard basalt stratum 5.0 to 6.5 m below the surface of the existing ground (the existing road). Therefore, the survey team selected this bedrock as the bearing stratum for Abutments A1 and A2.

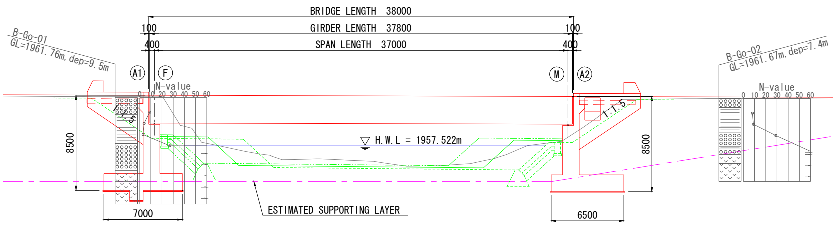


Figure 2-2-11 Location of the assumed rock surface of the bearing stratum (Gogecha Bridge)

ii) Structures of substructure and foundation works

The height of Abutment A1 was design at 8.5 m with the design height and the location of the bearing stratum (embedment of the depth of *ca.* 50 cm included in the design) taken into consideration. As its structure, a reverse-T type abutment was selected in accordance with Table 2-2-22 and spread foundation was adopted as the structure of foundation in accordance with Table 2-2-23.

For the same reasons, a reverse-T type abutment and spread foundation were selected as the structure and foundation, respectively, of Abutment A2.

Table 2-2-17 Selection of structure of substructure works

Bridge part	Structure type	Applicable height (m) 10	20	30	Characteristics
Abutment	1. Gravity type				With shallow support ground, the gravity type is suitable for direct foundation.
	2. Reverse T-style				Used in many bridges. Suitable for direct foundation/ pile foundation.
	3. Buttressed type				Suitable for tall abutments. Few materials are used for this type, but the lead time is long.
	4. Box type				Designed for tall abutments. The lead time is slightly long.
Pier	1. Column type				Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type				Relatively tall piers. Suitable for wide bridges. Their installation in a river may hinder water flow in time of flooding.
	3. Pile bent type				While they are the most cost efficient piers, they are not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow in time of flooding.
	4. Elliptical type				Tall bridge piers. Suitable for bridges with high external force.

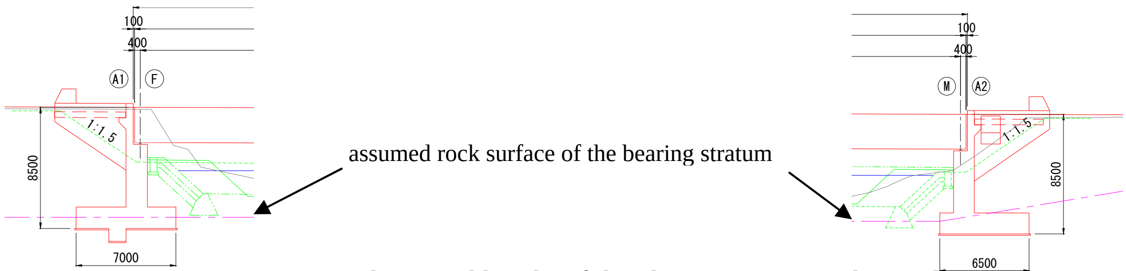


Figure 2-2-19 Shape and height of the abutments (Gogecha Bridge)

Table 2-2-18 Selection of structure of foundation work

Selection requirements \ Foundation types			Direct foundation	Cast pile foundation: RC pile	Cast pile foundation: PHC pile	Cast pile foundation: Steel pipe pile	Inner excavation pile foundation, PHC pile: Final impact driving method	Inner excavation pile foundation, PHC pile: Blast agitation	Inner excavation pile foundation, PHC pile: Concrete impact	Inner excavation pile foundation, Steel pipe pile: Final impact driving method	Inner excavation pile foundation, Steel pipe pile: Blast agitation	Inner excavation pile foundation, Steel pipe pile: Concrete impact	Cast in-situ pile foundaiton: All casing	Cast in-situ pile foundaiton: Reverse	Cast in-situ pile foundaiton: Earth drill	Cast in-situ pile foundaiton: Chicago board	Caisson foundation: Pneumatic	Caisson foundation: Open	Steel pipe sheet pile foundation	**underground continuous wall foundation**
Ground requirements	Below support layer	Soft ground in the interlayer	△	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○
Ground requirements	Below support layer	An extremely hard layer inside the inter layer	○	×	△	△	○	○	○	○	○	○	△	○	△	○	○	△	△	○
Ground requirements	Below support layer	Gravel in the interlayer: Gravel size 5 cm or below	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Ground requirements	Below support layer	Gravel in the interlayer: Gravel size 5 cm～10 cm	○	×	△	△	△	△	△	△	△	△	○	○	△	○	○	○	△	○
Ground requirements	Below support layer	Gravel in the interlayer: Gravel size 10 cm～50 cm	○	×	×	×	×	×	×	×	×	×	△	×	×	○	○	△	×	△
Ground requirements	Below support layer	The layer has liquefiable ground	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Ground requirements	Conditions of the support layer	Support layer depth: Below 5 m	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Ground requirements	Conditions of the support layer	Support layer depth: 5～15 m	△	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
Ground requirements	Conditions of the support layer	Support layer depth: 15～25 m	×	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Ground requirements	Conditions of the support layer	Support layer depth: 25～40 m	×	×	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
Ground requirements	Conditions of the support layer	Support layer depth: 40～60 m	×	×	△	○	△	△	△	○	○	○	△	○	×	×	△	○	○	○
Ground requirements	Conditions of the support layer	Support layer depth: 60 m or above	×	×	×	△	×	×	×	×	×	×	×	△	×	×	×	△	△	△
Ground requirements	Conditions of the support layer	Soil properties of the support layer: Cohesivvve soil (20 ≦ N)	○	○	○	○	○	×	△	○	×	△	○	○	○	○	○	○	○	○
Ground requirements	Conditions of the support layer	Soil properties of the support layer: Sand/ gravel (30 N)	○	○	○	○	○	○	×	○	○	×	○	○	○	○	○	○	○	○
Ground requirements	Conditions of the support layer	High gradient (30º or above)	○	×	△	○	△	△	△	○	○	○	○	△	△	○	○	△	△	△
Ground requirements	Conditions of the support layer	The surface of the support layer is severely uneven	○	△	△	○	△	△	△	○	△	△	○	○	○	○	○	△	△	○
Ground requirements	Groundwater	Groundwater level is close to the ground surface	△	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
Ground requirements	Groundwater	Significant amount of spring water	△	○	○	○	○	○	○	○	○	○	○	○	△	×	○	○	○	△
Ground requirements	Groundwater	Artesian groundwater 2 m above the ground surface	×	○	○	○	×	×	×	×	×	×	×	×	×	×	△	△	○	×
Ground requirements	Groundwater	Groundwater velocity is 3m/ min or above	×	○	○	○	○	×	×	○	×	×	×	×	×	×	○	△	○	×
Structural properties	Load size	Low vertical load (span length 20m or below)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	△	×	×
Structural properties	Load size	Moderate vertical load (span length 20m to 50m)	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Structural properties	Load size	High vertical load (span length 50m)	○	×	△	○	△	△	△	○	○	○	○	○	△	○	○	○	○	○
Structural properties	Load size	Horizontal load is lower than vertical load	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△
Structural properties	Load size	Horizontal load is higher than vertical load	○	×	△	○	△	△	△	○	○	○	○	○	○	○	○	○	○	○
Structural properties	Support type	Support pile	/	○	○	○	○	○	○	○	○	○	○	○	○	○	/	/	/	/
Structural properties	Support type	Friction pile	/	○	○	/	/	/	/	/	/	/	○	○	○	/	/	/	/	/
Construction requirements	Construction on water	Water depth below 5m	○	○	○	○	△	△	△	△	△	△	×	○	△	×	△	△	○	×
Construction requirements	Construction on water	Water depth 5m or above	×	△	△	○	△	△	△	△	△	△	×	△	×	×	△	△	○	×
Construction requirements	Limited work space		○	△	△	△	△	△	△	△	△	△	△	△	△	○	△	△	×	△
Construction requirements	Batter pile construction		/	△	○	○	×	×	×	△	△	△	△	×	×	×	/	/	/	/
Construction requirements	Effects of toxic gas		△	○	○	○	○	○	○	○	○	○	○	○	○	×	×	○	○	○
Construction requirements	Surrounding environment	Oscillation noise measures	○	×	×	×	△	○	○	△	○	○	△	○	○	○	○	○	△	○
Construction requirements	Surrounding environment	Effects on adjacent structures	○	×	×	△	△	○	○	△	○	○	○	○	○	△	△	△	△	○

2) Modjo Bridge

i) Selection of bearing strata

The geological survey revealed the existence of *ca.* 5 m-thick surface tuff layer, a thin sand layer beneath it and an almost-horizontally deposited semi-consolidated silt layer further below. N values varied significantly from one boring site to another.

At the location of Abutment A1, there is a hard silt layer (N value ≈ 70) at *ca.* 5 m from the ground surface. Thus, this layer was selected as the bearing stratum for A1. Also at the location of Abutment A2, the identical silt layer (presumably spreading horizontally) was selected as the bearing stratum, though the N value at this location was *ca.* 30.

At the location of Pier P1, the sandy soil layer with an N value of 50 or more at the depth of *ca.* 18 m from the ground surface was selected as the bearing stratum. At the location of Pier P2, the sandy soil layer at the depth of *ca.* 24 m, presumably the identical one, was selected as the bearing stratum.

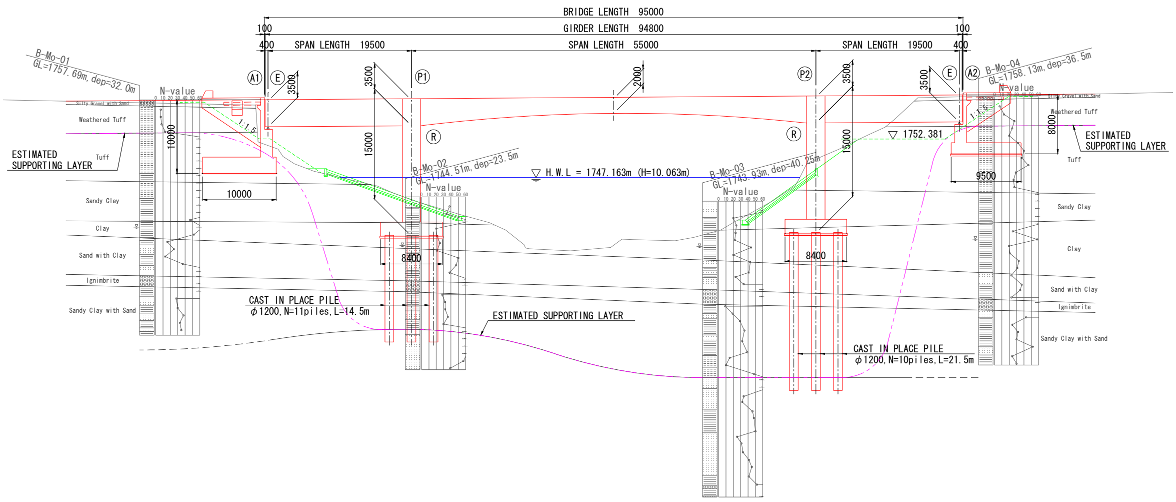


Figure 2-2-12 Location of the assumed rock surfaces of the bearing strata (Modjo Bridge)

ii) Structures of substructure and foundation works

The height of Abutment A1 was designed at 10.0 m in order to ensure the clearance of B/2 or more in front of the footing. As its structure and foundation, a reverse-T type abutment and spread foundation were selected in accordance with Table 2-2-17 and Table 2-2-18, respectively.

The height of Abutment A2 was designed at 8.0 m in order to create a *ca.* 2 m under clearance for workability and maintenance. As its structure and foundation, a reverse-T type abutment and spread foundation were selected in accordance with Table 2-2-17 and Table 2-2-18, respectively.

There should be covering of 1 m or more from the surface of the existing ground to the upper surface of the footing of Pier P1 and Pier P2 (to construct revetment around them). The height of the piers was designed at 15.0 m (from the bottom of the main girder to the bottom of the footing). A wall-type pier was adopted as the structure of the piers and the piers were to have oval-shaped cross-section in accordance with Table 2-2-17, as they were to be constructed in the river. Fully-cased cast-in-place piles were adopted as the structure of the foundation in accordance with Table 2-2-18.

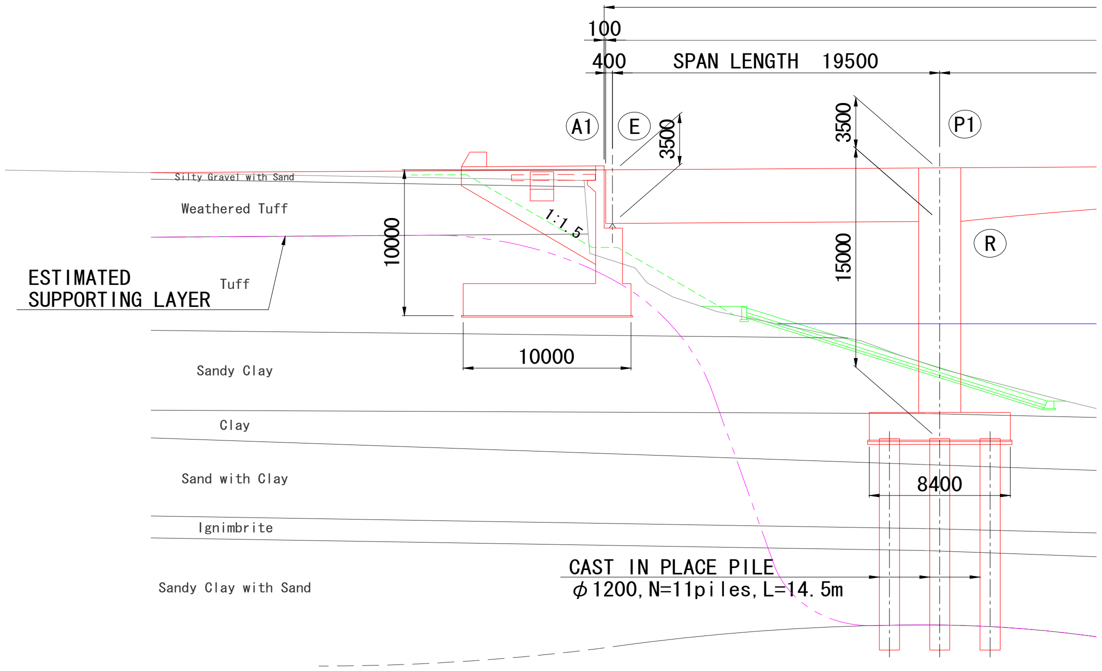


Figure 2-2-13 Shape and height of the substructure works (1/2) (Modjo Bridge)

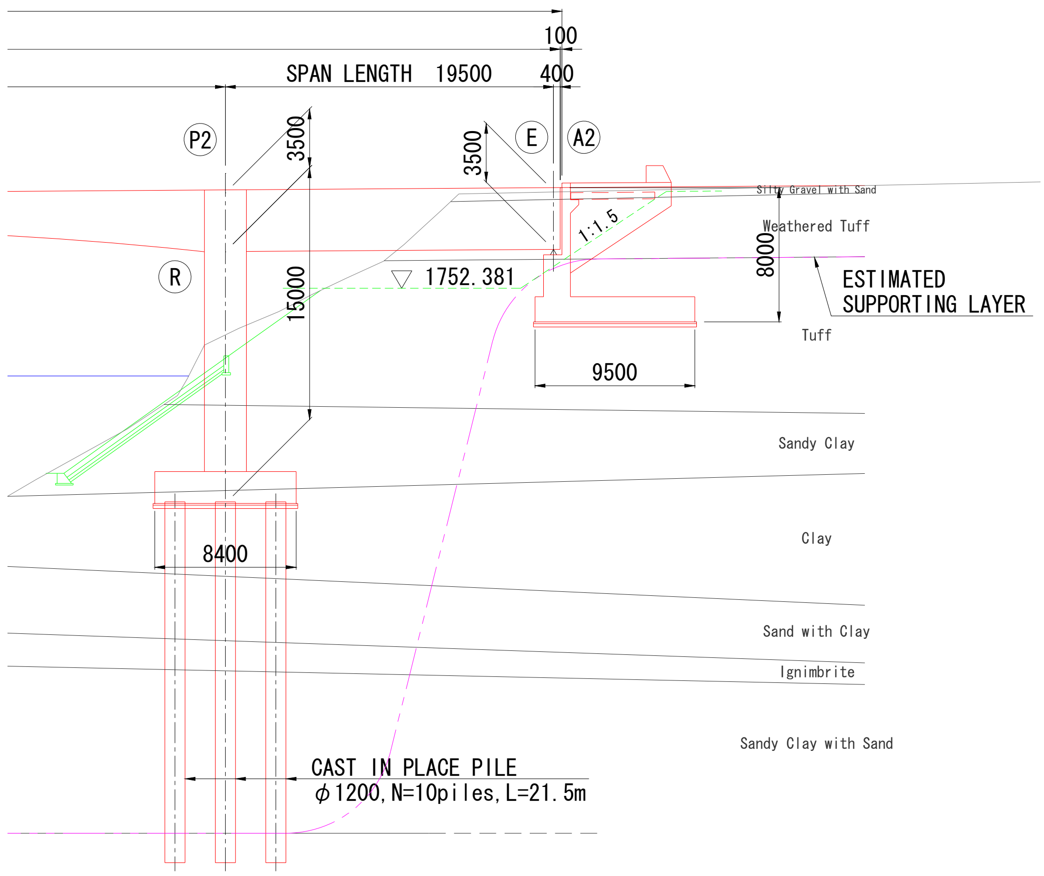


Figure 2-2-14 Shape and height of the substructure works (2/2) (Modjo Bridge)

(6) Examination on revetment and bed protection works

While revetment work will be required for the construction of Gogecha and Modjo Bridges because substructure works will be constructed in the river channels, it will not be required for the construction of Awash Bridge because substructure works will not be constructed in the river channel.

1) Gogecha Bridge

While the existing Gogecha Bridge has two spans, the new bridge will have one span. Because of this change in the design, revetment around the abutment will be included in the design. Since the flow velocity at the design flood discharge derived from non-uniform flow calculation is *ca.* 3 m/s, the design will include (1:1) mortar masonry revetments on the minimum required areas upstream and downstream of the abutments to protect the embankment around them. The slopes of the revetments will be constructed in the river channel after examining its current configuration so as not to change the level of flood water significantly after the construction of the new bridge.

2) Modjo Bridge

The design of the new Modjo Bridge includes construction of two piers in the river channel, which will require revetment to protect the areas of river banks below HWL to be excavated for the foundation works of the piers. Since the flow velocity at the design flood discharge derived from non-uniform flow calculation is *ca.* 3 m/s, mortar masonry revetment will be adopted in the design. The revetments and the existing river banks will be connected in such a way to ensure smooth flow of flood water along the river banks upstream and downstream of the revetments.

(7) Examination on access roads

1) Examination on compositions of pavement

i) Design life

The design life of the pavement of the road concerned shall be <u>20 years</u> as that of the trunk road shown in Table 2-2-19.

Road Classification	Design Period (Years)
Trunk Road	20
Link Road	20
Main Access Road	15
Other Roads	10

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Table 2-2-19 Design life of pavement

ii) Design traffic volume

a) Gogecha Bridge

As described in 2-1-3(3), Future Traffic Volume Estimates, A.A.D.T. traffic volume on Gogecha Bridge 20 years from now is estimated at 9,431 vehicles/day. The table below shows the estimates of the cumulative traffic volume (vehicle · one-way) during the design life.

Table 2-2-20 Cumulative traffic volume during the design life

	Cumulative traffic volume during the design life (T)							
	Car	S.Wagon & Pickup	S/Bus [<27 seat]	L/Bus [>27 seat]	S/Truck [< 30 Qt]	M/Truck [30-70 Qt]	H/Truck [>70 Qt]	T & T
Cumulative two-way traffic volume	11,623,726	14,457,406	16,820,412	1,780,414	13,761,449	4,687,470	9,721,045	8,020,615
Proportion of vehicles in the direction of heavier traffic	59.4%	61.0%	54.7%	53.6%	57.8%	63.7%	55.0%	57.2%
Cumulative one-way traffic volume	6,909,521	8,824,139	9,205,095	953,492	7,950,446	2,984,215	5,349,585	4,584,564

The average axle load of each vehicle type has been set as follows on the basis of the result of the survey of axle loads described in the F/S Survey Report on the Addis – Adama Expressway.

Table 2-2-21 Average axle load by vehicle type

	S/Truck [< 30 Qt]	M/Truck [30-70 Qt]	H/Truck [>70 Qt]	T & T
Average Load (Tn)	4.3	7.7	11.8	27.9

b) Modjo Bridge

As described in 2-1-3(3), Future Traffic Volume Estimates, A.A.D.T. traffic volume on Modjo Bridge 20 years from now is estimated at 11,910 vehicles/day. The table below shows the estimates of the cumulative traffic volume (vehicle · one-way) during the design life.

Table 2-2-22 Cumulative traffic volume during the design life

	Cumulative traffic volume during the design life (T)							
	Car	S.Wagon & Pickup	S/Bus [<27 seat]	L/Bus [>27 seat]	S/Truck [< 30 Qt]	M/Truck [30-70 Qt]	H/Truck [>70 Qt]	T & T
Cumulative two-way traffic volume	6,751,272	8,656,168	12,296,119	1,340,139	10,506,982	3,409,408	6,254,156	7,540,725
Proportion of vehicles in the direction of heavier traffic	64.9%	61.7%	55.1%	62.9%	61.2%	53.5%	54.0%	56.9%
Cumulative one-way traffic volume	4,382,580	5,340,247	6,772,847	842,768	6,434,846	1,822,640	3,376,797	4,294,144

The average axle load of each vehicle type has been set as shown in Table 2-2-21.

iii)Standards load equivalency factors

It was decided that the figures shown in the table below, which were provided in the Pavement Design Manual of Ethiopia, were to be used as factors to convert various axle loads of different types of vehicles derived from the result of the axle load survey by vehicle type to the standard load of 8.16 metric tons.

Equivalency Factors for Different Axel Loads

Wheel Load (single & Dual) (10^3kg)	Axel Load (10^3kg)	Equivalency Factor (EF)
1.5	3.0	0.01
2.0	4.0	0.04
2.5	5.0	0.11
3.0	6.0	0.25
3.5	7.0	0.50
4.0	8.0	0.91
4.5	9.0	1.55
5.0	10.0	2.50
5.5	11.0	3.93
6.0	12.0	5.67
6.5	13.0	8.13
7.0	14.0	11.30
7.5	15.0	15.50
8.0	16.0	20.70
8.5	17.0	27.20
9.0	18.0	35.20
9.5	19.0	44.90
10.0	20.0	56.50

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a) Gogecha Bridge

The total equivalent standard axle loads (ESAs) at Gogecha Bridge were estimated from the cumulative traffic volume during the design life as shown in the table below.

Gogecha Bridge

Type of Vehicle	Equivalency Factor	累計交通量	10^6 ESAs
Car	0	24,938,754	0.0
Bus	0.14	953,492	0.0
Truck	6.67	16,284,246	1.1
Truck-Trailer	11.47	4,584,564	0.5
		Total ESAs	1.6

Car	Car , S.Wagon & Pickup , S/Bus [< 27 seat]
Bus	L/Bus [> 27 seat]
Truck	S/Truck [< 30 Qt] , M/Truck[30-70 Qt] , H/Truck [> 70 Qt]
Truck-Trailer	T & T

The figure of the one-way ESAs is to be reduced in accordance with the number of lanes in each direction. As the section of the road surveyed has one lane in each direction, the 100 % figure will be used in the pavement design.

Number of Lanes in each direction	Percent of ESAs in design Lane
1	100
2	80 - 100
3	60 - 80

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Thus, the design ESAs of 1.6 are obtained from the equation below.

1.6 * 100% ＝ 1.6

Therefore, the traffic class T4 will apply to the pavement design of the access road to Gogecha Bridge.

Traffic classes	Range (10^6 ESAs)
T1	<0.3
T2	0.3 - 0.7
T3	0.7 - 1.5
T4	1.5 - 3.0
T5	3.0 - 6.0
T6	6.0 - 10
T7	10 - 17
T8	17 - 30

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b) Modjo Bridge

The total ESAs at Modjo Bridge were estimated from the cumulative traffic volume during the design life as shown in the table below.

Modjo Bridge

Type of Vehicle	Equivalency Factor	累計交通量	10^6 ESAs
Car	0	16,495,674	0.0
Bus	0.14	842,768	0.0
Truck	6.67	11,634,282	0.8
Truck-Trailer	11.47	4,294,144	0.5
		Total ESAs	1.3

Car	Car , S.Wagon & Pickup , S/Bus [< 27 seat]
Bus	L/Bus [> 27 seat]
Truck	S/Truck [< 30 Qt] , M/Truck[30-70 Qt] , H/Truck [> 70 Qt]
Truck-Trailer	T & T

The figure of the one-way ESAs is to be reduced in accordance with the number of lanes in each direction. As the section of the road surveyed has one lane in each direction, the 100 % figure will be used in the pavement design.

Number of Lanes in each direction	Percent of ESAs in design Lane
1	100
2	80 -100
3	60 -80

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Thus, the design ESAs of 1.3 are obtained from the equation below.

1.3 * 100% = 1.3

Therefore, the traffic class T3 will apply to the pavement design of the access road to Gogecha Bridge.

Traffic classes	Range (10^6 ESAs)
T1	<0.3
T2	0.3 -0.7
T3	0.7 -1.5
T4	1.5 -3.0
T5	3.0 -6.0
T6	6.0 -10
T7	10 -17
T8	17 -30

iv) Design of subgrades

The table below shows the classification of subgrades provided in the Pavement Design Manual of Ethiopia.

Table 2-2-23 Subgrade classification

Class	Range（CBR%）
S1	2
S2	3～4
S3	5～7
S4	8～14
S5	15～29
S6	30+

Since Gogecha and Modjo Bridges will be reconstructed at the current positions, the sections of the existing roads adjacent to both ends of the bridges will have to be excavated to allow construction vehicles access to the abutment construction sites during the construction and have to be filled back after the construction.

It has been decided to use the subgrade classification S5 in the design of subgrades, in order to be on the safe side, with the basic policy of using material with CBR20 or better for the backfilling

The table below shows the results of the modified CBR tests conducted at the boring sites in the planned project sites.

Bridge location	Boring site No.	Modified CBR (%)
Gogecha Bridge	B-GO-01	35.0
	B-GO-02	63.0
Modjo Bridge	B-MO-01-01	84.0
	B-MO-01-02	48.0
	B-MO-04-01	46.5
	B-MO-04-02	34.0

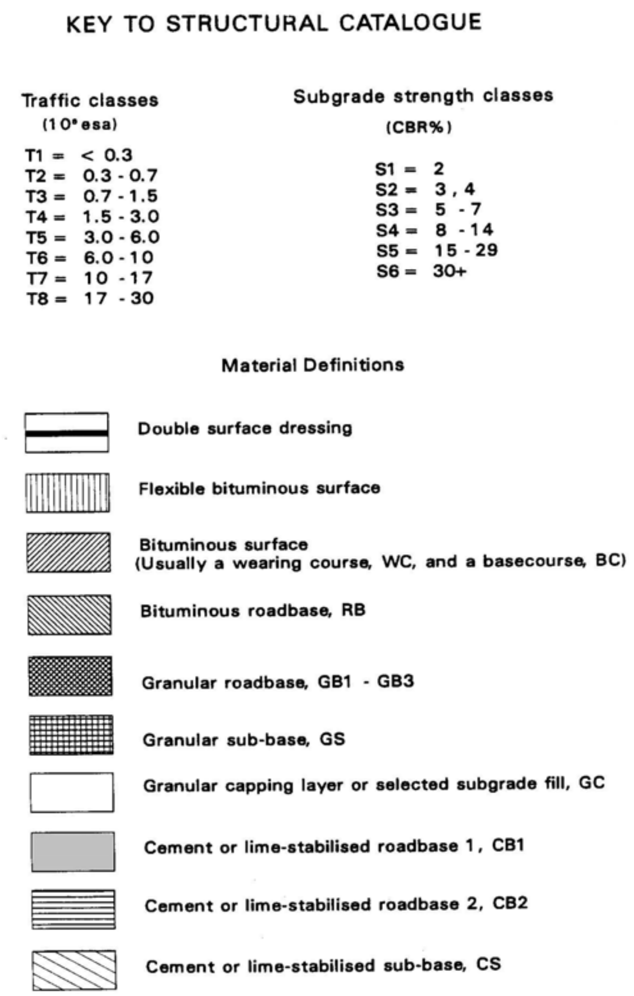
v) Establishment of pavement compositions

The design conditions examined as mentioned above were used for the examination on pavement structures.

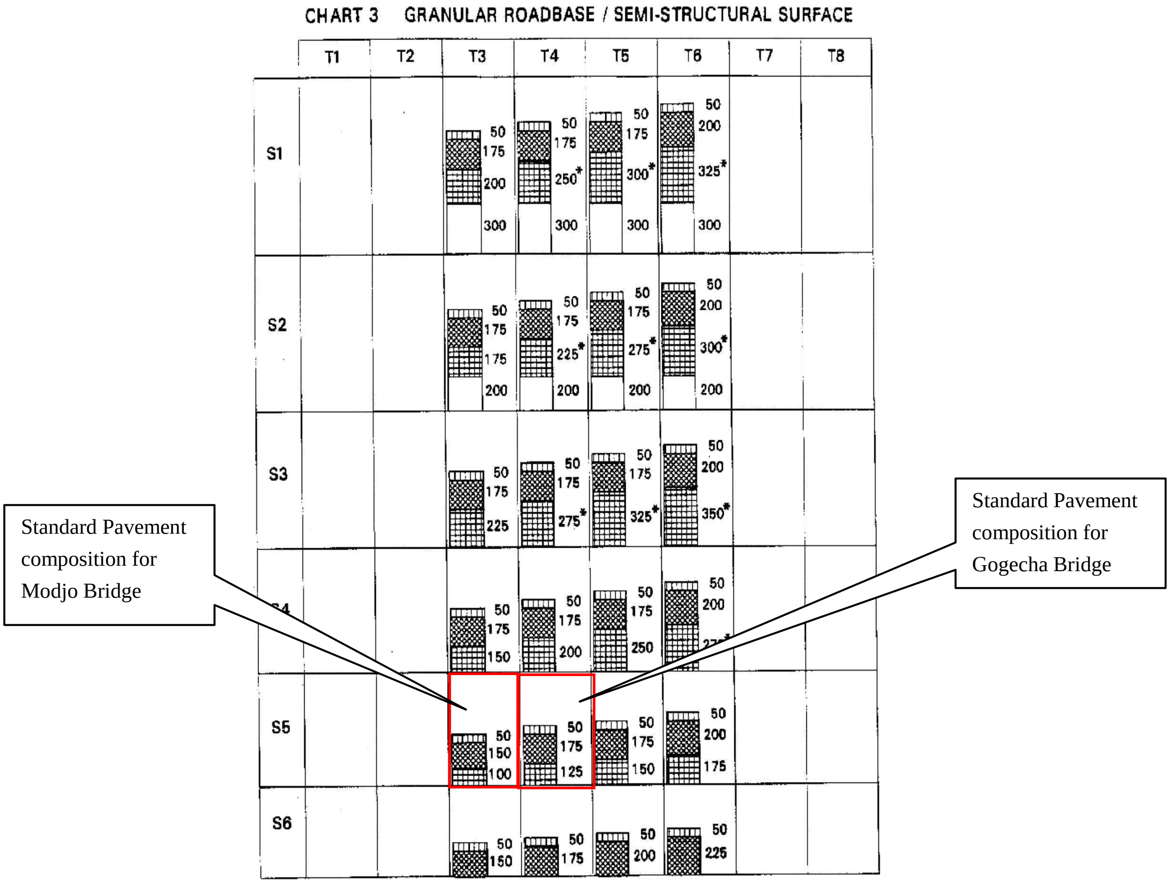
The Pavement Design Manual of Ethiopia provides standard pavement compositions by traffic class and design CBR class. In this survey, these standard compositions were used in the estimation of the construction costs.

Since the access roads to Gogecha and Modjo Bridges will have linear horizontal alignment and very small longitudinal slopes, use of the economically efficient granular roadbase is assumed in the pavement design.

A practical design of mixtures will be examined during the detailed design.



a) Standard pavement compositions of granular roadbase works



b) Examination on pavement compositions from the viewpoint of workability

The above-mentioned standard pavement compositions provided in the Ethiopian manual provide construction of bituminous roadbase directly on the surface of the existing subgrade. However, unevenness is likely to be created on the surface of the subgrade of soft rock in the sections of the road concerned. Therefore, it was decided to include construction of a subbase course as a leveling layer in the design.

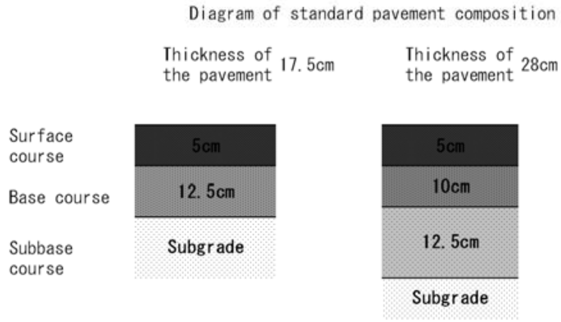
In order not to over-design the pavement structure in the design, the thickness of pavement in the modified composition was designed in such a way that the modified composition should have a TA value almost the same as that of the standard composition.

After the examination on the pavement thickness, it was decided that, while reducing the thickness of the base course from what provided in the standard pavement composition, *i.e.* 125 mm, to 100 mm, a 125 mm-thick subbase course was to be constructed with crusher-run.

The thickness of the subbase course is designed at 125 mm as it satisfies the condition for the minimum thickness of base course of three times the maximum grain size of pavement material (provided in the Asphalt Pavement Manual), *i.e.* crusher-run 40 – 0.

The table below shows the calculated TA values for the two pavement compositions.

Layer	Material	Equivalency factor	① Ethiopian Manual Original composition		② Workability considered Improved composition	
			Thickness (m)	TA value	Thickness (m)	TA value
Surface course	Hot asphalt mixture	1.00	0.05	0.05	0.05	0.05
Base course	Asphalt stabilized roadbase (hot)	0.80	0.125	0.10	0.10	0.08
	Mechanically stabilized crushed stone roadbase	0.35				
Subbase course	Crusher-run	0.20			0.125	0.03
		Cumulative TA value		0.15	≦	0.16



2) Thoughts on various types of pavement works

Use of asphalt concrete pavement, which has been used in most of the pavement works in Ethiopia, will be the basic policy for the pavement work on three bridges surveyed in this survey and the access roads on both sides of them.

Cement concrete pavement has been used in few projects and the system to maintain such pavement has problems in Ethiopia. Therefore, an agreement has been reached with ERA on adoption of asphalt concrete pavement for the project during the field survey.

Nonetheless, cement concrete pavement has been adopted for construction of some of the access roads to the construction sites for construction vehicles, which will be put into use for short periods of time, for efficient operation of the plant in accordance with the execution schedule.

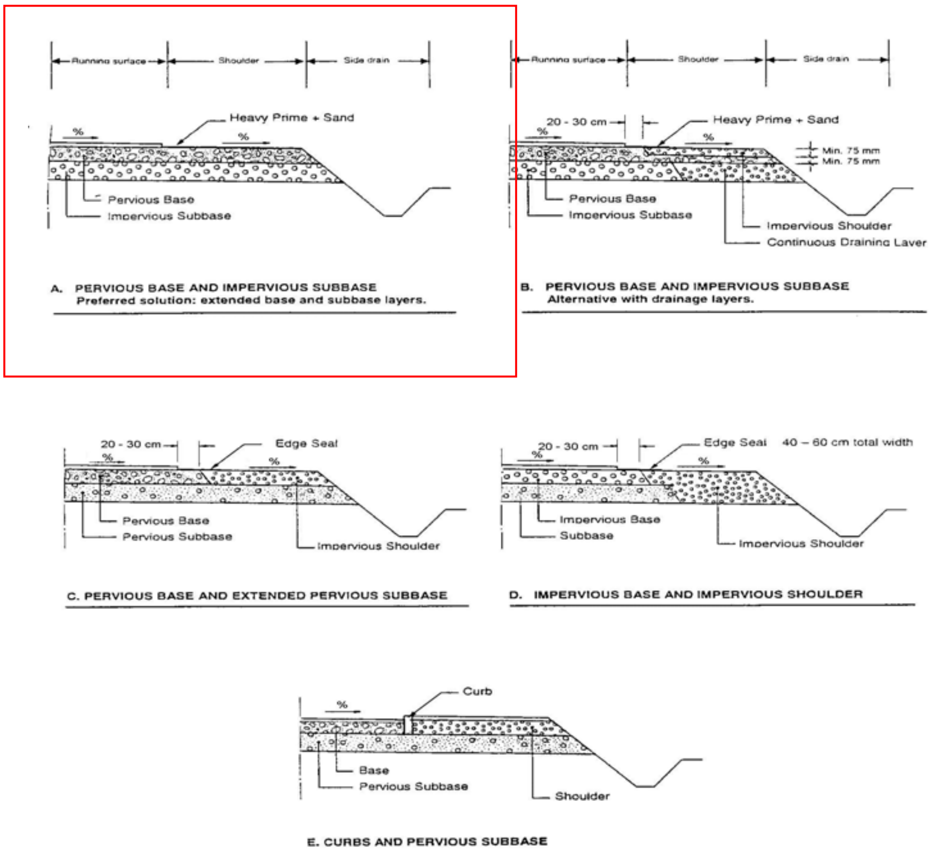
The manuals of Ethiopia mentioned below were followed in the selection of the pavement structures:

- Pavement Design Manual - Volume I – Flexible pavements and gravel roads; and
- Pavement Design Manual - Volume II – Rigid pavements.

3) Structure at the edge of pavement

Structure A with surface course only on the carriageway and base course exposed on the shoulders was selected among the options below, for economic efficiency and ease of maintenance. This is also the structure provided in the Ethiopian manual.

The same structure is used on the existing roads to which the access roads to the bridges are to be connected.



4) Examination on slope protection work

i) Gradients of slopes

In compliance with the Ethiopian manual, the gradients of slopes of embankment and cutting executed in the earthwork for the construction of the access roads have been designed as follows:

a) Embankment

The table below shows the standards for gradients of embankment slopes provided in the Ethiopian manual, which are to be followed. As the design embankment heights exceed 2 m on the front and the back of the abutments, gradient of 1:2.0 was adopted as a principle.

Table 6-1: Slope Ratio Table – Vertical to Horizontal

Material	Height of Slope	Side Slope		Back Slope	Zone Description
		Cut	Fill		
Earth or Soil	0.0 - 1.0m	1:4	1:4	1:3	Recoverable
	1.0 - 2.0m	1:3	1:3	1:2	Non-recoverable
	Over 2.0m	1:2	1:2	1:1.5	Critical
Rock	Any height	See Standard Details			Critical
Black Cotton Soil*	0.0 - 2.0m	-	1:6	-	Recoverable
	Over 2.0m		1:4		

*Move ditch away from fill as shown in Figure 6-2

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b) Cutting

A gradient of 1:1.0 for a back slope shown in the table below will be used as the standard for the gradient of slope of cutting.

Table 1: Side Slope and Back Slope

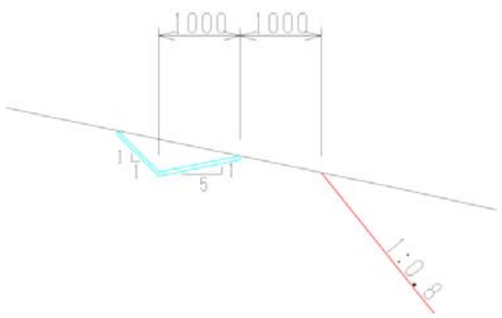
Material	Height of slope (H)	Side Slope (V to H)		Back Slope (V to H)	Zone
		Cut	Fill		
Earth or Soil	0.0 – 1.0 m	1:4	1:4	1:3	Recoverable
	1.0 – 2.0 m	1:3	1:3	1:2	Non – Recoverable
	Over 2.0 m	1:2	1:2	1:1.5	Critical
Rock	0.0 – 2.0 m	1:3	1:3	4:5	Non – Recoverable
	Over 2.0 m	1:2	1:2	1:1	Critical

ii) Slope drainage work

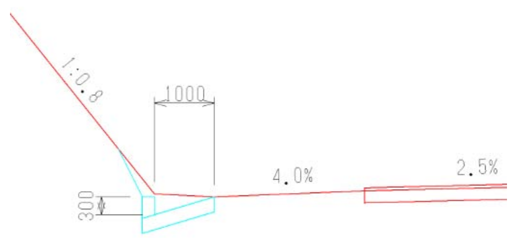
A good drainage plan will be required for maintenance of the stability of the slopes in future. Installation of appropriate drainage structures will be required in particular at the sections on both sides of Awash Bridge where a large-scale cutting is to be implemented.

Drainage facilities shall be constructed on the top the slopes in order to prevent drainage from the surrounding area from flowing down the slopes and at the bottom of the slope in order to prevent rainwater fallen on the slopes from flowing onto the road surface.

With a principle of following the drainage structures provided in the Ethiopian manual, the basic structures shown below were included in the design



Drainage on the top of a slope



Drainage at the bottom of a slope

(8) Outlines of the facilities

The table below summarizes the outlines of the facilities in this project derived from the above-mentioned examinations.

Table 2-2-30 Facility outlines (Gogecha Bridge)

Bridge structure		PC simple post-tensioned T-girder bridge
Bridge length		38 m
Width		Carriageway: 3.65 m × 2 = 7.3 m, Shoulders: 0.5 m × 2 = 1.0 m, sidewalks: 2.5 m × 2 = 5.0 m, Total = 13.3 m (Effective width), (gross width = 14.1 m)
Surface type		Asphalt pavement (70 mm on the carriageway)
Abutment structure		Abutment A1: Reverse-T type (with spread foundation) Abutment A2: Reverse-T type (with spread foundation)
Access road	Total length	On the starting point (Addis Ababa) side: *ca.* 124 m, on the terminal point (Djibouti) side: *ca.* 128 m, Total: 252 m
	Width	Carriageway: 3.65 m × 2 = 7.3 m, Shoulders: 3.0 m × 2 = 6.0 m, Total: 13.3 m (effective width)Soft shoulders: 0.5 m × 2 = 1.0 m, Total: 14.3 m (gross width)
	Surface	Asphalt pavement (surface course: 50 mm, base course: 175 mm, subbase course: 125 mm)

Table 2-2-1 Facility outlines (Modjo Bridge)

Bridge structure		PC continuous rigid-frame box-girder bridge with three spans connected
Bridge length		20.0 m + 55.0 m + 20.0 m = 95.0 m
Width		Carriageway: 3.65 m × 2 = 7.3 m, Shoulders: 0.5 m × 2 = 1.0 m, Sidewalks: 2.5 m × 2 = 5.0 m, Total: 13.3 m (effective width), (gross width: 14.1 m)
Surface type		Asphalt pavement (70 mm on the carriageway)
Abutment structure		Abutment A1: Reverse-T type (with spread foundation) Abutment A2: Reverse-T type (with spread foundation)
Pier structure		Pier P1: Oval-shaped cross-section (with pile foundation) Pier P2: Oval-shaped cross-section (with pile foundation)
Access road	Total length	On the starting point (Addis Ababa) side: *ca.* 95 m, on the terminal point (Djibouti) side: *ca.* 77 m, total: 172 m
	Width	Carriageway: 3.65 m × 2 = 7.3 m, Shoulders: 3.0 m × 2 = 6.0 m, Total: 13.3 m (effective width) Soft shoulders: 0.5 m × 2 = 1.0 m, Total: 14.3 m (gross width)
	Surface	Asphalt pavement (surface course: 50 mm, base course: 175 mm, subbase course: 125 mm)

2-3 Outline design drawings

The outline design drawing prepared on the basis of the basic design mentioned above are shown in the following pages

- Figure 2-3-1 General View of Gogecha Bridge
- Figure 2-3-2 General View of Modjo Bridge (1)
- Figure 2-3-3 General View of Modjo Bridge (2)

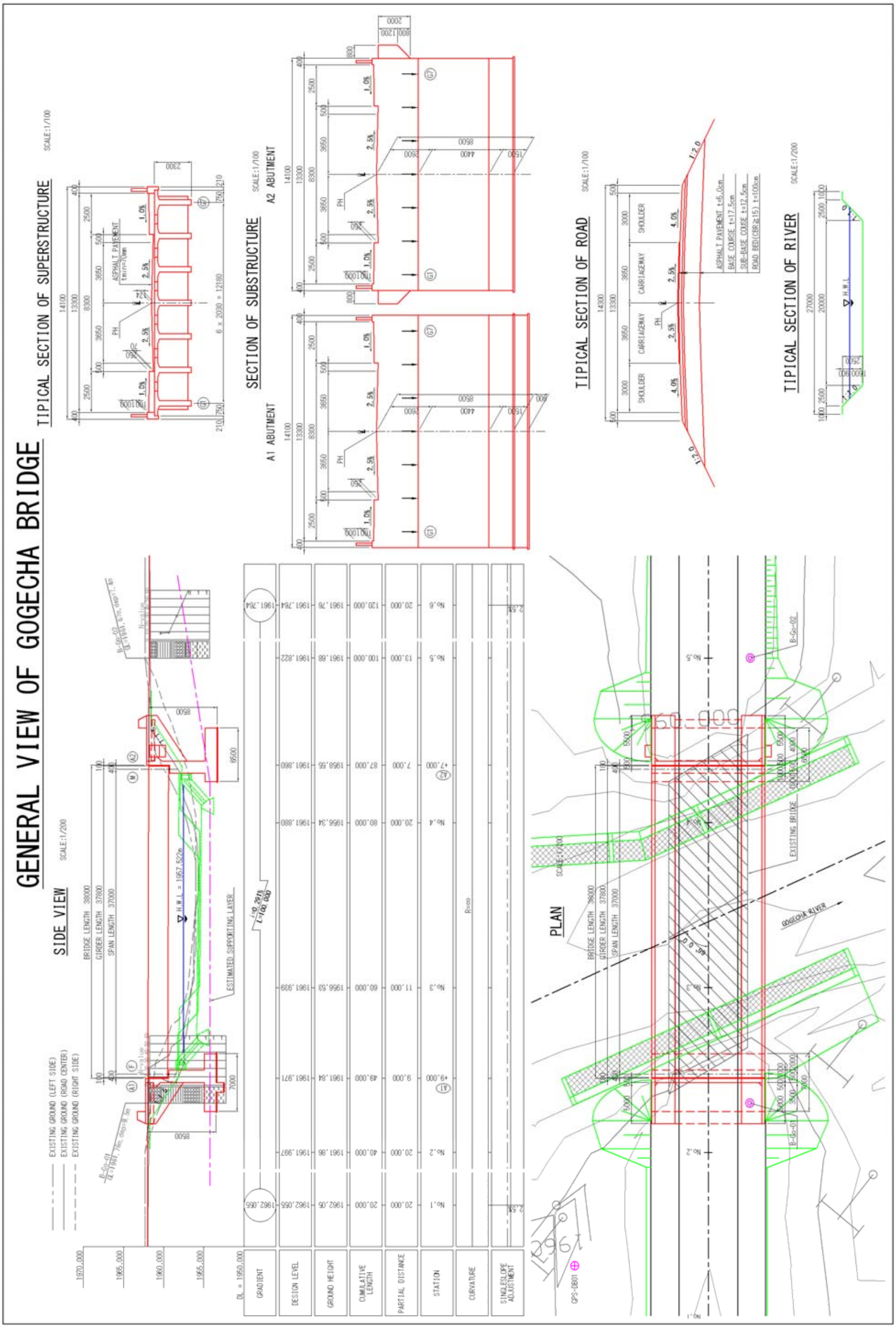


Figure 2-3-1 General View of Gogecha Bridge

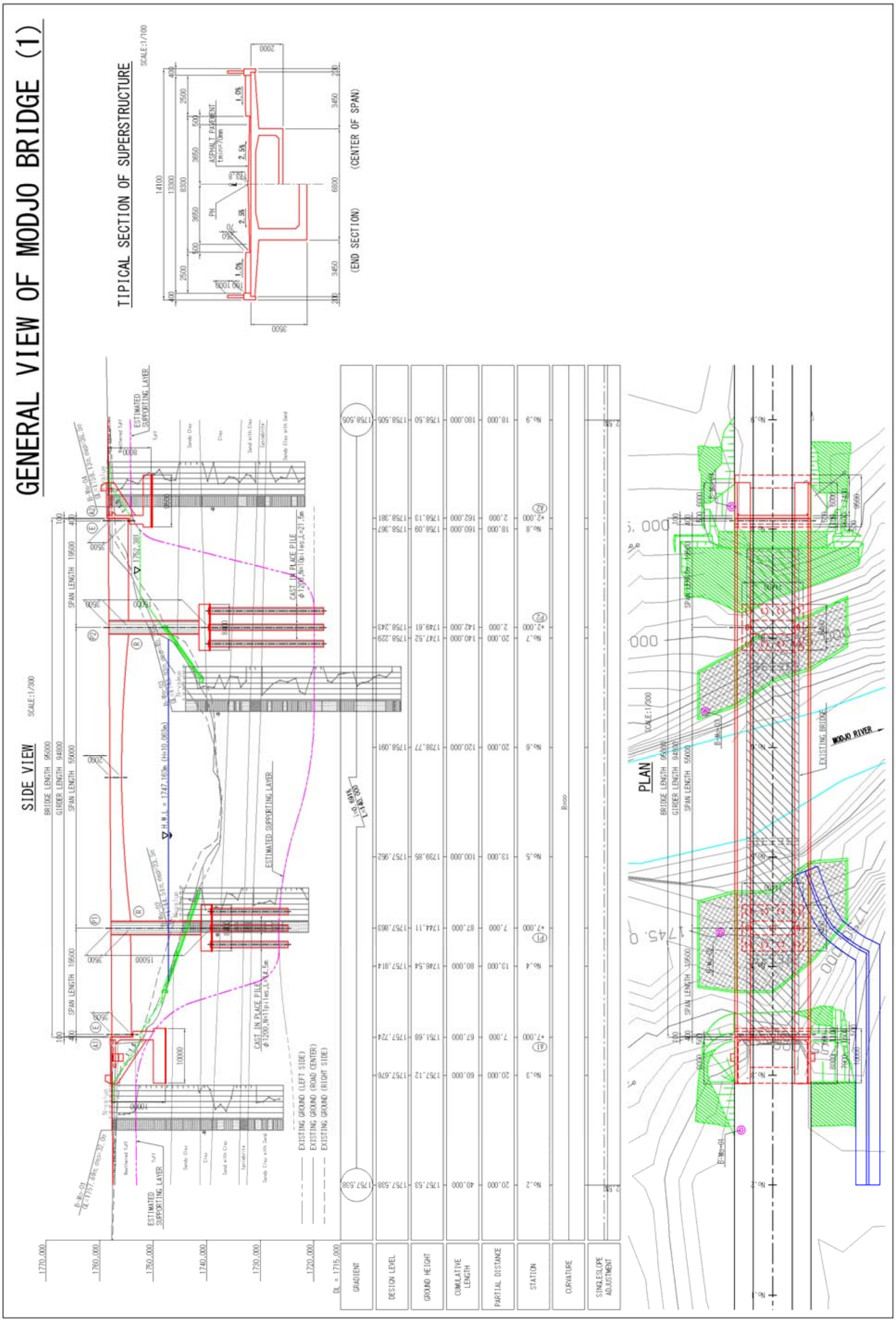


Figure 2-3-2 General View of Modjo Bridge (1)

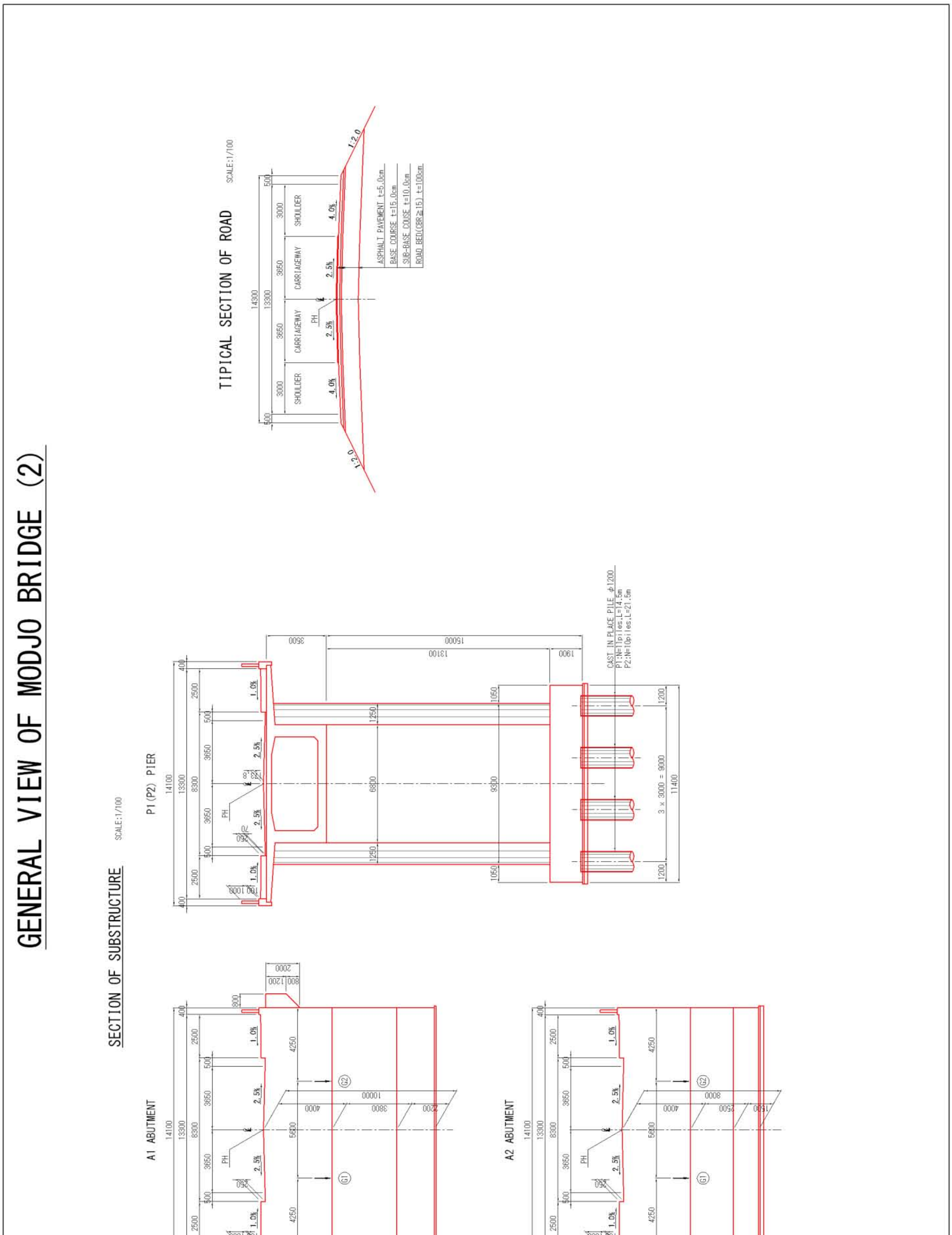


Figure 2-3-3 General View of Modjo Bridge (2)

2-4 Implementation Plan

2-4-1 Implementation policies

Under the assumption that this project is to be implemented within the framework of the donor country's Grant Aid, the following will be considered as the basic policies for the examination on construction methods.

① In order to contribute to creation of employment opportunities and promotion of technology transfer, the project shall utilize local engineers, laborers, materials and equipment as much as possible.

② Close communication shall be established between the Government of the Federal Democratic Republic of Ethiopia (Ethiopian Government), the consultant and the contractor for smooth implementation of this project.

③ The Ethiopian Government shall be requested to secure land required for the implementation of this project (removal of houses and compensation for land expropriation) by its commencement as a work in the scope of works of the recipient country.

④ Steep slopes and exposed rock surface characterizes the natural condition of the construction sites. At such sites, there is a high risk of workers and equipment at work slipping down slopes in the rainy seasons. Appropriate construction methods and implementation schedule shall be designed with such a risk taken into consideration.

⑤ A practicable implementation schedule incorporating all possible measures for safety management during the construction shall be designed with the periods required for procurement of materials and equipment and adoption of appropriate construction methods under the restrictive topographic condition of landlocked Ethiopia taken into consideration.

2-4-2 Implementation Conditions

(1) Maintenance of safety during the construction period

The following are the principal measures for the maintenance of safety during the construction period.

- Since the access roads to the construction sites for the construction vehicles diverge from the existing A1 Trunk Road at all three sites, traffic controllers shall be stationed at the junctions of the access roads and the trunk road and sufficient numbers of construction signboards, traffic signs and traffic safety equipment shall be installed at appropriate locations.
- At sites where certain work has to be implemented in a river, implementation of work near a river should be minimized in the rainy seasons because the water level may rise suddenly at some of these sites.

(2) Environmental conservation during the construction period

The following are the principal measures for environmental conservation during the construction period.

- Creation of dust by the traffic of construction vehicles shall be suppressed with measures such as spraying water and imposing speed limit.
- Because of noise and vibration created by construction machinery, construction work shall not be implemented in the early morning or in the night.
- Since the construction vehicles will use the detours, measures shall be taken to minimize adverse effects caused by the traffic of vehicles and machinery involved in this project on the traffic of ordinary vehicles.

(3) Strict adherence to the Labor Standard Act

The contractor shall adhere to the laws and regulations on construction work which are in force in Ethiopia, respect appropriate labor conditions and customs associated with employment, prevent conflicts with laborers and maintain the safety of work with them.

(4) Strong awareness against danger at the project sites

The construction site is far from the presumed mined area and has been searched for landmines. The construction will commence under the assumption that the site is free of landmines. Nevertheless, people involved in the construction work shall always remain on the watch for landmines with the above-mentioned fact in mind.

(5) Customs clearance

All construction materials and equipment procured from the donor country and third countries (including South Africa) will be transported to and unloaded in Djibouti and cleared customs. Therefore, the number of days required for the transport, unloading and customs clearance shall be estimated and the estimated number of days shall be taken into consideration when designing the implementation plan.

(6) Emphasis on quality control of concrete

The substructure work of constructing Abutments A1 and A2 of the two bridges and Piers P1 and P2 of Modjo Bridge and the superstructure work of constructing concrete girders are considered principal construction works in this project of constructing the three bridges. In short, the concrete work is considered as the principal work. Therefore, the construction shall have to be executed with the highest priority on the quality control of concrete, including quality control of materials such as aggregate, sand, water and cement, regulations on specifications of a concrete mixing plant, regulations on transport of concrete and management of concrete casting and curing.

2-4-3 Scopes of Works

If this Grand Aid project is to be implemented, the scopes of works of the donor country's side and the Ethiopian Government will be as follows:

Table 2-4-1 Scopes of works of the Donor Country's side ant the Ethiopian Government

Scope of works of the Japanese side	Scope of works of the Ethiopian side
・Implementation of the cooperation project described in the "Basic Plan," *i. e.* construction of new Gogecha Bridge (bridge length = 38 m) with access road (40 m) and new Modjo Bridge (bridge length = 95 m) with access road (40 m) ・Construction and removal of temporary facilities (material/equipment yards, offices, etc.) ・Safety measures for the works and general traffic passing through the construction areas during the construction period ・Measures to prevent environmental pollution by the construction work during the construction period ・Procurement, import and transport of construction materials and equipment described in "Procurement Plan": Re-export of imported equipment ・Preparation of implementation design, tender documents and agreements, assistance in tender and supervision of the construction work described in "Consultant Supervision", including monitoring of the environment management plan	・Land expropriation required for this project, removal of facilities and houses to be affected by the project and smooth relocation of residents ・Provision of lots for the temporary facilities required for this cooperation project free of charge ・Issuance of IDs to the people involved in the construction and stickers to construction vehicles ・Provision of a waste material disposal plant required for this project ・General monitoring of the construction areas during the construction period ・Supervision by relevant personnel of the Government of Ethiopia during the construction period ・Removal of the existing bridges ・Exemption from customs duties, domestic taxes and other levies in the taxation system imposed by the Ethiopian Government ・Assistance to Japanese nationals and nationals of third countries involved in the project in their entry and stay in Ethiopia ・Payment of bank commissions (opening of a bank account and processes of authorization to pay (AP))

2-4-4 Consultant Supervision

(1) Basic policies for the consultant supervision

Under the assumption that this project is to be implemented within the framework of the Donor Country's Aid, the following have been selected as the basic policies for the consultant supervision.

- Since quality of construction work affect the life and durability of the completed facilities significantly, the consultant shall perform supervision with quality control as the highest priority issue. Since Modjo Bridge is a long bridge (95 m) and uses the box-girder structure, the concrete work for superstructure and substructure works should be closely monitored.
- The next highest priority shall be placed on the supervision of the progress of the project, safety and payment.
- In order to perform the supervision mentioned above, the contractor and the consultant shall inspect the construction sites together and hold a regular meeting every week to verify problems and discuss measures against the problems.

- In addition, representatives of the client of the project/the office in charge of road construction and maintenance, the Ethiopian Roads Authority, the contractor and the consultant hold regular monthly meetings to verify problems and discuss measures against them.
- The consultant shall employ a local engineer as an assistant to the full-time on-site supervisor and facilitate technology transfer in consultant supervision, including methods for quality control, progress management and safety management.
- Instruction to the contractor and minutes of all the meetings shall be recorded in writing and reporting to the client shall be done in writing.

(2) Consultant's supervisory work

The major components of the works included in the Consultancy Agreement are as follows:

1) Tender document preparation stage

The consultant will prepare implementation design of each facility in accordance with the conclusions of the outline design survey report. Subsequently, the consultant will prepare construction agreement documents and obtain approval for the following documents from ERA of the Ethiopian Government.

- Design Report
- Drawings
- Tender documents

2) Construction tender stage

ERA, with assistance from the consultant, will select a donor country's contractor in an open tender. The agent selected by the Ethiopian Government who takes part in the processes from the open tender to the conclusion of a construction agreement shall be authorized to give approval to all the matters concerning the construction agreement. The consultant shall provide assistance to ERA in the following services:

- Tender notice
- Pre-qualification
- Tender and evaluation of bids

3) Construction supervision stage

After the conclusion of a construction agreement between the contractor selected in the tender and the representative of the Ethiopian Government, ERA, the consultant will issue an order to commence the construction to the contractor and commence construction supervision. The consultant will report progress of the construction directly to ERA, the Embassy of Donor country in Ethiopia and send monthly reports by mail to other relevant personnel and offices, if necessary. The consultant will supervise the contractor in administrative activities related to the progress and quality of the work, safety and payment and in the technical aspect including provision of measures and suggestions to improve the construction work.

The consultant will conduct a defect inspection a year after the completion of the supervision. This inspection will be the last of the consultancy services.

(3) Personnel plan

The personnel required in each of the detailed design, construction tender and construction supervision stages and their duties are as follows:

1) Detailed design stage

- The Project Manager will supervise the technical aspect and general coordination of the detailed design and act as the primary contact person for the client
- A bridge engineer (superstructure work) will carry out field surveys, structural calculation, preparation of drawings and quantity surveying for the superstructure design
- A bridge engineer (substructure work) will carry out field surveys, structural calculation, stability calculation, preparation of drawings and quantity surveying for the substructure design
- A road engineer will carry out linearity calculation, selection of the final standard section, examination on slope protection work, road drainage design, preparation of drawings and quantity surveying for the road design
- A river engineer will carry out field surveys, structural calculation, stability calculation, preparation of drawings and quantity surveying for the river structure design
- A person in charge of implementation schedule and estimation will prepare an implementation schedule and carry out estimation using design quantities and unit prices of works derived from the outcome of the detailed design.
- A person in charge of tender documents will prepare tender documents

2) Construction tender stage

The consultant will provide assistance to ERA in finalization of pre-qualification and tender documents, implementation of the pre-qualification and evaluation of bids.

- The Project Manager will supervise the above-mentioned consultancy services throughout the tender process
- A bridge engineer will approve tender documents and provide assistance in bid evaluation

3) Construction supervision stage

- Project Manager will supervise the consultancy services in general in the construction supervision
- A full-time on-site engineer will take overall responsibility of the on-site construction supervision, report the progress of the construction to the relevant Ethiopian authorities and hold discussion with them
- A structural engineer will revise the implementation schedule for the bridge and revetment works, supervise the concrete work and control PC tension in superstructures. (S)He will verify the bottom surface for the foundation work to be revealed after excavation and, if necessary, take charge of adjustment on-site of the foundation work.

2-4-5 Quality control plan

The following table shows the quality control plan for this project.

Table 2-4-2 List of quality control items (draft)

Item			Test Method	Frequency of Test
Subgrade (macadam)	Blended material		Liquid limit, plasticity index (<sieve No. 4)	For each blend
			Particle-size distribution (blending)	〃
			Aggregate abrasion loss test	〃
			Aggregate density test	〃
			Maximum dry density (compaction test)	〃
	Laying		Density test (compaction rate)	Once/day
Prime coat / tack coat	Material	Bituminous material	Quality certificate	For each material
			Application amount	Per 500 m^2
Asphalt	Material	Bituminous material	Quality certificate, ingredient analysis table	For each material
		Aggregates	Particle-size distribution (blending)	For each blend, once/month
			Water absorption	For each material
			Aggregate abrasion loss test	〃
	Blending test		Stability	For each blend
			Flow value	〃
			Porosity	〃
			Aggregate porosity	〃
			Tensile strength (indirect)	〃
			Residual stability	〃
			Design asphalt amount	〃
	Laying		Mixing temperature	As needed
			Rolling temperature	For each transport
			Marshall test	About once/day
Concrete	Material	Cement	Quality certificate, chemical & physical test results	For each material
		Water	Ingredient test result	For each material
		Admixture	Quality certificate, ingredient analysis table	For each material
		Fine aggregates	Oven dry density	For each material
			Grain size distribution, fineness modulus	〃
			Percentages of clay lumps and soft particles	〃
		Coarse aggregates	Oven dry density	For each material
			Flake content	〃
			Particle-size distribution (mix)	〃
			Sodium sulfide diagnosis (missing mass)	〃
	At the time of blend test		Compressive strength test	For each blend
	At the time of laying		Slump	Once/batch
			Temperature	Once/day
	Strength		Compressive strength test (7 days, 28 days)	Once/day or = 50 m^3
Steel bars	Material		Quality certificate, tensile test result	For each lot
Structural steel	Material		Mill sheet	For each lot
Coating	Material		Quality certificate, ingredient table	For each lot
Bearing	Material		Quality certificate, strength test result	For each lot
Lighting equipment	Material		Quality certificate, strength test result	For each lot

2-4-6 Procurement Plan

(1) Procurement of construction materials

Construction materials which can be produce locally include sand, aggregate, base course materials. The rest will be imports.

The basic policies for the procurement of materials are as follows:

- An imported material will be procured if it is always available at the market and has sufficient quality.
- A product which cannot be procured locally will be procured from donor country or third countries. Decision on procurement sources will be made after comparing such factors as prices, qualities and periods required for customs clearance.

The table below shows potential sources of procurement of major construction materials.

Table 2-4-3 Possible Procurement Sources of Main Construction Materials

Item	Source			Reason for choosing procurement from Donor
	Local	Donor country	Third country	
PC steel		○		Not marketed in the country. Although procurement from a neighboring third country is possible, specifications may not be satisfied.
Steel handrail		○		Because handrails are highly visible to users, products from a neighboring third country may result in uneven quality and inferior workmanship.
Steel for temporary works		○		Leased products that cannot be procured locally will be procured from Japan.
Rubber bearing		○		Not marketed in the country. Although procurement from a neighboring third country is possible, quality of material (rubber) is uneven and specifications of this project may not be satisfied.
Shape steel		○		Not marketed in the country. Although procurement from a neighboring third country is possible, specifications may not be satisfied.
Bituminous material	○			
Aggregate	○			
Asphalt bituminous material	○			
Portland cement (blended cement)	○			
Expansion device		○		Not marketed in the country. Although procurement from a neighboring third country is possible, quality of material is significantly uneven and specifications of this project may not be satisfied.
Cement additive		○		Procured from Japan considering quality.
Steel bars			○	Scarcely marketed in the country. Procured from South Africa considering quality and supply quantities.
Timber for formwork	○			
Diesel oil	○			
Gasoline	○			
Bridge deck waterproof materials		○		Procurement from local sources and neighboring countries is difficult. When used locally, these are usually imported from Japan, Europe, or the US.

(2) Construction machinery

Local offices of ERA and local construction companies own general construction machinery used for road repair. However, construction machinery including large cranes and cantilever erection equipment used for bridge construction and equipment for casting concrete including concrete mixer trucks and concrete pump trucks, an asphalt plant, a concrete plant and a crusher plant for aggregate production will be procured from Donor country.

There are several companies leasing construction machinery. However, none has been found in either Nazret City, the city closest to the construction sites, or in the neighborhood of the sites. These companies have only small numbers of equipment and demand for them reportedly peaks at the beginning of the dry season. Nonetheless, possibility of procuring general-purpose bulldozers, back hoes and damp trucks, etc. on a rental basis will be investigated.

A large construction company owns its own asphalt-cement plant and concrete plant in Addis Ababa and sells asphalt mixture and ready-mixed concrete. However, it is not possible to rent these plants in any form.

The survey team confirmed several crusher plants owned by aggregate manufactures in operation in the suburbs of Addis Ababa. They are of fixed type for the companies' use and none can be considered for procurement. Table below shows the possible sources of the main construction machinery and reasons for procurement in Donor country.

Table 2-4-4 Possible Procurement Sources of Main Construction Machines

Type	Specifications	Source			Reason for choosing procurement from Donor country
		Local	Donor	Third country	
Bulldozer	15t	○			
Backhoe	0.6m3	○			
Dump truck	10t	○			
Wheelloader	1.2m3	○			
Truck crane	20 t			○	
Crawler crane	60～80 t		○		Procured from Japan because local procurement is difficult and leasing from a third country (South Africa) is impossible.
Motor grader	3.1m	○			
Road roller	10-12 t	○			
Tire roller	8-12 t	○			
Vibrating roller	0.8-1.1 t	○			
Tamper	60-100kg		○		Procured from Japan because local procurement is difficult and leasing from a third country (South Africa) is impossible.
Large breaker (attachment)	1,300kg			○	
Concrete plant	0.5m3	○	○		Procured from Japan because local procurement is difficult and leasing from a third country (South Africa) is impossible.
Road sprinkler	5500-6000lit	○			
Steel wire jack	225 t	○			
Erection girder			○		Procured from Japan because local procurement is difficult and leasing from a third country (South Africa) is impossible.

Chapter 3 Obligations of the Recipient Country

The duties to be performed by the Ethiopian Government with regard to the implementation of this project by Japanese Government are as follows:

3-1 General matters in the Donor Country's Aid

- To provide data and information required for the project implementation
- To secure land required for the project implementation (land for road construction, work areas, camp yards and material/equipment depots)
- To level each construction site before commencement of the construction
- To open an account under the name of the Ethiopian Government with a bank in Donor country and issue Authorization to pay"
- To unload goods destined for Ethiopia quickly at the unloading sites and process application for tax and customs duties exemption appropriately
- To exempt donor country's corporations and nationals involved in this project from customs duties, domestic taxes or any other taxes imposed upon provision of products or services described in the authenticated agreement.
- To allow people involved in the project entry into Ethiopia and their stay in Ethiopia and Donor country for the implementation of the work, in accordance with the approve agreement or with regard to the service provision
- To grant permission or other authorization for the project implementation, if necessary.
- To maintain, manage and protect the facilities to be constructed in the project correctly and effectively.
- To bear the all the costs within the scope of works of the project except those which should be borne by the Donor country's Aid

3-2 Matters specific to this project

- Removal of facilities and houses affected by the construction
- Securing of land required for this project in addition to the sites of the existing roads
- Provision and leveling of lots for the temporary yards
- Places to collect construction materials
- Provision of place to dispose of waste soil and a waste material disposal plant

(To be completed prior to the Prequalification (PQ) notice)

- General monitoring of the construction areas during the construction

Chapter 4 Project Operation and Maintenance Plan

The Ethiopian Government will supervise implementation and maintenance of this project. The Road Network Management Division in the Engineering and Regulatory Department has jurisdiction over maintenance of bridges and roads and the Bridge Management Section in the same division is in charge of maintenance of bridges and structures. The Pavement Management Section in the Road Network Management Division is responsible for road maintenance except for those on brides and structures.

In the implementation structure for the maintenance of the two bridges, Gogecha and Modjo Bridges, ERA Head Office carries out surveys of current situation, prepares a repair and renovation plan and applies for budgetary funding and ERA local offices repair and renovate the bridges. Alem Gena Regional Office is responsible for Gogecha and Modjo. The maintenance works after the completion of this project are classified into those to be implemented every year on a regular basis and those to be implemented once in several years. The works mentioned below are required for this project.

(1) Inspection and maintenance required to be implemented every year

- Removal of sand and waste accumulated in drain pipes, near bearings and in drain ditches including side ditches on the bridge surface and cleaning of the pipes, bearings and ditches
- Maintenance of the traffic safety works, such as reapplication of paint on signs on road surface.
- Inspection and repair of the revetment and bed protection works after flood.
- Removal of stones fallen down and washed-away trees after the flood
- Weeding on shoulders and slopes

(2) Maintenance to be implemented once in several years

- P Patching or overlaying of pavement on the bridge surface and access roads to be implemented every five years or so
- Replacement of expansion joints every 10 years or so

In this project, the revetment and bed protection works play an important role in protecting the bridges. These works are designed to stand the 100-year design flood discharge. However, these structures may collapse or be washed away because of unpredictable local erosion or a flood larger than the 100-year flood. The survey team requests ERA to establish a system in which a section in charge of the revetment and bed protection works inspects bridges immediately after flood and, if damage or collapse has been confirmed on these works, ERA is able to repair damage or collapse immediately. If such damage or collapse is left unrepaired, the back-filled earth behind an abutment may be washed away and the loss of the earth may develop into subsidence of the abutment and shut-off of traffic, in the worst case scenario.

Chapter 5 Project Cost Estimation

5-1 Initial Project Cost

5-1-1 Cost Born by the Government of Ethiopia

Table 5-1-2 Costs borne by the Ethiopian side

	Compensation item	Costs to be borne (Thousand Birr)
Gogecha Bridge	(1) Power poles	3.51
	(2) Telegraph poles	0.34
	(3) A tin-roofed shack and fence	49.35
	(4) Ditch made of concrete blocks	50.00
	Total	103.20
Modjo Bridge	(5) Power poles	3.12
	(6) Telegraph poles	0.68
	(7) Ditch made of concrete blocks	364.00
	(8) Eucalyptus trees	15.03
	Total	393.63
(9) Bank services charges		99.76
Grand total		596.59

5-2 Operation and maintenance costs

The main maintenance works for the new bridges and the access roads to be developed in this project are daily inspection, cleaning and repair as described in Table 5-2-1. Ethiopian Roads Authority (ERA) will be responsible for the maintenance works. The maintenance costs (as an annual average) are estimated at 228,000 birr. Since this figure is 0.18 % of the maintenance budget of ERA of 125.4 million birr (for Fiscal 2008/2009), it has been concluded that ERA is capable of providing sufficient maintenance.

Table 5-2-1 Main maintenance items and costs

Classification	Frequency	Inspection part	Work content	Estimated costs (birr)		Remarks
				per work	per annum	
Maintenance of drain ditches	Twice a year	Drainage on the bridge surface	Removal of sand deposit	4,988	9,976	
		Side ditches	Removal of sand deposit	356	713	
Maintenance of the traffic safety works	Once a year	Marking	Re-application of paint	1,469	1,469	Estimated with 40 % of the miscellaneous expenses
Road maintenance	Twice a year	Shoulders and slopes	Weeding	18,128	36,256	
Maintenance and repair of pavement	Every five years	Pavement surface	Repair of overlays and cracks	195,622	39,124	Estimated at 10 % of direct construction costs (miscellaneous expenses: 40%)
Replacement of bearings and expansion joints	Every ten years			1,403,793	140,379	Removal costs estimated at 10 % of the direct construction costs (miscellaneous expenses: 40%)
Annual average of the above-mentioned maintenance costs (birr)					227,918	