(B) Grand Etang Road

2-2-1 Design Policy

The basic design concept of for improvement of Grand Etang Road and its bridges consists of 4 four parts, that is : (1) Management plan; (2) Local condition; (3) Applied Design Standard; and (4) Construction Schedule and Implementation Program.

(1) Management Plan

For the preparation of the management plan of for improvement of Grand Etang Road and its bridges, it is necessary to understand that the aim of the main task of the project is to provide the infrastructure required to fully enable the distribution and marketing function of the fishery facility in Grenville, as the central fish market in the second most important city of Grenada, along with the simultaneous improvement of this fishery facility.

At present, however, trucks carrying fishery products avoid to traveling on Grand Etang Road, because of its various constraints, such as geometric and vertical alignments, as well as narrow road sections and bridges, and travel much greater distances on other roads. Therefore, improvement of Grand Etang Road, which is the shortest route between Grenville and St. George's, the largest consuming city of fishery products, aims to divert those trucks carrying fishery products to Grand Etang Road with smooth and safe road condition in order to minimize transport duration and invigorate the fishery business in Grenada.

At the same time, improvement of Grand Etang Road also aims to upgrade the its function as one of the major arterial road of Grenada through taking measures to reduce with obstruction of smooth traffic flow at several bottle necks, serious traffic accidents, and the number of pedestrians without adequate safety protection.

(2) Local condition

1) Design Policy for Natural Conditions

a) Temperature and Humidity

Project sites on Grand Etang Road are located in a semi-tropical climate featuring high temperatures and high humidity. Since this kind of climate has a significant effect on metal structures, it is necessary to consider this fact in light of future maintenance. It is also necessary to give careful attention to the curing of concrete in the case of concrete bridges.

b) Amount of Rainfall and Water Level of Rivers

The average annual amount of rainfall along Grand Etang Road is very peculiar, at 1,500mm at Grenville and St. George's and 3,000-4,000mm at the peak of Grand Etang, respectively. Moreover, the dry and rainy seasons in Grenada are clearly distinct, and most rainfall is concentrated in the rainy season.

On the other hand, the condition of the river flow at each bridge site differs according to the results of hydraulic analysis. However, due to insufficient availability of data, it is necessary to consider a rather wide range for the results of analysis. Therefore, it is necessary to grasp the total condition of each river according to the results of site interviews on topics, such as rate of increase in water level, etc.

Since these conditions at project sites greatly affect implementation plans and construction schedules, it is necessary to consider these site conditions carefully when planning. In particular, it is necessary to prepare a construction plan for the completion of substructures, such as foundations, within the first dry season.

c) Earthquakes

The “seismic load” referred to in CUBIC Part 2 Section 3 is the standard applied for buildings in Grenada, and it is judged that this load can be applied for both civil engineering structures and architectural buildings. Accordingly, this standard will be used for the seismic design of bridges.

d) Scoring and depth of foundation structures

When designing foundation structures, due consideration should be paid to the determination of the depth of foundations, in order to cope with scoring around foundation structures during flooding.

2) Social Circumstances

For the preparation of the improvement plan for road sections and bridges on Grand Etang Road, when land acquisition is required, it must be limited only to unused land and must avoid moving houses and public facilities, in order to minimize the impact on the roadside environment. Sidewalks will also be installed at sections with many pedestrians.

3) Construction Conditions

There are only a limited number of civil engineers in Grenada, and this situation will be considered in the planning stage.

a) Construction materials, such as cement, iron bars, etc., depend on imports in Grenada. Hence, these materials will be brought either from Japan or a third country, after comparison of procurement cost.

b) It is necessary to use local construction firms as subcontractors and to utilize local labor as much as possible.

(3) Applied Design Standard

There is no own independent design standard for roads and bridges in Grenada. Since Japanese design standards were applied for every Grant Aid project in the civil engineering field, the following Japanese design standards are applied for design of roads and bridges under this Grant Aid program, in order to unify harmonize with other projects. The Government of Grenada has agreed with this concept.

- Geometric Design Standard of Roads : Japan Road Association

- Standard of Asphalt Pavement : Japan Road Association
- Specification for Highway Bridges : Japan Road Association

(4) Construction Schedule and Implementation Program

The construction period of improvement works for Grand Etang Road is one and a half years. Under this assumption, construction for this project is planned to commence either in October or November for both improvement of road sections and construction of new bridges. In addition, since this is just before the start of the dry season, it is necessary to plan the completion of construction works in rivers (construction of piers, etc.) within the first dry season in order to satisfy the engineering requirements.

2-2-2 Basic Plan

2-2-2-1 Improvement of Grand Etang Road

(1) Applied Design Standard

1) Geometric Design Standard of Road

a) Design Speed

The Grand Etang Road, which is the study road for this Basic Design Study, has gradually been improved to accommodate vehicle traffic on the mountainous road. The minimum curve radius is R=7.5m, and there are 9 locations where the curve radius is less than R=12. Also, the maximum gradient is i=16.6%, and there are 10 locations where the gradient is more than i=12%. Hence, horizontal and vertical alignment of this road is very bad.

Table 2-29 shows the results of the traffic volume counting measurement survey. Considering the existing road condition and traffic condition, design speed for the new alignment was determined as V=40km/h and V=30km/h according to the Geometric Design Standard, and the road design works have been performed. On the other hand, at the road sections slated for widening with that have geographical constraints, road improvement design has been performed in order to secure the minimum carriageway width to accommodate vehicles pass-bying each other, regardless of the design speed and the Geometric Design Standard.

Table 2-29 Present Traffic Volume on the Grand Etang Road

Section	Traffic Volume (Vehicles/day)	Number of Pedestrians (Persons/day)	Note
I-1	6,700	640	
I-2	5,700	590	Vendome Bridge
II-1	1,600	50	
II-2	1,700	330	Hair-pin Curve Birch Grove Bridge
III-1	1,700	70	Balthazar Bridge St. Cyr Great River Bridge
III-2	3,200	60	

b) Geometric Design Standard

Based on the determined design speed, the geometric design standard utilized in the Study was determined as shown in Table 2-30.

Table 2-30 Geometric Design Standard Utilized in the Study

Item	Unit	Standard Value	
Design Speed	km/hr	40	30
Minimum Curve Radius	m	60 (50)	30
Superelevation Run-off Ratio		1/100	1/75
Stopping Sight Distance	m	40	30
Maximum Vertical Gradient	%	7.0 (10.0)	8.0 (11.0)
Vertical Curve Length (VCL)	m	35	25
Radius of Vertical Curve	m	450	250

( ) Exceptional value

2) Design Standard of Bridge

a) Design Live Load

Based on the traffic volume of heavy vehicles with 25 tons gross weight on the Grand Etang Road, the A- type live load in the Specification for Highway Bridges (Japan Road Association) is applied for the live load used for the design of bridges in the Study. Also, the loading method specified in the Specification for Highway Bridges is used as the loading method in the Study.

b) Seismic Load

Since there is no own independent seismic data in Grenada, K'=0.14 is applied as the maximum design seismic coefficient based on the Caribbean Uniform Building Code Part 2/Sec.3. Please refer to the detailed explanation in 2-2-2-3 (1) 1) d)Seismic force (Page 2-60 and 61.)

c) Other Loads

Other loads specified is in the Specification for Highway Bridges is applied for other loads used for the design of bridges in the Study.

d) Strength of Material

i) Strength of concrete

<u>Superstructure</u>

PC-T shaped bridge :σ_{ck}=400kgf/cm^2

<u>Substructure</u>

Abutment and pier : σ_{ck}=240kgf/cm^2

Un-reinforced concrete : σ_{ck}=180kgf/cm^2

ii) Iron bar

SD35 or SD295 equivalent

iii) Prestressing steel

Prestressing steel strand 12T12.7

3) River Bed Protection and Revetment Work

The Government Ordinance for Structural Standard of River Administration Facilities (River Bureau, Ministry of Construction, Japan) is used as a reference for the design of river bed protections and revetment works related to the improvement of bridges in the Basic Design Study.

4) Cross-Sectional Elements

Based on the function, traffic volume, and site investigation of the Grand Etang Road as well as results of discussion with officials from the Ministry of Works, Communications and Public Utilities, the minimum cross-sectional element for the improvement of roads is defined as shown in Figure 2-10.

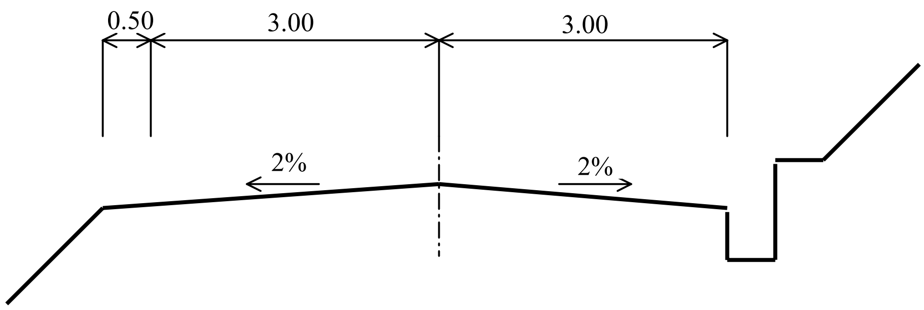


Figure 2-10 Minimum Cross-Sectional Element for Road Improvement

Also, the standard real width of a bridge is defined as W=7.50m shown in Figure 2-11, in order to unify harmonize with the cross-section of roadway sections.

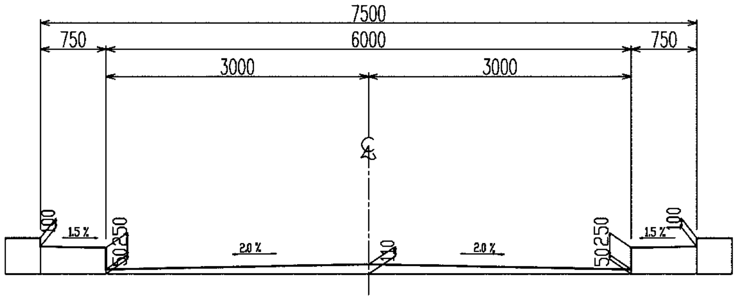


Figure 2-11 Standard Cross-Section of Bridge

(2) Improvement of Road Sections

1) Hair-pin Curve Section (km.10+840～km.11+220)

a) Outline of the improvement plan

This road section is judged to be in the worst condition on of any on Grand Etang Road from horizontal and vertical alignment points of view. The existing carriageway is very narrow, with as little as 4.0m in average width for 380m of length, while there are three sharp bends, including a hair-pin curve, and the average vertical gradient is 12%. Hence, this location is a bottleneck for traffic flow. On the cut slope of the existing road, there are outcrops of hard lavas are cropped out, as separated gravel shaped pieces of lavas have formed large boulders. Since there is no detour road, every vehicle should utilize this road. As a result, improvement of this section is planned, as not to totally completely changing the horizontal alignment, but to widening the existing road for on the valley side.

b) Horizontal alignment

- At the 100m-long length section from the beginning points at km 10+840 and km10+940, retaining walls in good condition is exist on the valley side, and it is will be possible to utilize these in the future. However, the guardrails installed on the retaining wall were have been damaged. On the other hand, the cut slope of the right side of the existing road, only at this section, is not high, only at this section and there is are no boulders. Hence, the improvement of this section is planned as by shifting the road center to the right side (hill side) by cutting into the slope.
- At the 180m length section between km10+940 and km 11+120, outcrops of many large gravel shaped boulders are outcropped on are on the right side slope, and it is impossible to widen the road by cutting into the right slope with while allowing traffic. Therefore, improvement of this section is planned as by shifting the road center to the left side (valley side) without cutting into the existing slope.
- At the 80m length section from between km 11+140 and km11+220, the geographical conditions and

soil conditions are similar to the beginning section mentioned above. Hence, the improvement of this section is also planned as by shifting the road center to the right side (hill side) by cutting into the slope.

c) Vertical alignment

Since this improvement plan is focused on the widening of the existing road, the height of the planned road sections are will be adjusted with the to suit existing road height, and no modification of the vertical alignment is will be made.

d) Cross-section

i) Cross-sectional elements

The minimum carriageway width of 6.0m is secured in the improvement plan. In addition, since because of the existing winding road alignment, the part of land remaining after the improvement is also planned as carriageway. On the other hand, a protection shoulder of W=0.5m is planned to be constructed along the left side (valley side) of the carriageway in order to provide space for the installation of traffic safety facilities, i.e., guard fences (guardrails) and curve mirrors. Also, construction of U-shaped side ditches at the bottom of the slope on the hill side is also planned in order to prevent erosion of base course of road and slope.

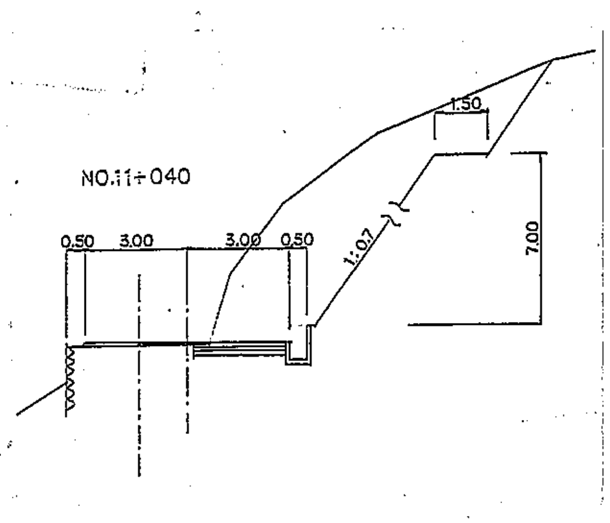
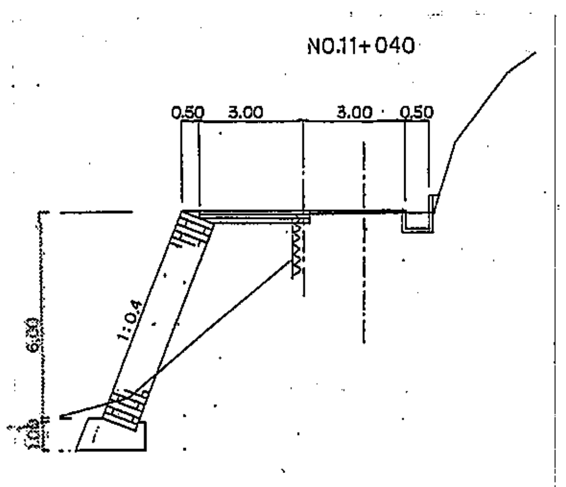
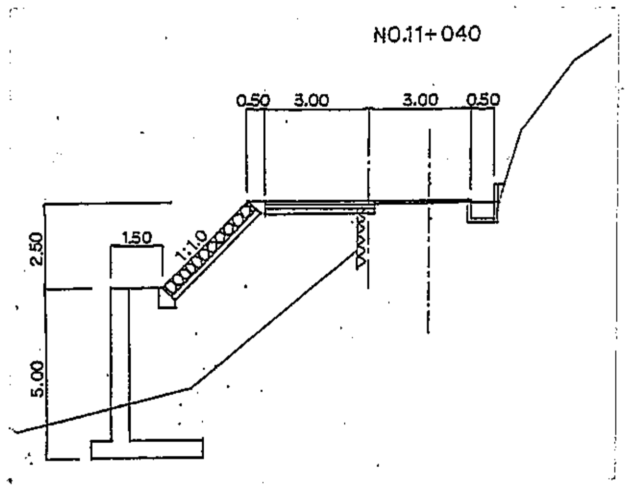
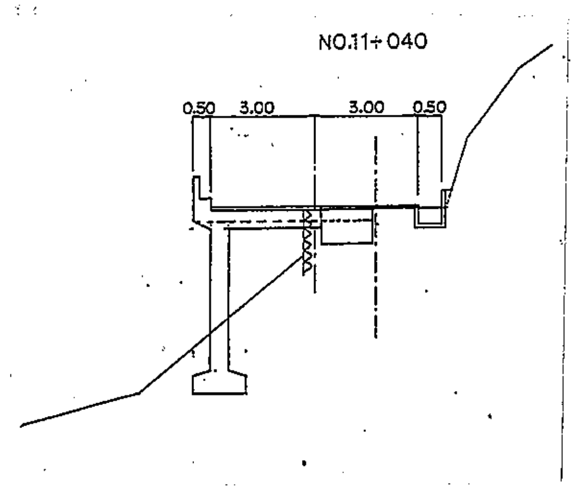
ii) Embankment section

Since this section is located in a very steep mountainous area, embankment should be planned by in construction of structures. Therefore, comparison of improvement types at this section is made, as shown in Table 2-31, and the crib type retaining wall is selected as the most suitable type of structure in this section. However, the stone masonry type retaining wall is also adopted for sections with less than 3m of embankment height.

iii) Cutting section

At the beginning and the end of the section, the existing road is planned to be widened by cutting into the existing slope. The present slopes formed by cutting into volcanic ash sediments by at a 1:0.5 gradient with vegetation are observed as to be in stable condition. Even though the desirable gradient of for cutting into slopes is 1:1.0, the present slope is stable by at a 1:0.5 gradient. Hence, a 1:0.7 gradient is adopted for the cutting into slopes in the improvement plan. In addition, berm steps of 1.5m widths are planned to be constructed on the cutting slope for each 7m of cutting height.

Table 2-31 Comparison of Improvement Alternative at Hair-pin Curve Section

Alternative	Alternative A (Cutting Type)	Alternative B (Crib Type Retaining Wall)	Alternative C (Reversed T-Shaped Retaining Wall)	Alternative D (One Side Path Type)
Present Condition	This road section is judged to be in the worst condition of any on Grand Etang Road. The existing carriageway is very narrow, with as little as 4.0m in average width for 380m of length, while there are three sharp bends, including a hair-pin curve, and the average vertical gradient is 12%. Hence, this location is a bottleneck for traffic flow. On the cut slope of the existing road, there are outcrops of hard lava , as separate pieces of lava have formed large boulders. Since there is no detour road, every vehicle must utilize this road.			
Design Condition	Design Vehicle : Vehicle smaller than ordinary truck, Length 10m, Width 2,5m, Overhang at front side 1.5m, Wheel base 5.0m, Minimum turning radius 9m Carriageway Width : 6.0m Traffic Control : At least one-lane is planned to be secured during construction. If one-lane control length will be extended more than 300m, a waiting bay will be provided at the middle of traffic control section. If closure of road will be required, maximum duration should be less than 6 hours (to avoid peak hours in the morning and the evening) in the day time or at night.			
Sketch				
Outline of Plan	To cut the existing hill and secure 6m of carriageway and a side ditch on the hill side	At the existing hill side, only side ditches are installed. Widening is made on the valley side by embankment To secure 6m carriageway width		
		Crib type retaining wall is constructed to protect the embankment from the edge of the road	Reversed T-shaped retaining wall is constructed at the bottom of the embankment. In order to prevent effect of evacuation of foundation for the existing road, retaining wall is constructed far from the existing road by utilizing the bottom of the embankment In order to minimize height of retaining wall, stones are pitched on the slope of embankment.	One side path is constructed at extended part from the existing road
Advantage Disadvantage	× Construction is difficult due to large boulders on the slope × Road closure for long period is required ○ Economically reliable	○ It is possible to secure traffic on the existing road during construction ○ Construction work at site is easy because pre-cast parts are only formed at site ○ Most economical within embankment plans	○ It is possible to secure traffic on the existing road during construction × Construction is difficult because construction of reversed T-shaped retaining wall on steep slope is required.	× Economically unreliable × Road closure for long period is required
Comparison of Cost	○	○	△	×
Evaluation Result	×	○	△	×
	Alternative B is proposed, because it is possible to secure the traffic, easier construction works, and economically reliable.			

Legend - ○ : Desirable, △:Fair, ×:Undesirable

2) Approach Roads of Vendome Bridge (km 5+855 - km 5+960)

a) Outline of the improvement plan

At this location, construction of new approach roads is planned in order to utilize new bridge with 8m of width, which was constructed 10 years ago. Then, horizontal alignment will also be improved, as well as besides securing two lanes on the bridge. Since new road will be constructed, design speed is defined as V=30km/h.

b) Horizontal alignment

In order to improve horizontal alignment as more straight alignment, a normal line connecting between the center of the existing road at the end point and the center of the new bridge is extended to the beginning point, and a minimum radius of R=50 is adopted as run-off with the existing road the beginning point.

c) Vertical alignment

In order to minimize the pavement thickness on the new bridge, the vertical alignment is planned at 8% downgrade from both beginning and end connection points with the existing road toward the new bridge. Also, adoption of 49m of vertical curve length results in a minimum pavement thickness of 5.5cm on the new bridge. In addition, since the sag of the vertical curve is shifted 3m from the A2 abutment, rain water is planned to be drained for drainage without puddling accumulating on the bridge section.

d) Cross-Section

i) Cross-sectional element

The carriageway width of the new approach road is defined as 6m, considering the width of adjacent road sections. Since the width of the new bridge is 8m, and this new bridge is located at the entrance of Grand Etang Forest Reserve and many hikers are walking along the Grand Etang Road here, a 1m width of protection shoulder is planned to be constructed.

ii) Left side embankment

On the left side of the proposed access roads, the ground level is about 5m lower than the planned road height, and there is a small stream. If the embankment is planned by soil structure, the bottom of the slope can reach the stream. Hence, construction of a stone masonry retaining wall is planned at this location. In order to minimize the height of retaining walls at 5m, construction of a large foundation is planned at certain points where the height of retaining walls is expected to be more than 5m.

iii) Between the existing road and the new approach road

Many hikers and tourists park their vehicles on the shoulder of the existing road, because this location is at the entrance of the Grand Etang Forest Reserve. Hence, in order to provide parking space on the existing road space after completion of the new approach road, it is planned to make gaps between the existing road and the new approach road flat in order to secure entry of vehicles into the existing road space.

iv) Other soil works

Other than the above-mentioned soil works, no more large-scale civil works, such as cutting and embankment, are required. Hence, slope gradients are planned at 1:1.0 and 1:1.5 for cutting and embankment, respectively.

v) Side ditches

Since every side ditch in the Grand Etang Forest Reserve was constructed as an unsupported ditch from the landscape point of view, side ditches in this approach section are also planned to be unsupported ditches.

e) Additional works for the bridge (box culvert)

This improvement is planned to utilize an unused new bridge constructed 10 years ago. Therefore, construction of new concrete railings and rehabilitation of scored points on the lower edge of the concrete riverbed are included in the improvement plan.

3) Approach Roads to Birch Grove Bridge

a) Outline of the improvement plan

As described in the bridge planning section, many houses are located along the existing road near Birch Grove Bridge. Hence, construction of a new bridge is planned at the same location as the existing bridge, in order to avoid land acquisition. In addition, since the horizontal and vertical alignment of existing roads is not good, improvement of alignment by higher design speed may require land acquisition as well as engender difficulty of access from houses due to higher road height. Therefore, design speed at this location is set at 30km/h.

b) Horizontal alignment

The horizontal alignment at the new bridge site is set between a police box and a bar located at the beginning side of the bridge, without effect on either structure. Also, connection to the existing road at the beginning and end points is planned by R=40m and R=100 curve alignments respectively, to coordinated with the existing road.

c) Vertical alignment

The planned height of the bottom of the girder of the new bridge is determined to be same as the height of the bottom of girder of the existing bridge, based on the results of hydrological analyses described below.

Height of existing road surface	132.0.5m
Height of existing girder	-0.968m
Height of planned girder	+1.000m
Gradient and pavement thickness	+0.110m
Planned height of road surface on the bridge	132.177m

As a result, a minimum vertical curve of R=250m is used for the new bridge, in order to adjust the height of A1 and A2 abutments to be on the same level. Also, the run-off gradient on the beginning side is set at 6.2% to secure the minimum vertical clearance (R=250m) on the bridge. On the other hand, the run-off gradient on the end side is set as 7.8% to: 1) avoid big gaps between the carriageway height and the entrance of houses, and 2) secure 25m of minimum vertical curve length.

d) Cross section

i) Cross-sectional elements

The width of the new bridge is planned to be a 6.0m carriageway with 0.75m sidewalks on both sides, and the total width is 8.5m. Therefore, the width of approach roads is planned similarly, i.e., a 6.0m carriageway and installation of sidewalks (0.75m) on both sides, as long as it does not effect houses.

ii) Embankments at approach sections

Embankments at the approach sections of abutments are planned to be gravity type retaining walls for the following reasons:

- It is necessary to minimize the area for land acquisition.
- Stone masonry retaining wall is economical and easy to construct because the height of embankments is about 2m.

4) Approach Roads to Balthazar Bridge

a) Outline of the improvement plan

As described in the bridge planning section, construction of a new bridge is planned on the upstream side of the existing Balthazar Bridge. Therefore, approach roads are planned to connect the existing road and the new bridge, and the design speed is set at 40km/h in consideration of the horizontal and vertical alignment of the adjacent section of the existing road.

b) Horizontal alignment

Since construction of a new bridge is planned on the upstream side in order to secure smooth horizontal alignment, it is necessary to keep the distance between the center of the existing bridge and the new bridge at 11.0m because of the effects of construction of the new bridge on the existing bridge.

The running velocities of many vehicles on the existing road are high because of good horizontal alignment. Therefore, an R=150m S-curve, which is capable of a design speed of 60km/h, is adopted at the run-off section between the existing road and a new approach road for the beginning of this section. On the other hand, an R=180m curve is set between the EC-normal line of the existing curve and the normal line of the new bridge in order to secure smooth running condition.

c) Vertical alignment

The planned height of the bottom of the girder of the new bridge is determined to be the same as the height of the bottom of the girder of the existing bridge, based of the results of hydrological analyses described below.

Height of existing road surface	54.600m
Height of existing girder	-0.647m
Height of planned girder	+1.000m
Gradient and pavement thickness	+0.110m
Planned height of road surface on the bridge	55.063m

In order to minimize the height of substructures and avoid convex type vertical alignment on the bridge, a crest with a drain slope of 0.6% is adopted. As a result, length of sag is minimized and smooth vertical alignment is secured at the beginning point of the approach road. Also, run-off length is minimized and an economical plan is realized, because of the lower embankment height, by adopting a minimum vertical curve length of L=35m at the end point of the approach road.

d) Cross section

i) Cross-sectional elements

The width of the new bridge is planned to be a 6.0m carriageway with 0.75m sidewalks on both sides. Therefore, the width of approach roads is planned similarly, i.e., a 6.0m carriageway and installation of sidewalks (0.75m), which can also function as protection shoulders, on both sides, for the whole stretch of the approach roads, because there is no obstruction such as a house.

ii) Side ditch

The whole stretch of the approach roads is planned with embankments. Since the height of embankments close to the new bridge will be high, it is necessary to consider measures to prevent erosion by rain water. Hence, installation of U-shaped ditches at the edge of the carriageway is planned to secure drainage of the embankment shoulder. In addition, an unsupported ditch is adopted to secure drainage at the bottom of the embankment slope, as with the existing road.

5) Pavement Design

a) Design traffic volume

i) Hair-pin curve section

Design traffic volume for pavement design for the hair-pin curve section is calculated using 12 hours of traffic volume at the II-2 section, multiplied by the following factors:

Traffic volume of heavy vehicles (T)

= Traffic volume (vehicles/12 hours) × Day/night ratio × Increment ratio (5 years)

×Heavy vehicle ratio × One direction

= 1,388 vehicles/12 hours × 1.26 × 1.13 × 0.099 × 0.5

= 98 vehicles/day/direction

Thus, the range of the design traffic volume at this location is L-type traffic (less than 100).

ii) Approach roads to Vendome Bridge

Design traffic volume for pavement design for the approach roads to Vendome Bridge is calculated using 12 hours of traffic volume at the II-1 section, multiplied by the following factors:

Traffic volume of heavy vehicles (T)

= Traffic volume (vehicles/12hours) × Day/night ratio × Increment ratio (5 years)

×Heavy vehicle ratio × One direction

= 1,249 vehicles/12hours × 1.26 × 1.13 × 0.099 × 0.5

= 88 vehicles/day/direction

Thus, the range of the design traffic volume at this location is L-type traffic (less than 100).

iii) Approach roads to Birch Grove Bridge and Balthazar Bridge

Design traffic volume for pavement design for the approach roads to Birch Grove Bridge and Balthazar Bridge are calculated using 12 hours of traffic volume at the III-1 section, multiplied by the following factors:

Traffic volume of heavy vehicles (T)

= Traffic volume (vehicles/12 hours) × Day/night ratio × Increment ratio (5 years)

×Heavy vehicle ratio × One direction

= 1,349 Veh./12hours × 1.26 × 1.13 × 0.099 × 0.5

= 95 vehicles/day/direction

Thus, the range of the design traffic volume at this location is L-type traffic (less than 100).

b) Pavement thickness

Based on the results of the above-mentioned calculations, design traffic volume at all four locations is within the range of L-type traffic. Therefore, according to the typical pavement thickness defined in the Standard of Asphalt Pavement (Japan Road Association), the pavement thickness for the Study is defined as:

Design condition :	Range of design traffic volume	= L-type traffic
	Design subgrade CBR	= 2

Pavement thickness

Surface course	: t = 5cm
Upper subbase course	: t = 20cm
Subbase course	: t = 20cm
Thickness with relative strength	: TA' = 17.0

The pavement of the existing road consists of double layers of hot asphalt mixture. This is because that the Public Works Department employed double layers in order to increase durability of pavement. Hence, pavement thickness with double layers is studied without lowering the relative strength at this thickness. As a result, thickness of pavement is obtained as follows, while satisfying the conditions:

Typical pavement thickness

Surface course	: t = 5cm
Binder course	: t = 5cm
Upper subbase course	: t = 10cm
Subbase course	: t = 15cm
Thickness with relative strength	:TA'=1.00×5+1.00×5+0.35×10+0.25×15
	= 17.25 ≧17.0

Therefore, this typical pavement thickness is used for the design of pavement in the Study.

(3) Bridge Planning

1) Matters to be Considered in Bridge Planning

- For the construction of new bridges to replace the existing Birch Grove Bridge and Balthazar Bridge, the width of bridges should be harmonized with the width of the road sections in order to prevent these bridges from becoming traffic flow bottlenecks. Also, sidewalks should be built on these bridges to secure the safety of pedestrians.
- Regarding the natural environment, since Grenada is located in a subtropical zone, the rainy season and dry season are clearly separated with high temperature and high humidity, and this kind of climate is harsh on civil engineering structures. Hence, for selection of bridge types, it is necessary to avoid bridge types with a high burden of maintenance cost, such as metal bridges, on consideration of the harsh natural environment. Also, it is necessary to select substructure types with shorter construction periods in order to enable completion of construction works within a single dry season, because substructure construction is carried out in the riverbed.
- The Birch Grove Bridge is located in a residential area. Hence, a large increment of road height will

greatly affect houses located along the approach roads and yield negative effects, such as increments in the area of land acquisition. Therefore, it is necessary to select a bridge type with almost the same structural height as the existing Birch Grove Bridge.

- During flooding on both rivers, there are many drifting objects, such as timber. Hence, in order to prevent blockage conditions on river cross-sections, the minimum clearance of new bridges should be the same as the existing bridges.
- For St. Cyr Great River Bridge, rehabilitation of the scored portion and parts of the slabs is necessary, together with the installation of traffic safety devices.

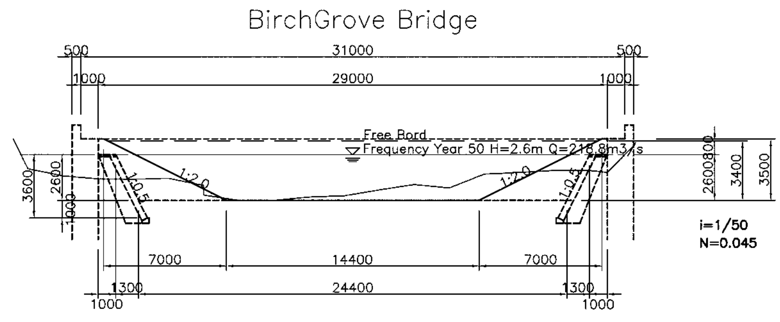
2) Design High Water Volume

Based on the probable rainfall intensity, water discharge volume at each bridge site is calculated by using the Rational Formula. Then, the velocity of highest water flow by 50-year probability is estimated and design high water volume is calculated. As a result, design water discharge volume at the highest water flow in 50-year probability is calculated as follows:

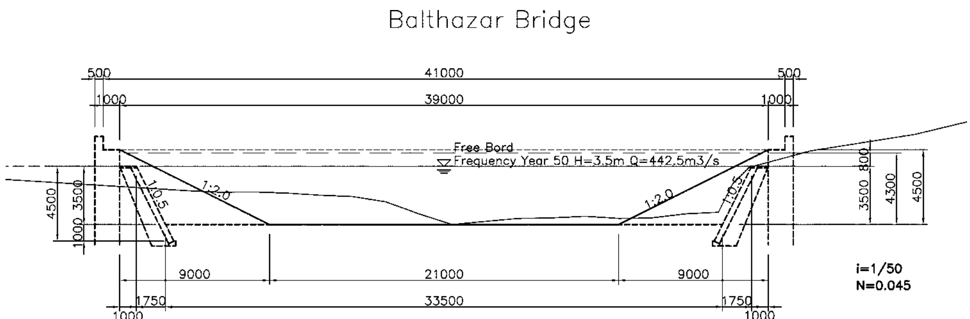
- Birch Grove Bridge : 218.8m³/s
- Balthazar Bridge : 442.5m³/s
- St. Cyr Great River Bridge : 465.5m³/s

3) Design River Cross Section

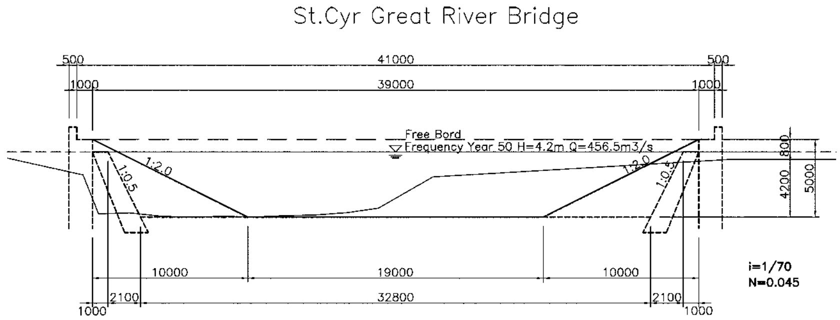
Based on the design water discharge volume at each bridge location calculated above, design river cross section at each bridge location is determined by using the Manning Formula and shown in Figure 2-12.



Birch Grove Bridge



Balthazar Bridge



St. Cyr Great River Bridge

Figure 2-12 Design River Cross Section at Each Bridge Location

4) Design High Water Level

Until now, no river improvement works have been carried out at each bridge location, and river improvement works may not be carried out in the future in consideration of the land-use around the bridges. Therefore, revetment protection works based on the design river cross sections are limited to only the 20 to 30m adjacent to the planned bridges within the approach revetment construction areas, and the natural rivers will remain at other locations in the same condition as at present. Hence, to consider the shape of flood water for relatively long distances, river cross sections on both up- and downstream sides of bridge locations are considered to be insufficient, even though river improvement works are carried out only at bridge locations according to the design river cross section. Thus, there is a possibility that the design high water level with river improvement works at the bridge location may be affected by high water levels on both up- and downstream sides, if the water level is high. The level of effects depends on the water discharge volume and the variations in river cross sections. Under the assumption that sedimentation will continue similarly on both up- and downstream sides, even after completion of river-bed improvement works, the high water level at the design river cross section is adopted from the higher design water level either at the existing river cross section or the design river cross section.

As a result, design high water level at each bridge site is determined as follows:

- Birch Grove Bridge : 2.6m above the river-bed
- Balthazar Bridge : 3.5m above the river-bed
- St. Cyr Great River Bridge : 4.2m above the river-bed

5) Selection of Location for New Bridges

For selection of location for new bridges, the following comparative analyses are carried out.

a) Birch Grove Bridge

Due to the geographical condition and location of houses along the existing road, there are very limited alternative locations in the case of Birch Grove Bridge. Based on the comparison of advantages and disadvantages, construction of a new bridge at the existing bridge site is judged to be most suitable.

Location	Same Location	Upstream Side	Downstream Side
Advantages	• Desirable horizontal and vertical alignments Land acquisition area can be minimized • Safety of pedestrians can be secured by providing sidewalks	• Construction period can be shorter, if the existing bridge is used as a detour road • Safety of pedestrians can be secured by providing sidewalks	• Most desirable horizontal and vertical alignments to secure 40km/h design speed • Safety of pedestrians can be secured by providing sidewalks
Disadvantages	• Construction of a detour road is required during construction period • Construction period is longest because construction of a detour road and demolition of existing bridge are required	• Horizontal alignment is not good • T-shaped intersection is formed and there is a problem with traffic control in the intersection • It is necessary to acquire relatively large pieces of land	• Due to geographical conditions, there is a problem of horizontal and vertical alignment to connect with the access road • It is necessary to acquire land with shops and to shift a police box • Geographically, this alignment is rather unreasonable
Evaluation Result	○	△	×

Legend - ○: Good △: Fair ×: Bad

b) Balthazar Bridge

For Balthazar Bridge, if a new bridge is constructed in parallel with the existing bridge, it would be necessary to secure at least a 15m distance between the center of the existing bridge and the new bridge from a construction point of view. Also, the present horizontal alignment near the existing bridge is almost straight, hence land acquisition is necessary either to the left or the right of the existing road in order to provide the same service level as the existing road. However, there is no control object, such as a house, near Balthazar Bridge, and every piece land is either field or open space, hence it is possible to select alignments without constraint.

Therefore, since there is no constraint such as housing and geographical conditions at Balthazar Bridge site, construction of a new bridge on the upstream side, providing for the distance from the existing bridge required for construction, has advantages for construction cost and construction works, by utilizing the existing bridge as a detour road during construction, as described in the comparison table. In addition, it is not necessary to construct an access road for the construction and to demolish the existing bridge, and it is possible to shorten the construction period to about one month, by directly starting construction of the new bridge. As a result, it is possible to minimize the risk and complete substructures within the period of the first dry season.

Based on the comparison of advantages and disadvantages, construction of a new bridge on the upstream side of the existing Balthazar Bridge is judged to be the most suitable.

Location	Same Location	Upstream Side	Downstream Side
Advantages	• Desirable horizontal alignment to secure 40km/h design speed • Safety of pedestrians can be secured by providing sidewalks	• Construction period can be reduced to 1.5 months, without demolition of the existing bridge and construction of an access road • Most desirable and better horizontal alignment to secure 40km/h design speed • Even though land acquisition area is wider, agreement from every land owner had already been obtained • Since the existing bridge can be used as a detour road, it is not necessary to detour for a long distance • Safety of pedestrians can be secured by providing sidewalks	• Construction period can be reduced to 1.5 months, without demolition of the existing bridge and construction of an access roads. • Since the existing bridge can be used as a detour road, it is not necessary to detour for a long distance • Safety of pedestrians can be secured by providing sidewalks
Disadvantages	• Construction period is the longest because improvement of detour roads and demolition of the existing bridge are required • Land acquisition area can be minimized compared with other alternatives, however agreement from some land owners have not been obtained • Highest construction cost because demolition of the existing bridge and construction of an access road for construction are required	• It is necessary to acquire a wide area of land and demolition of the existing bridge	• Undesirable horizontal alignment compared with other alternatives • It is necessary to acquire a wide area of land • Number of land owners increases • Large volume of embankment is required at the left river side • The new bridge is located at the bend in the river and problems remain • It is necessary to acquire a wide area of land and demolition of the existing bridge
Evaluation Result	△	○	×

Legend: - ○: Good △: Fair ×: Bad

6) Selection of Bridge Type

a) Selection of Superstructure Type

Prior to the selection of the superstructure type, it is necessary to determine the number and length of spans for each bridge. Based on these determinations, the most suitable superstructure types are selected by comparison.

i) Number of spans

Table 2-32 shows the results of calculations for the bridge length and the number of spans based on the design river cross section and design high water volume.

Table 2-32 Bridge Length and Number of Spans

	Birch Grove Bridge	Balthazar Bridge	Note
Width of River (m)	29.0	39.0	
Design High Water Volume (m^3/s)	218.8	442.5	
Standard Span Length (m)	21.1	22.2	
Number of Spans	1	1（2）	( ) indicates with 5m easing provision
Bridge Length (m)	31.0	41.0	Determined from the width of river
Number of Spans of Existing Bridge	3	2	Compare number of spans

Note : Standard span length (m) based on the Government Ordinance for Structural Standard of River Administration Facilities, Japan：$L=20+0.005Q$,

where Q=Design High Water Volume (m^3/s)

Based on these results, the number of spans for Birch Grove Bridge and Balthazar Bridge are selected as 1 or 2 spans, if the Japanese Design Standard is applied. However, since no particular problem has occurred with the number of spans of the existing bridges, the number of spans of existing bridges is also included for purposed of comparison. Comparing a one-span bridge with a two- or three-span bridge, it is clear that the height of the girder is much greater in the case of a one-span bridge, and this causes higher planned road height with a longer approach road length and more necessary land. Therefore, the one-span type is excluded from the comparison.

ii) Selection of superstructure type

For the selection of bridge type, the suitable bridge type is selected based on comparison in the standard application of bridge type for length of span, shown in Table 2-33, in consideration of the following conditions:

- Bridge type for easy maintenance after construction
- Most economical type of bridge
- Bridge type with easy construction to complete construction of substructure within the first dry season
- Bridge type to minimize the structure height and necessary land for acquisition

Table 2-33 Standard Application of Bridge Type for Length of Span

Type of superstructure		Recommended Span length and Bridge	Curve		Ratio of (Height /(span length)
		50m 100m 150m	Structure	Deck	
Metal Bridge	S.composite girder bridge		○	○	1/18
	S.girder bridge		○	○	1/17
	C.girder bridge		○	○	1/18
	S.box-girder bridge		○	○	1/22
	C.box-girder bridge		○	○	1/23
	S. truss bridge		×	○	1/ 9
	C. truss bridge		×	○	1/10
	Reversed langer bridge		×	○	1/6.5
	Reversed lohse bridge		×	○	1/6.5
	Arch		×	○	1/6.5
PC Bridge	Pretensioned girder		×	○	1/15
	Hollow slab girder		○	○	1/22
	S.T-section girder		×	○	1/17.5
	S.composite girder		×	○	1/15
	Connected composite girder		×	○	1/15
	C.composite girder		×	○	1/16
	S. box girder		○	○	1/20
	C.box-girder (cantilever erection method)		○	○	1/18
	C.box-girder (incremental launching method or falsework Method)		○	○	1/18
	π-shaped rigid frame bridge		×	○	1/32
RC Bridge	Hollow slab girder		○	○	1/20
	C·solid rib arch bridge		○	○	1/ 2

Other than the typical bridge types mentioned above, every type of bridge that complies with each condition is included for purpose of comparison and shown in Table 2-34. In this case, since the main girders must be produced either in Japan or in a third country and require a higher maintenance cost, including re-painting work, a metal girder bridge is less favorable than a concrete bridge from the point of view of life-cycle cost. Therefore, metal girder bridges are excluded from the comparison.

Table 2-34 Comparison of Bridge Type

	Birch Grove Bridge		Balthazar Bridge
No. of Span	Two Spans	Three Spans	Two Spans
Alternative 1	Pre-Beam Type	PC T-Girder Type	Pre-Beam Type
Alternative 2	PC T-Girder Type	PC Hollow Slab Girder Type	PC T-Girder Type
Alternative 3	PC Hollow Slab Girder Type	—	PC Hollow Slab Girder Type
Alternative 4	—	—	PC I Girder Type (Composite Girder)

b) Selection of substructure type

- Both bridges are two-span types, and substructures consist of abutments and one pier.
- For both bridges, excavation level of the footing for substructure should be according to the same concept.
- Even though the depth of the load bearing layer depends on the results of the soil investigation, the depth and condition of soil at both locations are similar. Hence, the type of substructure for both bridges should be the same.
- According to the results of boring surveys, the load bearing layers are found at shallow depths, and it is not necessary to adopt special foundation works. Hence, the most economical type of foundation, i.e., sprend foundation, is adopted for abutments and piers.
- In consideration of boulders on the river bed and steep river bed gradient, the designated level of excavation for abutments is set as footing at the load bearing layer under the river bed level.
- To penetrate to the load bearing layer and to prevent the effects of scoring, about 2.0m of overburden thickness from the bottom of the deepest part of the river-bed is planned for the foundation of piers.

In consideration of the above-mentioned conditions for the selection of substructure type, the substructure types for both bridges are selected based on the comparison in Table 2-35. As a result, since the structural height of abutments is about 7.5m to 8.5m, the reversed-Ｔ-type abutment is selected from the point of view of economy and construction work (construction period, compaction of soil at the back of abutments, etc.). At the same time, the wall type pier is selected in order to minimize the obstruction of river flow, because a pier will be built at the center of the stream, and the percentage of area obstructed by the pier.

Table 2-35 Comparion of Substructure Type

	Type	Applicable Height (m) 10 20 30	Condition for Application
Abutment	1. Gravity type		Applicable for sprend foundation with shallow load bearing layer
	2. Reversed T-type		Many applications. Applicable for sprend foundation and pile foundation
	3. Counterforted type		Applicable for higher abutments. Longer construction period with limited quantity of materials
	4. Box-type		Developed for high height abutment. Longer construction period is required.
Pier	1. Column type		Applicable for low height pier, and constructed in a difficult position in the crossing and center of the river
	2. Rigid framed		Applicable for relatively higher height of pier with side bridge length May obstruct downstream in cases of flood water
	3. Pile bent		Most economical type, but unsuitable for bridge type with large horizontal force May obstruct downstream in case of flood water
	4. Elliptical (Wall type)		Applicable for high height pier and bridges with large external force

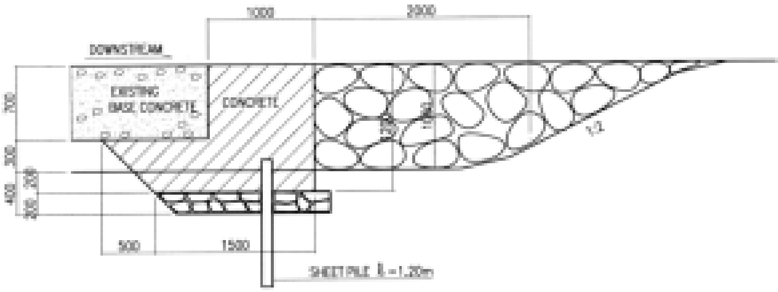
c) Selection of Bridge Type

Based on the bridge types in the comparison shown in Table 2-34, the suitable bridge types are studied. As a result, a two-span PC T-girder type bridge is selected as the most suitable bridge type for both Birch Grove Bridge and Balthazar Bridge, from the view points of structural characteristics, necessary construction work, construction period, and construction cost.

Comparisons of various factors for Birch Grove Bridge and Balthazar Bridge are shown in Table 2-36 and Table 2-37.

7) Rehabilitation of St.Cyr Great River Bridge

In order to prevent further scoring at the lower end of the concrete river-bed and further downstream, scoring prevention works are planned. The lower end of the concrete river-bed will be filled by concrete while scored parts of the further downstream will be filled by boulders available at the site, as shown in the drawing below.



For the three-span RC slabs on the Grenville side, where the lower part of the slabs has been exfoliated and the iron bars exposed, rehabilitation works are planned, including demolition of the exfoliated concrete, anticorrosive treatment of the exposed iron bars, pouring of mortar into the cracks on the slabs, and covering the entire section with concrete. In addition, in order to improve visual guidance on the bridge, particularly at nighttime, delineators will be installed on the curbs.

8) Revetment Protection

In parallel with the construction of new bridges to replace Birch Grove Bridge and Balthazar Bridge, construction of revetment protections is planned in order to protect abutments and to secure normal water flow during flooding near the bridge. The area of revetment protection is about 10m on both up- and downstream sides, and the abutment and revetment protection is planned to be fixed.

For the revetment protection, the stone masonry type, which is already adopted in Grenada and for which it is easy to obtain materials, is adopted for the Study. Even though the existing river beds are almost stable at the bridge sites, a penetration depth of about 1.0m is secured for the revetment protection, in order to cope with incidents such as partial scoring.

Table 2-36 Comparison of Bridge Type for Birch Grove Bridge

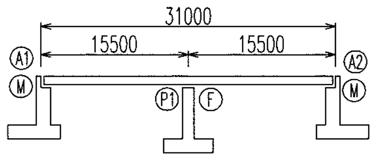
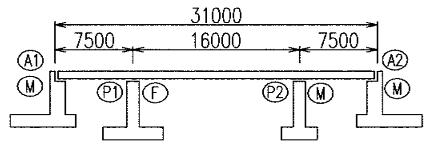
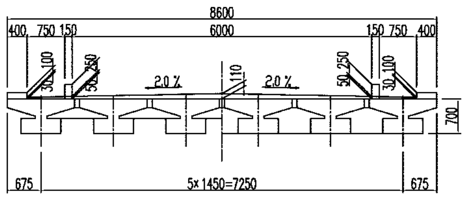
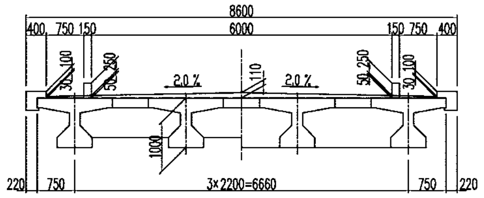
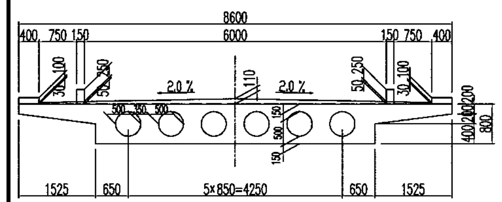
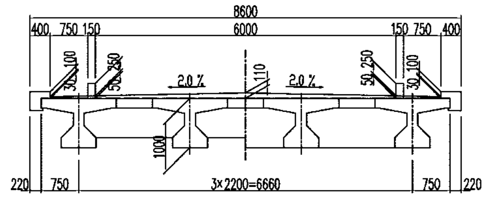
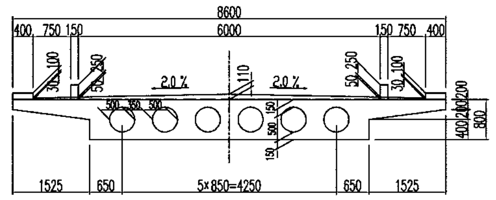
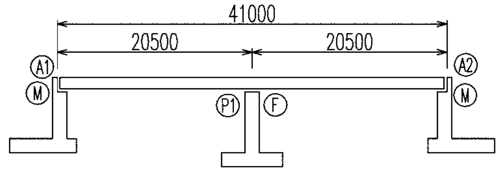
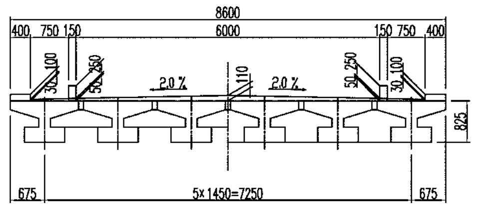
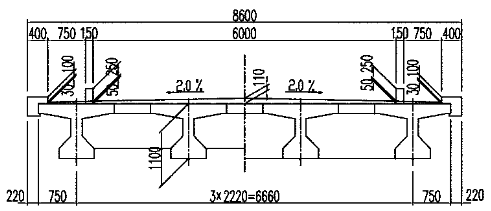
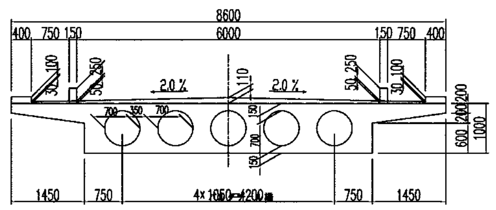
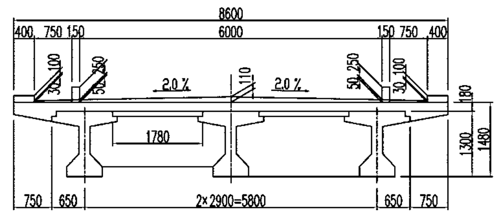
Item	Alternative 2-1 Pre-beam Type	Alternative 2-2 PC T-Girder Type	Alternative 2-3 PC Hollow Slab Type	Alternative 3-1 PC T-Girder Type	Alternative 3-2 PC Hollow Slab Type
Propotion of Spans	**Alternatives for Two Spans**  **Span Length : 15.5m+15.5m**			**Alternatives for Three Spans**  **Span Length : 7.5m+16.0m+7.5m**	
Cross Section					
Materials – Superstructure	Concrete 115m^3, Steel 48.0t	Concrete 109m^3,Iron bars 10.2t, Steel 2.1t	Concrete 134m^3, Iron bar 11.7t, Steel 3.2t	Concrete 114m^3, Iron bar 10.2t, Steel 2.1t	Concrete 135m^3, Iron bar 11.7t, Steel 3.2t
Materials – Substructure	Concrete 291.8m^3,Iron bar 34.7t	Concrete 271.9m^3, Iron bar 32.4t	Concrete 289.4m^3, Iron bar 34.4t	Concrete 286.0m^3, Iron bar 33.9t	Concrete 282.6m^3, Iron bar 33.4t
Construction Cost	×	○	○	△	△
Characteristics of Structure and Construction Works	·Height of structure h=0.750m ·Hindranced ratio for river by pier 5% ·Composit structure of metal girder and concrete girder ·Girder height is most low and connection with approach road i ·Metal girders are produced either in Japan or in the third count and composit struction is constructed at site ·Girder construction yard and transportation from the yarf is necessary ·Procurement of metal girders either from Japan or third country necessary and it takes long time ·After erection, cross girders and slabs are produced at site	·Height of structure h=1.05m ·Hindranced ratio for river by pier 5% ·T-shaped cross section with unification of main girder and slab ·After erection, girders are connected each other ·Height of struction is almost same as the existing bridge, hence there is no problem to connect with approach road ·If construction yard is available, production of girder can be performed during construction of substructures ·Construction period at site is shorter than the PC hollow slab type	·Height of structure h=0.85m ·Hindranced ratio for river by pier 5% ·To reduce the weight of structure by placing cylindrical frames in a slab ·Slab-girder type bridge with totally unification of main girder a slab with low height, hence, there is no problem to connect wi approach road ·For production and erection of superstructure, no heavy machinery (carne) is required ·Construction yard of girder is not necessary ·Higher risk for construction of girder during rainy season	·Height of structure h=1.05m ·Hindranced ratio for river by pier 10% ·T-shaped cross section with unification of main girder and slab ·After erection, girders are connected each other ·Height of struction is almost same as the existing bridge, hence there is no problem to connect with approach road ·If construction yard is available, production of girder can be performed during construction of substructures ·Construction period at site is shorter than the hollow slab type (next to Alternative 2)	·Height of structure h=0.85m ·Hindranced ratio for river by pier 10% ·To reduce the weight of structure by placing cylindrical frames in a slab ·Slab-girder type bridge with totally unification of main girder and slab with low height, hence, there is no problem to connect with approach road ·For production and erection of superstructure, no heavy machinery (carne) is required ·Construction yard of girder is not necessary ·Higher risk for construction of girder during rainy season
Erection Method and Construction Period	·Truck crane erection with bent supprot ·Construction period : 14 months	·Truck crane erection with bent supprot ·Construction period : 14 months	·Fixed support erection ·Construction period : 16.5 months	·Truck crane erection with bent supprot ·Construction period : 14.5 months	·Fixed support erection ·Construction period : 16.5 months
Materials, etc.	·Since metal girders are procured from Japan or third country, number of workers and procurement of materials in Grenada are limited	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.
Technology Transfer	·Since girders are produced either in Japan or third country, and erection of girder is difficult, technology transfer can not be expected	·It is possible to transfer technology of production and erection of PC girder	·It is possible to transfer technology of production and erection of PC girder	·It is possible to transfer technology of production and erection of PC girder	·It is possible to transfer technology of production and erection of PC girder
Maintenance	·Since metal girders are covered by concrete, painting is not necessary ·Routine maitenance as same as concrete bridge is required	·Routine maitenance is required	·Routine maitenance is required	·Routine maitenance is required	·Routine maitenance is required
Evaluation Result		◎			

Table 2-37 Comparison of Bridge Type for Balthazar Bridge

Item		Alternative 2-1 Pre-beam Type	Alternative 2-2 PC T-Girder Type	Alternative 2-3 PC Hollow Slab Type	Alternative 2-3 PC Composit Girder Type
Propotion of Spans		**Alternatives for Two Spans** 			
Cross Section					
Materials	Superstructure	Concrete 147.9m^3, Meta 67.0t	Concrete 145.9m^3, Iron bar 13.9t, Metal 2.9t	Concrete 205.1m^3, Iron bar 17.1t, Metal 4.8t	Concrete 191.6m^3, Iron bar 10.2t, Metal 2.1t
	Substructure	Concrete 427.7m^3, Iron bar 51.3t	Concrete 452.9m^3, Iron bar 54.3t	Concrete 489.2m^3, Iron bar 58.7t	Concrete 493.4m^3, Iron bar 59.2t
Construction Cost		×	○	○	△
Characteristics of Structure and Construction Works		·Structure height h=0.875m ·Composit structure of metal girder and concrete girder ·Girder height is most low and connection with approach road is easy ·Metal girders are produced either in Japan or in the third country, and composit struction is constructed at site ·Girder construction yard and transportation from the yarf is necessary ·Procurement of metal girders either from Japan or third country is necessary and it takes long time ·After erection, cross girders and slabs are produced at site	·Structure height h=1.15m ·T-shaped cross section with unification of main girder and slab ·After erection, girders are connected each other ·Ever height of struction is 1.15m, it is possible to adopt tranformed cros section, hence there is no problem to connect with approach road ·If construction yard is available, production of girder can be performed during construction of substructures ·Construction period at site is shorter than other types	·Structure height h=0.85m ·To reduce the weight of structure by placing cylindrical frames in a slab ·Slab-girder type bridge with totally unification of main girder and slab with lower height than alternative 2, hence, there is no problem to connect with approach road ·For production and erection of superstructure, no heavy machinery (carne) is required ·Construction yard of girder is not necessary ·Higher risk for construction of girder during rainy season ·Construction perio is longer than other types	·Structure height h=1.53m ·Composit type with I-shaped beam with site casted slab ·Since the structure height is higher than other types, problem of land acquisition to secure lands for longer approach road length ·Slabs are casted at the site and construction period is same as for the hollow slab type ·Heavey machinery (crane) is required for erection of girder because weight of girder is most heavy compared with other alternatives
Erection Method and Construction Period		·Truck crane erection with bent supprot ·Construction period : 14 months	·Truck crane erection with bent supprot ·Construction period : 14.5 months	·Fixed support erection ·Construction period : 16.5 months	·Truck crane erection with bent supprot ·Construction period : 15.5 months
Materials, etc.		·Since metal girders are procured from Japan or third country, number of workers and procurement of materials in Grenada are limited	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.	·Since most of construction works for both substructure and structure are performed at site, employment of many workers and procurement of local materials are expected.
Maintenance		·Since metal girders are covered by concrete, painting is not necessary ·Routine maitenance as same as concrete bridge is required	·Routine maitenance is required	·Routine maitenance is required	·Routine maitenance is required
Technology Transfer		·Since girders are produced either in Japan or third country, and erection of girder is difficult, technology transfer can not be expected	·It is possible to transfer technology of production and erection of PC girder	·It is possible to transfer technology of production and erection of PC girder	·It is possible to transfer technology of production and erection of PC girder
Evaluation Result			◎		

2-2-3 Basic Design Drawing

2-2-3-1 Improvement of Grand Etang Road

(1) Road Improvement Plan

Outlines and rough estimation of quantities of road improvement on Grand Etang Road are summarized in Tables 2-38 to 2-40, respectively, while drawings for the basic design are shown in Figures 2-13 to 2-16.

Table 2-38 Outlines of Road Improvement (1)

Item	Details	Contents	Note
a) Hair-pin curve section			
Area	Location	km 10+840 - 11+220	
	Road length	L=380m	
Alignment	Horizontal	Curve radius R=10m-100m	
	Vertical	Same gradient as the existing road	
Width	Total width	6.50m=0.50m (valley side shoulder)＋6.00m (carriageway)	
	Cross-grade	Average section I=2.0%, Maximum superelevation I=6.0%	
Pavement	Carriageway	Asphalt pavement (t=35cm)	
	Sidewalk	None	
Retaining wall	Crib type	Length L=153m, Height H=10.2 - 3.9m	
	Stone masonry	Length L= 15m, Height H=2.5 - 1.3m	
Drainage		U-shaped side ditch L=375m	Installed at hill side
Guard Fence		Guardrail L=297m	Installed at valley side
b) Approach roads of Vendome Bridge			
Area	Location	km 5+847 - 5+960	
	Road length	L=104.6m	
Alignment	Horizontal	Curve radius R=50m	
	Vertical	I=8.0%	
Width	Total width	8.00m=1.00m (shoulder)＋6.00m (carriageway)＋1.00m (shoulder)	
	Cross-grade	Average section I=2.0%, Maximum superelevation I=6.0%	
Pavement	Carriageway	Asphalt pavement (t=35cm)	
	Sidewalk	None	
Retaining wall	Stone masonry	Length L=14m, Height H=5.0 - 2.1m	
Drainage		Unsupported ditch L=92m	
Guard Fence		Concrete railing L=16.8m	Installed on the box culvert
		Guardrail L=23m	

Table 2-39 Outlines of Road Improvement (2)

Item	Details	Contents	Note
c) Approach roads of Birch Grove Bridge			
Area	Location	km 12+883.5 - 13+001.0	
	Road length	L=86.5m	
Alignment	Horizontal	Curve radius R=40m	
	Vertical	I=7.8～3.2%	
Width	Total width	7.50m=0.75 m (sidewalk) ＋ 6.00m(carriageway) +0.75 m (sidewalk)	
	Cross-grade	Average section I=2.0%, Maximum superelevation I=6.0%	
Pavement	Carriageway	Asphalt pavement (t=35cm)	
	Sidewalk	Asphalt pavement (t=15cm)	
Retaining wall	Gravity type	Length L=148.8m, Height H=0.2 – 1.4m	
Drainage			
Guard Fence			
Detour Road	Road	L=50m (including a temporary bridge)	Upper stream side
	Temporary bridge	Bridge length L=32m	
d) Approach roads to Barthazar Bridge			
Area	Location	km 15+910～16+145	
	Road length	L=194m	
Alignment	Horizontal	Curve radius R=150m - 180m	
	Vertical	I=4.4 - 1.78%	
Width	Total width	7.50m=0.75m(shoulder) ＋ 6.0m(carriageway) ＋ 0.75 m (shoulder)	
	Cross-grade	Average section I=2.0%, Maximum superelevation I=6.0%	
Pavement	Carriageway	Asphalt pavement (t=35cm)	
	Sidewalk	None	
Retaining wall	Crib type	None	
		None	
Drainage		L-shaped side ditch L=388m	
		Unsupported ditch L=113m	
Guard Fence		Guardrail L=139m	
Detour Road	Existing bridge	Bridge length L=33.2m	

Table 2-40 Rough Quantity Estimation for the Road Improvement

Item	Unit	Hair-pin Curve Section	Approach roads of Vendome Bridge	Approach roads of Birch Grove Bridge	Approach roads of Barthazar Bridge
Civil works					
Embankment	m^3	634	205	136	792
Cutting	-do-	2,853	191		283
Pavement works					
Subbase t=15cm	m^3	160	83	52	195
Upper subbase t=10cm	-do-	104	53	39	96
Binder course t=5cm	m^2	1,015	513	467	955
Surface course t=5cm	-do-	1,015	513	467	955
Guard fence					
Guardrail	m	297	23		139
Concrete railing	-do-		17		
Retaining wall					
Crib type	m^2	1,219			
Stone masonry	-do-	38	67		
Gravity type	m			149	
Drainage					
U-shaped side ditch	m	375			
L-shaped side ditch	-do-				388
Unsupported ditch	-do-		92		113
Detour road	m			50	33 (Existing bridge)

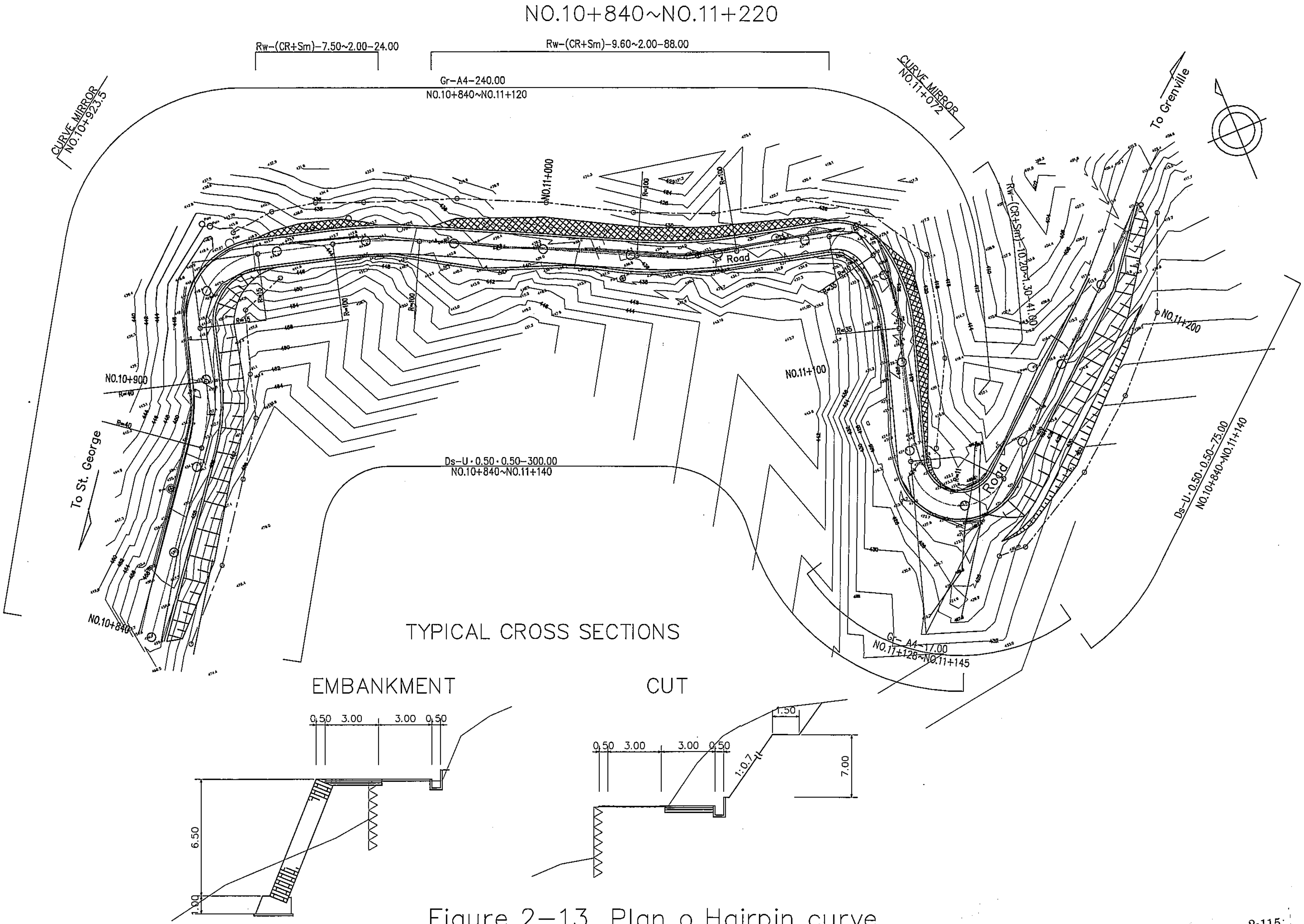
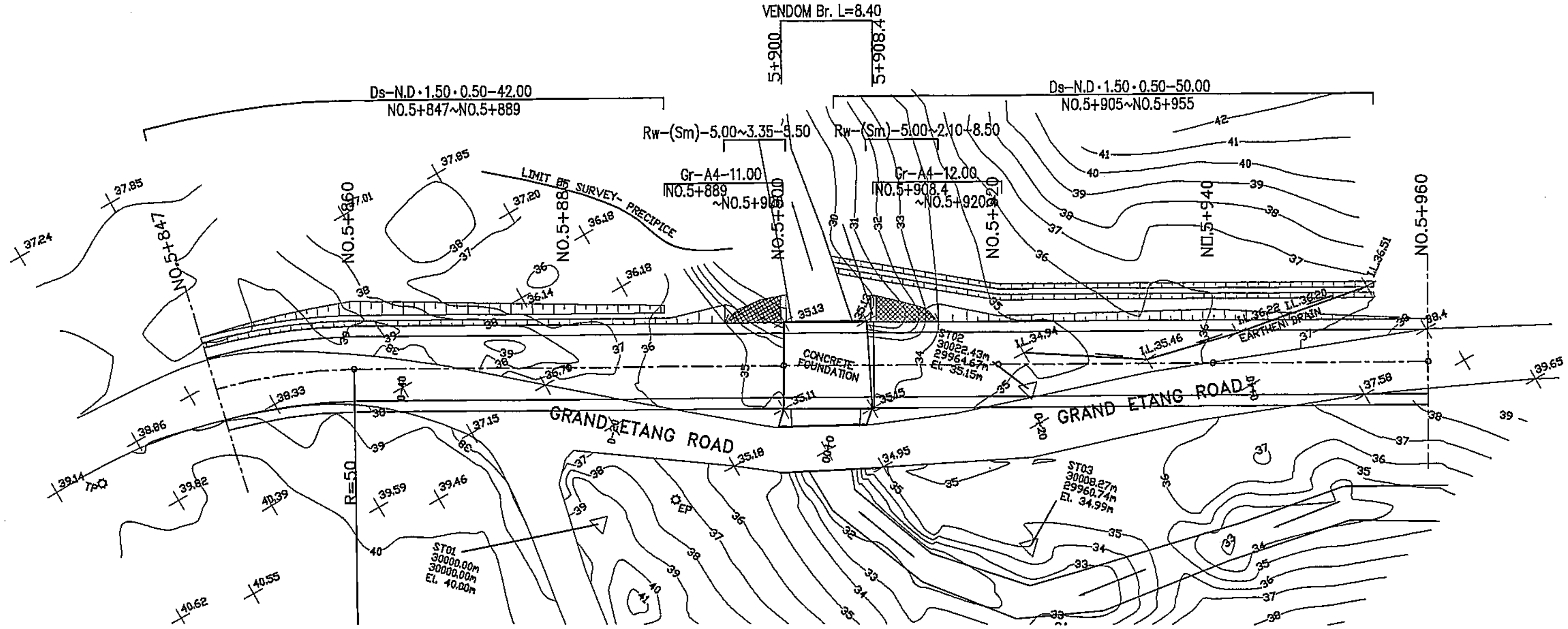
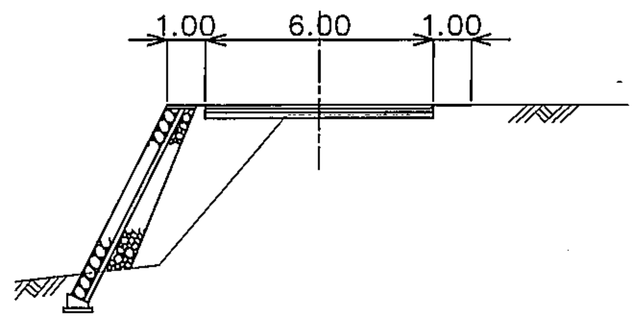


Figure 2–13 Plan o Hairpin curve

NO.5+847~NO.5+960



TYPICAL CROSS SECTION



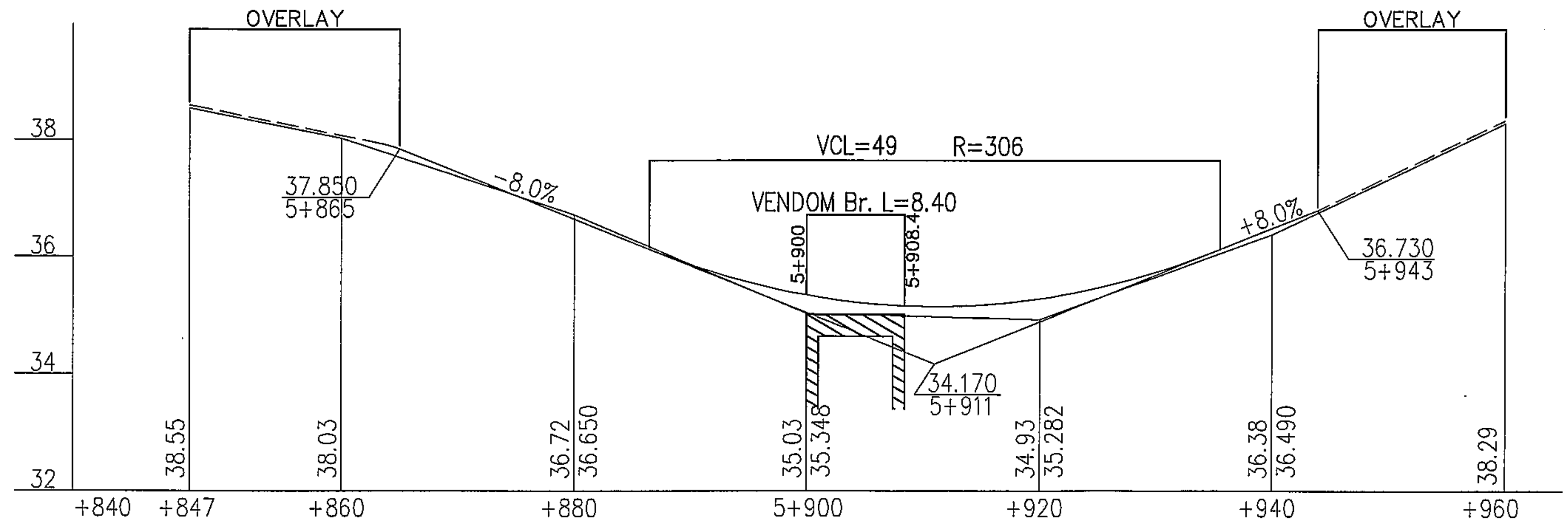


Figure 2–14 Plan of Approach Road of Vemdom Bridge

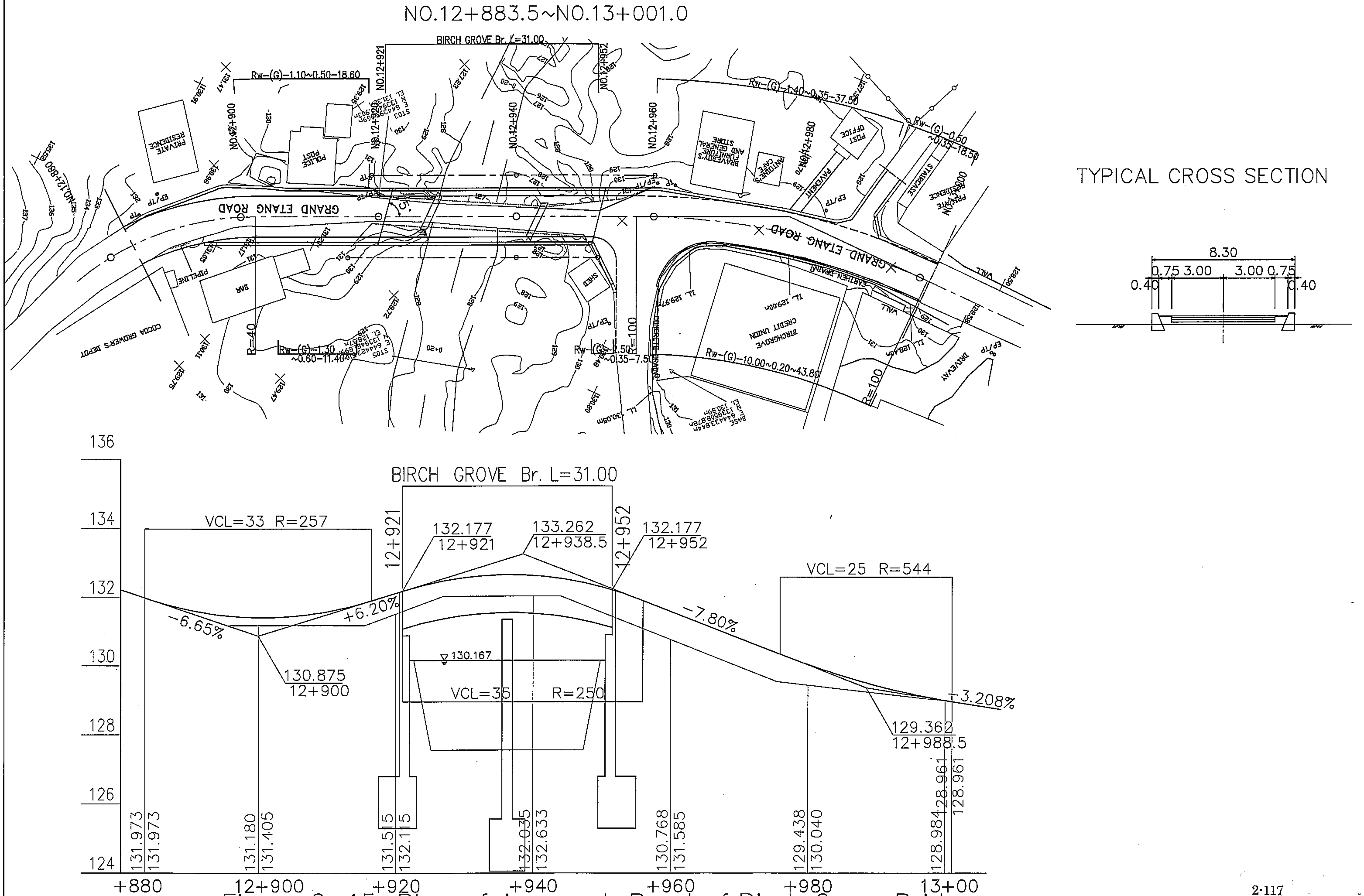


Figure 2–15 Plan of Approach Road of Birch Grove Bridge

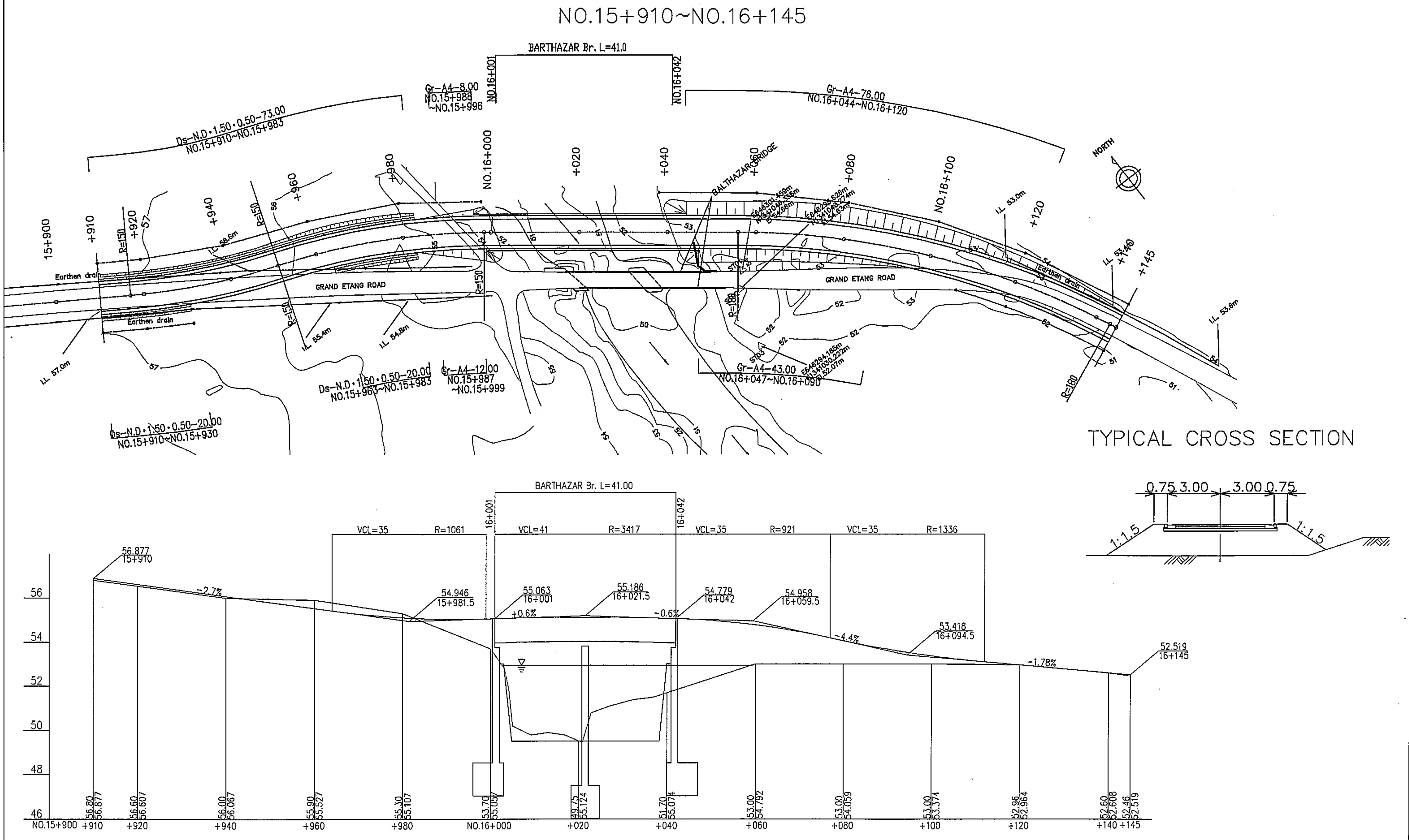


Figure 2–16 Plan of Approach Road of Balthazar Bridge

(2) Improvement of Bridges

Outlines and rough estimation of quantities of construction of new bridges and rehabilitation of bridge on Grand Etang Road are summarized in Tables 2-41 to 2-43, respectively, while drawings for the basic design are shown in Figures 2-17 and 2-19.

Table 2-41 Outlines of Improvement of Bridges

Item	Details	Contents	Note
a) Birch Grove Bridge			
Location		Same location as the existing bridge	
Area	Length	km No.12+921 - No.12+ 952	
Alignment	Horizontal	R=40m – Straight – R=100m	
	Vertical	Vertical curve length VCL=35m, Radius=250m	
Bridge	Superstructure Type	Two Spans PC Continuous T-Shaped Girder Bridge	
	Substructure Type	Two reversed T-type abutment, One wall type pier	
	Bridge Length	L= 31.000m	
	Span Length	15.05m+1.00m+15.05m	
	Width	8.30m=(carriageway)3.0×2＋(sidewalk)0.75×2+ (curb)0.4×2	
	Skew Angle	Right 80°	
	Cross-grade	I= 2.00%	
	Pavement	Asphalt pavement (Carriageway t=5.0cm, Sidewalk t=3.0cm)	
	Area of Bridge	257.3m²	
	Railing	Concrete railing + steel railing	
	Erection Method	Truck crane erection with bent support	
Revetment Protection	Stone Masonry	Length L=73.6m, Height H= 2.600m	
River-bed Protection		Stone masonry concrete	
b) Barthazar Bridge			
Location		Upper stream side of the existing bridge	
Area	Length	km No.16+001 - No.16+ 042	
Alignment	Horizontal	R=180m – Straight – R=150m	
	Vertical	Vertical curve length VCL= 41m, Radius R=3,417m	
Bridge	Superstructure Type	Two Spans PC Continuous T-Shaped Girder Bridge	
	Substructure Type	Two reversed T-type abutment, One wall type pier	
	Bridge Length	L=41.000m	
	Span Length	19.70m+1.00m+19.70m	
	Width	8.30m=(Carriageway)3.0×2 ＋ (Sidewalk)0.75×2+ (Curb)0.4×2	
	Skew Angle	Left 75°	
	Cross-grade	I=2.00 %	
	Pavement on carriageway	Asphalt pavement (t= 5.0cm)	
	Pavement on sidewalk	Asphalt pavement (t= 3.0cm)	
	Area of Bridge	340.3m²	
	Railing	Steel railing	
	Erection Method	Truck crane erection with bent support	
Revetment Protection	Stone Masonry	Length L= 76.6m, Height H= 3.500m	
River-bed Protection		Stone masonry concrete	

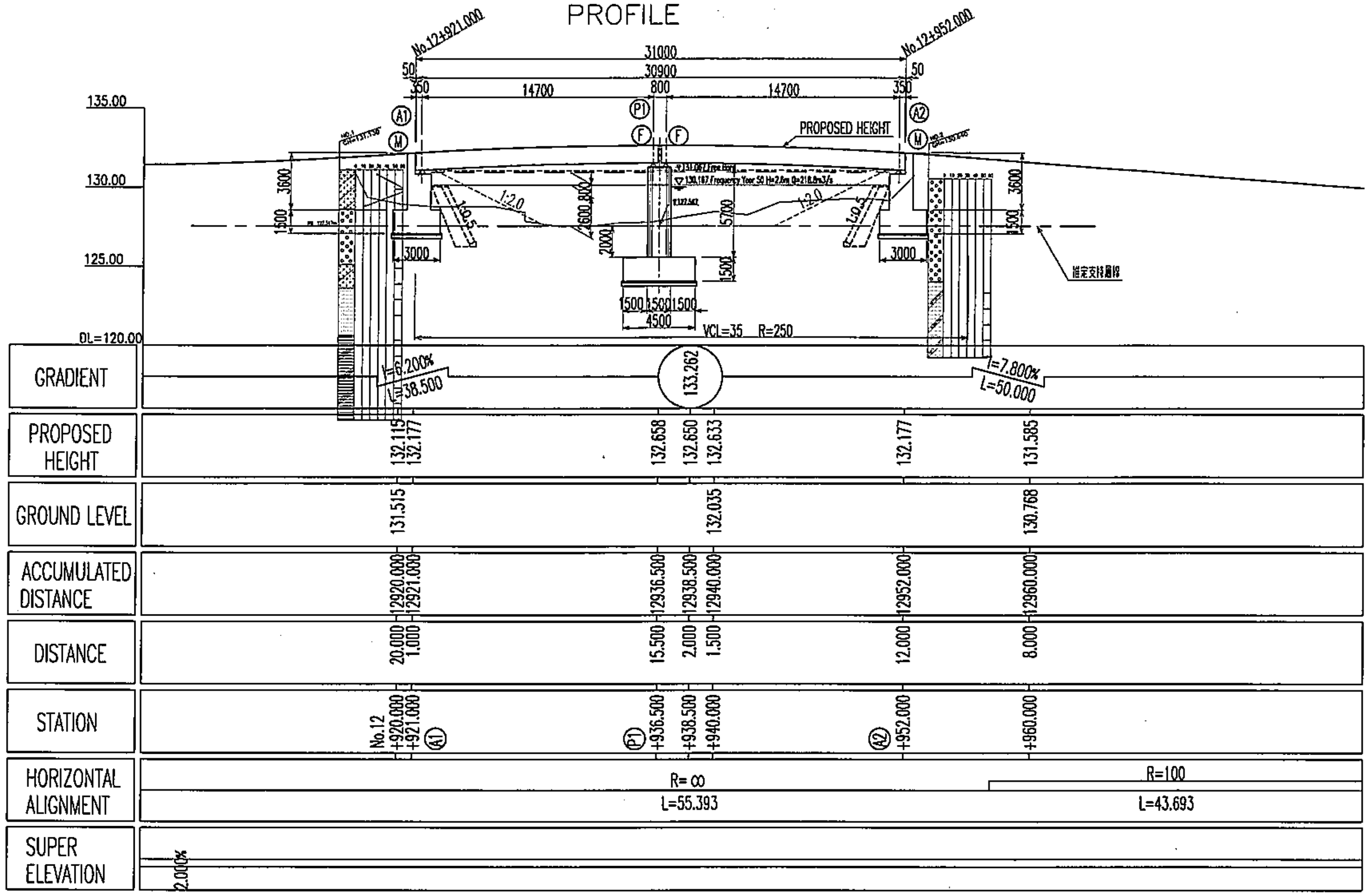
Table 2-42 Rough Quantity Estimation for Improvement of Bridges

Item	Contents	Unit	Birch Grove Bridge	Barthazar Bridge
Bridge				
Superstructure	Concrete (40N/mm^2)	m^3	92.7	120.3
	- ditto – (30N/mm^2)	〃	27.8	32.1
	- ditto – (24 N /mm^2)	〃	25.0	33.2
	Form	m^2	616.4	797.2
	Prestressing steel	ton	3.5	6.5
	Iron bar (equivalent to SD295)	〃	11.4	14.4
	Pavement on bridge surface (Asphalt)	m^2	231	306
	Extension of railing	m	62	82
Substructure	Concrete (24N/mm^2)	m^3	288	332
	Form (including round shaped form)	m^2	372	403
	Iron bar (equivalent to SD295)	ton	29	33
	Excavation for structures	m^3	968.0	1132.0
Revetment Protection	Stone masonry	m^2	214	299

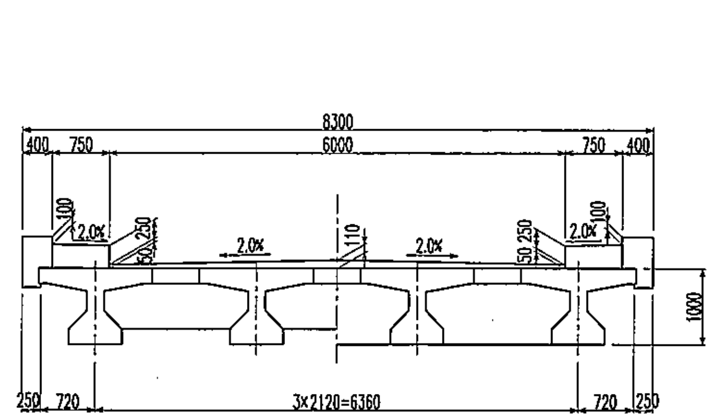
Table 2-43 Rough Quantity Estimation for Rehabilitation of Bridge

Item	Contents	Unit	St. Cyr Great River Bridge
Rehabilitation	Concrete for superstructrure (24N/mm^2)	m^3	6.2
River-bed Protection	Concrete (18 N/mm^2)	m^3	63.0
	Scouring prevention: Boulders +Concrete	m^3	96.0
Safety device	Delineator	unit	22

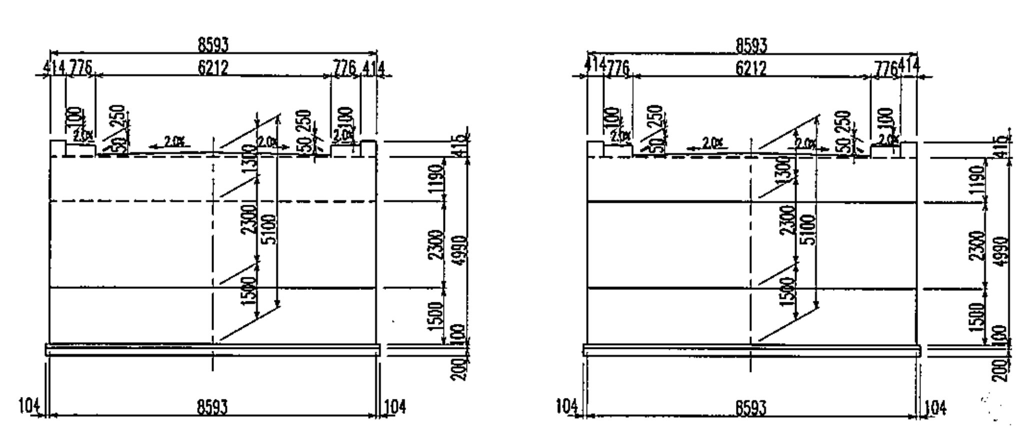
PROFILE



CROSS SETION OF PC-T GIRDER



ABUTMENT



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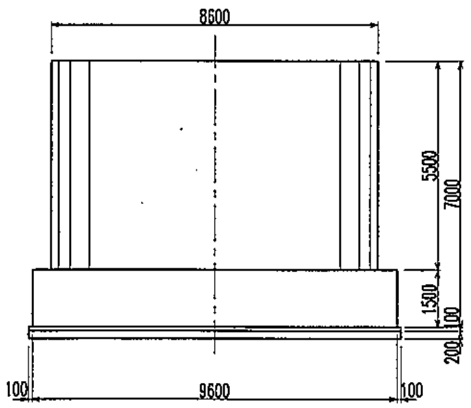


PLAN

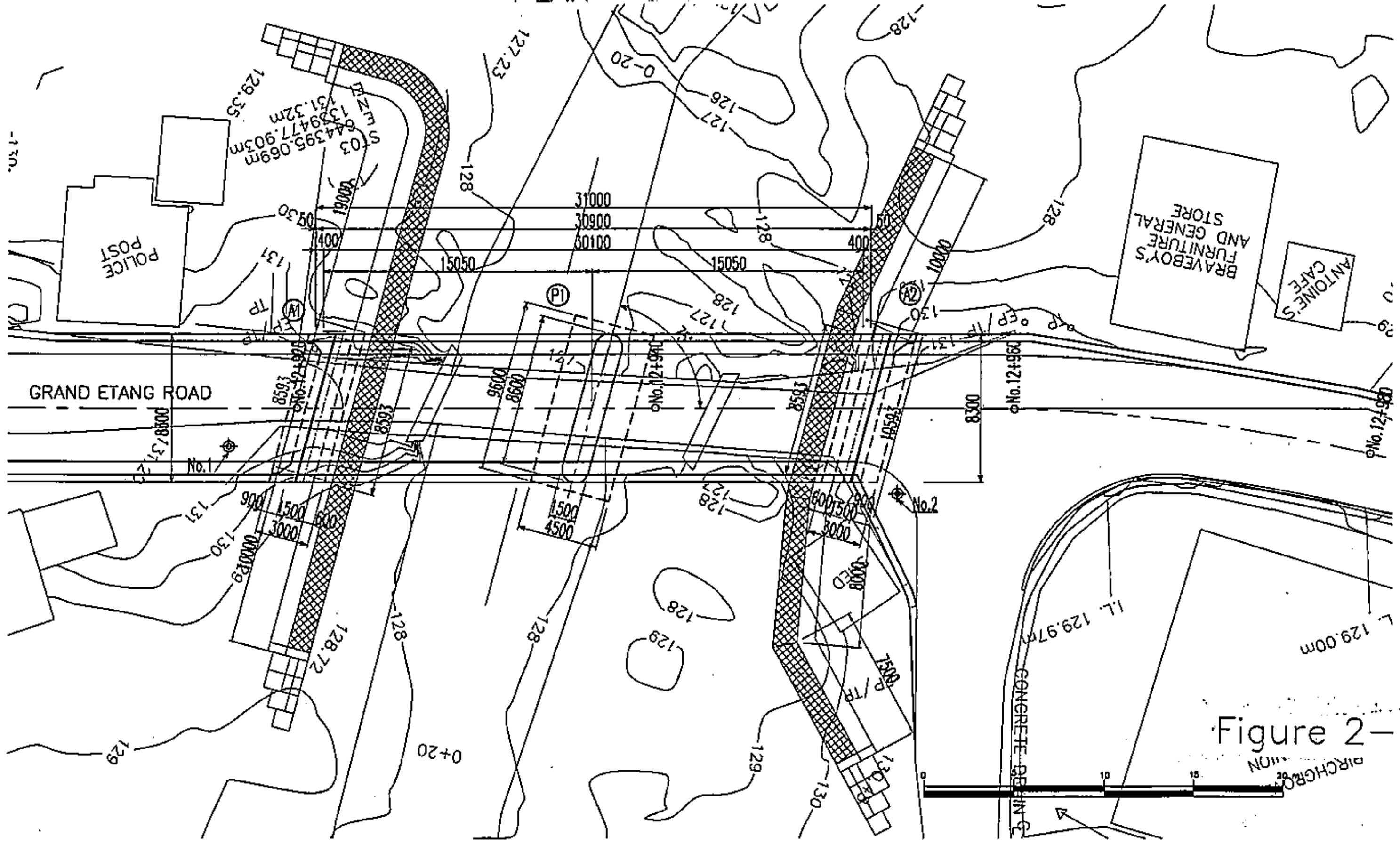
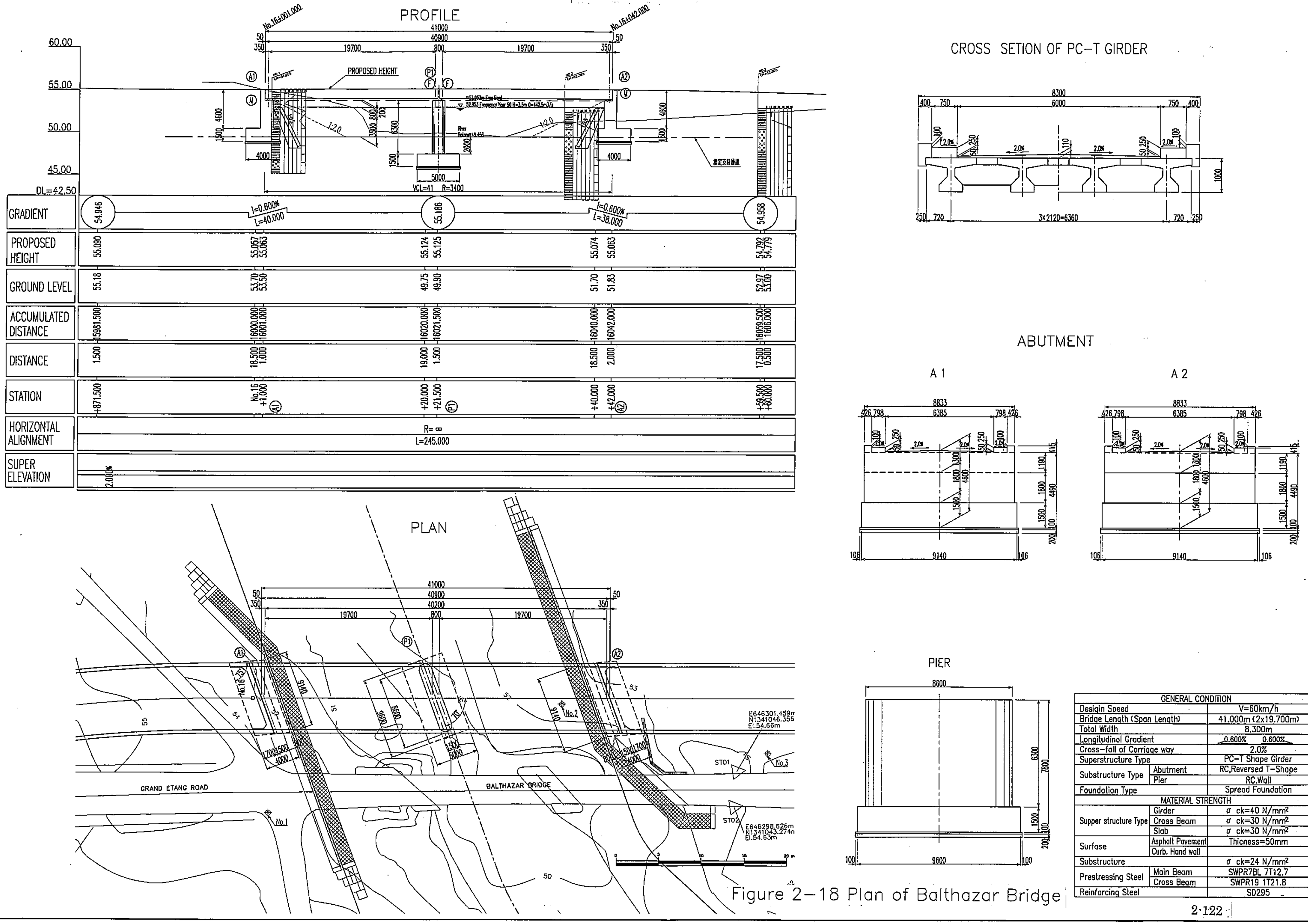


Figure 2–17 Plan of Birch Grove Bridge

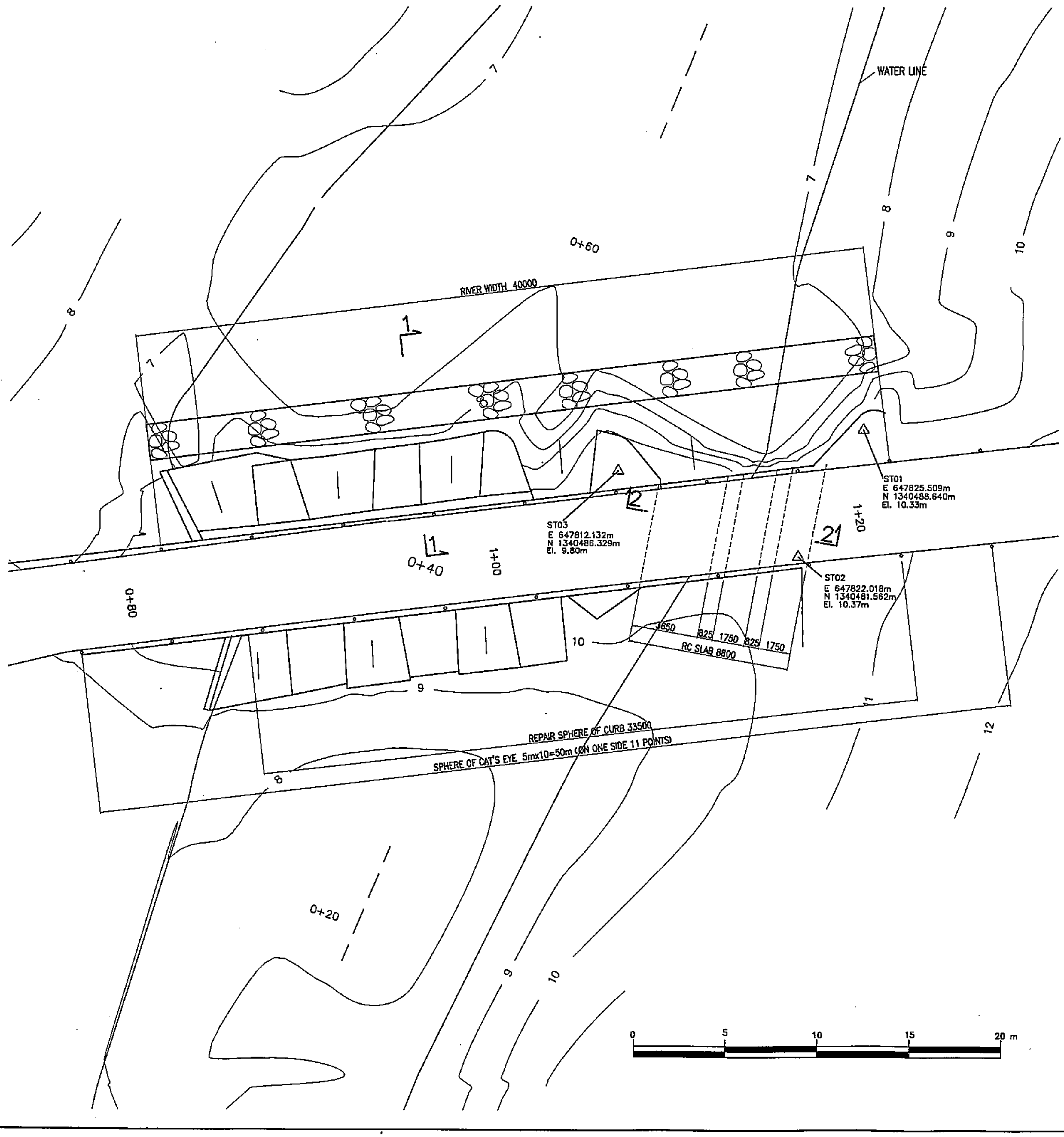
GENERAL CONDITION		
Desigin Speed		V=60km/h
Bridge Length (Span Length)		31.000m (2x14.700m)
Total Width		8.300m
Longitudinal Gradient		6.200% 7.800%
Cross-fall of Carriage way		2.0%
Superstructure Type		PC-T Shape Girder
Substructure Type	Abutment	RC,Reversed T-Shape
	Pier	RC.Wall
Foundation Type		Spread Foundation
MATERIAL STRENGTH		
Supper structure Type	Girder	σ ck=40 N/mm²
	Cross Beam	σ ck=30 N/mm²
	Slab	σ ck=30 N/mm²
Surfose	Asphalt Pavement	Thicness=50mm
	Curb. Hand wall	
Substructure		σ ck=24 N/mm²
Prestressing Steel	Main Beam	SWPR7BL 7T12.7
	Cross Beam	SWPR19 1T21.8
Reinforcing Steel		SD295



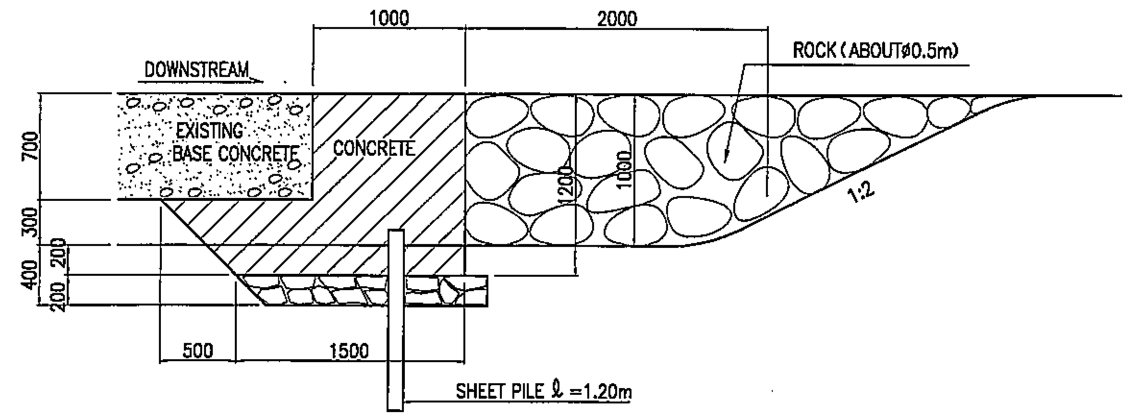
GENERAL CONDITION		
Desigin Speed		V=60km/h
Bridge Length (Span Length)		41.000m (2x19.700m)
Total Width		8.300m
Longitudinal Gradient		0.600% 0.600%
Cross-fall of Carriage way		2.0%
Superstructure Type		PC-T Shape Girder
Substructure Type	Abutment	RC,Reversed T-Shape
	Pier	RC.Wall
Foundation Type		Spread Foundation
MATERIAL STRENGTH		
Supper structure Type	Girder	σ ck=40 N/mm²
	Cross Beam	σ ck=30 N/mm²
	Slab	σ ck=30 N/mm²
Surfase	Asphalt Pavement	Thicness=50mm
	Curb. Hand wall	
Substructure		σ ck=24 N/mm²
Prestressing Steel	Main Beam	SWPR7BL 7T12.7
	Cross Beam	SWPR19 1T21.8
Reinforcing Steel		SD295

Figure 2-18 Plan of Balthazar Bridge

PLAN



1—1 SECTION



2—2 SECTION

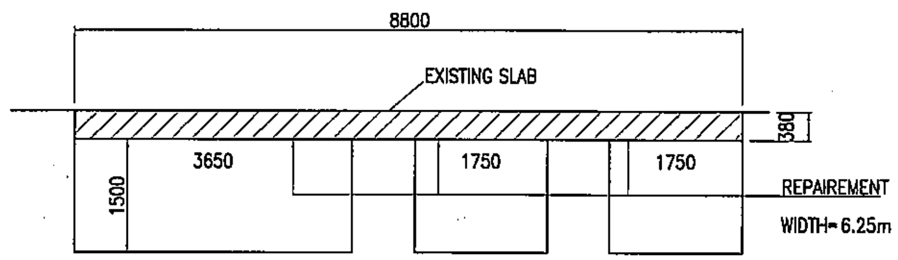


Figure 2—19 Plan of St. Cyr Greatriver Bridge