CHAPTER 5

APPLICABLE ROUTE AND BRIDGE TYPE

5. APPLICABLE ROUTE AND BRIDGE TYPE

5.1 Review of Existing Feasibility Studies

5.1.1 Overview of the Existing Feasibility Studies

Four different feasibility studies as shown below were carried out in the period running from 1989 to 2004. These feasibility studies are identified and summarised herein.

Table 5.1.1 Comparison of Basic Features in Existing Feasibility Studies

	1989 F/S	2000 F/S	2003 F/S	2004 F/S
Implementation Country	Soviet-Union	Japan	Japan	Ukraine
Counterpart	No information	Mikolaiv City	Mikolaiv City	Mykolaiv Region
Survey Company	Kievsoyuizdorproject	Japan Consulting Institute	Pacific Consultants International	Kievsoyuizdorproject
Reason for Survey		This project was identified as a key national project by the Ukrainian government.	Design Condition for Bridge was changed (aviation and navigation clearance)	The two F/S's executed by Japan reported that the Government of Japan had expressed interest in providing a loan for this project.
Outline of Survey Result	[Road Alignment Selection] 4 routes (different crossing points on Southern Bug river) were proposed and compared. The Bridge position selected by this F/S is the same as that for the current design stage.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 types. A cable-stayed bridge was recommended.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A suspension bridge was recommended.	[Road Alignment Selection] Comparison of Road alignment on the left-bank was implemented. It recommended "Route 1", which is located far from the city boundary line, as the best route. [Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A steel box-girder bridge was recommended.
Design Standard	SNiP[1]	SNiP	SNiP	DBN[2](and SNiP)

Source: JICA Survey Team

[1] Standards for design and construction of Russia
[2] Standards for design and construction of Ukraine. It was established instead of SNiP after independence from USSR

Existing feasibility studies are as follows.

(1) Feasibility Study in 1989 developed by “Kievsoyuizdorproject”

This was implemented during the Soviet-Union era.

Four (4) options for potential bridge locations were considered: three options northwest of the city and one south of the city. This choice was documented in the “Report on Selecting a Location for the Bridge Construction across the Southern Bug River near Mykolaiv”.

The study was approved by the Head of Mykolaiv Regional Executive Committee on July 12, 1989.

It was also approved by Decree No.100-r of the Ukraine Cabinet of Ministers, dated 22 Feb.1992.

(2) Feasibility Study in 2000 generated by “Japan Consulting Institute (JCI)”

This was the first of the feasibility studies conducted in an independent Ukraine.

Development of the transport sector is essential in promoting economic reformation: all donor agencies and Ukraine as well understand that provision of aid to this sector is most important.

In 1999, the city government requested the Japan Consulting Institute to conduct a feasibility study for realization of the project.

Review of previous feasibility study and comparison of alternative bridge types over Southern Bug River were implemented.

Three options (Steel deck box girder type, cable stayed type & suspension type) were compared, with a “Cable stayed bridge” proposed after the comparison. The estimated project cost was deemed to be reasonable. A geological survey was executed on both banks of the river.

(3) Feasibility Study in 2003 generated by “Pacific Consultants International (PCI)”

The document prepared by PCI in 2003 titled "Preparation Survey on the Project of Construction of Mykolaiv Bridge in Ukraine" should be the basis for this current 2011 survey.

The Feasibility study was conducted because of changes in design conditions: aviation and navigation clearances were changed.

The navigation issue is described in article 5.1.2 and navigation dimensions and aviation limitations for each Feasibility is indicated in Table 5.1.4.

Three options (Steel truss type, cable stayed type, and suspension type) were compared, with a “Suspension bridge” recommended after the comparison.

(4) Feasibility Study in 2004 generated by “Kievsoyuzdorproect”

Mykolaiv regional state administration was the main counterpart during this study.

Three options (Steel deck box girder bridge, cable stayed bridge, and suspension bridge) were compared, with a “Steel deck box girder bridge” recommended after the comparison. DBN (Ukrainian design standard) was used for this study.

5.1.2 Alignment of the bridge and approach road

1) Locations of the Bridge

Alternative alignments of the bridge were examined as in the first feasibility study in 1989. The bridge location north west and upstream of the existing Varvarovsky bridge over the Southern Bug River was recommended in this Study because it had the least effect on the social environment, i.e. minimal resettlement, and reasonable construction cost.

The proposed location of the bridge over the Southern Bug River has not been altered through the four feasibility studies.

2) Alignment of the approach road to the bridge on the left-bank

It was considered that the road alignment on the left-bank of the Southern Bug River be changed.

Background of this change is reported as follows.

- The legislation regarding land ownership, land-use system, and procedures for land ownership was changed.
- The city administration introduced changes to the general layout of the city by expanding residential development in the northwest direction between P-06 highway and the Southern Bug River.
- It was planned that a residential community would be built to partially occupy the land previously intended to be used for left-bank approaches to the bridge.

Considering the above circumstances, this feasibility study proposed three options for the alignment on the left-bank.

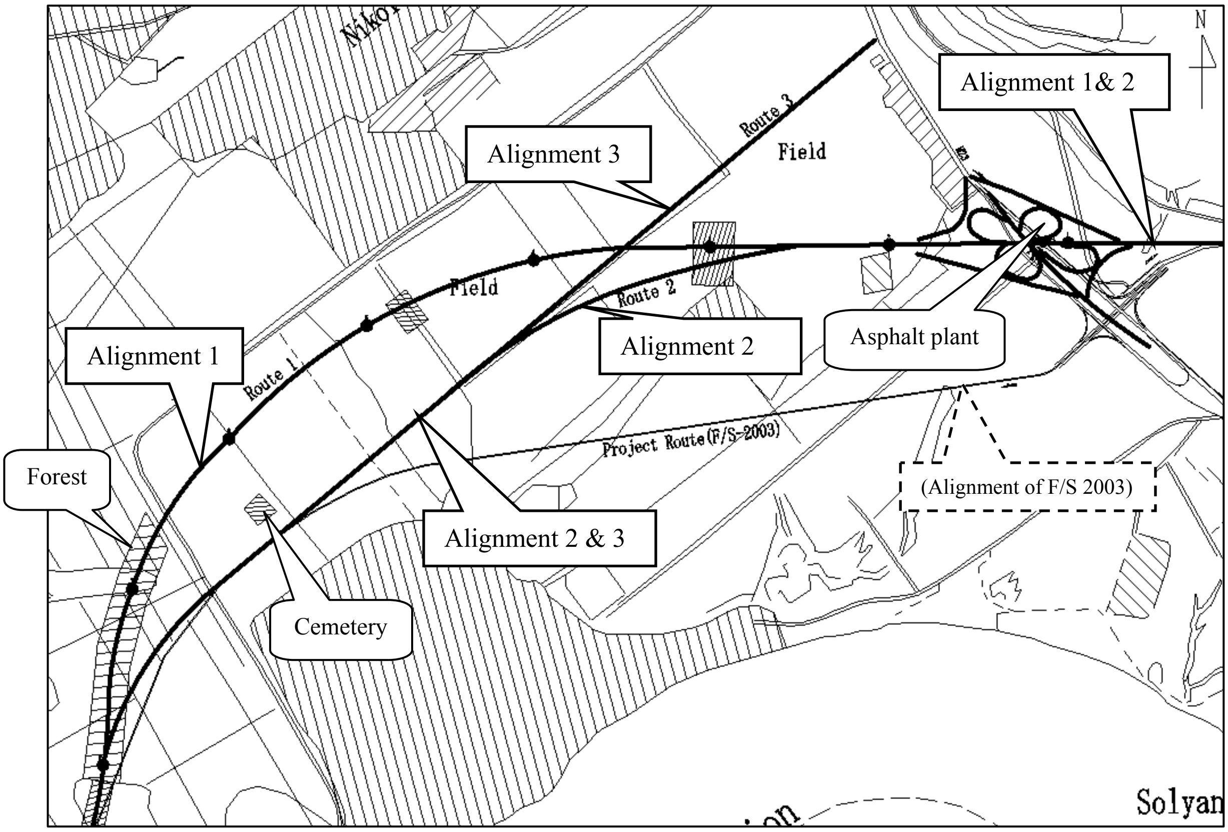
Alignment 1: The alignment has one angular rotation on the horizontal curve (Radius= 3000m) where the road runs almost parallel to the city boundary and would be more than 200m away from the airport boundaries at the point of nearest approach.

Alignment 2: This alignment is considered to minimise road length. It is closer to the city boundary, and goes between the boundary and an existing cemetery. The alignment has two angular rotations with radii of 1000m.

Alignment 3: This alignment is considered to minimise land acquisition. It runs together with alignment 2 (Radius=1000m) on its west side, and then connects to the P-06 at almost a 90^{o} angle. The alignment coincides with the existing P-06 for a section with a length of 2.2km.

The locations of the above-mentioned alignments and the old alignment (F/S in 2003) are shown in Figure 5.1.1.

The comparison of the 3 alignments on the left bank is shown in Table 5.1.2.



Source : JICA Survey Team

Figure 5.1.1 Proposed Alignments on Left-Bank

Table 5.1.2 Comparison of Proposed Alignments on the Left-Bank

		Alignment 1		Alignment 2		Alignment 3	
Road Length(Total)	km	8.432		8.123	○	9.642	
- new road - existing road	km km	8.432 -		8.123 -		6.540 3.102	○
Used land(Total)	ha	42.8		40.9	○	47.7	
- Agricultural - Forestry - Right of way of existing road	ha ha ha	31.0 8.6 0.6		30.0 8.1 0.6		24.6 8.1 9.0	○
Construction Cost	million Hryvnas	159.4		153.5		148.4	○
Minimum Horizontal Curve	m	R=3000	◎	R=1000		R=1000	
Connection to M23		Full Access Interchange (clover-shape)	◎	Full Access Interchange (clover-shape)	◎	Intersection at grade (T-shape*2)	

Source: JICA Survey Team

This feasibility study proposed “Alignment 1” as the best of all because;

a) Alignment 1 is a continuous line which meets the requirements of “landscape design”.

b) Alignment 1 does not cross security or sanitary areas of the airport or the cemetery, and provides access to the cemetery from the city.

c) Alignment 1 moves through more elevated locations allowing reduction in the length of overpasses required to link disconnected areas.

The following may be considered as disadvantages of "Alignment 1";

e) It is slightly longer than "Alignment 2".
f) Relocation of Asphalt plant of Mykolaiv Regional Office will be required (Alignment 3 does not need this).

Additional comments according to review by JICA survey team are shown below:

About a): "Alignment 1" and "2" have continuous lines, but "Road class 1st" should have more than 1200m as minimum radius of curve as specified by DBN. In light of the above, "Alignment 1" is better than "2" for road service.

About b): All alignments succeed in avoiding the cemetery. However, there is a small interchange connecting the city road to the highway. As such, "Alignment 1"is much better because it is located far from the cemetery (no impact for cemetery land).

In consideration of the above and with due respect to the proposal of the feasibility study in 2004, "Alignment 1" was chosen as the best route for a 1st class highway.

5.1.3 Optimum Type of Main Bridge

Optimum type of main bridge over the Southern Bug River recommendations;

- Cable stayed bridge was recommended in the feasibility study in 2000 as a result of the comparison with steel box girder with orthotropic deck and suspension bridge type.
- Suspension bridge type was recommended in the feasibility study in 2003 as a result of the comparison with steel truss bridge and cable-stayed bridge.
- Steel box girder with orthotropic deck was recommended in the feasibility study in 2004 as a result of the comparison with cable stayed bridge and suspension bridge.

5.1.4 Economic and Financial Analysis

Economic and financial analyses were only carried out in the feasibility studies of 2000 and 2003. The result of EIRR on the base case was 17.1% and 21.5% in 2000 and 2003 respectively. The results show that the project would be feasible.

The calculated FIRR without interest cost was 7.6% and 9.4% in 2000 and 2003 respectively. The FIRR value was judged to be low.

5.1.5 Navigation Issues

The recommended optimum bridge type for the main span of the Mykolaiv Bridge is different in the feasibility studies described above. It is clearly recognized that Navigation clearance influenced the optimum bridge type strongly.

Navigation width was 120m in the feasibility study in 2000, 300m in 2003 and 2x120m in 2004; resulting in different choices for the optimum bridge type.

Therefore, careful examination is required regarding navigation issues.

5.1.6 Road Design

Main Geometric parameters of the project road are shown in Table 5.1.3.

Table 5.1.3 Comparison of Road Design Conditions in Existing Feasibility Studies

	1989 F/S	**2000 F/S**	**2003 F/S**	**2004 F/S**
Category of Road	1-a (Number of traffic lanes:4)			
Length of Road	12.75km			13.19km
Design Speed	150km/h			
Typical width of road	3.75+(3.75*2)+6.0+(3.75*2)+3.75 Carriageway:3.75、Median:6.0m、 Shouder:3.75m(Hard shoulder:0.75m)			3.9+(3.75*2)+6.0+ (3.75*2)+3.9
Horizontal alignment road (Left-Bank)		R＝2500		R＝3000
Maximum vertical gradient		3.0%		2.0%
Interchange shape (Connect to P06)	—	—	Diamond-shape	Cloverleaf-shape
Interchange shape (Connect to M14)	—	—	3-leg Y-shape Junction (1 point overpass)	
Thickness Of pavement	—	70cm		73cm
Overhead clearance of crossing roads	—	5.5m		5.0m

Source : JICA Survey Team

5.1.7 Bridge Design

Design conditions for the bridge design of each Feasibility Study are summarized in Table 5.1.4.

Table 5.1.4 Comparison of Bridge Design Conditions in Existing Feasibility Studies

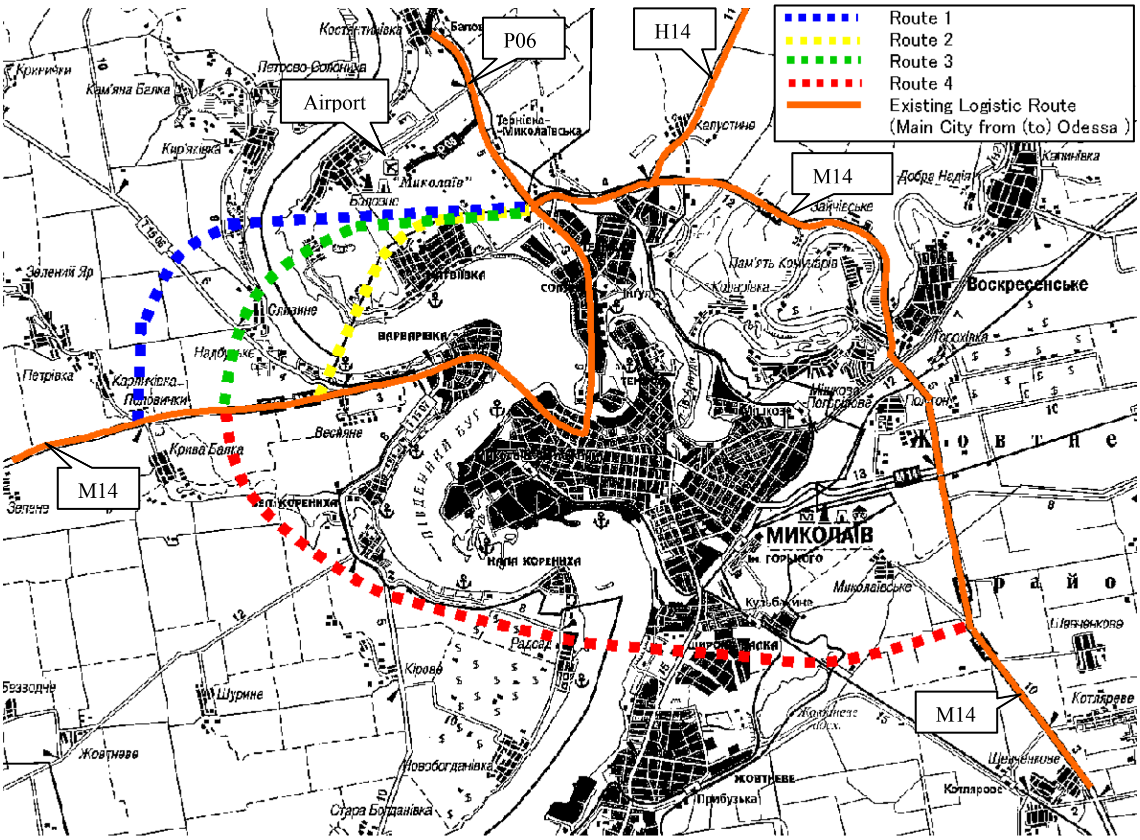
	Length of the Bridge (m)	Length of the Main Bridge (m)	Length of the Approach Bridge (m)	Main Part of Superstucture	Main Span (m)	Road Width (m)	Construction Cost	Recommended
2000 FS								Unit: Yen millon
	2,000.0	390.0	1,610.0	Steel Deck Box Girder Type	130.0	25.60		
	2,000.0	**920.0**	**1,080.0**	**Cable Stayed Br.**	**460.0**	**25.60**		◎
	1,996.0	1,750.0	246.0	Suspension Type	1,000.0	25.60		
	Navigation Clearance				Aviation Control(m)		Economic and Finacial Analysis	
	Width(m)	Heigth(m)	Number	Navigation Centerline(m)	Heigth(m)		EIRR(%)	FIRR(%)
	120.0	14.5	2	360 ※Read a Pilot Chart	－		17.09	7.61
2003 FS	Length of the Bridge (m)	Length of the Main Bridge (m)	Length of the Approach Bridge(m)	Main Part of Superstucture	Main Span (m)	Road Width (m)	Construction Cost	Recommended
								Unit: US$ millon
	2,275.0	700.0	1,575.0	Truss Type	400.0	25.60		
	2,275.0	760.0	1,515.0	Cable Stayed Type	460.0	25.60		
	2,475.0	**1,200.0**	**1,275.0**	**Suspension Type**	**800.0**	**25.60**		◎
	Navigation Clearance				Aviation Control(m)		Economic and Finacial Analysis	
	Width(m)	Heigth(m)	Number	Navigation Centerline(m)	Heigth(m)		EIRR(%)	FIRR(%)
	300.0	20.0	1	200	145.00		21.50	9.40
2004 FS	Length of the Bridge (m)	Length of the Main Bridge (m)	Length of the Approach Bridge(m)	Main Part of Superstucture	Main Span (m)	Road Width (m)	Construction Cost	Recommended
								Unit: UAH milon
	2,007.4	**883.4**	**1,124.0**	**Steel Deck Box Girder**	**126.0**	**27.44**		◎
	2,015.2	824.0	1,191.2	Cable Stayed Type	412.0	27.44		
	2,231.5	1,200.0	1,031.5	Suspension Type	800.0	27.44		
	Navigation Clearance				Aviation Control(m)		Economic and Finacial Analysis	
	Width(m)	Heigth(m)	Number	Navigation Centerline(m)	Heigth(m)		EIRR(%)	FIRR(%)
	120.0	13.5	2	500	－		－	－

Source: JICA Survey Team

*1--- "Construction Cost" means total of "direct cost for construction", "assembly cost" "equipment cost" and "other indirect cost". However, "Construction Cost" in 2004 FS shows only "direct cost for construction."

5.2 Selection of the Highest Priority Route

The current bridge location over the Southern Bug River is based on route selection of the first F/S executed by Kievsoyuizdorproekt in 1989. This section shows the review of route selection which considered 4 alternatives. The social environment of Mykolaiv and surrounding areas has changed in the 20 years since that F/S, which necessitated a review.



Source: JICA Survey Team (refer to F/S 2003)

Figure 5.2.1 Four Alternative Routes across Southern Bug River (F/S in 1989)

(1) Outline of 4 Routes (Starting Points described from eastern bank)

Route 1: The starting point of the route is the intersection of P-06 and M-14. The road then runs straight westwards to cross the Southern Bug River. It connects with the M-14 further westwards than other alternatives because of its straight alignment at the bridge and left-bank sections. The route would necessitate relocation of houses in the right bank area.

Route 2: The starting point of the route is the same as that for "route 1". The road then runs in a southwest direction. It has a straight alignment and large radius curve along the boundary of Mykolaiv city before crossing the Southern Bug River. The route is the shortest among alternatives. However, the Southern Bug River has a small curve and a landslide prone area on the right bank at the bridge crossing point. The route does not necessitate house relocation.

Route 3: The route is located between "route 1"and "route 2". House relocation required is less than that for "route 1". Besides, the river has a gentler curve at bridge crossing point compared to "route 2".

Route 4: The starting point of the route is the M-14 road which is located in the southeast suburb of Mykolaiv city. The route then runs straight in a western direction to cross the Southern Bug River. The route would form the southern half of a ring road for Mykolaiv city. The route would form a southern bypass compared to the northern bypass formed by the other three alternatives. The route is the longest of the 4 alternatives.

(2) Evaluation of Routes in F/S Stage

The result of the route evaluations is shown in Table 5.2.1.

Table 5.2.1 Comparison of 4 Alternatives at F/S stage

	Good points	Bad points
Route-1 L=14.6km	➢ Shortest bridge length ➢ Better Geological condition	➢ Approximately 100 households need to be resettled on right bank ➢ Very close to the airport and affects radio control system ➢ Access road length is 3.6km longer than route-2
Route -2 L=11.0km	➢ No household or facility would need to be relocated ➢ Shorter bridge length ➢ Total project road length including bridge section is the shortest	➢ Soil conditions in the river are not good ➢ Right bank is susceptible to landslide due to steep slope
Route -3 L=12.83km		➢ Bridge length is longer ➢ Approximately 15 households need to be resettled on right bank. ➢ This route runs close to the silicate wastewater treatment facility on right bank
Route -4 L=29.92km	➢ Suitable alignment for traffic to the Rostov – Odessa direction	➢ Total project road length including bridge section is the longest ➢ Navigation clearance is larger due to large-scale boats, which leads to high bridge construction costs

Source: F/S 2003

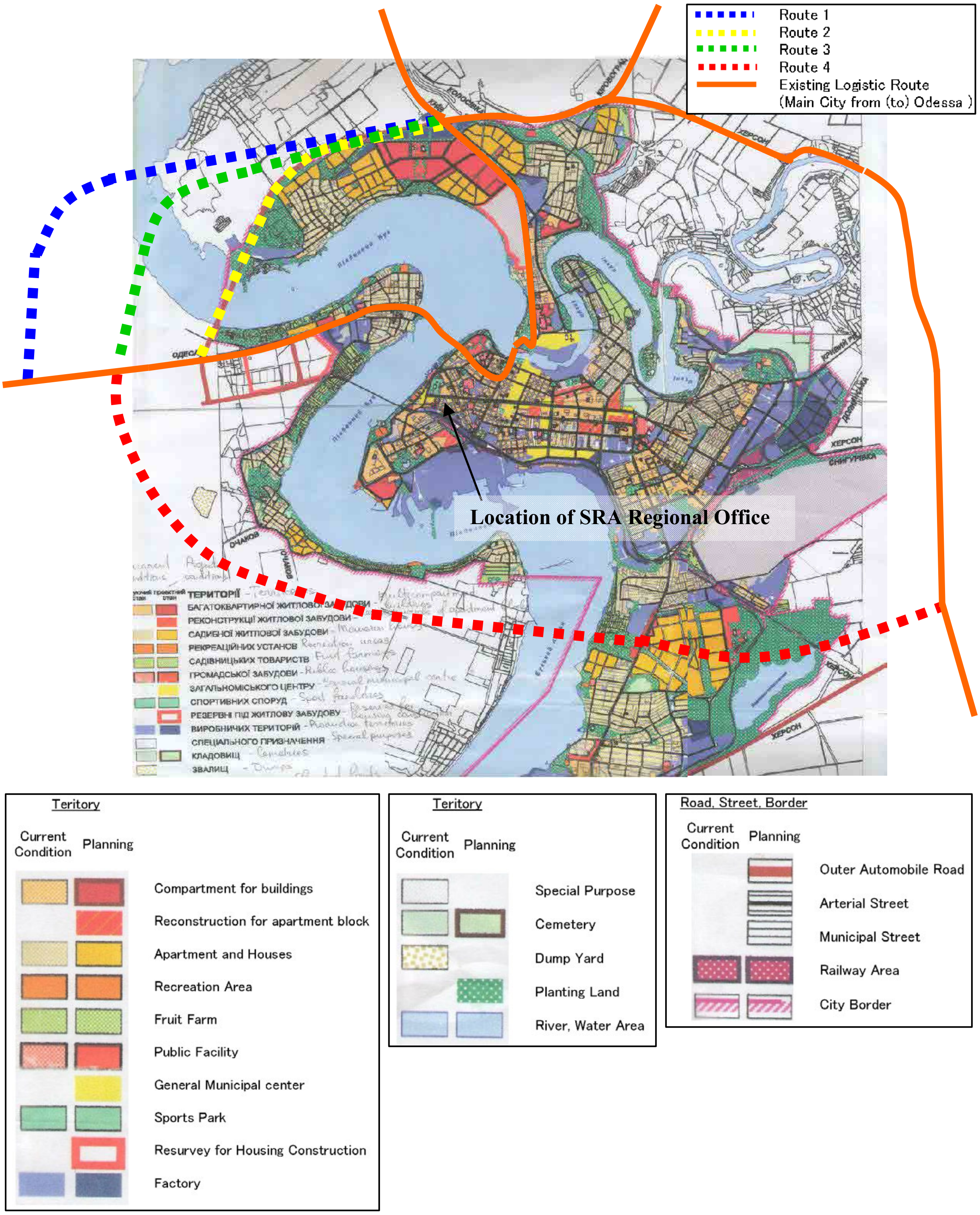
According to the table above, route 2 was selected as the most suitable for the proposed road and bridge crossing because it had shorter lengths of the bridge and approach road and it hardly had any relocation of houses. The route was also aligned with future development plans for Mykolaiv city as shown in Figure 5.2.2.

(3) Significant Changes to Project Environment after F/S in 1989

Circumstances changed after Ukraine acquired independence. As regards circumstances pertinent to route selection, the environment changed as follows.

1) Drawing up of Land use plan for Mykolaiv city

Mykolaiv city drew up a land-use plan after the F/S, such that the development area for the project road was more limited than before. In fact, the location of the project road (route 2) was moved a little towards the north by the F/S in 2004. “Route 4” passes through a residential area and sports field so that its environmental impact is far more adverse than before. The land-use planning map is shown in Figure 5.2.2.



Source: JICA Survey Team

Figure 5.2.2 Four Alternatives Superimposed on Land-use Planning Map for Mykolaiv City

2) Decline of shipbuilding industry

The ship-building industry has declined compared to 20 years ago. Therefore, ship traffic volume is lower than before.

3) Implementation of enhancement projects for existing roads

Road enhancement projects have been executed for some roads in Ukraine. Pertinent to the project area, an enhancement project was implemented for the existing M-14 from Mykolaiv to Kherson in 2007 under local Budget. The road sector in the area surrounding Mykolaiv is growing in importance.

4) Beginning of development plan for Ochakov port

Odessa and Ilyichevsk ports are the hub ports on the Black Sea in Ukraine now. The Ochakov port development plan started in 2008 to complement logistics capabilities on the Black Sea given that the capacity of the main ports would not be adequate in the future. The opening of Ochakov port would lead to an expansion of traffic volume through Mykolaiv.

(4) Review of Comparison of 4 Alternatives Considering Changes in Project Environment

Table 5.2.2 shows the review of comparison of alternative routes in light of the afore mentioned changes to the project environment.

Table 5.2.2 Review of Comparison of 4 Alternatives Considering Changes in Project Environment

	Route-1		Route -2		Route -3		Route -4	
	F/S	This Study	F/S	This Study	F/S	This Study	F/S	This Study
Road length	△	⇒△	◎	⇒◎	○	⇒○	×	⇒×
Bridge construction costs (Bridge length, Height)	◎	⇒◎	○	⇒○	△	⇒△	×	⇒△
Geological conditions	◎	⇒◎	△	⇒△	○	⇒○	○	⇒○
Relocation of houses	×	⇒×	◎	⇒◎	△	⇒△	△	⇒×
Location as East-West corridor along Black Sea		○		○		○		◎
Alignment with land-use plan for Mykolaiv city		○		○		○		×
Relationship with Ochakov Port		○		○		○		◎

Source:JICA Survey Team ◎ : Excellent、○ : Good、△ : Below Average、× : Poor

Some circumstances pertinent to the project changed after the F/S. “Route 1”, ”Route 2” and “Route 3” remained in almost the same locations after incorporating the changes. Thus evaluation of route selection would involve comparison of the northern bypass routes (routes 1, 2 and 3) against the southern bypass route (route 4).

If attention is focused on the logistics network, the southern bypass has an advantage, because it is located far from the city centre and the route is a shortcut in the east to west directions as a corridor along the Black Sea. However, the volume of ships is increasing on the downstream side of the Southern Bug river, implying that “route 4” would require more countermeasures to deal with increased traffic of ships compared to the northern bypass routes. In addition, “route

4” has the longest approach road that would have to be newly-constructed. Therefore, “Route 4” would be more expensive and less environmentally friendly than was assumed at the F/S stage.

On the other hand, the northern bypass routes (routes 1, 2 and 3) would be implemented at lower cost than the south bypass route because of shorter approach roads and lower traffic volume of ships. Furthermore, in light of the development plan for Mykolaiv city, the northern bypass routes are more advantageous in terms of environmental impacts and land acquisition for the project. These gaps in advantages have become bigger since the F/S stage in 1989.

In terms of the wider network, the northern bypass routes are better than the southern bypass route. And according to Table.5.2.1 “Route 2” is the best route of the northern routes. The reasons are as follows.

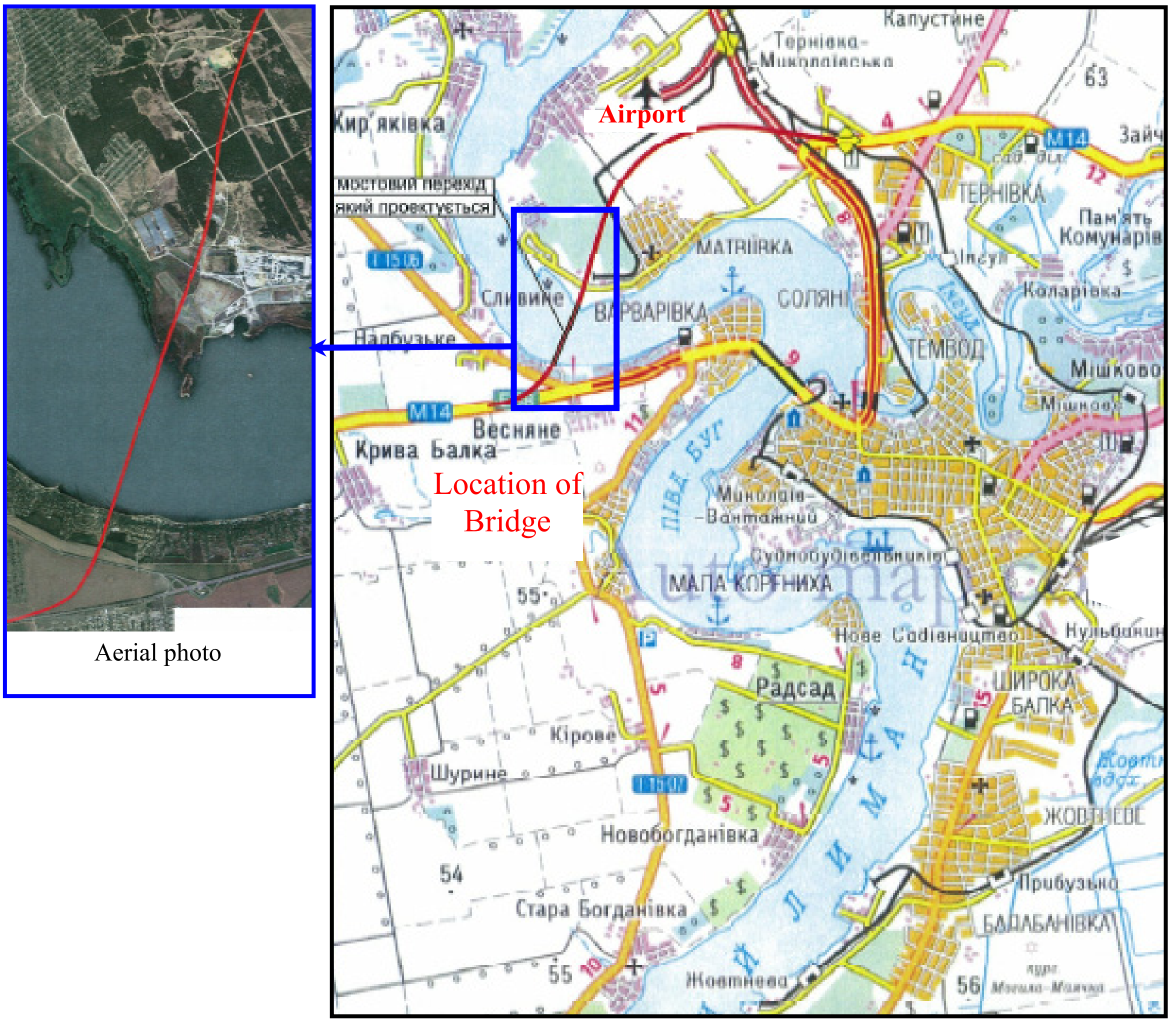
- “Route 2” requires hardly had any relocation of houses.
- Approach road length of “Route 2” is shortest and bridge length is shorter than route 3 and 4.
- “Route 1” and “Route 3” will locate on the extension of an airport runway and may partially conflict with airspace restriction (Figure 5.3.5(b)).

5.3 Basic Design for Mykolaiv Bridge

5.3.1 Design Condition

(1) Location of the Bridge

The location of the bridge is determined to be the same as the location proposed in the F/S in 2004 (see section ‘5.2 Selection of the Highest Priority Route’ in this report). The bridge location is proposed to be approximately 9 km upstream of the existing Varvarovsky Bridge. The right bank (western side) of the crossing point is observed to be a landslide prone area with a slope of 15 degrees. On the left bank (eastern side), there is a flat area with forest, cultivated field and the Mykolaiv Air Port which is located 5 km north-northeast of the proposed bridge.



Source: JICA Survey Team

Figure 5.3.1 Map Showing Location of the Proposed Bridge

(2) Road

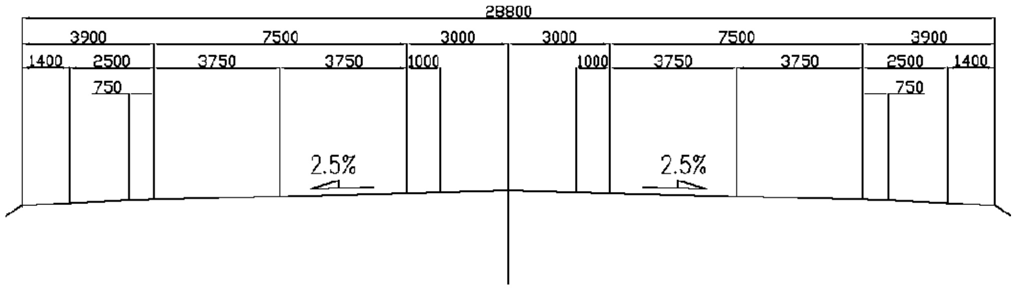
1) General

a) Road category: 1-b

b) Design speed: 140 km/h

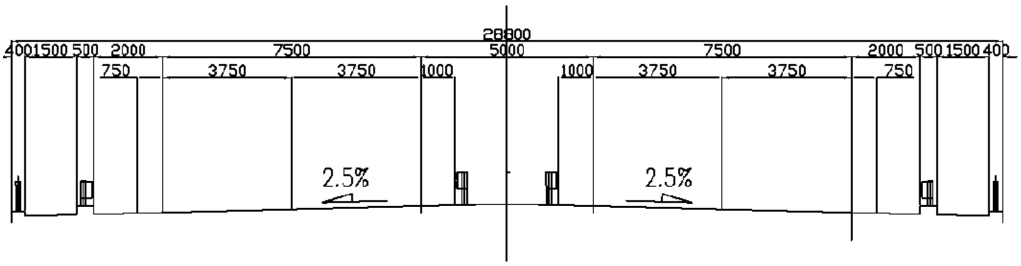
c) Dimensions of the road width

Side walk is not installed in the cross-section of the Road.

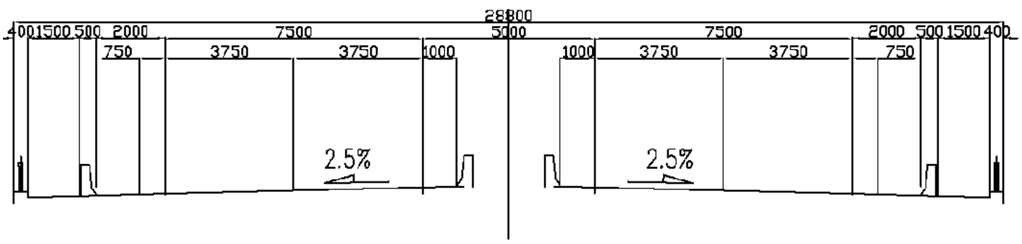


(a) Cross-section at Road

Side walk and/or inspection way should be installed at the Main and Approach Bridges.



(b) Cross-section at Main Bridge



(c) Cross-section at Approach Bridge

Figure 5.3.2 Standard Cross-section

2) Alignment

The horizontal and vertical alignments of the bridge route were determined in section "5.2 Selection of the Highest Priority Route" of the report, with due consideration given to land use, conditions of the waterway in the river and conditions of the intersection with the road "T1506".

■ Horizontal Alignment of the Bridge Section

R=∞ (Straight)

■ Vertical Alignment of the Bridge Section

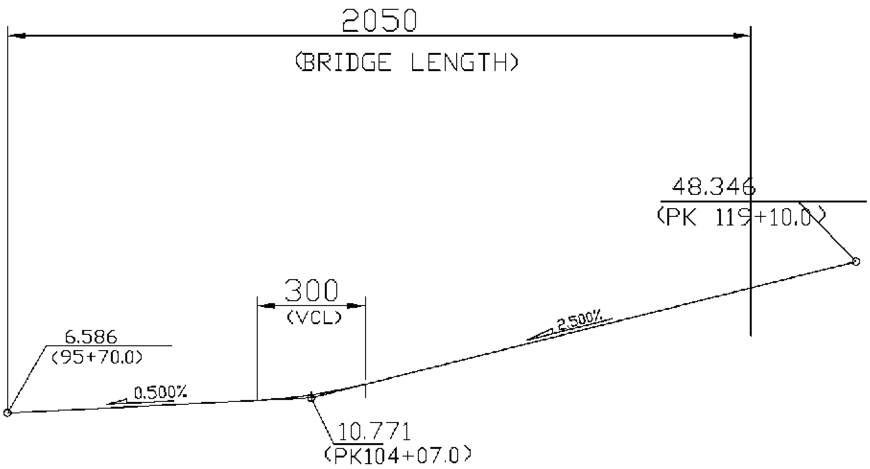


Figure 5.3.3 Horizontal and Vertical Alignments at the Mykolaiv Bridge

(3) Design standards and specifications

In principle, DBN series should be used for the design of the bridges as the design standards or specifications.

However Japanese standards such as the specifications of Honshu-Shikoku bridges and the specifications for highway bridges should be applied to the long span bridges because of its actual previous applications.

Japanese Standard and Specifications shall be used for the design and construction of SPSP foundations because it had been developed and constructed in Japan.

(4) Waterway for the Southern Bug River

1) Dimensions of the Waterway

The conditions of the waterway over the Southern Bug River are stipulated in the "DSTU 8.2.3-1-95: Navigation Clearance under Bridges on Inland Waterways (GOST26775-97)" and the class of waterway to be applied to the Southern Bug River should be "3. Trunk" according to the UKRVODSHLYAH (Ukrainian Marine and River Fleet State Enterprise on Waterways).

Table 5.3.1 Class of Waterways and Target Vessels

Class	Depth of the navigable Channel		Estimated width/length of vessels/ships		Estimated height of the vessels (m)
	Guaranteed (m)	Medium-navigation (m)	Ship (m)	convoys of rafts (m)	
1.Over Trunk	3.2	3.2	36 / 220 or 29 / 280	110 / 830 or 75 / 950	15.2
2.Ditto	2.5 to 3.2	2.9 to 3.4	36 / 220	75 / 950	13.7
3.Trunk	1.9 to 2.5	2.3 to 2.9	21 / 180	75 / 680	12.8
4.Ditto	1.5 to 1.9	1.7 to 2.3	16 / 160	50 / 590	10.4
5.Local	1.1 to 1.5	1.3 to 1.7	16 / 160	50 / 590	9.6
6.Ditto	0.7 to 1.1	0.9 to 1.3	14 / 140	30 / 470	9.0
7.Ditto	0.7	0.6 to 0.9	10 / 100	20 / 300	6.6

Source: DSTU8.2.3-1-95

Table 5.3.2 Dimensions of the Waterway

Class of the waterway	Height (Minimum)	Width of waterway B	
		Fixed Bridge	Bascule Bridge
1	2 (m)	3 (m)	4 (m)
1.Over Trunk	17,0	140	60
2. Ditto	15,0	140	60
3.Trunk	13,5	120	50
4.Ditto	12,0	120	40
5.Local	10,5	100/60	30
6.Ditto	9,5	60/40	-
7.Ditto	7,0	40/30	-

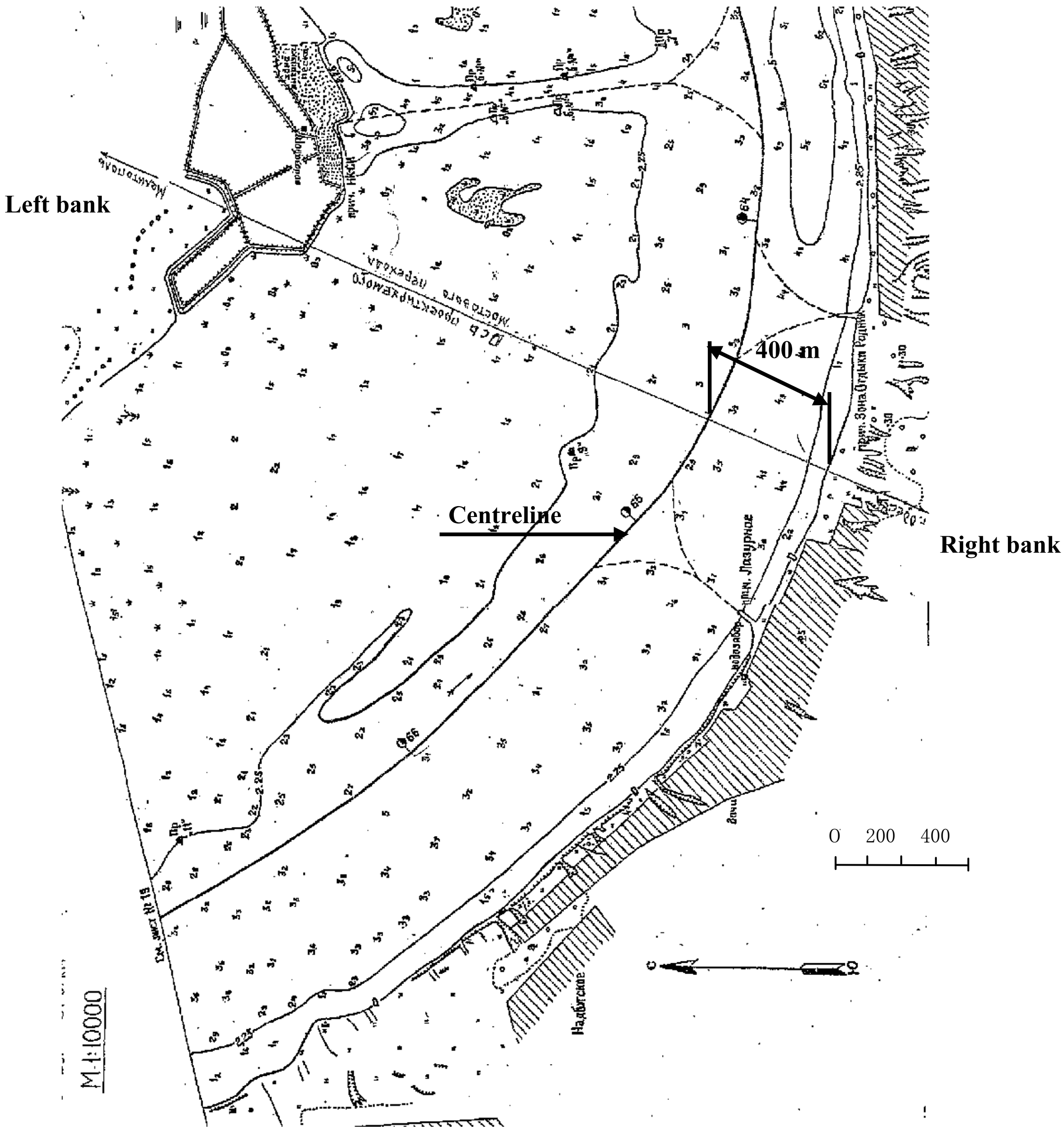
1) Following article should be described in the "4.9, DSTU 8.2.3-1-95".
Fixed bridges should have, as a rule, at least two courses of waterways……..etc.

Source: DSTU8.2.3-1-95

2) Centreline of the waterway

The location of the centreline for the waterway can be defined based on Figure 5.3.4 provided by State enterprise Ukrainian Water Ways "UKRVODSHLYAH."

The distance between the centreline and the right bank is 400m which is determined with scale-up procedure on the map.



Source: Ukrainian Water Ways

Figure 5.3.4 Centreline of the Waterway

3) Waterway

Navigation clearance for the Southern Bug River shall follow the regulation “DSTU 8.2.3-1-95”, and it shall be 120m in width and 13.5m high for each way. Considering the specific conditions stated below, the Survey Team confirmed the validity to have a pier between the two waterways for both directions. Ukrainian Water Ways replied to this proposal in a letter, Ref.No.2-12/350 dated 28.12.2010 (see Appendix 1). Based on the letter, the survey team adopted a single course with a 240m-waterway instead of a two-way course of 2x120m-waterways with a centre pier.

The specific conditions at the Mykolaiv Bridge site are as follows.

- Proposed bridge location is on a curved of the river where the velocity of the river stream varies depending on the position (inside or outside of the corner).
- Visibility at the bridge site is sometimes reduced by foggy weather
- The centre pier between the two navigable spans is NOT preferable considering accidental collision of vessels into the pier under the above mentioned conditions.

The Survey Team also studied the case of a two-way course (2x120m-waterways with centre pier) for reference purposes.

(5) Restrictions for Aviation

According to a letter from International Airport Mykolaiv , Ref. No 1058 dated 24.12.2010 (see Appendix 1), they have no objection and no restriction regarding dimensions of the bridge indicated in Figure 5.3.5. However, obstruction markings on the pylons shall be required and exact location and dimensions of pylons shall be submitted to the Airport at the next design stage for their approval.

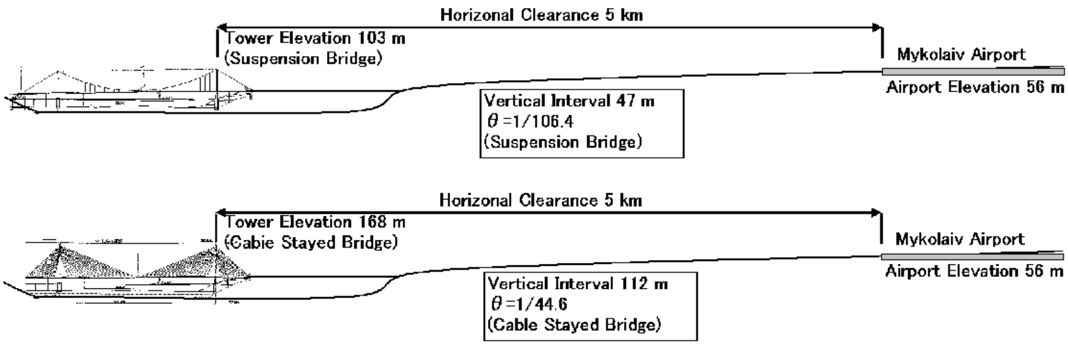
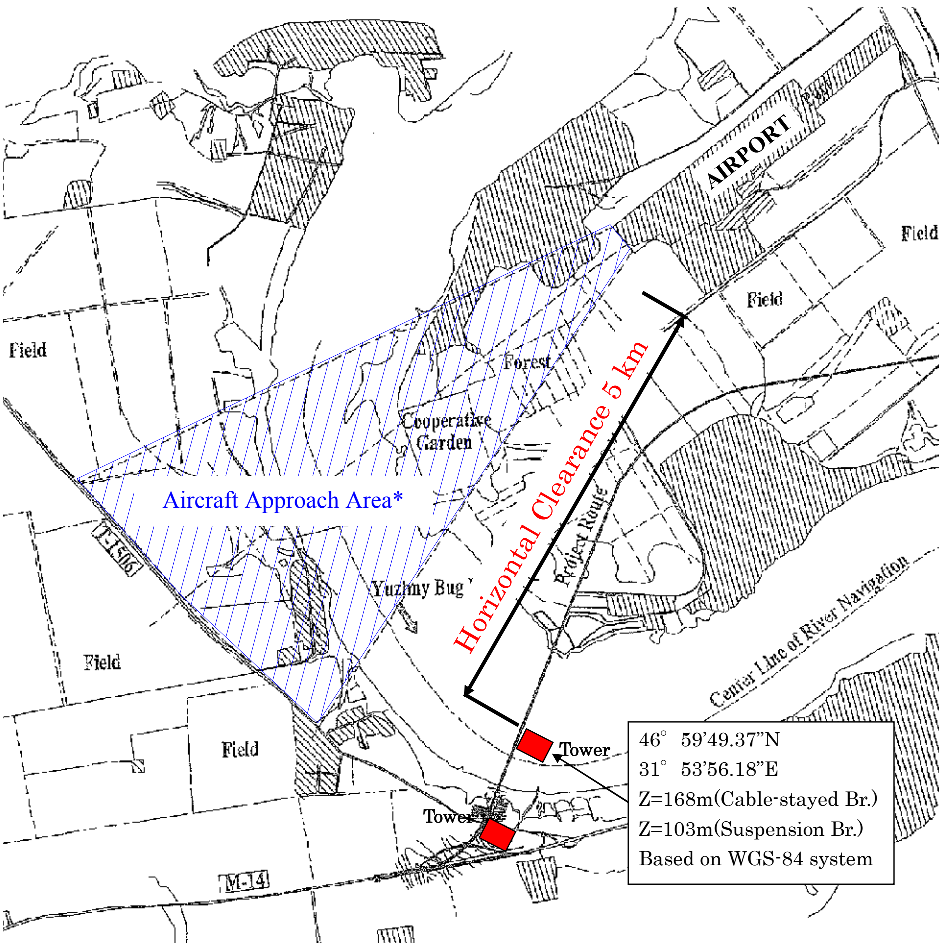


Figure 5.3.5 (a) Condition of the Proposed Bridges vis-à-vis Aviation Restrictions



* "Aircraft Approach area" does not mean restricted area for building height. Generally, Building height is restricted in all direction at surrounding Airport.

Figure 5.3.5 (b) Condition of the Proposed Bridges vis-à-vis Aviation Restrictions

(6) Geological Data

Geological profile at the bridge area is shown in Figure 5.3.6.

Bearing stratum of the foundation for the bridges is composed of stiff and semi-stiff lime clay as indicated in Figure 5.3.6.

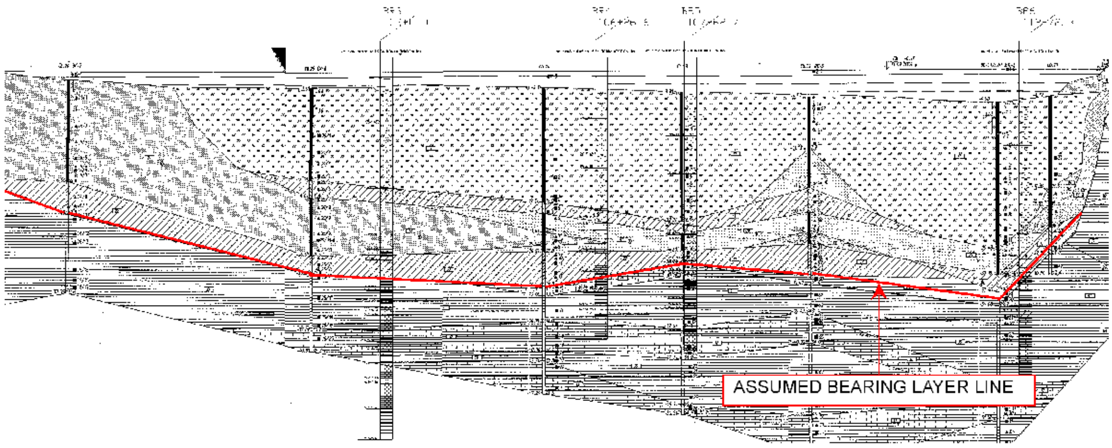


Figure 5.3.6 Geological Profile

(7) Vessel Collision Force

a) Target type of vessels

It is stipulated that the length of the target type of vessel in the trunk class waterway of "DSTU 8.2.3-1-95" is 180m and the water depth of the waterway is 5m. Generally, any vessels with 180m length have more than 5m to 10m draft excluding barge type vessels. Therefore target type of vessel might be of barge type as indicated in Figure 5.3.7.

In this case, dead weight tonnages of barges are estimated at 9,000DWT.

Push tow unit :
(4 x 2250t)

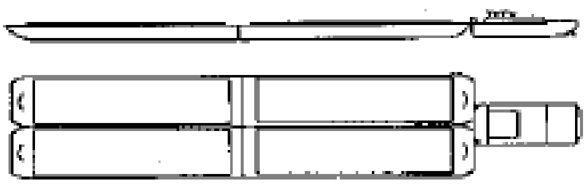


Figure 5.3.7 Target Barge

b) Collision speed

It was hypothesized that collision of vessels with bridge piers would occur when their power unit fails to operate, when they lose control and drift. Therefore collision speed of the vessel should be the velocity of the river flow.

Observed maximum velocity of the river flow is 0.83m/s (exceedance probability=1%)

c) Vessel collision force

Collision force shall be determined using the equation below.

Source: Guide specification and commentary for vessel collision design of highway bridges, AASHTO

$$P_s = 220(DWT)^{1/2}\left[\frac{V}{27}\right] \qquad (3.9\text{-}1)$$

where

P_s =equivalent static ship impact force (kips)
DWT =deadweight tonnage of ship (tonnes)
V =ship impact speed (fps)

Target vessel	9,000 DWT
Collision speed	0.83 m/s
Collision force	9,500 kN

(8) Ice Load

Ice load should be defined based on the following equation stipulated in the "DBN V.1.2-15:2009".

$$F_1=\psi_1 \cdot R_{zn} \cdot b \cdot t,\ кН\ \ (тс); \qquad (K.1)$$

Ψ1 Shape coefficient. =1.0 in case of rectangular structure.

Rzn Ice resistance , 735 kPa (t/m^2)

b Pier width at ice impact level (m)

t Ice thickness(m) = 0.44 m based on the F/S report in 2004

Relationship between "b" and ice load "F1" is indicated in Figure 5.3.8.

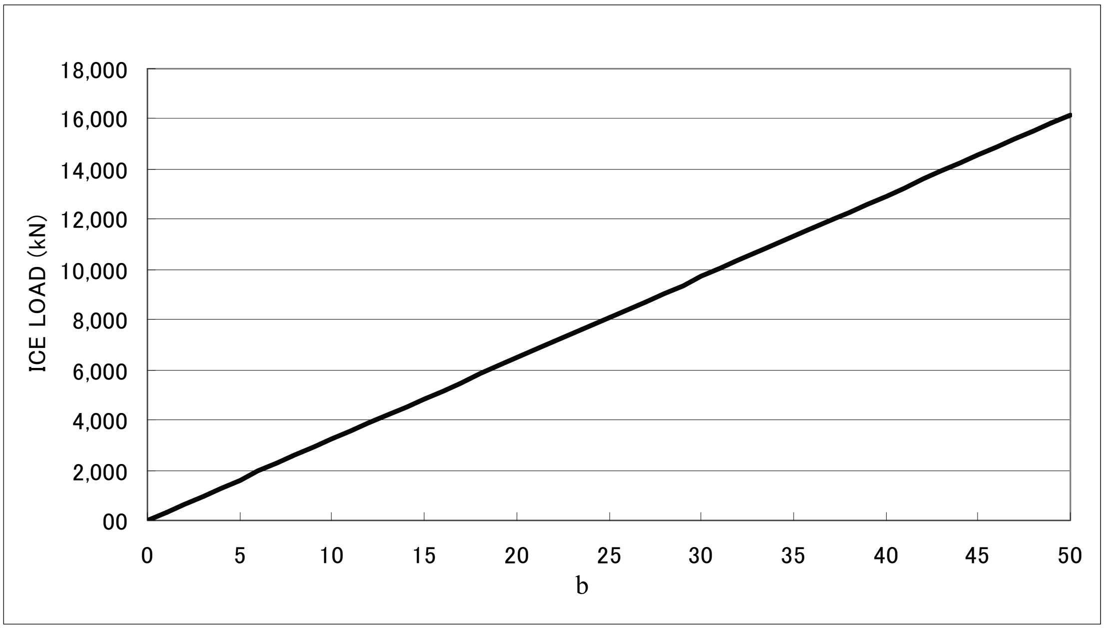


Figure 5.3.8 Ice Load against Pier Width

(9) Seismic Load

According to “DBN V.1.2-15:2009”, “DBN V.1.1-12:2006“ and “ DBN V.2.3-22:2009“, the seismic scale, i.e. MSK, at the proposed location is “6” for a 5% probability over 50 years i.e. a return period of 1000 years.

Based on the above DBN, seismic loads only need to be applied to structural designs for expected earthquake events greater than “MSK7”.

Therefore Seismic load could be neglected in this design.

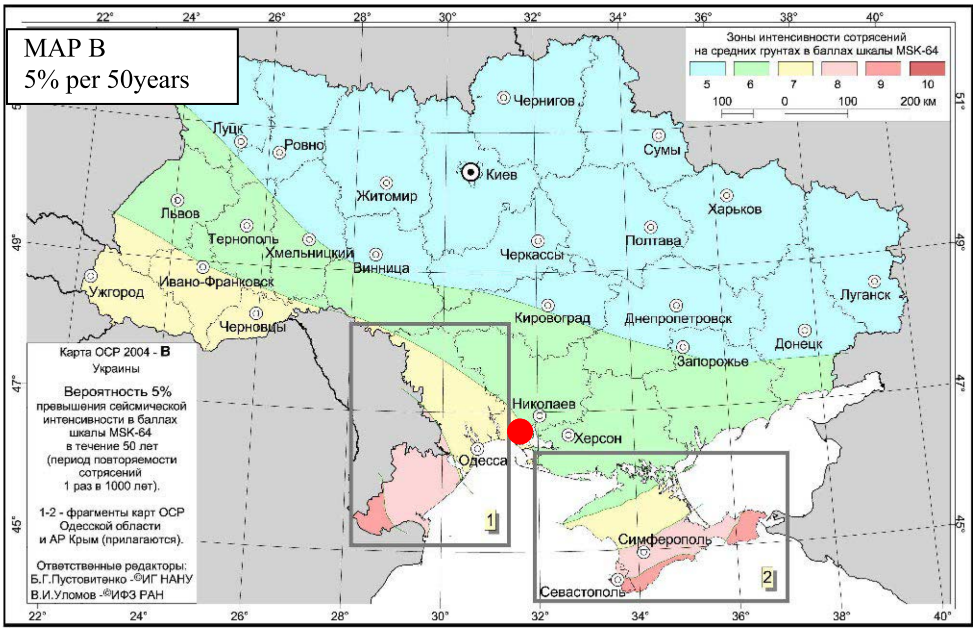


Figure 5.3.9 Seismic Hazard Map

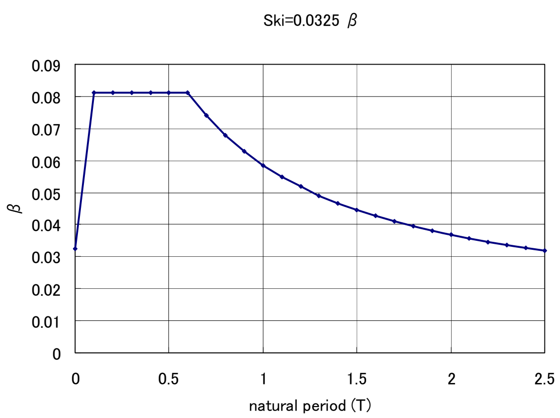


Figure 5.3.10 Response Spectrum

However the effect of an earthquake should be considered in the design of important bridges with long-spans, such as suspension bridges.

Based on the above DBN, the response spectrum (=$K_1 \times K_2 \times K_3 \times S_{0ki}$,refer to DBN V.1.1-12:2006) caused by an “MSK7” is indicated in Figure 5.3.10.

It is determined that

in the preliminary design for the suspension bridge, the effect of earthquake is estimated as horizontal force, i.e. “self-weight×0.1”.

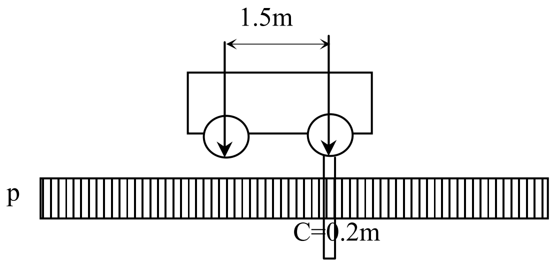
(10) Live Load

“AK load” or “NK-cart load” should be applied as a vehicular live load in accordance with “DBN V.1.2-15-2009”.

AK load (Model-1)

AK load consists of "uniformly distributed load" and "tandem load" and both loads should be considered simultaneously.

- Uniformly distributed load: p=0.98K=0.98×15=14.7 kN/m
- Tandem load: P=9.81K=9.81×15=147.15kN



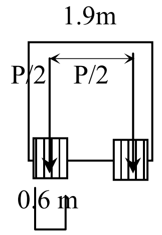
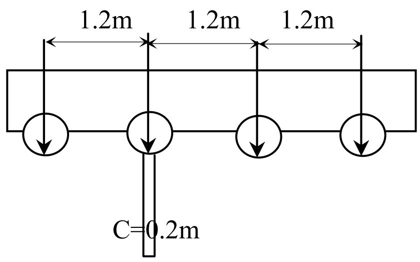


Figure 5.3.11 AK Load

- Number of lanes should be determined by division of road width by 3.5m.
- AK loading rules should be as follows.
+ Minimum distance from a center of lane to fence, barrier, parapet and curb should be 1.5m.
+ Minimum distance between centres of lanes should be 3.0m.

NK cart (Model-2) load: not to be combined with seismic load



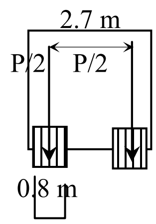


Figure 5.3.12 NK Load

NK-100: P=245 kN (Axle load)

Pedestrian live load: Uniformly distributed load

a) For a "Pedestrian bridge" and "sidewalk of a City Bridge" : q= 3.92 kN/m^2
b) For sidewalks in combination with other vehicular loads: q= 1.96 kN/m^2

Based on a provisional estimation, AK load effect would be approximately equal to Japanese live load.

(11) Wind Load

1) Approach Bridge

Based on the DBN, the following limit state should be considered.

a) Limit tolerance value
b) Operational value

Load intensity: Wm= γf × Wo × C

- Limit tolerance value =1.15 x 51.0 x (1.65 x 2.25 x 1.2)=261kgf/m^2
- Operational value = 0.5 x 51.0 x (1.65 x 2.25 x 1.2)=114kgf/m^2

where･･･

γ_f: Load factor 1.15 and 0.5 at limit tolerance value and operational value respectively.

Wo: wind velocity (return period is 50 years), Mykolaiv is area 3, V=29m/s, P=500Pa(51kg/m2)

C: drag coefficient and altitude modification factor

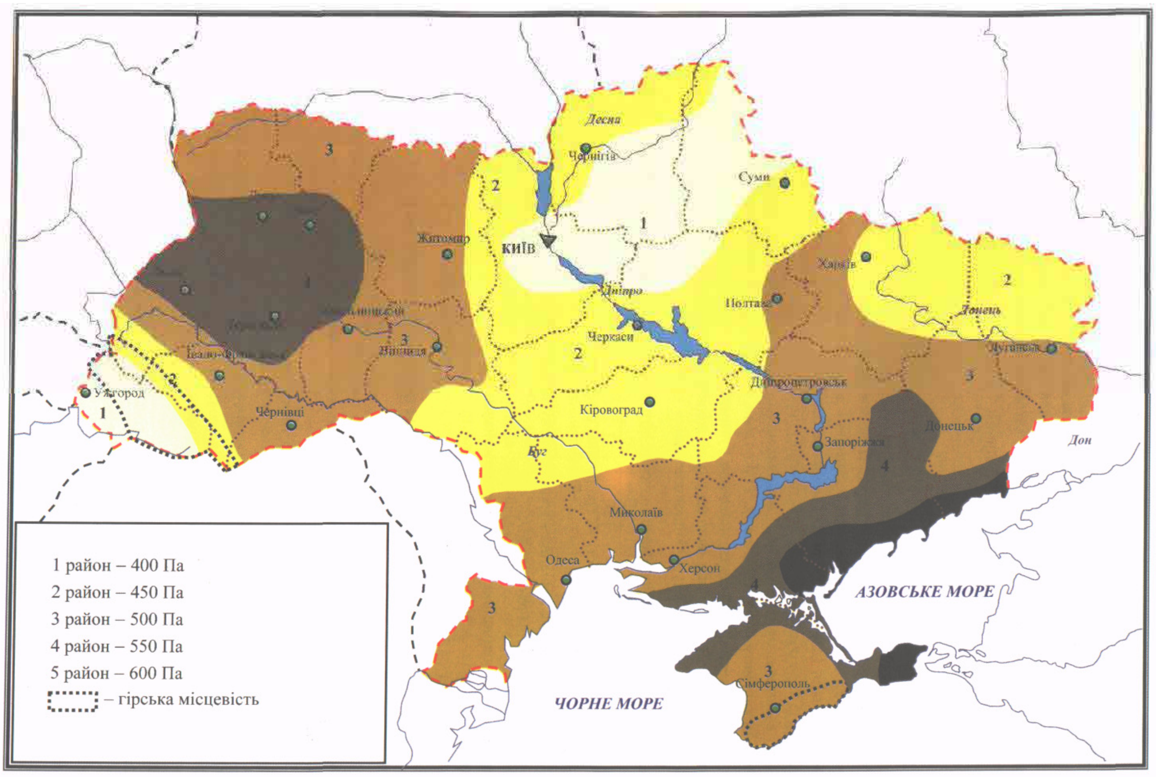


Figure 5.3.13 Zoning Map of Wind Velocity

2) Main bridge

Honshu-Shikoku bridge specification should be used instead of DBN.

Wind velocity 32m/s should be applied as a design wind speed with a return period of 100 years based on the wind speed of 29m/s for a return period of 50 years.

(12) Temperature

Highest and lowest ambient temperatures from 1876 to 2009 are 40.1 degrees and 29.7 degrees respectively. Maximum and minimum temperatures of structures are modified based on the above ambient temperatures.

Ten, five and Zero degrees are added to the highest temperature as a structural temperature in case of steel structures, composite structures and concrete structures respectively. Minimum structural temperature can be obtained from minimum ambient temperature multiplied by 0.98, 0.98 and 0.92 respectively.

Temperatures to be applied to the design is shown in Table 5.3.3.

Table 5.3.3 Structural temperature

	Classification		
	Steel bridge	Steel-concrete composite bridge	Concrete bridge
Maximum temperature	50.1	45.1	40.1
Minimum temperature	-29.1	-29.1	-27.3

Expected mean temperature during the construction period may be 10 degrees Celsius.

5.3.2 Location of Abutments

(1) East Side Abutment: A1

Location of abutment (A1) should be determined at the left river bank as shown in Figure 5.3.14.

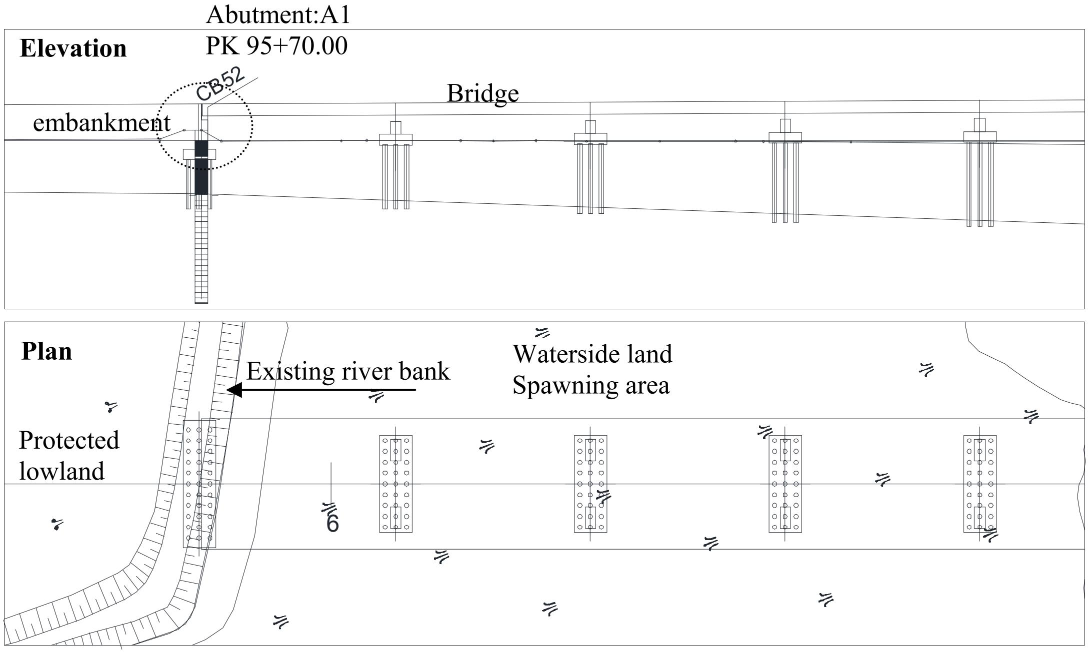


Figure 5.3.14 Location of Abutment A1

There is a shallow water area with hydrophilous plants, which is 200 to 300m in length. If a banking structure is applied to the area, the length of the bridge is shortened and consequently has a lower construction cost.

However, the area should be conserved as a spawning area, territory for various creatures and area for water-purification by hydrophilous plants.

Therefore above the option is not suitable to the location for abutment A1

(2) West Side Abutment: A2

Abutment A2 should be located beyond the landslide area as shown in Figure 5.3.15.

The location of A2 was determined to have approximately a 10m margin in length from the landslide point as indicated in Figure 5.3.15.

Accordingly the bridge length was determined to be 2050m.

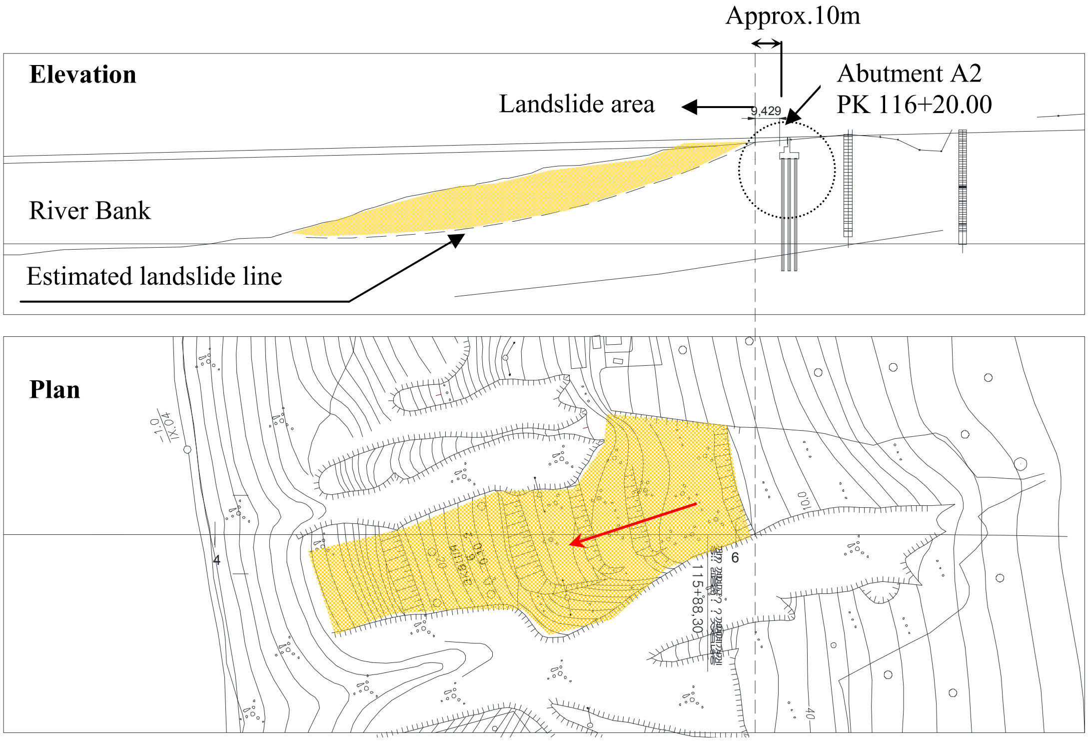


Figure 5.3.15 Location of Abutment A2

5.4 Main Bridge Type

5.4.1 Selection of Superstructure Type

The superstructure type was determined based on the case in which the navigation channel of 240m would not be divided. For reference purposes, the case in which the navigation channel is composed of 120m (navigation width) + (pier width) + 120m (navigation width) was also investigated.

The centre span length of the main bridge should be 480m assuming that the navigation width is 240m and the pier width and construction margin are 120m. This construction margin of 120m is considered as a normal value described in Section 5.4.2.

The alternative bridge types were proposed with reference to the span length mentioned above and the maximum span length of existing bridge types is shown in Table 5.4.1.

As can be discerned from the table, the ***PC-box girder*** bridge type is not applicable for the required span range from 290m to 360m since its limit of applicability is set at 250m. The type with hinges is not listed considering the issue of long-term creep deflection. The ***steel-box with orthotropic deck*** bridge type of the scale of 300m spans has not been constructed since 1974 due to the rise of cable stayed bridges in recent years. The ***truss bridge*** type with span limits of 400m in the continuous system was also considered as an alternative. The ***arch bridge*** type, which is normally constructed in mountainous or valley areas, is judged as inappropriate for the topographic condition of this project despite the fact that the span length is within the applicable range. The ***extradosed bridge*** type with its limit of applicability set at spans of 275m is also not applicable for the required span range. The ***suspension- and cable- stayed bridge types*** are appropriate for the long span structure and were thus lined up as alternatives.

In case the navigation channel was to be divided, the steel-box with orthotropic deck bridge type, which was proposed as the most appropriate in the feasibility study of 2004, would be selected.

Applicable bridge types shall be determined as follows:

1) Alternative 1: Suspension bridge
2) Alternative 2: Cable stayed bridge
3) Alternative 3: Steel truss bridge
4) Referential alternative: steel-box with orthotropic deck (Divided navigation channel)

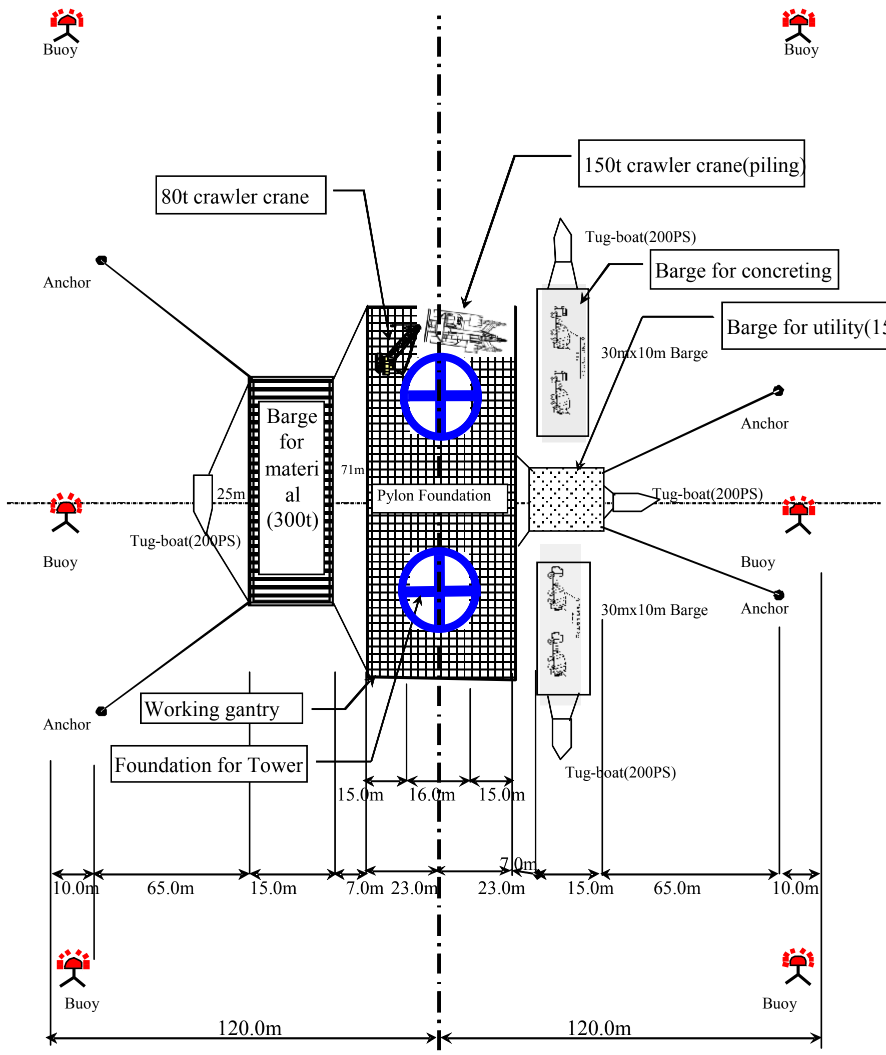
Table 5.4.1 Past Record of Various Types of Bridge

Bridge Type		World			Japan		
		Bridge Name	Span (m)	Location/ Year	Bridge Name	Span (m)	Year
PC-box Girder br.	Hinge	Stolmasudet	301	Norway/1998	Ejima Br.	250	2004
	continuation	-	-	-	Hirahara Br.	170	1990
	Rigid Frame	-	-	-	Nagaragawa Viaduct	156	1999
Steel box girder br.		Ponte Cost a Silva	300	Brazil/1974	Kaita Br.	250	1991
Truss br.	**continuation**	**Astoria Bridge**	**376**	**USA/1966**	Ikitsuki Br.	**400**	**1991**
	Gerber	Quebec Bridge	549	Canada/1917	Minato Br.	510	1974
Arch br.	Steel	Shanghai Lupu Br.	550	China/2003	Kuko Br.	380	(2011)
	concrete	Wargzhou Yargtze Br	425	China/1997	Fujigawa Br.	265	2005
Extradosed	PC	-	-	-	Tokunoyama Hattoku Br.	220	2006
	Composite	Japan-Palau Friendship Br.	247	Palao/2003	Kisogawa Br.	275	2002
Cable stayed br.		**Sutong Br.**	**1,088**	**China/2007**	**Tatara Br.**	**890**	**1999**
Suspension br.		**Great belt east**	**1,624**	**Denmark/1998**	**Akashi Kaikyo Br.**	**1991**	**1998**

5.4.2 Span Length for the Navigation Part

Span length of the navigation part should be determined with consideration of the following items.

- Span length shall conform to the requirements for the dimensions of the waterway after completion of the bridge.
- During construction, the requirements of the waterway should be maintained because of long term safe construction, and various risks such as vessel collision and impacts of construction accidents to 3rd parties should be eliminated.
- Area required for the construction of the tower/pylon is shown in Figure 5.4.1.
- Refer to Figure 5.4.1 necessary area, i.e. length from the center of the tower to the edge of the waterway, should be 120m.



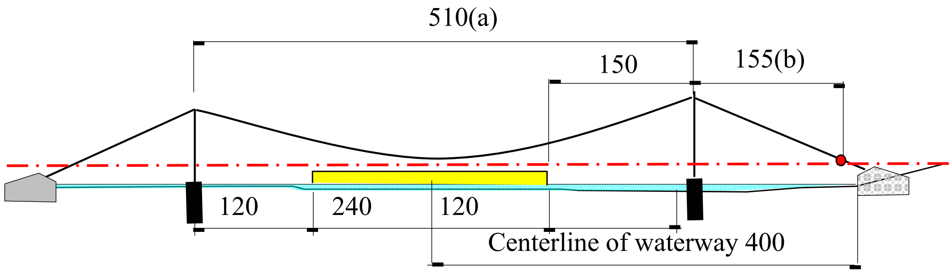
Remarks:
The figure indicates arrangement of necessary facilities during construction of the foundation for the Towers.

Figure 5.4.1 Construction Plan for Foundation of Tower/Pylon

● **Suspension bridge:**

Minimum length of the main span for the suspension bridge should be 480m considering 240m-waterway plus 120m-workspace for construction work adjacent to the waterway. In such a case, the right side anchorage will be located near the right river bank. Therefore the anchorage should be installed on the right bank for easy construction.

Finally main span length should be 510m because of preferable span ratio between main span(a) and side span(b), i.e. b/a= 0.2 to 0.25 should be adopted.



Preferable span ratio: b/a=0.20 to 0.25

Figure 5.4.2 Illustrative Drawing for Main Span Length

● **Cable stayed bridge:**

Minimum required span length for main span should be 480m considering waterway width and margins identical to those for a suspension bridge.

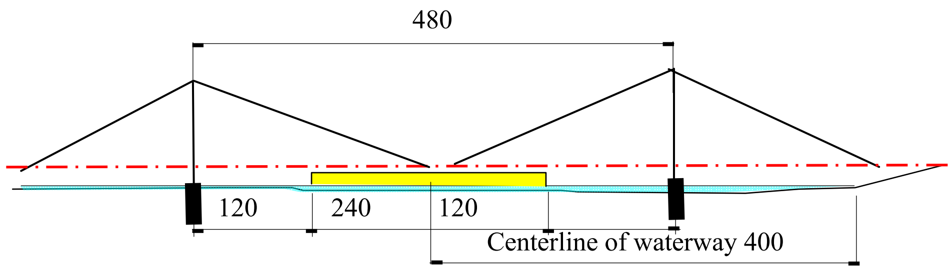


Figure 5.4.3 Illustrative Drawing for Main Span Length

● **Steel truss bridge (continuous structural type):**

The maximum span length in the world for a continuous steel truss bridge is 400m.

Therefore four hundred meter main-span length should be adopted to eliminate construction risks. In this case, the construction margin may be reduced from 120m to 80m.

● **Steel box girder with orthotropic steel deck:**

This alternative will be for reference only due to the fact that it would have a pier between the 120m-waterways.

Main span of a steel box girder should be 130m considering 120m-waterway plus 10m width for the pier.

● **Supplemental explanation regarding the suspension bridge and the cable stayed bridge.**

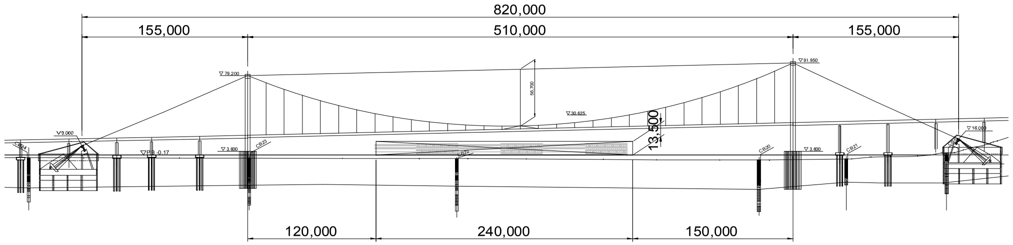
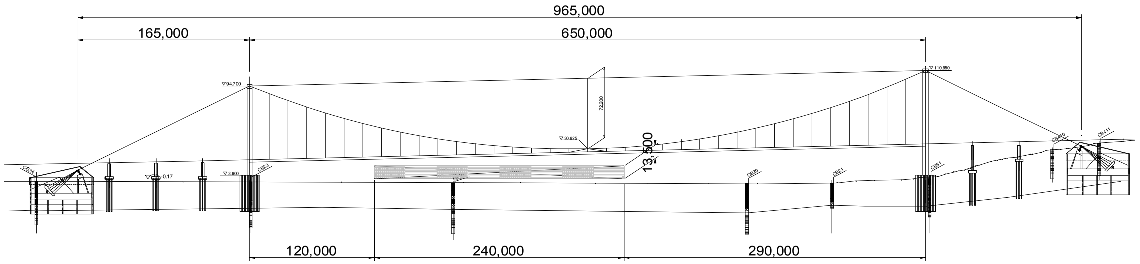
Large scale construction works in the river may take a long time and increase construction cost.

If the construction cost were considerably affected, the main span length would have to be revised in such a way that the tower and pylon would be placed on the right river bank. In order to clarify this matter, supplemental comparison work was carried out.

Result of the comparison works are summarized in Table 5.4.2 and Table 5.4.3.

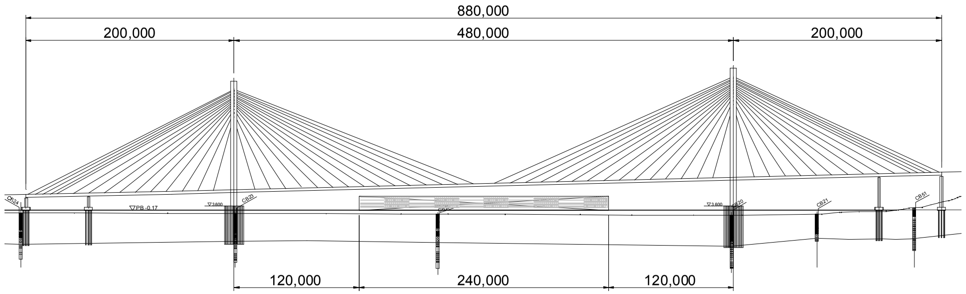
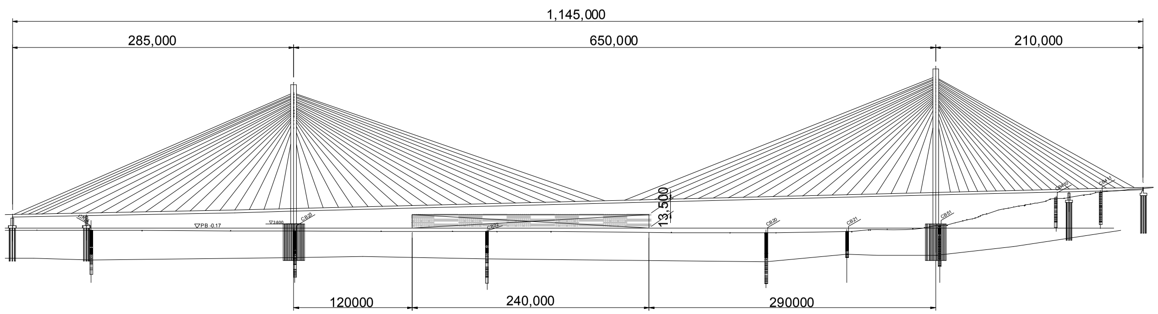
<u>Results clearly indicate that the alternatives with shorter spans are superior to alternatives with the longer spans.</u>

Table 5.4.2 Additional Stability of Suspension Bridge

	Plan	Side View	Cost		
Additional Study of Suspension Bridge	Plan A: Main Span L=510m	 Superstructure : Girder, Cable, Tower Substructure : Foundation, Anchorage Approach Bridge : as for constant bridge length comparison with Plan B (L=965m)	Structural Features	Arranging the Left Tower at 120m away from navigation channel to maintain safety margins for both construction and operation phases To arrange the Right Anchorage on land near river edge, then allocate the Right Tower at the position minimizing the main span.	
			Cost (Ratio)	Superstructure 0.514 Substructure 0.433 Approach Br. 0.053 Total cost 1.000	○
			Appraisal	Superior in cost against Plan B due to narrower main span.	◎
	Plan B: Main Span L=650m	 Superstructure : Girder, Cable, Tower Substructure : Foundation, Anchorage	Structural Features	Alternative to Plan A. The Position of the Right Tower is modifyed by moving it 140m further inland to improve constructability. Main span length (650m) is 140m larger than that of Plan A.	
			Cost (Ratio)	Superstructure 0.696 Substructure 0.547 Total cost 1.240	△
			Appraisal	Inferior in cost against Plan B. To accomplish the wider span, dimension of structural members shall be enlarged.	△

Note) ◎ : Superior ○ : Normal △ : Inferior

Table 5.4.3 Additional Study of Cable stayed Bridge

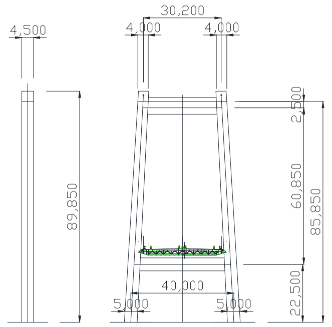
	Plan	Side view	Description		
Additional Strudy of Cable stayed Bridge	Plan A: Main Span L=480m	 Superstructure : Girder, Cable, Tower Substructure : Pier, Foundation Approach Bridge : as for constant bridge length comparison with Plan B (L=1145m)	Structural Features	Arranging both towers at 120m away from navigation channel to maintain safety margins for both construction and operation phases Symmetrical span arrangement with 480m-main span.	
			Cost (Ratio)	Superstructure 0.765 Substructure 0.146 Approach Br. 0.090 Total cost 1.000	○
			Appraisal	Superior in cost against Plan B due to narrower main span.	◎
	Plan B: Main Span L=650m	 Superstructure : Girder, Cable, Tower Substructure : Pier, Foundation	Structural Features	Alternative to Plan A. The position of the Right Tower is modified by moving it 170m further inland to improve constructability. Asymmetrical span arrangement with 650m-main span.	
			Cost (Ratio)	Superstructure 1.119 Substructure 0.172 Total cost 1.290	△
			Appraisal	Inferior in cost against Plan B. To accomplish the wider span, dimension of structural members shall be enlarged.	△

Note) ◎ : Superior ○ : Normal △ : Inferior

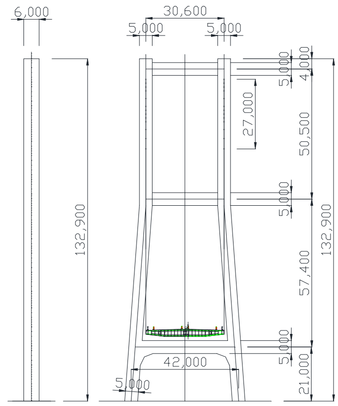
5.4.3 Selection of Substructure Type

For the substructure, the wall shaped reinforced concrete pier was basically applied.

The final shape of the pylons shall be determined in the selected bridge type based on consideration of aesthetics. The basic pylon shapes for the cable stayed- and suspension-Bridges are shown in Figure 5.4.4.



(Suspension Bridge)



(Cable Stayed Bridge)

Figure 5.4.4 Basic Shapes of Pylons

5.4.4 Selection of Foundation Type

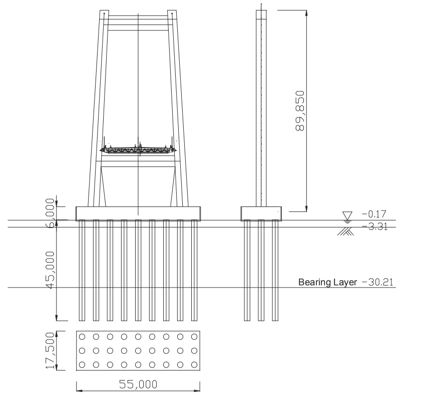
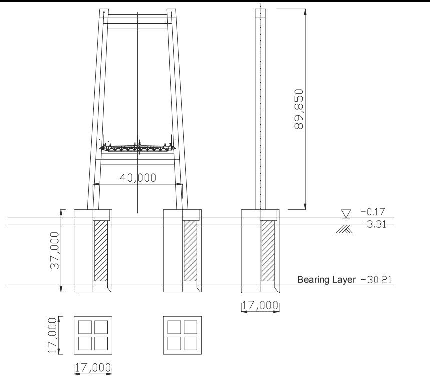
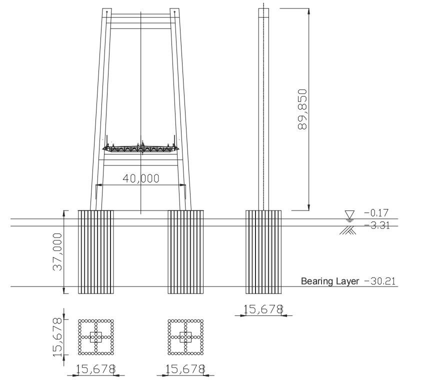
(1) Pylon Foundation Type of the Main Bridge

The following foundation alternatives were lined up considering the loading scale (center span of suspension- and cable stayed- bridges: from approx. 500m to 600m), the construction condition (Water depth of constructed area: from approx. 5m to 7m, winter concreting etc.) and the foundation condition (Depth of bearing layer: approx. 35m from river bed, Sapropel).

1) Alternative 1: Cast in place Pile Foundation
2) Alternative 2: Open Caisson Foundation
3) Alternative 3: Steel Pipe Sheet Pile Foundation (SPSP)

Table 5.4.4 shows the study results of pylon foundation type for the main bridge. Alternative 3, SPSP, was selected from among the alternatives. For the truss bridge, SPSP would also be applied since the bridge scale is almost the same and other conditions are similar. For the steel-box with orthotropic deck, SPSP would also be applied considering the investigation results of the approach bridge foundation described in Section 5.5.3.

Table 5.4.4 Comparison of Pylon Foundation Alternatives (for Suspension Bridge, S=510m)

	Case 1 Hypostyle Foundation (Cast in situ Pile D=2.5m)	Score	Case 2 Open Caisson	Score	Case 3 Steel Pile Sheet Pile (Steel Pile D=1.2m)	Score
Outline Drawing		—		—		—
Cost	Item / Cost (Ratio) Concrete for Pile cap 0.613 Cast in situ Pile 0.817 Total Cost **1.430**	△	Item / Cost (Ratio) Top Slab 0.136 RC Caisson 1.887 Total Cost **2.023**	△	Item / Cost (Ratio) Top Slab 0.107 Steel Piles 0.893 Total Cost **1.000**	○
Landscape Aesthetics	• Pile cap to be exposed above water level is large. Rust protection for steel casing pipes are required for maintaining good aesthetics.	△	• Top slab to be exposed above water level is small. Rust protection is not necessary.	○	• Steel sheet piles are exposed above water level, thus rust protection is essential to maintain good aesthetics.	△
Structural Features	• Analysis is based on elastic foundation of which length is semi-infinite. Due to the longer salient length of pile, non-linear characteristics should be considered. • Steel casing is neglected from Cross-section calculation.	○	• Analysis is based on elastic foundation of which length is finite. Vertical loads are supported by subgrade reaction, and horizontal loads are supported by subgrade and surrounding soil reactions. • Caisson should be filled with certain material, which works for stabilization of the caisson.	○	• Analysis is based on finite length of elastic foundation. Sheet pile is composed of concrete filled steel piles connected by low rigidity joints. • Shear plates and studs are used for connection between steel piles and top slab, and transmit working loads thereof.	△
Construction Workability	• Precast formwork can facilitate construction of pile cap on water. • Expertise in pile construction (excavation and stabilization of bore hole) is required.	△	• Soft soil at riverbed shall be improved for stability of filled coffer dam and for avoiding over-settling of caisson. • Countermeasure against river pollution are required due to vast amount of excavation.	△	• Steel pile should be connected by welding on river. • Joints are likely to be stuck if bearing stratum is boulder or rock. In that case, countermeasures are necessitated.	△
Maintenance	• Maintenance work for aesthetics is necessary.	△	Good in maintenance workability.	○	Maintenance work for aesthetics is necessary.	△
Environmental Feature	• Environmental protection measures for surplus excavated material and discharging water are necessary.	△	• River pollution is a considerable risk due to vast amount of excavation and filling of coffer dam with material so as to stabilise it.	△	• Less surplus excavation material is produced.	○
Appraisal	inferior in cost. Little allowance for bearing resistance of foundation.	△	Inferior in cost, construction workability and environmental feature.	△	Superior in structural feature and cost.	◎

Note) ◎:Superior ○:normal △:Inferior

(2) Anchorage Foundation

The following foundation alternatives are lined up considering the loading scale (center span: from approx. 500m to 600m), the construction condition (Water depth of constructed area: from approx. 5m to 7m, winter concreting etc.) and the foundation condition (Depth of bearing layer: approx. 35m from river bed, Sapropel).

The investigation was carried out for the foundations within the river and on land separately.

1) Alternative 1: Open Caisson
2) Alternative 2: SPSP Foundation

The stability calculations for the anchorage foundation revealed the following.

- Open Caisson foundations with the same dimensions as SPSP foundations would not be stable.

(Calculated eccentricity of resultant force (Be=14.1m) exceeds allowable value (Ba=8.0m)

- SPSP foundation is suitable rather than Open-caisson foundation because of presence of thick soft soil layer

Therefore the SPSP foundation should be selected for the foundation of the Anchorage.

5.4.5 Evaluation of Main Bridge Structure

(1) Evaluation Method

Evaluation of the alternatives was carried out by AHP (Analytic Hierarchy Process) method. (Refer **Appendix 5: Priority Ordering Method for Bridge Type Selection)**

(2) Attributes for Bride Type Selection

the following attributes were selected for bridge type evaluation by AHP

a) Construction cost
b) Navigation safety
c) Merit for Ukraine: environmental effects, technical transfer and use of Ukrainian resources.
d) Aesthetic features
e) Construction difficulty
f) Maintenance cost

(3) Scale of Relative Importance

Scale of relative importance used in the AHP is shown in Table 5.4.5.

Table 5.4.5 Scale of Relative Importance

1	A is equal to B
3	A is slightly more important or favorable than B
5	A is considerably important or favorable than B
7	A is strongly more important or favorable than B
9	A is extremely more important or favorable than B
2,4,6,8	Intermediate intensities between above numbers

(4) Weight for Attributes

Weights for attributes were determined as follows.

Table 5.4.6 Weights for Attributes

	Construction cost	Navigation safety	Merit for Ukraine	Aesthetic features	Construction difficulty	Maintenance cost	Multiple mean
Construction cost	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**2.994**
Navigation safety	**0.50**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	**1.258**
Merit for Ukraine	**0.33**	**0.50**	**1.00**	**2.00**	**3.00**	**4.00**	**1.258**
Aesthetic features	**0.25**	**0.33**	**0.50**	**1.00**	**2.00**	**3.00**	**0.792**
Construction difficulty	**0.20**	**0.25**	**0.33**	**0.50**	**1.00**	**2.00**	**0.505**
Maintenance cost	**0.17**	**0.20**	**0.25**	**0.33**	**0.50**	**1.00**	**0.335**
Total	**2.45**	**4.28**	**7.08**	**10.83**	**15.50**	**21.00**	**7.862**
Weight	**0.38**	**0.25**	**0.16**	**0.10**	**0.06**	**0.04**	**-**

(5) Pair wise Matrix between bridge Type and Attribute-table

(a) Construction Cost

Estimated construction costs are tabulated in Table 5.4.7

Table 5.4.7 Construction Cost

	Ratio of Cost	Remarks
Suspension Br.	1.075	
Cable-stayed Br.	1.000	
Truss Br.	1.312	
Steel box girder	0.666	For reference only

Pair-wise matrix for “construction cost” based on above estimation is as follows.

Table 5.4.8 Pair-wise Matrix for "Construction Cost"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	0.50	3.00	0.20	0.740
Cable-stayed Br.	2.00	1.00	4.00	0.25	1.189
Truss Br.	0.33	0.25	1.00	0.14	0.328
Steel box girder	5.00	4.00	7.00	1.00	3.44
Total	8.33	5.75	15.00	1.59	5.697
Priority	0.13	0.21	0.06	0.80	-

(b) Navigation Safety

Pair-wise matrix for "navigation safety" is as follows.

Table 5.4.9 Pair-wise Matrix for "Navigation Safety"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	2.00	3.00	7.00	2.546
Cable-stayed Br.	0.500	1.00	2.00	6.00	1.565
Truss Br.	0.33	0.50	1.00	5.00	0.953
Steel box girder	0.14	0.17	0.20	1.00	0.263
Total	1.97	3.67	6.20	19.00	5.327
Priority	0.48	0.29	0.18	0.05	-

(c) Merit for Ukraine

Pair-wise matrix for "merit for Ukraine" is as follows.

Table 5.4.10 Pair-wise Matrix for "Merit for Ukraine"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	2.00	3.00	5.00	2.340
Cable-stayed Br.	0.500	1.00	2.00	3.00	1.316
Truss Br.	0.33	0.50	1.00	2.00	0.758
Steel box girder	0.20	0.33	0.50	1.00	0.426
Total	2.03	3.83	6.50	11.00	4.841
Priority	0.48	0.27	0.16	0.09	-

(d) Aesthetic Features

Pair-wise matrix for "aesthetic features" is as follows.

Table 5.4.11 Pair-wise Matrix for "Aesthetic Features"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	3.00	7.00	5.00	3.201
Cable-stayed Br.	0.33	1.00	5.00	3.00	1.492
Truss Br.	0.14	0.20	1.00	0.33	0.310
Steel box girder	0.20	0.33	3.00	1.00	0.667
Total	1.67	4.53	16.00	9.33	5.670
Priority	0.56	0.26	0.05	0.12	-

(e) Construction Difficulty

Pair-wise matrix for "construction difficulty" is as follows.

Table 5.4.12 Pair-wise Matrix for "Construction Difficulty"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	1.00	5.00	3.00	1.968
Cable-stayed Br.	1.00	1.00	5.00	3.00	1.968
Truss Br.	0.20	0.20	1.00	0.33	0.339
Steel box girder	0.33	0.33	3.00	1.00	0.756
Total	2.53	2.53	14.00	7.33	5.031
Priority	0.39	0.39	0.07	0.15	-

(f) Maintenance Cost

Pair-wise matrix for "maintenance cost" is as follows.

Table 5.4.13 Pair-wise Matrix for "Maintenance Cost"

	Suspension Br.	Cable-stayed Br.	Truss Br.	Steel-box	Multiple mean
Suspension Br.	1.00	1.00	2.00	0.50	1.000
Cable-stayed Br.	1.00	1.00	2.00	0.50	1.000
Truss Br.	0.50	0.50	1.00	0.33	0.536
Steel box girder	2.00	2.00	3.00	1.00	1.861
Total	4.50	4.50	8.00	2.33	4.397
Priority	0.23	0.23	0.12	0.42	-

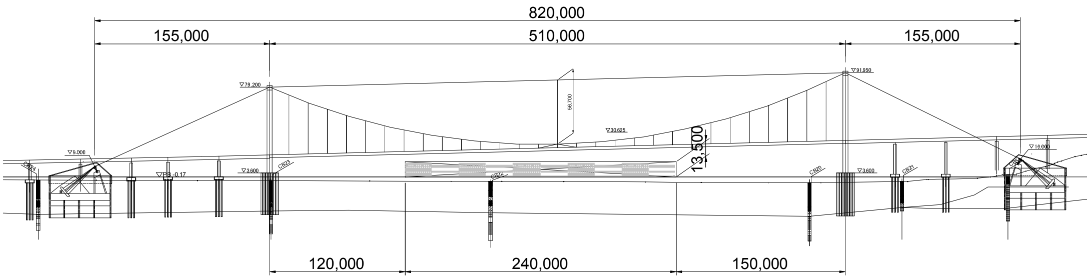
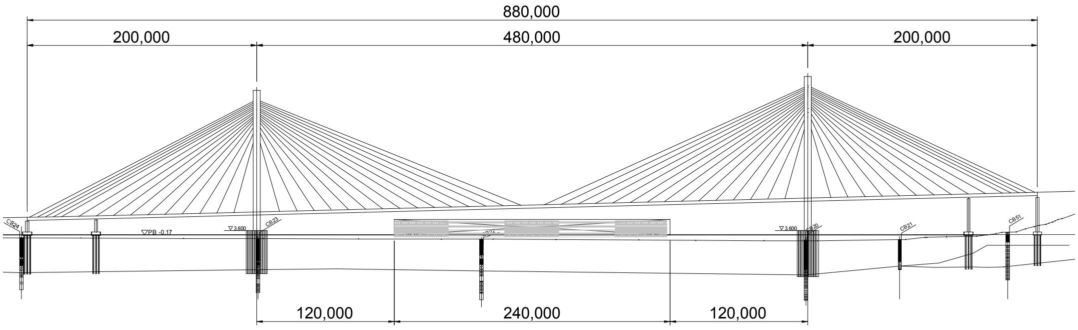
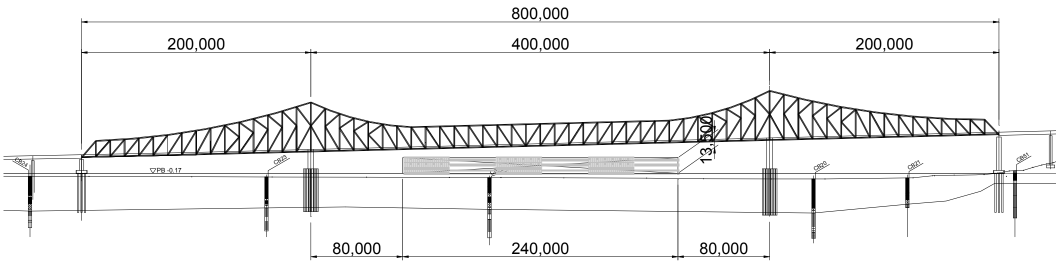
(6) Conclusions of AHP

Table 5.4.14 shows the conclusions of the "AHP".

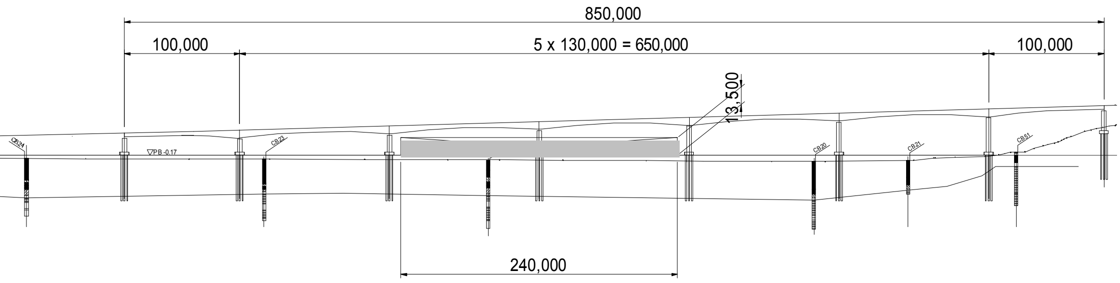
The alternative 1, i.e. Suspension bridge, has the highest-priority.

Table 5.4.14 Estimation of Priority

	Evaluation factor						Evaluated priority	
	Construction cost	Navigation safety	Merit for Ukraine	Aesthetic features	Construction difficulty	Maintenance cost	Priority	Rank
Weight	0.38	0.25	0.16	0.10	0.06	0.04		
Suspension bridge	0.13	0.48	0.48	0.56	0.39	0.23	0.34	(1)
Cable-stayed bridge	0.21	0.29	0.27	0.26	0.39	0.23	0.26	(2)
Truss bridge	0.06	0.18	0.16	0.05	0.07	0.12	0.11	(3)
Referential alternative								
Steel-box bridge	0.60	0.05	0.09	0.12	0.15	0.42	0.30	-

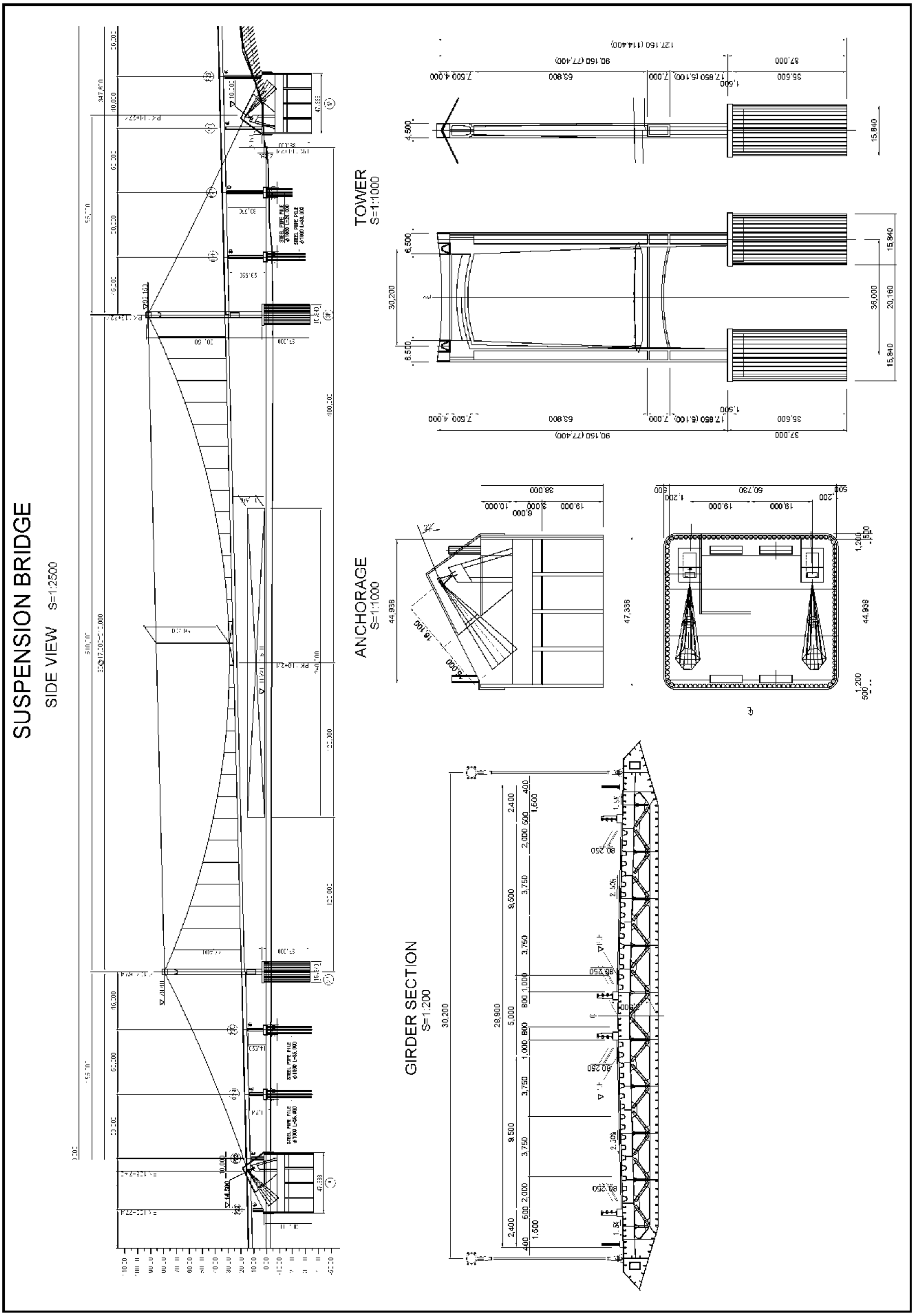
	Side View
Plan A: Suspention Bridge	Navigation channel: 240m x 1 Safety margin: 120m + 150m 
Plan B: Cable Stayed Bridge	Navigation channel: 240m x 1 Safety margin: 120m x 2 
Plan C: Steel Truss Bridge	Navigation channel: 240m x 1 Safety margin: 80m x 2 

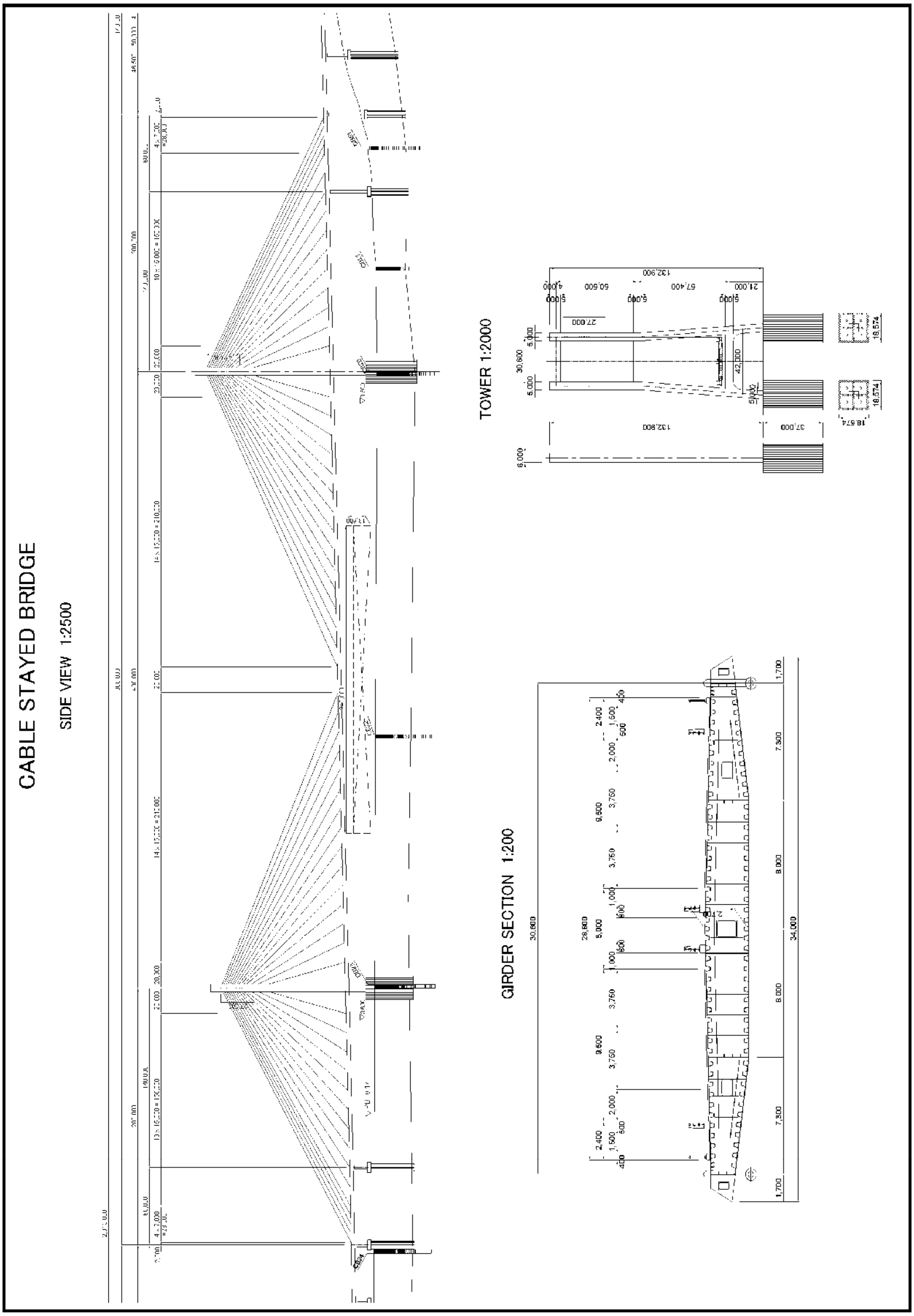
Comparison of the Plans (constant bridge length comparison inclusive of Main Bridge and Approach Bridge)			
Plan A: Suspension Bridge	Construction Prime Cost (Ratio)	Main Br./ Superstructure (Girder, cable, tower) 0.348 Main Br./ Substructure (Foundation, anchorage) 0.293 Approach Br. (L=1540m) 0.390 Temporary bridge for construction 0.044 Total (Ratio):1.075	○
	Landscape Aesthetics	- Catenary curves of main cable stretch eyesight horizontally, and create visual comfort. - Aesthetic design is applicable to towers of cable stayed bridge as a symbolic landmark.	◎
	Structural Features	- The widest safety margin for navigation channel of all the plans. - Flat-hexagonal steel-box is adopted for improving wind-resistance stability and maintenance workability. - Steel pipe Sheet Pile foundation is adopted to conquest soft and deep subsoil features of riverbed.	○
	Construction Method	- Stiffening girders transported beneath the bridge by vessel are erected using lifting beam. - Use of slip form for RC tower enables reduction of construction period.	○
	Maintenance	- Periodical repaint is required for stiffening girders.	○
	Appraisal		○
Plan B: Cable Stayed Bridge	Construction Prime Cost (Ratio)	Main Br./ Superstructure (Girder, cable, tower) 0.560 Main Br./ Substructure (Foundation, Pier) 0.107 Approach Br. (L=1170m) 0.295 Temporary bridge for construction 0.038 Total (Ratio):1.000	○
	Landscape Aesthetics	- Aesthetic design is applicable to towers of cable stayed bridge as a symbolic landmark.	○
	Structural Features	- The design width of navigation channel can be reserved for 120m of safety margin against cramped requirement width of 240m. - Flat-hexagonal steel-box is adopted for improving wind-resistance stability and maintenance workability. - Steel pipe Sheet Pile foundation is adopted to conquest soft and deep subsoil features of riverbed.	○
	Construction Method	- Cantilever erection method is suitable for construction of superstructure. - Use of slip form for RC tower enables reduction of construction period.	○
	Maintenance	- Periodical repaint is required for stiffening girders.	○
	Appraisal		○
Plan C: Steel Truss Bridge	Construction Prime Cost (Ratio)	Main Br./ Superstructure (main truss, lateral bracing, cross beam, etc) 0.878 Main Br./ Substructure (Foundation, Pier) 0.082 Approach Br. (L=1250m) 0.316 Temporary bridge for construction 0.036 Total (Ratio):1.312	△
	Landscape Aesthetics	- Vexatious complication of members over the carriageway sometimes give oppressive feeling to road users.	△
	Structural Features	- Main span length (400m) is determined referring to empirical & applicable span length for this bridge type, and 80m of clearance between pier and navigation is reserved for safety margin. - Use of high-strength steels (TH690 & HT780), which is not necessary for other plans, are required. - Huge gross weight of steel is required due to the magnitude of main span with 4 lane carriageway, thus adoption of this bridge type is out of economical range.	△
	Construction Method	- Although Cable erection method or Floating-crane erection method will be selected. - Inferior in construction workability due to that the gross weight of members is larger than other plans.	△
	Maintenance	- Inferior in maintenance works due to vast number of structural member for superstructure - Icicle on structural members over carriageway should be treated for avoiding car accidents.	△
	Appraisal	Inferior in the aspects of construction cost, structural features, and maintenance facility.	△

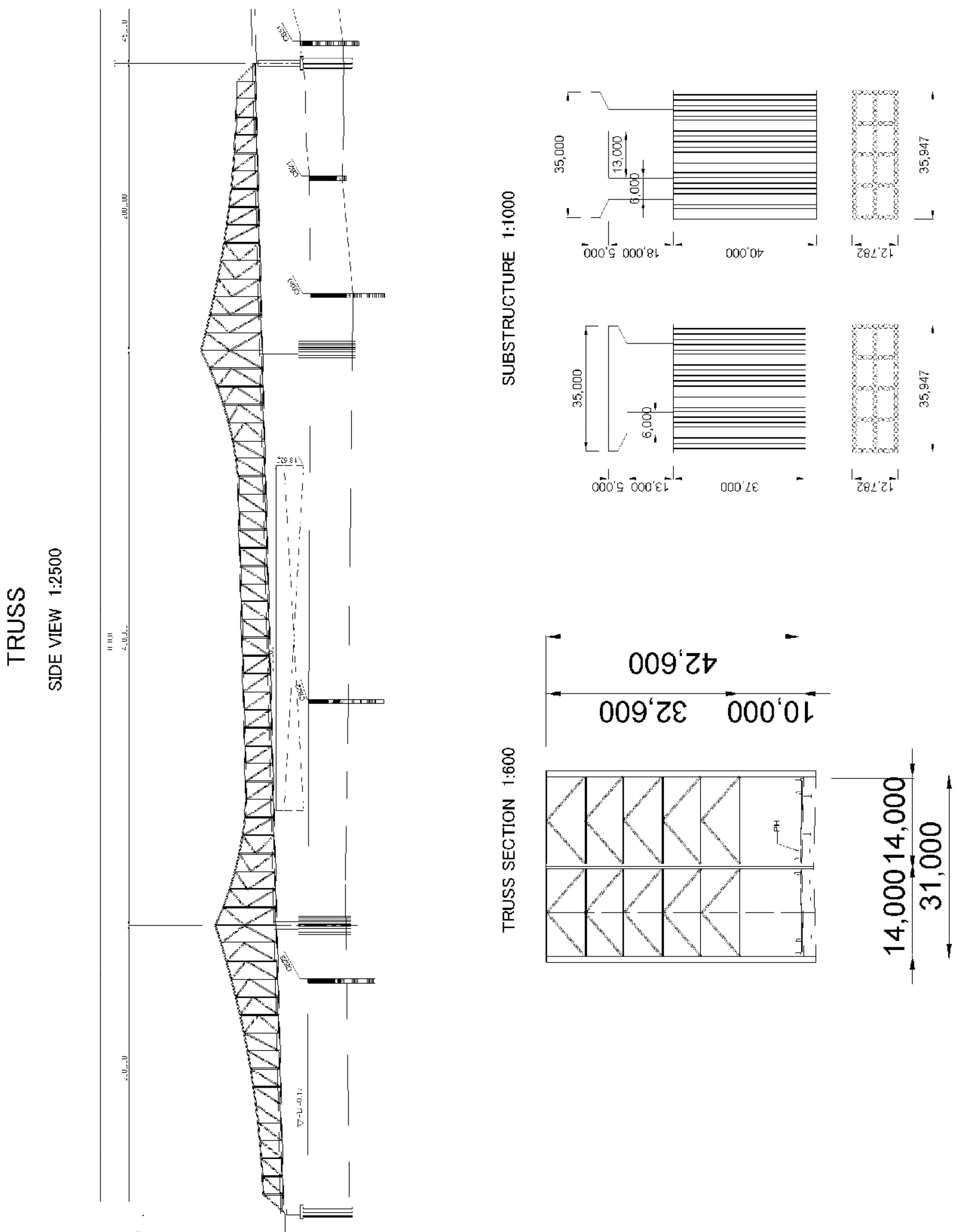
	Side View
Reference : Steel-box girder Bridge	Navigation channel: 120m x 2 Safety margin: little 

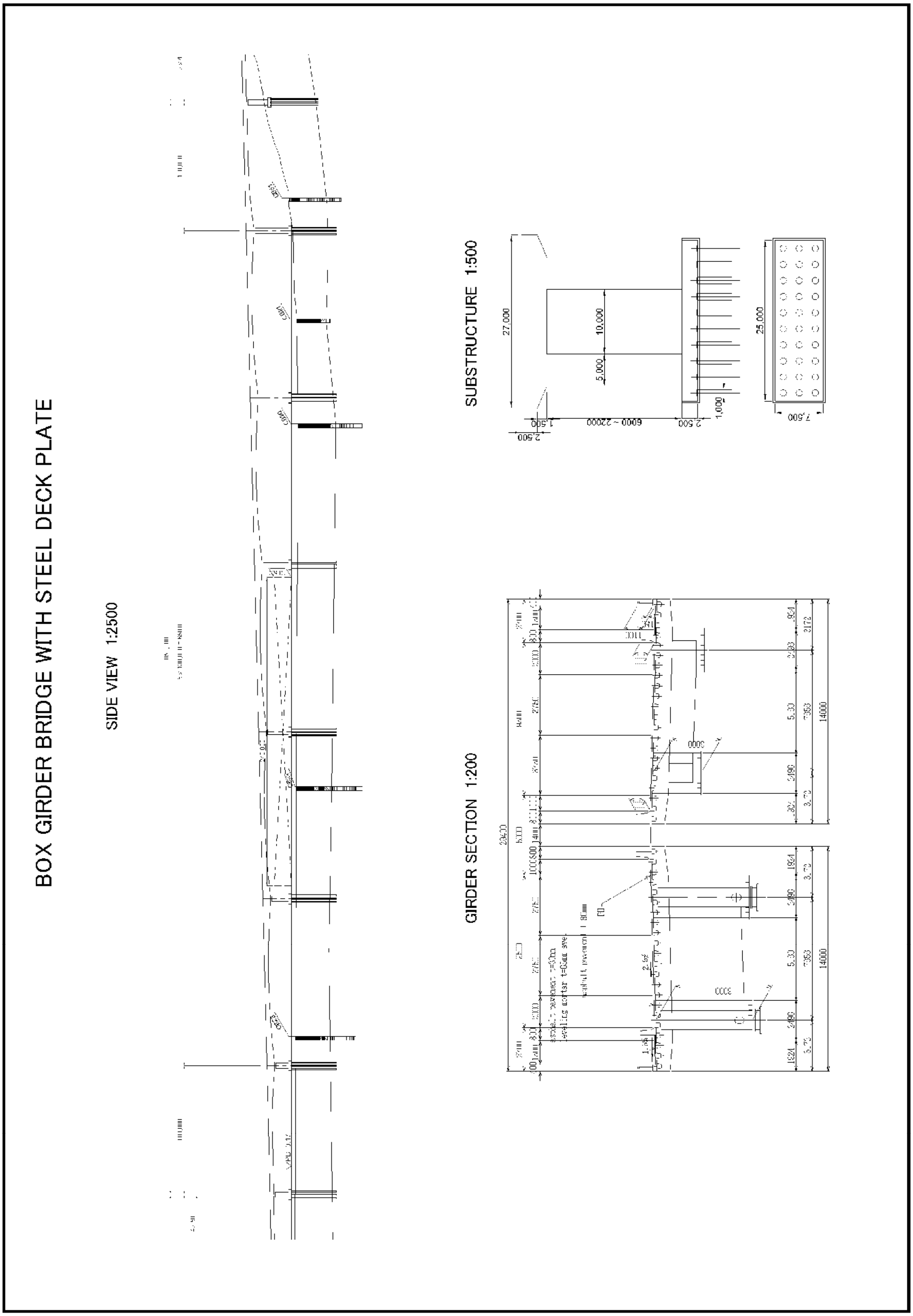
Comparison of the Plans (constant bridge length comparison inclusive of Main Bridge and Approach Bridge)			
Reference: Steel-box girder Bridge	Construction Prime Cost (Ratio)	Main Br./ Superstructure 0.283 Main Br./ Substructure (Foundation, Pier) 0.043 Approach Br. (L=1200m) 0.302 Temporary bridge for construction 0.038 Total (Ratio):0.666	◎
	Landscape Aesthetics	Ordinary bridge aspect, not to be a symbolic figure.	△
	Structural Features	- Intermediate pier in 240m-navigation channel is necessary due to the applicable max. span for this type of bridge. - Risk of vessels colliding with pier in navigation channel is concerned. - Hypostyle foundation with steel piles is selected in terms of magnitude of working loads and soft subsoil features.	△
	Construction Method	Procurement of Floating-crane (FC) is the key to construction (erection) of superstructure. If the FC can not be procured, construction costs would increase.	△
	Maintenance	Periodical repainting for steel girder is required.	○
	Appraisal	Risk of collision with pier negates positive aspects of the bridge type.	△

Note) ◎ : Superior ○ : Normal △ : Inferior


SUSPENSION BRIDGE
SIDE VIEW S=1:2500
TOWER
S=1:1000
ANCHORAGE
S=1:1000
GIRDER SECTION
S=1:200


CABLE STAYED BRIDGE
SIDE VIEW 1:2500
TOWER 1:2000
GIRDER SECTION 1:200


TRUSS
SIDE VIEW 1:2500
SUBSTRUCTURE 1:1000
35,000
13,000
6,000
18,000 5,000
40,000
12,782
35,947
35,000
6,000
13,000 5,000
37,000
12,782
35,947
TRUSS SECTION 1:600
42,600
32,600
10,000
14,000
14,000
31,000


BOX GIRDER BRIDGE WITH STEEL DECK PLATE
SIDE VIEW 1:2500
SUBSTRUCTURE 1:500
GIRDER SECTION 1:200

The construction outline of the superstructure and the SPSP

● **Suspension bridge**

(7) Construction Method

The suspension bridge construction method is briefly described according to the major superstructure components of 1) tower works, 2) cable works and 3) stiffening girder works. The explanatory execution step diagrams are shown on the next page.

1) Tower works

- Concerning the tower execution procedure, as is shown in Step 1, it is planned to adopt the tower crane method following completion of the foundation works.
- The tower crane method involves installing a tower crane totally independent of the tower and building the tower with site-cast concrete from this.
- The concrete frame is constructed using a sliding form.
- At the same time as building the tower in Step 1, a tower crane is installed and the abutment (anchorage) cable anchor frame is installed in preparation for the cable installation works.

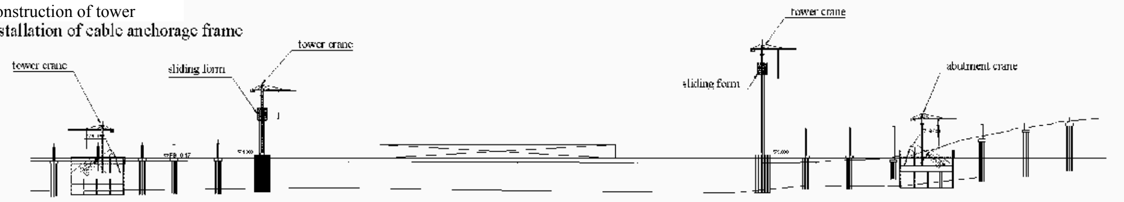
2) Cable works

- Concerning the cable construction method, as is shown in Step 2, following completion of the tower and installation of equipment on top of the tower, the cable preparation works are implemented.
- The cable works are broadly divided into the capable preparation works and the main cable works.
- The cable preparation works mainly comprise tacking the wire rope, installing the hauling system for drawing out the cable, and installing the catwalk, which is the scaffold for carrying out the cable placement work.
- As is shown in Step 3, the main cable execution procedure is carried out following completion of the cable preparation works.
- The main cable is installed by the air spinning (AS) method. The AS yard is located on the right bank and cables are erected going from the right bank to the left.
- The AS method, which entails spinning one cable wire at a time on-site overhead, is by far the most commonly adopted method on major suspension bridge projects overseas.

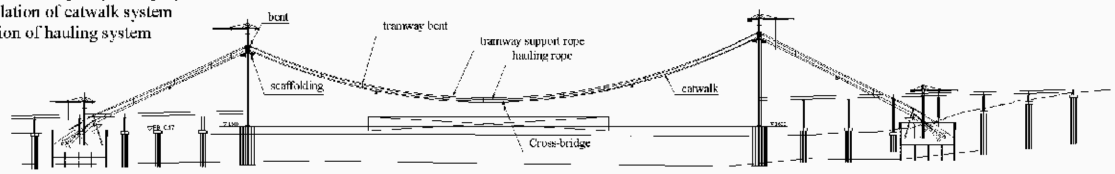
3) Stiffening girder works

- As is indicated in Steps 4 and 5, stiffening girders are directly suspended using a lifting device. Also referred to as the lifting crane method, this approach is a unique method for suspension bridges that entails using the existing main cable to place erection blocks that are carried on the river by barge.
- The assembly yard for the girder erection blocks is established near to the erection point.
- Erection blocks are transported using a barge to the place directly below the suspension point.
- In areas where the barge cannot approach close to the tower, the swing method is adopted. This entails moving the erection blocks in mid-air to the designated position through alternately suspending them from the lifting beam (the main erection machinery in the direct suspension method) and the temporary hanger rope.
- The side spans are constructed by the same method as the approach bridge.

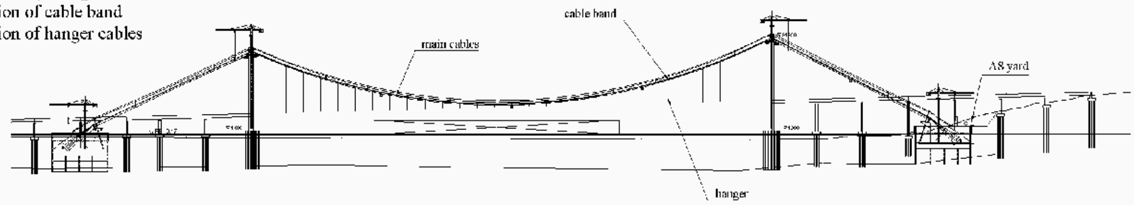
STEP-1
Construction of tower
Installation of cable anchorage frame



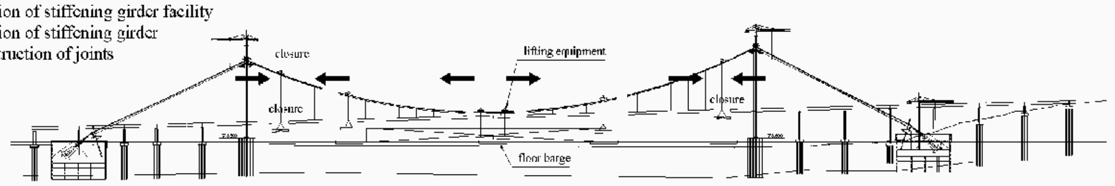
STEP-2
Installation of facilities and saddle for the tower top
Installation of gantry and spray saddle
Installation of catwalk system
Erection of hauling system



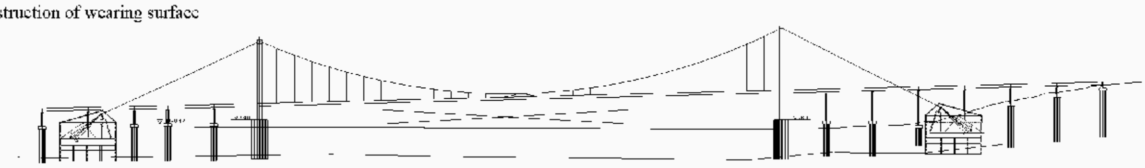
STEP-3
Installation of AS-facilities
Installation of main cables(AS-method)
Cable compacting
Erection of cable band
Erection of hanger cables



STEP-4
Erection of stiffening girder facility
Erection of stiffening girder
Construction of joints



STEP-5
Cable wrapping
Installation of accessories
Removal of catwalk
Construction of wearing surface



● **Cable stayed bridge**

(8) Construction Method

The cable-stayed bridge construction method is briefly described according to the major components of 1) pylon works and 2) girder and cable works. The explanatory execution step diagrams are shown on the next page.

1) Pylon works

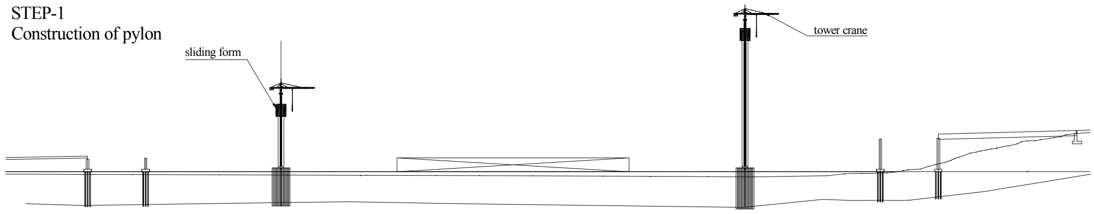
The construction procedure for the pylons is the same as for the towers described for suspension bridges.

- As is indicated in Step 1, following completion of the foundation works, it is planned to use the tower crane method to construct the pylons.
- The tower crane method involves installing a tower crane totally independent of the pylons and building the pylons with site-cast concrete from this.
- The concrete frame is constructed using a sliding form.

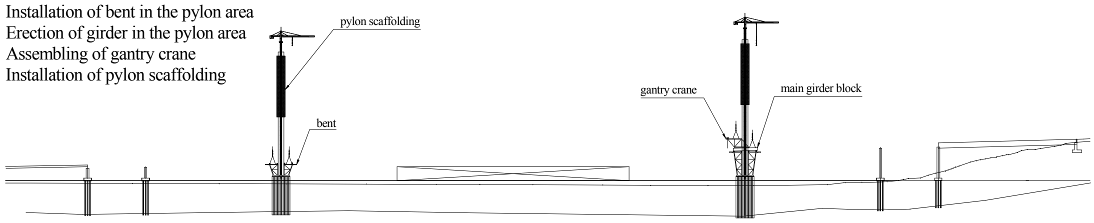
2) Girder and cable works

- Concerning the girder and cable works, the center span and side spans are constructed by the cantilever erection method starting from the pylons.
- Following completion of the pylons, as is indicated in Step 2, preparations for the girder and cable works entailing bent installation, pylon girder erection, gantry crane assembly and pylon scaffolding are carried out.
- As is indicated in Steps 3 and 4, girder erection blocks are transported using a barge and are directly suspended by gantry crane.
- The assembly yard for the girder erection blocks is established near to the erection point.
- Bridge multi-cables are used. Such cables have been widely used on cable-stayed bridges in overseas countries.
- As is shown in Steps 3 and 4, the cable placement procedure entails main girder erection → joint installation → cable placement.
- As is shown in Step 4, girder and cable installation from the pylons is closed at the central span.
- As is shown in Step 5, following closure in the central span, temporary equipment and installations are removed.

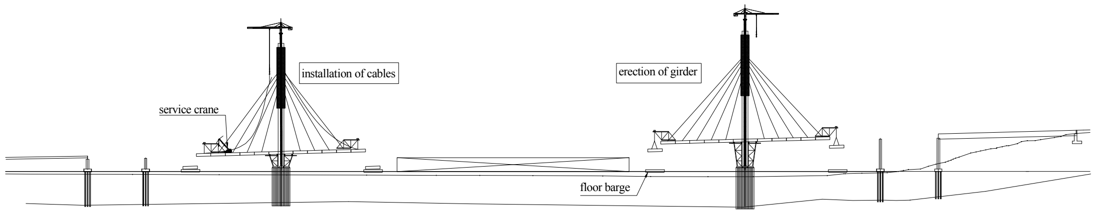
STEP-1
Construction of pylon



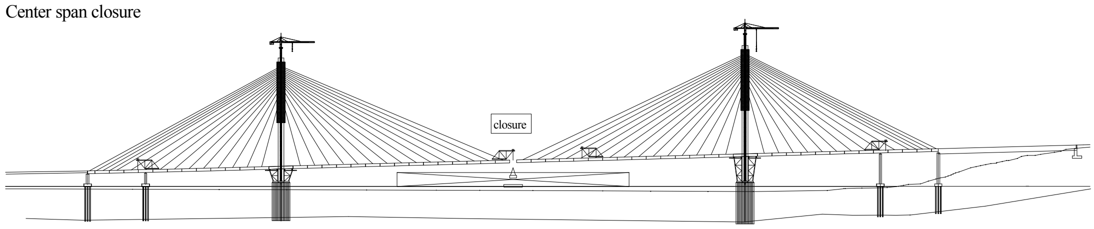
STEP-2
Installation of bent in the pylon area
Erection of girder in the pylon area
Assembling of gantry crane
Installation of pylon scaffolding



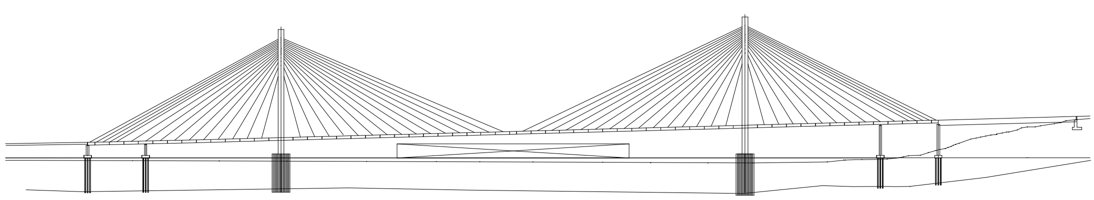
STEP-3
Cantilever construction of the center and side spans
Formation control



STEP-4
Center span closure



STEP-5
Disassembly of temporary works



●**Truss bridge**

(9) Construction Method

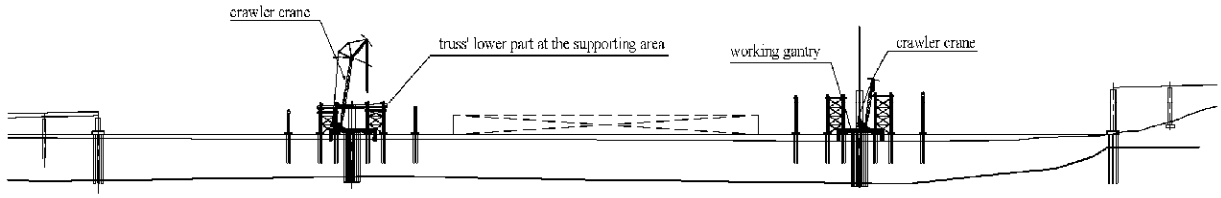
The construction method for truss bridges is briefly described below in reference to the step diagrams on the following page.

- As is shown in Steps 1 and 2, the intermediate supporting area (pier) is constructed by crawler crane upon installing the working gantries and bents.
- As is shown in Step 2, the center and side spans are constructed by the cantilever erection method upon installing the traveler crane on the bridge slab surface at the supporting area (pier).
- As is shown in Step 3, the truss bridge is constructed by assembling the steel members on site. These truss members are supplied from the supporting area (pier).
- Members that are supplied from the river are transported over the bridge slab surface under construction by carriage.
- As is shown in Step 4, the cantilever erection work is closed at the center span.
- As is shown in Step 5, following closure at the center span, the temporary equipment and installations are removed.

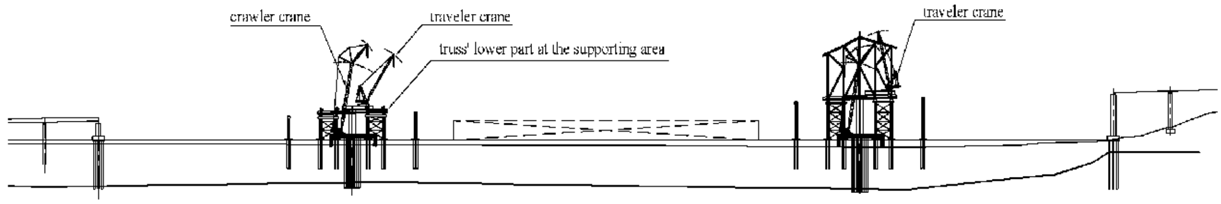
(10) Construction Issues

- Since members are assembled one at a time on-site, the construction schedule for truss bridges takes longer than for bridges that are assembled off-site.
- The large block erection method using a floating crane is also applicable but would require the procurement of a large type of floating crane and erection yard.

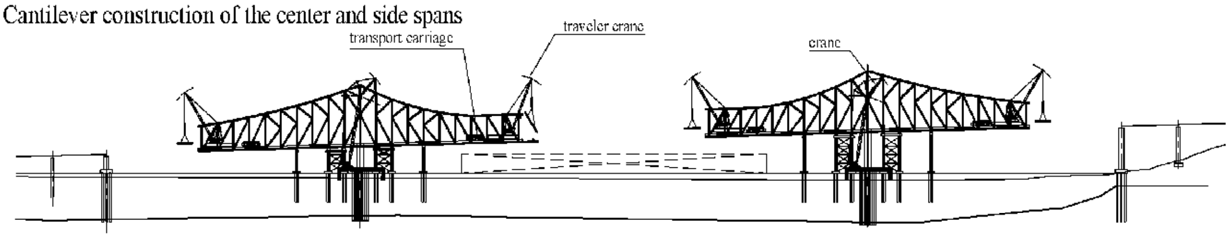
STEP-1
Installation of working gantry
Installation of bent
Erection of truss' lower part at the supporting area



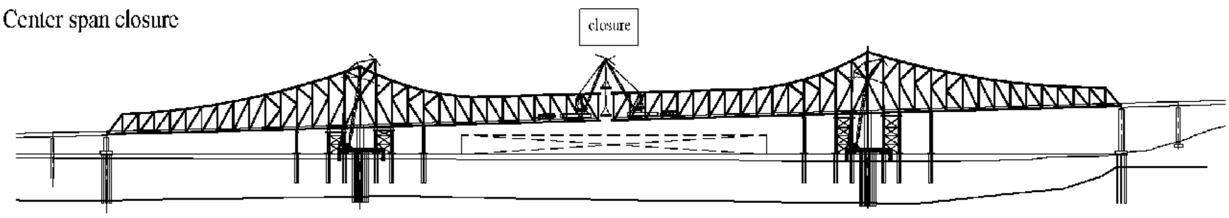
STEP-2
Assembling of traveler crane
Erection of truss' top part in the pylon area



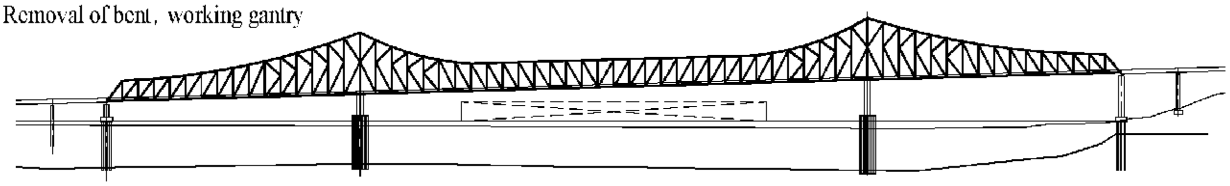
STEP-3
Cantilever construction of the center and side spans



STEP-4
Center span closure



STEP-5
Disassembly of traveler crane
Removal of bent, working gantry



● **Box girder**

(11) Construction Method

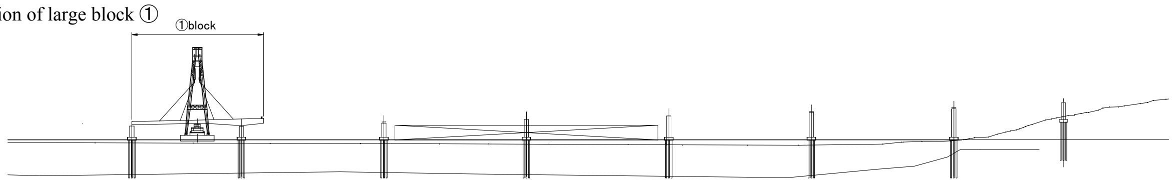
The construction method for box girder bridges is briefly described below in reference to the step diagram on the following page.

- As is shown in Steps 1, 2 and 3, in view of the characteristics of this bridge type, the large block erection method using a floating crane is used to complete one span at a time.
- As is shown in Steps 3 and 4, in places inaccessible by floating crane due to the water depth, the bent erection method using the working gantry and crawler crane is applied.
- The main equipment comprises the floating crane (suspension class 1400t~2000t).

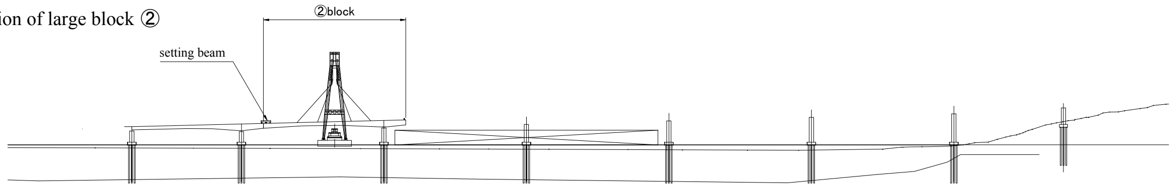
(12) Construction Issues

- It is necessary to procure a large floating crane (suspension class 1400t~2000t) during the construction period. However, large floating cranes are hard to find and suppliers are limited.
- A large assembly yard is needed to assemble a span of box girders, so temporary installation expenses are more expensive than in other bridge types.

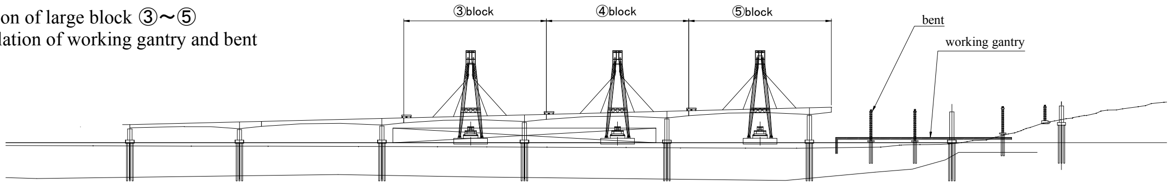
STEP-1
Erection of large block ①



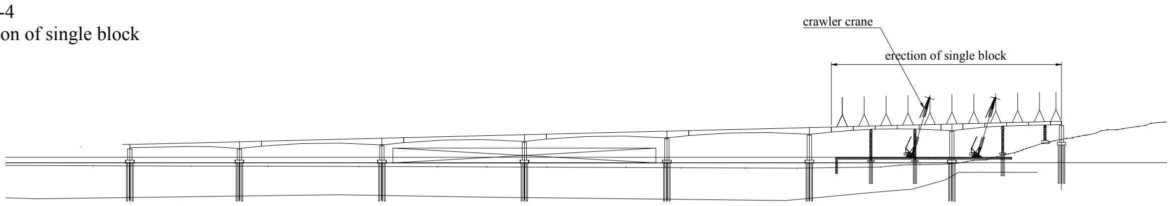
STEP-2
Erection of large block ②



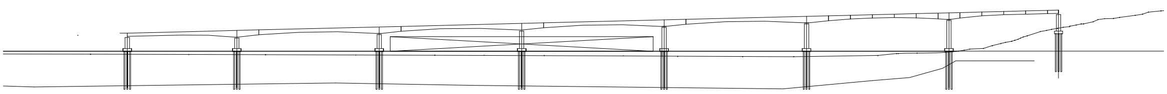
STEP-3
Erection of large block ③～⑤
Installation of working gantry and bent



STEP-4
Erection of single block



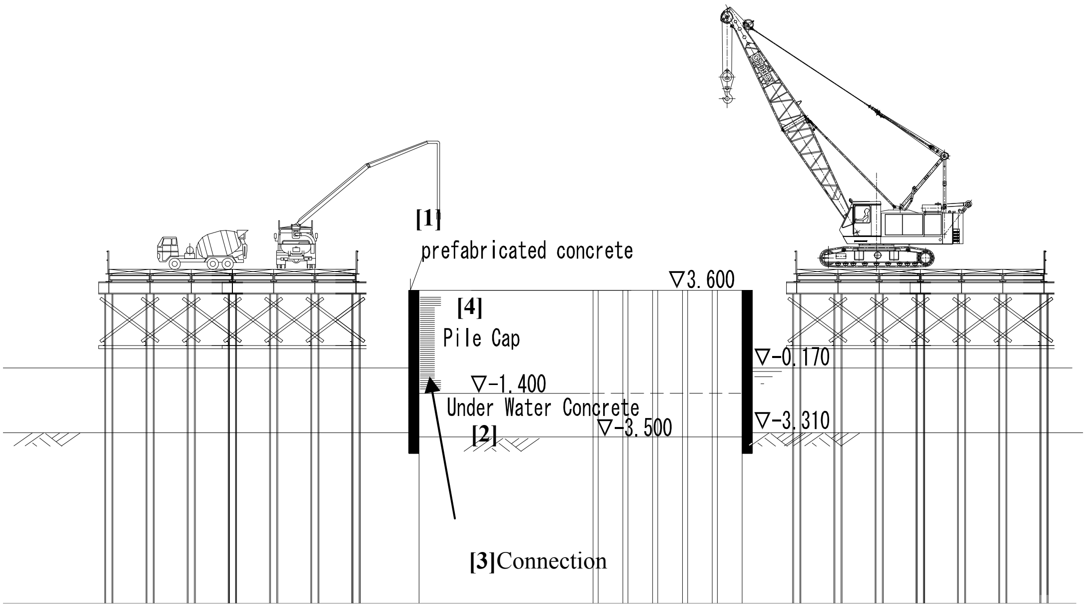
STEP-5
Removal of bent，working gantry



● **Construction outline of SPSP Foundation**

Construction steps are generally as follows:

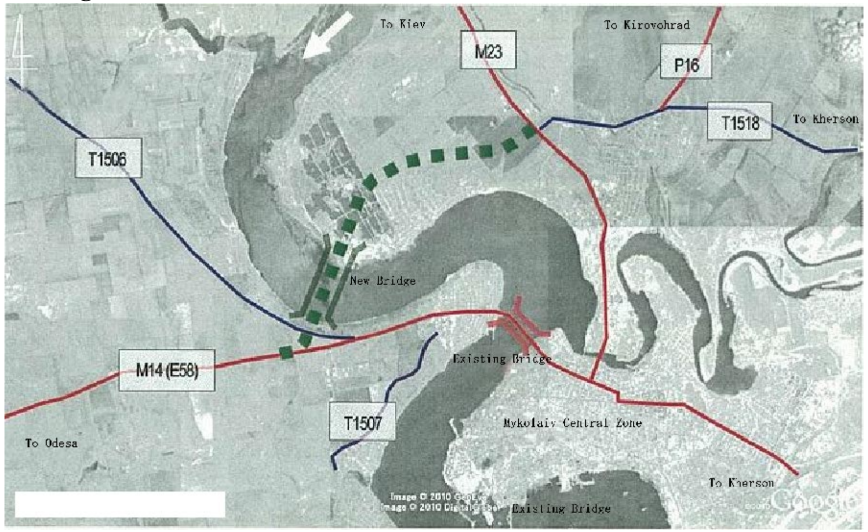
1) Driving of H-shaped guide steel from the working gantry and construction of the guide frame
2) Driving of SPSP Foundation (Vibro-pile drive using jetting, driving pile)
3) Excavation of river bed in the caisson using a pump in the water (EL-3.5m)
4) Installation of prefabricated concrete [1] preventing corrosion and mortar leakage along the Steel Pipe Sheet pile.
5) Welding of the angle members to the joints in the water preventing mortar leakage within the SPSP
6) Excavation and cleaning of joint pipe. Filling mortar into the joints.
7) Casting concrete inside the sheet piles by pumper truck (up to EL-3.6m)
8) Casting concrete (antiwashout under water concrete [2]) for pile caps
9) Start draining concurrently with monitoring for deformation of sheet pile
10) Connection of top slab [3]. For sheet pile, stiffening is not used.
11) Rebar arrangement for top slab and tower leg.
12) Casting concrete for top slab using pumper truck.



Construction Planning for SPSP Foundation

Study of Landscape Aesthetics for Mykolaiv Bridge
Landscape Characteristics and Essential Points for its Design

◆**Bridge Location**



◆**View of the bridge location**

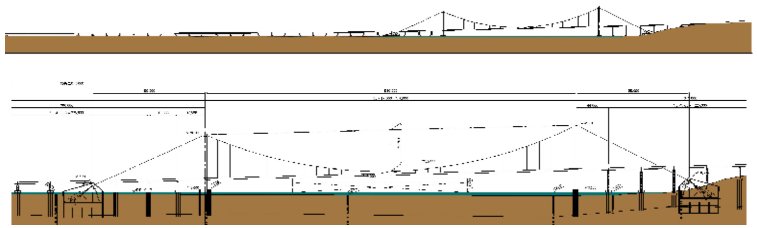
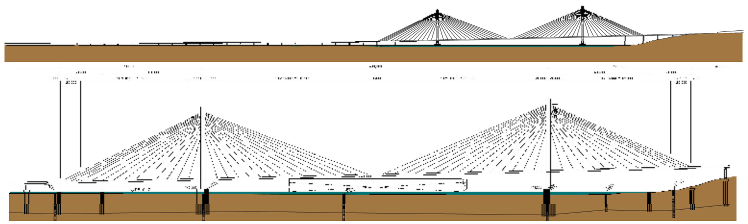
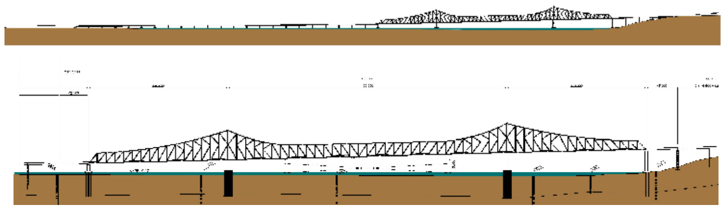
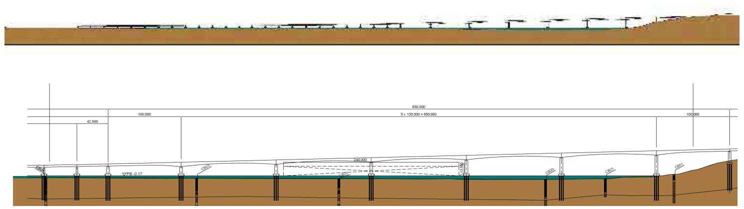
◆**Landscape Characteristics of MYKOLAIV Bridge**

- The planned bridge is located on a flat geologic formation with terrain that is flat and open.
- With the exception of some chimney pipes of factories seen on the left riverbank, there aren't many remarkably high buildings in the area.
- The planed road connects flat land on left bank and hilly land on right thereof with the road gradient of 2.5%. Due to such a road alignment plan, the difference in elevation as a consequence of relatively longer constant-gradient will be visually enhanced.
- Visibility of the main bridge from downtown Mykolaiv city could be difficult because of the S-shaped river and the distance from the downtown (5km).

◆**Essential Points of Landscape Architecture for MYKOLAIV Bridge**

- To harmonize the wide-open flat land with the bridge in terms of visual balances in the scenery.
- To assume the function of a landmark not only for road users but for passengers on the river.
- To blend in the rectilinear silhouette of the bridge side view, its alignment of 2.5% should coincide with the gradient of the landscape.
- To select the bridge type, to which application of landscape illumination is effective, so as to make it a landmark of the region.

Bridge Type Comparison with respect to Landscape Aesthetics

	Side View of overall Bridges and Main Bridge		Evaluation	
1			• The height of towers and total silhouette of the bridge are of a preferable magnitude in terms of balance of the artificial structure against the flat and open landscape. • The superstructure divides the side view of the towers with a preferable ratio. Additionally, the outline of the bridge is wrapped with the catenary curve of the main cable, which can harmonize with the rectilinear silhouette of the bridge side view.	◎
2			• As shown in the side view illustration, the height of the towers is outstanding and does not harmonize with the flat and open landscape. Moreover, the huge tower (hill side) adjacent to the hill gives a coercive impression. • The stay cables' rectilinear silhouette fails to augment the road gradient in a pleasant manner. Moreover, the narrower space beneath the girder of the main bridge spoils the beauty which a cable stayed bridge is associated with.	△
3			• Although the scale of the trusses, such as structural height, is adequate, this plan gives a heavy image due to the complicated components of the superstructure. • The truss bridge is composed of vast members, such that its silhouette gives a quite massive image. The rectilinear road alignment is enhanced accordingly.	△
—			• The silhouette of the bridge is simple and rectilinear, such that this plan can be said to be harmonized. However, this plan doesn't have a symbolic image. • Due to the evenly arranged spans of the main bridge with the plane structure, this plan doesn't have visual advantages to enable recognition of the navigation channel from far.	○

5.5 Approach Bridge Type

5.5.1 Selection of Superstructure Type

The economic and rational bridge types for middle-scale girders shown in Figure 5.5.1 are investigated for application in the span range from 30m to 60m.

The optimum span length which minimizes the total construction cost of the super- and sub-structures is estimated.

For the approach bridge, the separated structure in both directions is applied in consideration of constructability and cost.

Alternative 1	Alternative 2	Alternative 3	Alternative 4

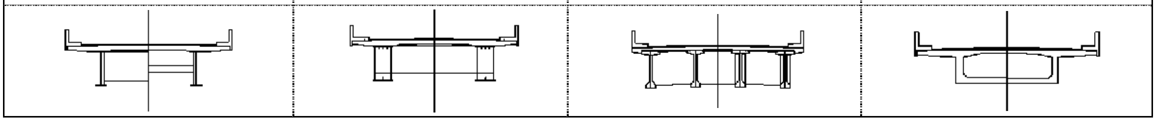


Figure 5.5.1 Alternatives for Approach Bridge

1) Alternative 1 : Steel I-girder type with prestressed concrete slab
2) Alternative 2 : Steel box-girder type with prestressed concrete slab
3) Alternative 3 : Prestressed concrete I-girder type
4) Alternative 4 : Prestressed concrete box-girder type

5.5.2 Selection of Substructure Type

As regards the substructure type of the approach bridge, the T-shaped pier, which is the most popular type for the medium scale spans, was applied.

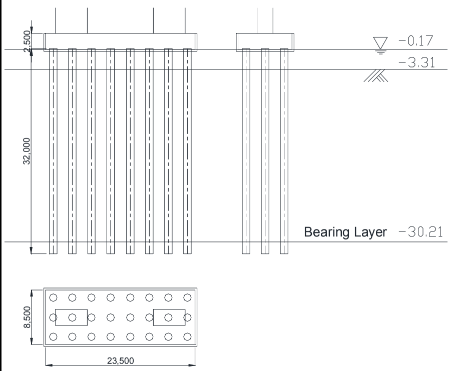
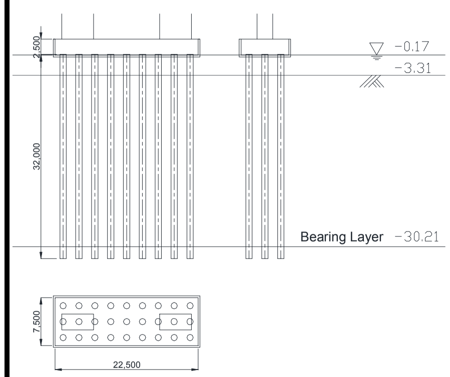
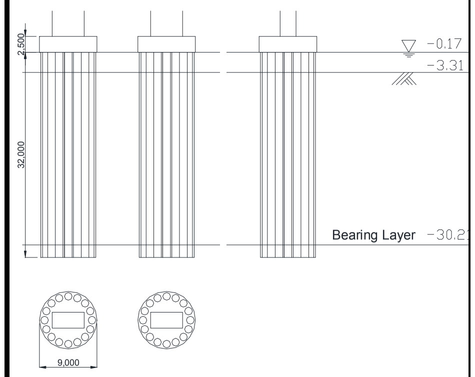
5.5.3 Selection of Foundation Type

The following foundation alternatives were lined up considering the loading scale (span: from approx. 30m to 60m), the construction condition (Water depth of constructed area: from approx. 1m to 3m, winter concreting etc.) and the foundation condition (Depth of bearing layer: approx. 35m from river bed, Sapropel).

1) Alternative 1: Cast in Place Pile Foundation
2) Alternative 2: Steel Pipe Pile Foundation
3) Alternative 3: Steel Pipe Sheet Pile Foundation (SPSP)

Table 5.5.1 shows the results of the evaluation of the optimum approach bridge foundation type. Alternative 2, the Steel Pipe Pile Foundation was selected because of followings.

- SPSP foundation type has advantage in economic efficiency rather than other foundation types.
  SPSP foundation type can minimize diffusion of the settled soft soil (sapropel).

	Case 1 Hypostyle Foundation (Cast in situ Pile D=1.2m)	Score	Case 2 Hypostyle Foundation (Steel Pipe Pile D=1.0m)	Score	Case 3 Steel Pile Sheet Pile (Steel Pile D=1.2m)	Score
Outline Drawing		—		—		—
Cost	Item / Cost (Ratio) Concrete for Pile 0.497 Cast in situ Pile 1.060 Total Cost 1.557	△	Item / Cost (Ratio) Concrete for Pile 0.424 Steel Pile 0.576 Total Cost 1.000	○	Item / Cost (Ratio) Top Slab 0.167 Steel Piles 1.950 Total Cost 2.117	△
Landscape Aesthetics	• Pile cap to be exposed above water level is large. Rust protection for steel casing pipes are required for maintaining a good	△	• Pile cap to be exposed above water level is large. Rust protection for steel pipes are required for maintaining a good aesthetics.	△	• Steel sheet piles are exposed above water level, thus rust protection is required for maintaining a good aesthetics.	△
Structural Features	• Analysis is basing on elastic foundation of which length is semi-infinite. Due to the longer salient length of pile, non-linear characteristics should be considered. • Steel casing is neglected from Cross-section calculation.	○	• Analysis is basing on elastic foundation of which length is semi-infinite. Due to the longer salient length of pile, non-linear characteristics should be considered. • Corrosion thickness of steel pipe is considered for Cross-section calculation.	○	• Analysis is basing on finite length of elastic foundation. Sheet pile is composed with concrete filled steel piles connected by low rigidity joints. • Shear plates and studs are used for connection between steel piles and top slab, and transmit working loads thereof.	△
Construction Workability	• Precast formwork can facile construction of pile cap on water. • Expertise knowledge for pile construction (excavation and stabilization of bore hole) are required.	△	• Precast formwork can facile construction of pile cap on water. • Pile is driven by vibro-hammer and/or drop-hammer from vessel. Driving procedure is simple, and construction period is shorter than others.	○	• Steel pile should be connected by welding on river. • Joints are likely to be stuck if bearing stratum is boulder or rock. In that case, countermeasures are necessitated.	△
Maintenance	• Maintenance work for aesthetics is necessary.	△	• Maintenance work for aesthetics is necessary.	△	• Maintenance work for aesthetics is necessary.	△
Environmental Feature	• Environmental measures for surplus soil and discharging water is necessary.	△	• Good for environment (little construction waste (excavated soil & bentonite water).	○	• Few surplus soil is made.	○
Appraisal	Economical and good structural feature.	○	Most economical & good structural feature.	◎	inferior in cost and construction workability.	△

Note) ◎:Superior ○:normal △:Inferior

Table 5.5.1 Comparison for Approach Bridge Foundation (for Steel Girder Bridge, S=45m)

5.5.4 Comparison Table for Approach Bridge

(1) Evaluation Method

Evaluation of the alternatives was carried out by AHP (Analytic Hierarchy Process) method, i.e. Priority Ordering Method for Decision Making.

Attributes and weights used in AHP are same as those in article 5.4.5.

(Refer to article 5.4.5)

(2) Pair Wise matrix between Bridge type and Attribute Table

(a) Construction Cost

Estimated construction costs are tabulated in Table 5.5.2.

Table 5.5.2 Construction Cost

Type of bridge		Ratio of Cost	Remarks
Alternative-1	Steel I-girder bridge	1.000	
Alternative-2	Steel box-girder bridge	1.303	
Alternative-3	PC-I girder	1.018	
Alternative-4	PC-box-girder	1.272	

Pair-wise matrix for "construction cost" based on above estimation is as follows.

Table 5.5.3 Pair-wise Matrix for "Construction Cost"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	7.00	2.00	5.00	2.030
Steel box-girder	0.14	1.00	0.50	1.00	0.644
PC-I girder	0.50	2.00	1.00	2.00	1.122
PC-box-girder	0.20	1.00	0.50	1.00	0.681
Total	1.84	11.0	4.00	9.00	4.478
Priority	0.45	0.14	0.25	0.15	-

(b) Navigation Safety

Pair-wise matrix for "navigation safety" is as follows.

Table 5.5.4 Pair-wise Matrix for "Navigation Safety"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	1.00	1.00	1.00	1.00
Steel box-girder	1.00	1.00	1.00	1.00	1.00
PC-I girder	1.00	1.00	1.00	1.00	1.00
PC-box-girder	1.00	1.00	1.00	1.00	1.00
Total	4.00	4.00	4.00	4.00	4.00
Priority	0.25	0.25	0.25	0.25	-

(c) Merit for Ukraine

Pair-wise matrix for "merit for Ukraine" is as follows.

Table 5.5.5 Pair-wise Matrix for "Merit for Ukraine"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	1.00	2.00	1.00	1.122
Steel box-girder	1.00	1.00	2.00	1.00	1.122
PC-I girder	0.50	0.50	1.00	0.33	0.661
PC-box-girder	1.00	1.00	3.00	1.00	1.201
Total	3.50	3.50	8.00	3.33	4.107
Priority	0.27	0.27	0.16	0.29	-

(d) Aesthetic Features

Pair-wise matrix for "aesthetic features" is as follows.

Table 5.5.6 Pair-wise Matrix for "Aesthetic Features"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	1.00	3.00	1.00	1.201
Steel box-girder	1.00	1.00	3.00	1.00	1.201
PC-I girder	0.33	0.33	1.00	0.33	0.577
PC-box-girder	1.00	1.00	3.00	1.00	1.201
Total	3.33	3.33	10.00	3.33	4.180
Priority	0.29	0.29	0.14	0.29	-

(e) Construction Difficulty

Pair-wise matrix for "construction difficulty" is as follows.

Table 5.5.7 Pair-wise Matrix for "Construction Difficulty"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	1.00	5.00	7.00	1.809
Steel box-girder	1.00	1.00	5.00	7.00	1.809
PC-I girder	0.20	0.20	1.00	0.33	0.487
PC-box-girder	0.14	0.14	3.00	1.00	0.628
Total	2.34	2.34	14.00	15.33	4.732
Priority	0.38	0.38	0.10	0.13	-

(f) Maintenance Cost

Pair-wise matrix for "maintenance cost" is as follows.

Table 5.5.8 Pair-wise Matrix for "Maintenance Cost"

	Steel I-girder	Steel box-girder	PC I-girder	PC box-girder	Multiple mean
Steel I-girder	1.00	1.00	0.20	0.20	0.585
Steel box-girder	1.00	1.00	0.20	0.20	0.585
PC-I girder	5.00	5.00	1.00	1.00	1.710
PC-box-girder	5.00	5.00	1.00	1.00	1.710
Total	12.00	12.00	2.40	2.40	4.590
Priority	0.13	0.13	0.37	0.37	-

(3) Conclusions of AHP

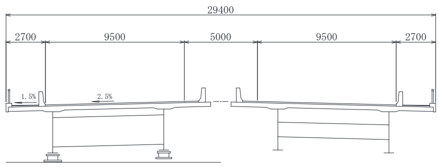
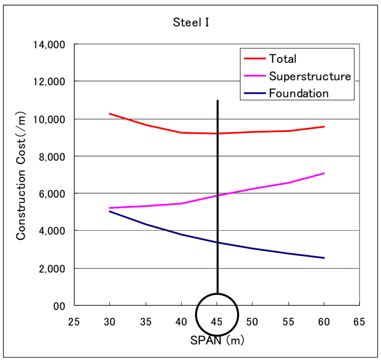
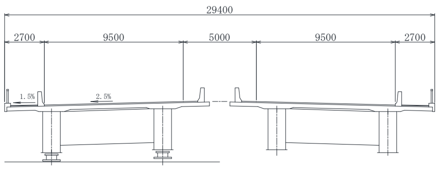
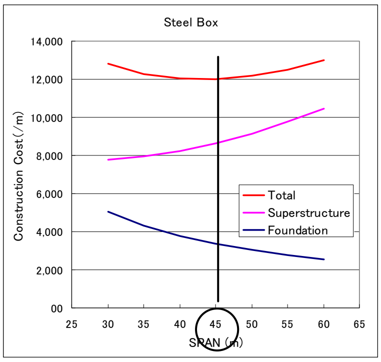
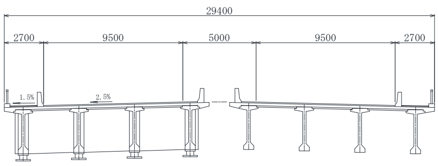
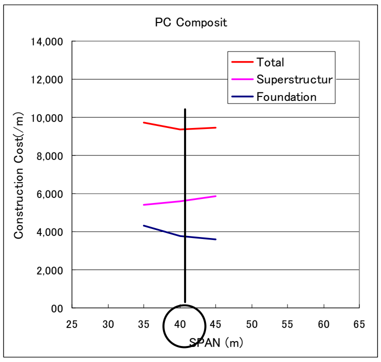
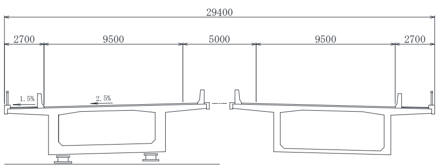
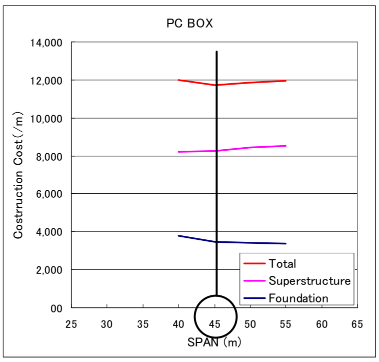
Table 5.5.9 shows the conclusions of the "AHP".

Alternative 1, i.e. Steel I-girder, has highest-priority.

Table 5.5.9 Estimation of Priority

	Evaluation factor						Evaluated priority	
	Construction cost	Navigation safety	Merit for Ukraine	Aesthetic features	Construction difficulty	Maintenance cost	Priority	Rank
Weight	**0.38**	**0.25**	**0.16**	**0.10**	**0.06**	**0.04**		
Steel I-girder	**0.45**	**0.25**	**0.27**	**0.29**	**0.38**	**0.13**	**0.338**	**(1)**
Steel box-girder	**0.14**	**0.25**	**0.27**	**0.29**	**0.38**	**0.13**	**0.220**	
PC-I girder	**0.25**	**0.25**	**0.16**	**0.14**	**0.10**	**0.37**	**0.220**	
PC-box- girder	**0.15**	**0.25**	**0.29**	**0.29**	**0.13**	**0.37**	**0.221**	**-**

Table 5.5.10 Comparison for Span Length

Types	Cross Section	Economical Span	Cost
I-section girder	 Support Section Middle Section		SPAN=45m Cost (Ratio) Superst.: 0.635 Subst. : 0.365 Total : **1.000** Appraisal: ◎
Steel box girder	 Support Section Middle Section		SPAN=45m Cost Superst.: 0.938 Subst. : 0.365 Total : 1.303 Appraisal: △
PC composite girder	 Support Section Middle Section		SPAN=40m Cost Superst.: 0.607 Subst. : 0.411 Total : 1.018 Appraisal: ○
PC-box Girder	 Support Section Middle Section		SPAN=45m Cost Superst.: 0.894 Subst. : 0.377 Total : 1.272 Appraisal: △

Note） ◎ : Superior ○ : Normal △ : Inferior

● **Construction outline of steel bridge**

(1) Construction Method

The bent erection method using a crawler crane from the working gantries (used for the substructure).

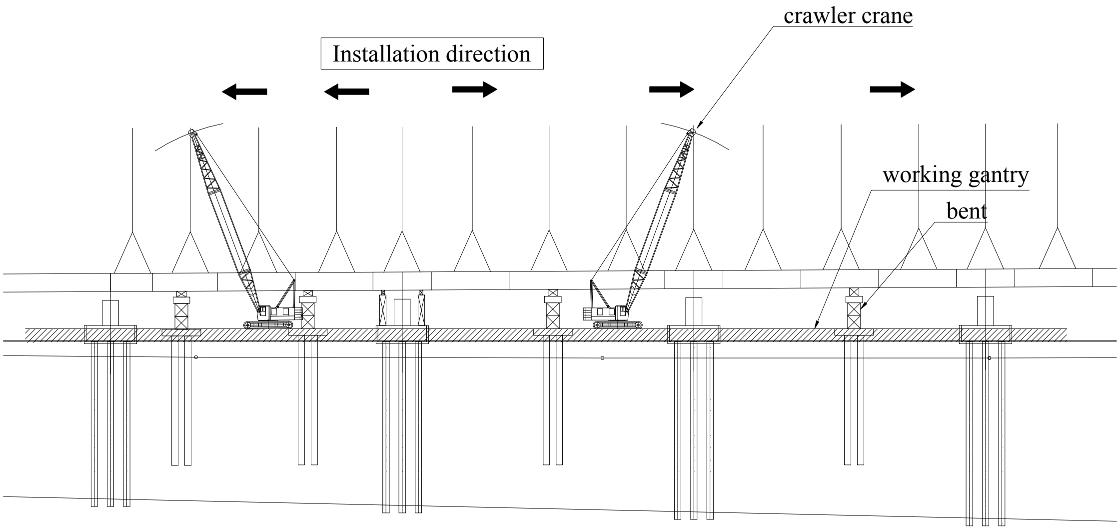
Main equipment

Crawler crane, working gantries, bent, etc.

(2) Construction Issues

The construction schedule is expected to be long due to the erection of members singly.

The large block erection method by the span is also applicable, however, it requires an erection yard.



5.6 Preliminary Design of the Bridge

5.6.1 Selection of Superstructure Type

(1) Superstructure Type for Main Span

As a result of the quantitative evaluation for cost, structure, construction, etc. the suspension bridge appeared to be the most appropriate type in which the navigation safety during construction and the aesthetic satisfaction are highly ensured.

Among the alternatives, the suspension bridge type also cleared economic issues and required no pier to be provided in the navigation channel, which would be detrimental due to the navigational conditions (curved channel and dense fog). The referential alternative D of steel-box with orthotropic deck providing a pier in the navigation channel was economical; it was however, disadvantageous in other aspects.

***Suspension Bridge with single span stiffened-girder or 3-span stiffened-girder**

Suspension bridge with single span stiffened-girder is supposed in course of selection procedure for bridge type. Suspension bridge with three (3)-span stiffened-girder can be proposed in lieu of single span type. The reason not to propose above is as follows.

- The selected type of the approach bridge, i.e., steel I-girder type with prestressed concrete slab, must be more economical rather than side span of suspension bridge with orthotropic box girder.
- Because main cables are positioned under stiffen girder height at side span of the right bank side, hanger cables can not be installed.
- If main cables move to above deck level, lager anchorage should be required and it cause to additional cost.

(2) Superstructure Type for approach portion

As a result of the quantitative evaluation for cost, structure, construction, etc. the steel I-girder type with prestressed concrete slab appeared to be the most appropriate one from an economic perspective.

5.6.2 Selection of Substructure Type

(1) Substructure and Foundation for the Main Bridge

Tower is generally made of reinforced concrete in no seismic area and steel structure in seismic area. The towers of suspension bridge are made of reinforced concrete because of weak seismic design force.

Foundation type, Steel Pile Sheet Pile (SPSP), for Anchorage and Tower is advantageous in economic and environmental aspect. Regarding environmental issue, SPSP can minimize diffusion of the settled soft soil (sapropel).

(2) Substructure and Foundation for the Approach Bridge

Pier has separated columns made of reinforced concrete for each direction but its pile cap is unified due to required arrangement of piles.

Steel Pipe Pile Foundation is superior to other type of foundations in respect to cost efficiency and environment aspect.

Multi-column foundation which pile cap is located above water surface is adopted because of non-requirement of cofferdam and excavation of soft soil layer (Sapropel) during construction period.

Multi-column foundation would be obstacle against to river flow.

However influence to river flow should be limited because of sufficient width of river at proposed location compare to narrow section at downstream.

5.6.3 Preliminary Design of the Bridge

Preliminary design of the bridge is carried out based on the selected type of the following structures.

- Main Bridge
  - Superstructure: Suspension Bridge with single span stiffened-girder
  - Tower : Rigid Frame made of reinforced concrete with portal shape
  - Foundation of Anchorage and Tower: Steel Pipe Sheet Pile
- Approach Bridge
  - Superstructure: Steel I-Girder with Prestressed Concrete Slab
  - Type of Pier: Twin Column/wall type
  - Foundation: Steel Pipe Pile, Multi-Column Type

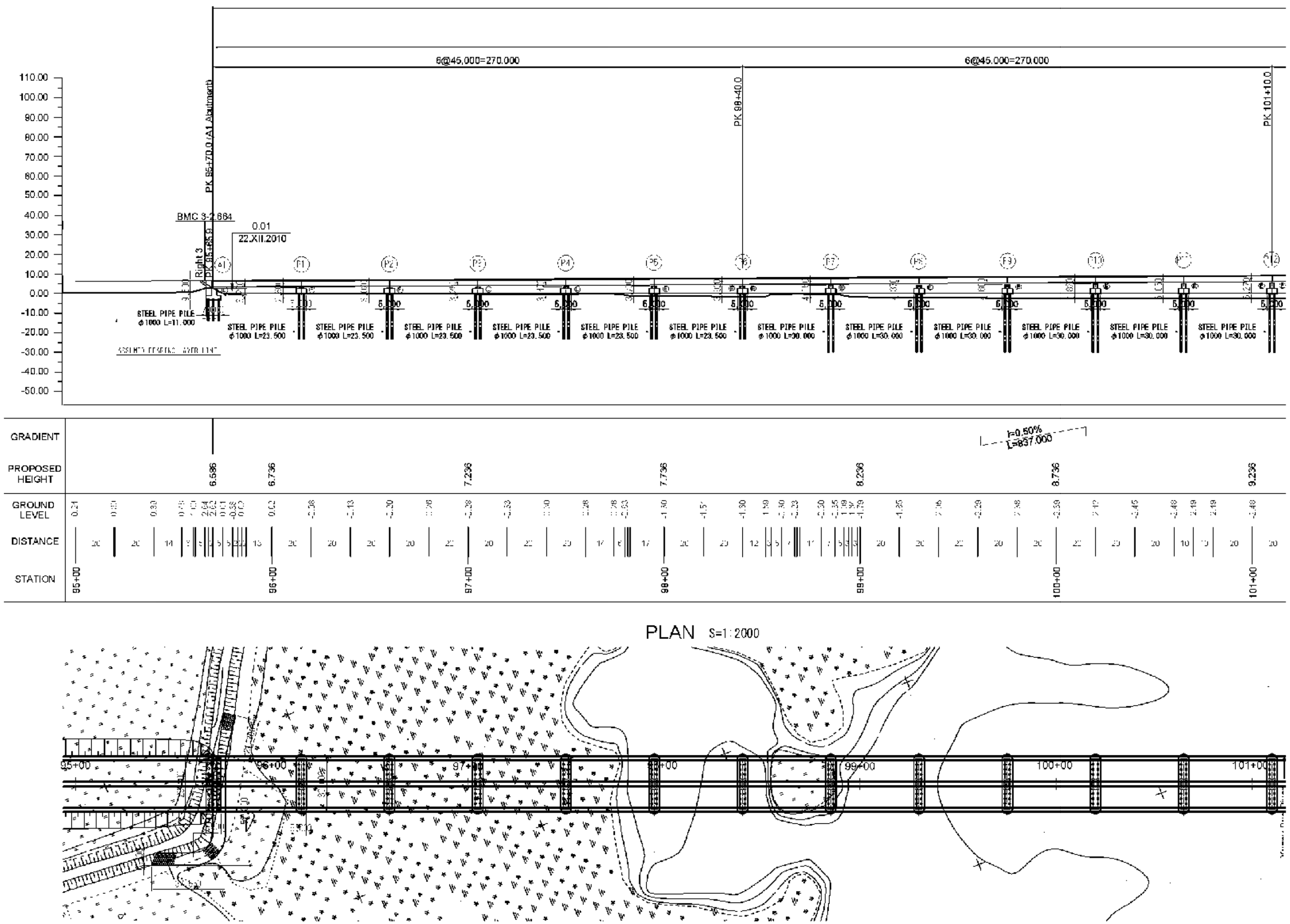
Results of the preliminary design are compiled in "Volume 2: Preliminary Design Drawings."

In the Volume 2, Design conditions, Results of the structural analysis and design calculations, Dimension of the structures and Maintenance plan are indicated together with drawings.

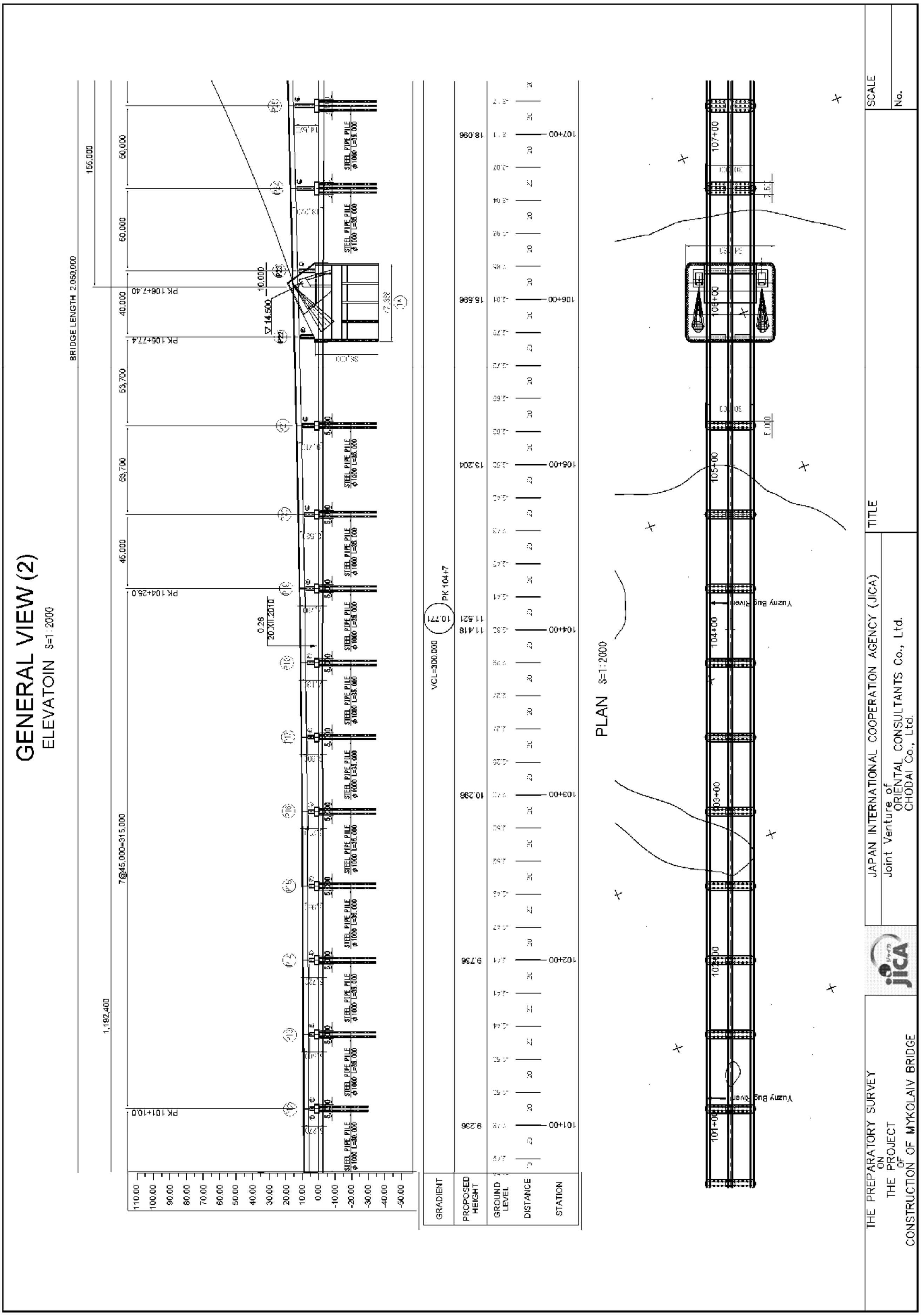
Especially, the dehumidification system that is state-of-the-art technology is recommended to prevent deterioration of the main cable system.

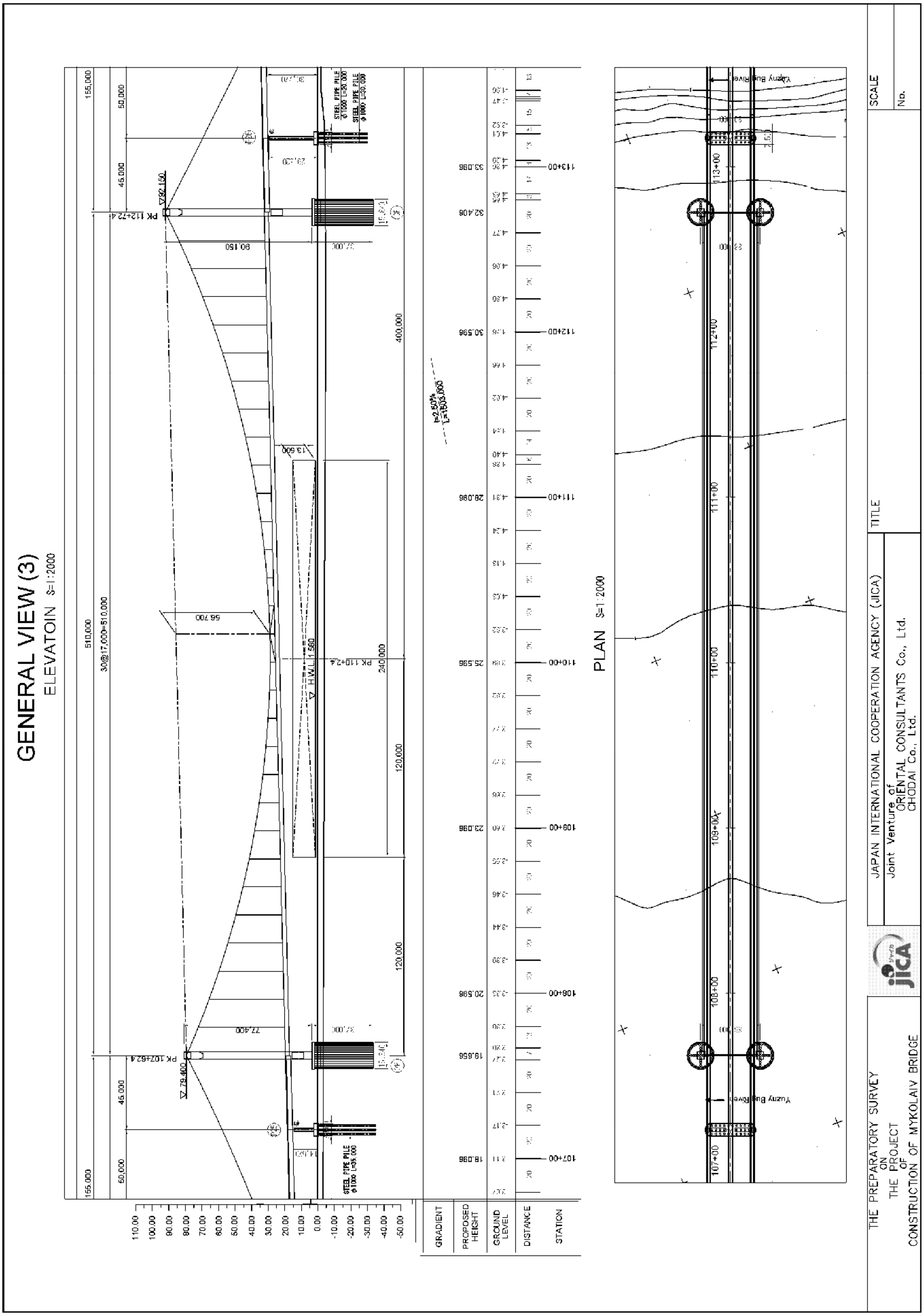
GENERAL VIEW (1)

ELEVATOIN S=1:2000



THE PREPARATORY SURVEY ON THE PROJECT OF CONSTRUCTION OF MYKOLAIV BRIDGE	JICA	JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) Joint Venture of ORIENTAL CONSULTANTS Co., Ltd. CHODAI Co., Ltd.	TITLE
			SCALE
			No.


GENERAL VIEW (2)
ELEVATOIN S=1:2000
PLAN S=1:2000
BRIDGE LENGTH 2,050,000
155,000
1,192,400
7@45,000=315,000
STEEL PIPE PILE
VCL=300,000
PK 104+7
Yuzny Bug River
GRADIENT
PROPOSED HEIGHT
GROUND LEVEL
DISTANCE
STATION
THE PREPARATORY SURVEY ON THE PROJECT OF CONSTRUCTION OF MYKOLAIV BRIDGE
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Joint Venture of ORIENTAL CONSULTANTS Co., Ltd. CHODAI Co., Ltd.
TITLE
SCALE
No.


GENERAL VIEW (3)
ELEVATOIN S=1:2000
PLAN S=1:2000
PK 107+62.4
PK 110+2.4
PK 112+72.4
H.W.L.1.560
STEEL PIPE PILE φ1000 L=35.000
STEEL PIPE PILE φ1000 L=20.000
STEEL PIPE PILE φ1000 L=30.000
510,000
30@17,000=510,000
155,000
50,000
45,000
400,000
240,000
120,000
i=2.50%
L=1503.000
GRADIENT
PROPOSED HEIGHT
GROUND LEVEL
DISTANCE
STATION
107+00
108+00
109+00
110+00
111+00
112+00
113+00
Yuzny Bug River
THE PREPARATORY SURVEY ON THE PROJECT OF CONSTRUCTION OF MYKOLAIV BRIDGE
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
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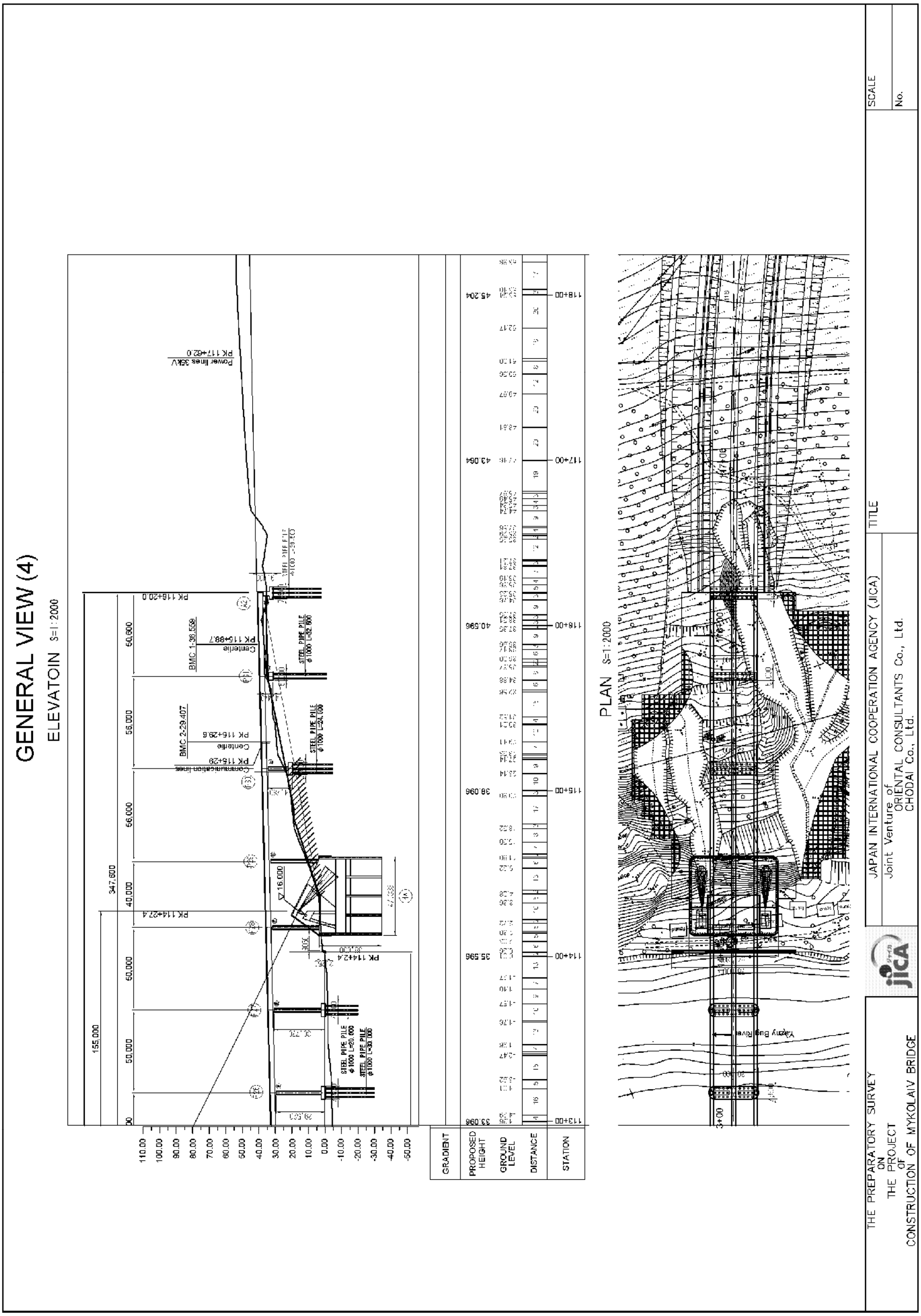
TITLE
SCALE
No.


GENERAL VIEW (4)
ELEVATOIN S=1:2000
PLAN S=1:2000
GRADIENT
PROPOSED HEIGHT
GROUND LEVEL
DISTANCE
STATION
STEEL PIPE PILE
Centerline
Communication lines
Power lines 35kV
Yuzhny Bug River
THE PREPARATORY SURVEY ON THE PROJECT OF CONSTRUCTION OF MYKOLAIV BRIDGE
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
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TITLE
SCALE
No.
JICA

5.7 Preliminary Design for Approach Road

5.7.1 Location of the Road

(1) Confirmation of Road Alignment

Alignment selection of the M-14 bypass road was implemented in the F/S in 2004, and it was reviewed by the JICA survey team (refer to ‘5.1.2 Alignment of the Bridge’ in this report). Here confirmation is shown for the road alignment as a “1-b class road”, after the topographic survey, DBN study and investigation of site condition.

1) Aspect of Alignment

Road class “1-b” is for a 140 km/h design speed. Horizontal alignment of M-14 bypass has 3 radiuses more than R=3000m and 1 radius (R=1200m), they are in compliance with DBN. A super elevated section (R=1200m) is on the right bank of the Southern Bug River, but this section has a shallow longitudinal gradient (0.5%). The crossing point of the Southern Bug River and P-06 highway, alignment is “straight” that is better for road users and better for longitudinal design, structural design and construction planning. The connection point with P-06 highway is a clover leaf junction; this is fitted road to users because it is a general style in Ukraine.

The above alignment factors satisfy the requirements for road service level as a “1-b”class road.

2) Number of Lanes

According to DBN V 2.3-4-2007, number of lanes is determined by traffic demand forecast, and target year is 20 years after motor road construction is completed.

Table 5.7.1 Traffic Volume and Number of Lanes

Terrain relief	Traffic volume (PCU/day)	Number of lanes
Plane and undulated	From more than 14000 to 40000	4
	From more than 40000 to 80000	6
	More than 80000	8
Mountain	More than 10000 to 34000	4
	More than 34000 to 70000	6
	More than 70000	8

Source: DBN V.2.3-4 -2007

Traffic volume on Mykolaiv Bridge will be 37600 PCU/day in 2035, and 42900PCU/day in 2040(refer to Table 4.2.21 “Future Traffic Volume at New Mykolaiv Bridge”). From them, the prospect traffic volume in target year (2038) is 40000 PCU/day approximately. This future traffic volume is considered Ochakov port development (100% completed) and toll free Mykolaiv Bridge. Thus considering number of traffic lane, “4 lanes” is fit.

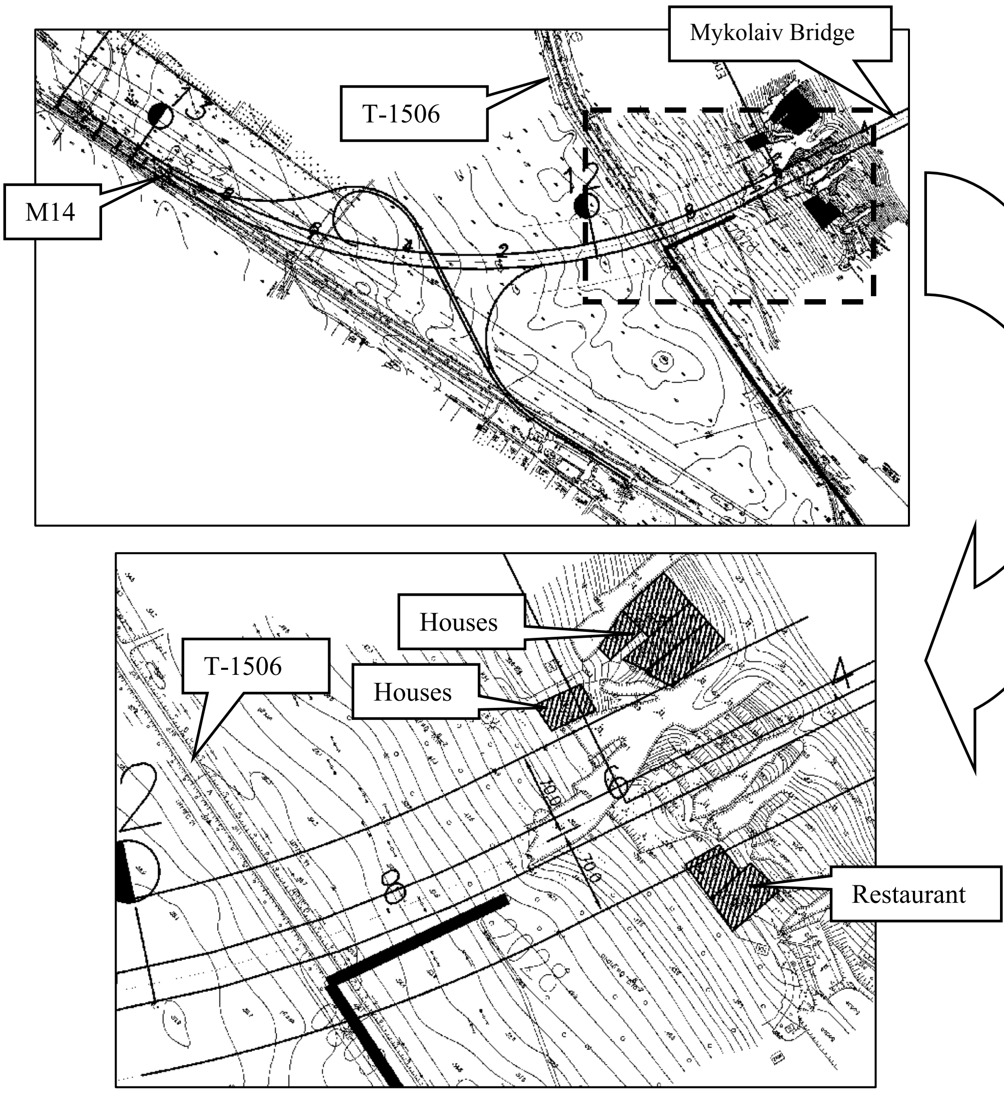
3) Impact on Land and Land users

The area of connection with P-06 will be constructed as a clover leaf junction, and land acquisition should be done over a wide area. There is an asphalt plant but it belongs to Mykolaiv government and it had already stopped operation.

There are small valleys at PK30 and PK50. The alignment was chosen to shorten the bridge in these sections by the F/S 2004. If these short bridges were to be eliminated, the M-14 bypass location should approach the airport and would be located quite near airport, in addition it also would increase destruction of forest land.

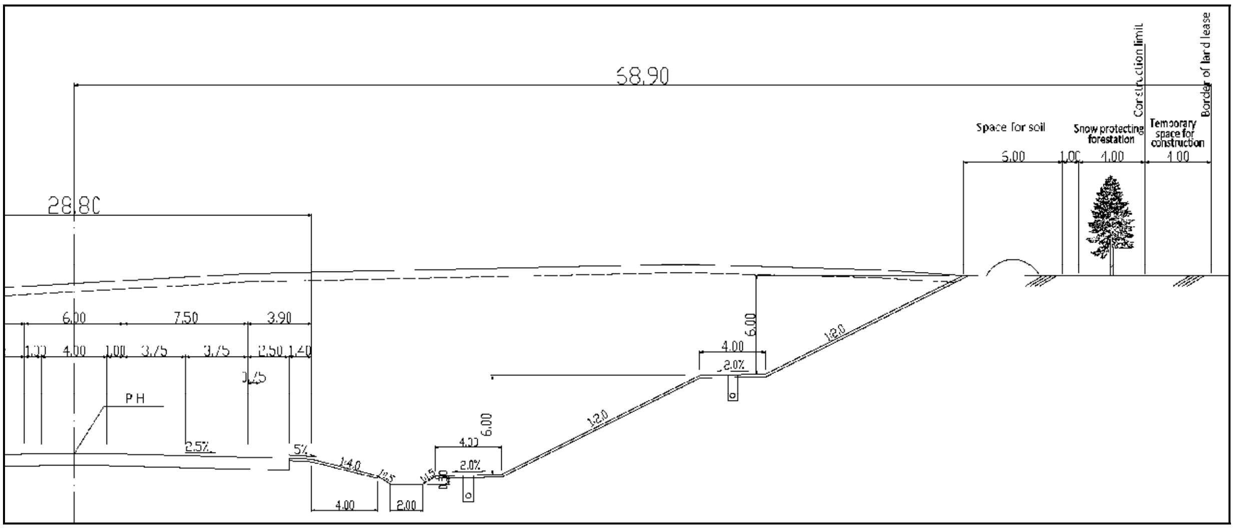
There is a cemetery at PK60 on the left side. The alignment was moved toward the north by the F/S 2004. It is now located far from the cemetery, so it is not necessary to execute land acquisition in cemetery area .

Approach road on the right bank, there are houses about 80-100m from the road centre line on both side (Figure 5.7.1).. If the alignment is shifted or a curve added, land acquisition will be needed from houses area. Because M-14 bypass road will be needed to set deep cut at this section to be set Mykolaiv Bridge lower. If the depth of cut is 12m, it will be ensured 70m each side for road area (Figure 5.7.2).



Source: JICA Survey Team

Figure 5.7.1 Approach Road on Right Bank and Location of Houses



Source: JICA Survey Team

Figure 5.7.2 Road Area of Each Side (Case: Cut depth 12m)

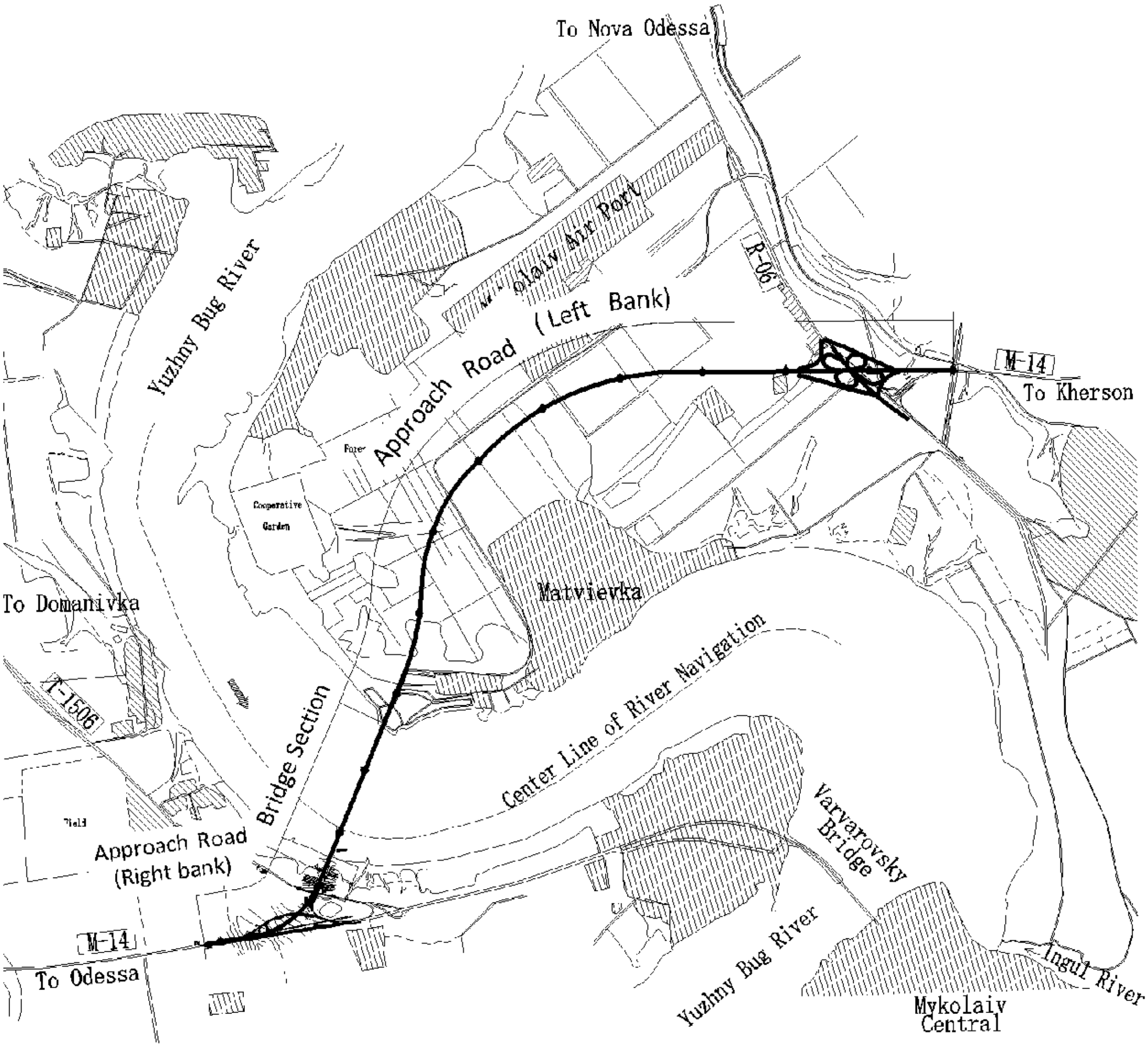
With the above considerations the alignment fits the updated conditions; therefore it is not necessary to change the alignment.

4) Longitudinal Alignment

The longitudinal alignment was reset in the preliminary design because of site conditions updated by the topographic survey. It is shown in “Appendix 4” and “Volume.2: Preliminary Design Drawings”.

(2) Location of the Road

The location of the road is determined to be the same location as proposed “Alignment 1” in the F/S in 2004 (refer to 5.1.2 Alignment of the Bridge’ in this report).



Source: JICA Survey Team

Figure 5.7.3 Location of the road (M-14 Bypass Road)

5.7.2 Constitution of the M-14 Bypass Road Construction Project

The M-14 bypass road consists of 3 sections; the approach road on the left bank, the bridge section and the approach road on the right bank. Furthermore, it has 2 junctions to connect the existing trunk roads (M-14, P-06) and relocation of P-06. Their project scale is shown in Table 5.7.2.

Table 5.7.2 Constitution of M-14 Bypass Road Project

Road		Scale of Road	Outline
M-14 Bypass	Approach Road (Left bank)	9.57km (4 lanes) PK 0-PK95+70	-Earthwork section -Fill section: 8.4km -Cut section:1.2km -5 small bridges and 1 small bridge for railway -3 minor intersections
	Bridge Section (Southern Bug River)	2.05km (4 lanes) PK95+70-PK116+20	-Suspension bridge :0.81km -Approach bridge:1.24km
	Approach Road (Right bank)	1.57km (4 lanes) PK116+20-PK131+92.99	-Earthwork section -Fill section: 0.5km -Cut section:1.1km -1 middle bridge for crossway
	Total	13.19km (4 lanes)	
Junction	North Junction (M14 bypass and P-06)	8 Ramp-ways Clover-leaf shape	Earthwork section
	South Junction (M14 bypass and M-14)	3 Ramp-ways 3-leg Y-shape	Earthwork section -1 small bridge for ramp-way
P-06	Relocation	1.3km (4 lanes)	Earthwork section -1 middle bridge

Source: JICA Survey Team

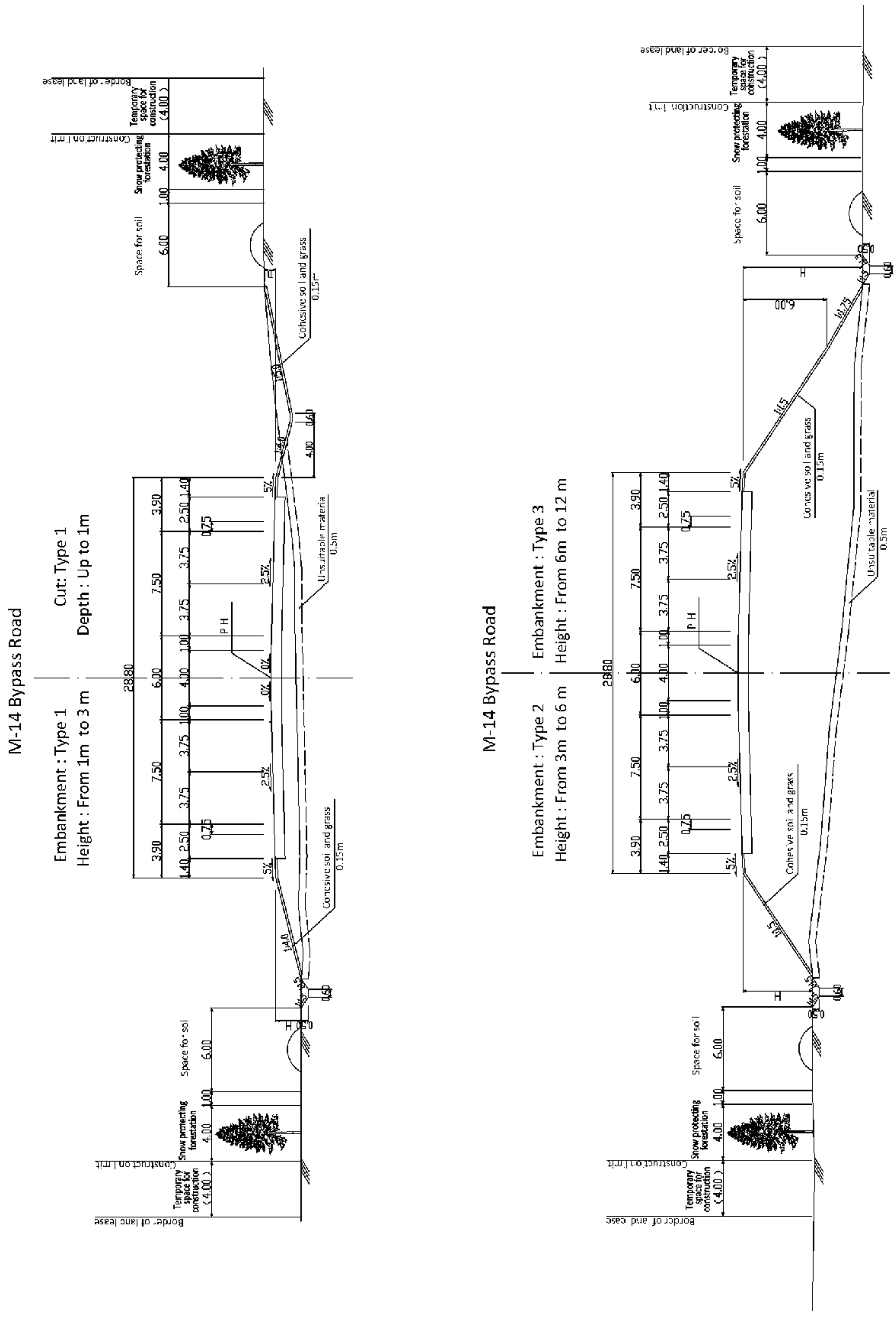


Figure 5.7.4 Typical Cross section (1)

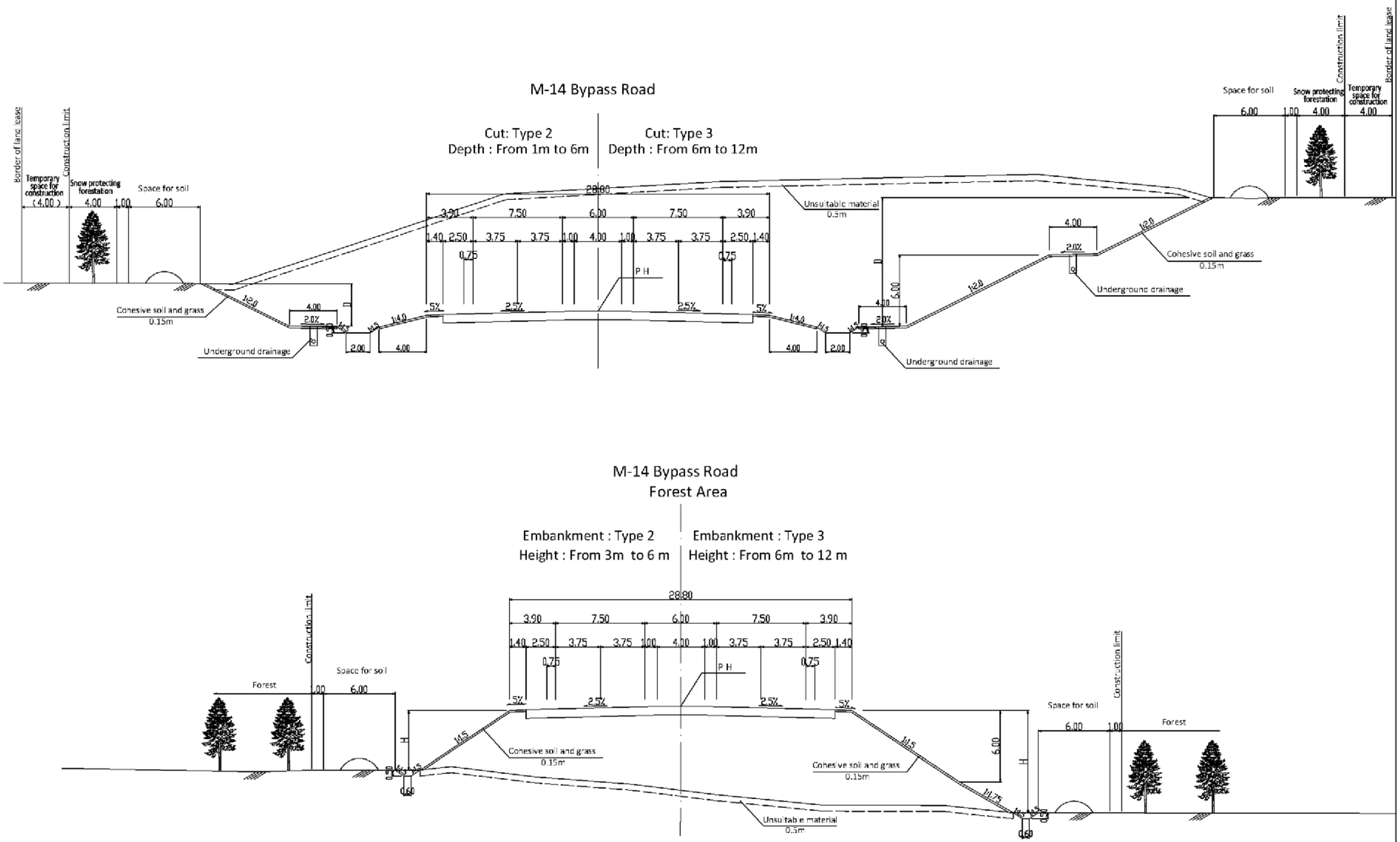


Figure 5.7.5 Typical Cross section (2)

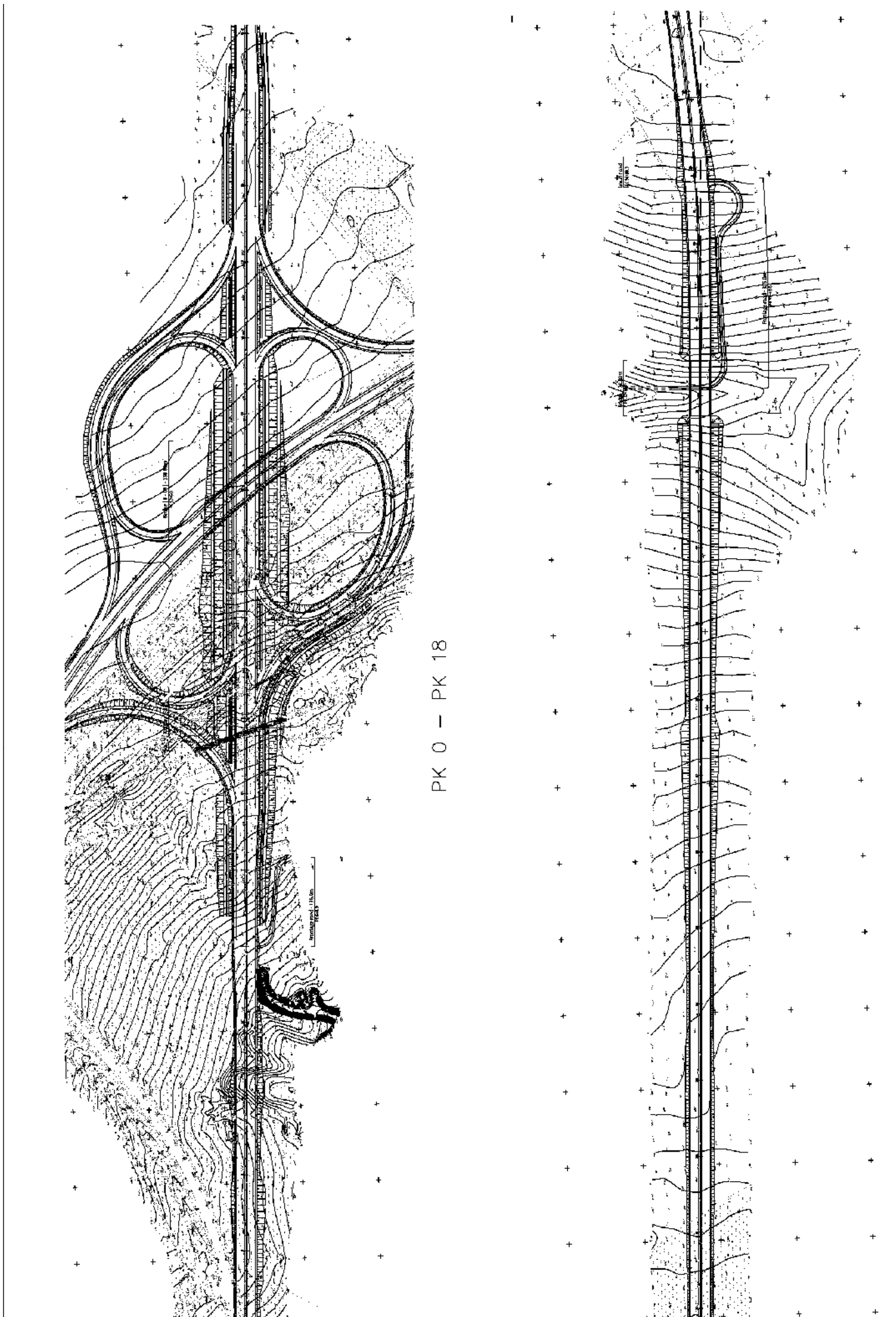


Figure 5.7.6 Plan of M-14 Bypass Road (1)

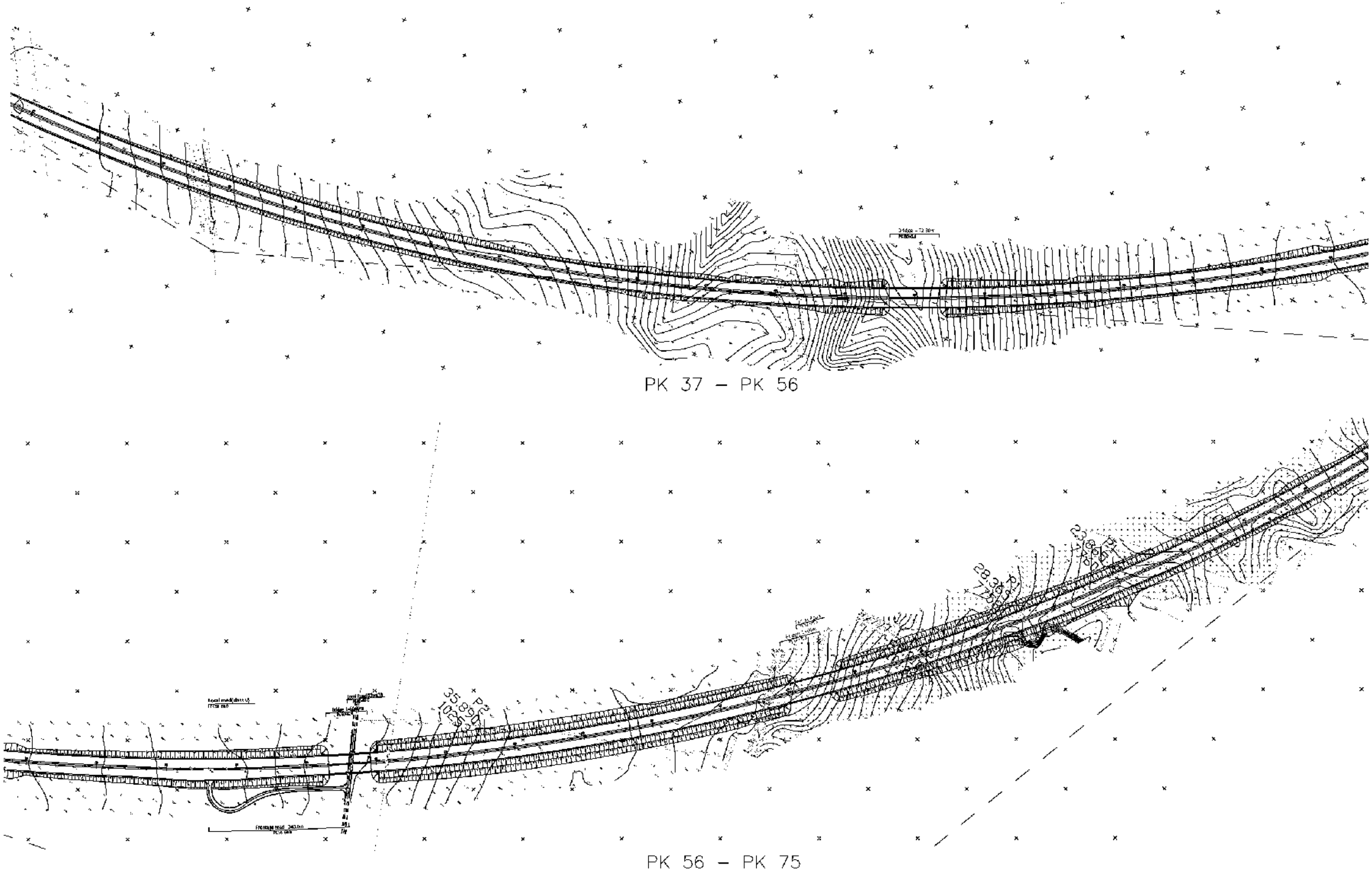


Figure 5.7.7 Plan of M-14 Bypass Road (2)

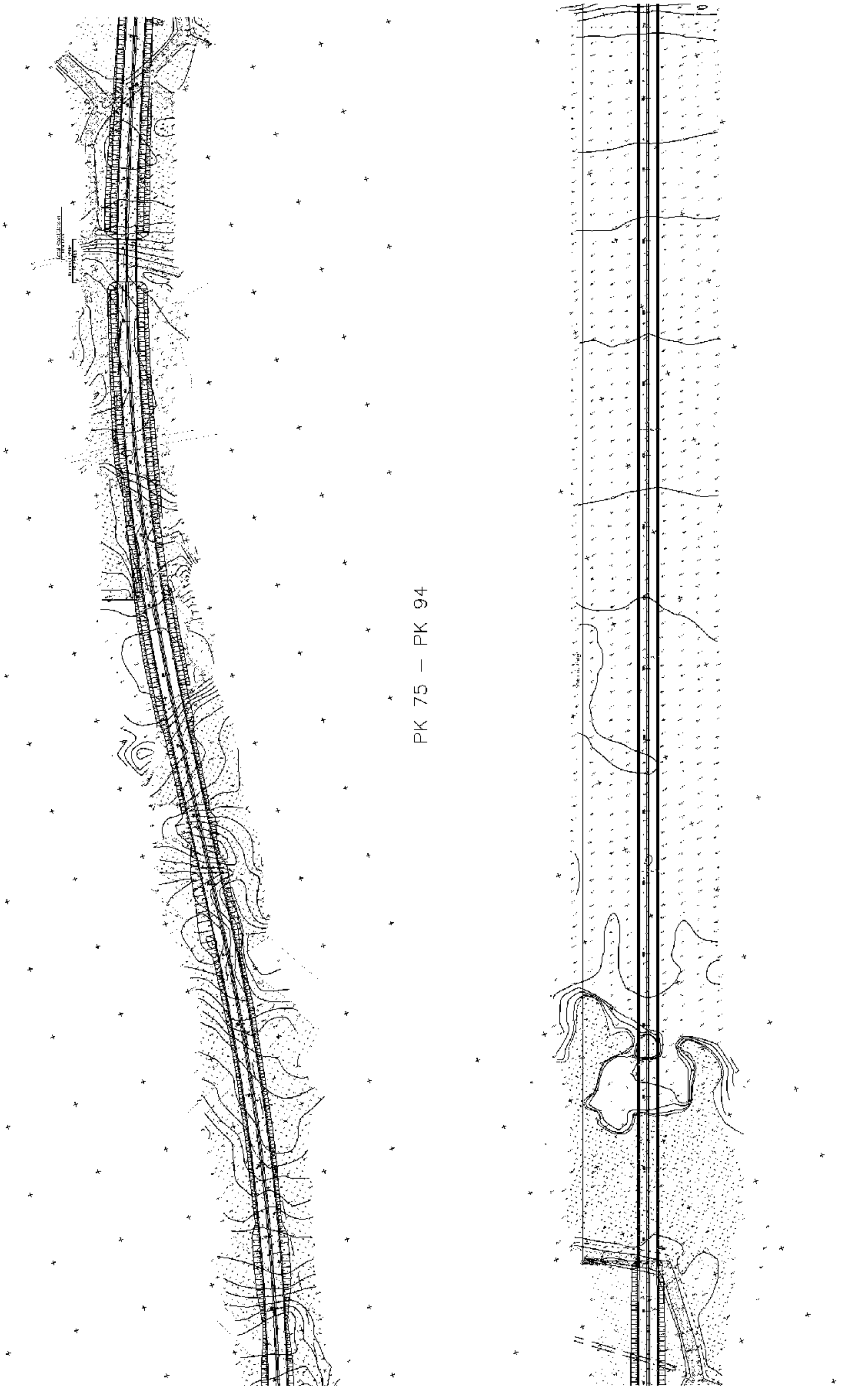


Figure 5.7.8 Plan of M-14 Bypass Road (3)

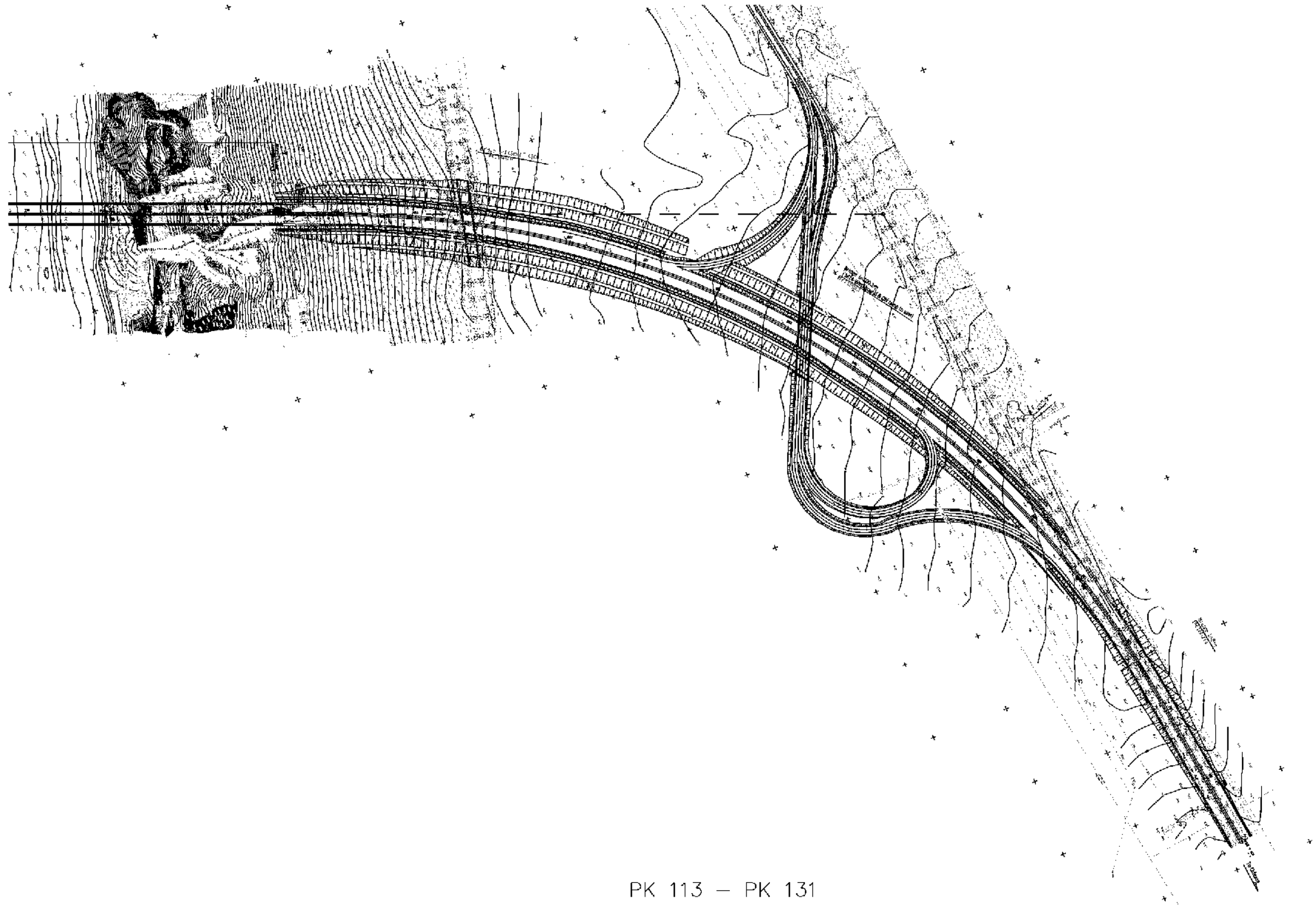


Figure 5.7.9 Plan of M-14 Bypass Road (4)

5.7.3 Design Condition

Design Condition and contents of the design are shown in “Volume.2: Preliminary Design Drawings”.

5.7.4 Current Site Condition of M-14 Bypass

Main current site conditions of M-14 bypass road are shown in the figures below.

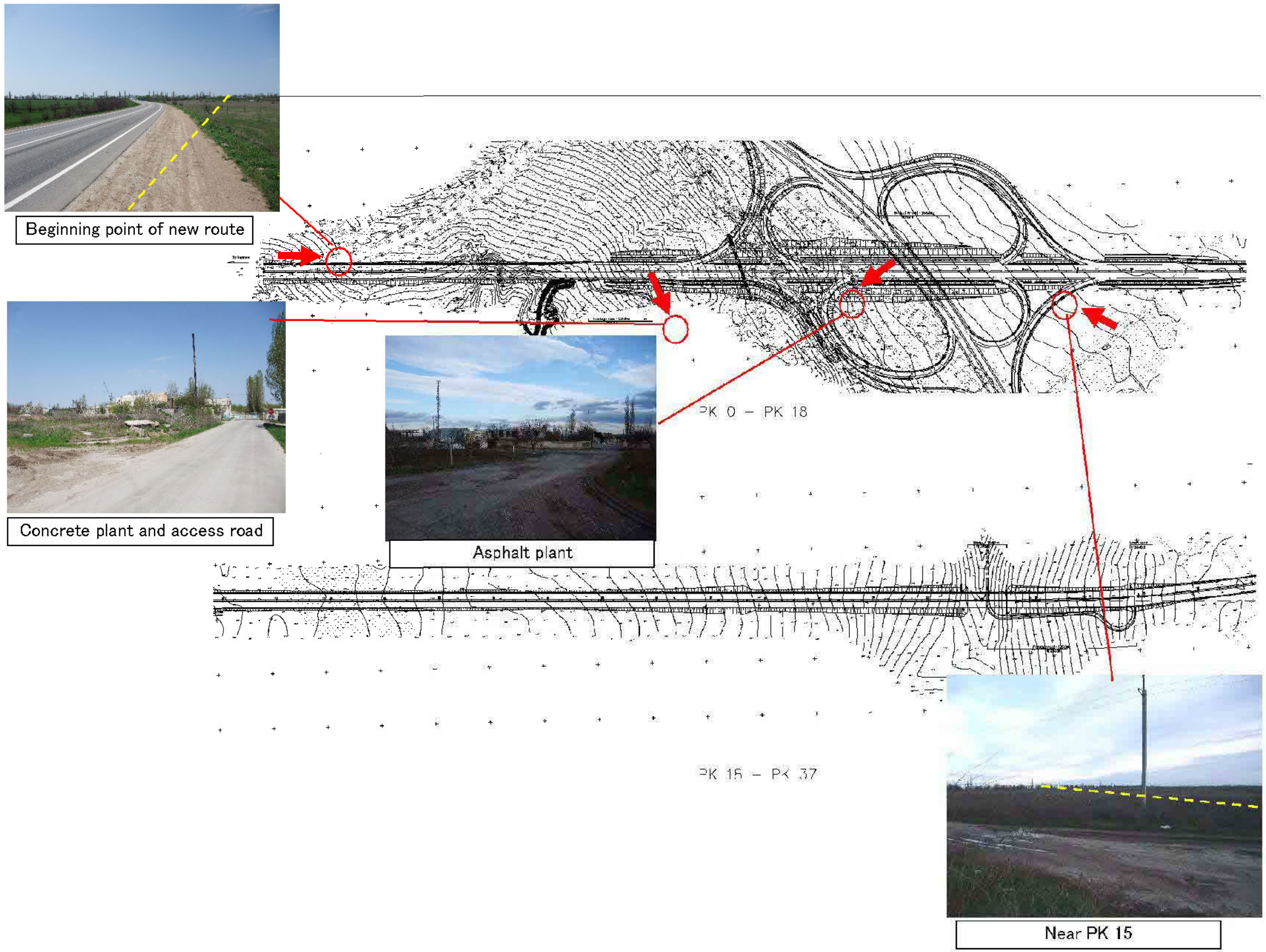


Figure 5.7.10 Current Site Condition of M-14 Bypass Road (1)

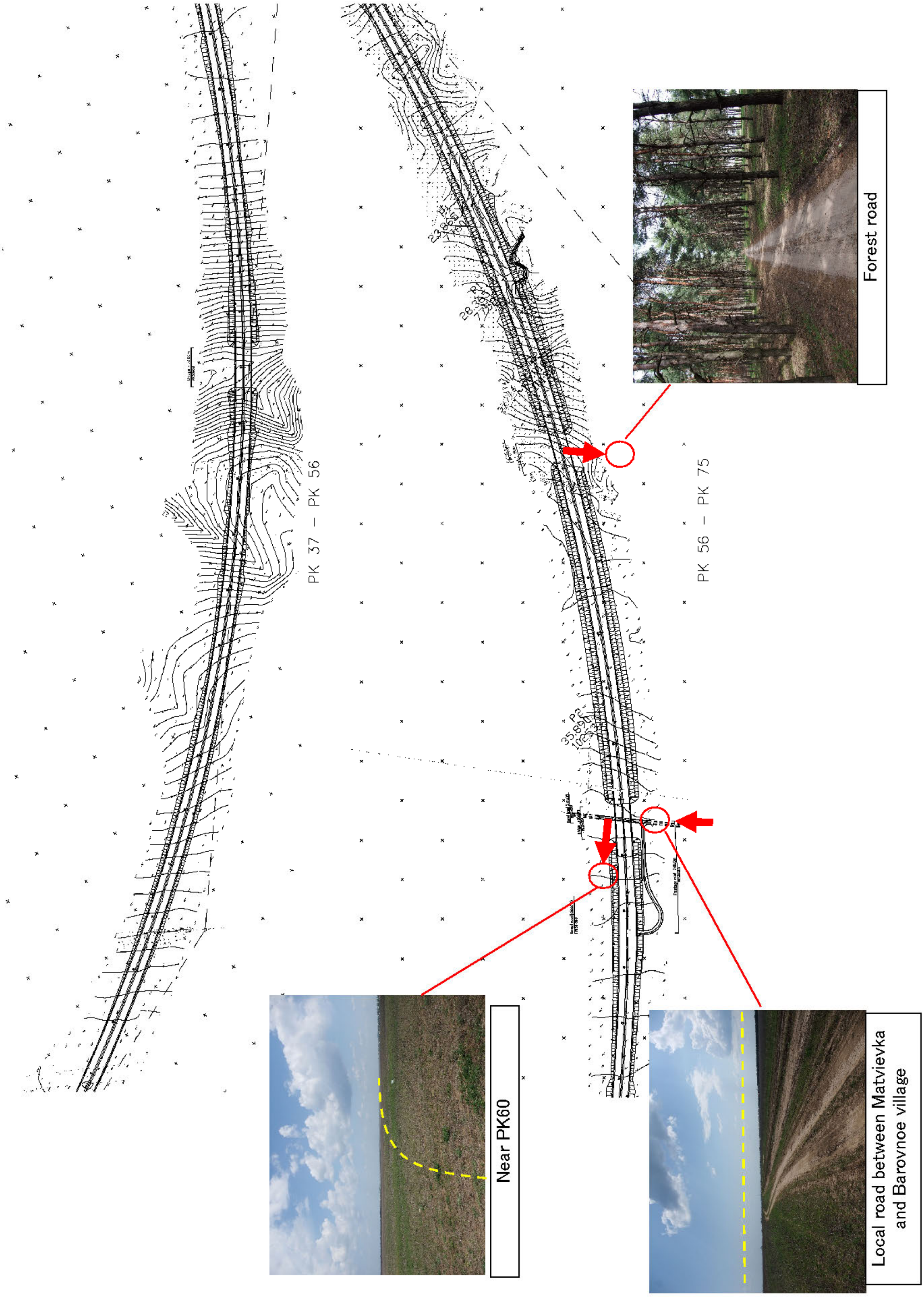


Figure 5.7.11 Current Site Condition of M-14 Bypass Road (2)

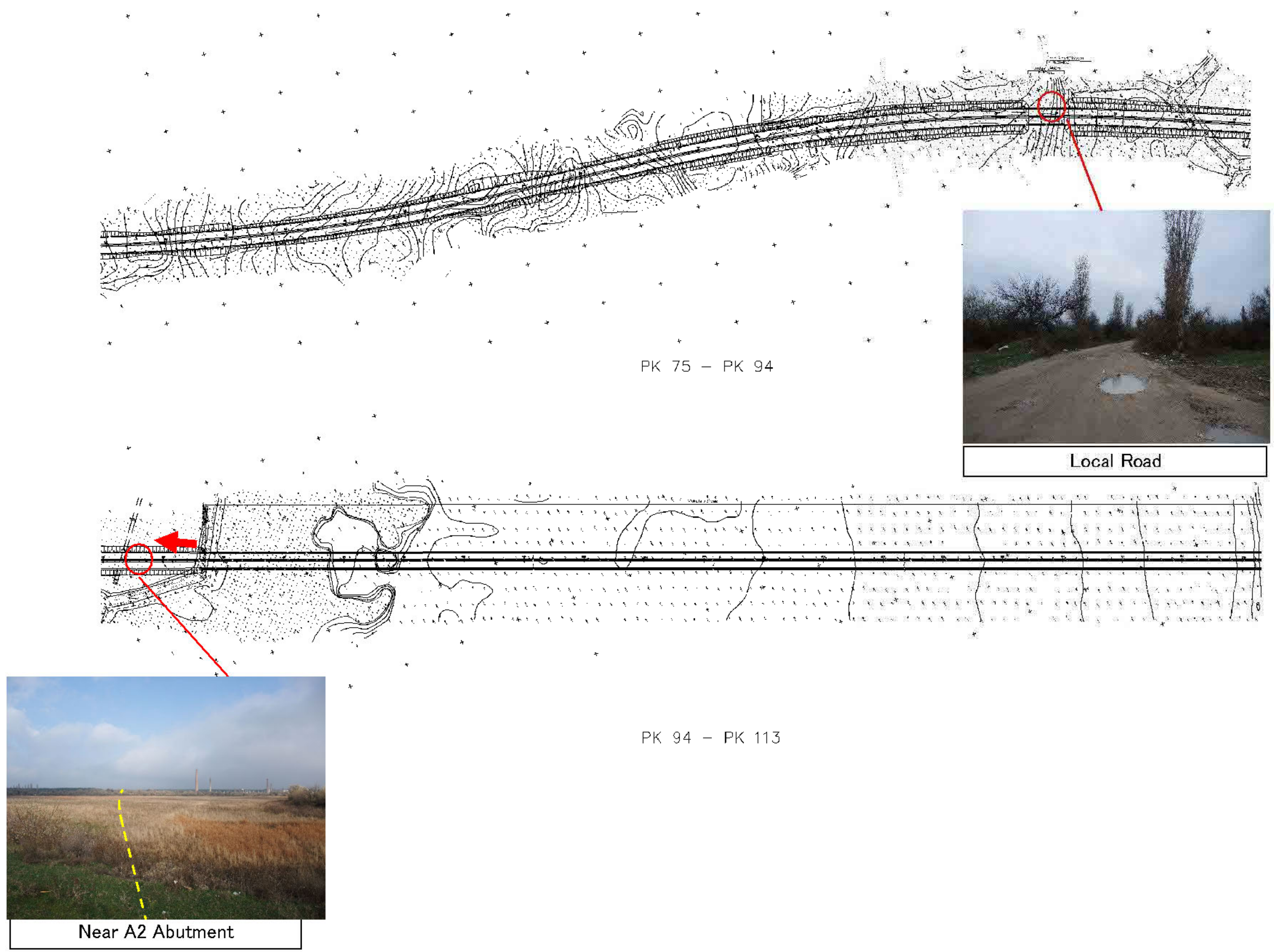


Figure 5.7.12 Current Site Condition of M-14 Bypass Road (3)

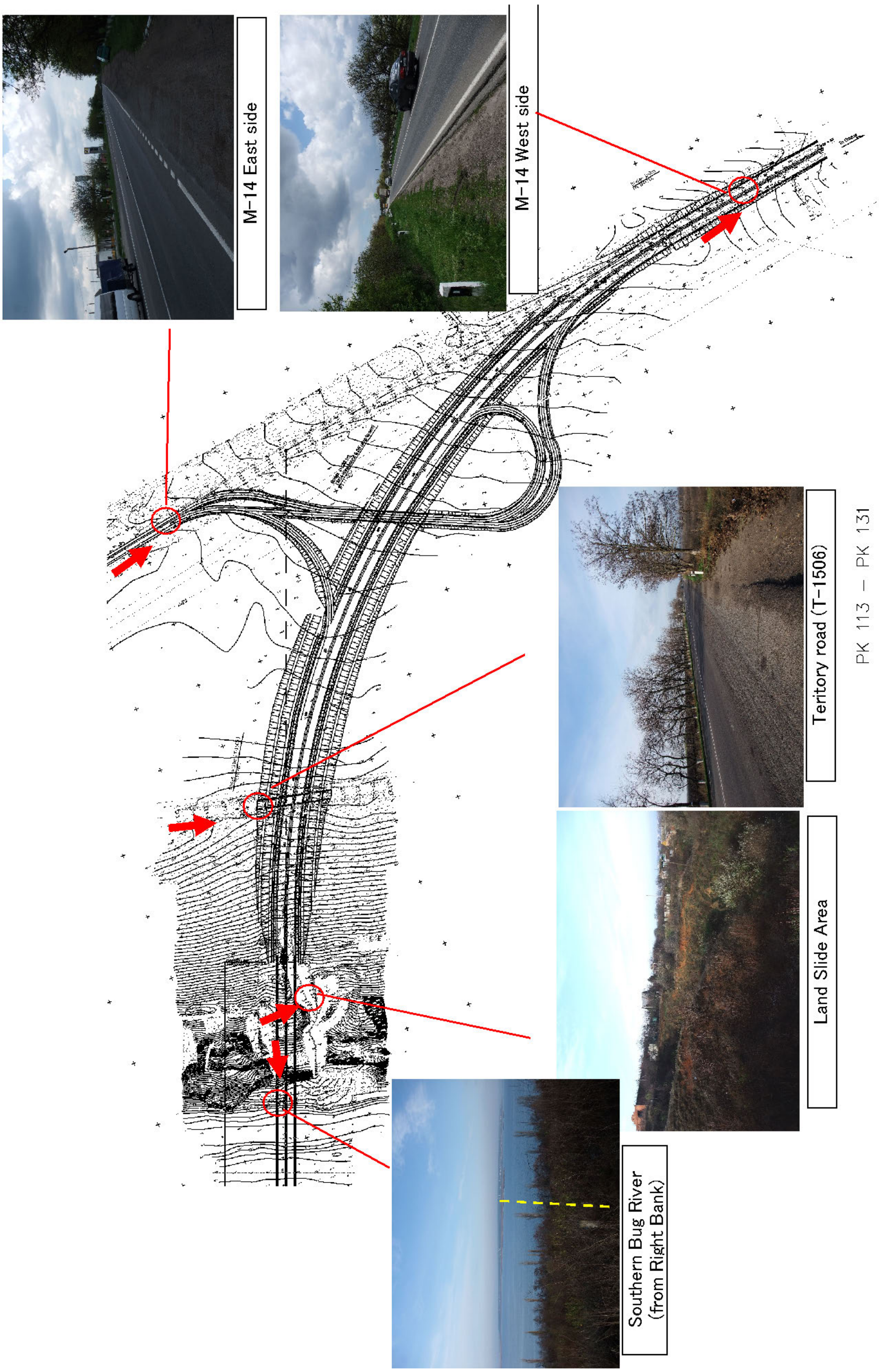


Figure 5.7.13 Current Site Condition of M-14 Bypass Road (4)