Table 2.5-6 Geometric Design Standard for Tan Vu Interchange

Geometric Items	Unit	Tan Vu-Lach Huyen Highway	Hanoi-Haiphong Expressway	Remarks
Design speed	km/h	80	120	
Deceleration lane	m	80	100	TCVN5729-97
Acceleration lane	m	160	200	TCVN5729-97
Taper	m	50	75	TCVN5729-97
Auxiliary lane	m	400(taper 60m)	——	22TCN273-01

Source: Study Team

Table 2.5-7 Adjustment factor of the speed-change lane length

The average grade of the speed-change lane(%)	≦2	>2-:-3	>3-:-4	>4-:-5
The factor of the deceleration lane of down grade	1.0	1.1	1.2	1.3
The factor of the acceleration lane of up grade	1.0	1.2	1.3	1.4

Source: Study Team

2.5.4. Pavement Design

(1) ***<u>Design Standards</u>***

The 22 TCN 274-01 and AASHTO[1] are applied to the design of pavement structure.

Table 2.5-8 Design Standards for Flexible Pavement Design

Design Input Requirements			**Value**	**Reference**
1	Design Variables	Performance Period (years)	15	22TCN274-01
		Analysis Period (years)	20	22TCN274-01
		Traffic		
		Equivalent Single Axle Load (ton)	8.0	22TCN274-01
		Directional Distribution Factor, DD	0.5	22TCN274-01
		Lane Distribution Factor, DL	0.8	22TCN274-01
		Reliability (%)	90	22TCN274-01
		Overall Standard Deviation	0.45	22TCN274-01
2	Performance Criteria	Initial Serviceability Index, p_0	4.2	22TCN274-01
		Terminal Serviceability Index, p_t	2.2	22TCN274-01
		Design Serviceability Loss, ΔPSI	2.0	22TCN274-01
3	Material Properties	Effective Roadbed Soil Resilient Modulus, M_R (psi)	1500 × CBR	Asphalt Inst.
		Layer Coefficient for Sub-base Course, a_3	Figure 9.3.5-2	22TCN274-01
		Layer Coefficient for Base Course, a_2	Figure 9.3.5-3	22TCN274-01
		Layer Coefficient for Asphalt Concrete, a_1	Figure 9.3.5-4	22TCN274-01
4	Pavement Characteristics	Drainage Coefficients for Base Course and Sub-base Course, m_2, m_3	1.15	22TCN274-01

Source: Study Team

[1] AASHTO: Guide for Design of Pavement Structure-1993

(2) Design Method

1) Equivalent Single Axle Load (ESAL)

As regards the specification for the design of flexible pavements, 22TCN 274-01 and AASHTO method of pavement design uses the ESAL of 8.0 tons (18 kips).

The ESAL values are estimated based on the standard axle load of 8.0 tons of AASHTO method. The summary of the design equivalent factors shall be applied for the project following the 22TCN 274-01 specification.

Table 2.5-9 Equivalency Factor of Vehicles

Type of Vehicle	Equivalent Factor
Passenger Car	0.001
Buses	0.56
3-axle or more	0.71
4-axles or less	0.72

Source: 22TCN 274-01 Table 3.6

2) Material Properties

Design of flexible pavement by AASHTO method requires the selection of the elastic modulus of asphalt concrete (E_{AC}). AASHTO recommends using values based on local practices.

However, in 22TCN 274-01, it is supposed that E_{AC} of a densely grade asphalt concrete will be determined in the range of 1,930 MPa (28,000 psi) to 2,070 MPa (300,000 psi).

Table 2.5-10 Material Properties

S.N	Pavement Material	CBR (%)	Elastic modulus (psi)
1.	Sub-grade	≥ 8	1500 × CBR (M_R)
2.	Aggregate Sub-base	≥ 30	14,500 (100Mpa)
3.	Aggregate Base	≥ 80	29,000 (200Mpa)
4.	Asphalt Concrete		300,000 psi (2070Mpa)

Source: 22TCN 274-01

3) Layer Coefficients

The layer coefficients are calculated from the chart (equation) given in AASHTO. These layer coefficients are used to convert the thickness of each layer into the strength of pavement structure in terms of structural number.

Table 2.5-11 Summary of Layer Coefficients of Pavement Materials

Material Type	Layer Coefficient
Aggregate sub-base course CBR≥30	0.11 (a_3)
Aggregate base course CBR≥80	0.13 (a_2)
Asphalt Concrete E_{AC} = 300,000 psi	0.37 (a_1)

Source: AASHTO

4) Determination of Design Structural Number (SN)

Various design data and parameters required to use the AASHTO design equation or the design nomo-graph are as follows:

$$\log_{10} W_{18} = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10} M_R - 8.07$$

where,

W_{18} = Estimated total 18-kip (8.0-ton) ESAL applications

Z_R = Standard Normal Deviate for the given Reliability (%)

S_0 = Overall Standard Deviation

M_R = Effective Roadbed Soil Resilient Modulus

ΔPSI = Design Serviceability Loss

SN = Design Structural Number

Table 2.5-12 Various Parameters in Solving the AASHTO Nomo-graph

No.	Parameters	Value	Remarks
1.	Reliability, R (%)	90	
2.	Standard Normal Deviate of R, Z_R	-1.282	
3.	Overall Standard Deviation, S_0	0.45	
4.	Estimated Total ESAL of 18-kips	Variable	
5.	Effective Roadbed Soil Resilient Modulus, M_R	1500×CBR	CBR≥ 8%
6.	Design Serviceability Loss, ΔPSI	2.0	

Source: AASHTO

5) Thickness of Asphalt Concrete Layers

AASHTO suggests a minimum thickness of asphalt concrete of 9 cm (3.5 inches) for traffic level from 2 to 7 million ESAL and 10 cm (4 inches) for traffic level greater than 7 million ESAL. However, it does not provide any information on asphalt concrete thickness requirement for different types of base strength.

At present, 12 cm of asphalt concrete (5 cm surface course and 7 cm binder course) on national highways is applied in Vietnamese practices for economical reasons

Based on this, it is concluded that 12 cm of asphalt concrete with 5 cm of surface course and 7 cm of binder course shall be taken as the minimum thickness requirement of asphalt concrete.

6) Thickness of Aggregate Base and Subbase Courses

The minimum thickness of base and sub-base layers is 15 cm (6 inches) as recommended by AASHTO. This minimum thickness is also judged to be practical during construction.

Various combinations of base and sub-base layer thickness are possible to satisfy the following SN equation;

$$2.54SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where,

- thicknesses are in cm
- a_1, a_2, a_3 are for asphalt concrete, base and sub-base courses as given in Table 2.5-7.
- m_2 and m_3 are 1.15 as given in Table 2.5-9.
- D_1, D_2, D_3 for thickness in cm of surface, base, and sub-base layers.

7) **Drainage Coefficients**

The drainage coefficients for base course and sub-base course are present for the quality of drainage of roadwork design.

Table 2.5-13 Drainage Coefficients

Quality of drainage	Percent of time that pavement structure is exposed to moisture levels approaching saturation		
	Less than 1%	1- 5%	5 – 25%
Excellent (2 hours)	1.40 – 1.35	1.35 – 1.30	1.30 – 1.20
Good (within 1 day)	1.35 – 1.25	1.25 – 1.15	1.15 – 1.00

Source: AASHTO

Considering the site conditions, where quality of drainage is not excellent, it is recommended that the drainage coefficient for both base course and sub-base course of m_i = 1.15 shall be applied.

(3) ***Pavement Design***

1) **Design Traffic Volume**

Design traffic volumes in the two different directions in Tan Vu IC – Cat Hai Island are shown in Table 2.5-14.

Table 2.5-14 Forecasted Traffic Volume (Section Tan Vu IC-Dinh Vu IZ)

Unit: Vehicle

Section: Tan Vu-Dinh Vu	Car	LGV	HGV
2015	3,960	1,243	1,317
2020	13,540	2,571	3,049
2030	48,000	8,107	14,287

Source: Study Team

2) **Equivalent Single Axle Load (ESAL)**

Traffic annual growth rate: 2015=>2020 is 8.8% (refer to separated traffic forecast report)

2020=>2030 is 2.3%

ESALs per year = (Vehicles/day)(Lane Distribution Factor)(day/year)(ESALs/Vehicle)

Table 2.5-15 Calculation Table for Tan Vu IC – Dinh Vu IZ (2015)

Kind of car		Calculation	ESALs per Year (2015)	
Car	Passenger Car	=(3960/day)(0.8)(365)(0.001)	=1,156	ESALs/Yr
LGV	3-axle or more	=(1243/day)(0.8)(365)(0.71)	=257,699	ESALs/Yr
HGV	4-axles or less	=(1317/day)(0.8)(365)(0.72)	=276,886	ESALs/Yr
Total			=535,741	ESALs/Yr
Rounded total			=540,000	ESALs/Yr

Source: Study Team

Table 2.5-16 Calculation table of Tan Vu IC-Dinh Vu IZ (2020)

Kind of car		Calculation	ESALs per Year (2020)	
Car	Passenger Car	=(13540/day)(0.8)(365)(0.001)	=3,954	ESALs/Yr
LGV	3-axle or more	=(2571/day)(0.8)(365)(0.71)	=583,020	ESALs/Yr
HGV	4-axles or less	=(3049day)(0.8)(365)(0.72)	=641,022	ESALs/Yr
Total			=1,177,996	ESALs/Yr
Rounded total			=1,180,000	ESALs/Yr

Source: Study Team

3) Design ESAL

The standard multiplier to calculate the compound growth is:

$$\text{Multiplier} = \frac{(1+g)n-1}{g}$$

$$\text{15 years design life: } 1{,}130{,}000\left(\frac{(1+0.088)5-1}{0.088}\right) + 2{,}380{,}000\left(\frac{(1+0.023)10-1}{0.023}\right) \approx 16{,}300{,}000$$

4) Elastic Modulus

a) Effective Roadbed Soil Resilient Modulus, MR

MR (psi) = 1500 × CBR (%)

Table 2.5-17 Design CBR Adopted Average Value of Material Survey Borrow Pit

Material Properties	Unit	Borrow Pit Name		
		Kinh Thay River Sand Pit	Van Uc River Sand Pit	Thai Binh River Sand Pit
Specific gravity	g/m^3	2.64	2.64	2.65
Max dry density	g/m^3	1.602	1.601	1.637
Optimum moisture content	%	18.02	17.90	17.18
Dry rest angle	degree	30^0 37'	25^o 15'	25^o 15'
CBR	%	7.5	8.3	9.3

Source: Study Team

Average CBR=8%, M_R (psi) = 1500 x 8 = 12,000 psi = 83MPa

5) Pavement Material Properties

Material properties are as follows:

Table 2.5-18 Pavement Material Properties

Pavement Material	CBR (%)	Elastic modulus (psi)
Aggregate Subbase	≥ 30	14,500 (E_{SB}, 100Mpa)
Aggregate Base	≥ 80	29,000 (E_{BS}, 200Mpa)
Asphalt Concrete		300,000 psi (E_{AC}, 2,070Mpa)

6) Determination of Design Structural Number (SN)

$$\log_{10} W_{18} = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10} M_R - 8.07$$

SN = 4.305

7) Thickness of Asphalt Concrete and Base layers

Thicknesses of layers are determined using the following equations:

$2.54SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$

---> $2.54*4.305=0.37*D_1+0.13*D_2*1.15+0.11*D_3*1.15$

The thickness of base of 15cm is temporarily selected.

---> 2.54*4.305 = 0.37*12+0.13*<u>15</u>*1.15+0.11*D3*1.15

D3 = -- = 34cm

The thickness of base of 20cm is temporarily selected.

$$\text{--->}\ 2.54*4.305 = 0.37*12+0.13*\underline{20}*1.15+0.11*D3*1.15$$

$$D3 = \text{-----------------------------} = 28cm$$

The thickness of base of 25cm is temporarily selected.

$$\text{--->}\ 2.54*4.305 = 0.37*12+0.13*\underline{25}*1.15+0.11*D3*1.15$$

$$D3 = \text{-----------------------------} = 22cm$$

The calculated results are given in Table 2.5-19

Table 2.5-19 Calculated Layer Thickness

W18	SN	mi	Calculated thickness (cm)				
			SB	BS	ACB	ACS	Total
16,300,000	4.305	1.15	34	15	7	5	61
			28	20	7	5	60
			22	25	7	5	59

Source: Study Team

8) Economical Considerations

Comparison of the results with the other highway projects indicates that the use of 5cm of A/C surface course and 7cm of A/C binder course is a common practice in Vietnam due to economical reasons.

The cost values shown in the table are the relative costs of the pavement structure considering the cost of asphalt concrete surface course as unity. The cost values are taken from the cost estimate report.

Table 2.5-20 Cost Comparison

Alternates	Thickness (cm)				Cost(VND/m^2)
	Sub-base	Base	AC binder	AC surface	
Alternate -1	34	15	7	5	638,416
Alternate -2	28	20	7	5	641,207
Alternate -3	22	25	7	5	643,951

Source: Study Team

The Study Team adopts Alternative 1 which excels in terms of economical efficiency from Table 2.5-20.

9) Selected Pavement Structure

After the above calculation, the following pavement structure is selected:

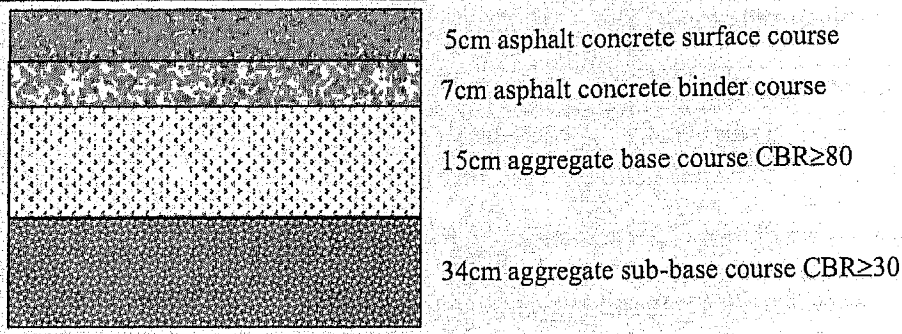


Figure 2.5-9 Pavement Structure Thickness

2.5.5. Bridge Design

(1) *Design Standard and Design Criteria*

Applied design standards and criteria for the bridge design are shown in Appendix-3 "Standards and Criteria for Bridge Design".

Basically, the bridges and structures in this Project shall be designed with the Vietnamese Design Standard (22 TCN 272-05) and AASHTO-LRFD (Load and Resistance Factor Design, 3rd Edition 2004) except for some items which should be considered in accordance with the other international standards.

The summary of applied design standards and specifications is shown in Table 2.5-21.

Table 2.5-21 Adopted Items for this Project

Item	Specifications	Standards
Design Method	Limit State Design	Vietnamese
Design Life	100 years	Vietnamese
Design Lane Width	3,600 mm or 3,750 mm	Vietnamese
Load Combination		Vietnamese
Live Load	HL-93	Vietnamese
Dynamic Load Allowance, IM	0.25 for main part of bridge	Vietnamese
Wind Load	Depend on the site	Vietnamese
Vessel Collision Force	Depend on the site	Vietnamese
Earthquake	Depend on the site	Vietnamese
Seismic Earth Pressure	Depend on the site	Japanese
Stress Loss in Tendons		Japanese
Creep & Shrinkage		Japanese / CEB-FIP
Pile Foundation Analysis	Displacement Method	Japanese

Source: Study Team

The items for which these standards cannot be appropriately applied shall be determined by referring to AASHTO (Allowable Stress Design Method, 17th Edition 2002) or Japanese Standard for Highway Bridge (JSHB-96).

(2) ***Typical Cross Sections in Bridge Section***

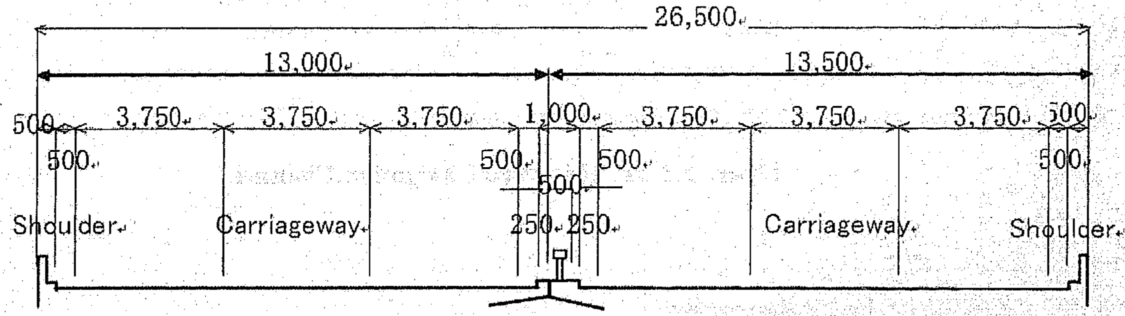
Typical cross sections of bridge section were updated during the discussion between JICA and MOT. The updated results are summarized in Appendix-10.

The typical cross sections of bridge are as shown in Figure. 2.5-10

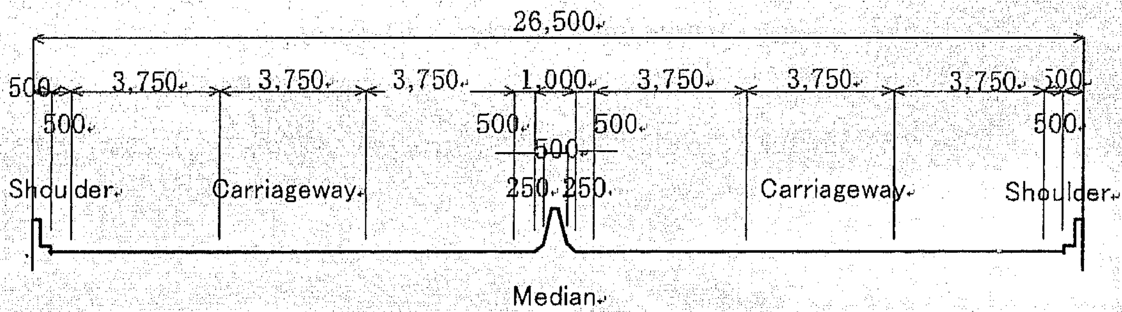
Table 2.5-22 Typical Cross Section of Bridge Section

Type	Cross Section	Remarks
H1	Separated Section	Applicable for Stage Construction
H2	Combined Section	

Type H 1: Highway Bridge - Separated Section



Type H 2: Highway Bridge - Combined Section



Source: Study Team

Figure 2.5-10 Typical Cross Sections of Bridge Section

(3) ***Crossing Facilities***

The bridge shall be constructed crossing over the following utilities:

1) Design Water Level for River/ Canal Crossing

Design water level is calculated as follows:

WL = 2.45m (High tide water level at 5% probability) + 1.41m (Effect of wave)

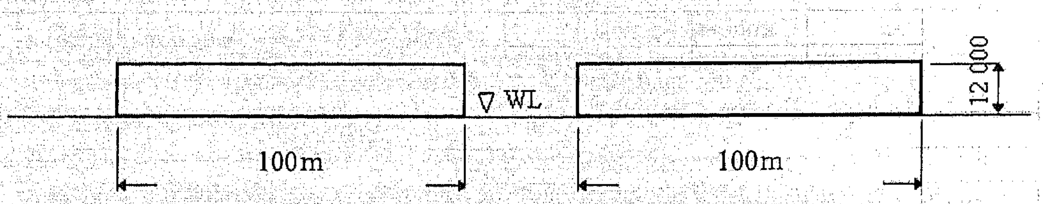
= 3.86m

Table 2.5-23 Design Water Level

Design Water Level = 3.86 m

2) Navigation Channel

The navigation channel for large vessels will be shifted to the northern side of deep sea port. The bridge shall have navigation for vessels of 1,000 DWT. The navigation clearance at Nam Trieu Channel is as follows:

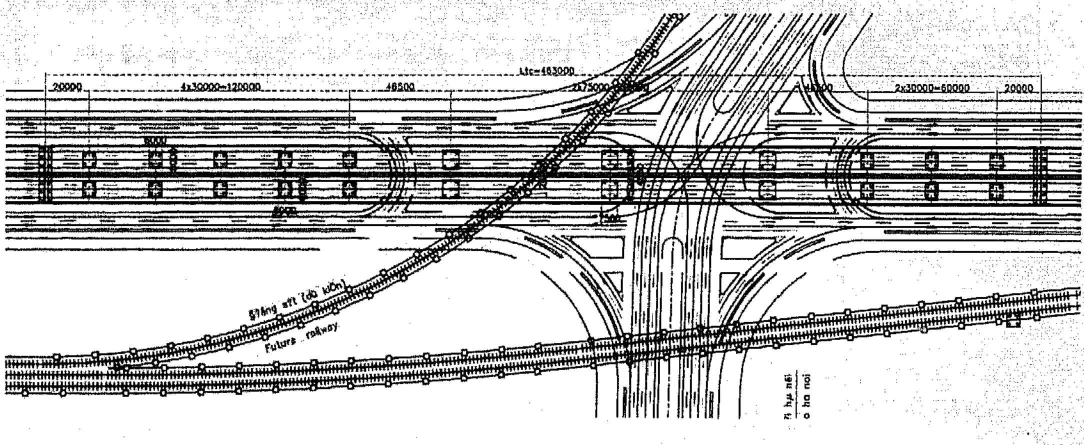


Source: Vinamarine Letter No. 192/TB-BGTVT dated 17 May 2009.

Figure 2.5-11 Required Navigation Channel

3) Flyover at No. 2 Intersection

No. 2 intersection is crossing the Dinh Vu Ring Road at Km 5+149.11. The Project road shall pass over the ring road through a flyover structure (refer to Section 2.5.3 above).

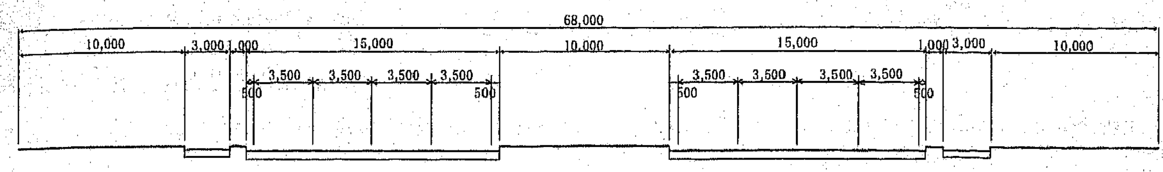


Source: Study Team

Figure 2.5-12 Flyover at No.2 Intersection

4) Ring Road in Dinh Vu Industrial Zone

Dinh Vu Ring Road is the most important arterial road in the industrial zone. It crosses the Project road at three (3) locations. Refer to Section 2.5.3 above.



Source: Hai Phong City Master Plan

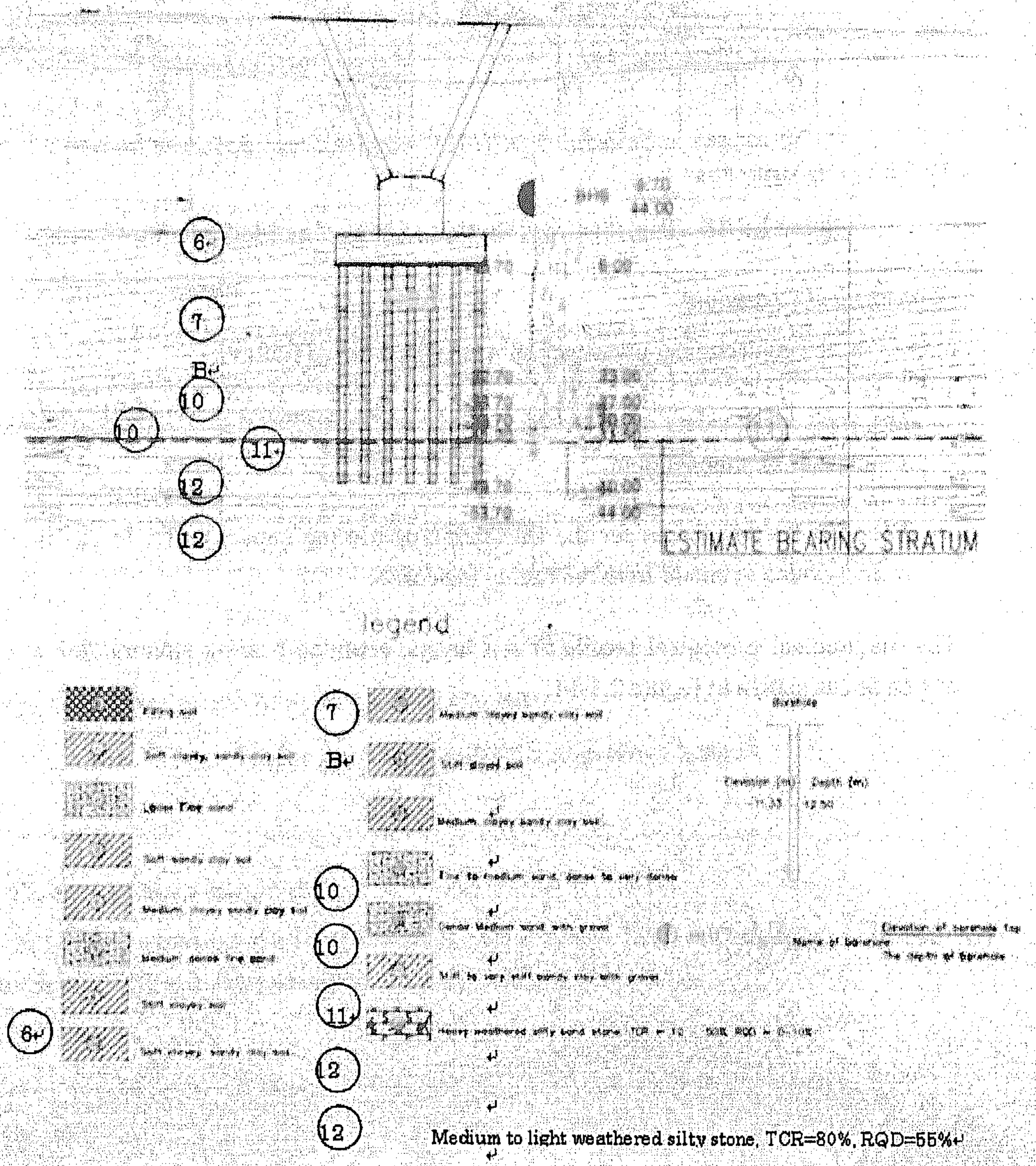
Figure 2.5-13 Typical Cross Section of Ring Road in Dinh Vu IZ

(4) Geotechnical Conditions

In the F/S, the geotechnical investigation was carried out as follows:

- The rock layer exists at about EL –41 m, which shows that N-value larger than 50 is assumed as bearing stratum.
- The skin friction forces for the calculation of bearing capacity of pile can be calculated from N-value obtained from the boring log charts.

The longitudinal geological profile of soil layers, assumed bearing stratum, and piles for the design are as shown in Figure 2.5-14.



Source: F/S Report (July 2009)

Figure 2.5-14 Longitudinal Geological Profile of Soil Layers, and Bearing Stratum

2.5.6. Cross Structure Design

(1) ***Drainage Box Culverts***

Data from the F/S on drainage box culverts crossing the Project road are updated as follows:

Table 2.5-24 List of Drainage Box Culvert

Order No.	Existing drainage culvert											Remark
	Station Km.. + ...	Direction of water	Type of Culvert	Side (m)			F (Km²)	Q_{tk} (m³/s)	Water level			
				Number of Culvert	F (B)	H			H_d (m)	□Bottom (m)	$H_{tk\%}$ (m)	
1	Km0+950	L-R	Box		3.00 x	3.00	0.20	13.30	3.85	-1.00	2.85	Drainage catchment
2	Km1+700	L-R	Box	8 x	4.00 x	4.00	8.20	172.1	4.87	-1.98	2.89	Drainage catchment
3	Km2+390	L-R	Circular		2.00		0.10	6.65			2.92	Drainage catchment
4	Km4+100	L-R	Box	3 x	4.00 x	4.00	1.00	66.50	2.22	0.80	3.02	Drainage catchment
5	Km10+058.30	R-L	Circular		1.25				1.40	1.30	2.70	Drainage of gutter
6	Km10+400	R-L	Circular		1.25					1.10	2.68	Drainage of gutter
7	Km10+659	R-L	Circular		1.25				1.68	1.00	2.68	Drainage of gutter
8	Km10+818	R-L	Box	2 x	4.00 x	3.00	0.50	33.30	2.57	0.10	2.67	Drainage catchment
9	Km13+980	R-L	Circular		1.25						2.59	Drainage of gutter
10	Km14+669	L-R	Box		1.50 x	3.00					2.57	Drainage on dyke
11	Km14+926	L-R	Box		3.00 x	3.00			3.27	-0.70	2.57	Drainage catchment
12	Km15+150	R-L	Box	3 x	4.00 x	4.00	3.50	66.50	4.34	-1.80	2.54	Drainage catchment
13	Km15+521.5	L-R	Circular		1.25				2.24	0.30	2.54	Drainage catchment
14	Km15+688	R-L	Circular		1.25				1.74	0.80	2.54	Drainage of gutter

Source: Study Team

(2) ***Underpass Box Culverts***

Data from the F/S on underpass box culverts crossing the Project road are updated as follows. Two underpasses are planned in Cat Hai Island.

Table 2.5-25 List of Underpass Box Culvert

Station	Type of Culvert	Width	Height	Length
Km10+128.1	Box	4.00m	3.20m	29.5m
Km13+600	Box	4.00m	320m	29.5m

Source: Study Team

2.5.7. Soft Ground Treatment

In this Study, soft ground sections were not updated. In the F/S, it is reported that soft ground is laid for the whole stretch of the Tan Vu – Lach Huyen Highway

(1) ***Soft Ground Section where Countermeasure NOT Required***

Table 2.5-24 shows the soft ground sections where countermeasure is not required during the F/S.

Table 2.5-26 Location of Soft Ground (where Countermeasure is not Required) in F/S

	Station	Distance (m)	Condition of calculation		Without treatment			
			Thickness. of soft soil layers (m)	Height of EM (m)	Factor of safety (Fs)	Con. Sett. Sc (m)	Total. Sett. S (m)	Sett. Within 15 years after pavement (m)
1	Tan Vu Interchange		32.0	10.0	0.562	2.12	2.54	0.96
2	Km00+258.00-Km01+634.00	1376.0	32.0	3.3	1.219	1.02	1.22	0.56
3	Km01+765.00-Km02+542.00	777.0	32.0	3.6	1.194	1.09	1.31	0.65
4	Km03+130.00-Km04+738.00	1608.0	28.0	4.0	1.096	1.11	1.33	0.51
5	Km05+430.00-Km07+250.00	1820.0	25.0	4.8	0.936	1.24	1.49	0.32
6	Km10+100.00-Km10+450.00	350.0	25.0	1.7	1.843	0.32	0.38	0.08
7	Km10+920.00-Km13+300.00	2380.0	15.0	3.6	1.133	0.69	0.83	0.06
8	Km13+300.00-Km13+950.00	650.0	14.0	2.8				
9	Km13+950.00-Km15+320.00	1370.0	22.0	4.5	1.032	0.82	0.98	0.44
10	Km10+450.00-Km10+920.00	470.0	6.0	2.2	1.841	0.26	0.31	0.23
11	Km15+320.00-Km15+874.00	554.0	17.0	2.7	1.841	0.26	0.31	0.23

Source: F/S Report (July 2009)

Section No. 5 in the above table is included in the approach bridge section.

(2) Soft Ground Section where Countermeasure Required

In the F/S, there are nine countermeasures proposed for soft ground treatment. Those should be further investigated and studied in the detailed design stage.

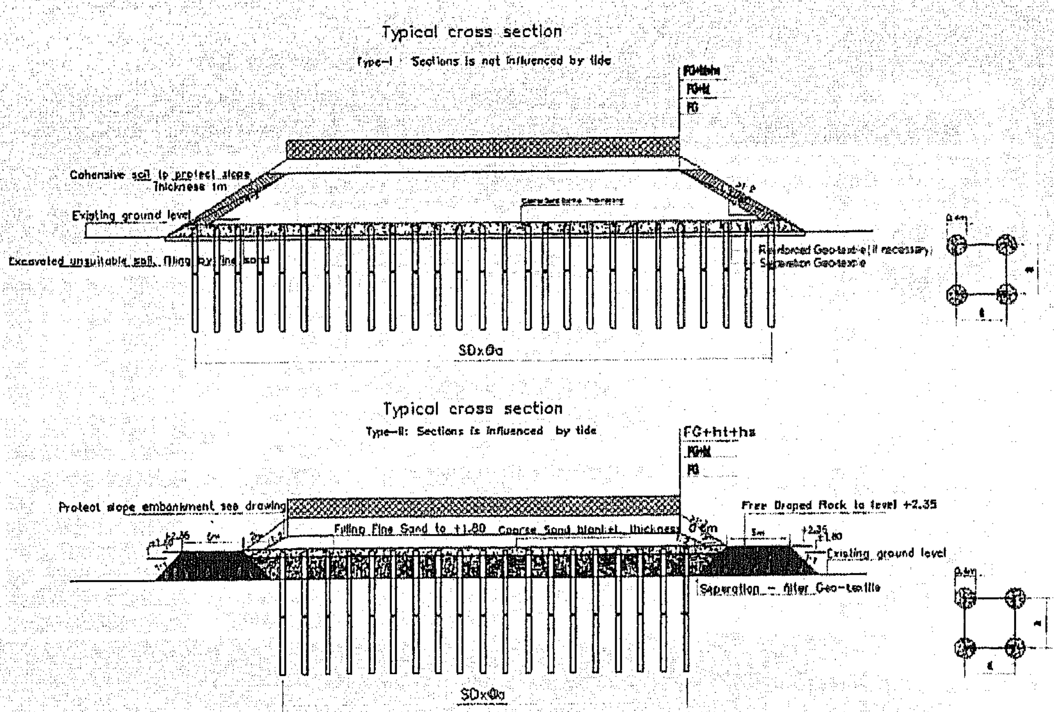
Table 2.5-27 List of Soft Ground Countermeasures in F/S

No	Soft soil treatment content																		Results of treatment			
	Treatment by SD or Replacement			Height of surcharge (m)	Thick. Of sand blanket (m)	Filling										Berm		Reinfor. Geotex. 200kN/m (layer)	Factor of safety affter complete Fs	U (%)	Resi. Sett. (cm)	Rate of Sett. (cm/year)
						Stage 1			Stage 2			Stage 3+4			Total of construc. Time (days)							
	SD	Spacing (m)	Depth (m)			H1 (m)	Rate of filling (cm/day)	Waiting time (day)	H2 (m)	Rate of filling (cm/day)	Waiting time (day)	H3 (m)	Rate of filling (cm/day)	Waiting time (days)		B (m)	H (m)					
1	SD	1.5x1.5	26		2.5	5.00	10	60	2.50	10	60	5.0	10	150	425	65	3.5	2	1.401	92	17.5	1.84
2	SD	1.8x1.8	16.0		1.2	4.50	10	150							225				1.432	76	24.2	2.04
3	SD	1.8x1.8	18.0		1.3	3.50	10	60	1.40	10	90				229				1.430	83	18.9	4.74
4	SD	1.8x1.8	15.0		1.3	4.00	10	75	1.30	10	90				248				1.459	76	26.8	2.34
5	SD	1.5x1.5	20.0		1.5	4.00	10	500	1.30	10	500	1	10	500	1863				1.404	86	17	0.53
6	Replacement		1.5																		28	
7	SD	2.0x2.0	13.0		0.8	4.4	10	180							254			1	1.424	85	10.4	3.39
8	Replacement		2.0																			
9	SD	1.5x1.5	20.0		1	4	10	60	1.5	10.00	90				235			1	1.447	95	4	3.28
10	Normal filling																					
11	Normal filling																					

Source: F/S Report (July 2009)

(3) Typical Cross Section of Soft Ground Treatment

1) Sand Drain



Source: F/S Report (July 2009)

Figure 2.5-15 Typical Cross Section of Soft Ground Treatment (Sand Drain)