5.4.6 Sedimentation Regime and Characteristic of External Forces by Output of Calculation

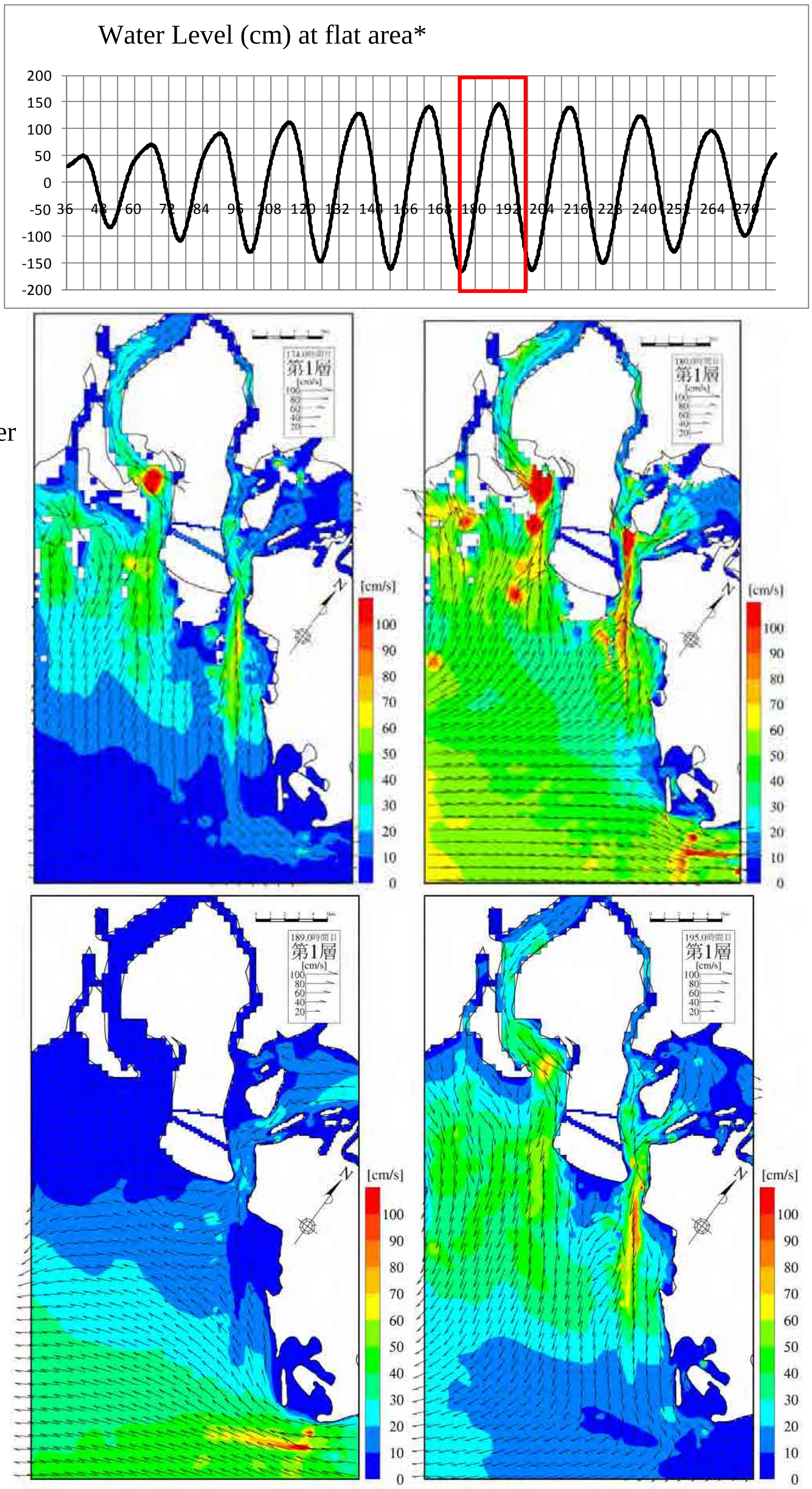
1) Distribution of Current Velocity

First Layer

Ebb Tide

First Layer

Flood Tide



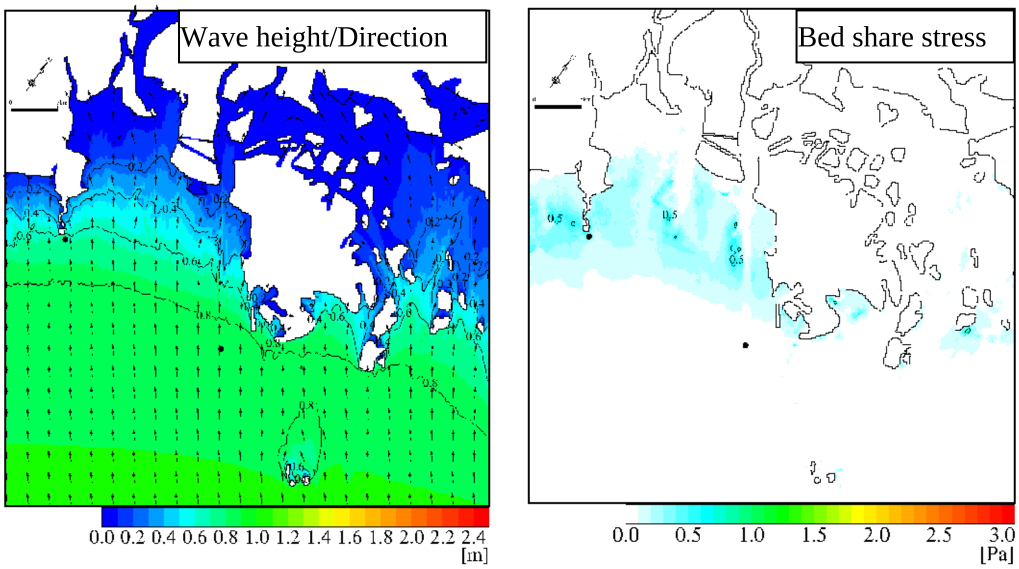
Note:* Flat area means the place where 100m west from the edge of channel.

Figure 5.4.23 Current Velocity and Vector in the First Domain (Phase 2: Spring Tide)

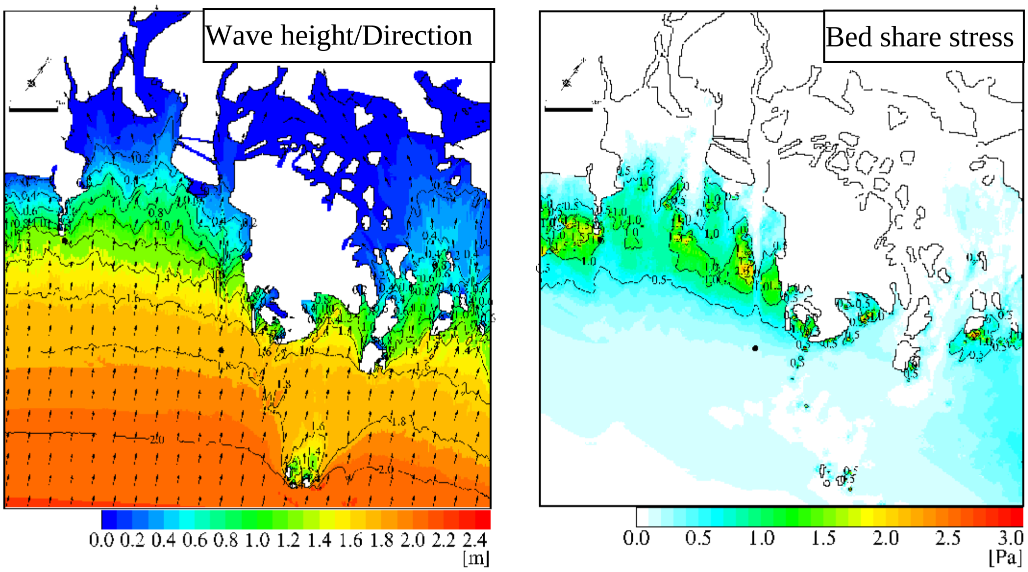
2) Bed Share Stress by Waves and Current

a) Bed Share Stress by Waves

The simulation outputs of bed share stress by energy averaged waves are shown in Figure 5.4.24 through Figure 5.4.25.

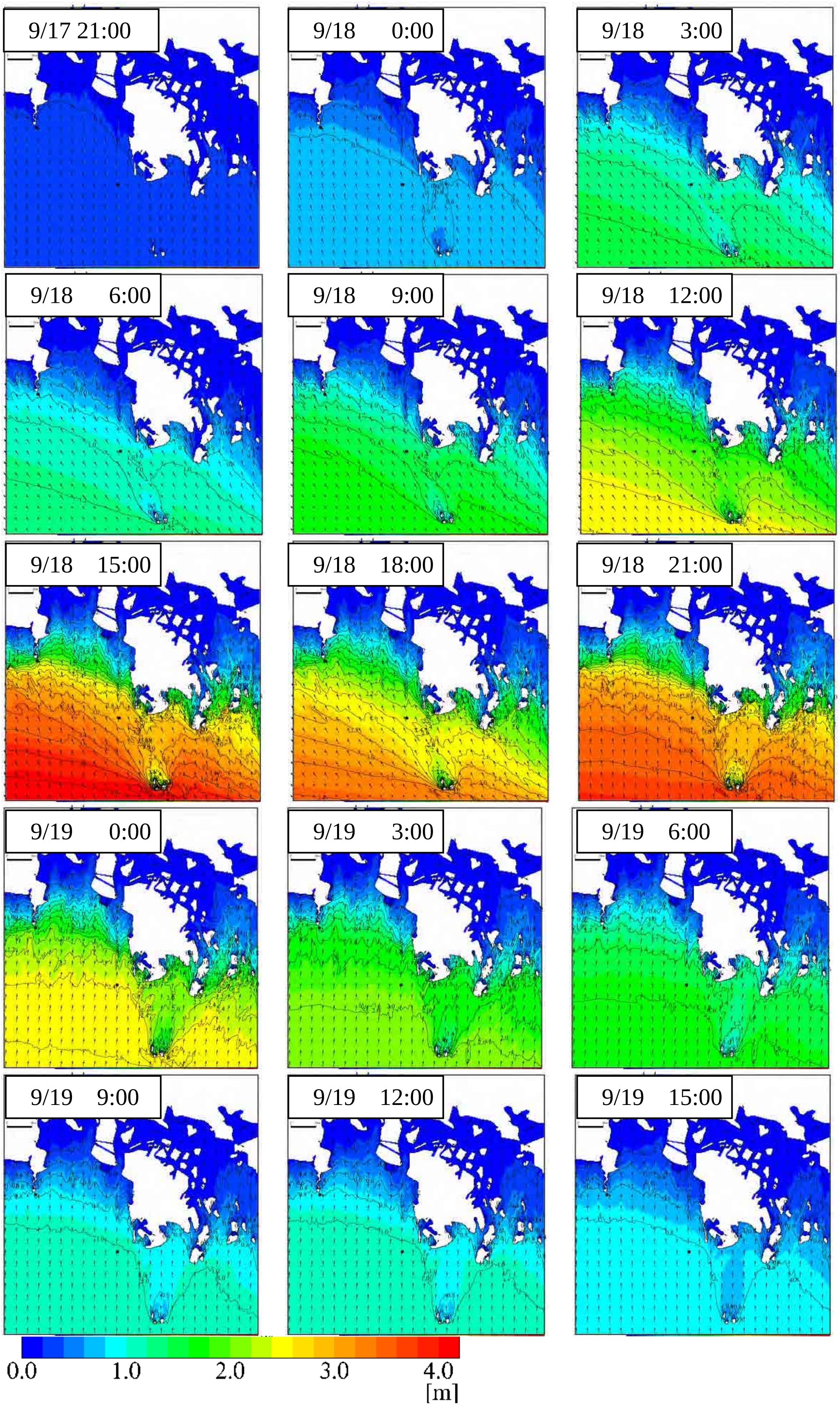


(Energy Averaged wave: At Hon Dau Wave Height 0.88m, Wave Period 4.8sec., Wave Direction SE)



(Storm Wave: At Hon Dau Wave Height 2.58m, Wave Period 6.1sec., Wave Direction SSE)
Note: For median grain size 0.075mm (between silt and fine sand), 0.075mmof Critical Shields Numbers= 0.2
Bed Share Stress→0.24Pa

Figure 5.4.24 Simulation Output of Waves and Bed Share Stress

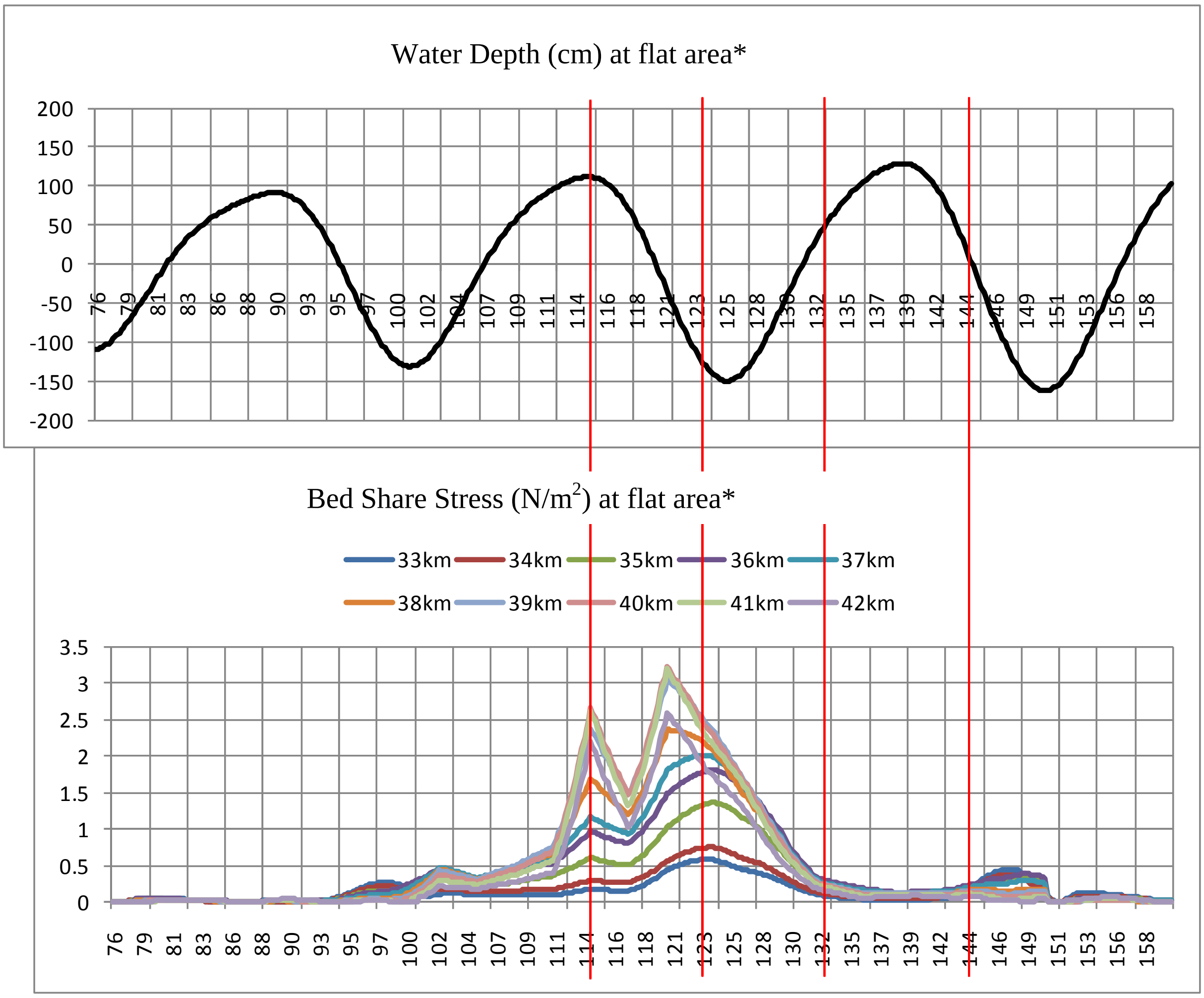


(Phase1, Storm Waves)

Figure 5.4.25 Simulation output of Waves (Phase1)

3) Bed Share Stress on Waves and Current Phases

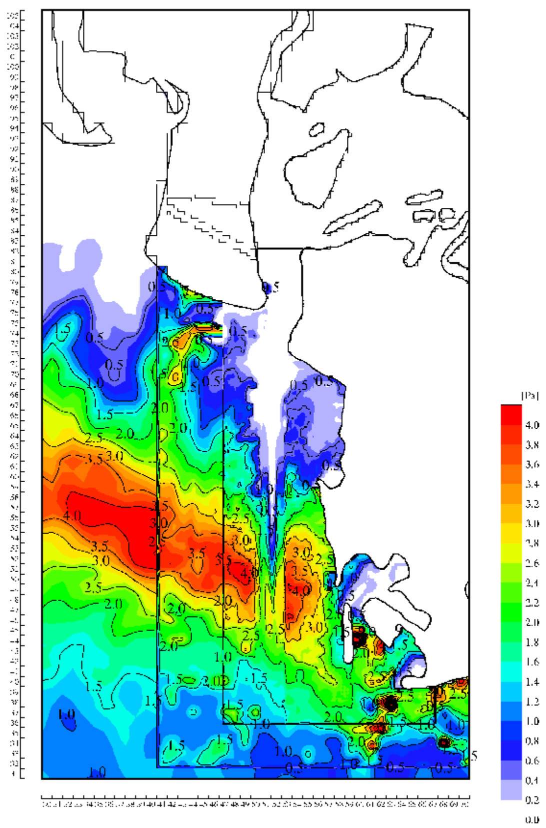
The simulation of bed share stress for Phase1 (Highest Wave) in time sequence is shown in Figure 5.4.26. The first-time peak of stress occurs in flood tide, and the second-time peak of stress occurs in ebb tide. In Figure 5.4.27, the simulation output of bed share stress before and after flood and ebb tide are shown.



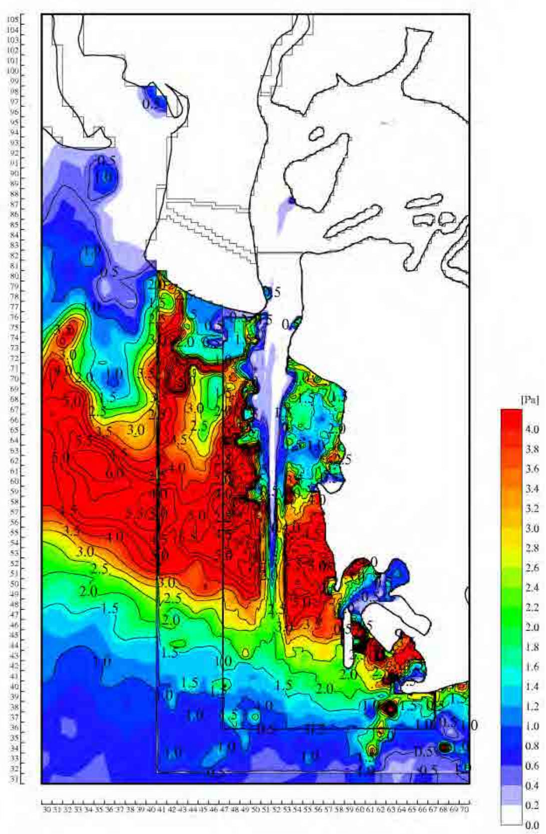
Note:* Flat area means the place where 100m west from the edge of channel.

Figure 5.4.26 Longitudinal Distribution of Bed Share Stress with time sequence (Phase1, Highest Wave)

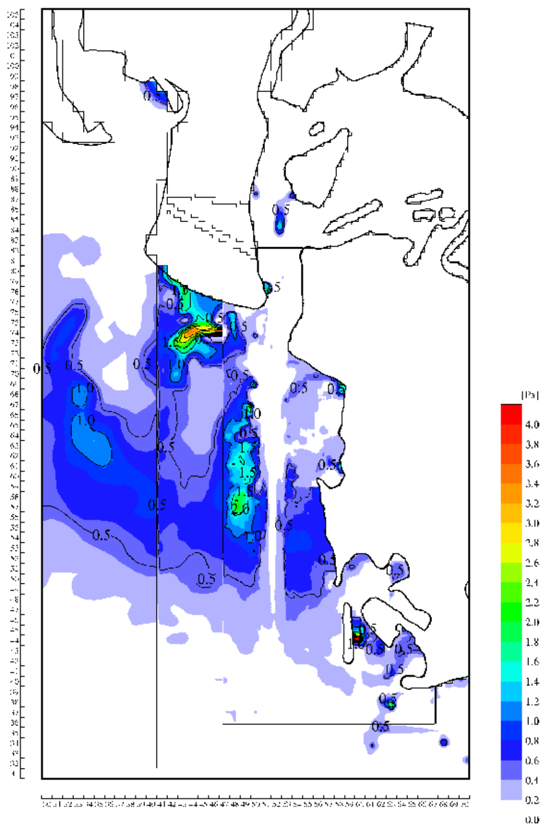
T=114hour (First Peak, Flood tide)



T=123hour (Second Peak, Ebb tide)



T=132hour (Flood tide)



T=144hour (Ebb tide)

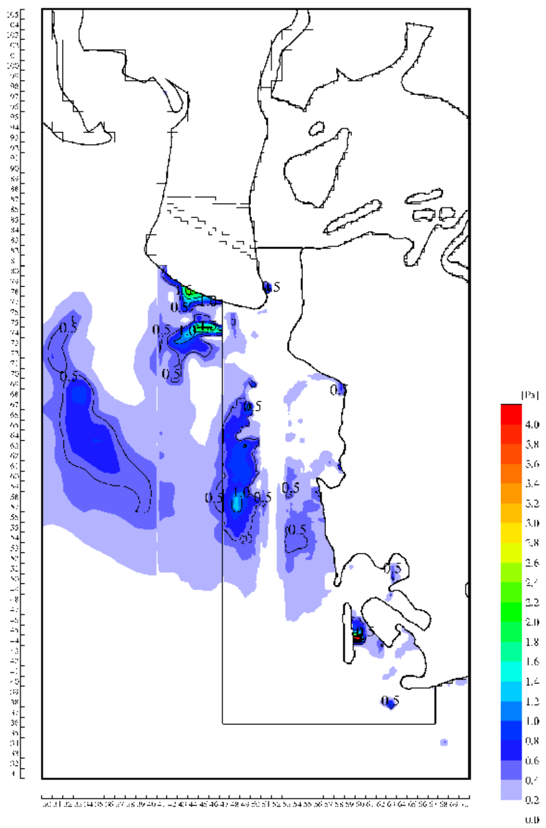
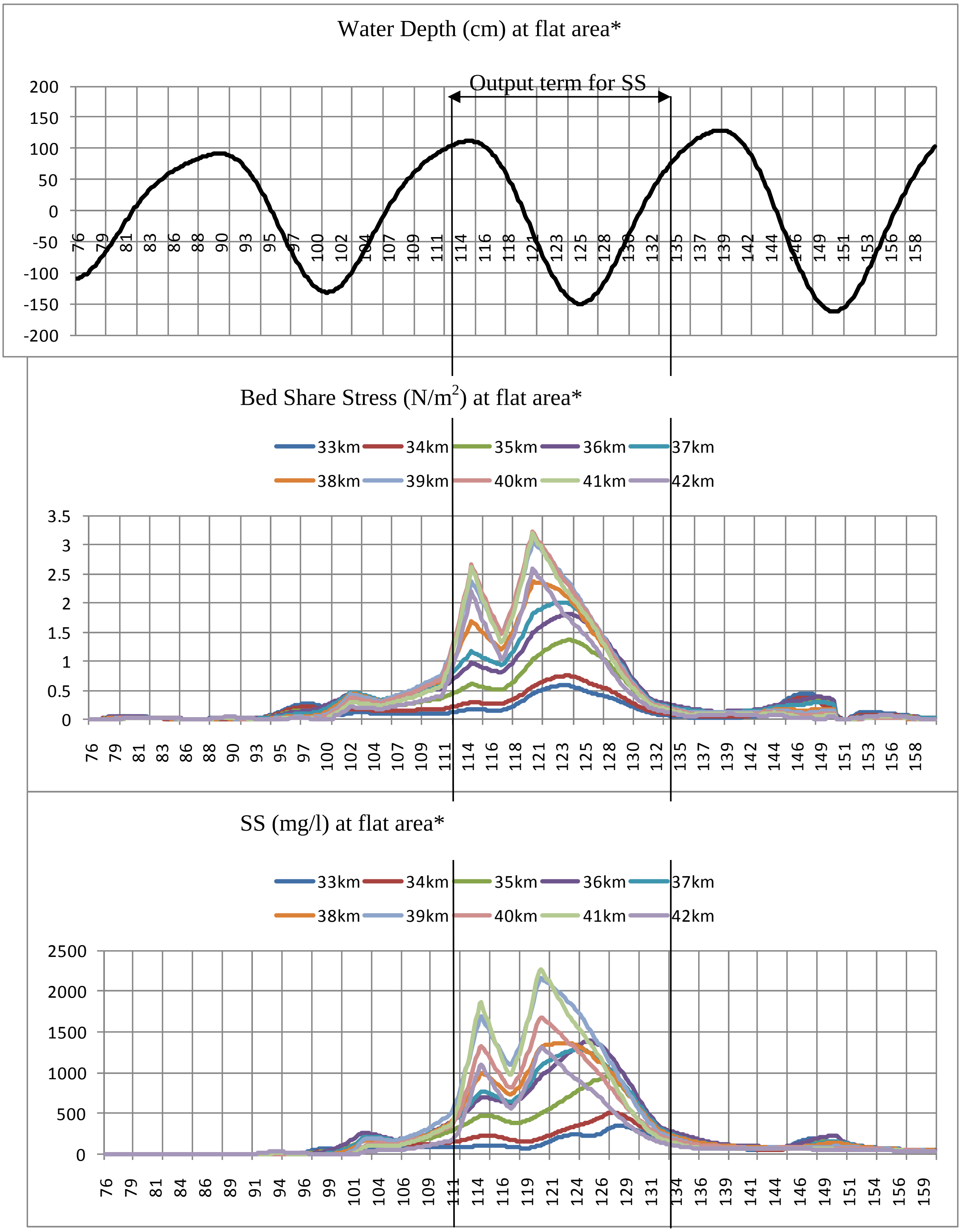


Figure 5.4.27 Output of Bed Share Stress before and after Strom Wave under Wave and Current Phases

4) Output of SS Density by Modeling

The SS density in Phase1 (Highest Wave) calculated in time sequence is shown in Figure 5.4.28. And the planar distribution of SS density simulated is outputted in Figure 5.4.29.



Note:* Flat area means the place where 100m west from the edge of channel.

Figure 5.4.28 SS Distribution with Water Depth and Bed Share Stress (Phase 1, Highest Wave)

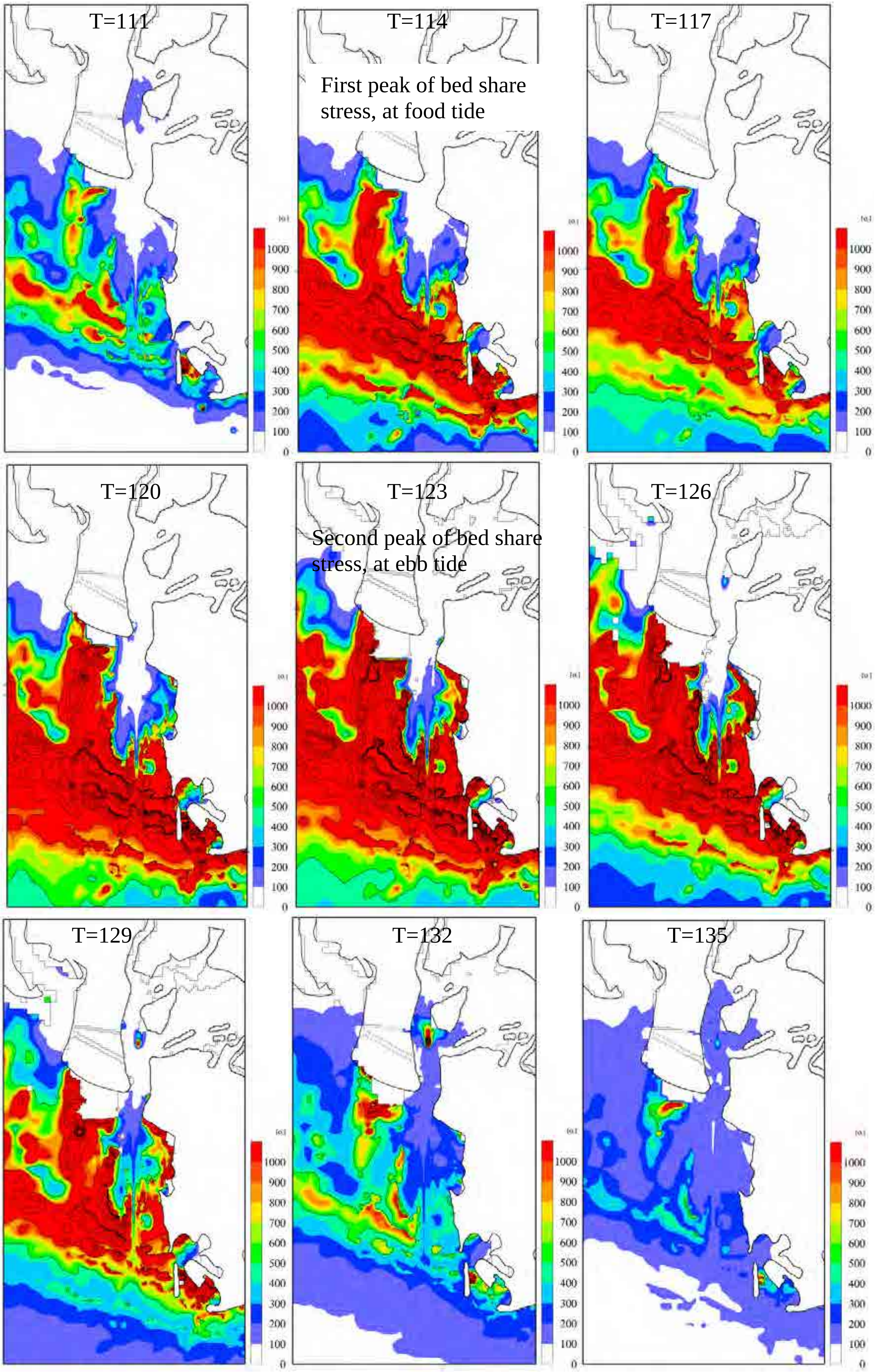
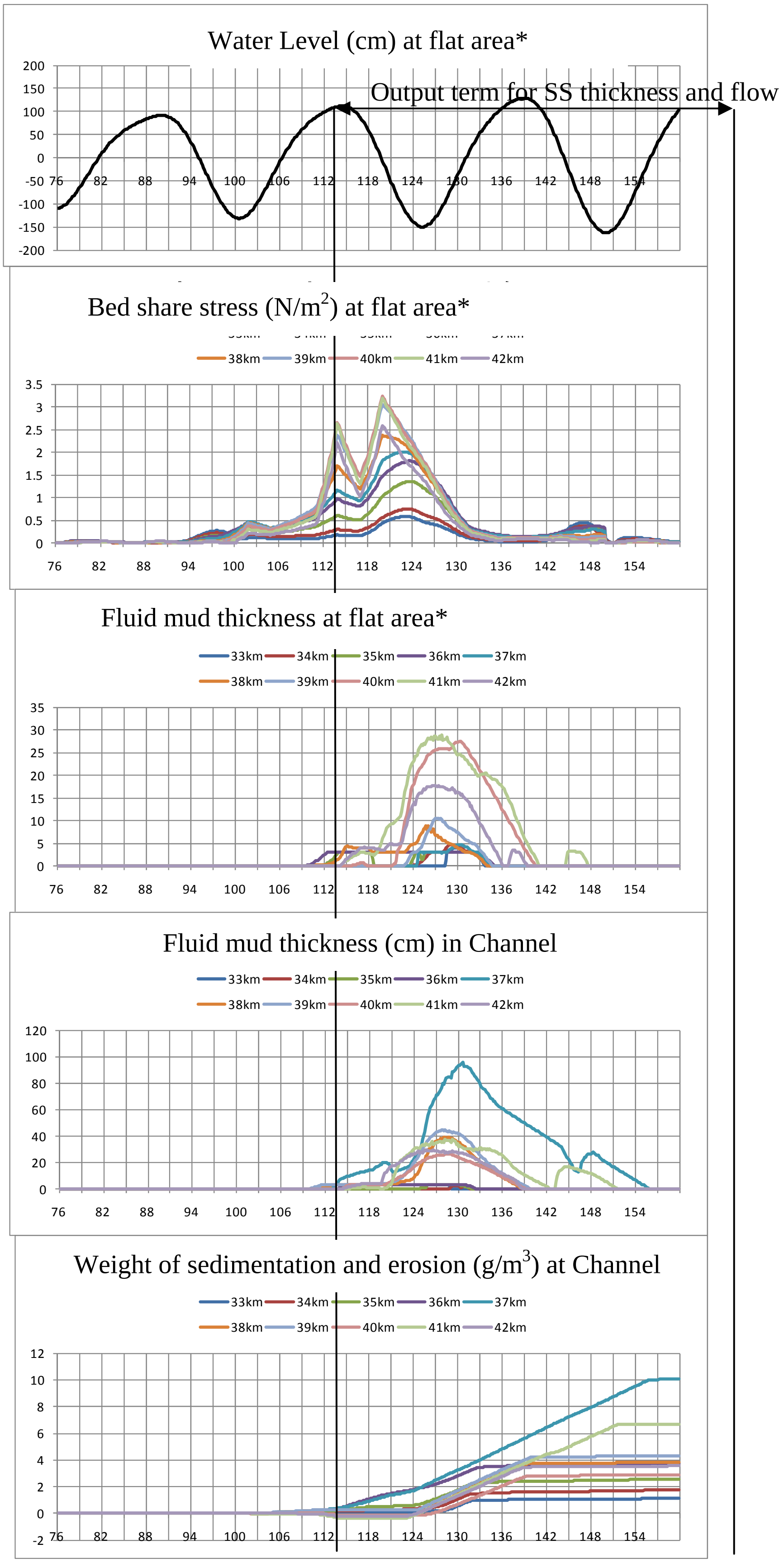


Figure 5.4.29 SS Distribution in the Seventh Layer (Phase1, Highest Wave)

5) Assessment on Behavior Characteristic of Fluid Mud

The cross-sectional behavior of fluid mud such as thickness of its layer, and erosion and sedimentation in time sequence is calculated, and its output is shown in Figure 5.4.30. And the planer distribution of fluid mud thickness for the wider domain and the domain of channel are shown in Figure 5.4.31 through Figure 5.4.34, respectively. Furthermore, the flow vector of fluid mud and contour of fluid mud thickness are shown in Figure 5.4.33 and Figure 5.4.34. And Figure 5.4.35 shows the longitudinal distribution of fluid mud thickness after 6 hours later from the peak of bed share stress under highest wave.

- In the broad domain, the fluid mud is spread widely after several hours from the peak of bed share stress. Especially, the thickness of fluid mud reaches to more than 1m in the channel. Also generally the fluid mud forms in where the bed share stress is more than 1Pa as well as SS are more than 1,000mg/l. The fluid mud seems to settle into the seabed after one day from the peak of the bed share stress. And the fluid mud stays much longer time in the channel than the flat area where is 100m west from the edge of the channel.
- Concerning the flow vector of fluid mud and its thickness, from 37km - 39km area fluid mud flows into the channel from west side after the first peak of bed share stress. At the second peak of bed share stress, broadly fluid mud flows into the channel from west side and simultaneously from east side of the channel. At the next timing of flood tide, fluid mud flows into the channel, and sedimentation is increased in the reach of 32km - 34km. Although fluid mud disappeared after time elapsed of 12 hours from the peak bed share stress, mud flow still moves into the deepened reach of the channel as shown in such as the T=153 hour.
- According to the longitudinal distribution of fluid mud in the channel, the thickness of fluid mud in east west flat is 40cm in maximum, and the thickness of fluid mud offshore from 38km shows a tendency to be more. The thickness of fluid mud in the channel is about 200cm in maximum, and its peak occurs in 36km and 38km - 39km reach.



Note:* Flat area means the place where 100m west from the edge of channel

Figure 5.4.30 Bed Share Stress, Thickness of Fluid mud and Erosion/Sedimentation Volume in time sequence (Phase 1, Highest Wave)

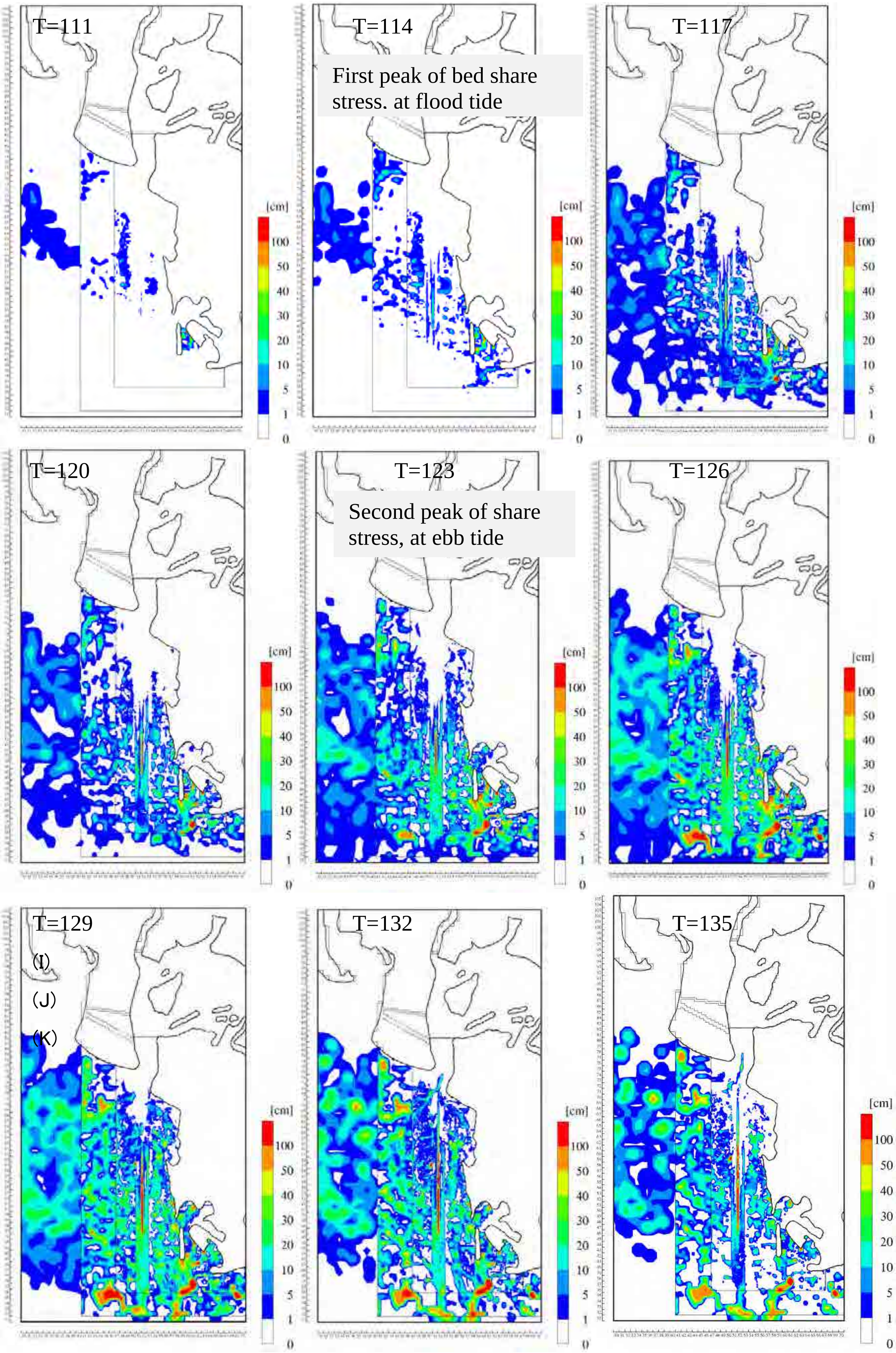


Figure 5.4.31 Distribution of Fluid mud thickness (Phase 1, Highest Wave)

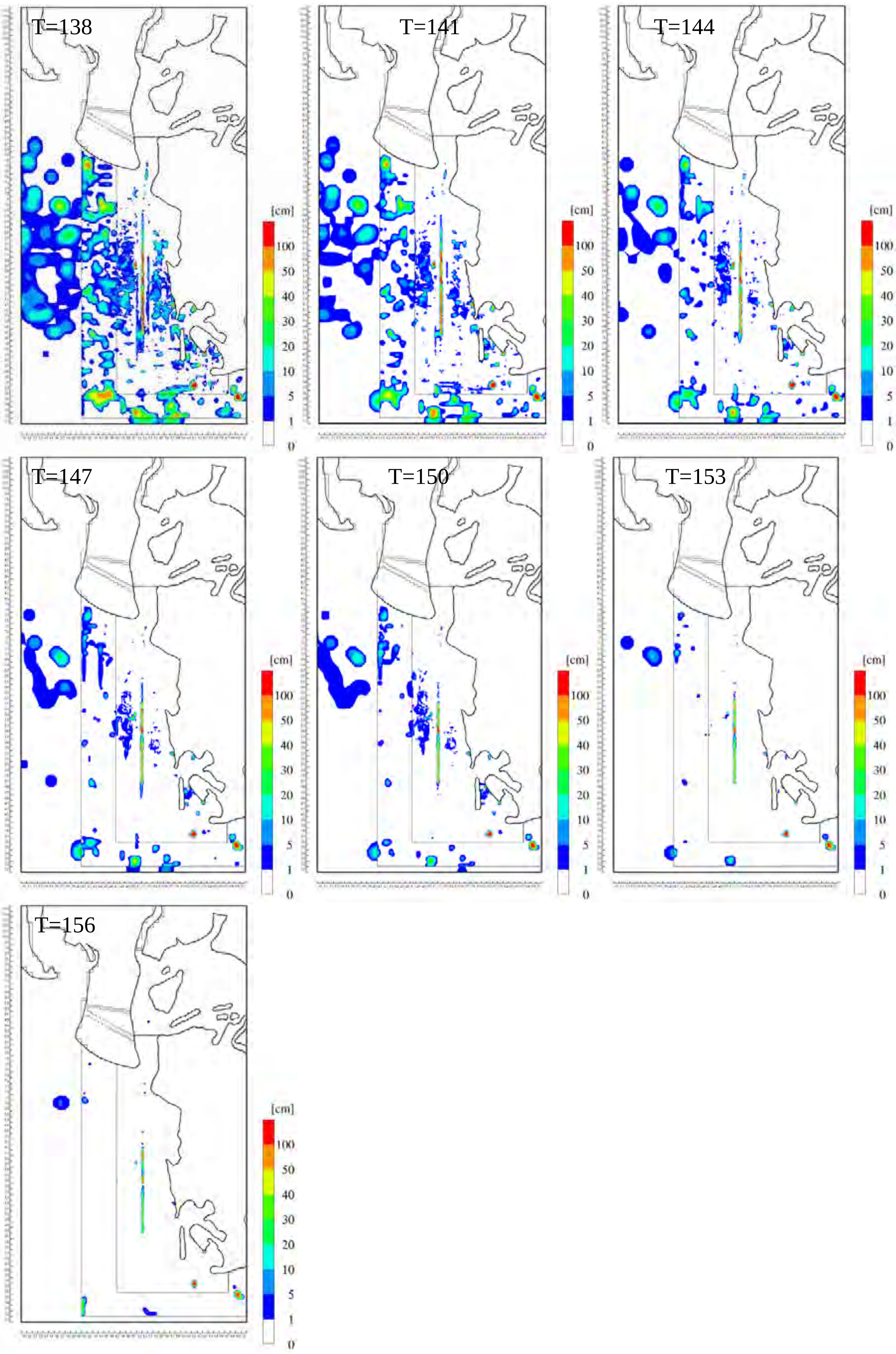


Figure 5.4.32 Distribution of Fluid mud thickness (Phase 1, Highest Wave)

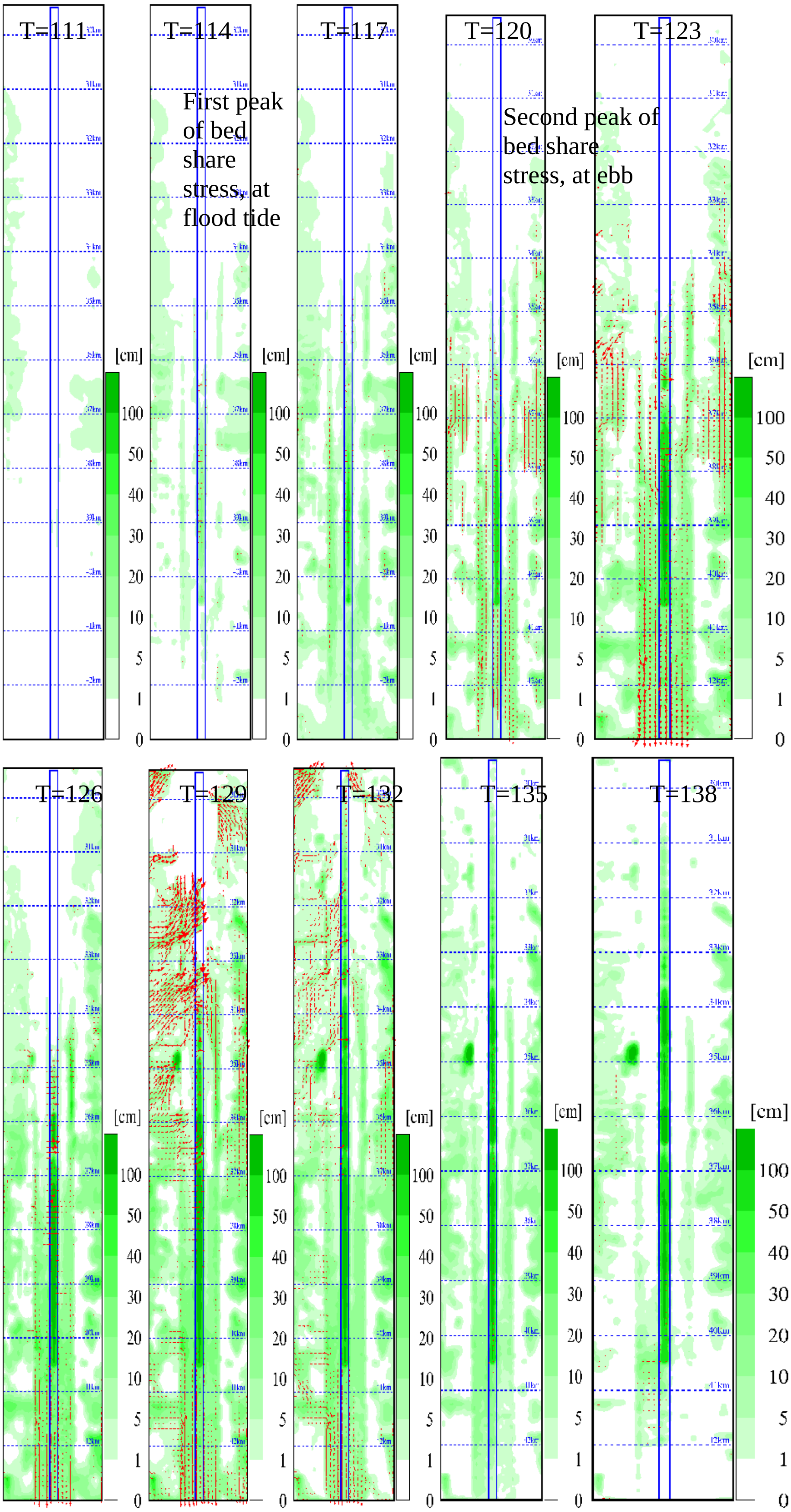


Figure 5.4.33 Flow Vector of Fluid Mud Movement (↑) and Contour of Fluid Mud Thickness (Phase1, Highest Wave in Channel Area)

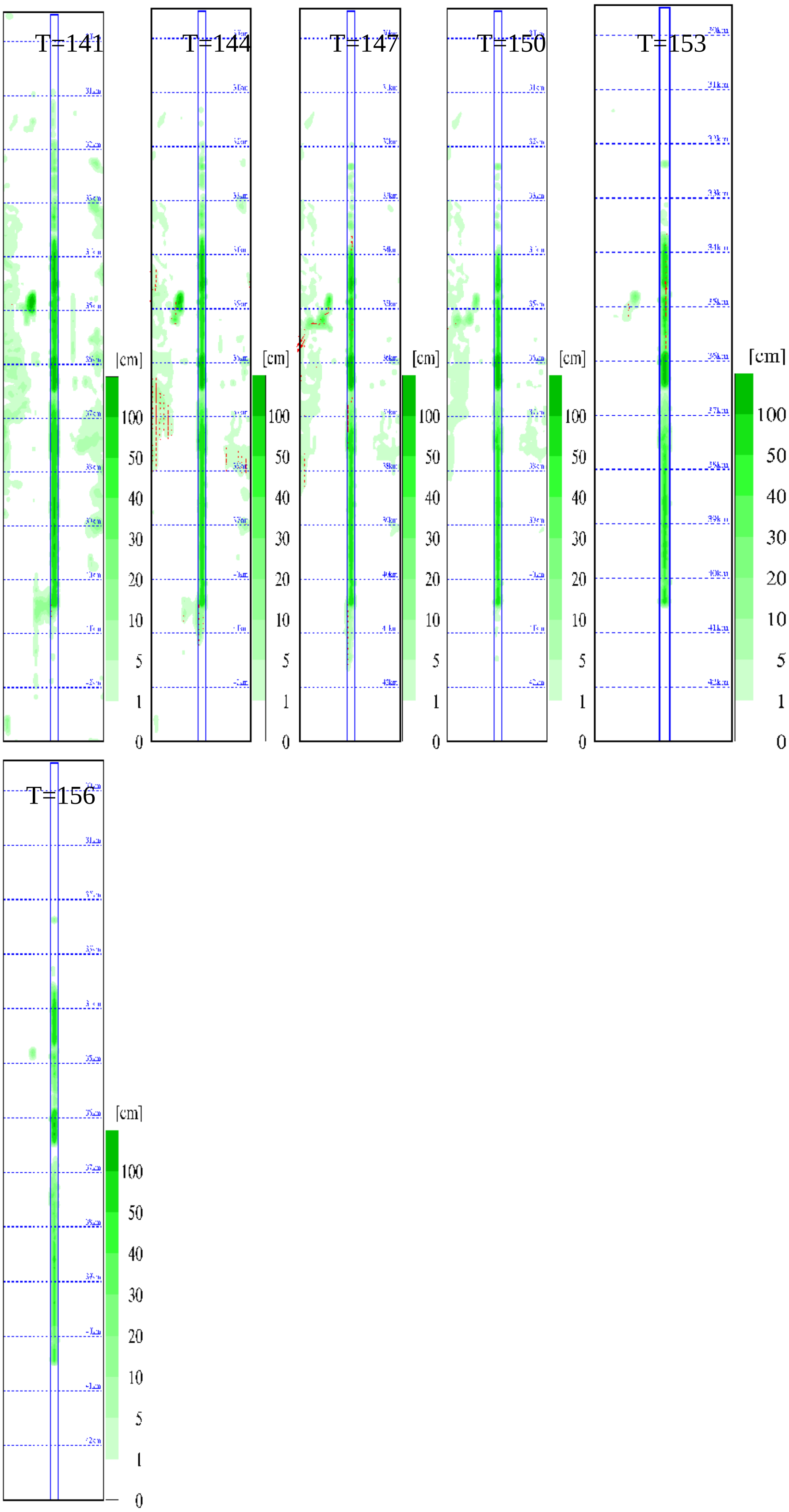
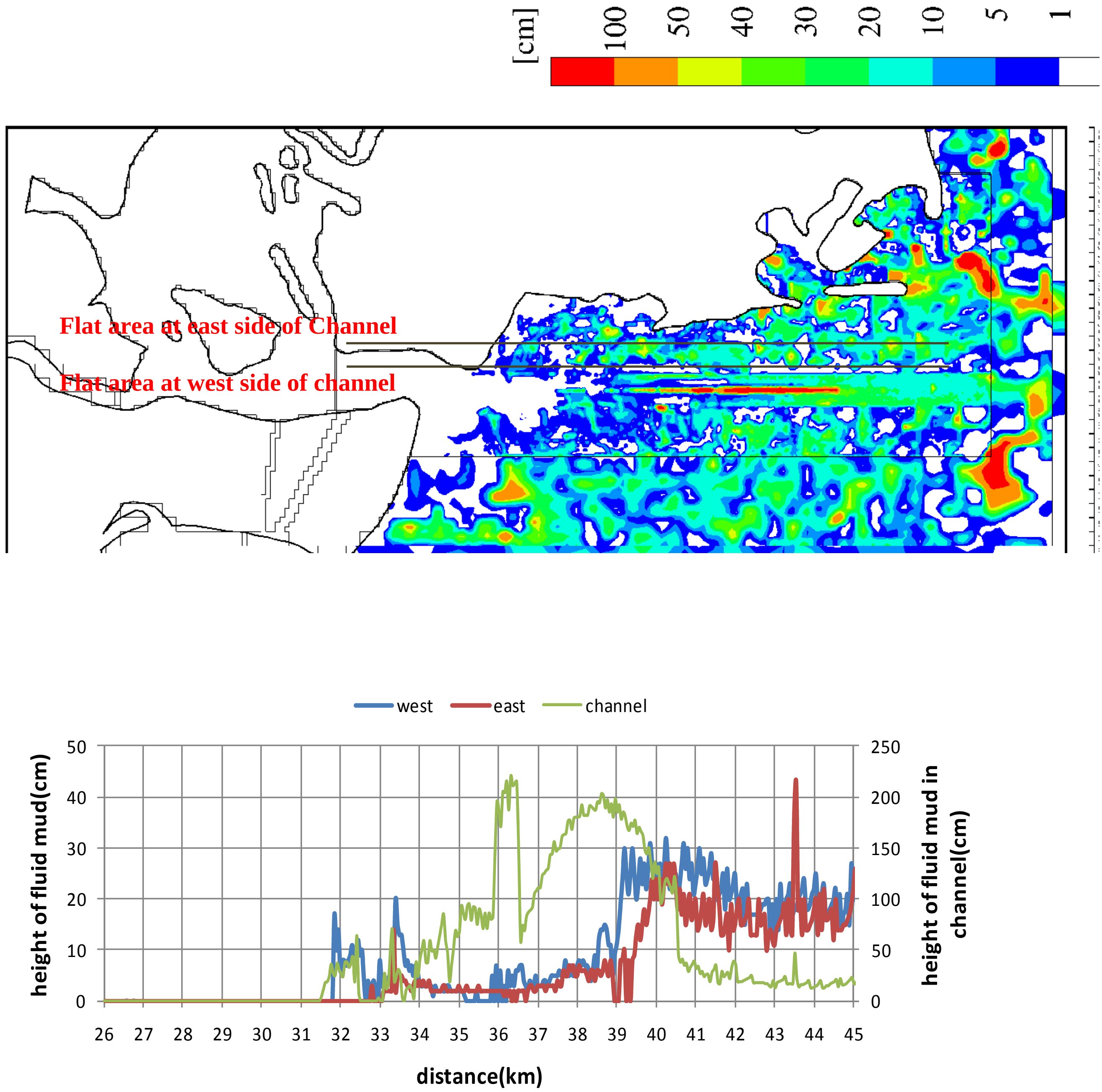


Figure 5.4.34 Flow Vector of Fluid Mud Movement (↑) and Contour of Fluid Mud Thickness (Phase1, Highest Wave in Channel Area)



Note:* Flat area means the place where 100m west from the edge of channel.

Figure 5.4.35 Longitudinal Distribution of Fluid mud thickness (Under Highest Wave after 6 hours of Peak of Bed Share Stress)

5.4.7 Sensitive Analysis of Fluid Mud

In Figure 5.4.36, the calculated sediment volume is shown with and without fluid mud. The case of without fluid mud means that the suspended mud only is considered.

Against 1,210,000-1,490,000 m^3 of the actual sediment volume in 2005, the simulated volume for (**Fluid Mud + Suspended Mud**) and (**Suspended mud only**) are **1,220,000 m^3** and **750,000 m^3**, respectively. Furthermore, in the section of 34km-37km where sedimentation is localized, the results show the greater sedimentation by fluid mud. Then, it is concluded that the fluid mud is considerably involved in the sediment mechanism of Lach Huyen Area.

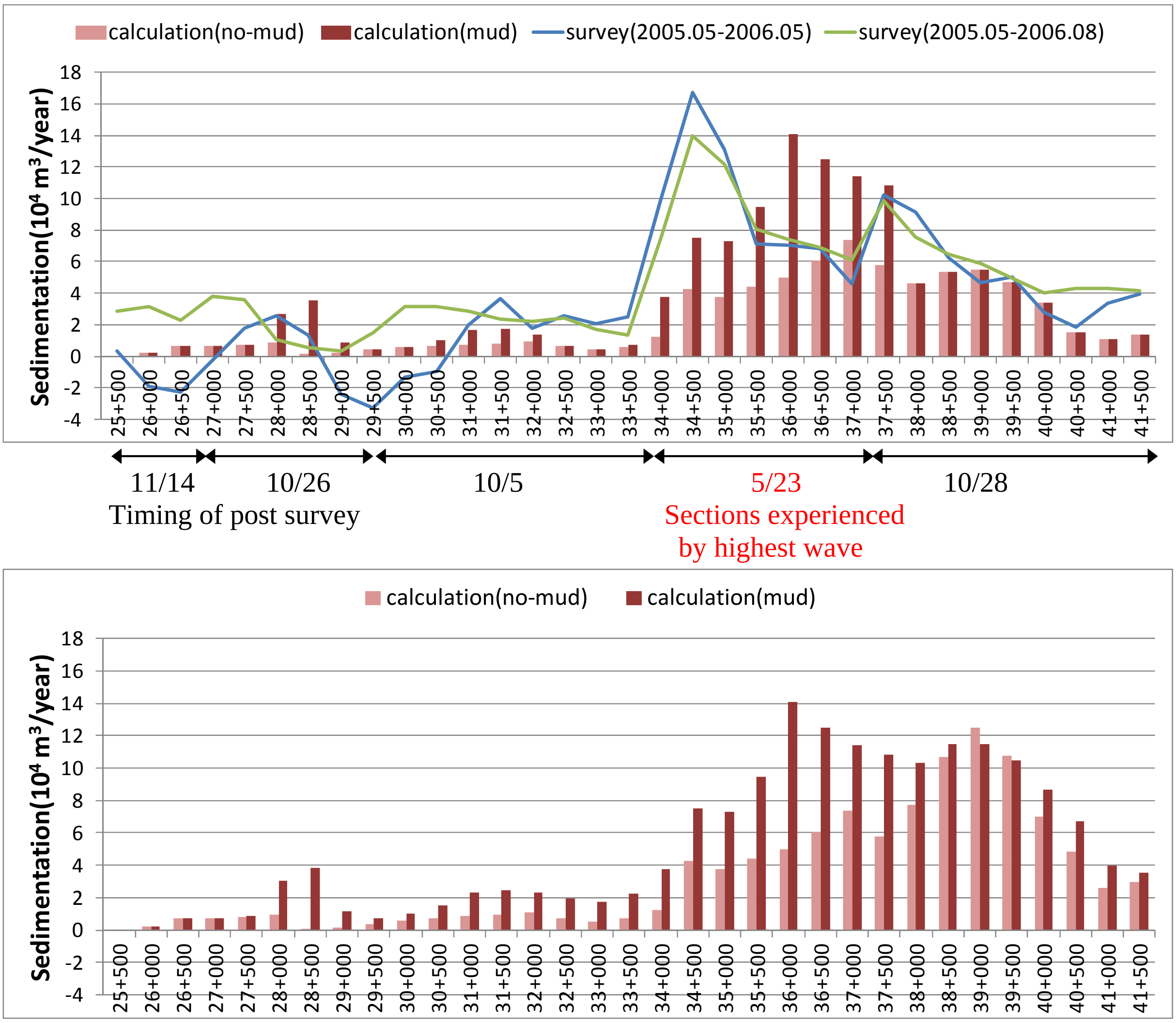


Figure 5.4.36 Difference of Sedimentation Volume with and without Fluid Mud (Phase 1)

5.5 Prediction of Sediment Volume on the Development Channel Configuration

5.5.1 Development of Channel Configuration

The existing channel has the configuration that the designed water depth is -7.8m C.D.L. (dredging depth) and -7.5m C.D.L. (nautical depth) with 100m channel width. This channel is planned to be deepened to -15.0m C.D.L. (dredging depth) and -14.0m C.D.L. (nautical depth) with 160m channel width.

In the development plan, the two container berths are located with the turning basin in land side area as shown in Figure 5.5.1. And the typical cross sections of channel are illustrated in Figure 5.5.2.

In order to evaluate the sediment degrees on the development plan of -10.0m channel, -12.5m channel also is simulated.

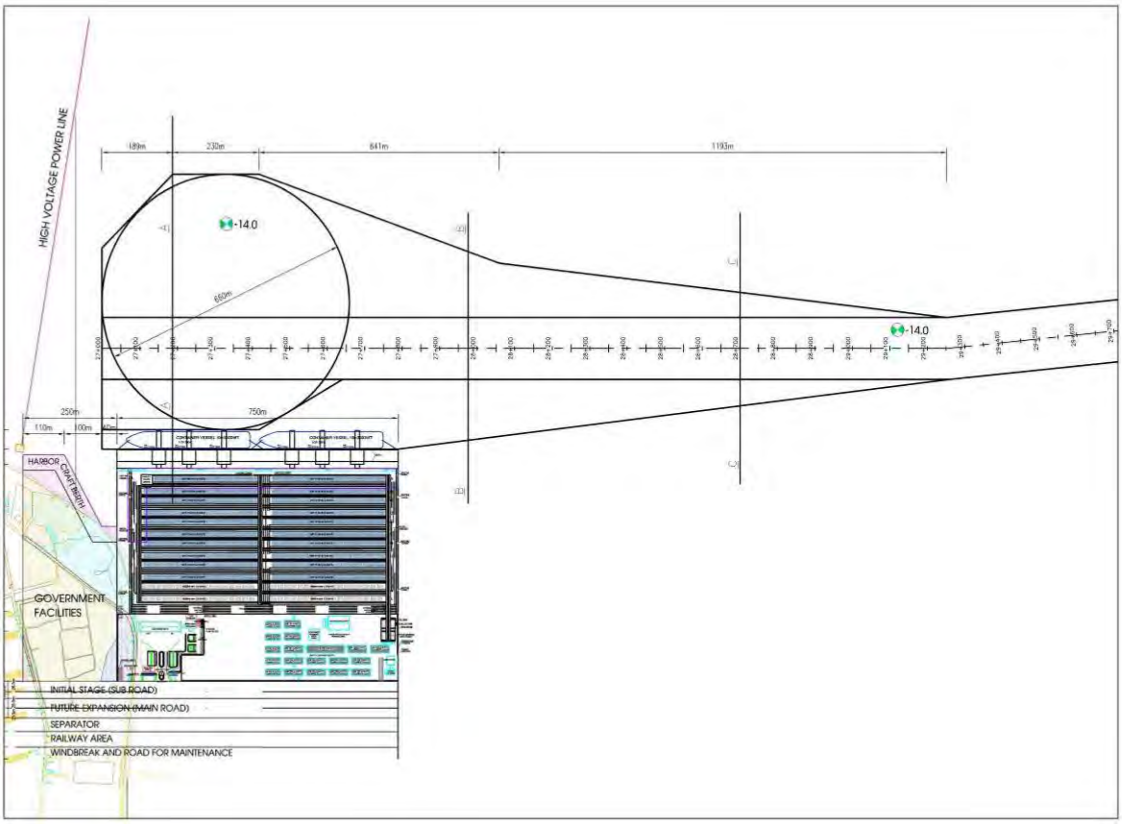


Figure 5.5.1 Container Terminal and Turning Basin

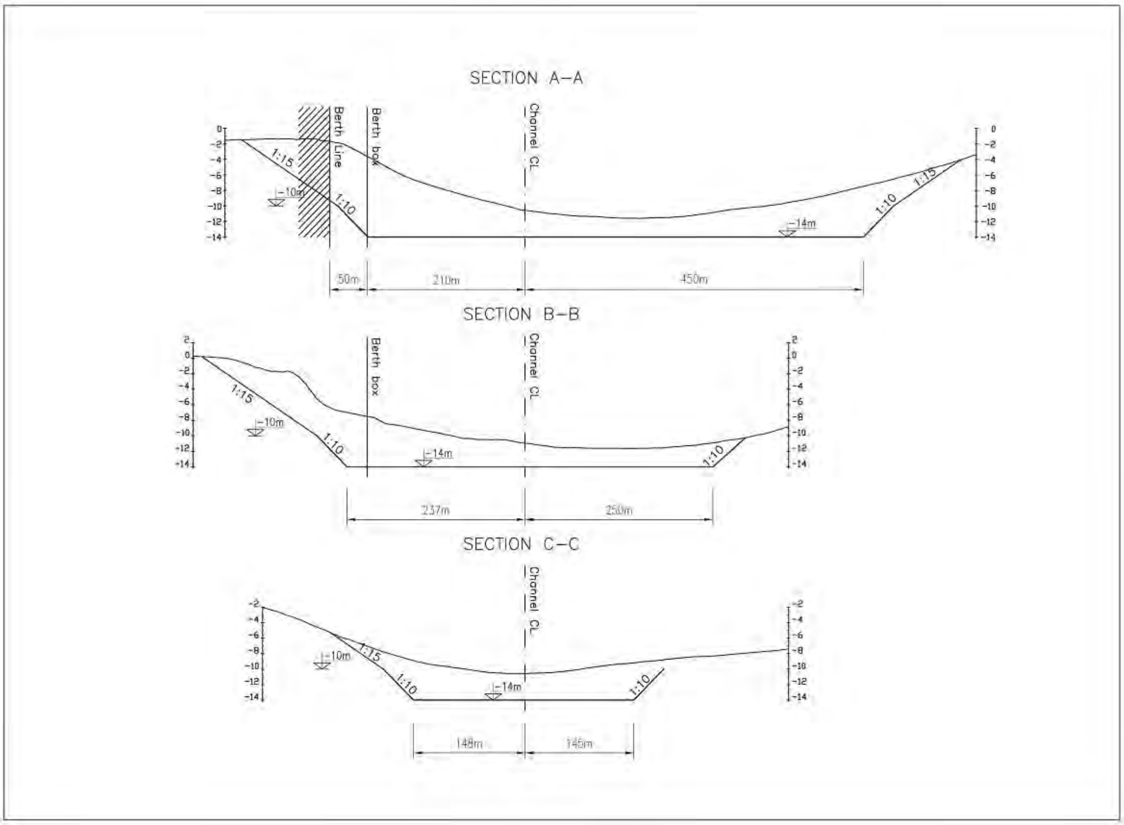


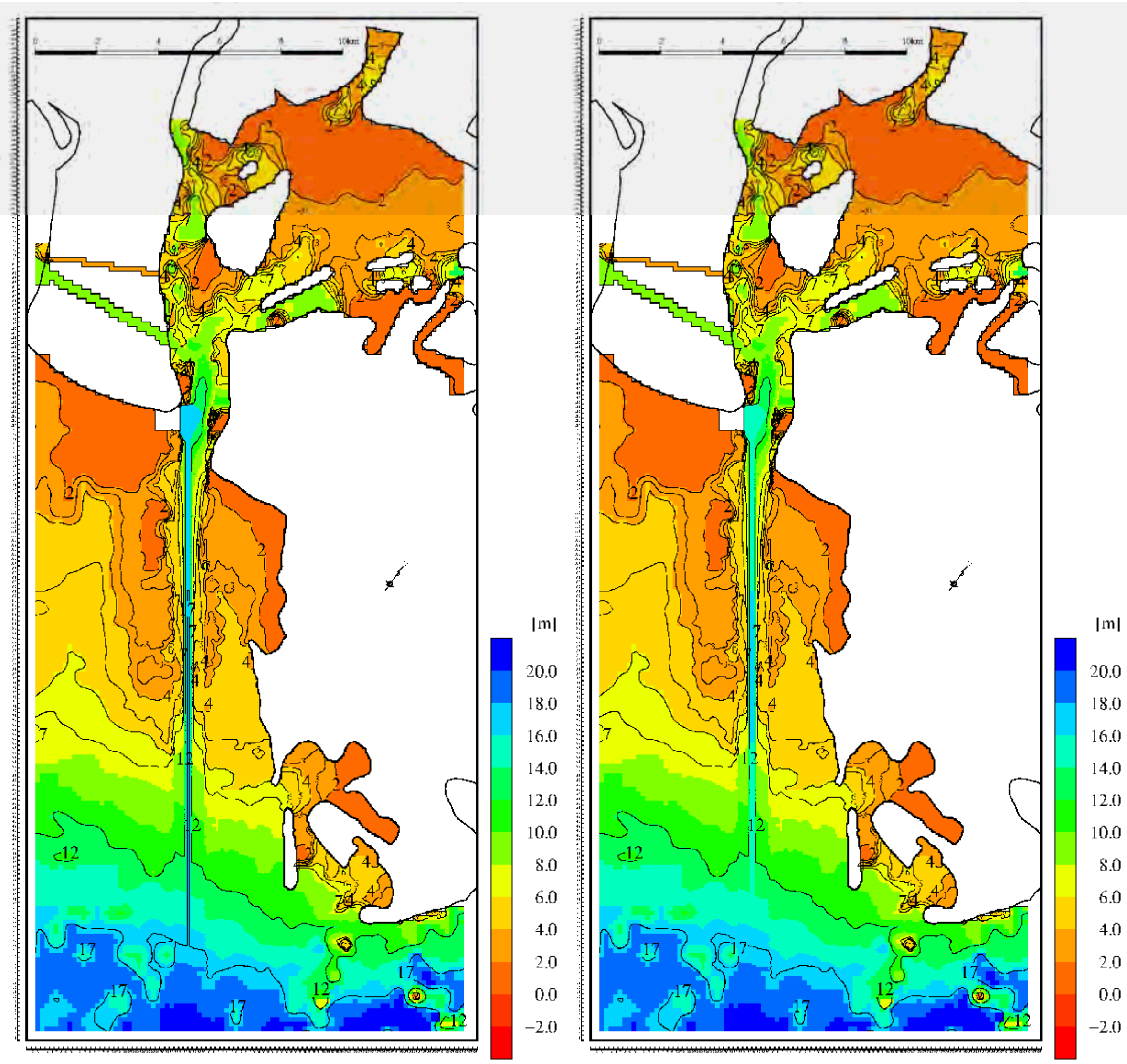
Figure 5.5.2 Plan of Turning Basin and Typical Cross Section of Development Channel

5.5.2 Bathymetry

The existing and planned bathymetries are shown in Figure 5.5.3.

Table 5.5.1 Study Alternatives

Cases	Channel Dimensions		Notes
	Water Depth (m)	Width (m)	Without countermeasure for reduction of sedimentation
Case-1	-14.0	160	
Case-2	-12.5	160	



Note: Water depth at M.S.L. (Unit: m)
(Case-1) -14m (Case-2) -12.5m

Figure 5.5.3 Bathymetry of Study Alternatives

5.5.3 External Force

1) Waves Conditions

For the planned channel configuration of -14.0m water depth with 160m width, the sediment volumes under three wave conditions those are the same conditions applied to the re-production of the existing 2005 conditions as well as average maximum wave.

Three cases are considered as the combination of wave conditions.

- Case 1: Energy Averaged Wave + 4 times of Highest Wave in 2005 bathymetry
- Case 2: Energy Averaged Wave + 4 times of Highest Wave for development plan
- Case 3: Energy Averaged Wave + 3 times of Average maximum wave for development plan

Table 5.5.2 Computation Duration and Accumulate Factor

Wave Conditions	Computation Duration	Correct Coefficient for Sedimentation Volume per Year
Energy Averaged Wave	15 days and nights	13.3
Highest Wave 4 times	About 6 days	4.63
Average maximum wave	About 6 days	3.0

2) Other Conditions

The other conditions such as tidal current, SS are as the same as the existing reproduction calculation.

5.5.4 Results of Predicted sediment Volume

Table 5.5.3 Predicted Sedimentation Volume(27 - 44km) Unit: million m^3

Development Plan		By Energy Averaged Wave	By Highest Wave (4 times action)	By Average Maximum Wave (3 times action)	Total
2005 Existing Bathymetry *		0.89	0.92	-	1.81
-12.5m water depth + 160mchannel width	Case-1	1.45	1.54	-	2.99
-14.0m water depth + 160m channel width	Case-2	1.60	1.68	-	3.28
	Case-3	1.60	-	0.94	2.54

Note: *The sedimentation volume of 2005 Existing bathymetry is computed under the highest wave condition that is applied to the whole sections differed from the reproduction of 2005 existing condition.

The results of the predicted sediment volume are tabulated in Table 5.5.3.

- Total predicted annual sediment volume under the highest wave condition is 2,994,000m^3 and 3,290,000m^3 for water depth of -12.5m and -14.0m, respectively. Comparing with the predicted annual volume for the 2005 existing bathymetry of 1,810,000m^3, the volume of the development channel is 1.5 times larger than the existing channel.
- The difference volume between the development plan of -12.5m and -14.0m is about 300,000 m^3 per year.
- On the longitudinal distribution of sedimentation volume, the large volume is sediment in the turning basin at 28km and offshore from 40km. In the section of 36km-39km it is noticed that large sedimentation is happened due to the mud flows from the point, where the sand spit is disrupted in both configurations of 2005 and the development of channel.
- And comparing the influences by two wave condition of the highest and average maximum wave, the predicted volume has not so much difference, each other.

Therefore, the predicted volume under the highest wave condition only is adapted for further study in consideration that the probability of typhoon hitting to this area is high as well as an underestimation shall be avoided.

6. REVIEW OF PORT PLANNING AND GENERAL LAYOUTS

6.1 Layout of Port Facilities for the Project

6.1.1 Terminal Space

All the containers which were unloaded at the time of previous call must be cleared before the next ship comes. The approximate number of ground slots can be estimated by assuming the dwelling time of container and stacking height. 7days and 2.5 high are normally used for a newly planned container terminal.

400,000TEUs per year is equivalent to 1,100TEUs per day. This means 550 TEUs for unloading (import) and 550 TEUs for loading (export). If an import container stays 7days on average, the number of containers in stock yard is 550 x 7 = 3850 TEUs. If an export container stays 5 days in the container terminal, the number of containers in the yard is 550 x 5 = 2,750. As a result, total number of containers in the yard is 6,600 TEUs. If they are stacked 2.5high, the necessary number of ground slot will be 6,600/2.5=2,640 TEUs.

However, it is more efficient if the slots are separated according to shipping lines, destination, type and size of containers, etc. To do so, the grand slots should be allocated 1.2 times mentioned above. That is 2,640 x 1.2 = 3,168 TEUs.

The number of ground slots in the Preparatory Survey is 47 x 6 x 10= 2,820 for dry containers, 17 x 6 x 2=204 for 40 ' reefer containers, and additional space for big size containers or longer containers. Therefore, Lach Huyen port will have enough space to handle 400,000 TEUs per berth per year according to the current terminal plan shown in the Preparatory Survey.

On the other hand, the berth occupancy ratio should be less than 70% to keep the waiting time small. If 80% of the berthing hour is usable for the gantry crane operation, total hours for gantry operation are 360 x 20hr x 0.7 x 0.8 = 4,032 hrs/year. If one quay must handle more than 400,000TEUs/year, gantry cranes must handle 400,000/4032=~100 TEU/hr. When all the containers are 40 ', the quay cranes must have the ability to handle 50 boxes/hr. Since 40' and 20' are mixed, 75 boxes per hour production will normally be needed.

As a result, the number of gantry cranes necessary to handle 400,000TEUs is three per berth, assuming that one gantry can handle 30 containers per hour.

According to the layout of Preparatory Survey, two continuous berths are planned. This arrangement is advantageous for utilizing cranes fully or maintenance of gantry cranes. When a big containership comes and unloads a large quantity of containers in a short time, the apron area should have enough width for the operation and for the traffic of the vehicles. According to the layout plan of Preparatory Survey, there is enough space at the apron area by means of reclaiming the back space of the platform.

6.1.2 Channel Dredging

Haiphong ports have utilized the river for the navigation channel which has 2-3m tidal range. The river mouth is shallow and has sedimentation. It has been very difficult to excavate and maintain a deep channel. People think it natural that ships must utilize the tide to enter the ports.

The Lach Huyen Port can be regarded as the first project towards creating deep sea berths in the northern region of Vietnam. The water depth of navigational channel is planned tentatively as -13m to -14m, because capital dredging and maintenance dredging will be costly. Depth of -14m allows Panamax type 50,000dwt ships to navigate with full draft, and 100,000dwt containerships with adjusted draft. Lach Huyen Port Area must be able to handle about 2,299,000TEUs, about 5 years after the completion of this stage. Six highly efficient terminals are necessary to meet the demand in 2020.

On the other hand, 420 container vessels of over 9,000 TEU capacity (100,000dwt class ship) are currently in service on the world main routes. The tendency for container vessels to become larger is continuing. Maersk Line ordered 30 container ships of 18,000TEU (=~200,000dwt) to a Korean Ship Building Company at the beginning of 2011. Among them, 10 ships will come into service on the world main routes in 2014.

As a result, container ships of 100,000dwt class will be deployed into the semi-trunk lines. In fact, a 130,000dwt container ship calls the port in Cai Mep - Thi Vai located in the southern part of Vietnam. Accordingly, it is probable that containerships of 100,000dwt class will call Lach Huyen Port.

Under the current conditions, demerits of shallow water are apparent:

- When a ship makes a round trip between 2 ports, a consigner will lose money if the ship cannot load the cargo to the ship's full capacity.
- When a ship calls some ports sequentially, making a draft adjustment may not always be easy. In this case, ship must skip the port.
- Losses caused by waiting time will increase if the ships must wait for the tide while the risks of accidents will increase.

The number of ship calls in 2020 will be 1,150 in order to carry 2,299,000TEUs, assuming a mega ship handles 2,000TEUs per one call. This means three or four calls per day. Navigation channel of Lach Huyen will also be used by 6,700 ships which call the Haiphong and Dinh Vu ports.

Demerits of the single-lane for long navigation channel are as follows:

- It will result in a tremendous amount waiting time and huge loss of money
- The risk of accidents occurring will be high, even if the VTS is used

People have to be more conscious about the necessity of maintaining a deep channel as well as the need for a two way channel which allows ships to navigate at any time.

6.2 Channel and Turning Basin

6.2.1 Review of Channel and Turning Basin

The existing access channel to Hai Phong port is divided into four (4) sections, i.e.

(1) Lach Huyen section: from Buoy No. 0 to Buoy No. 16-24 about 18.7 km long

(2) Ha Nam Canal section: from Buoy 19-24 to Buoy PBD4 about 6.3 km long

(3) Bach Dang river section: from PBD4 to Aviation Petrol Port (near Buoy 47-50) about 9.2 km long, and

(4) Cam River –Dinh Vu canal section: from Aviation Petrol Port to Binh ferry about 9.8 km long.

The Lach Huyen and Ha Nam Canal section is newly opened channel in January 2006 by relocation of the former Nam Trieu channel under the Phase 2 of Hai Phong Port Rehabilitation Project.

The access to the Lach Huyen new gateway port uses the above Lach Huyen section and the new international terminals locate at about 16 km distance from the entrance Buoy No.01. The access channel is almost straight with a length of about 16 km to the international terminal area. At present, the Lach Huyen passage section is dredged to CD -7.2 m in depth for a bottom width of 100 m to allow one (1) way traffic of 10,000 dwt vessels although larger vessels can use the channel under such conditions as favorable weather, high tide and the reduced draft so far. From the fairway buoy No.1, the ships enter the main channel where navigational buoys with marking in accordance with the IALA requirements are provided along the both sides of the channel. The area around the port of Lach Huyen falls within the IALA Maritime Bouyage System- Region A (Red to Port hand Marks & Green to Starboard hand Marks).

Tidal current is bi-directional with an average speed between 0.3 to 0.5 m/s though it may reach to the greatest speed at 1.5 to 1.8 m/s during ebb tides at the river estuaries. Fog with visibility of less than 1.0 km occurs in an average of about 21.2 days per annum or maximum 61 days per annum according to the previous report. The fog mainly occurs in winter season and in peak in March.

The following size of container vessel (50,000DWT fully loaded and 100,000DWT partially loaded) is planned as the targeted vessel to call the Port for the year from 2015 to 2020.

Table 6.2.1 Design Vessel

Vessel Type	Vessel Dimensions				Remarks
	DWT (t)	Loa (m)	Beam (m)	Draft (m)	
3,000-4,000 TEU	50,000	274	32.3	12.7	Fully loaded
8,000 TEU	100,000	330	45.5	11.7 (14.7)	Partially loaded (80% Fully loaded)

The conditions of Channel navigation are summarized as follows:

- Around the clock (24Hrs) operation
- One (1)-Way Navigation
- Tug-assisted for ship turning in turning basin and for berthing/deberthing

In this sub-section, the planning for channel and turning basin is reviewed base on the Design Guidelines and Codes & Practice of:

(1) PIANC (Approach Channels: A Guide for Design, Final Report of the Joint PIANC-IAPH Working Group II-30 in cooperation with IMPA and IATA, June 1997)

(2) Technical Standards and Commentaries for Port and Harbor Facilities in Japan, 2002

But channel and turning basin is carefully reviewed in DD Study in view of safe maneuverability of ship by applying ship maneuvering simulation study as reported in Sub-section 6.6 hereinafter.

1) Width of Channel

Considering the traffic volume in the year from 2015 to 2020, the channel should be planned as one-way channel which could manage the forecast number of calling vessels.

Channel widths depend on the size of ship to cater for the physical conditions of the site. Research and experience so far have shown that the required channel width depends particularly on environmental conditions such as cross currents and cross-current gradients (variation of these cross currents per unit length of channel), waves and swell, wind and visibility as well as on the accuracy of information regarding the ship's position and the easy "readability" of this information by navigators.

PIANC (Approach Channels: A Guide for Design, Final Report of the Joint PIANC-IAPH Working Group II-30 in cooperation with IMPA and IATA, June 1997) proposes the bottom width of the approach channel of straight sections given by the following.

$$W = W_{bm} + \sum W_i + W_{br} + W_{bg}$$

Table 6.2.2 Channel Maneuvering Conditions of Lach Huyen Channel

	Offshore Section (Not sheltered by Sand Protection Training Dyke)	In-port Section (Sheltered by Sand Protection Training Dyke)
Basic Maneuverability	moderate	
Vessel Speed	5-10 knot	0-5 knot
Prevailing Cross Wind	20 knot (Beaufort 5= 8-11m/s)	
Prevailing Cross Current	Negligible	
Prevailing Longitudinal Current	Average: 1 knot (0.3-0.5m/s), Maximum:2 knot (1.0-1.2m/s)	
Significant Wave Height (Hs) and Length (λ)	Hs<1m and λ=50m in 91% frequency of occurrence	
Aids to Navigation	Moderate with infrequent poor visibility	
Bottom Surface	Smooth and soft	
Depth of Waterway	14.0m (For 50,000 DWT full loaded: d=1.10 x ship draft) (For 100,000 DWT partial loaded: d=1.20x ship draft)	
Cargo hazard level	low	
Bank Clearance	Sloping channel edges and shoals	

In case of one way traffic channel, the width of channel required based on the PIANC design is summarized as follows for partially loaded 100,000DWT container vessel:

Table 6.2.3 Lach Huyen Channel: Offshore Section not sheltered by Sand Protection Training Dyke

	Item	Condition	Width
W_{bm}	Ship maneuverability	Moderate	1.5B
W_1	Vessel speed	Slow to Moderate	0.0B
W_2	Prevailing cross winds	Moderate (Beaufort 4-7)	0.4B
W_3	Prevailing cross current	Negligible	0.0B
W_4	Prevailing longitudinal current	Moderate (1.5 to 3.0 knot)	0.1B
W_5	Significant wave height (Hs) and length (λ)	Hs < 1.0m, λ<L	0.0B
W_6	Aids to navigation	Moderate with infrequent poor visibility	0.2B
W_7	Bottom surface	< 1.5 times ship draft and smooth and soft	0.1B
W_8	Depth of waterway	<1.25T	0.2B
W_9	Cargo hazard level	Low	0.0B
W_{br}	Bank clearance (red side)	Sloping Channel	0.5B
W_{bg}	Bank clearance (green side)	Sloping Channel	0.5B
Total			**3.5B**

B: Beam of vessel

Table 6.2.4 Lach Huyen Channel: In-port Section sheltered by Sand Protection Training Dyke

	Item	Condition	Width
W_{bm}	Ship maneuverability	Moderate	1.5B
W_1	Vessel speed	Slow	0.0B
W_2	Prevailing cross winds	Moderate (Beaufort 4-7)	0.5B
W_3	Prevailing cross current	Negligible	0.0B
W_4	Prevailing longitudinal current	Moderate (1.5 to 3.0 knot)	0.2B
W_5	Significant wave height (Hs) and length (λ)	Hs < 1.0m, λ<L	0.0B
W_6	Aids to navigation	Moderate with infrequent poor visibility	0.2B
W_7	Bottom surface	< 1.5 times ship draft and smooth and soft	0.1B
W_8	Depth of waterway	<1.5-1.15T	0.2B
W_9	Cargo hazard level	Low	0.0B
W_{br}	Bank clearance (red side)	Sloping Channel	0.3B
W_{bg}	Bank clearance (green side)	Sloping Channel	0.3B
Total			**3.3B**

B: Beam of vessel

On the other hand, a minimum value for the width of a one-way channel (width at full depth) would be 5 times the beam width (B) of the biggest vessel in the absence of cross currents according to UNCTAD proposal (Port Development: A Handbook for Planners in Developing Countries, United Nations Conference in Trade and Development, 1985). Namely, the total width of full-depth channel required for one-lane traffic may be taken to comprise, on straight reaches, maneuvering lane of about twice the vessel beam, plus one-and-a-half time the bean for bank clearance each side.

In consideration of current entrance width as a guide and best practices, a width of main channel of 3.5B (ship beam) is required, thus allowing the vessels to access the port at all tides and in normal weather conditions. And hence 160m width of the channel in the initial stage of Lach Huyen port development is recommended, which is equal to about 3.5 times the beam of the largest container vessel of 50,000DWT fully loaded and 100,000DWT partially loaded expected in 2015 to 2020. This channel width requires ship maneuvering with Proper tug assistance and appropriate navigation aids and control system such VTS.

- For 50,000DWT (B=33m): 32.3x3.5= 113m
- For 100,000DWT (B=45m): 45.5x3.5=159m →160m

2) Depth of Approach Channel

Generally, necessary UKC can be determined form following factors:

- draft,
- resultant vertical movements of vessels due to swell and waves, i.e. pitching, rolling and heaving,
- tendency of nearly parallel sinking with slight trim by the head known as squat, which appears under sailing shallow water,
- tidal level and water density,
- safety margin, Net UKC, depends on type of bottom (muddy, sandy or rocky).

A simpler way to allow for squat, draft and sounding uncertainties (and also to give a margin for safety) is to set a minimum value on water/draft ratio. In many parts of the world a value of 1.10 has come accepted although a value of 1.15 can be found.

Europe Maritime Pilot Association (EMPA) has made recommendation on the UKC of calling vessels at Rotterdam, Antwerp and Amsterdam as follows:

- UKC at open sea passage 20% or more of the draft
- UKC at off port fairway 15% or more of the draft
- UKC at port inside 10% or more of the draft

Summing up, an appropriate UKC should be 10 % of the draft along main channel and in port inside, thus requiring a depth of main channel and port basin of -14.0 m CD (= 1.1x12.7=14.0m) for 50,000 DWT fully loaded vessel.

3) Turning Basin

Vessels usually have to make more complicated maneuvers than in the approach channel. The most basic of these maneuvers is turning the vessel and it may be taken as a general indication of the space required to turn a vessel that a circle with a diameter four times the ship's length is required where there is no assistance from tugs. Where assistance from tugs available, a circle half this size is adequate. These are average figures and the actual area needed will depend, in addition, on wind, wave and current conditions in any particular case.

In order to accommodate future size of container vessel at new terminal, the new terminal should be planned to position at the offshore area enough to provide a water area for the turning basin suitable for the largest size of ships. In addition, taking the current turning basin width, best maneuvering practices require turning basin of 2.0 L (overall length of planned vessel) in tug assistance as well as the use of ship's cluster. Therefore, in order to accommodate a vessel having of 5,000 TEU or 8,000 TEU capacity, a turning basin of 660m diameter is recommended with provision of a safe clearance distance should for the edge of the circle of 50m off the cope line for vessels on the berths.

6.2.2 Rationale for Channel Water Depth of 14m from Initial Stage

1) General Considerations

(a) When containers are shipped by larger vessels, the shipping cost per TEU (twenty-foot equivalent unit) becomes cheaper i.e. "**Economy of Scale**". In order to enjoy the economy of scale, **the world container fleets are increasing in their size year by year.** Major shipping lines and alliances are striving to remain competitive in the global shipping market by deploying numbers of larger size vessels, especially in the main routes such as Asia - North

America and Asia - Europe. The Super Post Panamax container vessels with a capacity of around 100,000DWT are considered to be the majority of the fleet on Asia- North America and Asia-Europe trade lane by 2012.

(b) From the view point of **geographical location** of Lach Huyen Port, it is very likely that the container mother vessels (more than 50,000DWT) going on **Asia-North America route** will call at Lach Huyen Port.

(c) Traditionally, Northern Vietnamese export cargoes to USA are transshipped to mother vessels at ports of Hong Kong, Kaohsiung, Busan, etc. Therefore, bearing the **extra transshipment cost and the longer shipping time** are inevitable, and the economy of scale can't be achieved. If Lach Huyen Port can accommodate 50,000DWT to 100,000DWT mother vessels as direct calls, the shipping cost will be lowered, leading to increase in **competitiveness** of export goods prices and **decrease in domestic market prices** that will stimulate Vietnamese **national economy**.

(d) Based on the information from the shipping lines, if more than 1,000TEU/week of container cargoes is secured constantly, it will be feasible to **extend the service range of 100,000DWT mother vessels** in Asia-North America route from ports of Hong Kong, Kaohsiung up to Lach Huyen Port. The container demand for Asia – America route in Lach Huyen Port at 2020 was forecasted as 6,070 TEU/week for export and 9,900 TEU/week for import respectively, which proved that there will be **enough container volume for 100,000DWT container vessels to call at Lach Huyen Port** (10 vessels every week).

(e) 50,000DWT full loaded container vessel requires -14m water depth. This water depth should be available **at any tidal conditions** for such a large container vessel operation **to keep the fixed tight shipping schedule**. This is the international standard for international gateway ports like Lach Huyen Port.

(f) If a port requires large container vessels to **wait high tide** before entering or leaving, such a port will **lose the competitiveness** against other ports in the region that will also oppose the Government policy to change the export driven industrialized country by introducing the foreign direct investment. There are **many ports which have more than -14m berths already in the region** such as Shenzhen, Guangzhou, Manila, Laem Chabang, Port Klang, Cai-Mep, etc.

(g) In order to compare the financial viability between channel depth of -14m from initial stage and channel depth of -13m in initial stage and deepened to -14m later, a financial analysis was conducted from the investment view point, i.e., Case 1: -14m channel is constructed at once by ODA STEP loan and Case 2: -13m channel is constructed as 1st step development by ODA STEP loan and deepened to -14m as 2nd step development 5 years later by Vietnamese own budget. The result showed that NPV (Net Present Value) of Case 1 was USD 309.509 million and NPV of Case 2 was 614,513 million which means that Case 1 is financially more viable than Case 2.

(h) The exact maintenance dredging volume should be determined by the sedimentation simulation study result which is conducting now. However, it can be said that the difference of sedimentation volume between -13m depth and -14m depth navigation channels will be very small.

2) Lessons from Increasing Tonnage of Container Ships Calling at the Port of Ho Chi Minh

The tendency of upsizing in container vessel is continuing. Maersk Line ordered 30 container ships of 18,000TEU (=~200,000dwt) to the Korean shipbuilding company at the beginning of 2011. Among them, 10 ships will come into service on the world main routes in 2014. As a result, the container ships of 50,000dwt - 100,000dwt class will be deployed into the semi-trunk lines. In fact, a 130,000dwt container ship calls the port in Cai Mep - Thi Vai located southern part of Vietnam. From the above facts, it is almost apparent that the containerships of 100,000dwt class will call Lach Huyen Port.

Looking at carriers' arrangement for feeder service connecting to the deep sea trade (Trans-Pacific and Far East-Europe including Mediterranean) in 2006-2008, the tonnage less than 1000 TEU was adopted in general, for transshipments at Singapore, Tanjung Pelepas, Hong Kong and Kaohsiung. These feeder ships have maximum draft less than 10m due to restriction of the river port. In respect of Intra-Asia trade, the small-sized vessels were in service and had capacity of around 1200 TEU for the majority.

Table 6.2.5 Tonnage of feeder vessels in 2006-2007

Carrier	Trade	Service	Typical ships capacity (TEU)	DWT (ton)	LOA (m)	Max draft (m)
Hanjin/STX	Intra-Asia Feeder	NHS	800-1100	11,000	135	11
MOL	Feeder	VSS	620	-	-	-
K-Line	Intra-Asia Feeder	ASECO	550	-	-	-
Evergreen/ OOCL/YML	Feeder	HMC-KAO	1800	25,000	171	9.5
	Intra-Asia Feeder	JHX/JTV	1300-1500	20,000	166	9.6
MSC	Feeder	-	1900	30,000	220	11.6
APL	Feeder	HMX	700	8,000	121	6.6
TSK	Intra-Asia	TCX	900	-	-	-
WHL	Intra-Asia	JCV	766-917	-	-	-
TSL/SINOKOR	Intra-Asia	JHT	110-1200	13,000	141	9.5
Syms	Intra-Asia	-	56-684	-	-	-

Under the above situation, the container export movement in Vietnam had the rapid growth and indicated continuous increase in view of more than 10% for previous consecutive 3 years. Trans-Pac volume reached 500,000 TEU level in 2008. In addition, the deep sea carriers always have been required to reduce the operating cost per TEU by replacement with the large over-Panamax sized vessels. However, the draft restriction in the river port became serious problem to arrange for the large ship in the economical service and finally caused short space of the feeder vessels as well as congestion at the previous city port terminals (VICT, Saigon, Tankan and Cat Lai). Cai-MEP Thi Vai Port with 14m water depth was essential to comply with the above demand and requirements of the carriers. After the operation started, the berthing of the post-Panamax vessels has been increasing. In consideration of the main export commodities i.e. garments and footwear and of the destination to US and Europe, it is opined that the carriers was ready for arrangement of direct call at Ho Chi Minh port in view of less deviation from the main shipping route. Current berthing vessels of the major deep sea carriers are summarized with the ships capacity and specification as follows.

Table 6.2.6 Updated berthing vessels at Cai-Mep Thi Vai port

Carrier	Trade	Service	Typical ships capacity (TEU)	DWT (ton)	LOA (m)	Max draft (m)
APL/MOL/Hyundai	TP	PS1/2	6400	80,000	293	14
Maersk	TP	TP6	11000	116,100	365	15
Hanjin	TP	SJX	5700	68,000	278	14
CMA-CGM	MED	MEX	8500	107,000	335	14.5
	NE	FALS3	11300	130,000	366	15
	NE	FALS12	6700	78,000	302	14.2
NYK/OOCL/ HLC	TP	SCX	6500	81,000	295	13
	TP	AEX	6600	81,000	300	14
	NE	EU Loop D	6800	85,000	300	15
USAC	NE	AEC2	6900	85,000	305	14.5
K-L/Cosco/ YM/Hanjin	TP	Calcoa-A	4700	65,000	290	13.5
	NE	NE-5	5600	68,000	280	14
	TP/AW	AW-4	6300	78,000	285	14
	TP/AW	AW-5	5600	71,300	285	14

It is learnt that the above vessels have not been fully loaded in the berthing but the ships draft more than 85% may be required depending upon the port rotation in service.

In addition, it is also learnt that the operators currently have been in negotiation with the other major carriers for berthing of the Panamax ships as wells as Hamburg Süd and MISC. MSC is one of the mega operators in Europe and TP trade but currently have continued to feeder service consisting of 3 vessels with 1000 TEU capacity and is expected to plan the direct call of TP/Europe trade ships

Table 6.2.7 Potential carriers directly calling at Cai-Mep Chi Vai Port

Carrier	Trade	Service	Typical ships capacity (TEU)	DWT (ton)	LOA (m)	Max draft (m)
EMC	TP/AW	-	4200	55,000	290	12.6
	TP/MED	-	5700	64,000	294	12.7
HLC	TP/AW	PAX	4700	68,000	294	13.5
CMA-CGM	TP/AW	-	5000	65,000	294	13.5

According to the interview with the carriers, the more than 90% of the unloaded/loaded containers at Cai-Mep Thi Vai port have been using the barges for transportation to/fm the city.

In accordance with the data of Intra-Asia Discussion Agreement (IADA) by Intra-Asia container carriers association, the container volume of Vietnam also has large increase following the rapid growth of Intra-Asia trade. The data of 2010 shows 560,000 TEU (All Vietnam) with 10% growth of 2009's. So, the Intra-Asia carriers also have upgraded their service fleet to the larger vessels.

Table 6.2.8 Fleet size of Intra-Asia carriers in Japan-Ho Chi Minh trade

Carrier	Trade	Service	Typical ships capacity (TEU)	DWT (ton)	LOA (m)	Max draft (m)
MOL/RCL	Intra-Asia	-	1200	18,000	151	10
K-Line	Intra-Asia	-	1700	21,500	172	9.5
NYK/Hyundai	Intra-Asia	TWX	1200	17,800	163	8.5
Evergreen	Intra-Asia	NSC	1600	21,000	181	9.0
SITC	Intra-Asia	VTX	1100	16,500	152	8.3
TSL	Intra-Asia	JTV	1600	19,500	168	9.9
YML	Intra-Asia	JKS	1800	22,000	172	9.5
Wan Hai	Intra-Asia	JSV/JCV	1500	21,000	180	9.5
MCC	Intra-Asia	IA5	1700	25,000	188	10.5

The Intra-Asia trade fleets have been larger than the vessels in service in 2007 with increase of capacity at 20-30%. The service is still covering at VICT, Cat Lai, Saigon and ICD etc. It is expected that the fleet will be replaced by the vessels with the max. draft over 11-12m shortly, depending upon the cargo growth in future but they will need the berthing window at Cai-Mep Thi Vai port as the daft problem still exists at the city ports. The improvement of access road and the industry area development at the location near the port for shipper's premise/production facility are definitely encouraging utilization of the port in reference to the development progress of Laem Chabang port.

Considering the port of Lach Huyen, it is expected that the mega operators will consider planning for direct call of the over-Panamax Europe/Trans-Pacific trade vessels favorably and flexibly if their ships do not have any restriction in the draft. There may be needs to arrange for barge or feeder service to Haiphong port at the initial stage and the setting up of ICD near the city may be considered. The access road and bridge can resolve the disadvantage to Hai Phong port in the distance.

3) Cargo Demand and Channel Dimensions

According to the plan by MOT Decision, the Lach Huyen Channel will have the depth of -13m in 2015 and -14m in 2020, the width of 160m, and the length of 18km. The channel of -14m can serve for the container vessels of Panamax, 50,000dwt ship with full draft since the ship has 12.7m draft. To pass the shallow channel, however, the 100,000dwt class container ships must reduce a load temporarily or wait for the high tide.

A certain extent of disadvantages may occur if the channel depth is -13m, when the number of callings of more than 50,000dwt class containership increases to the Lach Huyen Port. The disadvantage of -13m depth may be stemmed out from:

- When a ship makes a round trip between 2 Ports, a consigner will lose money if the ship cannot load the cargo to the ship’s full capacity.
- When a ship calls some ports sequentially, the cases that the draft adjustment is difficult may occur. In this case, ship must skip the port.
- Losses caused by waiting time will increase, if the ships must wait for the tide. Nevertheless, the risks of accident will increase.

Therefore, Lach Huyen Port should avoid the outdated plan.

Lach Huyen Port has the hinterland of the Vietnamese capital region, and showing the vital evolution in the container traffic. In near future, with the increase of the calls of the large vessels at the Lach Huyen Port, the channel may have to accommodate “two direction traffic” as well as deep water. In the two way traffic, the channel width should be 480m in dimension, considering the case that the ships of 100,000dwt come and go at 4 knots velocity in the wind speed 10m/sec.

A preliminary staged plan proposed by the study team for future channel development is indicated in the Table 6.3.1 (refer to Sub Section 6.3 hereinafter). The channel due must be imposed properly, since the cost for the capital dredging and maintenance dredging must be properly born by the users. Table 6.3.1 roughly shows the quantity of dredging for the widening and deepening of the channel. It is proportional to the current dredging volume for the channel that has the width of 160m and the depth of -14m.

The volume for the maintenance dredging is assumed as 10% of the quantity of total dredging for every five years. Unit price of capital dredging is assumed as US$9.2/$m^3$, and unit cost of maintenance dredging as US$5.6/$m^3$. As a result, theoretical channel dues became US$ 26.6 per TEU in 2015, US$ 22.2 per TEU in 2020, and US$ 9.4 per TEU in 2030 as indicated in Table 6.3.2 (refer to Sub Section 6.3 herein after). The widening and deepening of channel requires very much volume of dredging, nevertheless the channel due estimated is not expensive comparing to the normal handling charges.

From above analysis, we would like to say that discussion should be also made as for the timing to consider the widening of channel width for two-way traffic to cope with the increase of ship calls in near future as well.

4) Channel Depth and Container Ship Size

Container ships of more than 45,000DWT in global container fleet at present are as shown in Table 6.2.9.

Table 6.2.9 Container Ship Size and Number in the World in 2011

Container Ship Size (DWT)	Number of Ship
45,000 – 60,000	611
60,000 – 80,000	562
80,000 – 100,000	220
More than 100,000	379

Figure 6.2.1 shows relation between above container ships and their full drafts.

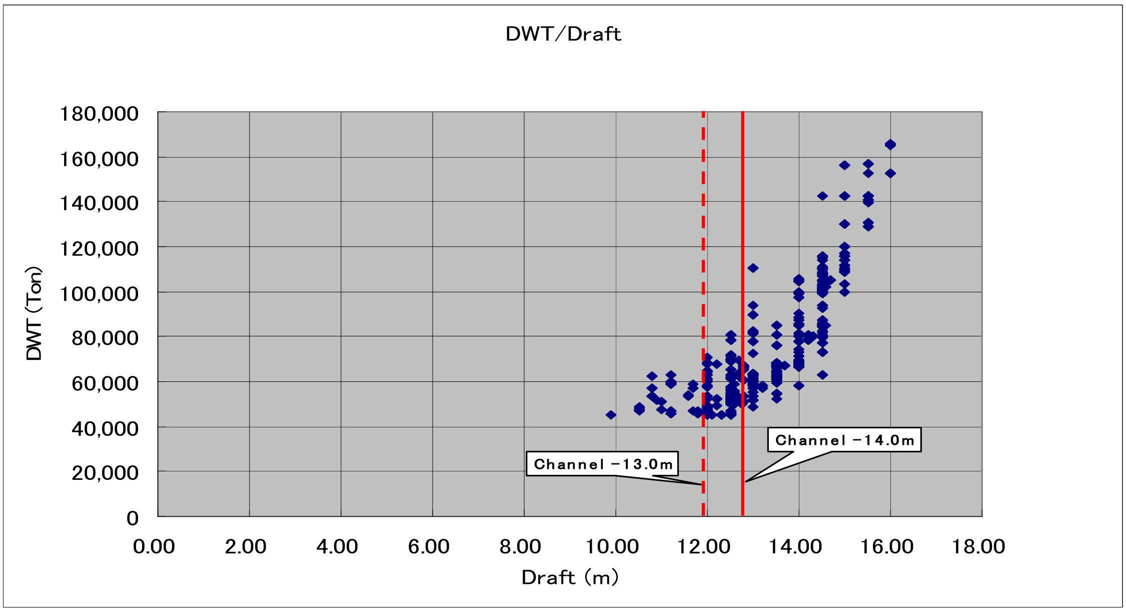


Figure 6.2.1 Relation between Large Container Ships and Its Full Draft

From above Table 6.2.9, it is known that even if depth is -14m, the channel can not afford to accommodate many large container vessels, much less the channel of -13m. Considering the global trend of container ship size which is becoming larger and larger, and actual calling of container vessels in Cai Mep – Thi Vai ports in south Vietnam in accordance with the development of deep sea ports, the Lach Huyen access channel should be developed to a depth enough to accommodate the expected larger size of vessels from initial stage.

5) Channel Depth ant Tide Levels

In MOT Decision 476/QD-BGTVT, it is mentioned that the water level (Tide Level) of 1.5m in 2015 and 0.6m in 2020 are required for design ship running.

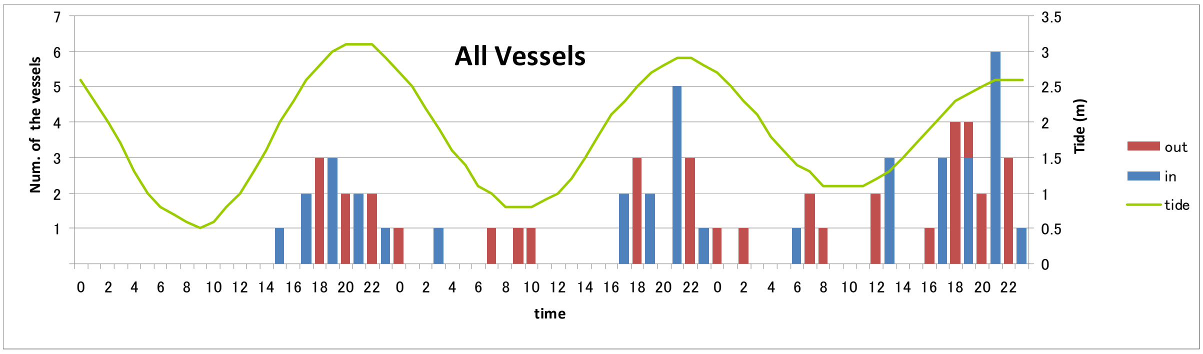
We should know that how many hours ships should wait for tide level become higher than 1.5m. Table 6.2.10 shows the tide levels which are lower than 1.5m in every day and every month at Hon Dau Tide Station. From this table, it is known that the hours below 1.5m tide level is 7.7 hours/day (32%) in average and 12 hours/day will occur several days in a year and the beginning and ending times of such low water level varies day by day.

Lach Huyen channel should be commonly used with more than 6,700 vessels for the existing Hai Phong port. Figure 6.2.2 shows typical pattern of all vessels for Hai Phong port passing through the existing Lach Huyen channel and Figure 6.2.3 shows passing pattern of relatively large vessels for Hai Phong port which concentrated at about 6 hours during high tide.

Green color time zone indicated in Table 6.2.10 shows the 6 hours of high tide in every day when calling/leaving vessels for Lach Huyen port will be hampered from the vessels for Hai Phong port.

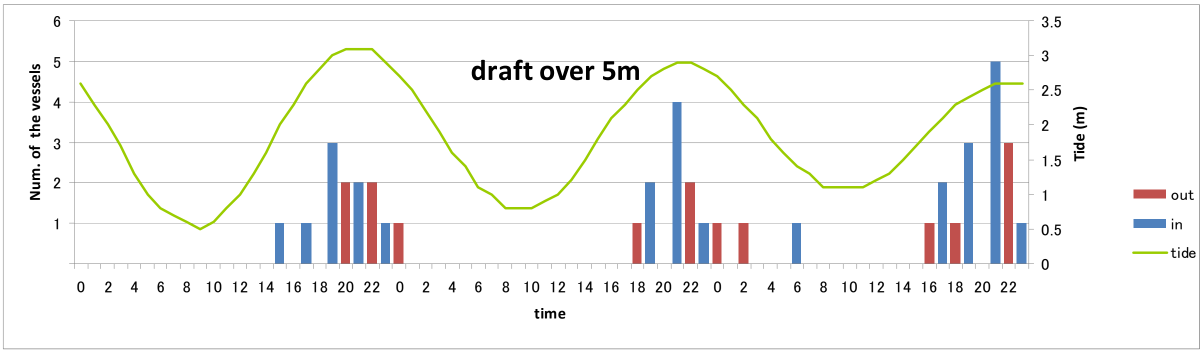
Therefore, only in white color time zone, vessels for Lach Huyen port can navigate relatively freely. However, even in the white color time zone, vessels for Lach Huyen port shall be restricted to pass the channel since the channel is one-way traffic.

In order to secure the enough passing time for the vessels for Lach Huyen port, yellow color time zone should be eliminated, which means that the channel depth of Lach Huyen port should be -14m CD from initial stage.



Source: VMS1 May 25, 2011

Figure 6.2.2 All Vessels passing Lach Huyen Channel for Hai Phong Port



Source: VMS1 May 25, 2011

Figure 6.2.3 Large Vessels passing Lach Huyen Channel for Hai Phong Port

It is common practice for the international shipping lines that large container ships shall be in service with fixed schedule. If shipping schedule must be changed every day, or ships should wait before enter to/leave from port, such a port will not be competitive with other international gateway ports that is heavy burden for economic development of northern region of Vietnam. Therefore Lach Huyen (Hai Phong international gateway) port should provide the access channel of -14m CD that allow free from restriction of tidal change for full loaded 50,000DWT container ship expected to call the port.

Table 6.2.10 Tide Level lower than 1.5m at Hon Dau Station (2009)

January

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.4	1.8	2.2	2.6	2.9	3.1	3.3	3.3	3.2	3.1	2.9	2.6	2.3	2.0	1.7	1.4	1.2	1.0	0.9	0.8	0.7	0.8	0.9	1.1
2	1.3	1.6	2.0	2.3	2.6	2.9	3.0	3.1	3.1	3.0	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.3	1.2	1.1	1.0	1.0	1.1	1.2
3	1.3	1.6	1.8	2.1	2.4	2.5	2.7	2.8	2.8	2.7	2.6	2.4	2.3	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.4	1.4
4	1.5	1.6	1.8	2.0	2.1	2.3	2.4	2.4	2.4	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.8	1.8
5	1.8	1.9	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.2
6	2.2	2.2	2.2	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.5	1.4	1.3	1.3	1.3	1.4	1.5	1.6	1.8	1.9	2.1	2.3	2.5	2.6
7	2.6	2.7	2.6	2.6	2.4	2.3	2.1	1.9	1.7	1.5	1.3	1.1	0.9	0.9	0.9	0.9	1.1	1.3	1.5	1.8	2.1	2.3	2.6	2.8
8	3.0	3.1	3.1	3.0	2.8	2.6	2.4	2.1	1.8	1.5	1.2	0.9	0.7	0.5	0.5	0.5	0.7	0.8	1.1	1.4	1.8	2.2	2.6	2.9
9	3.2	3.4	3.4	3.4	3.3	3.1	2.8	2.4	2.0	1.7	1.3	0.9	0.6	0.4	0.2	0.2	0.3	0.4	0.7	1.0	1.4	1.8	2.3	2.7
10	3.1	3.4	3.6	3.7	3.7	3.5	3.2	2.8	2.4	2.0	1.6	1.1	0.7	0.4	0.2	0.0	0.0	0.1	0.3	0.6	0.9	1.4	1.9	2.4
11	2.8	3.3	3.6	3.8	3.9	3.8	3.6	3.2	2.8	2.4	1.9	1.5	1.0	0.7	0.3	0.1	0.0	0.0	0.1	0.2	0.5	0.9	1.4	1.9
12	2.4	2.9	3.3	3.7	3.8	3.9	3.8	3.5	3.2	2.8	2.3	1.9	1.5	1.1	0.7	0.4	0.2	0.1	0.0	0.1	0.3	0.6	1.0	1.5
13	2.0	2.4	2.9	3.3	3.6	3.7	3.7	3.6	3.4	3.0	2.7	2.3	1.9	1.5	1.1	0.8	0.5	0.4	0.3	0.2	0.3	0.5	0.7	1.1
14	1.5	2.0	2.4	2.8	3.2	3.4	3.5	3.5	3.3	3.1	2.8	2.5	2.2	1.9	1.6	1.3	1.0	0.8	0.6	0.5	0.5	0.6	0.7	1.0
15	1.3	1.6	2.0	2.4	2.7	2.9	3.1	3.2	3.1	3.0	2.8	2.6	2.3	2.1	1.9	1.7	1.4	1.2	1.1	1.0	0.9	0.9	0.9	1.1
16	1.2	1.5	1.8	2.0	2.3	2.5	2.6	2.7	2.7	2.7	2.6	2.4	2.3	2.1	2.0	1.9	1.7	1.6	1.5	1.4	1.3	1.3	1.3	1.3
17	1.4	1.5	1.7	1.9	2.0	2.1	2.2	2.3	2.3	2.3	2.2	2.1	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.8	1.7	1.7	1.7	1.7
18	1.7	1.8	1.9	1.9	2.0	2.0	2.0	2.0	1.9	1.9	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1
19	2.1	2.1	2.1	2.1	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.3	2.4
20	2.5	2.5	2.5	2.4	2.3	2.2	2.0	1.8	1.6	1.4	1.2	1.1	1.0	1.0	1.0	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.6
21	2.7	2.8	2.8	2.7	2.6	2.4	2.2	2.0	1.7	1.4	1.2	1.0	0.8	0.7	0.7	0.8	0.9	1.1	1.4	1.7	2.0	2.2	2.5	2.7
22	2.9	3.0	3.0	3.0	2.9	2.7	2.5	2.2	1.9	1.5	1.2	0.9	0.7	0.6	0.5	0.5	0.6	0.8	1.1	1.4	1.7	2.0	2.4	2.7
23	2.9	3.1	3.2	3.2	3.2	3.0	2.7	2.4	2.1	1.7	1.3	1.0	0.7	0.5	0.4	0.4	0.4	0.5	0.8	1.1	1.4	1.8	2.2	2.5
24	2.8	3.1	3.2	3.3	3.3	3.2	3.0	2.7	2.3	1.9	1.6	1.2	0.9	0.6	0.4	0.3	0.3	0.4	0.5	0.8	1.1	1.5	1.9	2.3
25	2.7	3.0	3.2	3.4	3.4	3.3	3.2	2.9	2.5	2.2	1.8	1.4	1.1	0.8	0.5	0.4	0.3	0.3	0.4	0.6	0.9	1.2	1.6	2.1
26	2.5	2.8	3.1	3.3	3.4	3.4	3.3	3.0	2.7	2.4	2.0	1.6	1.3	1.0	0.7	0.5	0.4	0.3	0.4	0.5	0.7	1.0	1.4	1.8
27	2.2	2.6	2.9	3.2	3.3	3.4	3.3	3.1	2.9	2.5	2.2	1.9	1.5	1.2	0.9	0.7	0.6	0.5	0.4	0.5	0.6	0.8	1.1	1.5
28	1.9	2.3	2.7	3.0	3.2	3.3	3.3	3.1	2.9	2.7	2.4	2.1	1.8	1.5	1.2	1.0	0.8	0.7	0.6	0.6	0.6	0.8	1.0	1.3
29	1.7	2.1	2.4	2.7	2.9	3.1	3.1	3.0	2.9	2.7	2.4	2.2	1.9	1.7	1.5	1.3	1.1	1.0	0.9	0.8	0.8	0.9	1.0	1.2
30	1.5	1.8	2.1	2.4	2.6	2.8	2.8	2.8	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.1	1.2
31	1.4	1.7	1.9	2.1	2.3	2.4	2.5	2.5	2.5	2.4	2.2	2.1	2.0	1.9	1.8	1.8	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.4

<0.6m	<1.5m
60	241

Fecbruary

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.5	1.6	1.8	2.0	2.1	2.1	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
2	1.8	1.8	1.8	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.2	2.2
3	2.2	2.1	2.1	2.0	2.0	1.9	1.6	1.6	1.4	1.3	1.2	1.1	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.6	2.6
4	2.6	2.6	2.5	2.3	2.2	2.0	1.5	1.5	1.3	1.1	0.9	0.8	0.7	0.8	0.9	1.1	1.3	1.6	1.9	2.1	2.4	2.6	2.8	3.0
5	3.0	3.0	2.9	2.7	2.5	2.3	1.6	1.6	1.3	1.0	0.7	0.5	0.4	0.4	0.5	0.7	0.9	1.2	1.5	1.9	2.2	2.6	2.9	3.1
6	3.3	3.3	3.3	3.2	2.9	2.7	1.9	1.9	1.5	1.2	0.8	0.5	0.3	0.2	0.2	0.3	0.5	0.7	1.1	1.4	1.9	2.3	2.7	3.0
7	3.3	3.5	3.6	3.5	3.3	3.1	2.3	2.3	1.9	1.5	1.1	0.7	0.4	0.2	0.1	0.1	0.2	0.4	0.6	1.0	1.4	1.8	2.3	2.7
8	3.1	3.4	3.6	3.7	3.6	3.4	2.7	2.7	2.3	1.9	1.5	1.0	0.7	0.4	0.2	0.1	0.1	0.2	0.3	0.6	0.9	1.4	1.8	2.3
9	2.7	3.1	3.4	3.6	3.6	3.5	3.0	3.0	2.7	2.3	1.9	1.5	1.1	0.8	0.5	0.3	0.2	0.2	0.3	0.4	0.6	1.0	1.4	1.8
10	2.2	2.7	3.0	3.3	3.5	3.5	3.1	3.1	2.9	2.5	2.2	1.9	1.6	1.2	1.0	0.7	0.6	0.4	0.4	0.4	0.5	0.7	1.0	1.4
11	1.8	2.2	2.6	2.9	3.1	3.2	3.1	3.1	2.9	2.6	2.4	2.2	1.9	1.7	1.4	1.2	1.0	0.9	0.7	0.7	0.7	0.8	0.9	1.2
12	1.5	1.8	2.1	2.4	2.6	2.8	2.8	2.8	2.7	2.6	2.4	2.3	2.1	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.0	1.0	1.1	1.2
13	1.4	1.6	1.8	2.0	2.2	2.3	2.4	2.4	2.4	2.3	2.2	2.1	2.1	2.0	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.4
14	1.4	1.6	1.7	1.8	1.9	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.8	1.7	1.7
15	1.7	1.7	1.8	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.1	2.1
16	2.1	2.0	2.0	1.9	1.8	1.7	1.5	1.5	1.4	1.3	1.2	1.2	1.2	1.3	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.4	2.4	2.4
17	2.4	2.4	2.3	2.2	2.0	1.8	1.4	1.4	1.2	1.1	1.0	0.9	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.6	2.7
18	2.7	2.7	2.6	2.5	2.3	2.0	1.5	1.5	1.2	1.0	0.8	0.7	0.7	0.7	0.9	1.0	1.3	1.6	1.8	2.1	2.3	2.5	2.7	2.8
19	2.9	2.9	2.9	2.7	2.6	2.3	1.7	1.7	1.4	1.1	0.8	0.7	0.6	0.5	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.6	2.8
20	3.0	3.1	3.1	3.0	2.8	2.6	1.9	1.9	1.6	1.2	0.9	0.7	0.5	0.5	0.5	0.6	0.7	0.9	1.2	1.6	1.9	2.2	2.5	2.8
21	3.0	3.1	3.2	3.1	3.0	2.8	2.2	2.2	1.8	1.4	1.1	0.8	0.6	0.5	0.4	0.5	0.6	0.7	1.0	1.3	1.6	2.0	2.3	2.6
22	2.9	3.1	3.2	3.2	3.1	2.9	2.4	2.4	2.0	1.7	1.3	1.0	0.8	0.6	0.5	0.5	0.5	0.6	0.8	1.0	1.4	1.7	2.1	2.4
23	2.7	2.9	3.1	3.2	3.2	3.0	2.5	2.5	2.2	1.9	1.6	1.3	1.0	0.8	0.7	0.6	0.5	0.6	0.7	0.8	1.1	1.4	1.8	2.2
24	2.5	2.8	3.0	3.1	3.1	3.1	2.7	2.7	2.4	2.1	1.8	1.5	1.3	1.1	0.9	0.8	0.7	0.6	0.7	0.8	0.9	1.2	1.5	1.9
25	2.2	2.5	2.8	2.9	3.0	3.0	2.7	2.7	2.5	2.2	2.0	1.8	1.5	1.3	1.2	1.0	0.9	0.8	0.8	0.8	0.9	1.1	1.3	1.6
26	2.0	2.2	2.5	2.7	2.8	2.8	2.6	2.6	2.5	2.3	2.1	1.9	1.8	1.6	1.5	1.3	1.2	1.1	1.1	1.0	1.0	1.1	1.2	1.4
27	1.7	2.0	2.2	2.3	2.5	2.5	2.4	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.3	1.4
28	1.6	1.7	1.9	2.0	2.1	2.2	2.1	2.1	2.1	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.7	1.6	1.5	1.5	1.5

<0.6m	<1.5m
43	217

March

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.5	1.6	1.7	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.9	2.0	2.1	2.1	2.1	2.2	2.1	2.0	2.0	1.9	1.8
2	1.7	1.7	1.7	1.7	1.6	1.6	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.5	2.4	2.3	2.2
3	2.1	2.0	1.9	1.7	1.6	1.4	1.3	1.1	1.0	1.0	1.0	1.0	1.1	1.3	1.6	1.8	2.1	2.3	2.5	2.6	2.7	2.8	2.8	2.7
4	2.5	2.4	2.2	2.0	1.8	1.5	1.3	1.0	0.8	0.6	0.6	0.6	0.7	0.9	1.2	1.5	1.8	2.1	2.4	2.6	2.8	3.0	3.1	3.1
5	3.0	2.8	2.6	2.4	2.1	1.8	1.4	1.1	0.8	0.4	0.4	0.4	0.4	0.5	0.8	1.0	1.4	1.7	2.1	2.4	2.7	3.0	3.2	3.3
6	3.3	3.2	3.0	2.8	2.5	2.1	1.8	1.4	1.0	0.4	0.4	0.3	0.2	0.3	0.4	0.6	0.9	1.3	1.6	2.0	2.4	2.8	3.1	3.3
7	3.4	3.4	3.3	3.2	2.9	2.5	2.2	1.8	1.4	0.7	0.7	0.4	0.3	0.2	0.3	0.4	0.6	0.9	1.2	1.6	2.0	2.4	2.7	3.1
8	3.3	3.4	3.5	3.4	3.2	2.9	2.5	2.2	1.8	1.1	1.1	0.8	0.5	0.4	0.3	0.3	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.6
9	3.0	3.2	3.3	3.4	3.3	3.1	2.8	2.5	2.2	1.5	1.5	1.2	0.9	0.7	0.6	0.5	0.5	0.6	0.7	0.9	1.1	1.5	1.8	2.2
10	2.5	2.8	3.0	3.1	3.1	3.1	2.9	2.6	2.4	1.9	1.9	1.6	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.8	0.9	1.2	1.4	1.7
11	2.0	2.3	2.6	2.8	2.8	2.8	2.8	2.6	2.5	2.1	2.1	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.0	1.0	1.0	1.1	1.2	1.5
12	1.7	1.9	2.1	2.3	2.4	2.5	2.5	2.4	2.3	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.2	1.3	1.4
13	1.5	1.6	1.8	1.9	2.0	2.1	2.1	2.1	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.7	1.6	1.5	1.5	1.5
14	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	2.0	2.1	2.2	2.3	2.3	2.3	2.2	2.2	2.1	1.9	1.8	1.7
15	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.3	1.4	1.4	1.5	1.7	1.9	2.1	2.2	2.4	2.4	2.5	2.5	2.4	2.3	2.2	2.1
16	2.0	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.0	1.1	1.1	1.2	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.6	2.6	2.6	2.6	2.5
17	2.3	2.2	2.0	1.8	1.6	1.3	1.2	1.0	0.9	0.8	0.8	0.9	1.0	1.2	1.5	1.8	2.1	2.3	2.5	2.6	2.7	2.8	2.8	2.7
18	2.6	2.5	2.3	2.1	1.8	1.5	1.3	1.0	0.8	0.7	0.7	0.7	0.8	1.0	1.2	1.5	1.8	2.1	2.3	2.5	2.7	2.8	2.9	2.9
19	2.9	2.8	2.6	2.4	2.1	1.8	1.4	1.2	0.9	0.6	0.6	0.6	0.6	0.7	0.9	1.2	1.5	1.8	2.1	2.4	2.6	2.8	2.9	3.0
20	3.0	2.9	2.8	2.6	2.3	2.0	1.7	1.4	1.1	0.7	0.7	0.6	0.6	0.6	0.8	1.0	1.2	1.5	1.9	2.1	2.4	2.6	2.8	3.0
21	3.0	3.0	3.0	2.8	2.6	2.3	1.9	1.6	1.3	0.8	0.8	0.7	0.6	0.6	0.7	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.7	2.9
22	3.0	3.0	3.0	2.9	2.7	2.5	2.2	1.8	1.5	1.0	1.0	0.8	0.7	0.7	0.7	0.8	0.9	1.1	1.3	1.6	1.9	2.2	2.5	2.7
23	2.9	3.0	3.0	2.9	2.8	2.6	2.3	2.0	1.8	1.3	1.3	1.1	0.9	0.8	0.8	0.8	0.9	1.0	1.2	1.4	1.7	2.0	2.2	2.5
24	2.7	2.8	2.9	2.9	2.8	2.6	2.4	2.2	2.0	1.5	1.5	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.1	1.2	1.5	1.7	2.0	2.2
25	2.4	2.6	2.7	2.7	2.7	2.6	2.4	2.3	2.1	1.8	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.2	1.2	1.3	1.5	1.7	1.9
26	2.1	2.3	2.4	2.5	2.5	2.4	2.3	2.2	2.1	1.9	1.9	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.4	1.3	1.3	1.4	1.5	1.7
27	1.9	2.0	2.1	2.1	2.2	2.2	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.7	1.6	1.5	1.5	1.5	1.6
28	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.2	2.1	2.0	1.8	1.7	1.6	1.6
29	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.5	1.6	1.6	1.8	2.0	2.2	2.3	2.4	2.5	2.6	2.5	2.4	2.3	2.1	1.9	1.8
30	1.7	1.6	1.5	1.3	1.2	1.1	1.1	1.0	1.1	1.3	1.3	1.5	1.7	2.0	2.3	2.5	2.7	2.8	2.9	2.8	2.7	2.6	2.4	2.2
31	1.9	1.8	1.6	1.4	1.1	1.0	0.8	0.7	0.7	0.9	0.9	1.1	1.4	1.7	2.0	2.3	2.6	2.8	3.0	3.1	3.1	3.0	2.8	2.6

<0.6m	<1.5m
23	229

April

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.4	2.1	1.8	1.6	1.3	1.0	0.7	0.6	0.5	0.4	0.5	0.7	0.9	1.3	1.6	2.0	2.4	2.7	3.0	3.2	3.3	3.3	3.2	3.0
2	2.8	2.5	2.2	1.9	1.6	1.2	0.9	0.6	0.4	0.3	0.3	0.4	0.6	0.9	1.2	1.6	2.0	2.4	2.7	3.0	3.2	3.4	3.4	3.3
3	3.2	2.9	2.7	2.3	1.9	1.6	1.2	0.8	0.6	0.4	0.3	0.3	0.4	0.6	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.2	3.4	3.4
4	3.4	3.2	3.0	2.7	2.4	2.0	1.6	1.2	0.9	0.6	0.4	0.3	0.3	0.4	0.6	0.8	1.1	1.5	1.8	2.2	2.5	2.9	3.1	3.3
5	3.3	3.3	3.2	2.9	2.7	2.4	2.0	1.7	1.3	1.1	0.8	0.6	0.5	0.5	0.6	0.7	0.9	1.2	1.4	1.8	2.1	2.4	2.7	2.9
6	3.1	3.1	3.1	3.0	2.8	2.6	2.3	2.0	1.8	1.5	1.3	1.1	0.9	0.8	0.8	0.8	0.9	1.0	1.2	1.4	1.7	1.9	2.2	2.5
7	2.7	2.8	2.8	2.8	2.7	2.6	2.4	2.2	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.1	1.1	1.2	1.3	1.4	1.6	1.8	2.0
8	2.2	2.3	2.5	2.5	2.5	2.4	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.4	1.3	1.4	1.4	1.5	1.7
9	1.8	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.5	1.5	1.5
10	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.9	2.0	2.2	2.3	2.3	2.4	2.4	2.3	2.3	2.1	2.0	1.8	1.7	1.6	1.5
11	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.4	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.6	2.6	2.6	2.5	2.4	2.2	2.1	1.9	1.7
12	1.6	1.5	1.3	1.2	1.1	1.1	1.0	1.0	1.1	1.2	1.4	1.7	2.0	2.2	2.5	2.6	2.8	2.8	2.8	2.7	2.6	2.4	2.2	2.0
13	1.8	1.6	1.4	1.2	1.0	0.9	0.8	0.8	0.8	0.9	1.1	1.3	1.6	2.0	2.3	2.5	2.7	2.9	3.0	3.0	2.9	2.8	2.6	2.4
14	2.1	1.9	1.6	1.4	1.1	0.9	0.8	0.7	0.6	0.7	0.8	1.0	1.3	1.6	2.0	2.3	2.6	2.8	3.0	3.1	3.1	3.0	2.9	2.7
15	2.5	2.2	1.9	1.6	1.3	1.0	0.8	0.6	0.6	0.5	0.6	0.8	1.0	1.3	1.7	2.0	2.4	2.6	2.9	3.0	3.1	3.1	3.0	2.9
16	2.7	2.5	2.2	1.9	1.5	1.2	0.9	0.7	0.6	0.5	0.5	0.6	0.8	1.1	1.4	1.8	2.1	2.4	2.7	2.9	3.0	3.1	3.1	3.0
17	2.9	2.7	2.4	2.1	1.8	1.5	1.2	0.9	0.7	0.6	0.6	0.6	0.7	0.9	1.2	1.5	1.8	2.2	2.5	2.7	2.9	3.0	3.1	3.1
18	3.0	2.8	2.6	2.3	2.0	1.7	1.4	1.1	0.9	0.8	0.7	0.7	0.7	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.0	3.0
19	3.0	2.9	2.7	2.5	2.2	1.9	1.6	1.4	1.1	1.0	0.8	0.8	0.8	0.9	1.0	1.2	1.4	1.7	2.0	2.2	2.5	2.7	2.8	2.9
20	2.9	2.8	2.7	2.6	2.3	2.1	1.9	1.6	1.4	1.2	1.1	1.0	1.0	1.0	1.1	1.2	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.7
21	2.7	2.7	2.6	2.5	2.4	2.2	2.0	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.2	1.3	1.3	1.4	1.6	1.8	2.0	2.1	2.3	2.4
22	2.5	2.5	2.5	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.8	1.9	2.0	2.1
23	2.2	2.2	2.2	2.2	2.1	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.8	1.8
24	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.1	2.1	2.0	1.8	1.7	1.7	1.7	1.6
25	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.7	1.9	2.1	2.3	2.4	2.4	2.6	2.6	2.5	2.4	2.2	2.0	1.8	1.7	1.6
26	1.5	1.4	1.2	1.2	1.1	1.1	1.1	1.2	1.3	1.5	1.7	2.0	2.3	2.5	2.5	2.9	2.9	2.9	2.8	2.6	2.4	2.2	1.9	1.7
27	1.5	1.3	1.1	0.9	0.8	0.7	0.7	0.8	0.9	1.1	1.4	1.7	2.1	2.4	2.4	3.0	3.1	3.2	3.2	3.1	2.9	2.6	2.3	2.0
28	1.7	1.4	1.2	0.9	0.7	0.5	0.4	0.4	0.5	0.7	1.0	1.3	1.7	2.1	2.1	2.9	3.2	3.4	3.5	3.4	3.3	3.1	2.8	2.4
29	2.1	1.7	1.4	1.0	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.9	1.3	1.7	1.7	2.6	3.0	3.3	3.5	3.6	3.6	3.4	3.2	2.9
30	2.5	2.2	1.8	1.4	1.0	0.7	0.4	0.2	0.1	0.2	0.3	0.6	0.9	1.3	1.3	2.2	2.6	3.0	3.3	3.5	3.6	3.6	3.5	3.2

<0.6m	<1.5m
34	230

May

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.9	2.6	2.2	1.8	1.4	1.0	0.7	0.4	0.3	0.2	0.2	0.4	0.6	0.9	1.3	1.7	2.2	2.5	2.9	3.2	3.4	3.5	3.5	3.4
2	3.2	2.9	2.6	2.2	1.8	1.5	1.1	0.8	0.6	0.4	0.4	0.4	0.5	0.8	1.0	1.4	1.7	2.1	2.4	2.8	3.0	3.2	3.3	3.3
3	3.2	3.0	2.8	2.5	2.2	1.9	1.6	1.3	1.0	0.8	0.7	0.7	0.7	0.8	1.0	1.2	1.4	1.7	2.0	2.3	2.5	2.8	2.9	3.0
4	3.0	2.9	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.3	1.2	1.1	1.0	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.6
5	2.6	2.6	2.6	2.5	2.3	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.5	1.4	1.4	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0	2.1
6	2.2	2.2	2.2	2.2	2.1	2.1	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7
7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5
8	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.6	2.6	2.6	2.5	2.4	2.2	2.0	1.8	1.7	1.5
9	1.4	1.2	1.1	1.1	1.0	1.0	1.1	1.2	1.4	1.6	1.9	2.2	2.4	2.6	2.8	2.9	2.9	2.9	2.7	2.6	2.3	2.1	1.9	1.6
10	1.4	1.2	1.0	0.9	0.8	0.7	0.8	0.8	1.0	1.3	1.6	1.9	2.3	2.6	2.8	3.0	3.1	3.1	3.1	2.9	2.7	2.4	2.2	1.9
11	1.6	1.3	1.0	0.8	0.7	0.6	0.5	0.6	0.7	0.9	1.2	1.6	2.0	2.4	2.7	2.9	3.1	3.2	3.3	3.2	3.0	2.8	2.5	2.2
12	1.9	1.5	1.2	0.9	0.7	0.5	0.4	0.4	0.5	0.7	0.9	1.3	1.7	2.1	2.5	2.8	3.0	3.2	3.3	3.3	3.2	3.0	2.8	2.5
13	2.1	1.8	1.4	1.1	0.8	0.6	0.5	0.4	0.4	0.5	0.7	1.0	1.4	1.8	2.2	2.5	2.9	3.1	3.3	3.3	3.3	3.2	3.0	2.7
14	2.4	2.1	1.7	1.4	1.0	0.8	0.6	0.4	0.4	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.6	2.9	3.1	3.3	3.3	3.3	3.1	2.9
15	2.6	2.3	2.0	1.6	1.3	1.0	0.7	0.6	0.5	0.5	0.6	0.7	1.0	1.3	1.7	2.0	2.4	2.7	2.9	3.1	3.2	3.2	3.1	3.0
16	2.8	2.5	2.2	1.9	1.5	1.2	1.0	0.8	0.7	0.6	0.6	0.7	0.9	1.2	1.5	1.8	2.2	2.5	2.7	2.9	3.1	3.1	3.1	3.0
17	2.8	2.6	2.3	2.0	1.8	1.5	1.2	1.0	0.9	0.8	0.8	0.8	0.9	1.1	1.4	1.6	1.9	2.2	2.5	2.7	2.8	2.9	2.9	2.9
18	2.7	2.6	2.4	2.2	1.9	1.7	1.5	1.3	1.1	1.1	1.0	1.0	1.1	1.2	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.7	2.7	2.7
19	2.6	2.5	2.3	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.3	1.3	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.4	2.4
20	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.1	2.1
21	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.8	1.8
22	1.7	1.6	1.6	1.5	1.5	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.4	2.4	2.3	2.3	2.1	2.0	1.9	1.8	1.7	1.5
23	1.4	1.3	1.2	1.2	1.2	1.2	1.3	1.4	1.6	1.9	2.1	2.3	2.5	2.7	2.8	2.8	2.8	2.7	2.5	2.3	2.1	1.9	1.7	1.4
24	1.2	1.1	0.9	0.8	0.8	0.8	0.9	1.1	1.3	1.6	2.0	2.3	2.6	2.9	3.1	3.2	3.2	3.1	2.9	2.7	2.4	2.1	1.8	1.5
25	1.2	1.0	0.7	0.6	0.4	0.4	0.5	0.7	0.9	1.2	1.6	2.0	2.5	2.8	3.1	3.4	3.5	3.5	3.4	3.1	2.8	2.5	2.1	1.8
26	1.4	1.0	0.7	0.5	0.2	0.2	0.2	0.3	0.5	0.8	1.2	1.7	2.1	2.6	3.0	3.3	3.6	3.7	3.7	3.5	3.3	2.9	2.5	2.1
27	1.7	1.3	0.9	0.6	0.1	0.1	0.0	0.1	0.2	0.5	0.8	1.2	1.7	2.2	2.7	3.1	3.4	3.7	3.8	3.8	3.6	3.3	3.0	2.6
28	2.1	1.7	1.3	0.9	0.3	0.3	0.1	0.0	0.1	0.2	0.5	0.8	1.3	0.1	2.2	2.7	3.1	3.4	3.7	3.8	3.7	3.6	3.3	2.9
29	2.5	2.1	1.7	1.3	0.6	0.6	0.3	0.2	0.1	0.2	0.3	0.6	0.9	1.3	1.8	2.2	2.7	3.0	3.3	3.5	3.6	3.6	3.4	3.1
30	2.8	2.5	2.1	1.7	1.0	1.0	0.8	0.5	0.4	0.4	0.4	0.6	0.8	1.1	1.5	1.8	2.2	2.6	2.9	3.1	3.3	3.3	3.3	3.1
31	1.2	0.8	0.7	0.9	1.6	1.9	2.4	2.8	2.9	2.9	2.9	2.6	2.2	1.3	1.1	0.8	0.7	1.0	1.5	2.1	2.9	2.6	2.4	1.5

<0.6m	<1.5m
55	241

June

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.5	2.5
2	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.6	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.1
3	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.7
4	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.9	2.0	2.1	2.2	2.3	2.3	2.4	2.4	2.4	2.3	2.2	2.1	2.0	1.8	1.7	1.6	1.4
5	1.3	1.2	1.2	1.2	1.2	1.3	1.4	1.6	1.8	2.0	2.3	2.4	2.4	2.7	2.8	2.8	2.7	2.6	2.4	2.2	2.0	1.8	1.6	1.3
6	1.1	1.0	0.9	0.8	0.8	0.9	1.0	1.2	1.5	1.8	2.1	2.4	2.4	2.8	3.0	3.0	3.0	3.0	2.8	2.6	2.3	2.0	1.7	1.4
7	1.1	0.9	0.7	0.6	0.6	0.6	0.7	0.9	1.1	1.5	1.9	2.2	2.2	2.8	3.1	3.2	3.3	3.2	3.1	2.9	2.6	2.3	2.0	1.6
8	1.3	1.0	0.7	0.5	0.4	0.4	0.4	0.6	0.8	1.1	1.5	1.9	1.9	2.7	3.0	3.2	3.4	3.4	3.3	3.2	2.9	2.6	2.3	1.9
9	1.5	1.1	0.8	0.6	0.4	0.3	0.3	0.4	0.5	0.8	1.2	1.6	1.6	2.5	2.8	3.1	3.3	3.5	3.5	3.4	3.1	2.9	2.5	2.2
10	1.8	1.4	1.0	0.7	0.5	0.3	0.3	0.3	0.4	0.6	0.9	1.3	1.3	2.2	2.6	2.9	3.2	3.4	3.5	3.4	3.3	3.0	2.7	2.4
11	2.0	1.6	1.3	0.9	0.7	0.5	0.4	0.3	0.4	0.5	0.7	1.1	1.1	1.9	2.3	2.7	3.0	3.3	3.4	3.4	3.3	3.2	2.9	2.6
12	2.2	1.9	1.5	1.2	0.9	0.7	0.5	0.4	0.4	0.5	0.7	0.9	0.9	1.7	2.1	2.5	2.8	3.1	3.3	3.3	3.3	3.2	3.0	2.7
13	2.4	2.1	1.8	1.4	1.1	0.9	0.7	0.6	0.6	0.6	0.7	0.9	0.9	1.5	1.9	2.2	2.6	2.8	3.0	3.2	3.2	3.1	3.0	2.8
14	2.5	2.2	1.9	1.7	1.4	1.2	1.0	0.8	0.8	0.8	0.8	0.9	0.9	1.4	1.7	2.0	2.3	2.6	2.8	2.9	3.0	2.9	2.8	2.7
15	2.5	2.3	2.0	1.8	1.6	1.4	1.2	1.1	1.0	1.0	1.0	1.1	1.1	1.4	1.6	1.9	2.1	2.4	2.5	2.6	2.7	2.7	2.6	2.5
16	2.4	2.2	2.1	1.9	1.7	1.6	1.5	1.4	1.3	1.3	1.3	1.3	1.3	1.5	1.6	1.8	2.0	2.2	2.3	2.4	2.4	2.4	2.3	2.3
17	2.2	2.1	2.0	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.0	1.9
18	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.9	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.0	1.9	1.8	1.7	1.6
19	1.5	1.4	1.4	1.4	1.4	1.5	1.6	1.7	1.9	2.1	2.2	2.4	2.4	2.5	2.5	2.5	2.4	2.3	2.2	2.0	1.9	1.7	1.5	1.3
20	1.2	1.0	1.0	1.0	1.1	1.2	1.3	1.6	1.8	2.1	2.3	2.6	2.6	2.9	2.9	2.9	2.8	2.7	2.4	2.2	2.0	1.7	1.4	1.2
21	0.9	0.8	0.6	0.6	0.7	0.8	1.0	1.2	1.5	1.9	2.3	2.6	2.6	3.1	3.3	3.3	3.3	3.1	2.8	2.5	2.2	1.9	1.5	1.2
22	0.9	0.6	0.4	0.3	0.3	0.4	0.6	0.8	1.1	1.5	2.0	2.4	2.4	3.2	3.4	3.6	3.6	3.5	3.3	3.0	2.6	2.2	1.8	1.4
23	1.0	0.7	0.4	0.2	0.1	0.1	0.2	0.4	0.7	1.1	1.6	2.1	2.1	3.0	3.4	3.6	3.8	3.8	3.7	3.4	3.0	2.6	2.2	1.8
24	1.3	0.9	0.5	0.3	0.1	0.0	0.0	0.1	0.4	0.7	1.1	1.6	1.6	2.6	3.1	3.5	3.7	3.9	3.8	3.7	3.4	3.0	2.6	2.2
25	1.7	1.3	0.9	0.5	0.3	0.1	0.0	0.0	0.2	0.4	0.7	1.2	1.2	2.2	2.7	3.1	3.5	3.7	3.8	3.8	3.6	3.3	2.9	2.5
26	2.1	1.7	1.3	0.9	0.6	0.4	0.2	0.1	0.2	0.3	0.5	0.9	0.9	1.7	2.2	2.6	3.0	3.3	3.5	3.6	3.5	3.4	3.1	2.8
27	2.4	2.1	1.7	1.4	1.1	0.8	0.6	0.5	0.4	0.4	0.6	0.8	0.8	1.4	1.8	2.2	2.5	2.9	3.1	3.2	3.3	3.2	3.0	2.8
28	2.6	2.3	2.1	1.8	1.5	1.3	1.1	0.9	0.8	0.8	0.8	0.9	0.9	1.3	1.6	1.9	2.1	2.4	2.6	2.8	2.9	2.9	2.8	2.7
29	2.5	2.3	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.2	1.2	1.2	1.4	1.5	1.7	1.9	2.1	2.2	2.3	2.4	2.4	2.4	2.3
30	2.2	2.1	2.1	2.0	2.0	1.9	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	1.9

<0.6m	<1.5m
56	227

Table 6.2.11 Tide Level lower than 1.5m at Hon Dau Station (2009)

July

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.9	1.8	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.8	1.8	1.7	1.6	1.5
2	1.4	1.4	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.4	2.3	2.2	2.1	1.9	1.7	1.5	1.4	1.2
3	1.1	1.0	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.7	2.8	2.8	2.8	2.7	2.5	2.3	2.1	1.8	1.6	1.3	1.1
4	0.9	0.8	0.7	0.7	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.6	2.8	3.0	3.1	3.1	3.0	2.9	2.7	2.4	2.1	1.7	1.4	1.1
5	0.9	0.7	0.5	0.5	0.5	0.6	0.8	1.1	1.5	1.8	2.2	2.5	2.8	3.0	3.2	3.3	3.3	3.2	3.0	2.7	2.4	2.0	1.6	1.3
6	0.9	0.7	0.5	0.4	0.3	0.4	0.5	0.8	1.1	1.5	1.9	2.3	2.7	3.0	3.2	3.4	3.4	3.4	3.2	3.0	2.6	2.3	1.9	1.5
7	1.1	0.8	0.6	0.4	0.3	0.3	0.4	0.5	0.8	1.2	1.6	2.0	2.4	2.8	3.1	3.3	3.5	3.5	3.4	3.2	2.9	2.5	2.1	1.8
8	1.4	1.0	0.7	0.5	0.4	0.3	0.3	0.4	0.6	0.9	1.3	1.7	2.2	2.6	2.9	3.2	3.4	3.5	3.4	3.3	3.0	2.7	2.4	2.0
9	1.6	1.3	1.0	0.7	0.5	0.4	0.3	0.4	0.5	0.7	1.0	1.5	1.9	2.3	2.7	3.0	3.3	3.4	3.4	3.3	3.1	2.8	2.5	2.2
10	1.9	1.5	1.2	0.9	0.7	0.6	0.5	0.5	0.5	0.7	0.9	1.2	1.7	2.1	2.5	2.8	3.1	3.2	3.3	3.3	3.1	2.9	2.6	2.3
11	2.0	1.8	1.5	1.2	1.0	0.8	0.7	0.6	0.6	0.7	0.9	1.1	1.5	1.8	2.2	2.5	2.8	3.0	3.1	3.1	3.0	2.9	2.7	2.4
12	2.2	1.9	1.7	1.4	1.2	1.1	0.9	0.9	0.8	0.8	0.9	1.1	1.4	1.7	2.0	2.3	2.6	2.7	2.9	2.9	2.9	2.8	2.6	2.4
13	2.2	2.0	1.8	1.7	1.5	1.3	1.2	1.1	1.1	1.1	1.1	1.2	1.4	1.6	1.8	2.1	2.3	2.5	2.6	2.6	2.6	2.5	2.4	2.3
14	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.6	1.8	2.0	2.1	2.2	2.3	2.3	2.3	2.2	2.1	2.0
15	2.0	1.9	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.0	2.0	1.9	1.8	1.7
16	1.7	1.6	1.6	1.7	1.7	1.7	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.7	1.6	1.5	1.4
17	1.3	1.3	1.3	1.4	1.5	1.4	1.8	2.0	2.2	2.3	2.4	2.5	2.6	2.6	2.5	2.5	2.3	2.2	2.0	1.8	1.6	1.4	1.2	1.0
18	0.9	0.9	0.9	1.0	1.2	1.0	1.6	1.9	2.2	2.4	2.6	2.8	2.9	3.0	3.0	2.9	2.7	2.5	2.2	2.0	1.7	1.4	1.1	0.8
19	0.7	0.6	0.6	0.6	0.8	0.6	1.3	1.6	2.0	2.3	2.6	2.9	3.2	3.3	3.3	3.3	3.1	2.9	2.6	2.2	1.9	1.5	1.1	0.8
20	0.6	0.4	0.3	0.3	0.4	0.3	0.9	1.2	1.6	2.0	2.4	2.8	3.2	3.4	3.6	3.6	3.5	3.3	3.0	2.6	2.2	1.8	1.4	1.0
21	0.7	0.4	0.2	0.1	0.1	0.1	0.5	0.7	1.1	1.6	2.0	2.5	2.9	3.3	3.6	3.8	3.8	3.6	3.4	3.0	2.6	2.2	1.8	1.3
22	0.9	0.6	0.3	0.1	0.1	0.1	0.2	0.4	0.7	1.1	1.6	2.1	2.6	3.0	3.4	3.7	3.8	3.8	3.6	3.3	3.0	2.6	2.2	1.8
23	1.4	1.0	0.7	0.4	0.2	0.2	0.1	0.2	0.4	0.7	1.1	1.6	2.1	2.6	3.0	3.3	3.6	3.7	3.7	3.5	3.2	2.9	2.5	2.2
24	1.8	1.4	1.1	0.8	0.6	0.6	0.3	0.3	0.4	0.6	0.9	1.2	1.7	2.1	2.5	2.9	3.2	3.4	3.5	3.4	3.2	3.0	2.7	2.4
25	2.1	1.8	1.5	1.3	1.0	1.0	0.7	0.6	0.6	0.6	0.8	1.0	1.4	1.7	2.1	2.4	2.7	2.9	3.1	3.1	3.0	2.9	2.7	2.5
26	2.3	2.1	1.9	1.7	1.5	1.5	1.1	1.0	0.9	0.9	1.0	1.1	1.3	1.5	1.8	2.0	2.3	2.5	2.6	2.7	2.7	2.6	2.5	2.4
27	2.3	2.2	2.1	2.0	1.8	1.8	1.6	1.5	1.4	1.3	1.3	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.2	2.2	2.2	2.2	2.2	2.1
28	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.7
29	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.8	1.6	1.6	1.5	1.4	1.3
30	1.4	1.4	1.5	1.6	1.8	1.8	2.1	2.2	2.3	2.4	2.5	2.5	2.5	2.5	2.4	2.3	2.2	2.0	1.8	1.6	1.4	1.3	1.1	1.0
31	1.0	1.0	1.1	1.3	1.5	1.5	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.8	2.8	2.7	2.5	2.3	2.1	1.8	1.5	1.2	1.0	0.9

<0.6m	<1.5m
52	229

August

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.8	0.7	0.8	0.9	1.1	1.3	1.6	1.9	2.2	2.4	2.7	2.8	3.0	3.1	3.1	3.0	2.9	2.6	2.4	2.0	1.7	1.4	1.1	0.9
2	0.7	0.6	0.6	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.2	3.2	3.1	2.9	2.7	2.3	2.0	1.6	1.3	1.0
3	0.7	0.6	0.5	0.5	0.6	0.7	0.9	1.2	1.6	2.0	2.3	2.6	2.9	3.1	3.3	3.4	3.3	3.2	2.9	2.6	2.2	1.9	1.5	1.2
4	0.9	0.7	0.5	0.4	0.5	0.5	0.7	1.0	1.3	1.7	2.0	2.4	2.8	3.0	3.2	3.4	3.4	3.3	3.1	2.8	2.5	2.1	1.8	1.4
5	1.1	0.8	0.7	0.5	0.5	0.5	0.6	0.8	1.0	1.4	1.8	2.2	2.5	2.9	3.1	3.3	3.4	3.3	3.2	2.9	2.6	2.3	2.0	1.7
6	1.3	1.1	0.9	0.7	0.6	0.5	0.6	0.7	0.9	1.1	1.5	1.9	2.3	2.6	2.9	3.1	3.3	3.3	3.2	3.0	2.8	2.5	2.2	1.9
7	1.6	1.3	1.1	0.9	0.8	0.7	0.7	0.7	0.8	1.0	1.3	1.7	2.0	2.4	2.7	2.9	3.1	3.2	3.1	3.0	2.8	2.6	2.3	2.1
8	1.8	1.6	1.4	1.2	1.0	0.9	0.8	0.8	0.8	1.0	1.2	1.5	1.8	2.2	2.5	2.7	2.9	3.0	3.0	2.9	2.7	2.6	2.4	2.2
9	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	1.0	1.2	1.4	1.6	1.9	2.2	2.4	2.6	2.7	2.7	2.7	2.6	2.5	2.3	2.2
10	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.3	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.4	2.4	2.4	2.4	2.3	2.2	2.1
11	2.0	2.0	2.0	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.9
12	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0	1.9	1.9	1.8	1.7	1.6	1.6	1.6
13	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.0	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.2
14	1.3	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.6	2.7	2.7	2.6	2.6	2.4	2.3	2.1	1.9	1.7	1.5	1.2	1.1	0.9	0.9
15	0.9	1.0	1.1	1.3	1.6	1.9	2.1	2.4	2.6	2.8	3.0	3.0	3.0	3.0	2.9	2.7	2.4	2.2	1.9	1.6	1.2	1.0	0.8	0.6
16	0.6	0.6	0.7	0.9	1.2	1.5	1.8	2.2	2.5	2.8	3.0	3.2	3.3	3.4	3.3	3.1	2.8	2.5	2.2	1.8	1.4	1.1	0.8	0.6
17	0.4	0.4	0.4	0.6	0.8	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.4	3.6	3.6	3.5	3.2	2.9	2.6	2.2	1.8	1.4	1.0	0.7
18	0.5	0.3	0.3	0.3	0.5	0.7	1.0	1.3	1.7	2.1	2.6	3.0	3.3	3.5	3.7	3.7	3.5	3.3	2.9	2.6	2.2	1.8	1.4	1.0
19	0.7	0.5	0.4	0.3	0.3	0.5	0.6	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.5	3.6	3.6	3.5	3.2	2.9	2.5	2.2	1.8	1.5
20	1.1	0.9	0.7	0.5	0.4	0.4	0.5	0.7	0.9	1.3	1.7	2.1	2.5	2.9	3.2	3.4	3.5	3.4	3.3	3.1	2.8	2.5	2.2	1.9
21	1.6	1.3	1.1	0.9	0.7	0.7	0.6	0.7	0.8	1.0	1.3	1.6	2.0	2.4	2.7	3.0	3.2	3.2	3.2	3.0	2.8	2.6	2.4	2.2
22	2.0	1.8	1.6	1.4	1.2	1.0	0.9	0.9	0.9	1.0	1.1	1.4	1.7	2.0	2.2	2.5	2.7	2.8	2.8	2.8	2.7	2.6	2.4	2.3
23	2.2	2.1	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.2	1.2	1.3	1.5	1.7	1.9	2.1	2.2	2.4	2.4	2.4	2.4	2.3	2.3	2.3
24	2.3	2.3	2.2	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.5	1.5	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0
25	2.1	2.2	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.7
26	1.8	1.9	2.1	2.3	2.4	2.4	2.5	2.5	2.4	2.4	2.3	2.2	2.2	2.1	2.0	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.3
27	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.6	2.7	2.7	2.7	2.6	2.5	2.4	2.3	2.1	1.9	1.7	1.5	1.3	1.1	1.0	1.0	1.0
28	1.1	1.2	1.4	1.7	2.0	2.2	2.4	2.6	2.7	2.8	2.9	2.9	2.9	2.8	2.7	2.5	2.2	2.0	1.7	1.4	1.1	1.0	0.8	0.8
29	0.8	0.9	1.1	1.3	1.6	1.9	2.2	2.4	2.6	2.8	3.0	3.0	3.1	3.1	2.0	2.8	2.5	2.3	1.9	1.6	1.3	1.0	0.8	0.7
30	0.7	0.7	0.9	1.0	1.3	1.6	1.9	2.2	2.4	2.7	2.9	3.1	3.2	3.2	3.2	3.0	2.8	2.5	2.2	1.9	1.5	1.2	1.0	0.8
31	0.7	0.7	0.7	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.7	3.0	3.1	3.2	3.3	3.2	3.0	2.8	2.5	2.1	1.8	1.5	1.2	1.0

<0.6m	<1.5m
27	225

September

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.8	0.7	0.7	0.7	0.9	1.0	1.3	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.3	3.2	3.1	2.9	2.7	2.4	2.0	1.7	1.4	1.2
2	1.0	0.9	0.8	0.8	0.8	0.9	1.1	1.3	1.6	2.0	2.3	2.6	2.8	3.0	3.2	3.2	3.2	3.0	2.8	2.5	2.2	1.9	1.7	1.4
3	1.2	1.1	1.0	0.9	0.9	0.9	1.0	1.2	1.4	1.7	2.0	2.3	2.6	2.9	3.0	3.1	3.1	3.0	2.8	2.6	2.4	2.1	1.9	1.7
4	1.5	1.3	1.2	1.1	1.0	1.0	1.0	1.1	1.3	1.5	1.8	2.1	2.4	2.6	2.8	2.9	2.9	2.9	2.8	2.6	2.4	2.2	2.1	1.9
5	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.2	1.2	1.4	1.6	1.9	2.1	2.4	2.6	2.7	2.7	2.7	2.7	2.5	2.4	2.3	2.1	2.0
6	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.3	1.3	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.5	2.4	2.4	2.3	2.2	2.1	2.1
7	2.1	2.1	2.0	1.9	1.9	1.8	1.7	1.6	1.5	1.5	1.5	1.6	1.8	1.9	2.0	2.1	2.2	2.2	2.2	2.1	2.1	2.0	2.0	2.0
8	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.7	1.7	1.8	1.8	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.9
9	2.0	2.1	2.3	2.3	2.4	2.4	2.4	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.5	1.6
10	1.8	2.0	2.2	2.4	2.5	2.6	2.7	2.7	2.7	2.6	2.5	2.3	2.2	2.1	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.1	1.1	1.2
11	1.4	1.6	1.9	2.2	2.4	2.6	2.8	2.9	3.0	3.0	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.5	1.2	1.0	0.9	0.8	0.8	0.9
12	1.0	1.3	1.6	1.9	2.2	2.5	2.7	3.0	3.1	3.2	3.2	3.2	3.1	2.9	2.6	2.3	2.0	1.7	1.4	1.1	0.8	0.7	0.6	0.6
13	0.7	0.9	1.1	1.5	1.8	2.2	2.5	2.8	3.1	3.3	3.4	3.4	3.4	3.3	3.0	2.8	2.4	2.1	1.7	1.3	1.0	0.7	0.5	0.5
14	0.5	0.6	0.8	1.1	1.4	1.7	2.1	2.4	2.8	3.1	3.3	3.5	3.6	3.5	3.4	3.1	2.8	2.5	2.1	1.7	1.3	1.0	0.7	0.6
15	0.5	0.5	0.6	0.8	1.0	1.3	1.6	2.0	2.4	2.7	3.1	3.3	3.5	3.6	3.5	3.4	3.1	2.8	2.5	2.1	1.7	1.4	1.1	0.9
16	0.7	0.6	0.6	0.7	0.8	1.0	1.3	1.6	1.9	2.3	2.6	3.0	3.2	3.4	3.5	3.4	3.3	3.0	2.7	2.4	2.1	1.8	1.5	1.3
17	1.1	0.9	0.9	0.8	0.8	0.9	1.0	1.2	1.5	1.8	2.2	2.5	2.8	3.0	3.2	3.2	3.2	3.1	2.9	2.6	2.4	2.2	2.0	1.8
18	1.6	1.4	1.3	1.2	1.1	1.0	1.1	1.1	1.3	1.5	1.8	2.0	2.3	2.6	2.8	2.9	2.9	2.9	2.8	2.6	2.5	2.4	2.3	2.1
19	2.0	1.9	1.7	1.6	1.5	1.4	1.3	1.3	1.3	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.3
20	2.3	2.3	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.5	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.3
21	2.4	2.5	2.5	2.5	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.9	2.1
22	2.3	2.5	2.6	2.7	2.7	2.7	2.6	2.5	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.3	1.4	1.4	1.6	1.8
23	2.0	2.3	2.5	2.7	2.8	2.9	2.9	2.8	2.7	2.6	2.4	2.3	2.1	1.9	1.8	1.6	1.4	1.3	1.1	1.1	1.0	1.1	1.2	1.4
24	1.6	2.0	2.3	2.5	2.7	2.9	3.0	3.0	3.0	2.9	2.8	2.7	2.5	2.3	2.0	1.8	1.5	1.3	1.1	1.0	0.9	0.9	0.9	1.1
25	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.1	3.1	3.1	3.1	3.0	2.8	2.6	2.4	2.1	1.8	1.5	1.2	1.0	0.8	0.7	0.8	0.8
26	1.0	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.1	3.2	3.2	3.2	3.1	2.9	2.7	2.4	2.1	1.7	1.4	1.1	0.9	0.8	0.7	0.7
27	0.9	1.0	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.1	3.2	3.2	3.2	3.1	2.9	2.7	2.4	2.0	1.7	1.4	1.1	0.9	0.8	0.8
28	0.8	0.9	1.1	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.1	3.2	3.2	3.2	3.1	2.9	2.6	2.3	2.0	1.6	1.3	1.1	1.0	0.9
29	0.9	0.9	1.0	1.2	1.4	1.7	2.0	2.2	2.5	2.7	2.9	3.1	3.2	3.2	3.1	3.0	2.7	2.5	2.2	1.9	1.6	1.4	1.2	1.1
30	1.0	1.0	1.1	1.2	1.3	1.5	1.7	2.0	2.3	2.5	2.7	2.9	3.0	3.1	3.1	3.0	2.8	2.6	2.3	2.1	1.8	1.6	1.4	1.3

<0.6m	<1.5m
5	192

October

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.2	1.2	1.2	1.2	1.3	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.8	2.9	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4
2	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.6	1.8	2.0	2.2	2.4	2.6	2.7	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
3	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.6	2.7
4	2.0	2.0	2.0	1.9	1.9	1.8	1.7	1.7	1.7	1.8	1.9	2.0	2.1	2.1	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0
5	2.2	2.3	2.3	2.3	2.2	2.1	2.0	1.9	1.8	1.8	1.8	1.9	1.9	1.9	1.7	1.7	1.6	1.6	1.6	1.5	1.5	1.4	1.4	1.4
6	2.3	2.4	2.5	2.6	2.6	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.4	1.4	1.3	1.2	1.2
7	2.3	2.5	2.7	2.8	2.9	2.9	2.8	2.7	2.5	2.3	2.2	2.0	1.9	1.7	2.0	1.9	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.4
8	2.0	2.4	2.6	2.9	3.0	3.1	3.2	3.1	3.0	2.8	2.5	2.3	2.1	1.9	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.2	2.2
9	1.7	2.1	2.4	2.8	3.0	3.2	3.3	3.4	3.3	3.2	3.0	2.7	2.5	2.2	3.0	3.1	3.1	3.1	3.2	3.2	3.3	3.3	3.3	3.4
10	1.3	1.7	2.1	2.5	2.8	3.1	3.3	3.5	3.6	3.5	3.4	3.2	2.9	2.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5	4.6	4.7
11	0.9	1.3	1.7	2.1	2.5	2.8	3.1	3.4	3.6	3.6	3.6	3.5	3.3	3.0	4.1	4.3	4.5	4.7	4.9	5.1	5.2	5.4	5.6	5.8
12	0.7	1.0	1.3	1.6	2.0	2.4	2.8	3.1	3.4	3.5	3.6	3.6	3.5	3.3	4.3	4.6	4.8	5.0	5.3	5.5	5.7	6.0	6.2	6.4
13	0.6	0.8	1.0	1.3	1.6	2.0	2.3	2.7	3.0	3.2	3.4	3.5	3.5	3.4	4.2	4.4	4.7	5.0	5.2	5.5	5.7	6.0	6.2	6.5
14	0.8	0.8	1.0	1.1	1.3	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.3	3.3	3.8	4.0	4.2	4.4	4.7	4.9	5.1	5.4	5.6	5.8
15	1.2	1.1	1.1	1.2	1.3	1.4	1.6	1.8	2.1	2.3	2.6	2.8	2.9	3.0	3.1	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.5	4.6
16	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.8	1.9	2.1	2.3	2.4	2.6	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2
17	2.1	2.0	2.0	1.9	1.8	1.7	1.7	1.6	1.7	1.7	1.8	1.9	2.0	2.1	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
18	2.4	2.4	2.4	2.4	2.3	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.7	1.7	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.0	0.9	0.9
19	2.6	2.7	2.8	2.8	2.7	2.6	2.4	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.6	1.8	2.0	2.3
20	2.6	2.8	2.9	3.0	3.0	3.0	2.9	2.7	2.5	2.3	2.1	1.9	1.7	1.5	1.3	1.2	1.1	1.1	1.0	1.1	1.2	1.4	1.6	2.0
21	2.3	2.6	2.9	3.1	3.2	3.2	3.2	3.1	2.9	2.7	2.4	2.2	1.9	1.7	1.4	1.2	1.0	0.9	0.8	0.8	0.9	1.0	1.3	1.6
22	2.0	2.4	2.7	3.0	3.2	3.3	3.4	3.3	3.2	3.0	2.8	2.5	2.3	2.0	1.7	1.3	1.1	0.9	0.7	0.7	0.7	0.8	1.0	1.3
23	1.6	2.0	2.4	2.8	3.0	3.2	3.4	3.4	3.4	3.3	3.1	2.9	2.6	2.3	2.0	1.6	1.3	1.0	0.8	0.6	0.6	0.6	0.8	1.0
24	1.3	1.7	2.1	2.5	2.8	3.0	3.3	3.4	3.4	3.4	3.3	3.1	2.9	2.6	2.3	1.9	1.5	1.2	0.9	0.8	0.6	0.6	0.7	0.9
25	1.1	1.4	1.8	2.2	2.5	2.8	3.0	3.2	3.4	3.4	3.4	3.3	3.1	2.8	2.5	2.2	1.8	1.5	1.2	1.0	0.8	0.7	0.7	0.8
26	1.0	1.2	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.3	3.3	3.3	3.1	3.0	2.7	2.4	2.1	1.8	1.4	1.2	1.0	0.9	0.9	0.9
27	1.0	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.0	3.1	3.2	3.2	3.1	3.0	2.8	2.5	2.3	2.0	1.7	1.4	1.3	1.1	1.1	1.1
28	1.1	1.2	1.4	1.6	1.8	2.1	2.3	2.5	2.7	2.9	3.0	3.0	3.0	2.9	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.3
29	1.3	1.4	1.5	1.6	1.7	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.8	2.8	2.7	2.5	2.4	2.2	2.0	1.9	1.7	1.6	1.6	1.6
30	1.6	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.6	2.6	2.5	2.5	2.4	2.3	2.2	2.0	1.9	1.9	1.8	1.8	1.8
31	1.8	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.0	2.0	1.9	1.9	2.0	2.0	2.1

<0.6m	<1.5m
0	133

November

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.1	2.2	2.2	2.2	2.1	2.1	2.0	2.0	2.0	2.0	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.3
2	2.4	2.5	2.5	2.5	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.8	1.7	1.6	1.5	1.5	1.5	1.5	1.6	1.7	1.9	2.1	2.3
3	2.5	2.7	2.8	2.9	2.9	2.8	2.6	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.2	1.2	1.1	1.2	1.2	1.4	1.6	1.9	2.2
4	2.5	2.8	3.0	3.2	3.2	3.2	3.1	2.9	2.6	2.4	2.1	1.9	1.7	1.4	1.2	1.0	0.9	0.8	0.8	0.9	1.0	1.3	1.6	2.0
5	2.4	2.8	3.1	3.3	3.5	3.5	3.4	3.3	3.0	2.8	2.4	2.1	1.8	1.5	1.2	1.0	0.7	0.6	0.5	0.5	0.7	0.9	1.2	1.6
6	2.1	2.5	2.9	3.3	3.5	3.7	3.7	3.6	3.5	3.2	2.9	2.5	2.2	1.8	1.4	1.1	0.8	0.5	0.4	0.3	0.4	0.6	0.9	1.2
7	1.7	2.1	2.6	3.0	3.4	3.6	3.8	3.8	3.8	3.6	3.3	2.9	2.6	2.2	1.8	1.4	1.0	0.7	0.4	0.3	0.3	0.4	0.6	0.9
8	1.3	1.7	2.2	2.6	3.0	3.4	3.7	3.8	3.9	3.8	3.6	3.3	2.9	2.6	2.2	1.8	1.3	1.0	0.7	0.5	0.3	0.3	0.4	0.7
9	1.0	1.3	1.8	2.2	2.6	3.0	3.3	3.6	3.7	3.8	3.7	3.5	3.2	2.9	2.5	2.2	1.8	1.4	1.1	0.8	0.6	0.5	0.5	0.6
10	0.8	1.1	1.4	1.8	2.2	2.5	2.9	3.1	3.4	3.5	3.5	3.5	3.3	3.1	2.8	2.5	2.1	1.8	1.5	1.2	1.0	0.9	0.8	0.8
11	0.9	1.1	1.3	1.6	1.8	2.1	2.4	2.7	2.9	3.1	3.2	3.2	3.1	3.0	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.2
12	1.2	1.3	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.6	2.7	2.8	2.8	2.8	2.7	2.5	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.7
13	1.7	1.7	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.3	2.3	2.4	2.3	2.3	2.3	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1
14	2.1	2.1	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.1	2.2	2.4	2.5
15	2.5	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.8	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.5	1.6	1.7	1.9	2.1	2.4	2.6
16	2.8	2.9	2.9	2.9	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.1	1.2	1.3	1.5	1.9	2.2	2.5
17	2.8	3.0	3.2	3.2	3.2	3.2	3.0	2.8	2.5	2.2	2.0	1.7	1.4	1.2	1.0	0.9	0.8	0.7	0.8	0.9	1.1	1.5	1.9	2.3
18	2.6	2.9	3.2	3.4	3.5	3.4	3.3	3.2	2.9	2.6	2.3	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.5	0.6	0.8	1.1	1.5	1.9
19	2.3	2.7	3.1	3.3	3.5	3.6	3.6	3.4	3.2	2.9	2.6	2.3	1.9	1.5	1.2	0.9	0.7	0.5	0.4	0.4	0.6	0.8	1.1	1.5
20	2.0	2.4	2.8	3.2	3.4	3.6	3.6	3.6	3.5	3.2	2.9	2.6	2.2	1.8	1.4	1.1	0.8	0.6	0.5	0.4	0.5	0.6	0.9	1.1
21	1.6	2.1	2.5	2.9	3.2	3.4	3.6	3.6	3.6	3.4	3.1	2.8	2.5	2.1	1.7	1.4	1.0	0.8	0.6	0.5	0.5	0.6	0.7	1.0
22	1.4	1.8	2.2	2.6	2.9	3.2	3.4	3.5	3.5	3.4	3.3	3.0	2.7	2.4	2.0	1.6	1.3	1.0	0.8	0.7	0.6	0.6	0.7	0.9
23	1.2	1.6	2.0	2.4	2.7	3.0	3.2	3.3	3.4	3.4	3.3	3.1	2.8	2.5	2.2	1.9	1.6	1.3	1.0	0.9	0.8	0.8	0.8	1.0
24	1.2	1.5	1.8	2.1	2.5	2.7	3.0	3.1	3.2	3.2	3.2	3.0	2.8	2.6	2.3	2.1	1.8	1.5	1.3	1.1	1.0	1.0	1.0	1.1
25	1.2	1.4	1.7	2.0	2.3	2.5	2.7	2.9	3.0	3.0	3.0	2.9	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.2	1.3
26	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.6	2.7	2.8	2.8	2.7	2.6	2.5	2.3	2.2	2.0	1.8	1.7	1.6	1.5	1.5	1.5	1.5
27	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.4	2.5	2.5	2.5	2.5	2.4	2.3	2.2	2.1	1.9	1.8	1.8	1.7	1.7	1.7	1.8	1.8
28	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.8	1.8	1.8	1.8	1.9	1.9	2.0	2.1
29	2.2	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.5	1.5	1.6	1.7	1.9	2.0	2.2	2.4
30	2.5	2.6	2.7	2.6	2.6	2.5	2.4	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.2	1.2	1.3	1.5	1.7	2.0	2.3	2.5

<0.6m	<1.5m
26	173

December

	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0
1	2.7	2.9	3.0	3.0	3.0	2.9	2.7	2.5	2.2	2.0	1.8	1.6	1.3	1.1	1.0	0.9	0.8	0.9	1.0	1.2	1.4	1.8	2.1	2.5
2	2.8	3.1	3.3	3.4	3.4	3.3	3.1	2.8	2.5	2.2	1.9	1.6	1.3	1.0	0.8	0.6	0.5	0.5	0.6	0.8	1.1	1.4	1.9	2.3
3	2.7	3.1	3.4	3.6	3.7	3.6	3.5	3.2	2.9	2.5	2.2	1.8	1.4	1.1	0.7	0.5	0.3	0.3	0.3	0.4	0.7	1.0	1.5	1.9
4	2.4	2.9	3.3	3.6	3.8	3.9	3.8	3.6	3.3	2.9	2.5	2.1	1.7	1.3	0.9	0.6	0.3	0.2	0.1	0.2	0.4	0.6	1.0	1.5
5	2.0	2.5	3.0	3.4	3.7	3.9	4.0	3.9	3.7	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.5	0.3	0.1	0.1	0.2	0.4	0.7	1.1
6	1.6	2.1	2.6	3.1	3.4	3.7	3.9	3.9	3.8	3.6	3.3	2.9	2.5	2.1	1.6	1.2	0.8	0.5	0.3	0.2	0.2	0.3	0.5	0.8
7	1.2	1.7	2.2	2.6	3.0	3.4	3.6	3.8	3.8	3.7	3.4	3.1	2.8	2.4	2.0	1.7	1.3	1.0	0.7	0.5	0.4	0.4	0.6	0.8
8	1.0	1.4	1.8	2.2	2.6	2.9	3.2	3.4	3.5	3.5	3.4	3.2	2.9	2.6	2.3	2.0	1.7	1.4	1.2	1.0	0.8	0.8	0.8	0.9
9	1.1	1.3	1.6	1.9	2.2	2.4	2.7	2.9	3.0	3.1	3.1	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.3	1.2	1.2	1.2
10	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.6	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.7
11	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.0	2.0	1.9	2.0	2.0	2.0	2.0	2.1	2.1	2.1
12	2.1	2.2	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.8	2.0	2.1	2.3	2.4	2.5
13	2.6	2.6	2.6	2.6	2.5	2.4	2.2	2.1	1.9	1.7	1.6	1.4	1.3	1.2	1.2	1.2	1.2	1.3	1.5	1.7	2.0	2.2	2.5	2.7
14	2.8	2.9	3.0	3.0	2.9	2.7	2.5	2.3	2.1	1.8	1.5	1.3	1.1	0.9	0.8	0.8	0.8	0.9	1.1	1.4	1.7	2.0	2.4	2.7
15	2.9	3.1	3.2	3.3	3.3	3.1	2.9	2.6	2.3	2.0	1.7	1.4	1.1	0.8	0.7	0.5	0.5	0.6	0.7	1.0	1.3	1.7	2.1	2.5
16	2.8	3.1	3.3	3.5	3.5	3.4	3.3	3.0	2.7	2.3	1.9	1.6	1.2	0.9	0.6	0.5	0.4	0.3	0.4	0.6	0.9	1.3	1.7	2.2
17	2.6	3.0	3.3	3.5	3.6	3.6	3.5	3.3	3.0	2.6	2.3	1.8	1.4	1.1	0.8	0.5	0.3	0.3	0.3	0.4	0.6	0.9	1.4	1.8
18	2.3	2.7	3.1	3.4	3.6	3.7	3.6	3.5	3.2	2.9	2.5	2.1	1.7	1.3	1.0	0.7	0.5	0.3	0.3	0.3	0.4	0.7	1.0	1.5
19	2.0	2.4	2.8	3.2	3.4	3.6	3.6	3.6	3.4	3.1	2.8	2.4	2.0	1.6	1.2	0.9	0.7	0.5	0.4	0.3	0.4	0.6	0.9	1.2
20	1.7	2.1	2.5	2.9	3.2	3.4	3.5	3.5	3.4	3.2	2.9	2.6	2.2	1.9	1.5	1.2	0.9	0.7	0.6	0.5	0.5	0.6	0.8	1.1
21	1.5	1.9	2.3	2.7	3.0	3.2	3.4	3.4	3.3	3.2	3.0	2.7	2.4	2.1	1.7	1.4	1.1	0.9	0.8	0.7	0.7	0.7	0.8	1.0
22	1.3	1.7	2.1	2.4	2.7	3.0	3.1	3.2	3.2	3.1	2.9	2.7	2.4	2.2	1.9	1.6	1.4	1.2	1.0	0.9	0.9	0.9	1.0	1.1
23	1.3	1.6	1.9	2.2	2.5	2.7	2.9	3.0	3.0	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.1	1.2	1.3
24	1.4	1.6	1.8	2.1	2.3	2.5	2.6	2.7	2.7	2.7	2.6	2.4	2.3	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.4	1.4	1.5	1.5
25	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.6	1.7	1.7	1.8	1.8
26	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.1
27	2.2	2.3	2.3	2.3	2.3	2.3	2.2	2.1	2.0	1.9	1.7	1.6	1.5	1.4	1.3	1.3	1.4	1.5	1.6	1.8	1.9	2.1	2.3	2.4
28	2.6	2.6	2.6	2.6	2.5	2.4	2.3	2.1	1.9	1.7	1.5	1.3	1.1	1.0	1.0	1.0	1.1	1.2	1.4	1.6	1.9	2.2	2.4	2.7
29	2.8	3.0	3.0	3.0	2.9	2.7	2.5	2.3	2.0	1.7	1.4	1.2	0.9	0.7	0.6	0.6	0.7	0.8	1.0	1.3	1.7	2.0	2.4	2.7
30	3.0	3.2	3.4	3.4	3.3	3.1	2.9	2.5	2.2	1.9	1.5	1.2	0.8	0.6	0.4	0.3	0.3	0.4	0.6	0.9	1.3	1.7	2.2	2.6
31	3.0	3.3	3.5	3.7	3.6	3.5	3.3	2.9	2.5	2.1	1.7	1.3	0.9	0.6	0.3	0.2	0.1	0.1	0.3	0.5	0.9	1.3	1.8	2.3

<0.6m	<1.5m
59	234

6) Financial Viewpoint

It is considered that the financial assessment taking into considering of the funding condition is also important to determine the channel depth of this Project. Therefore, we conducted the financial comparison for the following 2 cases:

Case 1:

- Channel to be dredged -14m in 2015 by ODA STEP Loan.
- Additional maintenance dredging cost during 2015 to 2020 is considered.
- Capital dredging cost of 9.23 USD/m^3 and maintenance dredging cost of 5.64 USD/m^3 at 2009 price are applied. (Costs of TEDI's revised FS report are applied.)

Case 2:

- Channel to be dredged up to -13m in 2015 by ODA STEP Loan.
- Channel to be dredged up to -14m in 2020 by local fund.
- Capital dredging cost of 9.23 USD/m^3 in 2015 and 5.64 USD/m^3 in 2020 at 2009 price are applied.

The accumulated repayment amounts including maintenance dredging were calculated and the results are illustrated in Figure 6.2.4, Figure 6.2.5 and Figure 6.2.6 show the additional payments for Case 1 and Case 2 respectively.

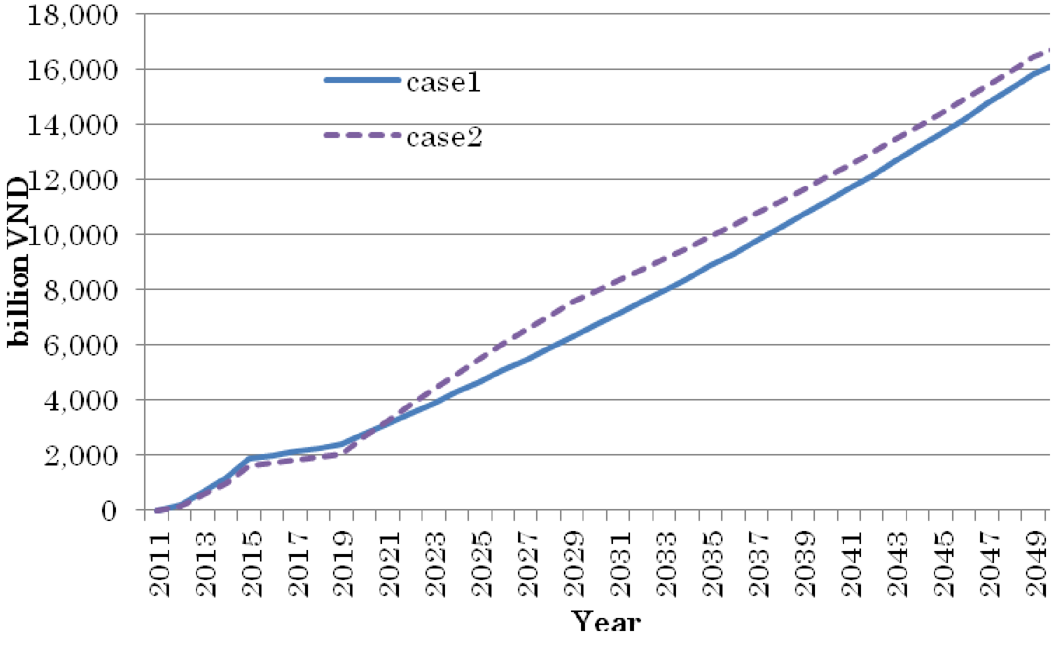


Figure 6.2.4 Accumulated Cash Flow of Case 1 and Case 2

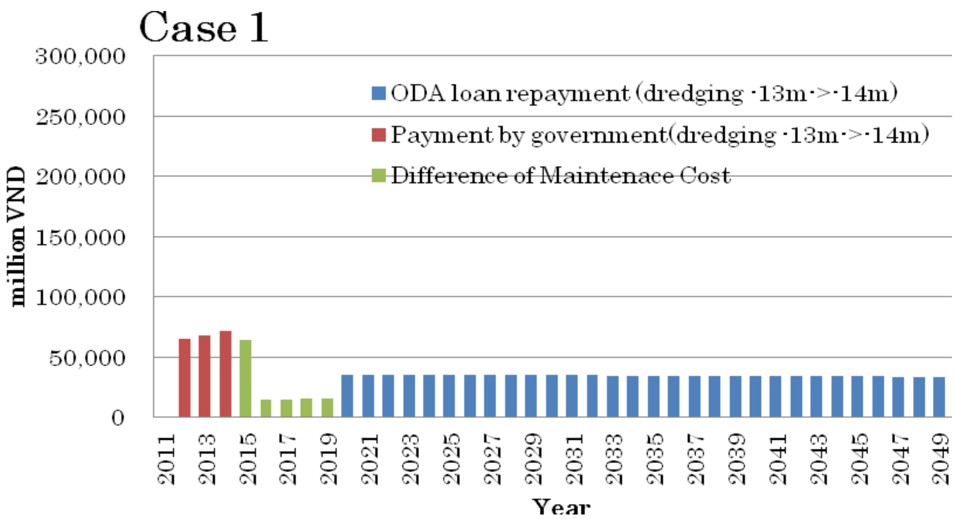


Figure 6.2.5 Additional Payment for Case 1

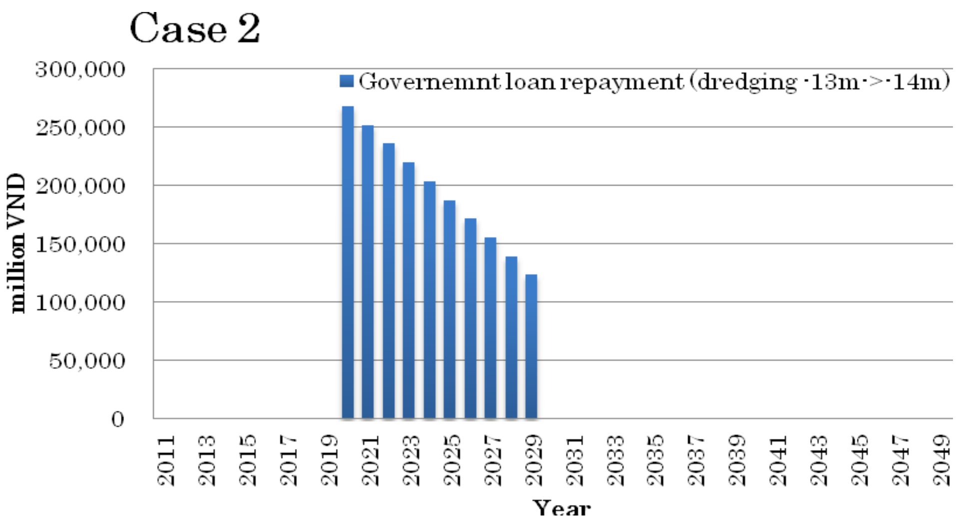


Figure 6.2.6 Additional Payment for Case 2

As known from Figure 6.2.4, it is obvious that Case 1 is less cost than Case 2 in total. From Figure 6.2.5 and Figure 6.2.6, NPV (Net Present Value) can be obtained at USD 309.509 million for Case 1 and USD 427,873 million for Case 2 (In Case 2, an economic loss for ship waiting cost will occur during 2015 to 2020. So if its loss is added to financial cost, NPV of Case 2 becomes USD 614,513 million) which means that Case 1 is financially more viable than Case 2.

The results of the above analysis is dependent upon annual maintenance cost burden of which the extent may vary due to possible channel sedimentation in the dredged channel, but it may indicate to be financially more viable to dredge up to -14m from initial stage by ODA STEP Loan than dredge up to -13m in 2015 by ODA STEP Loan and deepen to -14m in 2020 by GOV fund.

7) Economical Viewpoint

a) Case Study A

In order to determine the appropriate channel depth of initial stage of Lach Huyen port infrastructure construction project, the comparison of total cost of capital dredging, maintenance dredging and ship waiting is conducted for the case that the channel depth is dredged up to -13m CD in 2016 and deepened to -14m CD after 5 years, and the case that the channel depth is dredged to -14m CD in 2016.

The total cost is obtained by the following equation which is considered by the JICA DD Study team:

$$K = K_{cb} + \sum E + \sum C_{ct}$$

Where,

K: Total cost of investment, maintenance, ship waiting (USD)
K_{cb}: Capital Dredging Cost (USD)
E: Maintenance Dredging Cost (USD/year)
C_{ct}: Ship Waiting Cost (USD/year)
Interest Rate: 2%/year for investment cost

The result of above calculation is obtained as presented in Figure 6.2.7 and Table 6.2.12 below;

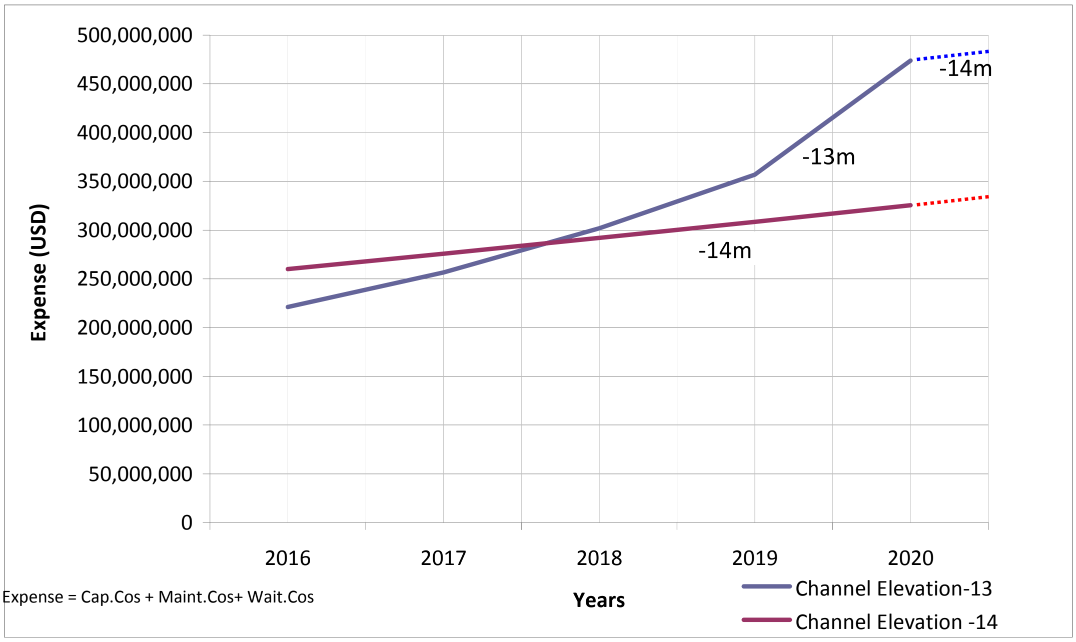


Figure 6.2.7 Total Cost of Channel Depth of -13m & -14m

Table 6.2.12 Total Cost of Channel Depth of -13m & -14m

	Total Cost in $ (Capital cost + mainternance Cost + Ship Waiting Cost)				
	2016	2017	2018	2019	2020
Channel Elevation-13	221,050,459	256,632,035	301,744,747	356,983,001	473,930,373
Channel Elevation -14	259,900,327	275,758,271	291,933,375	308,431,981	325,260,559

The total cost of above Figure 6.2.7 and Table 6.2.12 indicates accumulated costs from 2016 to 2020. From above figure and table, it is clear that the total cost for the case of channel depth of -14m CD from 2016 is about USD150 million lower than that of channel depth of -13m CD during 2016 to 2020 then become -14m CD.

Therefore, the channel depth of -14m CD from initial stage is economical and recommendable. The conditions of above calculation are as follows;

i) Unit price of capital dredging = 9.23 USD/m^3

Unit price of maintenance dredging = 5.64 USD/m^3

ii) Capital & Maintenance dredging volumes

	Capital Dredging Volume (m^3)	**Maintenance Volume (m^3/y)**
Channel Depth -13m	21,659,181	1,800,000
Channel Depth -14m	25,990,032	1,853,000

Note: The maintenance volumes in this table are the values of without sand protection dyke. The values with sand protection dyke are not simulated yet but it is expected to be approx. 50% of above volumes.

iii) Ship waiting cost

The ship waiting costs were calculated as shown in Table 6.2.13. In this calculation, following basic values were applied:

- The unit price of ship waiting is estimated by the JICA DD Study team.
- Share of cargo demand for Pacific trade and Intra Asia trade is applied the same shares estimated by the private operator of Berth No.1 & 2 (Refer to Attachment 1).
- The cargo exchange (loading + unloading) volumes (TEU's /vessel/ call) by ship size are also adopted the same values proposed by the private operator (Refer to Attachment 1).
- Waiting time for the vessels of Lach Huyen port is influenced not only by tidal water level but also by ship navigation to/from Hai Phong port (about 7,000 ship calls in 2009) and by the restriction of one-way traffic of Lach Huyen channel. However, only waiting time due to the change of tidal water level was considered conservatively for the estimation of ship waiting cost in this calculation.

It is believed that the advantage of channel development with the depth of -14m CD from initial stage is understood by the above comparison. However, if economically quantitative comparison is required, all costs should be converted to NPV (Net Present Value) and compared by the NPV of both case.

Followings are calculation results of NPV of both cases:

- Case 1: Channel depth of -13m in 2016 and -14m in 2020 and after.
  NPV of Cost = USD436.9 Million
- Case 2: Channel depth of -14m in 2016 and after.
  NPV of Cost = USD291.8 Million

NPV of cost of Case 2 is smaller than that of Case 1. Therefore, Case 2 is economically more viable than Case 1. (For detailed calculation, see Attachment 2)

Table 6.2.13 Ship Call and Waiting Cost of Lach Huyen Port

		Year	**2016**	**2017**	**2018**	**2019**	**2020**	
1		Container Crago/ Total (1000TEU)	582	979	1394	1828	2284	
	1	Cargo/Pacific (TEU)	251424	422928	602208	789696	986688	Ratio 43.2% applied from Private Invester
		Vessel Size (DWT)			50,000 - 100,000			
		Cargo Exchange Volume/Vessel (TEU)			1,150			1150TEU applied from Private Invester
		Number of Ship Call/year	219	368	524	687	858	
	2	Cargo/ Intra Asia by Foreign Ship (TEU)	297,518	500,465	712,613	934,474	1,167,581	90% of Intra Asia Cargo of 56.8% of Total
		Vessel Size (DWT)			30,000 - 50,000			
		Cargo Exchange Volume/Vessel (TEU)			575			575TEU applied from Private Invester
		Number of Ship Call/year	517	870	1239	1625	2031	
	3	Cargo/ Intra Asia by Vietnam Ship (1000TEU)	33,058	55,607	79,179	103,830	129,731	10% of Intra Asia Cargo of 56.8% of Total
		Vessel Size (DWT)			30,000 or less			
		Cargo Exchange Volume/Vessel (TEU)			200			200TEU applied from Private Invester
		Number of Ship Call/year	165	278	396	519	649	
		Total Number of Ship Call (call/Year)	**901**	**1516**	**2159**	**2831**	**3537**	
2	1	Pacific Trade						
		Vessel Size (DWT)			50,000			
		Ship Waiting Cost (USD/Hr)			4,178			
		Waiting Time/Vessel (hr/Vessel)			7.2			Water Level +1.5m (24hr * 30%)
		Waiting Cost (USD/year)	6,576,727	11,062,914	15,752,504	20,656,799	25,809,699	
	2	Intra Asia Trade by Foreign Ship						
		Vessel Size (DWT)			30,000			
		Ship Waiting Cost (USD/Hr)			3,109			
		Waiting Time/Vessel (hr/Vessel)			3.6			Water Level (24hr * 30%) * 50%
		Waiting Cost (USD/year)	5,791,829	9,742,614	13,872,526	18,191,519	22,729,448	
		Total Of Waiting Cost (USD/year)	**12,368,557**	**20,805,527**	**29,625,031**	**38,848,319**	**48,539,147**	

b) Case Study B

This case study is made by the same study method adopted in Revised FS report prepared by TEDI, i.e., following equation of sea channel design standards issued with Decision No. 115/QD-KT4 of Ministry of Transport is used:

$$K = 0.1K_{cbi} + E_i + \sum (C_{ctn})i \quad \Rightarrow \quad Min$$

Where:

K: Total cost of investment, maintenance, operation and ship waiting corresponding to the i-th channel depth (USD/year)

K_{cbi}: Cost of initial investment for building corresponding to i-th channel depth (USD/year)

E_i: Cost for annual maintenance and operation of channel corresponding to i-th channel depth (USD/year)

(C_{ctn})i: Annual cost for ship waiting for n-th water level corresponding to i-th channel depth (USD/year)

In stead of Revised FS of TEDI, new values of maintenance dredging volume, cargo volume and number of ship calls are applied for this case study. Further more, Revised FS of TEDI calculated for the year of 2015 only and made a conclusion but in this study the total costs of each year of initial stage are calculated and drew out a conclusion.

The result of calculation is obtained as shown in Figure 6.2.8.

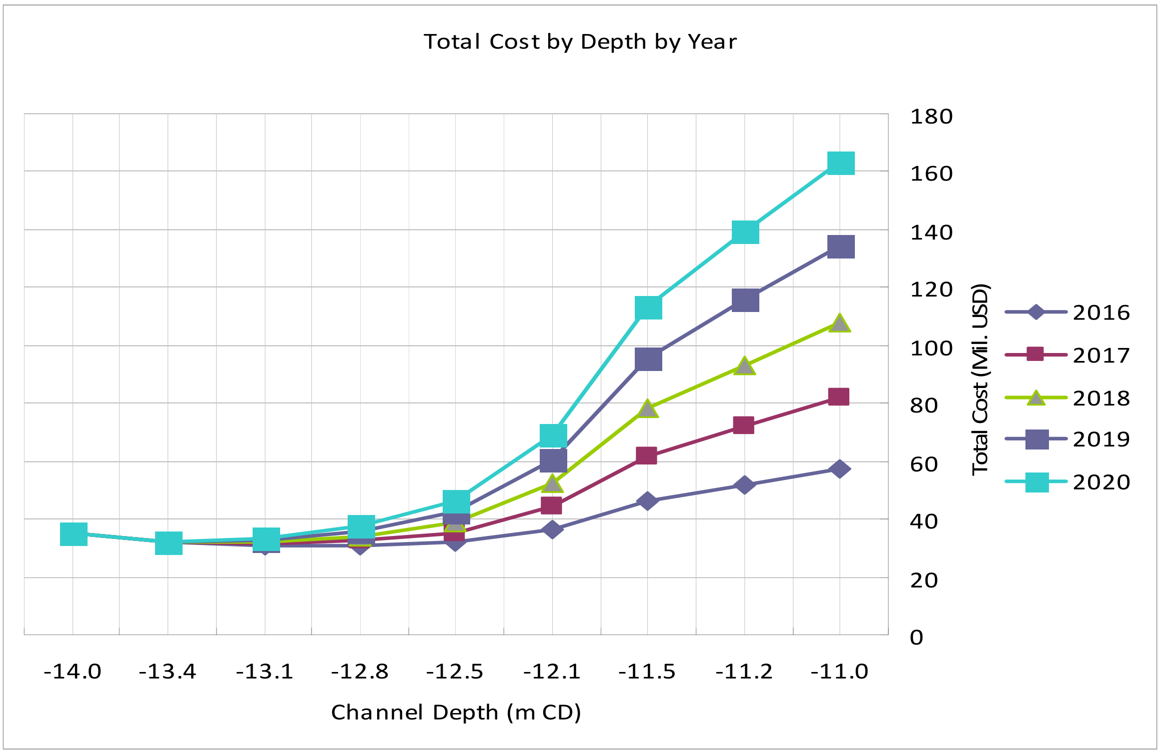


Figure 6.2.8 Total Cost of Channel by Depth by Year

Table 6.2.14 Total Cost of Channel by Depth by Year

Nautical Depth	Total cost (M$)				
	2016	2017	2018	2019	2020
-11.0	57.14	81.84	107.67	134.69	163.07
-11.2	51.58	71.97	93.30	115.59	139.02
-11.5	46.08	61.83	78.30	95.51	113.60
-12.1	36.67	44.25	52.16	60.44	69.14
-12.5	32.11	35.34	38.71	42.25	45.96
-12.8	31.06	32.59	34.19	35.86	37.62
-13.1	30.95	31.43	31.94	32.46	33.02
-13.4	31.80	31.86	31.92	31.99	32.06
-14.0	34.84	34.84	34.84	34.84	34.84

Figure 6.2.8 and Table 6.2.14 show that total costs increase corresponding to the decreasing of channel depth since ship waiting costs increase and total costs increase year by year since number of ship calls increase.

The calculation result showed that the total costs for channel depth of -13.1m CD in 2016 and 2017, and -13.4m CD in 2018 to 2020 are the lowest in each year but differences between the total costs for channel depth of -14m CD and these lowest total costs are very small as known from Figure 6.2.8 and the channel depths of lowest cost are more deeper than -13m CD.

Therefore, JICA DD Study team recommends that the depth of Lach Huyen port should be -14m CD from initial stage.

The conditions of above calculation are as follows;

i) Unit prices of capital and maintenance dredging are the same with the Case Study A.

ii) Capital & Maintenance dredging volumes are basically the same with the Case Study A.

iii) Ship calls in total are the same with the Case Study A, but in this calculation the ship calls by ship size are estimated as shown below by JICA DD Study team:

iv) Ship Waiting Cost

- Costs of ship waiting by ship size were estimated by JICA Study team (Same with Revised FS by TEDI).
- Ship waiting costs were calculated with the sea channel design standards of MOT applied for Revised FS of TEDI.

c) Consideration on Stage-Development of Navigation Channel

The purposes of a stage-development of navigation channel are as follows:

- To save the initial investment cost,
- To eliminate the risk of unknown maintenance dredging cost, and
- To eliminate the risk for the lack of port demand/calling of large vessels.

In case of Lach Huyen channel, above issues are considered as follows:

i) Initial Investment Cost

The initial investment cost can be saved at about USD50million (= 9.23$/m3 x 5.4 Mil.$m^3$) for -13m channel against -14m channel, which is about 20% of initial investment cost and it is an advantage of -13m channel. However, it should be noted that the initial investment cost is financed by low interest ODA fund (0.2%/year). So, if channel is developed -14m at once, ODA fund can cover the full investment cost but in case of stage-development, the investment cost at 2nd stage development should be mobilized from Vietnamese own budget for which high interest fund like a 8%/year will be required. Considering the necessity of fund arrangement for 2nd stage development after 5 years, no advantage is expected for the stage-development.

ii) Maintenance Cost

The estimation of sedimentation volume is technically difficult issue. Therefore, when high sedimentation is anticipated, it is wise to apply stage-development since it is possible to confirm the realistic sedimentation volume prior to proceed to the 2nd stage of channel development. In this Lach Huyen channel case, however, it is already recognized by the sedimentation simulation analysis that the difference of sedimentation volume between -13m deep and -14m deep of channel depth is very small, about 50,000m^3/year only. In this regard, therefore, the stage-development has no advantages for Lach Huyen channel.

iii) Demand of Large Vessel

It is forecasted that the container demand of Lach Huyen port will increase rapidly and will reach 2.3million TEUs by 2020 which will require the development of 5 to 6 sophisticated container berths for 50,000DWT (4,000TEU) to 100,000DWT (8,000 TEU) vessels.

In the container shipping market, the ship size for world trunk routes is increasing year by year and 180,000TEU (200,000DWT) container vessels are in operation already and the existing container vessels of less than 50,000DWT are cascading from trunk routes to the main feeder routes. From geographical view point, there are high possibilities that 100,000DWT container vessels of trans-pacific route (Asia – N.W. USA) will call to Lach Huyen port and 50,000DWT container vessels will be deployed for intra-Asia trade of Lach Huyen port.

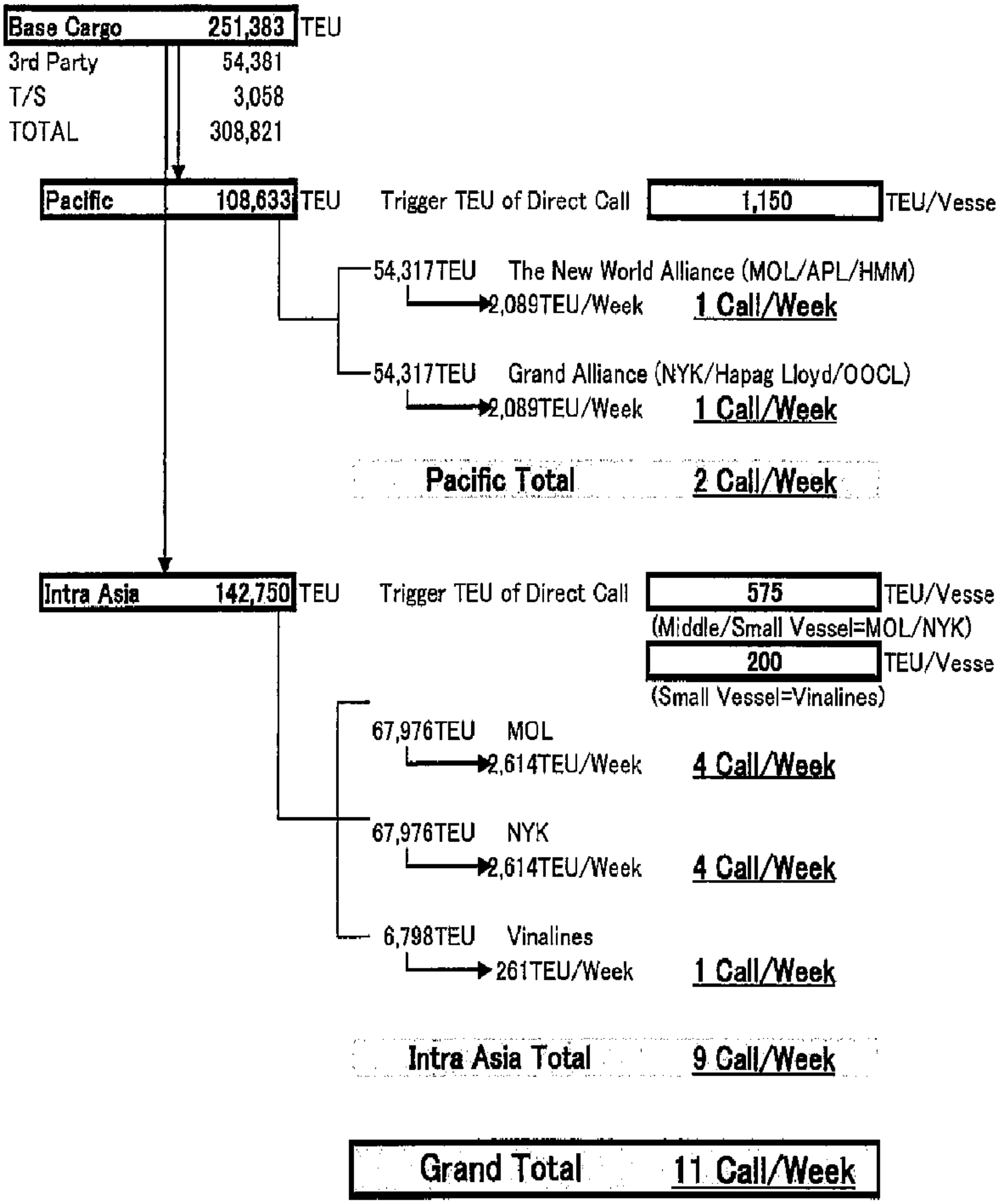
Actuary intended private operators of Lach Huyen container berth No.1&2 are expressed to deploy such a large size container vessel for their Pacific trade and Intra-Asia trade.

If the channel depth of Lach Huyen port is -13m CD, 50,000DWT container vessels (full load) can not enter/leave at any time but should wait the tide level of more than 1.0m. In the container shipping market, such large vessels should be operated with a fixed tight time schedule and avoid waiting time for water level which means that if the port requests waiting for tide, such a port will be avoided to call and will lose competitiveness against ports in the region and lose competitiveness for export/import business that will result decreasing of foreign direct investment into the northern region of Vietnam.

As explained above, from the view point of demand of cargo and large scale vessel, Lach Huyen port has enough potential and no reason to adopt stage-development for channel development.

Attachment 1

Table (6): Analysis of Cargo Volume and Calling Vessels in the Year 2015



Notice: Discussion purpose only.

Source: Private Operator (VINALINES, MOL, NYK, Itochu)

Attachment 2

(1) Evaluation of Case Study A for Comparison Study on Water Depth Alternatives

The two main methods of assessing a proposal's net social benefit are the *net present value* and the *benefit-cost ratio*. Net present value is the appropriate decision criterion to use in regulatory cost-benefit analysis which has been applied to select the best dredging plan of Lach Huyen Channel.

The net present value (NPV) of a project or regulation is the present value of estimated benefits minus costs. In mathematical terms, it is expressed as:

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \quad (1)$$

Where B_t is the benefit in year t, C_t is the cost in year t, and r is the discount rate. In general, the decision rule when using NPV is:

- Accept a policy only if NPV>0; and
- In deciding between alternative policies, select the one with the highest NPV.

The internal rate of return, r, describes the discount rate at which the present value of costs equals the present value of benefits.

It is assumed in this study that the benefits are equal for all alternatives. The best alternative will be the lowest C_t.

Two cases of dredging plan are taken into account as follows:

- Case 1: Channel water depth -13.0m is constructed by ODA loan in 2015 and it will be deepened to -14.0m by Vietnamese own budget in 2020.
- Case 2: Channel water depth -14.0m is constructed at once by ODA loan;

In terms of risk premium of Project, the interest rate r of 0.2% per year is applied in case of ODA loan. If Vietnamese own budget is mobilized, it is assumed that the investment fund of Investor will be 30% of total Project Cost Requirement and the loan of Project will be 70% from Local Commercial Banks and Foreign Trade Banks. Thus, the cost of capital is 2.0 %/year of the saving rate and in case of using the loan fund, the interest rate of the long terms debt is 8%[1]. The provision of 1% is provided for the risk prevention. The risk premium of the project therefore is 7.2%/year.

According to the above formula (1), the alternative, which has the smallest cost including total initial investment cost and the operation cost during Project life[2], will be provided the largest NPV. Therefore, in scope of this study, the comparison of water depth alternatives is only taken into account the total initial investment cost and operation cost during Project life. It shall be calculated by following formula:

$$C_t = C_0 + C\sum_{t=1}^{5} \frac{1}{(1+r)^t} \quad (2)$$

In Which:

C_t: Total initial investment cost and operation cost during Project life of 5 years.
C_0: Initial investment cost
C: Operation cost during Project life of 5 years

[1] Source: Vietcombank
[2] In scope of this study, it is only evaluated during 5 years of Project life

In terms of initial investment cost, the capital dredging volume is estimated for each alternative as follows:

- Water depth -14.0m: 25.99 mil. m^3
- Water depth -13.0m: 21.66 mil. m^3
- Unit price of 9.23 USD/m^3 can be applied for estimating such cost.

In terms of operation cost, the annual maintenance dredging cost and ship call & waiting cost are taken into account as follows:

- Annual maintenance dredging cost: According to siltation analysis, the annual dredging volume is estimated about 1.8 mil m^3 and 1.85 mil m^3 for water depth -13.0m and -14.0m respectively. Unit price of 5.64 USD/m^3 can be applied for estimating such cost.
- The number of ship call/year and the waiting time/vessel are presented in Table 6.2.15 below:

Table 6.2.15 Ship Call and Waiting Cost of Lach Huyen Port

No	Year	2016	2017	2018	2019	2020
1	Cargo/Pacific (TEU)	251,424	422,928	602,208	789,696	986,688
	Vessel Size (DWT)	50,000 – 100,000				
	Cargo Exchange Volume/Vessel (TEU)	1,150				
	Number of Ship Call/year	219	368	524	687	858
2	Cargo/Intra Asia by Foreign Ship (TEU)	297,518	500,465	712,613	934,474	1,167,581
	Vessel Size (DWT)	30,000 – 50,000				
	Cargo Exchange Volume/Vessel (TEU)	575				
	Number of Ship Call/year	517	870	1,239	1,625	2,031
3	Pacific Trade					
	Vessel Size (DWT)	50,000				
	Ship waiting Cost (USD/Hr)	4,178				
	Waiting Time/Vessel (Hr/Vessel)	7.2				
4	Intra Asia Trade by Foreign Ship					
	Vessel Size (DWT)	30,000				
	Ship waiting Cost (USD/Hr)	3,109				
	Waiting Time/Vessel (Hr/Vessel)	3.6				

C_t of each water depth alternative is summarized in Table 2 below:

Table 6.2.16 Total initial Investment Cost and Operation Cost during Project Life

Case Study	Construction Cost (mil.USD)		Operation Cost						Risk premium		Total cost during 5 years of Project (mil. USD) $C_t = C_o + C*\sum 1/(1+r)$^n		
			Annual maintenance dredging cost (mil. USD)	Waiting cost (mil. USD)					ODA loan	VN budget			
	2015	2020		2016	2017	2018	2019	2020	r_1	r_2	C_o	C*∑1/(1+r)^n	C_t
Water depth -13.0m	196.6	49.8	10.2	14.6	20.8	29.6	38.9	48.5	0.20%	7.20%	197	237.0	**433.6**
Water depth -14.0m	246.4	-	10.5	-	-	-	-	-	0.20%		246	51.9	**298.4**

According to Table 6.2.16, it is easily to realize that, Ct of the case 2 is the smaller than that of case 1. Therefore, the case 2 – Channel water depth -14.0m is constructed at once by ODA loan – is proposed as dredging plan of Lach Huyen channel.

6.3 Medium and Long – Term Port Development

6.3.1 Channel Alignment

Accidents can occur when the climate suddenly changes adversely. The channel must have adequate dimensions and alignment to enable easy maneuvering of vessels.

At Haiphong ports, the turning basin has been traditionally located in the course of the navigation channel. This definitely reduces the volume of dredging. However, it is suitable only when vessel traffic is light and when there is a limit in the dredging ability. Presently, 6,700 ships call each year at the Haiphong Area and Dinh Vu Area. The expansion projects of Dinh Vu area and Lach Huyen Area will also lead to more frequent ship calls.

Considering the above, a turning basin that is part of the navigation channel is not recommendable. A ship could face a dangerous situation if it obliged to stop and wait in the narrow channel when it finds a large vessel in its course. Basically, we have to take it into consideration that a ship loses control when its speed becomes very slow. Ship's fate will be ruled by wind and tidal current and it may not be able to avoid going aground.

From the above reason, it is recommended that the navigation channel be relocated to the outside of the turning basin. The layout plan in the future should also be modified so that the ships may pass the outside course of the turning basin. A proposal to enhance navigation safety is indicated in the Figure 6.3.1.

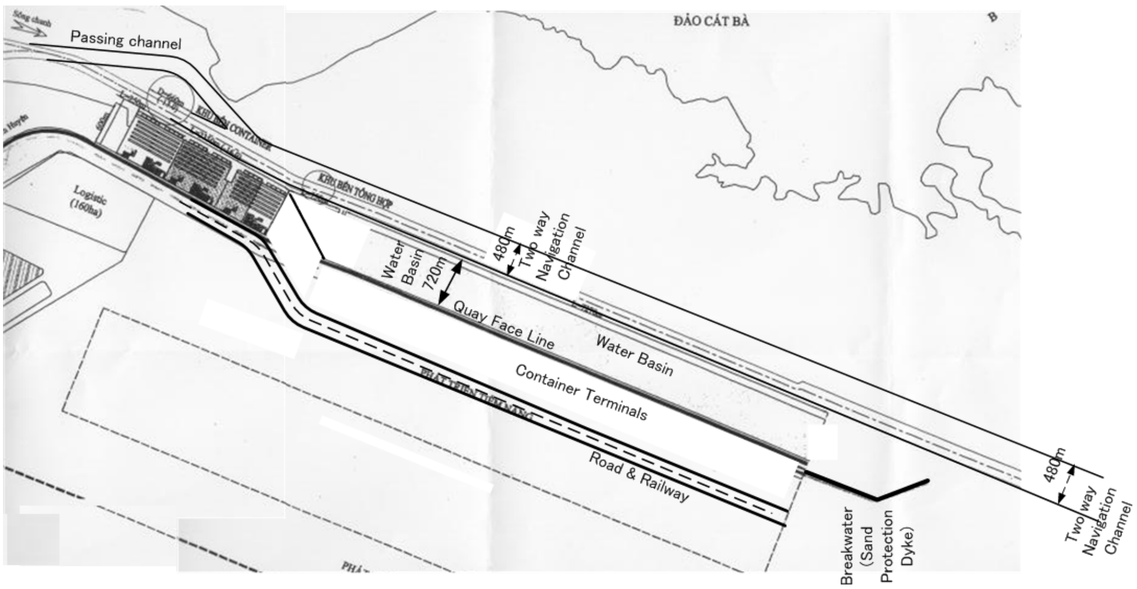


Figure 6.3.1 Concept of the channel alignment and quay face line

6.3.2 Expansion of the Navigation Channel

The planned channel has a width of 160m. This allows a 100,000 dwt container vessel to navigate with navigation aids (buoys) located at both sides and intervals within 1,000m. The buoys should be the "pole with universal joint" type that have small radius of turning around. However, a single lane will cause much trouble in the future.

Northern part of Vietnam has unfavorable climatic conditions for navigation, such as fogs, strong winds, and typhoons. Foggy days, visible less than 1km, occur 0.4 days/month during January to April. Winds are strong from May to November, and those over 10m/sec are observed 2.2% of the year.

Since Lach Huyen Port is the main port in the northern region and has the capital of Vietnam as the hinterland, the cargo demand is large. With the increase of ship calls, two-directional traffic will necessary in future. To allow two- directional navigation for 100,000dwt ships, 480m is needed for the ships to navigate at low speed under adverse climatic conditions. Namely, the navigation speed of the 100,000dwt container vessel is assumed at 4 knots, and the wind speed 10m/sec.

A preliminary stage plan is proposed by the DD team and it is indicated in the Table 6.3.1.

Table 6.3.1 Stage Plan for Lach Huyen Channel

	1st stage (2015)	**2nd stage (2020)**	**3rd stage (2025)**	**4th stage (2030)**
Channel Depth	-14m	-14m	-14m	-16m
Channel Width	160m	320m	480m	480m
Quay Depth	-16m	-16m	-16m	-16m
Capital Dredging Volume (million m^3)	30	40	40	30
Annual Maintenance Dredging Volume (million m^3/ year)	0.6	1.4	2.2	2.8

The channel dues must be imposed properly for the cost for the capital dredging and maintenance dredging to be borne by the users. Table 6.3.2 roughly shows the quantity of dredging for the widening and deepening of the channel. It is proportional to the current dredging volume for the channel that has a width of 160m and depth of -14m.

The volume for the maintenance dredging is assumed as 10% of the quantity of total dredging every five years. Unit Price of Capital Dredging Cost is assumed as US$9.2-/$m^3$, and unit Cost of Maintenance Dredging as US$5.6-/$m^3$.

A consigner has to pay US$ 26.6 per TEU in 2015, US$ 22.6 per TEU in 2020, and US$9.4 per TEU in 2030. The channel dues will be acceptable to the users, since it will not be expensive compared to the normal handling charges.

Table 6.3.2 Channel Due

	2015	**2020**	**2030**
Cumulative Dredging Volume (mill. m^3)	30	70	140
Annual Maintenance Dredging Volume (mill. m^3)	0.6	1.4	2.8
Payment per year (US$ million)	21.3	49.7	99.4
CONTAINER (mill. TEU)	0.80	2.2	10.6
Channel Due/TEU (US$)	26.6	22.6	9.4

6.3.3 Anticipated Problems

1) Supporting Force needed for a Large Crane

When calling ships become large, upsizing of the crane and high-speed of cargo handling are required. However, this means that the self-weight and the payload of a crane increases. For instance, if a crane picks up two boxes at the same time, the payload becomes double. If a crane picks up 4 boxes at a time the payload becomes 4 times.

The crane load was generally regarded as 1,000 tons in the past, however it will be 1,500 tons or 2,000 tons to accommodate larger ships. The quay structure shall have enough bearing capacity to support such heavy loads that are likely to act on it in the future.

2) Counter Measures for Wind

With upsizing of the crane, the wind force which a crane receives increases. Two new container cranes fell down in Cai Lan port in 2006. It is necessary to avoid such incidents. Generally, the crane engine does not have enough power to move against the wind, when wind speed exceeds 10m/sec. Although the crane also has an apparatus to hold rails which is called rail clamp, it has no power to stop the crane against the strong wind. A crane operator is almost helpless in such cases.

Therefore it is recommendable to furnish many anchor holes to stop the crane such as at intervals of 2m. The bolts should be fitted to the crane, and should be inserted in the holes whenever a crane operator feels danger. After that, the crane must be tied using the proper anchorage apparatus.

In addition, it is desirable if the weight of the crane is movable toward a safer position to prevent falling down.

3) Calmness in the port basin

As a port is located at the coastal area, the effect of long period wave becomes an important factor, especially as ship size increases.

To stop the movement of a huge ship generated by the long period waves is very difficult even with strong mooring ropes. The surge can be a fatal problem for cargo handling operation. Problems related to surge have been experienced at piers in J-zone of Long Beach, in Hitachi Naka, in Tomakomai, to name a few.

Since the Lach Huyen port faces the ocean, waves will easily invade into the port basin. When the agitation in the port basin becomes an issue, it is recommendable to examine a V-shaped channel which disperse wave by means of refraction of waves. However, sedimentation may occur as the area becomes calm. Therefore it will be necessary to stop the inflow of muddy water by furnishing a sand protection dyke. On the other hand, dredging volumes will become substantially smaller.

And efficiency of the dredging will rise if a pocket is dredged at the area sedimentation accumulates. If the place of sedimentation is outside of the channel, dredging the channel will become much easier. That is why the method of V-channel is worth testing, if the surge problem is not negligible.

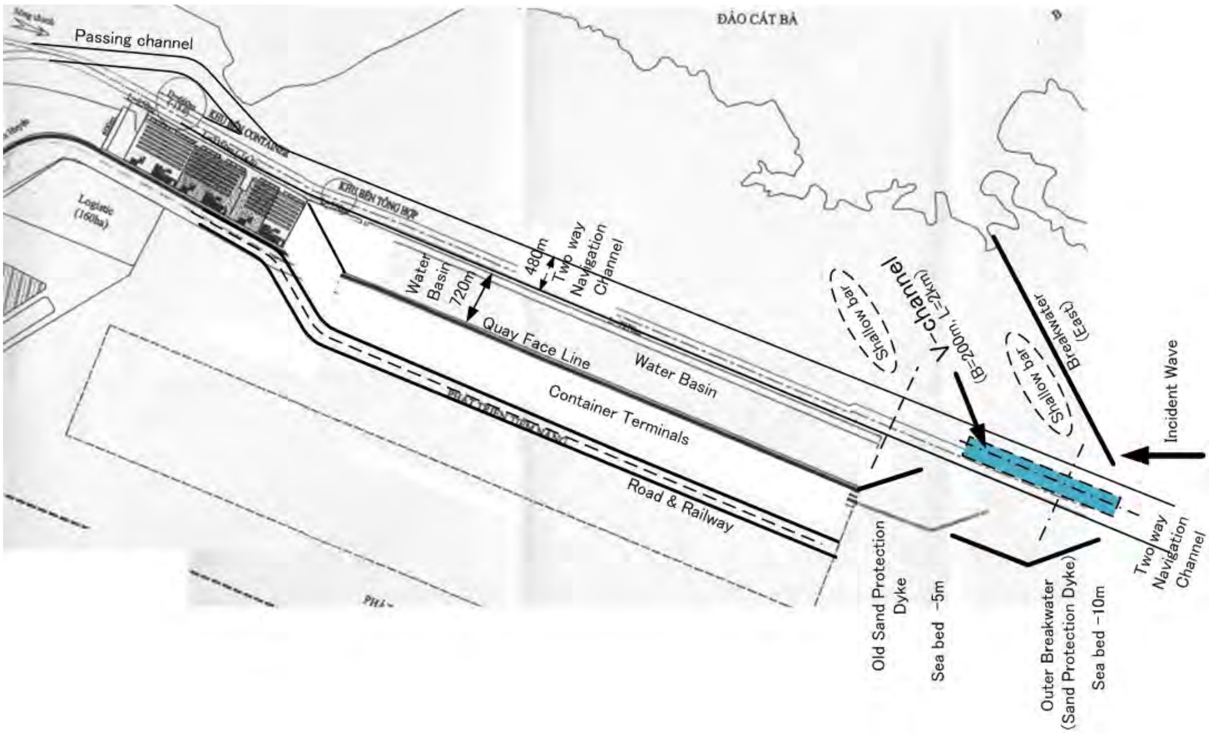


Figure 6.3.2 A Future Plan for Calm Basin (with V-channel)

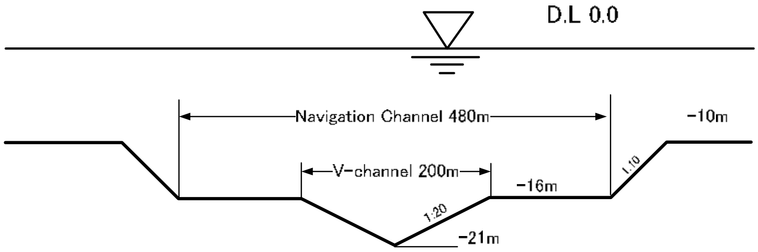


Figure 6.3.3 Cross Section of V-channel

6.4 Calmness of Port

Calmness of port is one of the important factors for smooth port operation. The Lach Huyen port is planned to construct at the south-east end of Cat Hai island. The general port layout is as shown in Figure 6.4.1, and the port is presently planned to be constructed with the outer revetment of 3,230m and the training dike of 7,600 m to protect port facilities from waves and channel sedimentation. In this section, the calmness of port in front of the wharf has been examined by analyzing wave conditions and calculating wave transformation.

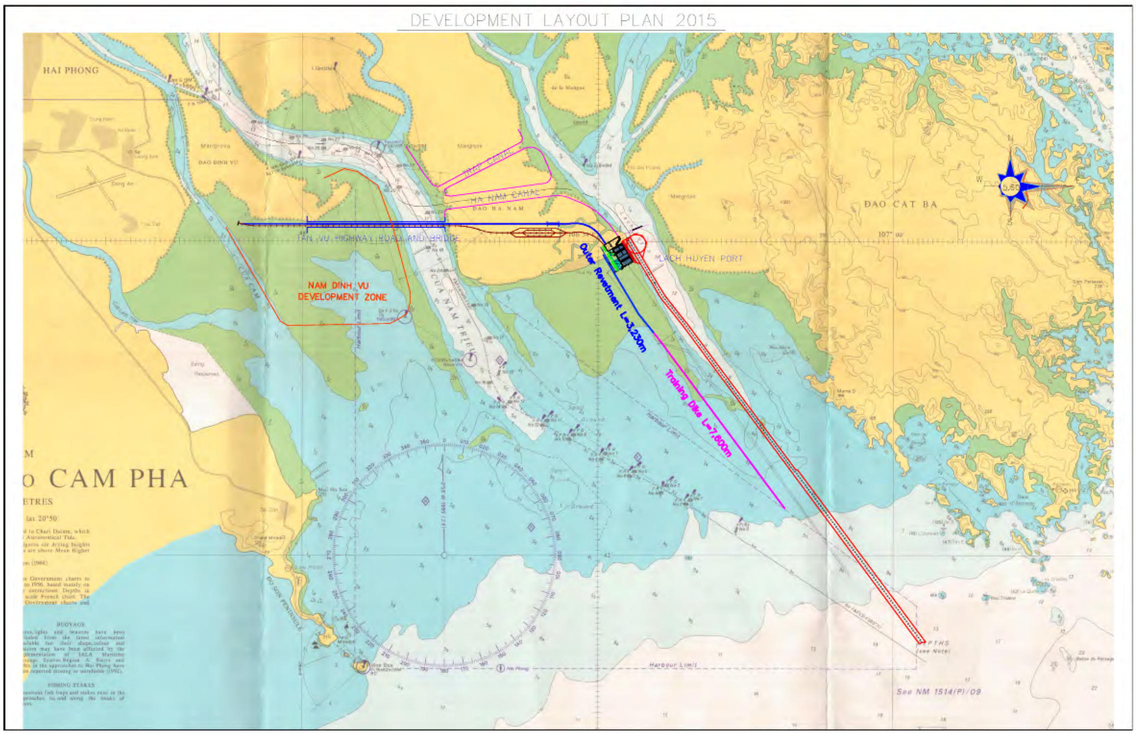


Figure 6.4.1 General Port Layout

6.4.1 Wave Frequency analysis

In order to examine the calmness, a reliable wave frequency table is required based on the relatively long-term wave observation or the result of wave forecasting and hindcasting. For Lach Huyen port area, a set of wave observation data at the offshore of Lach Huyen channel is now available as the reliable observation data. The wave observation had been conducted for about one year from July, 2005 to August, 2006 with an advanced wave meter of AWAC. In addition, the wave forecasting and hindcasting has been conducted in the section 2.5 in Chapter 2. The wave estimation is conducted by using wind field data extracted from the global objective analysis data and the time series of wave height, period, and direction have been calculated for 7 years of 2001 to 2007 by one-point spectral method. The result is verified with the observation data and is confirmed to be available for the wave frequency analysis.

Figure 6.4.2 shows that a comparison between the estimated wave height and the observed wave height at the offshore of Lach Huyen Channel. The curve colored black shows the wave estimation result. As shown in Figure 6.4.2, the estimated result shows good agreement with the observed wave height and it can be used for the wave frequency analysis.

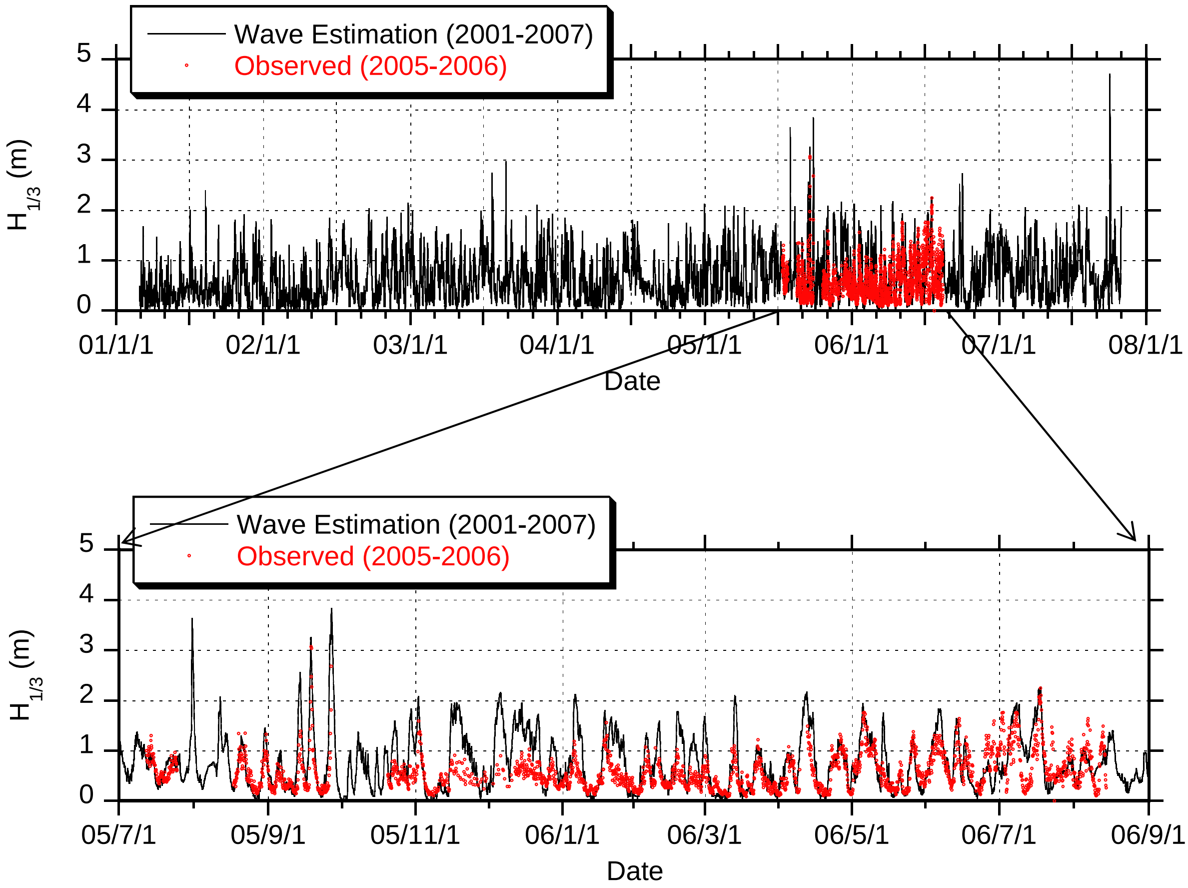


Figure 6.4.2 Comparison between the observed wave height and estimated wave height

1) Wave frequency of wave height by period

Table 6.4.1 and Table 6.4.2 are wave frequency of wave height by period based on the observed data and the estimated data, respectively. Figure 6.4.3 and Figure 6.4.4 show the probability of occurrence in wave period. From the observed data of Table 6.4.1 and Figure 6.4.3, it is found that dominant wave period over 1.0 m in wave height is 5.0~6.0 seconds and the estimated data of Table 6.4.2 and Figure 6.4.4 shows the same tendency.

2) Wave frequency of wave height by direction

Table 6.4.3 and Table 6.4.4 are wave frequency of wave height by period based on the observed data and the estimated data, respectively. Figure 6.4.5 and Figure 6.4.6 show their wave rose. The observed data shows that the dominant wave direction is from ESE – SSE. The estimated wave data shows that the dominant wave direction concentrates in the direction of SSE. The percentage of occurrence in SE – S is 65.5 % for the observed data and 59.8 % for the estimated data. Therefore, it can be considered that the estimated data shows almost the same tendency of the observed data about wave direction.

Table 6.4.1 Frequency between wave height and wave period by the observed wave(2005-2006)

H(m) / T(s)	0.00 ～ 0.25	0.25 ～ 0.50	0.50 ～ 0.75	0.75 ～ 1.00	1.00 ～ 1.50	1.50 ～ 2.00	2.00 ～ 2.50	2.50 ～ 3.00	3.00 ～	Sum	p(%)
0.0～2.0	0	0	0	0	0	0	0	0	0	0	0.00
2.0～3.0	40	36	0	0	0	0	0	0	0	76	2.98
3.0～4.0	212	286	41	1	0	0	0	0	0	540	21.16
4.0～5.0	122	415	324	116	39	0	0	0	0	1016	39.81
5.0～6.0	32	114	222	199	201	21	1	0	0	790	30.96
6.0～7.0	8	9	13	13	38	24	3	0	0	108	4.23
7.0～8.0	2	3	0	0	3	2	2	0	0	12	0.47
8.0～9.0	0	1	0	1	1	1	0	1	2	7	0.27
9.0～10.0	0	1	0	0	0	0	0	0	0	1	0.04
10.0～11.0	1	0	0	0	0	0	0	0	0	1	0.04
11.0～12.0	0	1	0	0	0	0	0	0	0	1	0.04
12.0～13.0	0	0	0	0	0	0	0	0	0	0	0.00
Sum	417	866	600	330	282	48	6	1	2	2552	
p(%)	16.34	33.93	23.51	12.93	11.05	1.88	0.24	0.04	0.08		
Σp(%)	16.34	50.27	73.79	86.72	97.77	99.65	99.88	99.92	100.00		

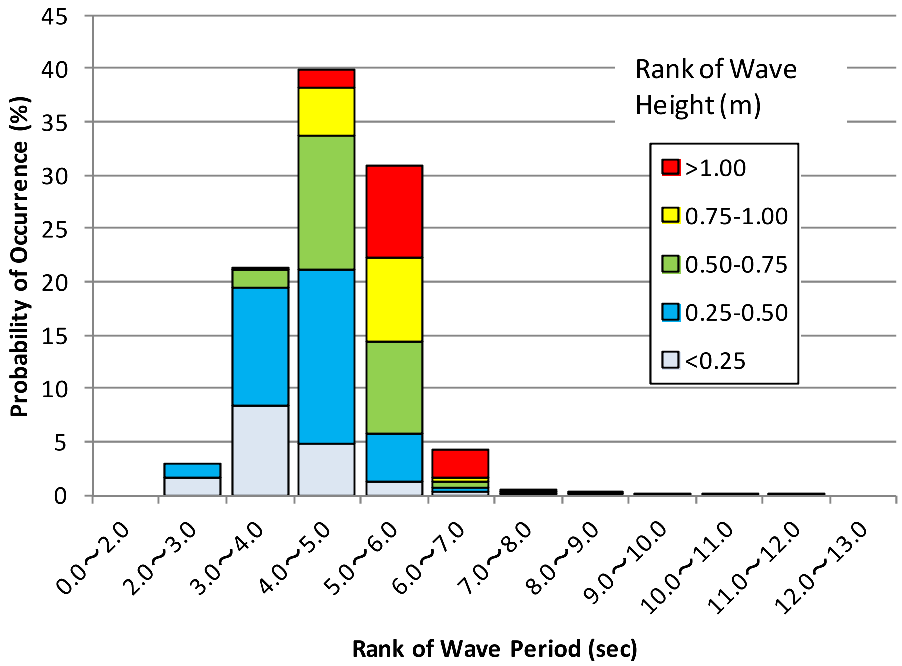


Figure 6.4.3 Probability of occurrence in wave period by the observed wave (2005-2006)

Table 6.4.2 Frequency between wave height and wave period by the estimated wave (2001-2007)

Height(m) / Period(s)	0.00 ～ 0.25	0.25 ～ 0.50	0.50 ～ 0.75	0.75 ～ 1.00	1.00 ～ 1.25	1.25 ～ 1.50	1.50 ～ 1.75	1.75 ～ 2.00	2.00 ～ 2.25	2.25 ～ 2.50	2.50 ～	Sum.	p(%)
0～4	0	0	0	0	0	0	0	0	0	0	0	0	0.00
4～5	5515	5724	4689	3153	1222	130	0	0	0	0	0	20433	34.95
5～6	4486	3740	3059	3144	3636	3364	1760	542	88	3	0	23822	40.75
6～7	2660	1117	719	525	345	284	268	310	179	60	36	6503	11.12
7～8	1083	1581	671	332	129	92	41	30	19	29	96	4103	7.02
8～9	435	941	982	439	92	40	21	4	2	0	18	2974	5.09
9～10	132	50	137	117	55	0	0	0	0	0	0	491	0.84
10～11	42	2	14	0	0	0	0	0	0	0	0	58	0.10
11～12	24	4	0	0	0	0	0	0	0	0	0	28	0.05
12～13	29	7	0	0	0	0	0	0	0	0	0	36	0.06
13～14	7	2	0	0	0	0	0	0	0	0	0	9	0.02
14～	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Sum.	14413	13168	10271	7710	5479	3910	2090	886	288	92	150	58457	
p(%)	24.66	22.53	17.57	13.19	9.37	6.69	3.58	1.52	0.49	0.16	0.26		
Σp(%)	24.66	47.18	64.75	77.94	87.31	94.00	97.58	99.09	99.59	99.74	100.00		

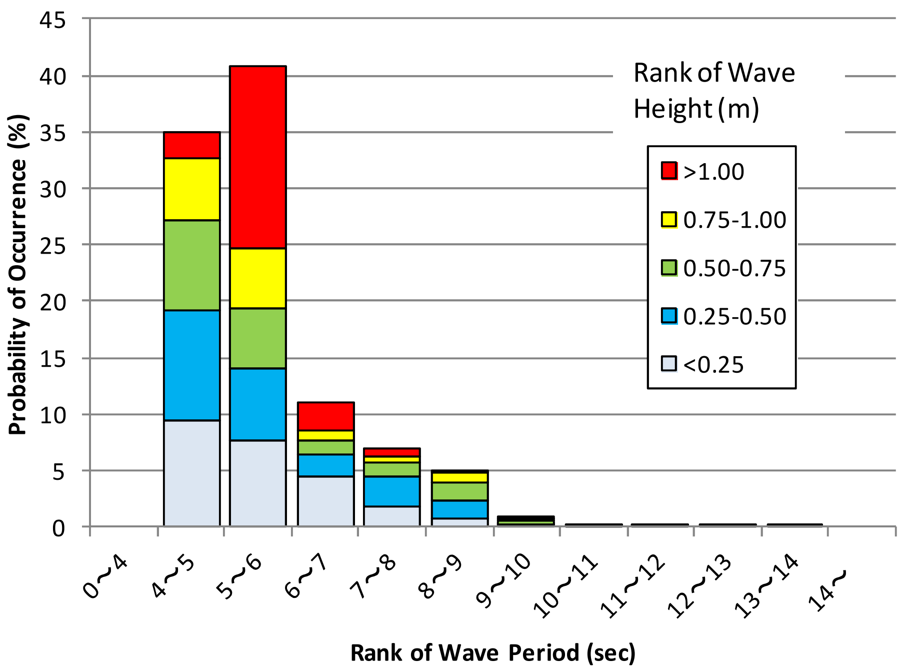


Figure 6.4.4 Probability of occurrence in wave period by the estimated wave (2001-2007)

Table 6.4.3 Frequency between wave height and direction by the observed wave (2005-2006)

H(m) / Dir.	0.00 ～ 0.25	0.25 ～ 0.50	0.50 ～ 0.75	0.75 ～ 1.00	1.00 ～ 1.50	1.50 ～ 2.00	2.00 ～ 2.50	2.50 ～ 3.00	3.00 ～	Sum	p(%)
N	19	20	3	0	0	0	0	0	0	42	1.73
NNE	0	9	1	1	0	0	0	0	0	11	0.45
NE	1	8	0	0	0	0	0	0	0	9	0.37
ENE	15	18	9	1	4	0	0	0	0	47	1.94
E	11	58	88	29	6	1	1	0	0	194	8.01
ESE	40	146	152	72	37	1	0	1	1	450	18.59
SE	88	278	179	116	116	12	0	0	1	790	32.63
SSE	66	220	125	82	96	26	2	0	0	617	25.49
S	49	59	33	17	13	5	3	0	0	179	7.39
SSW	12	11	2	3	5	1	0	0	0	34	1.40
SW	4	4	1	8	6	1	0	0	0	24	0.99
WSW	2	2	3	1	0	1	0	0	0	9	0.37
W	0	0	1	0	0	0	0	0	0	1	0.04
WNW	1	1	0	0	0	0	0	0	0	2	0.08
NW	6	2	1	0	0	0	0	0	0	9	0.37
NNW	0	3	0	0	0	0	0	0	0	3	0.12
Sum	314	839	598	330	283	48	6	1	2	2421	
p(%)	12.97	34.66	24.70	13.63	11.69	1.98	0.25	0.04	0.08		
Σp(%)	12.97	47.62	72.33	85.96	97.65	99.63	99.88	99.92	100.00		

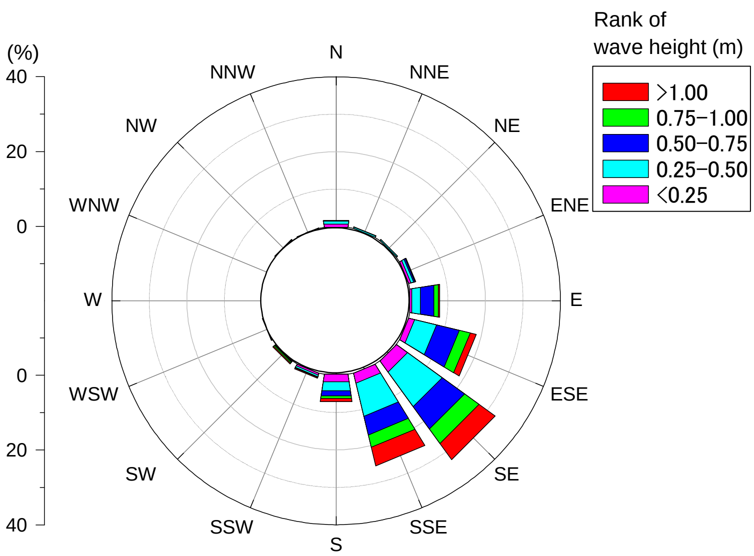


Figure 6.4.5 Wave Rose by the observed wave (2005-2006)

Table 6.4.4 Frequency between wave height and direction by the estimated wave (2001-2007)

Height(m) / Direc.	0.00 ~ 0.25	0.25 ~ 0.50	0.50 ~ 0.75	0.75 ~ 1.00	1.00 ~ 1.25	1.25 ~ 1.50	1.50 ~ 1.75	1.75 ~ 2.00	2.00 ~ 2.25	2.25 ~ 2.50	2.50 ~	Sum.	p(%)
N	0	0	0	0	0	0	0	0	0	0	0	0	0.00
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0.00
NE	16	116	545	1027	1338	755	420	261	28	8	3	4517	7.73
ENE	101	271	479	751	905	1027	609	185	80	3	13	4424	7.57
E	404	551	974	859	491	345	199	38	17	17	8	3903	6.68
ESE	3354	3330	2357	991	306	203	60	18	14	11	22	10666	18.25
SE	204	43	21	13	3	0	0	0	0	0	0	284	0.49
SSE	10274	8846	5835	4019	2406	1577	801	372	149	53	104	34436	58.91
S	60	11	60	45	26	1	0	10	0	0	0	213	0.36
SSW	0	0	0	5	4	2	1	2	0	0	0	14	0.02
SW	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSW	0	0	0	0	0	0	0	0	0	0	0	0	0.00
W	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0.00
NW	0	0	0	0	0	0	0	0	0	0	0	0	0.00
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Sum.	14413	13168	10271	7710	5479	3910	2090	886	288	92	150	58457	
p(%)	24.66	22.53	17.57	13.19	9.37	6.69	3.58	1.52	0.49	0.16	0.26		
Σp(%)	24.66	47.18	64.75	77.94	87.31	94.00	97.58	99.09	99.59	99.74	100.00		

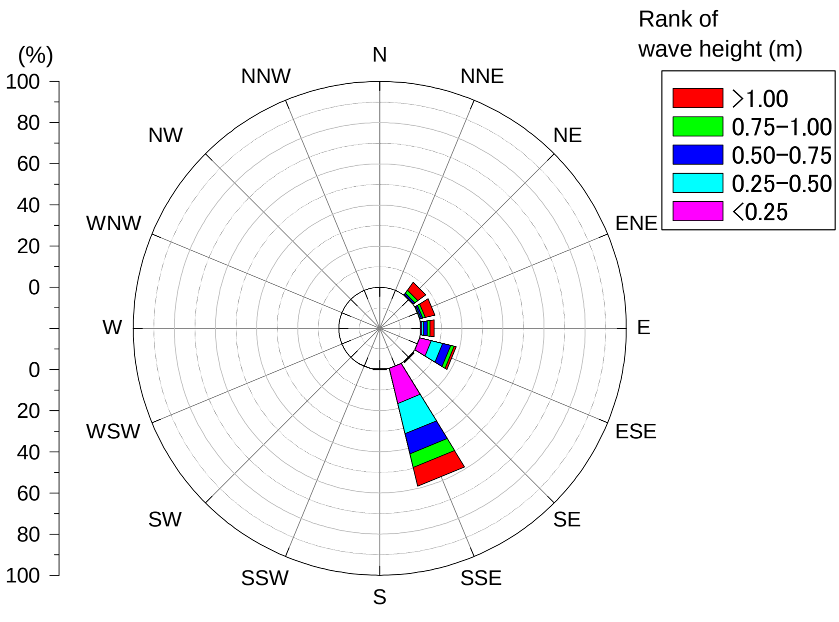


Figure 6.4.6 Wave Rose by the estimated wave (2001-2007)

6.4.2 Method of Calmness analysis

The calmness of port in front of the wharf has been examined by using the wave frequency tables obtained by the wave estimation data and the calculated wave height in front of the wharf by wave transformation calculation.

1) Layout of the Port

The general port layout of Lach Huyen port consists of port facilities of land fill area, outer revetment, and training dike as shown in Figure 6.4.7. The wharf is located at the east side of the port. The calmness analysis of the wharf is conducted for the following four layouts as shown in Figure 6.4.8.

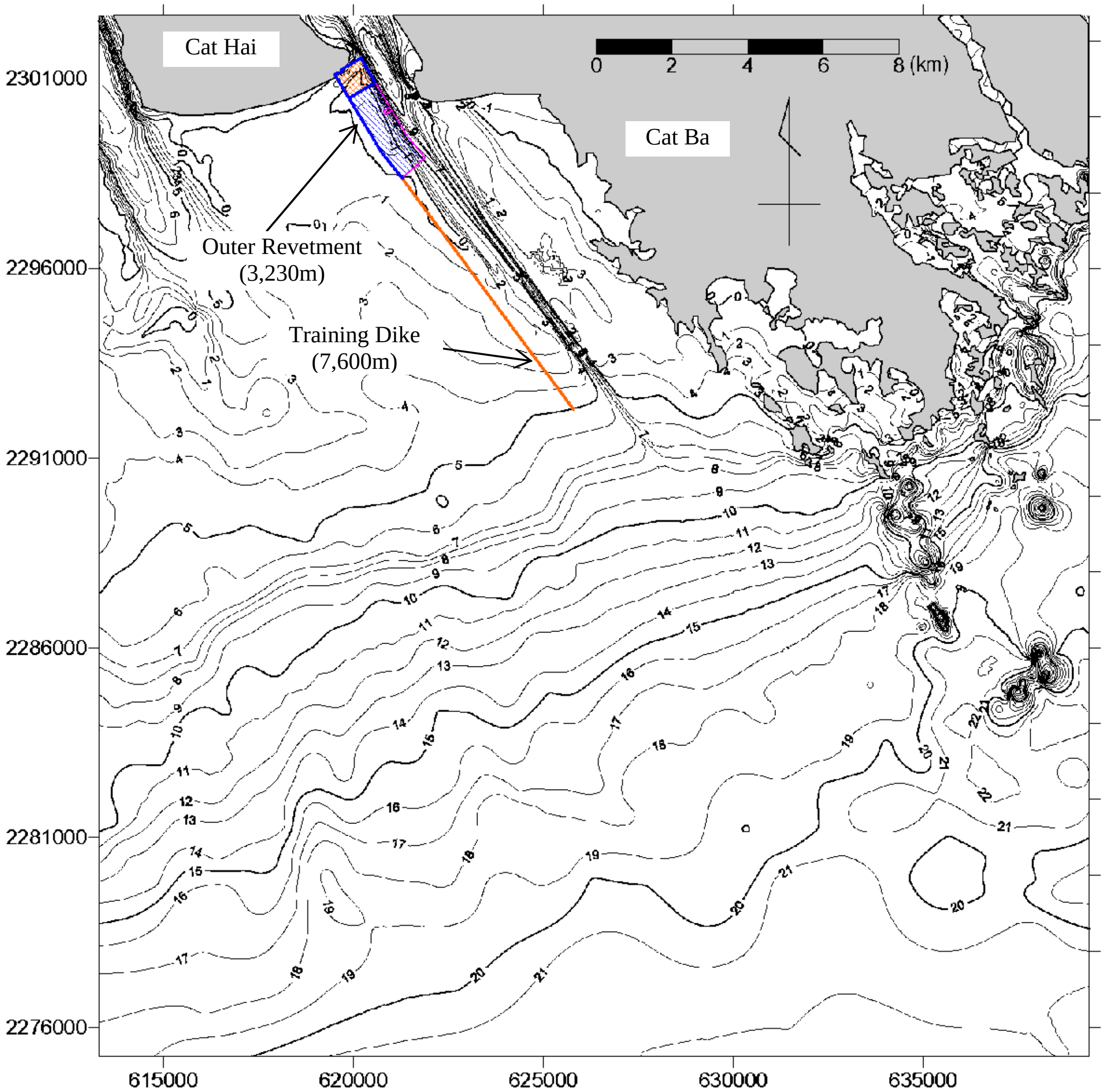
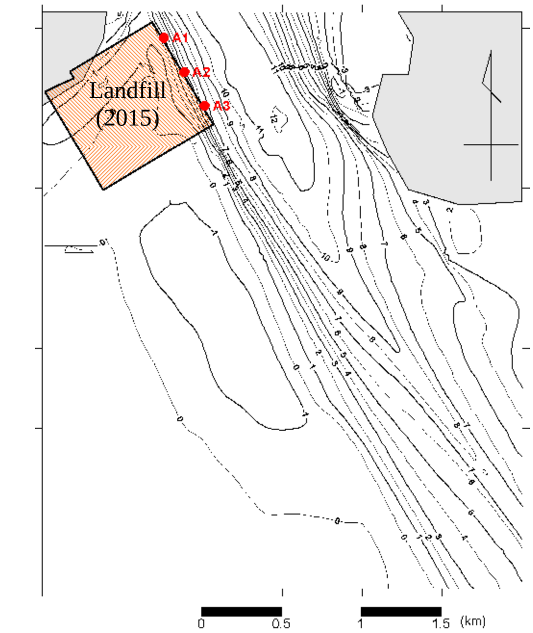
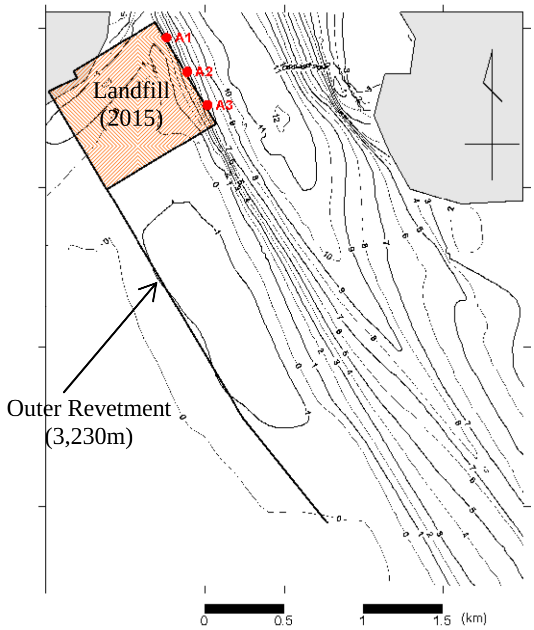


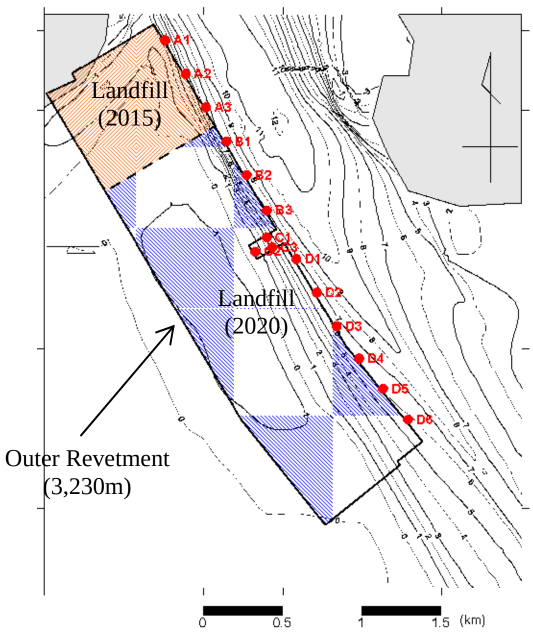
Figure 6.4.7 Calculation area of wave transformation



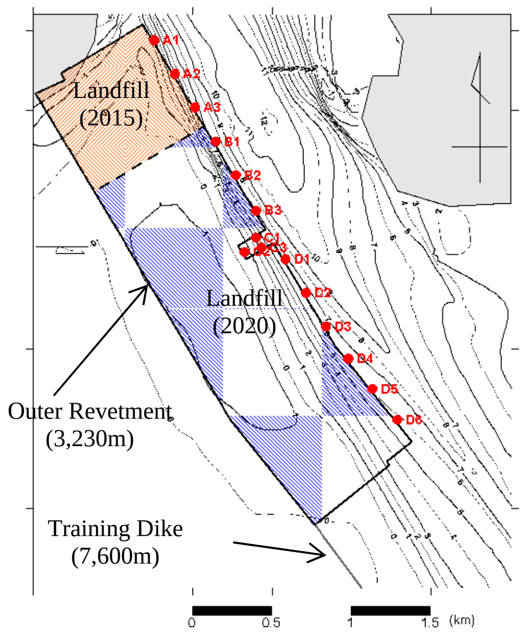
a) Landfill(2015) without Outer Revetment



b) Landfill(2015) with Outer Revetment



c) Landfill(2020) without Training Dike



d) Landfill(2020) without Training Dike

Figure 6.4.8 Layouts of Port for Calmness Analysis and the estimation points

2) Criterion of Calmness

Calmness of the port of Lach Huyen against wind waves has been examined by using the criterion shown in Table 6.4.5. The calmness has been examined for normal wave condition and abnormal wave condition. For the normal wave condition, the criterion is set as 0.5 m of the critical wave height in front of wharf taking the vessel size of 50,000 DWT into account, and the rate of effective working days is calculated to examine if the rate exceeds 97.5 % or not. For the abnormal wave condition, the critical wave height in front of the wharf of 1.5 m is applied.

Table 6.4.5 Criterion of the calmness analysis

Location	Normal Condition		Abnormal Condition
	Wave Height ($H_{1/3}$)	Rate of effective working days	Wave Height ($H_{1/3}$)
Lach Huyen Port	<0.5m	>97.5 %	<1.5m

3) Incident wave

Wave height in front of the wharf is evaluated by wave transformation calculation. The incident offshore wave for the normal wave condition and the abnormal wave condition are set as shown in Table 6.4.6. For the normal wave condition, the two wave period are selected as representative period. The period of 6.0 seconds is selected as the dominant wave period for normal wave and that of 8.0s is selected as the representative of higher waves.

For the abnormal condition, the two incident waves are set as the waves equivalent to the wave with a return period of 50 years for ESE and SSE in the wave direction.

The tide level for all wave transformation calculation below is set as M.W.L.

Table 6.4.6 Incident wave condition

Condition	Incident Wave Height (m)	Wave Period (sec)	Wave Direction	Remark
Normal	1.0	6.0	E, ESE, SE, SSE, S, SSW	
	1.0	8.0	E, ESE, SE, SSE, S, SSW	
Abnormal	7.31	13.3	ESE	Wave with a return Period of 50 years
	5.74	13.3	SSE	

4) Wave transform calculation

For numerical analysis of wave transformation, the wave energy balance equation with addition of the wave diffraction term and the energy dissipation term by breaking is employed. The basic equation of the model is written as,

$$\frac{\partial}{\partial x}(SV_x)+\frac{\partial}{\partial y}(SV_y)+\frac{\partial}{\partial \theta}(SV_\theta)=\frac{\kappa}{2\sigma}\left\{(cc_g\cos^2\theta S_y)_y-\frac{1}{2}cc_g\cos^2\theta S_{yy}\right\}-\varepsilon_b S \qquad \textbf{(6.4.1)}$$

where, $S(f,\theta)$ is the directional wave spectral density, (x,y) are the horizontal coordinates, θ the wave direction measured counterclockwise from the x axis, ε_b the coefficient of energy dissipation, and the characteristic velocities, (V_x,V_y,V_θ), are defined as follows:

$$V_x=c_g\cos\theta \qquad \textbf{(6.4.2)}$$

$$V_y = c_g \sin\theta \tag{6.4.3}$$

$$V_\theta = \frac{c_g}{c}\left(\frac{\partial c}{\partial x}\sin\theta - \frac{\partial c}{\partial y}\cos\theta\right) \tag{6.4.4}$$

where c is the wave celerity and c_g the group velocity. The first term in the right side of Eq. (6.4.1) is the additional term for representing wave diffraction, where σ is the wave angular frequency and κ is the coefficient to optimize the degree of diffraction, the typical value of which is 2.5.

The Lach Huyen port is located on a shoal spreading in the south of Cat Hai island, and the topography around the port is relatively complex as shown in Figure 6.4.8. Therefore, wave transformation is calculated taking effects of wave breaking into account, the Goda's breaking index of

$$\frac{H_b}{L_0} = A_b\left\{1 - \exp\left[-1.5\frac{\pi h_b}{L_0}\left(1 + 15\tan^{4/3}\beta\right)\right]\right\} \tag{6.4.5}$$

where L_0, h_b, and $\tan\beta$ are the offshore wave length, the depth of wave breaking, and the bottom slope, respectively. Also, A_b is the coefficient and in the following calculations, A_b = 0.18 is applied.

The wave reflection from the wharf, the outer revetment, and the training dike is also taking into account, the reflection coefficients of which are 0.9 for the wharf and 0.4 for the outer revetment and the training dike.

6.4.3 Result of Calmness analysis

1) Relative wave height (H/H_0) in front of the wharf (Normal wave condition)

Wave transformation calculations for the normal wave condition have been carried out for total 48 cases (= 4 layouts x 2 waves of the wave period of 6.0 sec. and 8.0 sec. x 6 wave directions) to obtain the relative wave height in front of the wharf, the offshore wave height of which is 1.0m. Figure 6.4.9 and Figure 6.4.10 show the distribution of the relative wave height as examples of wave transformation calculations. As shown in the figures, it is found that the wave height in front of the wharf is smaller than 0.2 m in almost all cases and the area is well sheltered from waves.

2) Wave height (H) in front of the wharf (Abnormal wave condition)

Wave transformation calculations for the abnormal wave condition have been carried out for the four types of the port layout. The distribution of wave height around the port area is shown in Figure 6.4.11 and Figure 6.4.12. As shown in the figures, it is found that the wave height in front of the wharf is smaller than 0.5 m in almost all cases even under the abnormal wave condition.

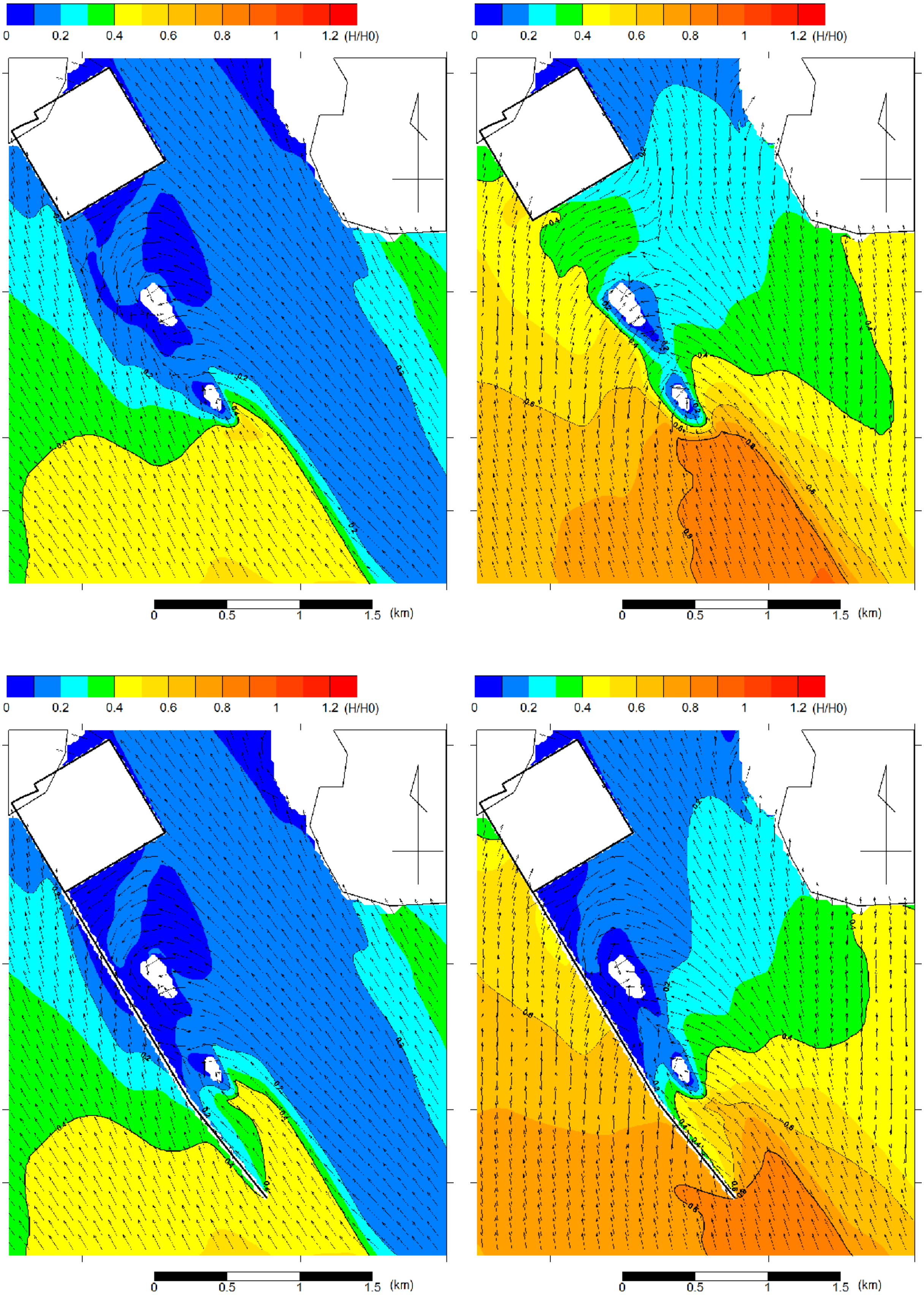


Figure 6.4.9 Wave ratio (H/H_0) around port area for the layout type-a(top) and type-b(bottom) (H_0=1.0m, T=6.0s, Dir.=ESE(left), SSE(right))

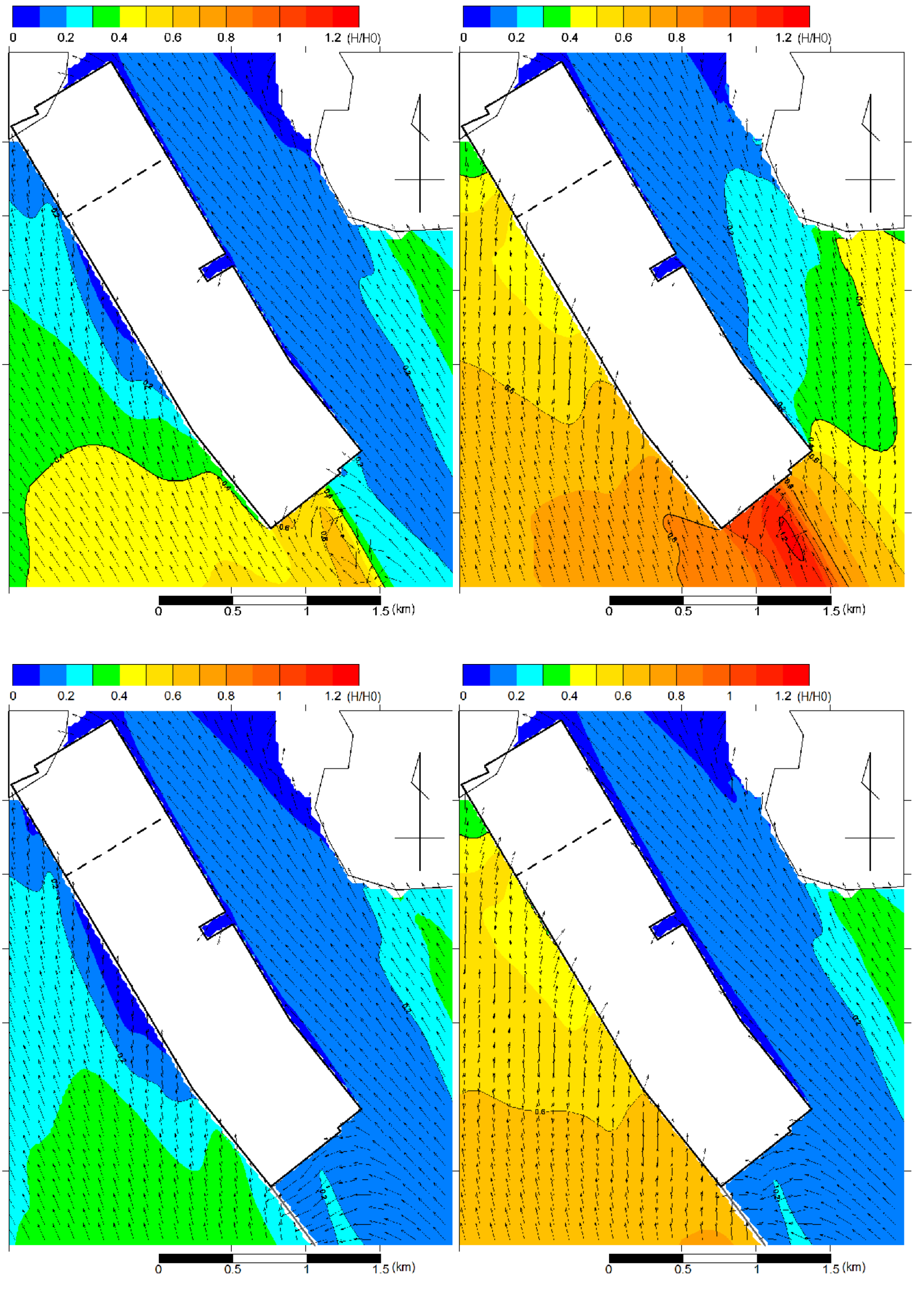


Figure 6.4.10 Wave ratio (H/H_0) around port area for the layout type-c(top) and type-d(bottom) (H_0=1.0m, T=6.0s, Dir.=ESE(left), SSE(right))

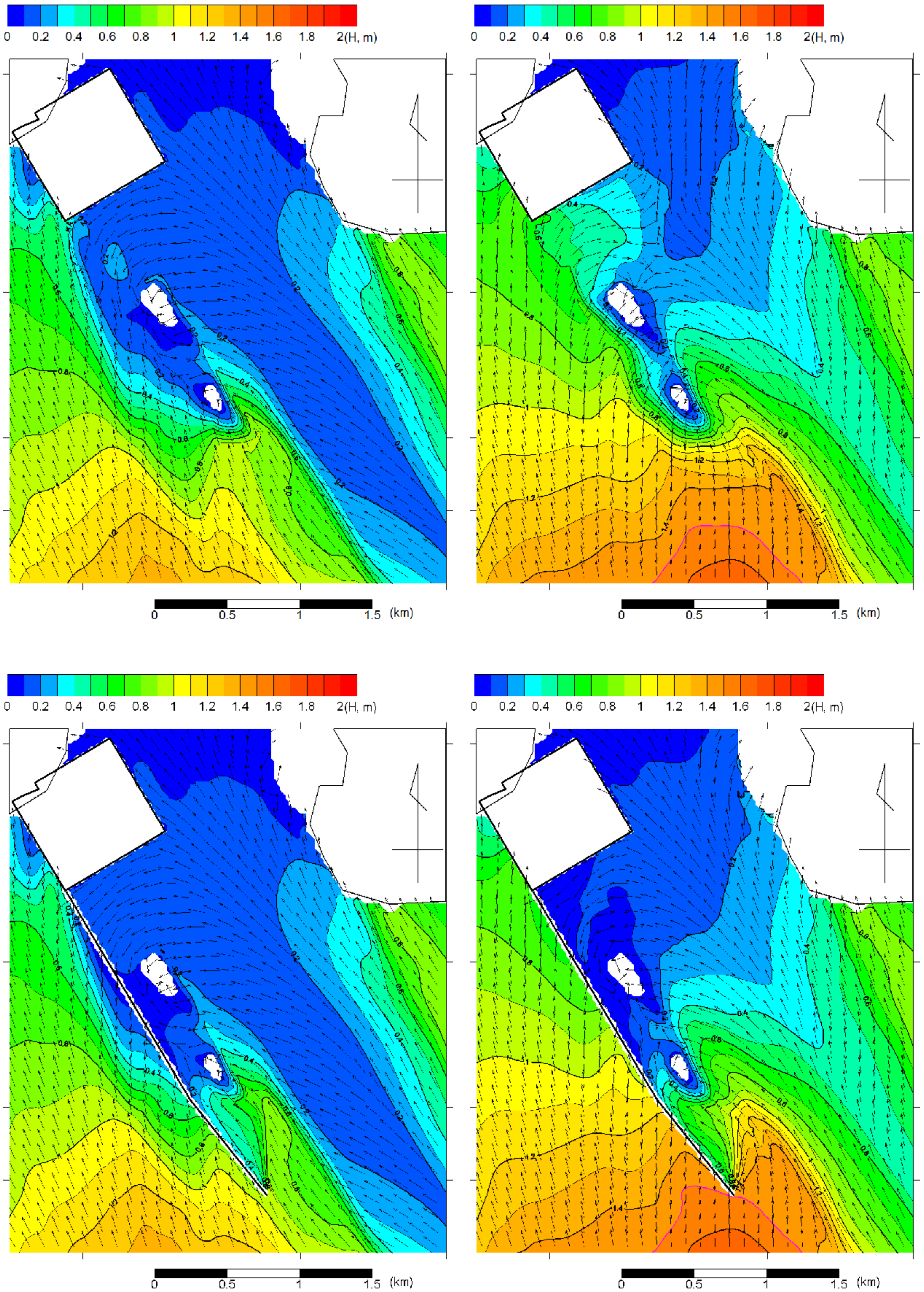


Figure 6.4.11 Wave Height around port area for the layout type-a(top) and type-b(bottom) (Abnormal condition, H_0=7.3m, T=13.3s, Dir.=ESE(left), H_0=5.7m, T=13.3s, Dir.=SSE(right))

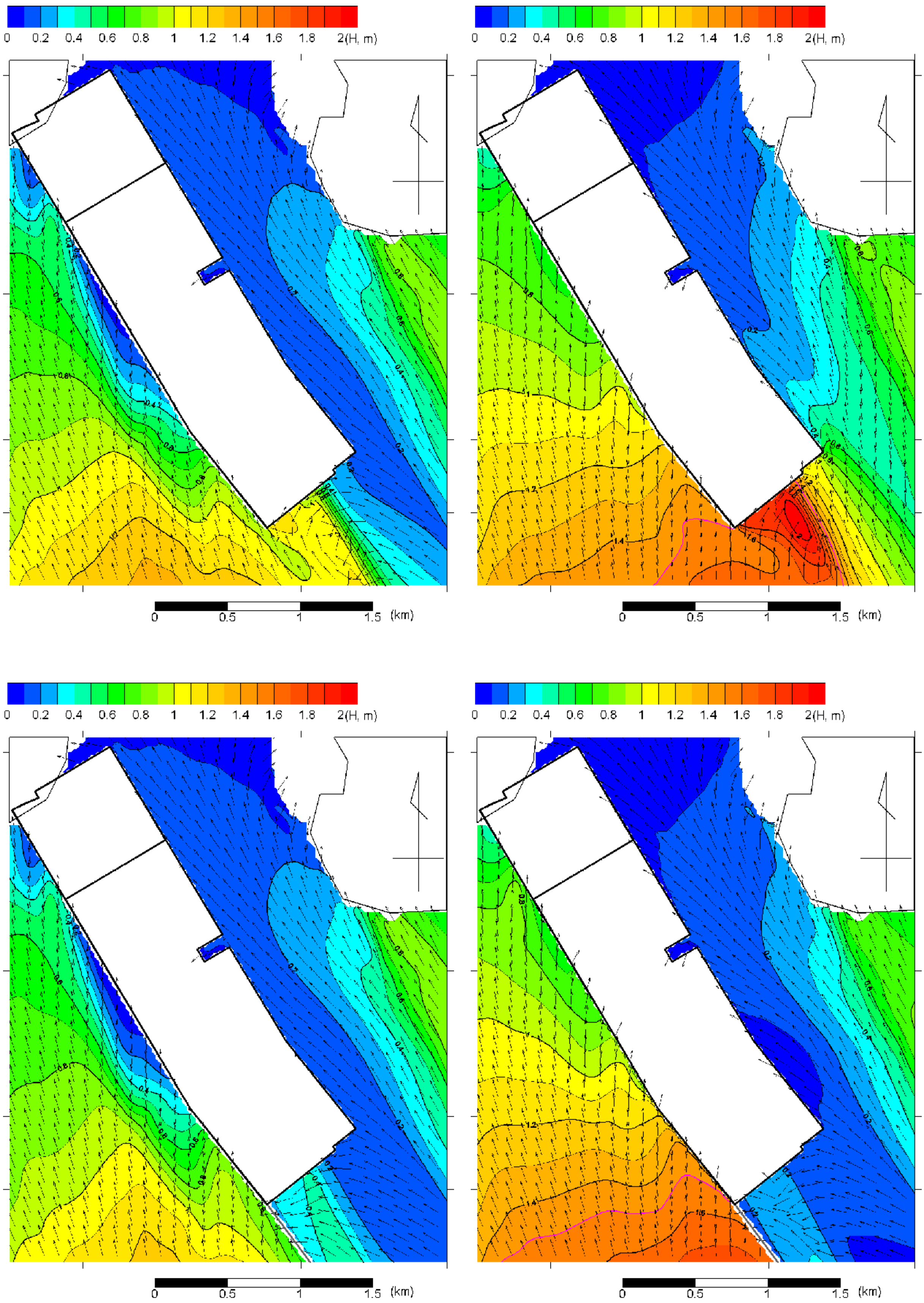


Figure 6.4.12 Wave Height around port area for the layout type-c(top) and type-d(bottom) (Abnormal condition, H_0=7.3m, T=13.3s, Dir.=ESE(left), H_0=5.7m, T=13.3s, Dir.=SSE(right))

3) Rate of effective working days under normal wave condition

The rate of effective working days is calculated to estimate the calmness. The rate of effective working days is calculated by using the wave frequency tables shown in Table 6.4.2 and Table 6.4.4 and the calculated wave height ratios for the period of 6.0 s and 8.0 s in front of the calculation points.

The wave height ratio between offshore incident wave height and wave height in front of the wharf calculated by the wave transformation model are summarized in Table 6.4.7 through Table 6.4.10 for the estimation points of A1 – D6 as shown in Figure 6.4.8. From the tables, it is found that the wave height in front of the wharf increases as the point moves in the offshore direction. Also, at a same point, the wave height decreases as the protection works of the outer revetment and the training dike extends.

The calculated results of the rate of effective working days for the four layouts are summarized from Table 6.4.11 to Table 6.4.14. All values of the rate of effective working days are less than 97.5 % and the result indicates that the calmness of the wharf of Lach Huyen port is sufficient for all layouts examined in this study.

4) Calmness under abnormal wave condition

To estimate the calmness under abnormal condition, the wave height in front of the wharf is calculated and examined if the wave height exceeds the critical wave height of 1.5 m. Table 6.4.15 and Figure 6.4.17 show the calculation results of wave height in front of the wharf under abnormal wave condition. The values of the wave height at the points of A1 – D6 are low enough comparing to the critical wave height of 1.5 m. The result indicates that the calmness of the wharf of Lach Huyen port is sufficient under abnormal condition.

Table 6.4.7 Ratio of Wave height in front of the wharf (type-a)

type-a	T=6.0s						T=8.0s					
Point	E	ESE	SE	SSE	S	SSW	E	ESE	SE	SSE	S	SSW
A1	0.063	0.084	0.088	0.090	0.084	0.074	0.041	0.051	0.057	0.059	0.057	0.053
A2	0.065	0.088	0.095	0.097	0.091	0.080	0.043	0.054	0.064	0.065	0.063	0.059
A3	0.071	0.095	0.115	0.119	0.113	0.101	0.045	0.057	0.078	0.081	0.078	0.074
B1	0.088	0.119	0.221	0.245	0.253	0.249	0.051	0.065	0.169	0.185	0.192	0.192
B2	0.088	0.119	0.217	0.245	0.257	0.254	0.052	0.066	0.167	0.185	0.193	0.195
B3	0.090	0.122	0.201	0.227	0.235	0.228	0.053	0.068	0.146	0.162	0.169	0.168
C1	0.081	0.109	0.186	0.211	0.221	0.214	0.048	0.061	0.140	0.158	0.166	0.165
C2	0.071	0.095	0.187	0.217	0.232	0.228	0.047	0.059	0.154	0.177	0.189	0.188
C3	0.082	0.111	0.190	0.216	0.227	0.220	0.049	0.062	0.144	0.165	0.174	0.172
D1	0.095	0.128	0.219	0.253	0.267	0.259	0.056	0.072	0.164	0.189	0.199	0.197
D2	0.098	0.133	0.250	0.299	0.322	0.317	0.057	0.074	0.200	0.237	0.253	0.251
D3	0.100	0.137	0.284	0.349	0.385	0.385	0.058	0.075	0.240	0.289	0.312	0.311
D4	0.103	0.141	0.317	0.399	0.446	0.450	0.060	0.078	0.280	0.342	0.371	0.371
D5	0.106	0.147	0.350	0.446	0.500	0.504	0.064	0.083	0.318	0.391	0.425	0.424
D6	0.109	0.152	0.373	0.482	0.544	0.547	0.068	0.090	0.345	0.430	0.469	0.466

*Remark) The wharf does not exist in front of the points B1 to D6 in the layout type-a, but the values are calculated for reference.

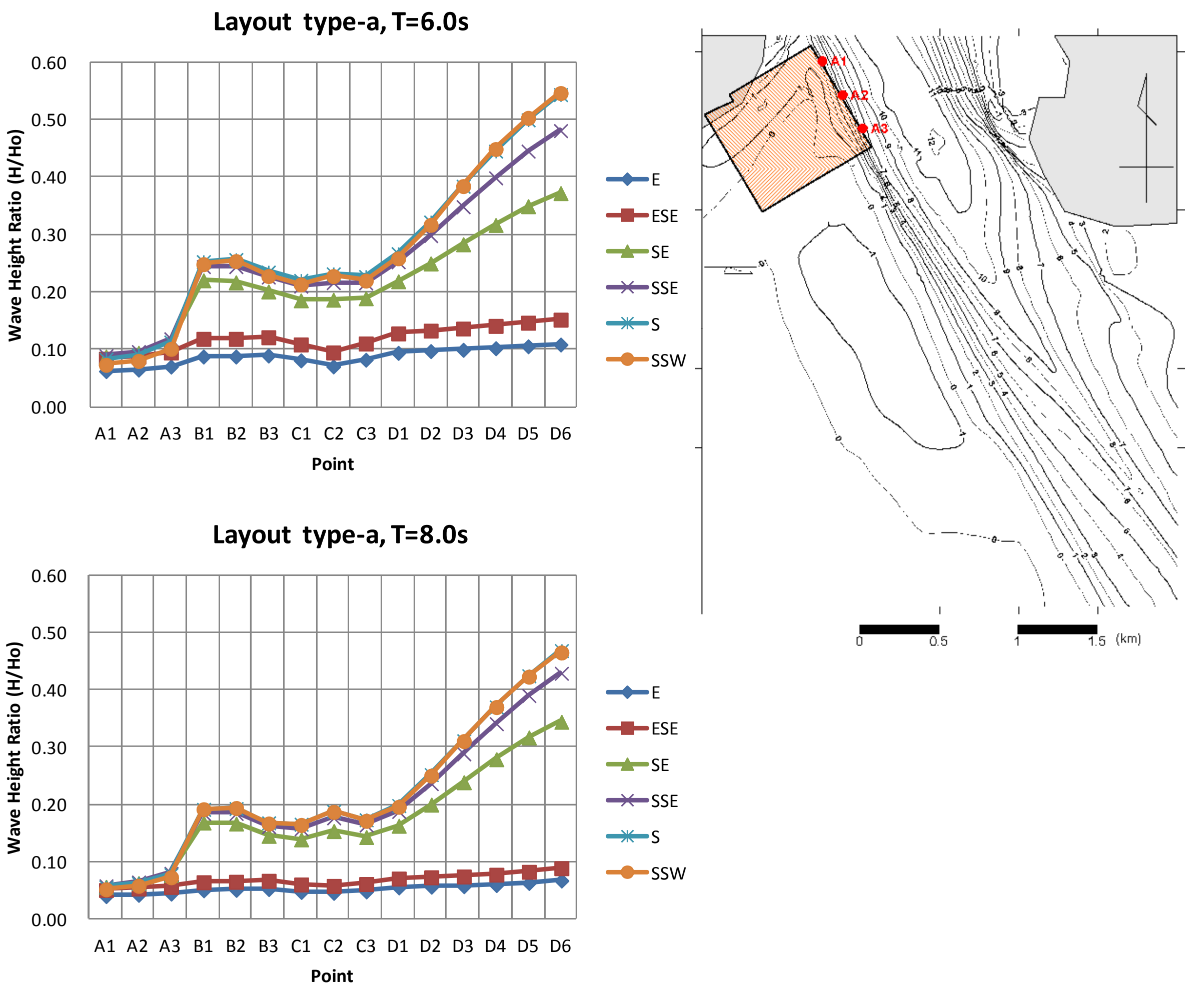


Figure 6.4.13 Wave ratio (H/H_0) in front of the wharf (type-a)

Table 6.4.8 Ratio of Wave height in front of the wharf (type-b)

type-a	T=6.0s						T=8.0s					
Point	E	ESE	SE	SSE	S	SSW	E	ESE	SE	SSE	S	SSW
A1	0.063	0.084	0.086	0.087	0.080	0.068	0.041	0.051	0.054	0.055	0.051	0.046
A2	0.065	0.088	0.093	0.094	0.087	0.074	0.043	0.054	0.060	0.061	0.058	0.052
A3	0.071	0.095	0.110	0.113	0.105	0.090	0.045	0.057	0.070	0.071	0.068	0.061
B1	0.088	0.119	0.158	0.164	0.155	0.134	0.051	0.065	0.095	0.099	0.094	0.086
B2	0.088	0.119	0.162	0.172	0.165	0.145	0.052	0.066	0.101	0.107	0.104	0.096
B3	0.090	0.122	0.174	0.188	0.184	0.165	0.053	0.068	0.113	0.123	0.122	0.114
C1	0.081	0.109	0.163	0.180	0.180	0.163	0.049	0.062	0.114	0.128	0.130	0.122
C2	0.071	0.095	0.150	0.170	0.174	0.160	0.047	0.059	0.115	0.132	0.136	0.129
C3	0.083	0.111	0.170	0.190	0.191	0.174	0.049	0.062	0.123	0.140	0.143	0.135
D1	0.095	0.128	0.204	0.231	0.235	0.215	0.056	0.072	0.149	0.169	0.173	0.163
D2	0.098	0.133	0.234	0.273	0.283	0.262	0.058	0.074	0.184	0.215	0.222	0.210
D3	0.100	0.137	0.267	0.319	0.337	0.315	0.058	0.076	0.222	0.263	0.275	0.261
D4	0.103	0.142	0.304	0.373	0.401	0.381	0.060	0.079	0.264	0.318	0.336	0.321
D5	0.106	0.147	0.339	0.426	0.468	0.453	0.064	0.083	0.303	0.371	0.397	0.383
D6	0.109	0.152	0.363	0.468	0.524	0.517	0.068	0.090	0.332	0.415	0.450	0.439

*Remark) The wharf does not exist in front of the points B1 to D6 in the layout type-b, but the values are calculated for reference.

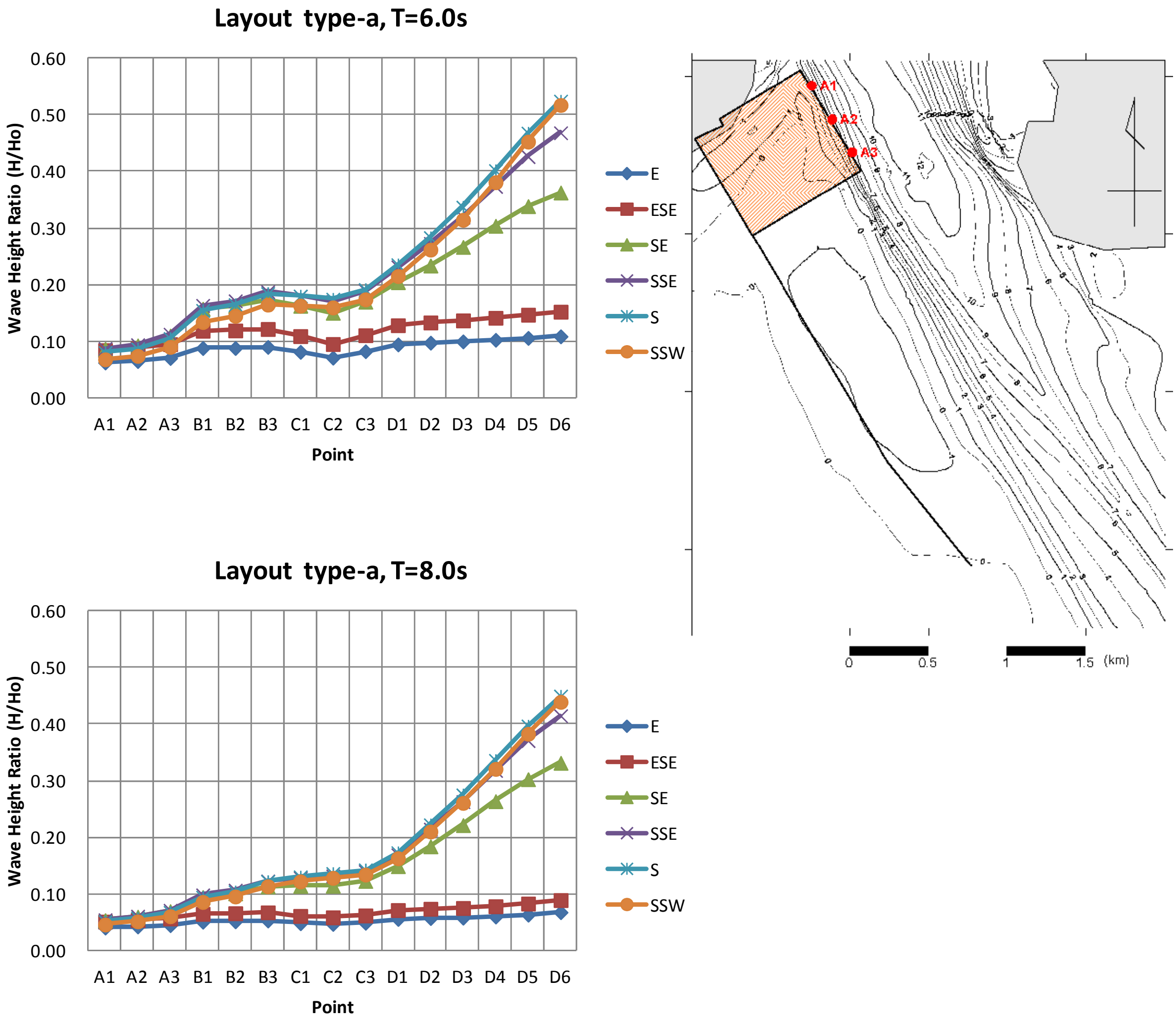
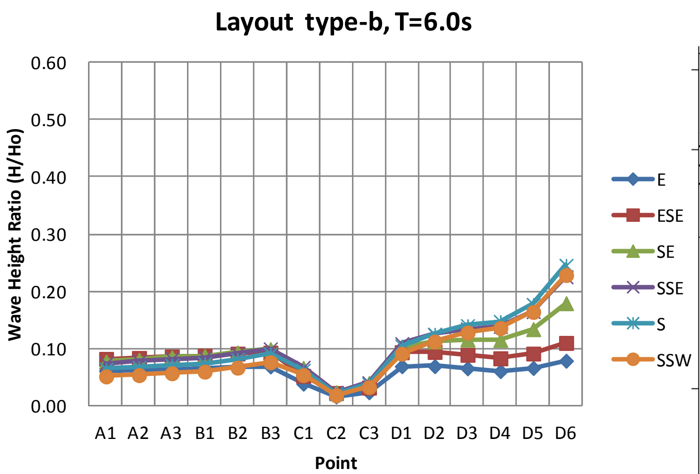
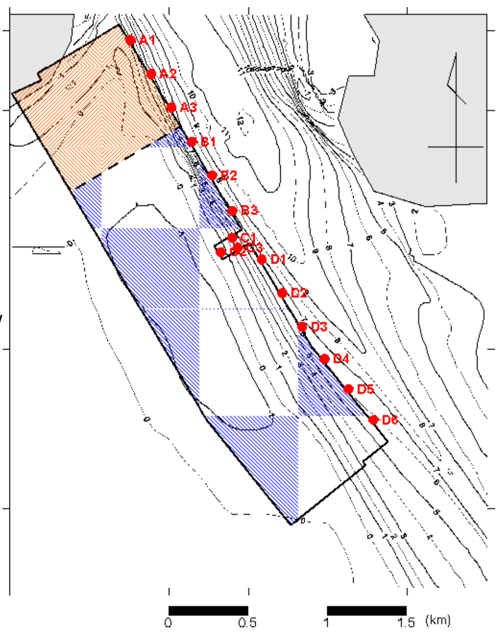


Figure 6.4.14 Wave ratio (H/H_0) in front of the wharf (type-b)

Table 6.4.9 Ratio of Wave height in front of the wharf (type-c)

type-b	T=6.0s						T=8.0s					
Point	E	ESE	SE	SSE	S	SSW	E	ESE	SE	SSE	S	SSW
A1	0.061	0.082	0.078	0.075	0.065	0.052	0.042	0.052	0.047	0.045	0.040	0.034
A2	0.062	0.084	0.081	0.078	0.067	0.054	0.044	0.055	0.051	0.049	0.043	0.037
A3	0.064	0.086	0.085	0.082	0.071	0.057	0.045	0.057	0.055	0.053	0.047	0.039
B1	0.065	0.088	0.087	0.085	0.074	0.060	0.047	0.058	0.058	0.056	0.049	0.041
B2	0.068	0.092	0.093	0.092	0.081	0.067	0.049	0.062	0.063	0.061	0.055	0.047
B3	0.069	0.093	0.099	0.100	0.091	0.076	0.050	0.063	0.069	0.069	0.063	0.056
C1	0.039	0.053	0.067	0.068	0.063	0.054	0.036	0.044	0.057	0.057	0.053	0.047
C2	0.017	0.023	0.024	0.024	0.022	0.019	0.021	0.025	0.025	0.025	0.023	0.020
C3	0.024	0.032	0.040	0.041	0.038	0.033	0.022	0.027	0.033	0.033	0.031	0.028
D1	0.069	0.094	0.103	0.109	0.105	0.091	0.052	0.065	0.078	0.083	0.080	0.073
D2	0.070	0.094	0.113	0.125	0.125	0.113	0.052	0.065	0.091	0.102	0.104	0.096
D3	0.066	0.090	0.116	0.135	0.140	0.128	0.049	0.062	0.101	0.120	0.126	0.118
D4	0.061	0.083	0.115	0.139	0.148	0.136	0.045	0.057	0.107	0.131	0.139	0.131
D5	0.066	0.092	0.134	0.165	0.177	0.164	0.048	0.061	0.127	0.157	0.168	0.159
D6	0.079	0.110	0.180	0.226	0.246	0.229	0.056	0.073	0.171	0.214	0.230	0.218





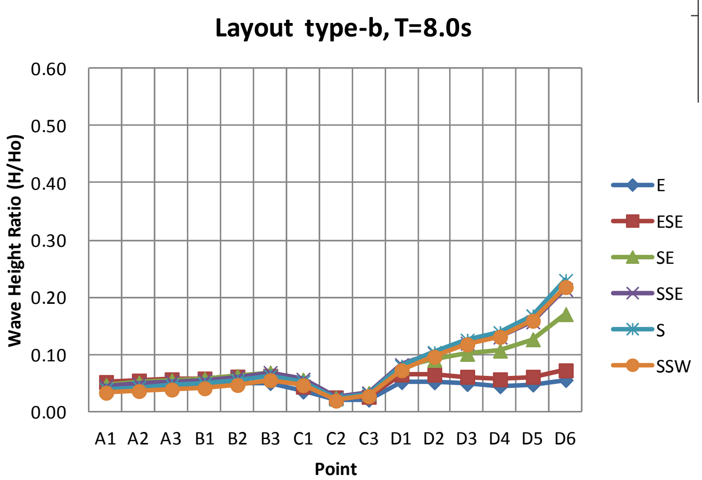


Figure 6.4.15 Wave ratio (H/H_0) in front of the wharf (type-c)

Table 6.4.10 Ratio of Wave height in front of the wharf (type-d)

type-c	T=6.0s						T=8.0s					
Point	E	ESE	SE	SSE	S	SSW	E	ESE	SE	SSE	S	SSW
A1	0.060	0.080	0.072	0.065	0.051	0.036	0.040	0.050	0.042	0.038	0.030	0.022
A2	0.061	0.081	0.075	0.067	0.052	0.036	0.042	0.052	0.046	0.041	0.032	0.023
A3	0.063	0.084	0.079	0.071	0.055	0.038	0.044	0.054	0.050	0.044	0.034	0.025
B1	0.064	0.085	0.080	0.072	0.055	0.038	0.045	0.056	0.051	0.046	0.035	0.025
B2	0.066	0.089	0.085	0.076	0.058	0.040	0.047	0.059	0.055	0.049	0.038	0.027
B3	0.067	0.090	0.088	0.079	0.060	0.041	0.048	0.060	0.058	0.052	0.040	0.028
C1	0.038	0.052	0.058	0.051	0.037	0.024	0.035	0.043	0.047	0.041	0.031	0.021
C2	0.017	0.022	0.021	0.018	0.013	0.008	0.021	0.025	0.021	0.018	0.013	0.009
C3	0.023	0.031	0.035	0.031	0.023	0.015	0.021	0.026	0.027	0.024	0.018	0.012
D1	0.068	0.090	0.086	0.076	0.058	0.040	0.050	0.062	0.058	0.051	0.040	0.028
D2	0.067	0.090	0.085	0.076	0.058	0.040	0.049	0.061	0.057	0.050	0.039	0.027
D3	0.063	0.084	0.080	0.071	0.054	0.037	0.046	0.056	0.050	0.045	0.035	0.025
D4	0.058	0.077	0.074	0.065	0.050	0.034	0.041	0.051	0.045	0.040	0.031	0.022
D5	0.062	0.083	0.081	0.072	0.055	0.037	0.043	0.053	0.050	0.044	0.034	0.025
D6	0.071	0.094	0.094	0.083	0.064	0.044	0.047	0.059	0.058	0.051	0.040	0.028

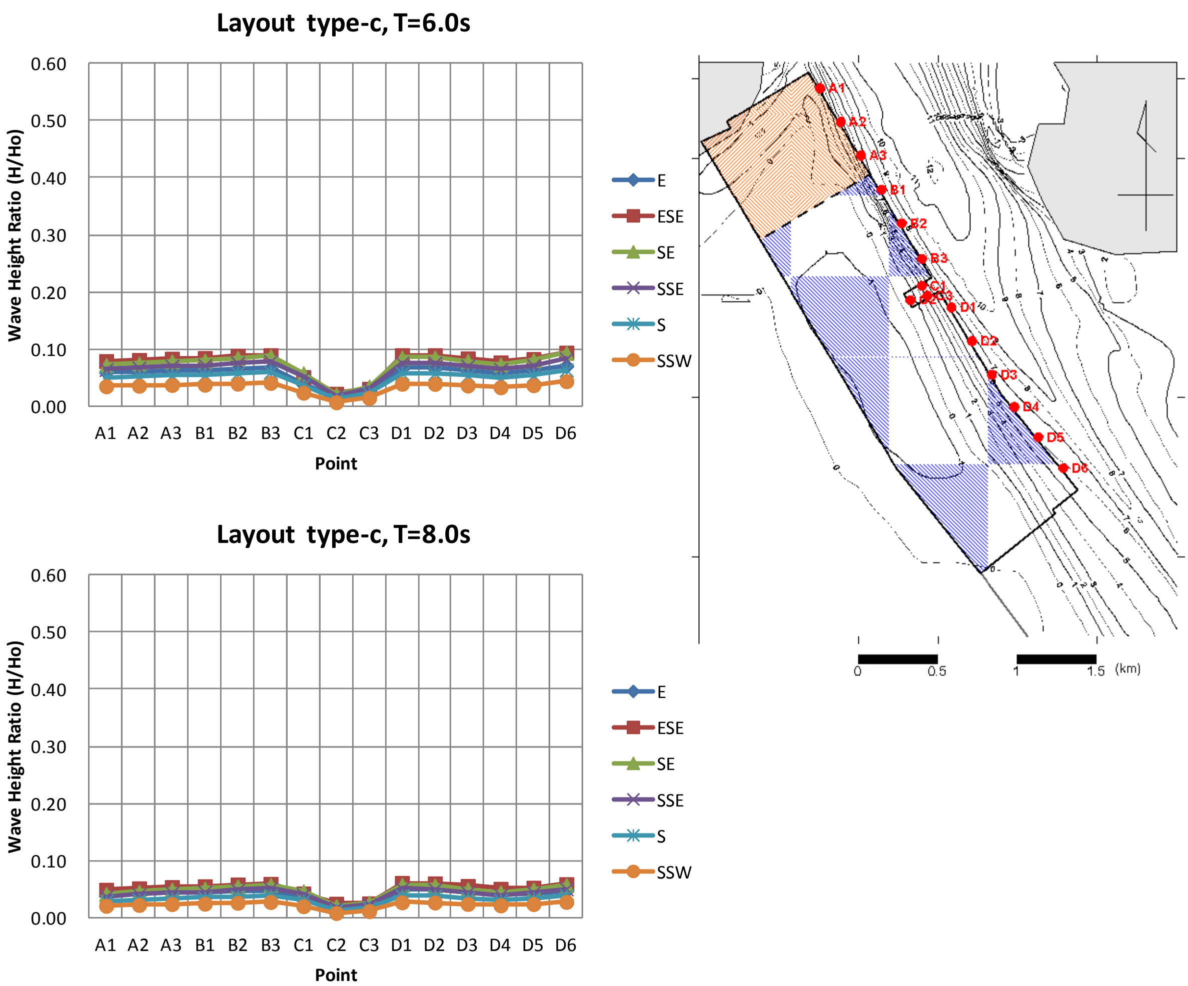


Figure 6.4.16 Wave ratio (H/H_0) in front of the wharf (type-d)

Table 6.4.11 Calculated results of the rate of effective working days in front of the wharf

type-a	Probability exseeding the critical wave height (%)						Rate of effective working days (%)
	Wave Direction						
Point	E	ESE	SE	SSE	S	SSW	
A1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B1	0.000	0.000	0.000	0.275	0.008	0.000	99.72
B2	0.000	0.000	0.000	0.275	0.008	0.002	99.71
B3	0.000	0.000	0.000	0.275	0.000	0.000	99.72
C1	0.000	0.000	0.000	0.178	0.000	0.000	99.82
C2	0.000	0.000	0.000	0.178	0.000	0.000	99.82
C3	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D1	0.000	0.000	0.000	0.589	0.008	0.002	99.40
D2	0.000	0.000	0.000	1.775	0.017	0.005	98.20
D3	0.000	0.000	0.000	4.610	0.018	0.008	95.36
D4	0.000	0.000	0.000	5.228	0.053	0.014	94.71
D5	0.000	0.000	0.000	8.373	0.115	0.021	91.49
D6	0.000	0.000	0.000	9.344	0.115	0.021	90.52

*Remark) The wharf does not exist in front of the points B1 to D6 in the layout type-b, but the values are calculated for reference.

Table 6.4.12 Calculated results of the rate of effective working days in front of the wharf

type-b	Probability exseeding the critical wave height (%)						Rate of effective working days (%)
	Wave Direction						
Point	E	ESE	SE	SSE	S	SSW	
A1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B2	0.000	0.000	0.000	0.178	0.000	0.000	99.82
B3	0.000	0.000	0.000	0.178	0.000	0.000	99.82
C1	0.000	0.000	0.000	0.178	0.000	0.000	99.82
C2	0.000	0.000	0.000	0.178	0.000	0.000	99.82
C3	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D1	0.000	0.000	0.000	0.275	0.000	0.000	99.72
D2	0.000	0.000	0.000	0.679	0.008	0.002	99.31
D3	0.000	0.000	0.000	2.098	0.018	0.005	97.88
D4	0.000	0.000	0.000	4.610	0.053	0.008	95.33
D5	0.000	0.000	0.000	8.373	0.053	0.014	91.56
D6	0.000	0.000	0.000	9.344	0.115	0.021	90.52

*Remark) The wharf does not exist in front of the points B1 to D6 in the layout type-b, but the values are calculated for reference.

Table 6.4.13 Calculated results of the rate of effective working days in front of the wharf

type-c	Probability exseeding the critical wave height (%)						Rate of effective working days (%)
	Wave Direction						
Point	E	ESE	SE	SSE	S	SSW	
A1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D2	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D3	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D4	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D5	0.000	0.000	0.000	0.178	0.000	0.000	99.82
D6	0.000	0.000	0.000	0.366	0.000	0.000	99.63

Table 6.4.14 Calculated results of the rate of effective working days in front of the wharf

type-d	Probability exseeding the critical wave height (%)						Rate of effective working days (%)
	Wave Direction						
Point	E	ESE	SE	SSE	S	SSW	
A1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
A3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
B3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
C3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D1	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D2	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D3	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D4	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D5	0.000	0.000	0.000	0.000	0.000	0.000	100.00
D6	0.000	0.000	0.000	0.000	0.000	0.000	100.00

Table 6.4.15 Wave Height in front of the wharf under abnormal condition

Layout	type-a		type-b		type-c		type-d	
Point	ESE	SSE	ESE	SSE	ESE	SSE	ESE	SSE
A1	0.098	0.088	0.098	0.085	0.108	0.072	0.108	0.068
A2	0.113	0.105	0.113	0.101	0.120	0.087	0.120	0.083
A3	0.112	0.151	0.112	0.112	0.121	0.091	0.121	0.086
B1	0.106	0.223	0.107	0.128	0.127	0.096	0.127	0.091
B2	0.112	0.219	0.113	0.146	0.139	0.110	0.139	0.103
B3	0.116	0.197	0.117	0.183	0.143	0.131	0.143	0.115
C1	0.127	0.227	0.129	0.191	0.127	0.137	0.127	0.117
C2	0.132	0.244	0.135	0.211	0.099	0.063	0.099	0.055
C3	0.128	0.237	0.131	0.211	0.105	0.099	0.105	0.084
D1	0.119	0.291	0.121	0.282	0.155	0.156	0.154	0.120
D2	0.118	0.369	0.120	0.360	0.153	0.188	0.152	0.118
D3	0.11	0.458	0.112	0.447	0.140	0.212	0.139	0.101
D4	0.103	0.555	0.103	0.548	0.118	0.247	0.116	0.071
D5	0.114	0.629	0.114	0.626	0.123	0.305	0.116	0.084
D6	0.134	0.675	0.134	0.673	0.141	0.516	0.130	0.101

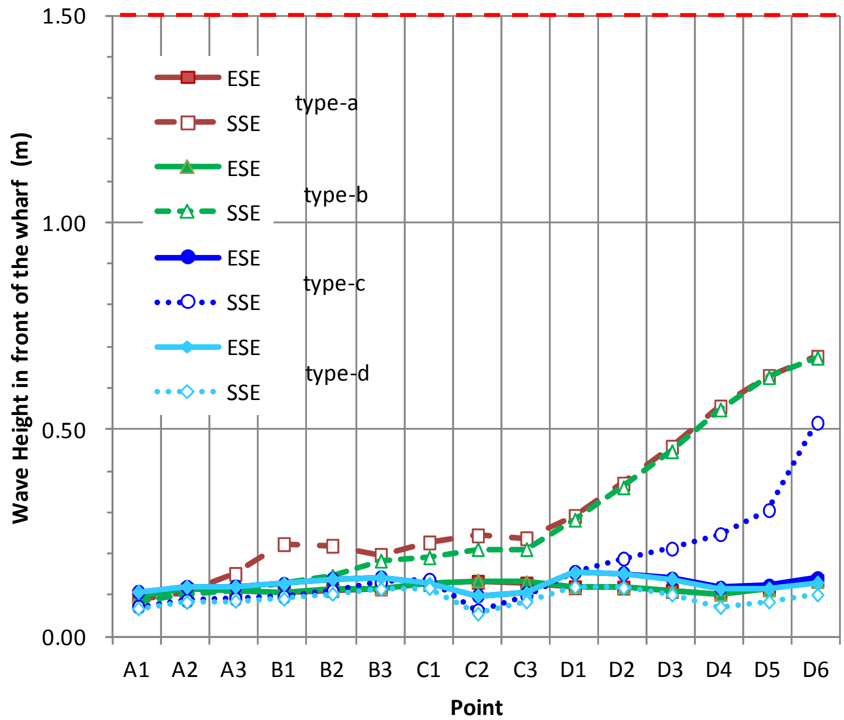


Figure 6.4.17 Wave height in front of the wharf under abnormal condition

6.4.4 Summary of Calmness analysis

Calmness in front of the wharf of Lach Huyen port has been examined for normal and abnormal wave condition. The calmness in normal wave condition has been estimated by calculating the rate of effective working days taking the wave frequency of wave height, period, and direction into account. Also, the calmness in abnormal wave condition has been estimated by the wave height in front of the wharf. The examination has been conducted for four different layouts of port facilities and protection works.

As the result, it is confirmed that the calmness of the wharf is sufficient with more than 97.5 % of the rate of effective working days for normal wave condition and less than 1.5 m in wave height in front of the wharf for abnormal conditions.

6.5 Navigational Safety

6.5.1 Natural Environment

According to SAPROF REPORT, since the wind velocity range of under 10m/sec accounts for 97.8% in all, the occurrence of strong wind is rare. However, prevailing wind direction of over 10m/sec is SSE (37%) and East (24%), and in case of the East wind, the vessel that enters to port receives wind from starboard quarter. It has the amount of the rainfall of 1,600mm during the rainy season (from May to October) in HAI PHONG. And in the data in 1992, rainfall day (amount of rainfall; over 0.1mm) recorded 113days in annum. Fog frequency has tendency that concentrate from December to April, the frequency of fog is 21.2days (average 6.5 day/month) in annum (1984-2004).

And average tidal current velocity is from 0.3 to 0.5m/sec (survey Jan. 1987), it is not so serious to large vessel. However, due to the effects of wind and wave generated flow, the current velocity becomes the maximum speed of 1.0 to 1.2m/sec (2.0 - 2.3knots) at flood as well as ebb tide and may reach to the greatest speed at from 1.5 to 1.8m/sec (2.9 – 3.5knots) during ebb tides at the river estuaries. Since it is expected that current direction is alongside the river, the influence by current is small because the vessel receives current from head on or following. However, when the vessel is berthing / un-berthing under the strong current, in addition as the other vessel is mooring, the risk that vessel goes close to the mooring vessel or the border of the turning basin becomes high.

The height of tide is about 3.5m (HWL) in flood tide, and the ebb tide is almost same of CD (Chart Datum), mean water level is about 2.0m.

Table 6.5.1 shows minimum UKC (Under Keel Clearance) in regulation of HAI PHONG PORT. The regulation of $_{min}$UKC is stipulated until LOA200m. In case of this, UKC is stipulated 0.9m, it is insufficient for over LOA330m container vessel.

In Japan, generally, vessel has to ensure 10% of their draft as $_{min}$UKC, if it applies to 50,000DWT vessel that is designed 13.0m as Full draft, it is required 1.3m as $_{min}$UKC. And in case of 100,000DWT that is designed Partial load, draft is assumed to be 11.8m (80% of Full load), $_{min}$UKC is required 1.2m. Therefore, it is necessary to revise the regulation concerning $_{min}$UKC until receiving design vessel in the future.

Table 6.5.1 Minimum UKC (Regulation of HAI PHONG)

LOA(Length Over All) : (m)	Draft (m)	$_{min}$UKC (m)
LOA ≤ 160	D ≤7.0	0.3
	7.0 < D ≤ 8.0	0.4
	D > 8.0	0.5
160 < LOA ≤ 170	D ≤ 7.0	0.4
	7.0 < D ≤ 8.0	0.5
	D > 8.0	0.6
170 < LOA ≤ 180	D ≤ 7.0	0.5
	7.0 < D ≤ 8.0	0.6
	D > 8.0	0.7
180 < LOA ≤ 190	D ≤ 7.0	0.6
	7.0 < D ≤ 8.0	0.7
	D > 8.0	0.8
190 < LOA ≤ 201	D ≤ 7.0	0.7
	7.0 < D ≤ 8.0	0.8
	D > 8.0	0.9

6.5.2 Traffic Environment

1) Vessel Traffic

According to SAPROF REPORT, the annual record shows that 2,960 vessels entered to HAI PHONG PORT, and the maximum number of the vessel was 16 in day. Although the maximum number of the vessel on each hour was 4, there was no leaving vessel. And when the entering vessels and the leaving vessels existed at same time, the number of entering vessel were 2 or 3, the leaving vessels were 2, therefore it is not congested situation presently.

Most of the vessels that are entering (or leaving) to HAI PHONG PORT use tide. Table 6.5.2 and Table 6.5.3 show the list of entering/leaving vessel at VTS on 24th and 25th in May, 2011. As the Table shows, the vessel in HAI PHONG tends to follow the tide, it has possibility that the time of entering or leaving does not disperse, and the vessel may pass at the same time in short period. And this tendency appears more in deep draft. If this tidal timing and design vessel's passing timing are same, the waiting influence by the large vessel may increase.

As SAPROF REPORT shows, the waiting influence by the large vessel is inferred small from the number of vessel in 2006. However, the handling cargos and entering vessels are more and more increase in Vietnam. Therefore, it is necessary to evaluate about efficiency of the vessel traffic in prospective cargo volume.

Table 6.5.2 Number of Vessel on May 24, 2011 by Time

Day		day 24																							
Hour	draft	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Enter	-5m				1														1						
	5-6m																		1				1		
	6m-																				2		4		1
	total				1														2		2		5		1
Leave	-5m										1	1								2				1	
	5-6m								1																
	6m-	1																		1				2	
	total	1							1		1	1								3				3	
Tide (m)		2.7	2.5	2.2	1.9	1.6	1.4	1.1	1	0.8	0.8	0.8	0.9	1	1.2	1.5	1.8	2.1	2.3	2.5	2.7	2.8	2.9	2.9	2.8

Table 6.5.3 Number of Vessel on May 25, 2011 by Time

Day		day 25																							
Hour	draft	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Enter	-5m														3				1				1		
	5-6m																								
	6m-							1											2		3		5		1
	total							1							3				3		3		6		1
Leave	-5m								2	1				2						2	1	2			
	5-6m																			1					
	6m-	1		1														1		1				3	
	total	1		1					2	1				2				1		4	1	2		3	
Tide (m)		2.7	2.5	2.3	2.1	1.8	1.6	1.4	1.3	1.1	1.1	1.1	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.6	2.6	2.6

2) Activity of Fishing Boats

The fishing activities is catching small fishes by the fixed shore net, the throwing net, the setting bait net and so on around shallow water area. There is no large fishing boat that is catching fishes by the trawl net. The trawl net fishing boats are carried out on offshore. The relative large fishing boats that have the boom with the net from the bow are catching squid, however their operations are not carried out in the channel.

Although basically the fishing boats operations are not carried out in the channel, if they were to work in the channel, the Maritime Administration would instruct directly them to go out from the channel by their boat.

In this way, it is not influenced to the vessel that is passing the channel by competition with fishing boats, however, the fishing boat that is operated close to the channel might have a capsizing risk by ship waves.

Since these fishing boats do not have VHF, they are not able to get information from VTS. Therefore, tug boat that proceeds from the vessel has to give the fishing boats warning.

6.5.3 Pilots

The foreign vessel that 100GT or more (the domestic vessel; 2,000GT or more) is compelled to have the pilot, therefore, almost foreign vessels have the pilot, and in the domestic vessel, it is also high possibility that it has the pilot.

There are 46 pilots in HAI PHONG area (as of 2011.5). As Table 6.5.4 shows, the pilot's certification is classified into 4 by their career. The pilot is able to get the Class III by building their career under the instructor as an internship after graduated from maritime university. The pilot is able to promote to higher rank their certification by building their career and taking program.

The pilot who is able to maneuver 100,000DWT container vessel is the Premier Class (10 pilots).

Although the pilot station was located in southern NAM TRIEU CHANNEL (20-40.0N, 106-51.0E), it is relocated to southern LACH HUYEN CHANNEL presently by taking actual condition into consideration.

Table 6.5.4 Classification of Pilot

Classification of Pilot	Maneuverable Vessel Size	Maneuverable Vessel Length (LOA)	Number of Pilots (as of 2011.5)
Class III	- 4,000GT	- 115m	17
Class II	4,000 – 10,000GT	115 – 145m	8
Class I	10,000 – 20,000GT	145 – 175m	11
Premier Class	20,000GT -	175m -	10

6.5.4 Tug Boats

Table 6.5.5 shows the number of tug boats in HAI PHONG PORT. In the present situation, there is only one 3,200HP tug boat in HAI PHONG PORT.

Table 6.5.5 The Number of the Tug boats in HAI PHONG (2010.4)

Port	Tug boat Company	Nos. of Tug	Capacity
Main Port, Chua Ve, Doan Xa, Dinh Vu	Port of Haiphong	2	500 HP
		1	800 HP
		2	1,200 HP
		3	1,300 HP
		1	3,200 HP
Transvina, Green port, Nam Hai	Marina Hanoi & Falcon	2	1,200 HP
		2	800HP

In the SAPROF REPORT, the requirement tug force of the design container vessel (LOA;337m) by static estimation shows 3 tug boats are required under the 10m/s wind (100.3ton). And under the stronger wind, 4 tug boats are required (refer to Table 6.5.6). Actually, since almost container vessels have the side thrusters, it is possible to reduce tug boat though, it is necessary to study about requirement of tug boat function (power, number of tug) under the wind, tide condition by quantitative method like a ship handling simulation.

Table 6.5.6 Tug Force Requirement for Model Ship

Model Ship	LOA	337.0m
	LPP	321.0m
	Breadth	45.6m
	Draft	12.7m (UKC10% in depth 14m)
	Vessel Side Area above WL	9,458m^2
Estimated Wind Force	Wind Velocity	Wind Force
	5m/sec	25.1t
	8m/sec	64.2t
	10m/sec	100.3t
	15m/sec	144.5t
	20m/sec	225.7t
Assumed Power of 3,200Hp Tugboat	Maximum Power	Push: 46.0t Pull: 39.8t
	Usual Power (85% of Maximum Power)	Push: 39.1t Pull: 33.8t

Table 6.5.7 shows the requirement on tug boat assistance by the vessel length. Assistance by the tug boat is compulsory for all vessels except the ones having LOA less than 80m. Requirement on tug boat depends on the vessel length. In the regulation of HAI PHONG, the category of maximum length is over 160m, however design container vessel's length will be over 300m, therefore regulation should be revised on basis of future's plan.

Table 6.5.7 Requirement of Assistance Tug Boat

Vessel Length (LOA)	Required Nos. of Tug	Required Tug Power	
80 – 90m	1	500HP	
90 – 110m	2	500HP, 800HP	Total pulling power: at least 1,300HP
110 – 130m	2	800HP, 1,000HP	Total pulling power: at least 1,800HP
130 – 150m	2	1,000HP, 1,200HP	Total pulling power: at least 2,200HP
150 – 160m	2	1,000HP, 3,000HP	Total pulling power: at least 4,000HP
160m -	3	1,000HP * 2 3,000HP	Total pulling power: at least 5,000HP

6.5.5 Navigation Assistant Function

1) Vessel Traffic Service (VTS)

Basically, ship management in Vietnam is same in northern part and southern part of Vietnam. Namely, planning of vessel’s berth and un-berth schedule is made by Maritime Administration after consulting with port operators (they operate terminal, and arrange the tug boat) and pilots in order to not encounter with other ship. This schedule is sent to the VTS station twice a day (10:00 / 16:00). If schedule is modified, rescheduled plan is sent properly to the VTS station by e-mail, fax and so on.

The SAPROF REPORT reported that the vessels are managed by time adjustment in almost whole area except admitted encounter. However, by additional survey, although vessel traffic control is managed by VTS in HA NAM CHANNEL, in other area including LACH HUYEN CHANNEL, vessels are not controlled by VTS. Consequently, in the present situation, encounter with vessel occurs in LACH HUYEN CHANNEL.

Due to channel restricted, the design container vessel is impossible to encounter with other vessels in the LACH HUYEN CHANNEL, and also the design vessel is impossible to exist with other vessels in the turning basin at same time. Under the present method that is adjusting the ship's time schedule, it is difficult to avoid encountering with other vessels. When the design container vessel enters to LACH HUYEN CHANNEL, one way control is indispensable by VTS like a HA NAM CHANNEL. Therefore, it is necessary to study about control method until beginning terminal operation.

The traffic control area and control duration should be studied by the maneuvering condition (maneuvering area, maneuvering time) that takes the external force (wind, current) into consideration of the design vessel. And it is necessary to study by quantitative method like a ship-handling simulation.

In SAPROF REPORT it was assumed that it is possible to manage encounter by adjustment of ship's time schedule and VTS, however, LACH HUYEN CHANNEL is necessary to be managed as the control channel, in case of this, VTS control is more difficult than the present, the manual control has limitation to manage vessels. Therefore, it is necessary that VTS system is improved to be semi-automatic control based on PC.

Since operators are not able to watch around container terminal and LACH HUYEN CHANNEL from VTS, it is proper to install the camera to watch the small ship such as fishing boat that is difficult to confirm by the radar.

2) Navigation Buoy

The depth of water in the design channel is planned to be 14m, and the design vessel 50,000DWT container vessel's full draft is 13m, 100,000DWT container vessel's partial draft is 11.8m (80% full draft 14.8m). H/d (H: depth of water, d: draft) that is based on LWL (CD+0.43m) is from 1.1 to 1.2, it means it does not have enough Under Keel Clearance (UKC).

Therefore, for the large vessel that is restricted navigation area, it is necessary to point the edge of the channel where the depth is secured.

And tidal current of LACH HUYEN CHANNEL becomes strong under the ebb tide or flood tide, besides, in case of mixing wind and wave, the moving range of the floating buoy is larger than usual (generally, floating buoy's moving range is twice the depth of water), it has possibility that the floating buoy does not point exact position.

Therefore, Spar Buoy that does not move easily by current and wind should be installed at the design channel.

Table 6.5.8 Specification Plan of Buoy

Specification		Example
Type	Spar Buoy	Spar Buoy
Light Source	LED	Height: abt.21.0m
Source of Power	Solar Cell	Focal Plane Height: abt.7.6m
Flashing	Synchronized	Weight: abt.5.8t
Luminous Range	more than 4nm	

Figure 6.5.1 Example of Spar Buoy

In SAPROF REPORT, the arrangement of the navigation buoy was proposed to install one after the other at one side. Generally, the buoy arrangement is proper to install at the both side. However, design Channel does not have enough width from view point of large vessel (100,000DWT), in this situation, it has possibility that buoy becomes obstacle to the large vessel. Consequently, SAPROF REPORT proposed the alternate arrangement.

In this way, in HAI PHONG, it has possibility that visibility is restricted by rainfall and fog throughout the year. And in the additional survey, pilot had comment that they are concerned about the alternation buoy arrangement under the restricted visibility condition. Consequently, buoy arrangement is proper to install on the both side of the channel.

Concerning installation interval, it is proper to refer Technical Standards of Ports/Harbors, 2010 (channel width 160m: 1,217m, channel width 210m: 1,856m) and the present installation interval (about 1,600m) and the shape of new design channel. And concerning No.0 buoy, according to the present state, it is proper to install at 2km offshore from the channel.

Figure 6.5.2 shows the buoy arrangement of the LACH HUYEN New Channel.

The philosophy of buoy arrangement is shown as follows.

a) Arrange at the curve
b) Arrange at different channel width
c) Arrange to refer the Technical Standards of Ports/Harbors in the straight section
    Channel width 160m : 1,217m or less
    Channel width 219m : 1,856m or less
    *However, distance of buoy should be set to recognize the distance of the other ships or obstacle by visual easily.

Table 6.5.9 Buoy Interval by Technical Standards of Ports/Harbors ver.2010

Measure that Recognition of deviation	Buoy Interval	Necessary Route Width
Recognize deviation by buoy	1,217m (0.66 nm)	160m (0.5L, 3.5B)
	1,856m (1.00 nm)	210m (0.6L, 4.6B)

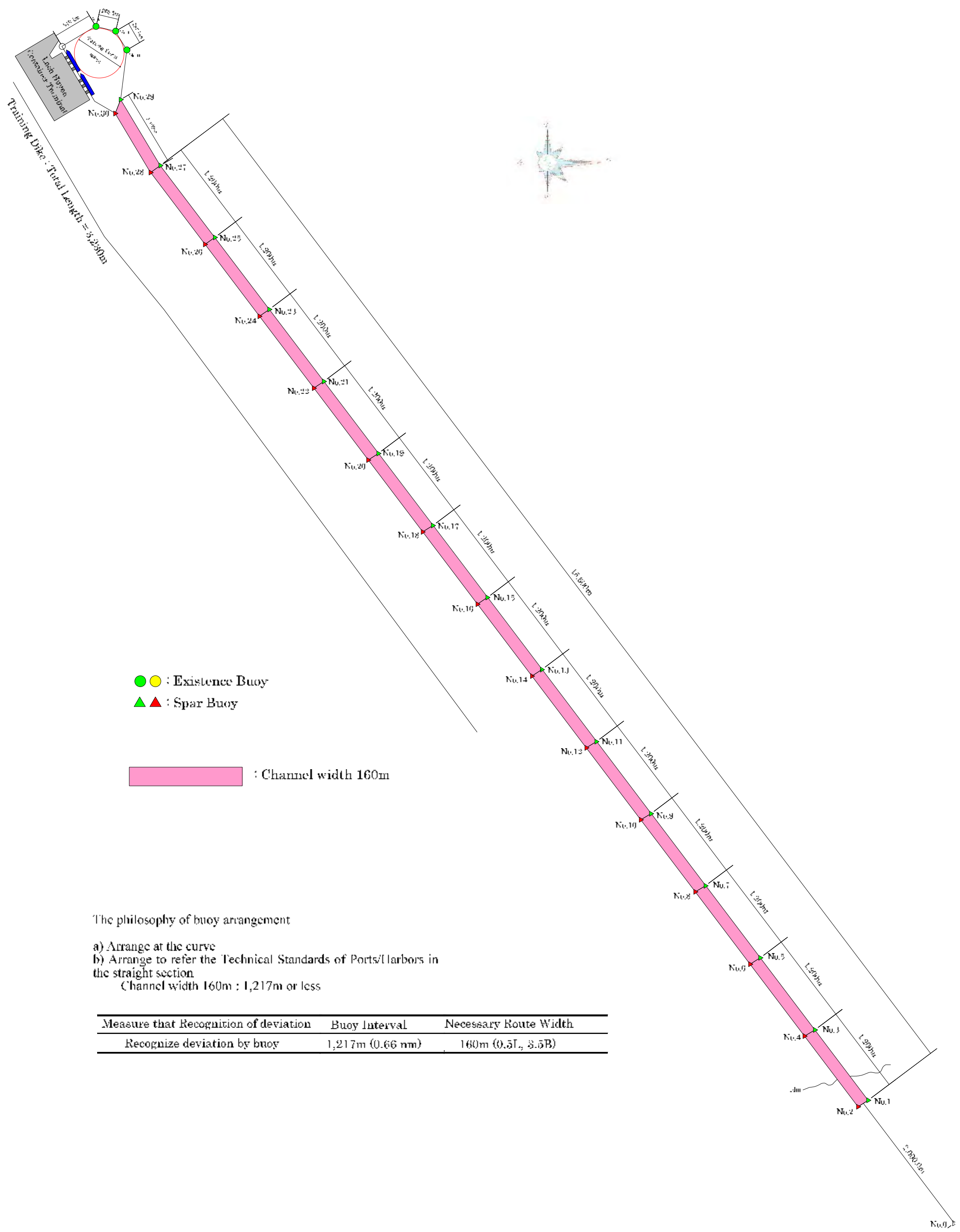


Figure 6.5.2 Buoy Arrangement of the LACH HUYEN New Channel

3) Light Beacon on Training Dike

It is planned to construct the training dike of 7.6km from the channel edge at the position of 100m. Against the height of the training dike, the depth of water at high tide (HWL) is CD+3.55m (MHWL: CD+3.05m), therefore the training dike could be submerged and becomes invisible.

According to SAPROF REPORT, the depth of water in fairways other than the LACH HUYEN CHANNEL is very shallow and a navigation of a large vessel is impossible, therefore construction of the training dike does not affect directly to the large vessel. However, since small craft and boats are possible to use the fairway, the light beacon on the training dike is necessary for these small ships.

Table 6.5.10 shows the specification plan of the light beacon on the training dike.

Table 6.5.10 Specification Plan of Light Beacon on Training Dike

Specification		**Example**
Type	Light Beacon	Straight Light Beacon 5m Type
Height of Light	more than 5m	Height: abt.5.43m
Light Source	LED	Height of light: abt.2.25m
Source of Power	Solar Cell	Weight: abt.395kg
Luminous Range	more than 5km	
Installation Interval	2,000m	

Figure 6.5.3 Example of Light Beacon (Straight Light Beacon 5m Type)

4) Pilot Assistance System

In recent year, equipment of ECDIS and AIS are stipulated as world standard, hereby vessel has been able to confirm other vessel easily, and this visual information is extremely effective for passing narrow channel and congestion area.

The AIS information is effective in order to know the own location and other vessel's condition in LACH HUYEN CHANNEL too. However, in the approach situation and berthing situation, the pilot is handling the vessel at wing side of the bridge, in case of this, pilot is not able to confirm directly this information. Although the pilot is able to know this information from ship's officer or tug boat, it is lack of the immediacy, and it is possible to inform by mistake.

Therefore, in the situation of ship-handling at wing side, it is necessary pilot is able to confirm the information immediately, for that reason, the information assistance unit should be mobile.

Table 6.5.11 shows the specification of Pilot Assistance System. This unit is able to get information (location, velocity, heading etc.) from AIS Pilot Plug that is installed in the bridge. Therefore, the pilot brings just only PC and AIS Pilot Plug cable to the vessel. By using electric chart, the information unit is able to show the ship's posture that is changing at every moment from bird view.

To assist the ship's handling, it should be able to show various information. In the situation of passing in the LACH HUYEN CHANNEL, it shows the deviation from the channel center, the distance to the next waypoint and ETA (Estimation Time of Arrival). And the situation of the approaching and berthing situation, it shows lateral distance and longitudinal distance from the berth, the access speed to the berth.

However, since the accuracy of location depends on GPS of the vessel, it is possible to have the error in several meters. Therefore, in the berthing situation, the pilot should handle the vessel by seeing berth and ship's side directly.

Since the design container vessel that uses the new terminal occupies wider area in the channel and in turning basin, the condition (location, posture etc.) of the design vessel has possibility that influence other vessels. Therefore, by dint of having such device in each pilot, it is possible to increase the safety in the whole sea area with VTS.

Table 6.5.11 Specification of Pilot Assistance System

Function of Pilot Assistance System	
Device	Mobile Computer
	Ship's location
	Velocity
	Lateral speed
	Heading
	COG (Course On the Ground)
Information	Deviation from the center of channel
	Distance to next waypoint
	Distance to the berth
	*Their information display on computer screen.
	*Vessel's track display on computer screen
	Risk of Collision to Vessel and Land
AIS Data	Use AIS PILOT PLUG
Chart	ECDIS
Other function	AIS Monitoring (Display other vessel that has AIS device on screen)

Figure 6.5.4 Example of Pilot Assistance System

6.5.6 Recommendation

1) Traffic Control and VTS Center

According to SAPROF REPORT, it was assumed that the avoiding of vessel's encounter is managed by adjustment of the ship's time schedule in the whole area in HAI PHONG. However, from additional survey, it turned out only HA NAM CHANNEL is managed as a traffic control channel without the encounter.

As the design large vessel passes in LACH HUYEN CHANNEL, to encounter other vessel is extremely dangerous. Therefore, LACH HUYEN CHANNEL must be managed as a traffic control channel.

The channel length of new design channel is about 18km, due to reducing velocity, it is assumed that it requires 1 hour or more for passing through the channel. In case of un-berthing situation, since ship requires rotating, it is necessary to additional time. When the encounter ship is in same time, it is affected by long waiting time. Therefore, depending on utilization of the channel in the future, it is desirable to study about the waiting area that is setting in the present situation.

Concerning VTS equipments, due to the increasing complexity of traffic control, it is desirable to strengthen the functions that are traffic observation, obtaining ship's passing data automatically.

- Automatic acquirement of the passing time of vessels
- Automatic renewal of the passing time schedule
- Alert system (in case of encounter to vessel)
- Camera system that is for watching against small craft, fishing boat around channel

2) Training for VTS Operators

As the design large vessel passes in the LACH HUYEN CHANNEL, it is necessary that the channel is managed one way as a traffic control channel. In this case, required control time may become long, and traffic control channel increases to 2 sections in addition to HA NAM CHANNEL, so it is assumed that it is difficult to operate by the present method, and it is necessary to direct ships by the operator.

Therefore, it is necessary to study the education system for operators in accordance with world standard.

3) Arrangement of the Navigation Buoy

Although according to SAPROF REPORT, the buoy arrangement was thought that it is desirable to be installed one after the other, it is proper to install pair of buoy at channel edge according to the pilot's opinion and the consideration that is the ship-handling under the restricted visibility condition by rainfall and fog.

4) Installation of the Meteorological Buoy

In case of maneuvering (passing, approaching, berthing, un-berthing, rotating) under the restricted navigation area like LACH HUYEN CHANNEL, the vessel receives strong influence from external force that is wind, current and wave.

Therefore, when the vessel enters to the port, it is important to know the natural condition, and it is proper to install the meteorological buoy for getting information.

And it is desirable that vessel is able to get information directly from the meteorological buoy by AIS.

5) Pilot Assistance System

The ship’s handling in the narrow channel requires high accuracy about the positioning control and the ship's posture control. In the situation of the approaching to the berth and berthing/un-berthing in such channel, the vessel receives external effect strongly as slowdown, and the difficulty of control is getting higher. Therefore, to support of safety navigation, it is essential to get accurate information and immediately.

As SAPROF REPORT shows, it is essential to install the information assistance unit for the pilots, and this unit should be mobile to confirm anywhere in bridge. In addition, the system should have a competent to show ship’s prediction tracks in order to know their risk of collision.

6.6 Ship Maneuvering Simulation Study

6.6.1 Objective

The width of New LACH HUYEN Channel is designed 160m in the present plan. Since LOA (Length Over All) of the designed container vessel is assumed 300m or more, the available maneuvering area of this vessel is extremely restricted. When such large vessel passes in the shallow channel, the shallow water effect occurs, and the maneuverability reduces. Moreover, the LACH HUYEN Channel has strong tidal current. Due to this, it is required high skill to control ship's posture and ship's position. Therefore, it is essential to verify safety of maneuvering by designed container vessel under the severe condition (narrow, shallow, strong tidal current). And it is necessary to study the acceptance standard manual and maneuvering support function by the result of verification.

6.6.2 Simulation Conditions

1) Simulator Ship Model

The Super Post Panamax (100,000DWT / 8,000-9,000TEU) container vessel was the maximum size of the designed ship in this plan. Therefore, in the simulator verification, this maximum size vessel was assumed as the target ship model. Table 6.6.1 shows the specification of the simulator ship model.

Table 6.6.1 Specification of the Container Vessel Model in Simulator

	Simulator Model Ship
Capacity (TEU)	8,000－9,000
Dead Weight Tonnage	99,500
Gross Tonnage	98,700
LOA (m)	336.0
LBP (m)	318.3
Beam MLD (m)	45.8
Molded Depth (m)	24.4
Full loaded Draft (m)	14.0
Experimental Draft (m)	12.7
Vessel Side Area above WL	7,766.6m^3
Side Thruster	Bow : 27.01 tons
Propeller	FPP×1 93,361ps

2) Designed LACH HUYEN Channel

Figure 6.6.1 shows the ground plan of the designed LACH HUYEN Channel and the anchorage. The navigation buoy that shows the channel was assumed Spar Buoy type on the basis of BD report. And No.31 - No.33 buoys that show the anchorage were assumed a floating buoy type.

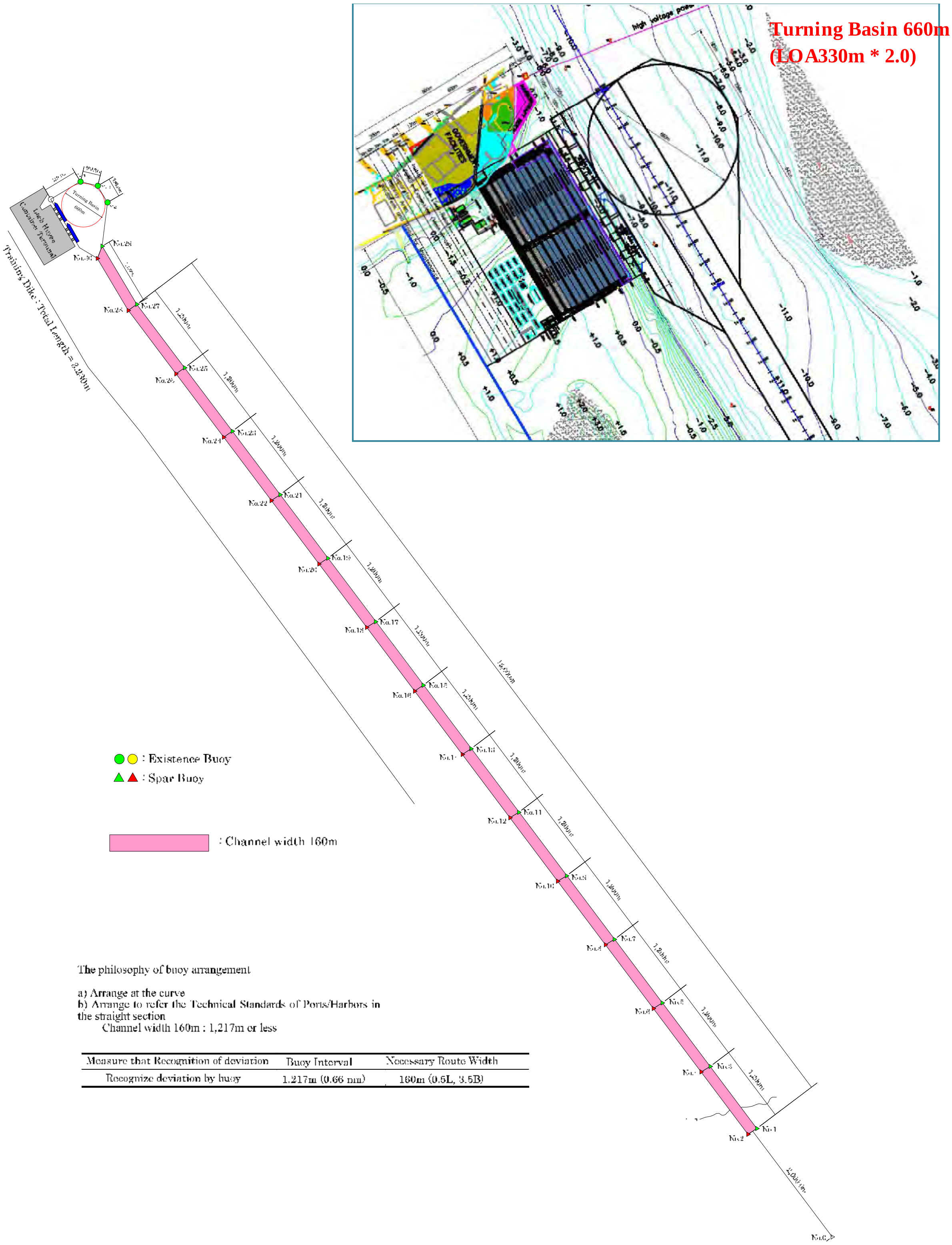


Figure 6.6.1 Designed LACH HUYEN Channel and Anchorage

3) Natural Conditions

Table 6.6.2 shows the natural conditions in the simulation.

Table 6.6.2 Natural Conditions

Wind	12.0m/sec (avr.) *abeam direction
Tidal current	3.5knots *around estuary
Wave	1.5m at offshore

4) Tugboat

The tugboat in the simulation was assumed to 3,200ps tugboat based on the actuality of tugboat in HAI PHONG Prot. However, in case the thrust was insufficient in this verification, the tugboat was changed to the 4,000ps tugboat.

Table 6.6.3 3,200PS / 4,000PS Tugboat Model

	3,200PS	4,000PS
Maximum Power	Push : 46.0 ton Pull : 39.8 ton	Push : 56.2 ton Pull : 49.7 ton
Usual Power (85% of Maximum Power)	Push : 39.1 ton Pull : 33.8 ton	Push : 47.8 ton Pull : 42.2 ton

5) Maneuvering Person

In Vietnam, the pilot's qualification is classified in 4 classes that are from Class III to Premier Class. In case of the designed large vessel, the Premier Class pilot will be handling the vessel. Therefore, in this simulator verification, it was assumed to maneuver by the Premier Pilot.

6.6.3 Results of Simulator Verification

Table 6.6.4 shows the cases of the Ship-Handling Simulator verification that were executed.

Regarding maneuvering, basically, it was carried out by Vietnamese pilots. Although the basic cases were carried out by them, other additional cases were carried out by Japanese captain who belongs to the simulator company. In addition, the basic cases were assumed that the ship sails in the channel, berthing / un-berthing situation under the strong same way current that becomes difficult to maneuver.

Table 6.6.4 Simulator Verification Case

No.	Maneuvering Situation	Design	Berthing Side	Target Berth	Natural Conditon					Tugboat		Verification Objective
					Wind		Wave	Current(knot)		HP	Num.	
1	Channel Passing	Original Plan	-	-	53.8 deg	12m/s	1.5m	flood tide	3.5	3,200	2	Verification about safety of channel passing
2												
3	Berthing	Original Plan	Head Out	Southern Berth	59.5 deg *onshore wind	12m/s	0.8m	flood tide	3.5	3,200	2	*Verification about approach maneuvering under same way current *Verification about turning and berthing maneuvering under same way current
4												
5									1			
6												
7		Widening Plan		Southern Berth					3.5			
7-2												
7-3				Northern Berth								
8		Original Plan	Head In	Southern Berth				ebb tide				Verification about turning and berthing maneuvering under reverse current
9	Un-Berthing	Original Plan	Head In	Northern Berth	59.5 deg *onshore wind	12m/s	0.8m	ebb tide	3.5	3,200	2	Veriication about un-berthing and turning maneuvering from portside head in *difficulty is high in ebb tide (same way current)
10												
11												
12									1.7			
12-2		Widening Plan							1.7	4,000	3	
13								flood tide	3.5	3,200	2	
13-2										4,000	2	
13-3				Southern Berth					3.5	3,200	2	
14		Original Plan	Head Out	Northern Berth				ebb tide	3.5	3,200	2	Veriication about un-berthing maneuvering from starboard side head out *difficulty is high in ebb tide (same way current)
14-2									1.7	4,000	2	
14-3		Widening Plan							3.5			
15								flood tide	3.5	4,000	2	

*yellow: These cases were carried out by Vietnamese

1) Passing in the LACH HUYEN Channel

Table 6.6.5 shows the ship's motion states under the passing situation in the channel. In the result of verification, the ship was able to passage in the center of the channel even if the ship was having strong wind (12m/sec) from abeam direction. In addition, the leeway angle was small (abt.0.2^{o}), the lateral speed was also small. Therefore it is considered that it was easy to control ship's posture. However, regarding the passage in the channel, even if the ship was able to passage of the center in the channel, since the distance to channel edge was only 50m-60m. Therefore, this situation was not enough space for the maneuvering.

The maneuvering time was 33 minutes from the channel entrance (No.1, No.2 buoy) to No.21 and No.22 buoy (Case1).

Table 6.6.5 Ship's Motion States and Amount of Rudder from No.3,4 Buoy to No.17,18 Buoy

		Case1	Case2
Leeway Angle (avr.)		0.17^{o}	0.16^{o}
Lateral Speed (avr.)		3.7cm/sec	3.5cm/sec
Rate of Usage of Rudder	43.0%	43.0%	37.0%
	29.8%	29.8%	37.8%
	11.5%	11.5%	14.1%
	9.6%	9.6%	9.0%
	6.2%	6.2%	2.2%

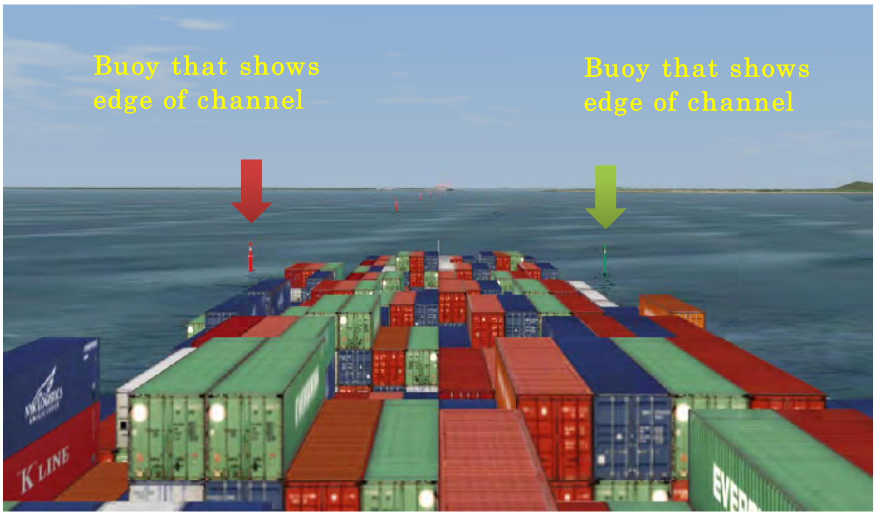


Figure 6.6.2 Situation of Passage in LACH HUYEN Channel

2) Approach to Anchorage from LACH HUYEN Channel

The No.30 buoy that shows west edge of the connection that was between the channel and the anchorage was removed according to Vietnamese pilot's opinion. In the actual operation, when the ship is coming to the anchorage, tugboats have already taken their tug line to the ship. Under this situation, No.30 buoy might become obstacle for assistance by tugboat.

The important factor in approach situation is possibility of ship's posture control and positioning control under the low speed. Especially, under the same way current (flood tide), the maneuverability is extremely reduced. Due to this, it has to have high speed that exceeds the tidal current velocity in order to keep the maneuverability. However in this case, it has a risk that enters to the anchorage under the high speed.

In the result of verification, under the same way current, the pilot reduced ship's speed in order to enter to the anchorage under the low speed. Due to this, it was not able to get enough maneuverability. Eventually, the ship was drifted to lee side with 45cm/sec, and the ship approached close to the west side edge of the channel (Case3). And regarding the rate of amount of rudder, more than 20 degrees rudder occupied 70%-90%. Fundamentally, under the strong wind that is receiving from abeam, a ship has leeway angle considering drifting influence. However, in this case, since the channel width is narrow, it is difficult to approach the anchorage considering the leeway angle, and also the pilot's mental load is large.

Therefore, it is necessary to avoid entering to port under the strong same way current (strong flood tide).

Table 6.6.6 Ship's Motion States and Amount of Rudder in Approach Situation (3.5knot)

	Case3		Case4	
	Leeway Angle	Lateral Speed	Leeway Angle	Lateral Speed
No.25 - No.27	2.0^{o}	-11.0cm/sec	6.5^{o}	-30.2cm/sec
No.27 - No.29	9.4^{o}	-45.6cm/sec	10.3^{o}	-44.0cm/sec
Rate of Usage of Rudder (from No.27 buoy to entrance of anchorage)	less than 5^{o}	10.1%	less than 5^{o}	20.9%
	5 – 10^{o}	1.2%	5 – 10^{o}	2.9%
	10 – 15^{o}	1.0%	10 – 15^{o}	2.9%
	15 – 20^{o}	1.7%	15 – 20^{o}	2.9%
	more than 20^{o}	86.1%	more than 20^{o}	70.5%
Maneuvering Time (No.27 buoy - Anchorage)		18min		20min

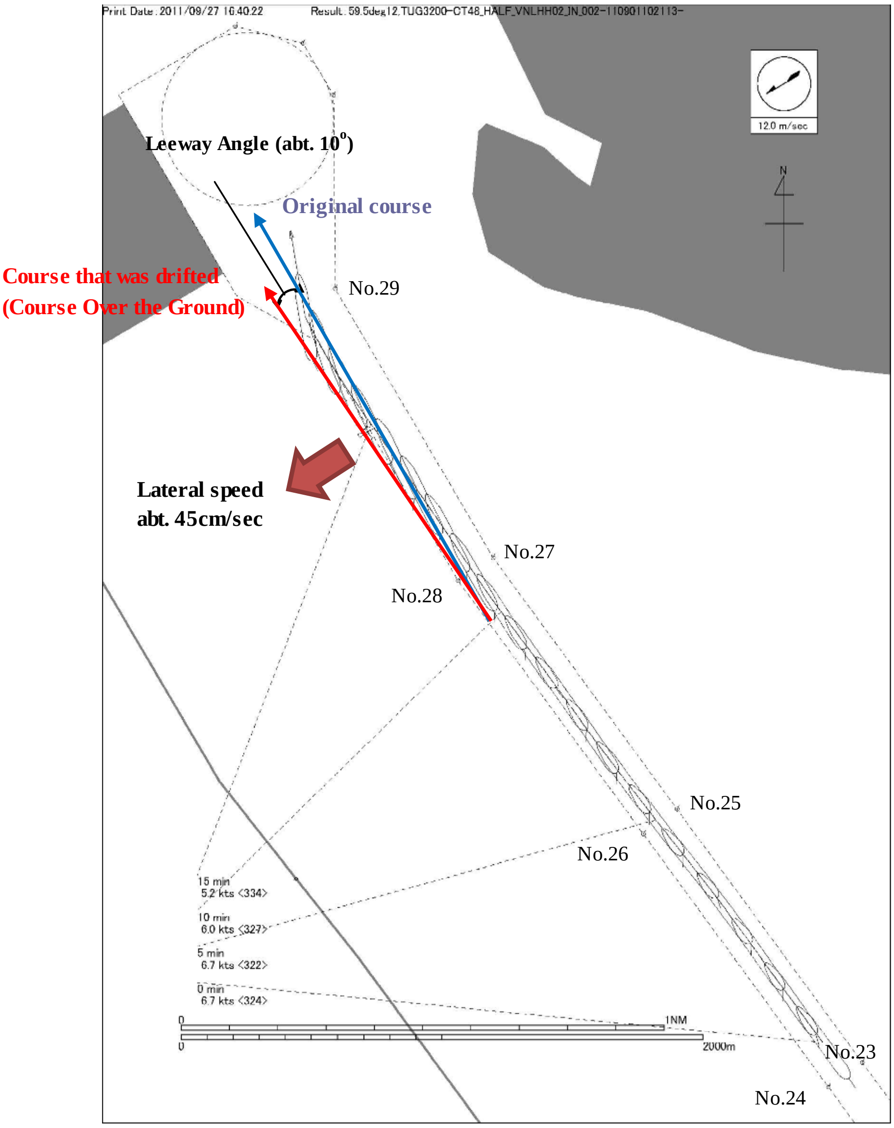


Figure 6.6.3 Ship's Track in Approach Situation (Case3: No.23-No.29)

The simulator verification (Case5, Case6) was carried out under the low tidal current (1.0knot) on the basis of the result of strong tidal current (3.5knots). In the result, the leeway angle and the lateral speed became small compared with strong current, in addition, amount of the rudder also was reduced. However, since entrance width was not enough, the ship was not able to passage while having the leeway angle that was consider drifting to lee side. Due to this, the ship approached close to the channel edge. Therefore, under the designed anchorage, it should set a limitation to use in less than 1.0knot.

Table 6.6.7 Ship's Motion States and Amount of Rudder in Approach Situation (1.0knot)

	Case5		Case6	
	Leeway Angle	Lateral Speed	Leeway Angle	Lateral Speed
No.25 - No.27	2.0°	-13.2cm/sec	2.1°	-12.5cm/sec
No.27 - No.29	6.0°	-31.7cm/sec	5.8°	-27.5cm/sec
Rate of Usage of Rudder (from No.27 buoy to entrance of anchorage)	less than 5°	42.1%	less than 5°	15.4%
	5 – 10°	1.1%	5 – 10°	1.7%
	10 – 15°	1.1%	10 – 15°	1.7%
	15 – 20°	1.1%	15 – 20°	2.3%
	more than 20°	54.6%	more than 20°	79.0%
Maneuvering Time (No.27 buoy - Anchorage)		16min		18min

In the result (Case3-Case6), it was found out it was important to control ship's posture and position properly in the channel. Especially, in the maneuvering under the strong wind, the ship had to have a leeway angle to avoid drifting to the lee side when the ship enters to the anchorage. However, under the original design, since anchorage entrance width was narrow, it was extremely difficult to enter while having leeway angle. Therefore, to passage safely under the strong natural condition, it is desirable to expand the anchorage entrance width as wide as possible.

It was carried out verification under the anchorage design that was enlarged between the channel and the anchorage as shown Figure 6.6.4 (It calls this shape "Channel widening plan"). This shape was designed on the basis of pilot's opinion.

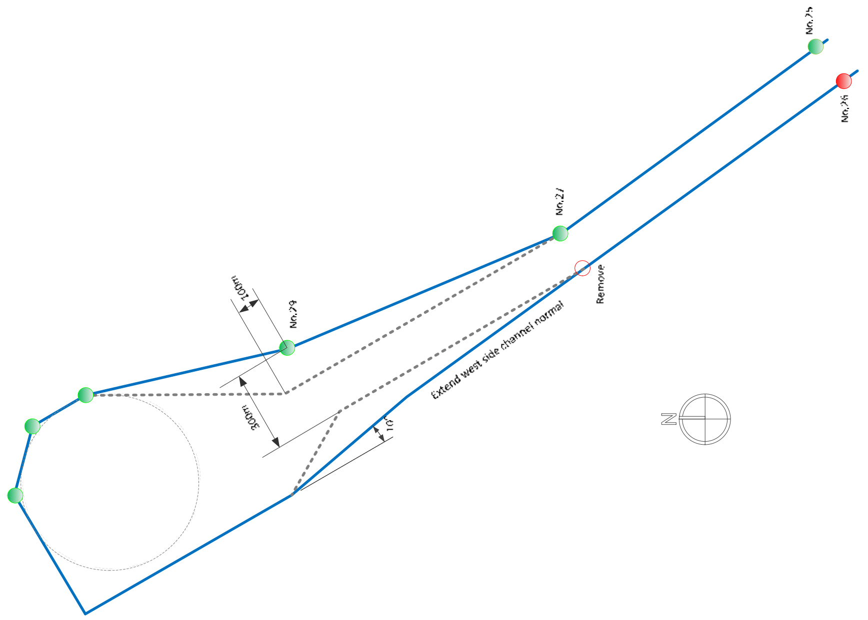


Figure 6.6.4 Channel Widening Plan

Although the drifting impact was not so different compared with the original plan, the rate of amount rudder of more than 20^{o} was reduced greatly since the width was expanded. In addition, the ship was drifted to the channel west side edge, however it did not deviate from the channel, and it had enough space to control the drift.

Figure 6.6.5 shows the ship's track in case of having leeway angle. It was possible to passage in around the channel center by having the leeway angle. However, in the maneuvering that has leeway angle, since it is different between the ship's heading and the course over the ground (COG). Due to this, if there is not enough space for maneuver, its difficulty is extremely high and pilot's mental load is also high.

Table 6.6.8 Ship's Motion States and Amount of Rudder in Approach Situation (Channel widening plan / Current 3.5knots)

	Leeway Angle	Lateral Speed
No.25 - No.27	1.9^{o} (2.0)	-12.0cm/sec (-11.0)
No.27 - No.29	8.4o (9.4)	-45.0cm/sec (-25.6)
Rate of Usage of Rudder (from No.27 buoy to entrance of anchorage)	less than 5^{o}	48.8% (10.1)
	$5 – 10^{o}$	1.7% (1.2)
	$10 – 15^{o}$	1.7% (1.0)
	$15 – 20^{o}$	1.7% (1.7)
	more than 20^{o}	46.3% (86.1)
Maneuvering Time (No.27 buoy - Anchorage)		19min

*( ): result of original plan (Case3)

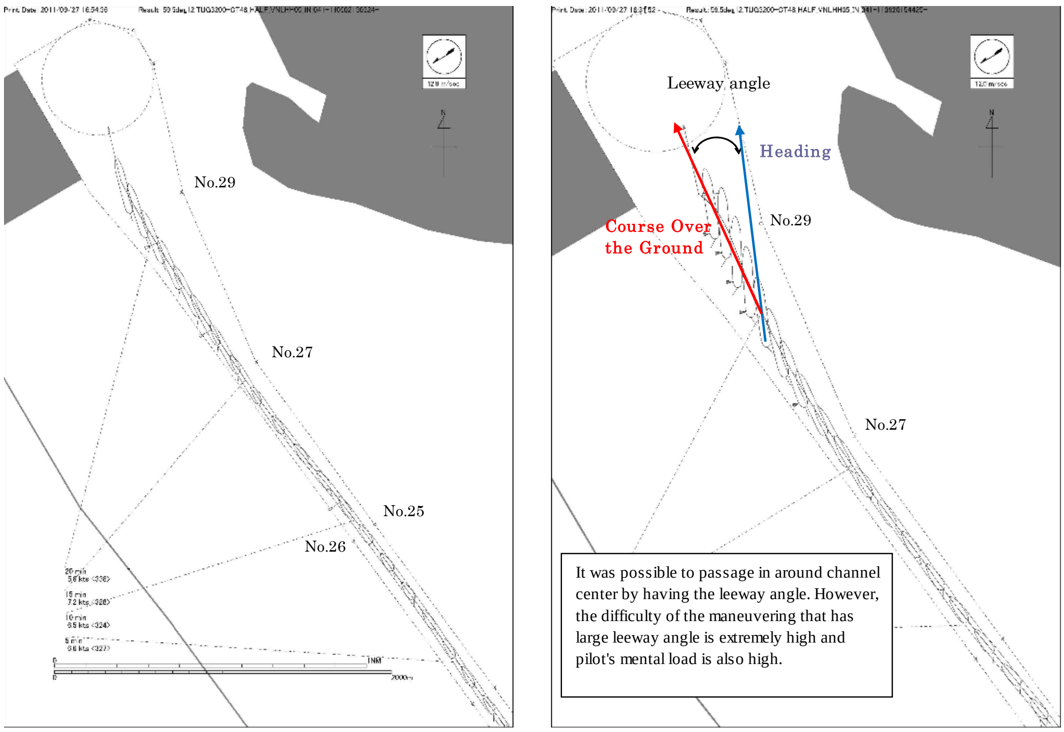
Under the reverse strong current (ebb tide), although the ship's velocity is decreased, the maneuverability is not reduced. Therefore, it is easy to maneuver compared with the same way strong current (flood tide).

According to the result of verification, the leeway and the lateral speed around entrance of the anchorage extremely was reduced compared with the same way current (leeyway:1.7^{o}, lateral speed:-8.5cm/sec). Regarding approach maneuvering, it is considered that it is possible to maneuver under the reverse strong current in the original anchorage plan.

Table 6.6.9 Ship's Motion States in Approach Situation under Reverse Current (Anchorage shape :Original Plan / Current 3.5knots)

	Leeway Angle	Lateral Speed
No.25 - No.27	2.8^{o} (1.9)	-16.3cm/sec (-12.0)
No.27 - No.29	1.7^{o} (8.4)	-8.5cm/sec (-45.0)
Rate of Usage of Rudder (from No.27 buoy to entrance of anchorage)	less than 5^{o}	17.6% (48.8)
	5 – 10^{o}	6.2% (1.7)
	10 – 15^{o}	6.2% (1.7)
	15 – 20^{o}	8.8% (1.7)
	more than 20^{o}	61.3% (46.3)
Maneuvering Time (No.27 buoy - Anchorage)		17min

*( ): result of original plan (Case3)



*right figure: considering leeway angle

Figure 6.6.5 Ship's Track in Approach (Case7: Channel Widening Plan)

3) Berthing Maneuvering

In the berthing maneuvering by the pilot of HAI PHONG, in case of the same way current (flood tide), they berth the ship as the starboard side head out in order to stabilize with ship's posture. In this case, it needs rotate the ship in front of the berth. And in case of reverse current (ebb tide), they berth the ship as the port side head in.

As indicated previously, since the maneuverability is reduced under the flood tide, it was shown difficult situation in controlling the ship's posture and ship's position in approach to the anchorage. However, after entering the anchorage area, even if tidal current was strong, the ship was able to rotate in front of the southern berth and the ship was able to move to the berth parallel while controlling ship's posture. However, in this case, the ship approached close to the mooring vessel, it shows the high difficulty of the maneuvering under the strong tidal current. Since northern berth is located at the back of southern berth, a ship is able to enter with high speed. However, when a vessel is mooring on southern berth, northern berth's ship has to rotate in front of mooring vessel. Therefore, it needs exact positioning control not to approach close to the mooring vessel. In addition, in case of the flood tide, since the ship is drifted to north side, it needs attention not to approach close to northern edge of the anchorage.

According to the result, it was possible to rotate at proper position in the anchorage while controlling influence by wind and current, and it was possible to berth while controlling ship's posture. Regarding the lateral speed, the lateral speed was reduced to less than 5cm/sec at 20m from the berth (Case7-3). It was proper speed control.

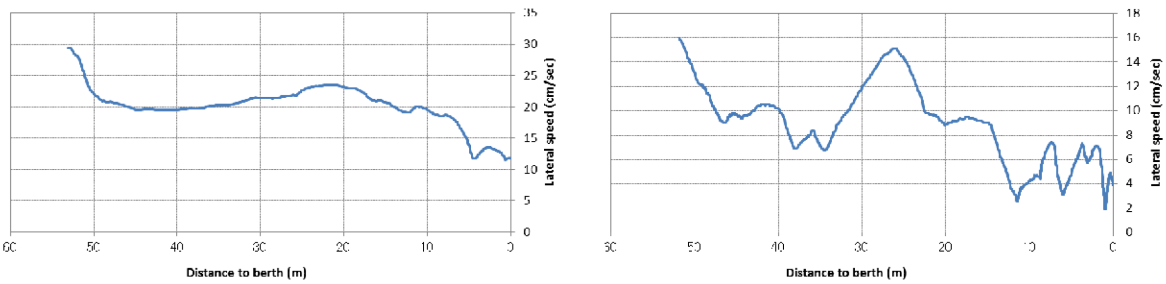


Figure 6.6.6 Lateral Speed in Berthing Situation (Case4, Case7-3)

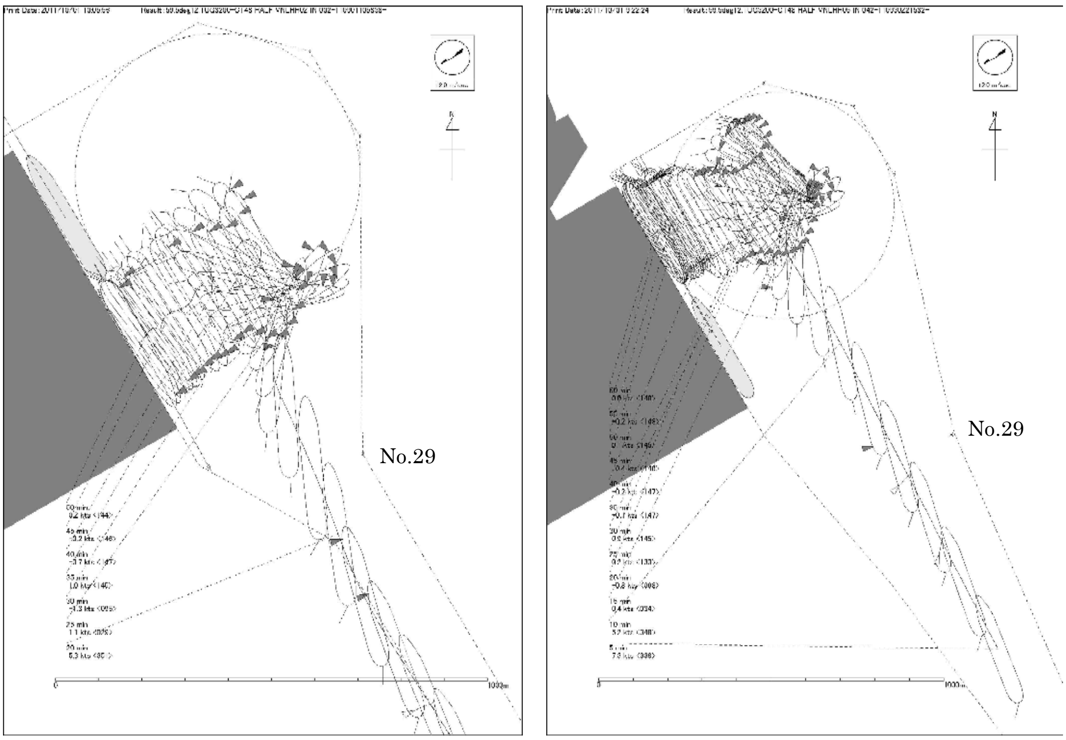


Figure 6.6.7 Ship's Track of Berthing Situation (Case4, Case7-3)

In the berthing maneuvering under the reverse current (ebb tide), since the ship is berthed as the port side head in, the maneuvering becomes easy compared with the same way current (flood tide). In the result of verification, it was possible to stop parallel in front of the berth, and it was possible to berth while keeping ship's posture parallel. And in the final phase of the berthing, the lateral speed was 12cm/sec.

4) Un-berthing Maneuvering

a) Un-berthing from Port Side Head In

i) The Same Way Current

In case of the un-berthing that is necessary rotating, since the ship's posture becomes abeam against tidal flow during turning, the drifting to downward flow becomes problem. After turning, tide becomes the same way current, and the ship has almost no speed. Therefore, the difficulty of the ship's posture control on entering to narrow channel is extremely high.

In the result, while receiving tidal flow from abeam during turning, the ship was drifted to downward flow. Eventually, the ship was drifted to the channel entrance before end of the turning. The lateral speed in drifting to downward flow reached 339.1cm/sec (Case9). In this situation, it no longer can control ship's posture.

The next verification was carried out by the pilot’s recommendation that 2 tugboats were arranged at the stern (Case11). However the ship was drifted to downward flow during turning in the same way as previous cases. Therefore, it was carried out under the half of the maximum current (1.7knots, Case12). Although the drifting to downward flow became small compared with under maximum current (3.5knots), the drifting speed exceeded 200cm/sec, and it was not able to control the drifting during the turning. Therefore, it was carried out under the three 4,000ps tugboats in order to increase the control ability of the drifting impact and the turning force. However, in the same way as other cases, the ship was drifted to downward flow.

Therefore, under the ebb tide (the same way current), if the ship is un-berthing from the portside head in, it is necessary to set the limitation of usage by tidal current.

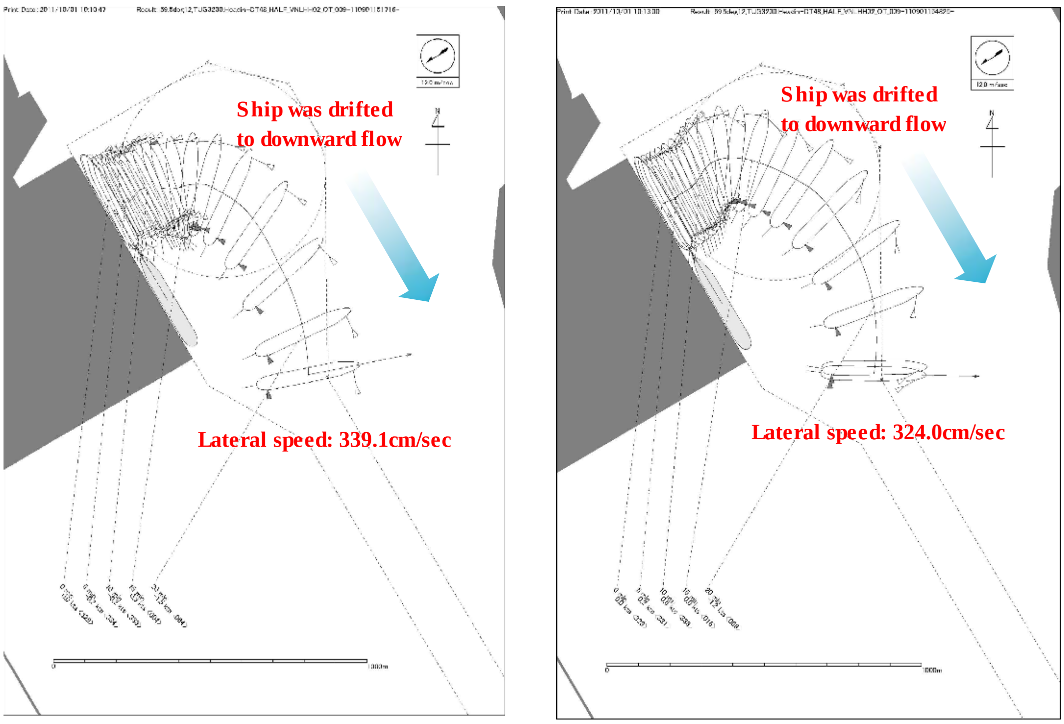


Figure 6.6.8 Ship’s Track in Un-Berthing from Port Side Head In Situation (Case9, Case10)

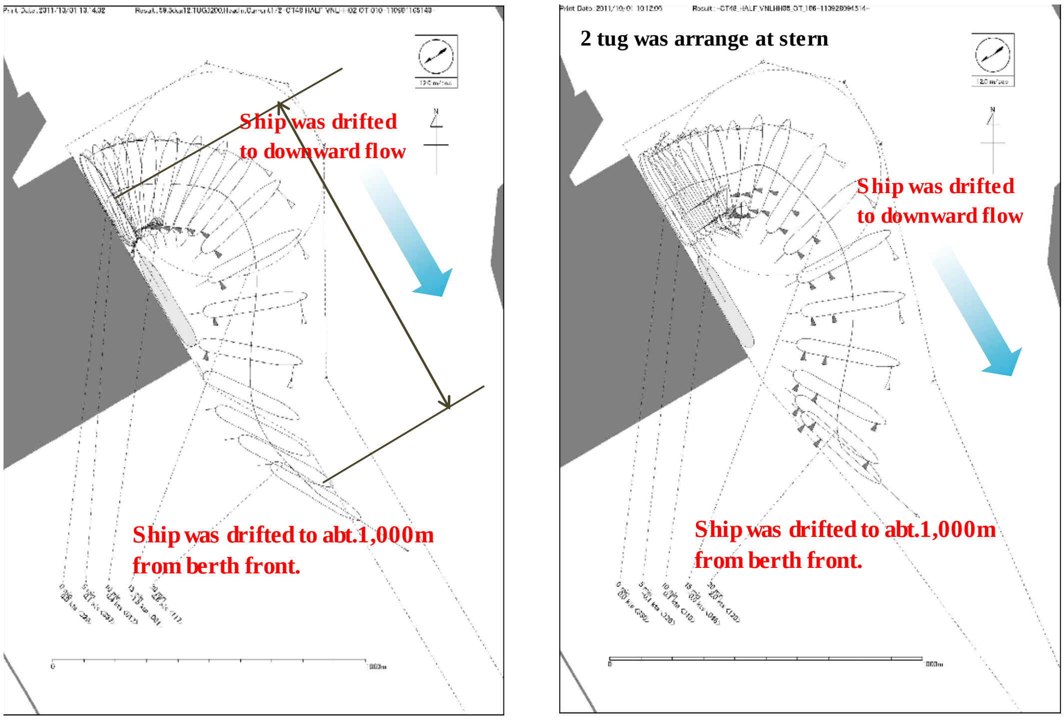


Figure 6.6.9 Ship's Track in Un-Berthing from Port Side Head In Situation (Case12, Case12-2)

ii) The Reverse Current

Since the maneuverability is not reduced under the reverse current, the un-berthing maneuvering and the turning positioning control becomes easy compared with the same way current (ebb tide). However, it is considered that the difficulty that the ship approaches to the channel while receiving strong reverse current in the unstable states after turning is extremely high. Therefore, in this verification case, the anchorage shape was assumed the channel widening plan in which the channel entrance designed widely (Case13).

According to the result, it was able to un-berthing from the berth against wind by 3,200ps tugboat. However, since the ship was not able to control ship's position during turning, it was drifted to the edge of the anchorage. Therefore, it was carried out the verification by 4,000ps tugboat (Case13-2). According to the result, although the ship was drifted to north side of the anchorage, the ship was able to rotate while controlling ship's posture and it was possible to approach to the channel. However, as the figure shows, since the ship was drifted close to the north side of the anchorage by tidal current, this tidal current condition is considered the limit in the maneuvering in which turning is required in front of the northern berth. In case the un-berthing from the southern berth, it was possible to control easily, since the maneuvering space of the downward flow side was larger.

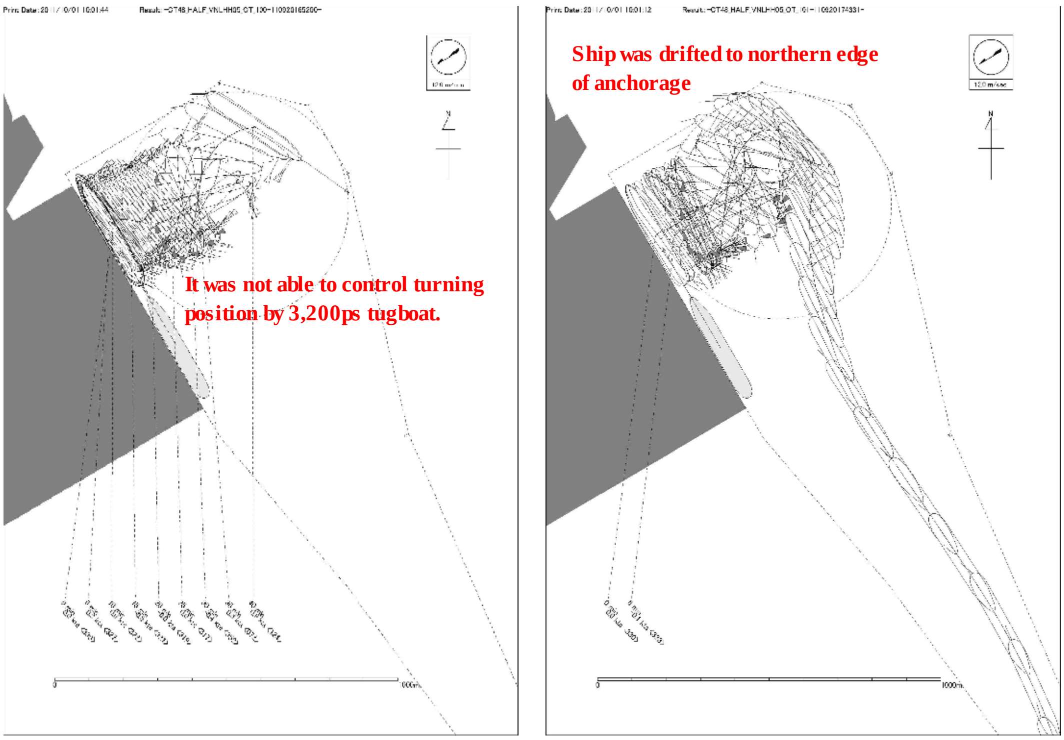


Figure 6.6.10 Ship's Track in Un-Berthing under Reverse Current (Case13, Case13-2)

b) Un-berthing from Starboard Side Head Out

In the case of the un-berthing from the starboard side head out, since it is not required the turning in front of the berth, the maneuvering becomes easy compared with the port side head in. However, under the same way current (ebb tide) that the maneuverability is reduced, the possibility of positioning control and ship's posture control becomes matter.

According to the result of verification, the ship was not able to have enough distance from the berth by 3,200ps tugboats against the strong onshore wind under the strong tidal current (Case14). In the process of the approach to the channel, the ship was drifted to lee way since the ship was not able to have enough maneuverability. Due to this, the ship approached close to the edge of channel west side.

Therefore, the simulation was carried out under 1.7knot that was the half of maximum current velocity (Case14-2). And the tugboats were assumed 4,000ps in order to get stronger pulling power in un-berthing. According to the result, since the tugboat's power was increased, the ship was able to have enough distance from the berth. And the falling of maneuverability by tidal current became small since the tidal current velocity became low. It became to be possible to control ship's posture and position compared with strong current (Case14). However, it was not able to approach while having the leeway angle since the channel entrance was narrow, and the ship sailed while drifting to lee side.

Under the tidal current in which the maneuverability becomes low, to maneuver while considering the drifting influence is extremely difficult and dangerous. Therefore, it is necessary to extend the channel entrance in order to approach safely while having the leeway angle by wind and tidal current.

According to the result of verification (Case14-3), since the channel entrance became wider, the ship was able to approach to the channel while having leeway angle that was considered the drifting to lee side.

The maneuvering under the reverse current was different from the same way current (ebb tide). This maneuvering became easy compared with the same way current since the maneuverability was not reduced.

According to the result of verification, although the ship was having the influence of drifting to lee side, since the maneuverability was not reduced, it was possible to control the ship's posture during approaching to the channel entrance, and there was no problem in maneuvering.

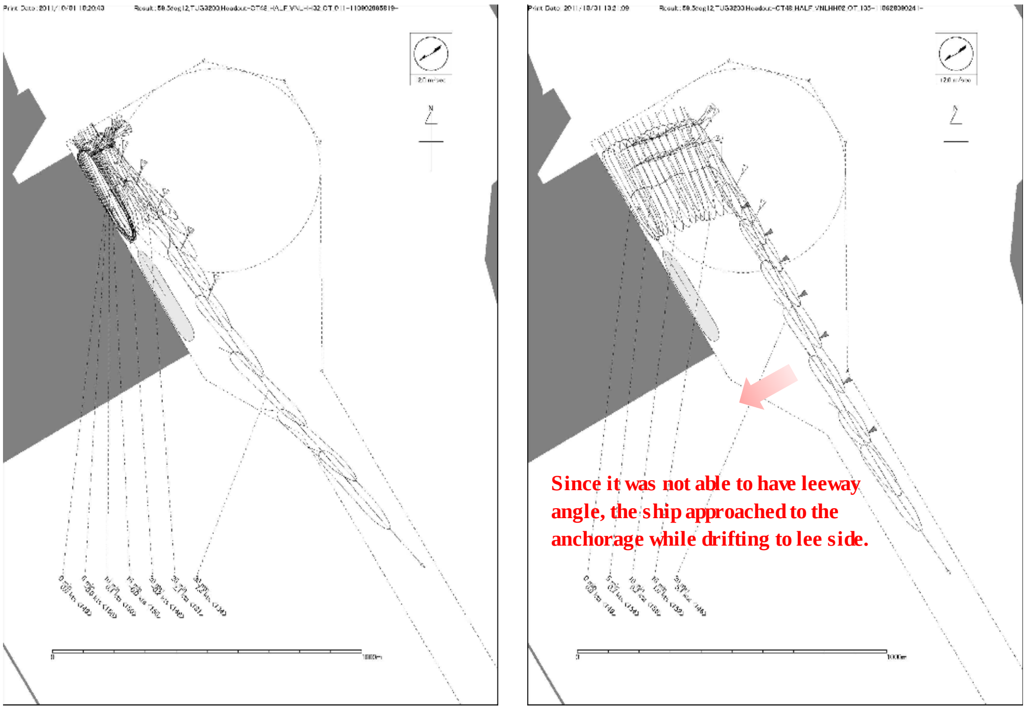


Figure 6.6.11 Ship's Track in Un-Berthing from Starboard Side Head Out (Case14, Case14-2)

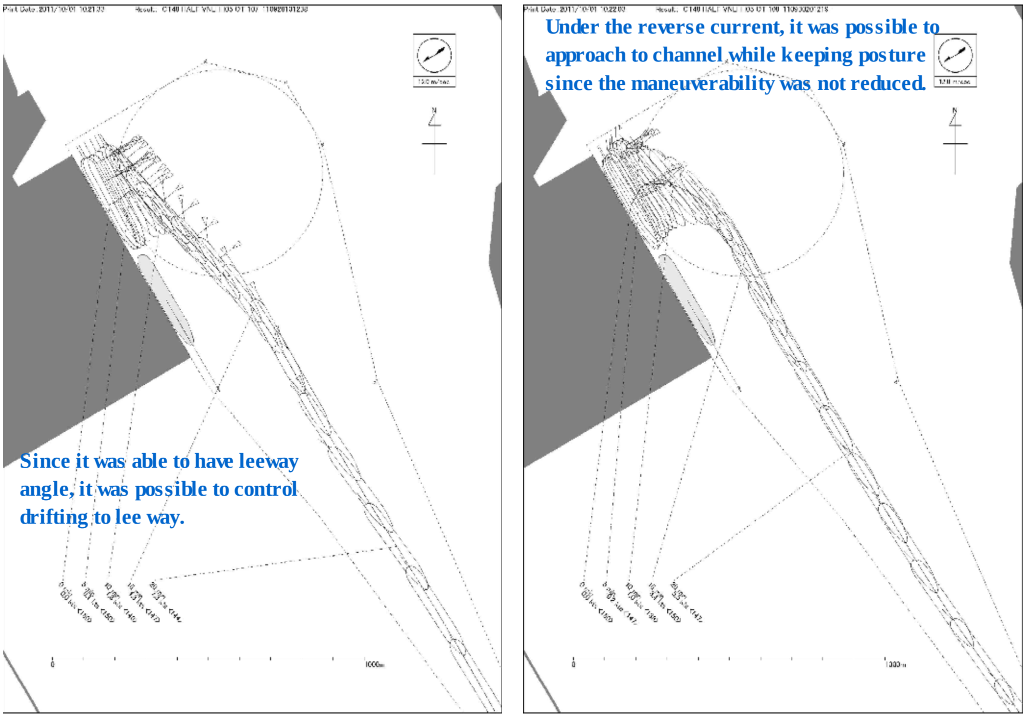


Figure 6.6.12 Ship's Track in Un-Berthing from Starboard Side Head Out (Case14-3, Case15)

6.6.4 Evaluation

Table 6.6.10 shows the verification cases.

Table 6.6.10 The Result of Verification

No.	Maneuvering Situation	Design	Berthing Side	Target Berth	Natural Conditon		Tugboat		Verification Objective	Possibility of Maneuvering
					Current(knot)		HP	Num.		
1	Channel Passing	Original Plan	-	-	flood tide	3.5	3,200	2	Verification about safety of channel passing	Possible *one way essential
2										
3	Berthing	Original Plan	Head Out	Southern Berth	flood tide	3.5	3,200	2	*Verification about approach maneuvering under same way current *Verification about turning and berthing maneuvering under same way current	Impossible
4										
5						1				Possible *However, maneuvering difficulty is high since can not have leeway angle.
6										
7		Widening Plan		Southern Berth		3.5				Possible
7-2										
7-3				Northern Berth						Possible
8		Original Plan	Head In	Southern Berth	ebb tide				Verification about turning and berthing maneuvering under reverse current	Possible
9	Un-Berthing	Original Plan	Head In	Northern Berth	ebb tide	3.5	3,200	2	Veriication about un-berthing and turning maneuvering from portside head in *difficulty is high in ebb tide (same way current)	Impossible
10										
11										
12						1.7				Impossible
12-2		Widening Plan				1.7	4,000	3		Impossible
13					flood tide	3.5	3,200	2		Impossible
13-2							4,000	2		Possible
13-3				Southern Berth		3.5	3,200	2		Possible
14		Original Plan	Head Out	Northern Berth	ebb tide	3.5	3,200	2	Veriication about un-berthing maneuvering from starboard side head out *difficulty is high in ebb tide (same way current)	Possible *However, difficulty of controlling ship's posture is high under the same way current.
14-2						1.7	4,000	2		Possible
14-3		Widening Plan				3.5				Possible
15					flood tide	3.5	4,000	2		Possible

*yellow: These cases were carried out by Vietnamese

1) Passage in the LACH HUYEN Channel

According to the result of verification, it was possible to control the ship's posture under the strong wind and strong tidal current. However, in the passing of the channel, even if the ship was in position in the center of the channel, the distance to the edge of the channel is only 50m or 60m, it is not enough space for maneuvering. Therefore, it is necessary to limit ship traffic as the one way channel for the safety of large ship's passage.

To respond by own ship maneuvering when the large ship encounters other ship in the narrow channel is extremely difficult and dangerous. Therefore, the channel maintains as the ship traffic control channel, and it is necessary to be managed by VTS to avoid the overtaking and the crossing by small crafts in the channel.

Since the water depth in HAI PHONG Port is shallow, most of the ships are using the tide. In addition, since the tidal cycle in HAI PHONG Port is one time in the day, a lot of ships are entering, leaving the port at the same time with the high tide. Therefore, the one way traffic control in long periods would be a large impact to other ships. In this verification, the passage time in the channel was 53 minutes (from No.1 buoy to the anchorage). And if it is necessary to rotate in front of the berth, it needs about 20 minutes in additional. Moreover, if the shift time of the traffic control takes into account, the ship traffic control time would be more than half an hour.

And if the number of the large container vessel that uses the LACH HUYEN container terminal increases in the future, it has possibility that the influence of wait occurs between the arriving ship and the leaving ship. Therefore, LACH HUYEN Channel has to be maintained as the two way channel in the future.

2) Approach to the Anchorage

As the ship approaches the anchorage, ship's velocity was decreased. In the verification, it was about 6knots at the last way point (No.27, No.28 buoy), and the velocity was decreased until about 5knots when the ship came into the anchorage. The ship receives strong impact from wind, tidal current under the low speed. Depending on the wind direction, the ship is drifted larger. In this case, it is significant to keep the ship's posture properly. However, under the same way current (flood tide), it becomes extremely difficult to keep ship's posture by own ship rudder since maneuverability is reduced. In addition, since the speed on the ground is higher than the tidal current velocity, it is not able to use the engine strongly to keep the ship's posture. Therefore, it has to keep the ship's posture by the ship's thruster and the tugboats. However, if the ship has the velocity, the thrust power of the ship's thruster and tugboat is not able to put forth sufficiently.

The result of the maneuvering in the original anchorage plan was different by the tidal flow direction (ebb tide / flood tide). In case of the flood tide (the same way current), in addition to reducing the maneuverability, since the entrance of the connection between the channel and the anchorage was narrow, it was not able to approach while having the leeway angle. Due to this, the ship was drifted to lee side. Therefore, it is necessary to establish the tidal velocity limitation that is less than 1.0knot under the original anchorage plan.

In case of the ebb tide, since the maneuverability is not reduced, it was able to approach to the anchorage while keeping ship's posture under the strong tidal current.

In this way, the matter of the approach maneuvering is to control the ship's posture to not deviate from the channel under the flood tide (the same way current) in which the maneuverability reduces. However, it was possible to resolve by widening connection area between the channel and the anchorage. According to the result of the channel widening plane, it was possible to approach while having leeway angle, or even if the ship was drifted to lee side, the ship was able to be sailing in the channel.

3) Berthing Maneuvering

In the berthing maneuvering, it had the matter under the flood tide (the same way current). In the berthing under the flood tide, the ship was berthed as the starboard side head out after the rotating in front of the berth in order to get the ability of the ship's posture control. In case of the berthing under the ebb tide (reverse current), since it was not necessary to rotate in front of the berth after entering the anchorage, the difficulty of maneuvering was low.

According to the result of verification, in the approach situation, it was considered that the tidal current limitation was necessary under the original anchorage plan in order to be able to approach safely to the narrow entrance while keeping the ship's posture. However, after entering to the anchorage, it was possible to be rotated while controlling ship's position properly under the strong tidal current since the maneuvering space was enough. Afterwards, it was possible to become berthing posture properly.

In the berthing situation after the rotating, it was necessary to control the ship's posture while keeping parallel and it had to control the lateral speed to not become too large. According to the result of verification, it was able to be berthed in lateral speed 5cm/sec-12cm/sec while keeping the ship's posture parallel, while using thruster and tugboats.

4) Un-Berthing Maneuvering

In the un-berthing maneuvering, it also had the matter under the ebb tide (the same way current). If the ship is berthed as the port side head in, it is necessary to rotate when the ship is leaving from the berth. According to the result of verification, in the turning maneuvering under the strong ebb tide, the ship was drifted largely to downward flow during turning. Besides, this was not able to control by three 4,000ps tugboats under the tidal current 1.7knots in the channel widening plan.

Therefore, the un-berthing from the port side head in has to be used under the small tidal current (less than 1.0knot).

In case of the un-berthing from the starboard side head out, it is not necessary to rotate. However, under the ebb tide that the maneuverability is reducing, it needs to keep the ship's posture and ship's position toward the channel entrance. This maneuvering difficulty is high.

According to the result of verification, under the original anchorage plan, the ship approached close to the west edge of the channel. Because the channel entrance was narrow, the ship was not able to have the leeway angle in order to control the drifting by wind. However, it was able to maneuver under the smaller tidal current (1.7knots) even if it was under the original anchorage plan. Or under the channel widening plan, it was able to maneuver even if the tidal current was strong (3.5knots).

And in case of the un-berthing under the reverse current (flood tide), there was no problem in the maneuvering.

6.6.5 Recommendation

1) Ship Traffic Control in LACH HUYEN Channel

The designed channel width 160m that was calculated by PIANC (Permanent International Association of Navigation Congress) was assumed as the one way channel.

According to the verification results, the maneuvering space was not enough even if the large vessel was sailing in the center of the channel. Therefore, encountering other ships in the channel is impossible. Therefore, LACH HUYEN Channel has to be the one way channel as same as HA NAM Channel. In addition, it is necessary to limit overtaking, crossing by the small crafts in the channel, and it is necessary to control and monitoring the ship traffic by VTS. To do so, it is necessary to improve the remote monitoring functions such as the ITV camera, Rader, AIS monitoring system and so on in the LACH HUYEN Channel.

2) The Arrangement of the Navigation Buoy

It was confirmed that the arrangement of the navigation buoy that were located in the design were proper. However, it is appropriate to remove the buoy that is located at the entrance of the anchorage due to become obstacle to the assistance by the tugboat.

Table 6.6.11 Removing Navigation Buoy from the Design

Channel and Anchorage Shape	Removing Buoy from Design
Original plan	No.30
Channel widening plan	No.28, No.30

3) Arrangement of Tugboat

According to the result of verification, it is possible to maneuver in berthing, un-berthing, turning by 3,200ps tugboat. However, under the strong wind (12m/sec) that was assumed in this verification, the tugboat's power is desirable to assume 4,000ps in order to maneuver safer and quickly.

4) The Using Limitation under the Tidal Current

The tidal current limitation is different by the anchorage shape (Original plan / Channel widening plan). The tidal current limitation in respective plan shows below.

Table 6.6.12 Tidal Current Limitation (Original plan)

Berthing/Un-berthing	Berthing States	Current Direction	Current Limitation
Entering Port		Flood tide	less than 1.0knot
		Ebb tide	-
Leaving Port	Port side head in	Flood tide	-
		Ebb tide	only slack tide
	Starboard side head out	Flood tide	-
		Ebb tide	less than 2.0knots

Table 6.6.13 Tidal Current Limitation (Channel widening plan)

Berthing/Un-berthing	Berthing States	Current Direction	Current Limitation
Entering Port		Flood tide	-
		Ebb tide	-
Leaving Port	Port side head in	Flood tide	-
		Ebb tide	only slack tide
	Starboard side head out	Flood tide	-
		Ebb tide	-

5) The Shape of the Connection between the Channel and Anchorage

In the original channel and anchorage plan, it is necessary to establish the tidal current limitation in order to use safely under the same way current (entering port: flood tide, leaving port: ebb tide).

Most of the ships in HAI PHONG Port are using the tide. If the tidal limitation is established in the designed container terminal, the large container vessel would compete with these ships that are using HAI PHONG Port. This meaning, it not only gives the large impact to other ships, it is considered that the container vessel is not able to enter / leave to port depending on the situation. In addition, the liner ship such as the container vessel, such a limitation becomes big problem in the arrangement ship.

Therefore, the anchorage shape is desirable to consider the widening plan that is widening connection between the channel and the anchorage. In the container terminal that will play role as the international port, any conditions that limit their terminal operation should be eliminated as much as possible. In that sense, it is essential that the anchorage shape will be enlarged.

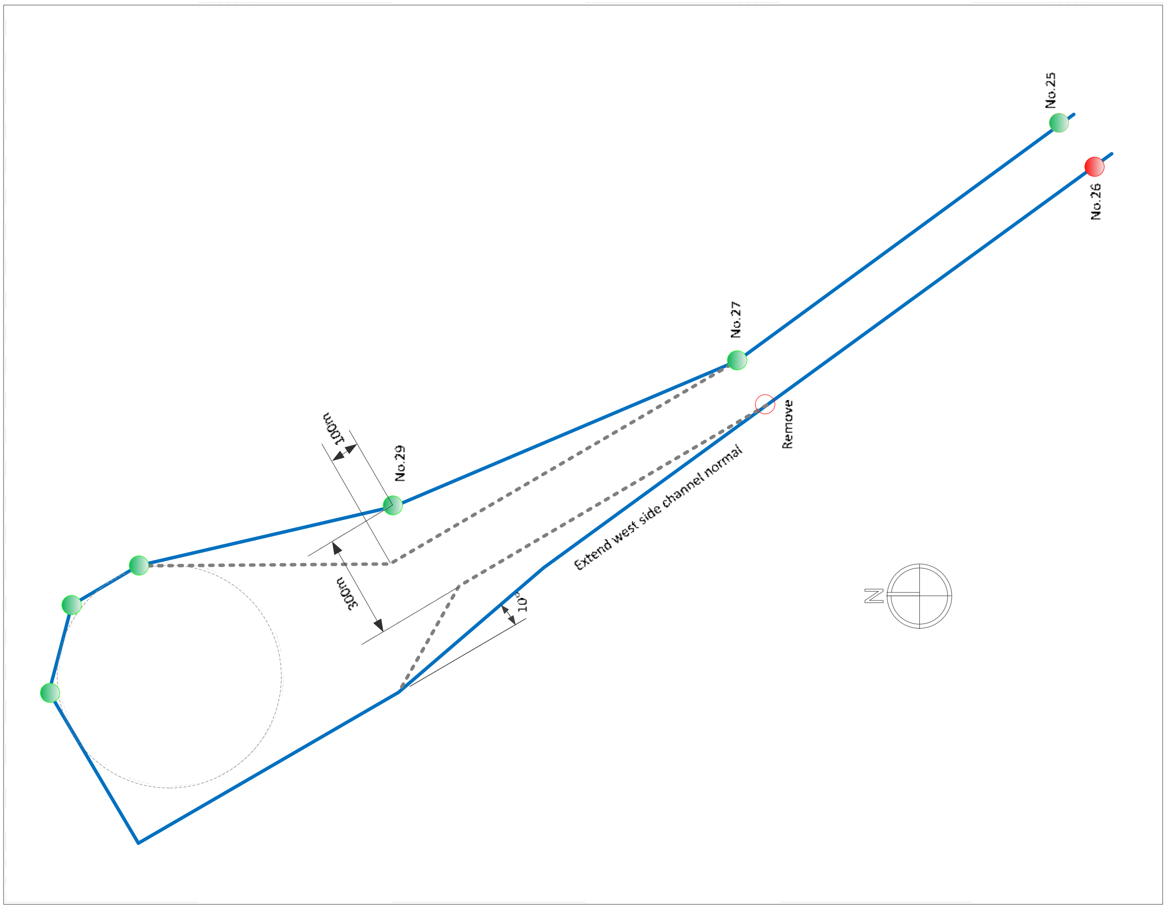


Figure 6.6.13 Channel widening plan

6) Necessity of the Training for Pilots

It was confirmed that the maneuvering to the container terminal in the LACH HUYEN Channel and the anchorage was required extremely difficult maneuvering depending on the natural condition. The drifting impact due to wind and current that was seen in the verification has risk to cause the accident such as ship grounding, collision, touching with high voltage cable etc. And, if such accidents occur, the damage that gives to the environment and resident's life is extremely high.

Therefore, it is desirable to carry out the training for pilot to enhance maneuvering skill using a ship-handling simulator in order to be able to respond appropriately in any natural conditions, berthing conditions, ship traffic conditions.

7) Necessity of the Training for VTS Operator

If the ship traffic control as the one way is conducted in the channel, the time of the control will become quite long, moreover, control channel will increase to 2 sections in addition to HA NAM Channel. Such a control is difficult to operate under the present control in which the ships are managed by berthing / un-berthing time. And it is required advanced channel management skill of the ship traffic control.

Therefore, it is necessary to consider installing the training system, the education system that is conformable with world standard of the ship traffic control operator.

6.7 Terminal Road Design

6.7.1 Traffic Demand of Terminal Access Road

Volume of container is forecasted as 2,282,000TEU in 2020. It will be transported through a road, a railroad, or the other modes such as small ships.

Assuming 80% of containers will be transported through the road, the port road should transport 1,826,000 TEU/Year. Since 40’ trailer will be mainly used for transportation, 912,800 cars per year will pass the road in both directions because import or export needs the same number of empty containers.

As for the general cargo, assuming an allotment by transportation mode like Table 6.7.1 and assuming that 10-ton trucks will be used for road transportation, 198,900 cars per year will use the road. Therefore, the large-sized vehicle will pass 1,111,700 times per year in total.

Assuming that these cars will be distributed evenly in 10 working hours per day, the traffic volume is estimated as 309 cars/hr.

The above is mainly the large freight car. Ancillary vehicles will be generated by the port activity. Assuming these additional cars as 15%, total number of cars to pass the port road is forecast as 355 cars.

Table 6.7.1 Estimation of Car Traffic on the Port Road

Item	Year	
	2020	2030
Container (000TEU)	2,282	9,490
Road (80%)	1,826	7,592
Rail (15%)	342	1,424
Other (5%)	114	475
General Cargo(000ton)	2,652	9,308
Road (75%)	1,989	7,446
Rail (15%)	398	1,396
Other (10%)	265	465
Number of Vehicles per year		
Container Trailer (40')	912,800	3,796,000
Truck (10ton)	198,900	744,640
Large Vehicle Total	1,111,700	4,540,640
Working Hour/Year	3,600	3,600
Large Vehicle/hr	309	1,261
Additional Vehicle(15%)	46	189
Total Vehicle/Hr	355	1,450
Design Capacity per lane	500	500
Required Number of Lanes	0.7	2.9

6.7.2 Lane Arrangement

The design capacity of the port road is normally 500 /lane/hr. On the other hand, the port road which is adjacent to the container terminal shall have a minimum of two lanes. One lane is a slow speed lane and the other lane is a normal speed lane.

In addition to above passing lanes, parking lane, shoulder, median and sidewalk should be provided as well. Parking has two lanes along the terminal fence in order to secure enough parking capacity. Shoulder for motor-bike passage and emergency parking at accident is provided in both sides, and the width is 2.0 m.

Median is 20 m in width which is 120 % of overall trailer length. It allows trailers to turn without inconveniencing other cars. Sidewalk is provided in both sides. Both sides of sidewalk have different widths, namely 4.5 m at terminal side and 2.5 m of the opposite side, since much pedestrian volume is expected at terminal side.

The total road width behind terminal is planned to be 53.5 m for year 2020 as shown in Figure 6.7.1.

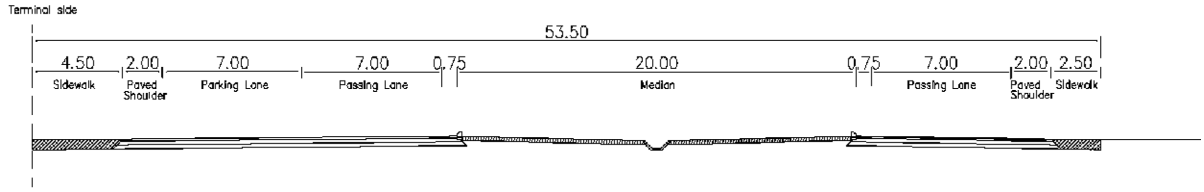


Figure 6.7.1 Typical Cross Section of Road Behind Terminal in 2020

Future develop plan should be also considered when the development plan is established even for the initial stage. However, there is no concrete future port development plan to date, therefore, it is assumed that eight lanes of passing lane are required for future road expansion along the 15 km long berths.

Considering the smooth traffic flow of road in the port, terminals along access channel shall be divided into several groups, and four lanes of traveling lane are provided just behind the terminals, and eight lanes of passing lane are provided behind traveling lane (see Figure 6.7.2 and Figure 6.7.3).

Total road width will be 114 m in the future.

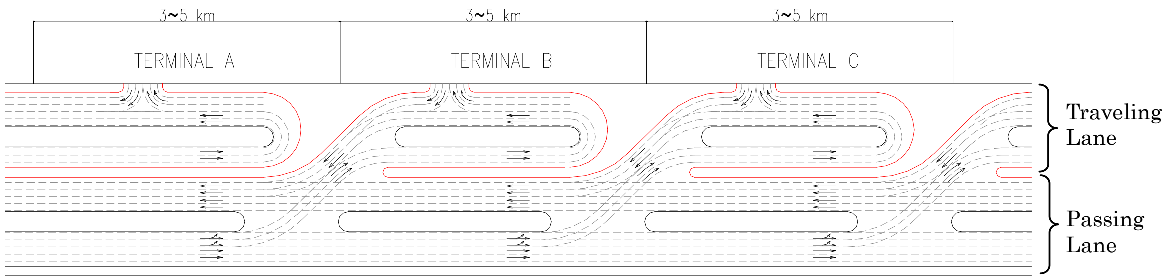


Figure 6.7.2 Layout of Traveling Lane and Passing Lane

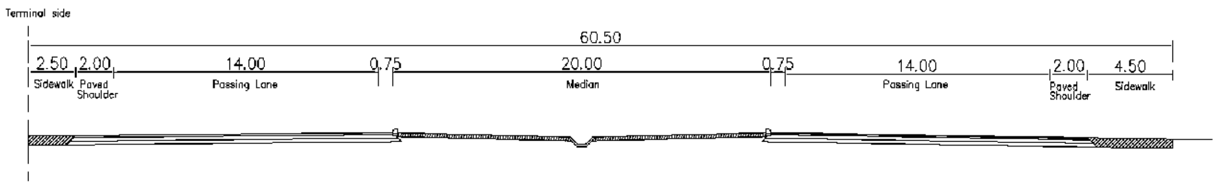


Figure 6.7.3 Typical Cross Section of Passing Lane (Future)

40 m wide of railway space will be secured for the future development as well, although the schedule of railway construction has not been fixed to date. Typical cross section of road and railway area behind terminal is shown in Figure 6.7.4.

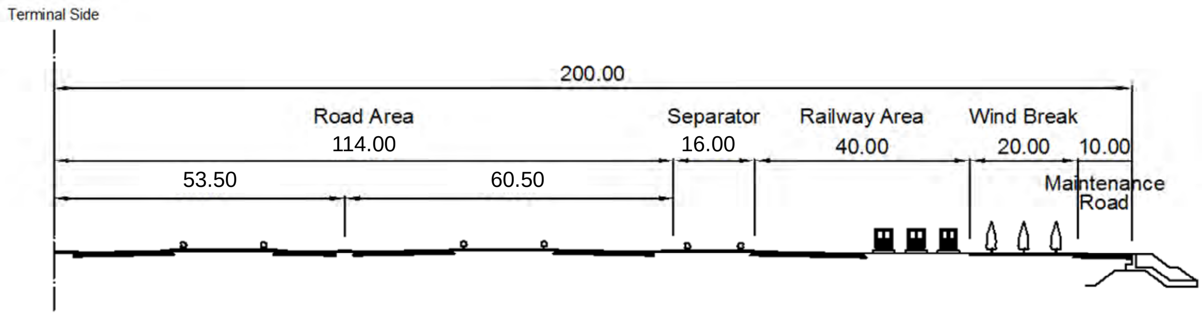


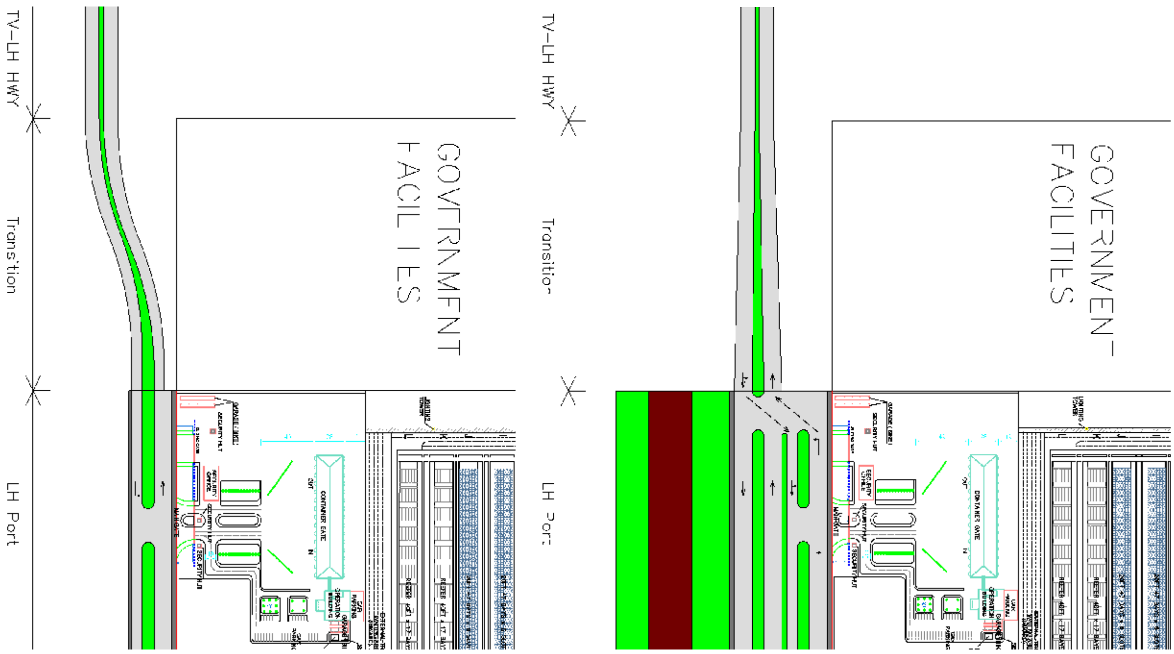
Figure 6.7.4 Typical Cross Section of Road and Railway Behind Terminal (Future)

6.7.3 Connection between Tan Vu- Lach Huyen Highway and Port Area

Connecting point between Tan Vu-Lach Huyen Highway and port road (road behind terminal) will be changed from initial stage to future stage in accordance with the expansion of port road development.

The alignment of Tan Vu- Lach Huyen Highway is planned based on the future plan of the port road, and therefore, transition section must be provided at the initial stage.

The image of transition is shown in Figure 6.7.5. The length of transition section is 290 m, and it starts from Km15+630.



Initial Stage Future Stage

Figure 6.7.5 Transition between Tan Vu-Lach Huyen Highway and Port Road

6.8 The Scope of Work and Contents

6.8.1 Contents of the Project by MOT Decision

MOT approved the Hai Phong International Gateway Seaport Construction Investment Project for the commencement stage by the Decision No. 476/QD-BGTVT, dated 15 March, 2011 with key contents divided into two (2) components, i.e., Component A which shall be implemented by VINAMARINE implementation agency MPMU II under the Government budget (ODA and counter fund) and Component B which shall be responsible by Joint Venture between VINALINES and Japanese partners to be implemented for the objectives of the Project.

To meet the demand for accepting container vessel with tonnage up to 50,000 DWT full load and 100,000 DWT less load

(1) Component A (Public):

(a) Vessel Channel

(b) Turning Basin

(c) Breakwater (Outer Breakwater) and Sand (Protection) Dyke

(d) Port Service Road in administration area

(e) Architectural Works in the area for state management agencies

(2) Component B (Private):

(a) Container Berth Construction including Soil Retaining Wall

(b) Barge Berth

(c) Reclamation and Soil Improvement including Road and Yard inside the port

(d) Architectural facilities for Container Berth

(e) Utilities for Container Berth

(f) Cargo handling equipment

In addition to above, Component A includes “Land Clearance and Resettlement” to be implemented in accordance with by Document 1665/TTg-CN dated 17 October 2006 and Component B includes compensation work and land clearance to be implemented in accordance with the regulation.

6.8.2 Demarcation of Work Contents for Public Sector and Private Sector

Based on the above Decision, two (2) options for the demarcation of scope of works for public sector and private sector were proposed as follows:

(1) Option 1: In case the item of land reclamation and soil improvement belongs to Component B

(2) Option 2: In case the item of land reclamation and soil improvement belongs to Component A

Through discussion with MOT in a course of Detailed Design Study, it was settled that Option 2 was applied to the Project provided the cost burden share for land reclamation and soil improvement shall be negotiated and determined between the Government of Vietnam and Private operator.

Based on this understanding, JICA Study Team considers that the scope of the work for Public and Private Component as well as the work covered by JICA ODA loan finance for the Project was allocated as summarized in table below:

Table 6.8.1 Demarcation of Scope of Works for Public Sector and Private Sector

Work Item		Public		Private
		VN	JICA ODA	
1	**Dredging and Dumping**			
1.1	Dredging Vessel Channel		●	
1.2	Dredging Turning Basin		●	
1.3	Dredging Berth Box Area			●
1.4	Seabed Slope Excavation under Terminal Berth			●
1.5	Dredging Service Boats Berth/Barge Berth		●	
2.	**Container Terminal**			
2.1	Land Reclamation w/t Soil Improvement and Embankment		●	
2.2	Berth Construction			●
2.3	Barge Berth			●
2.4	Yard & Road Pavement			●
2.5	Architectural Facilities			●
2.6	Utilities			●
2.7	Cargo Handling Equipment			●
3.	**Port Service road**			
3.1	Land Reclamation and Embankment		●	
3.2	Surface Pavement w/t Soil Improvement		●	
4.	**Outer Revetment (Breakwater)**		●	
5	**Sand Protection Dyke**		●	
6	**Public Related Facilities**			
6.1	Land Reclamation		●	
6.2	Service Boat Berth with Berth fitting utility facilities		●	
6.3	Road Pavement	●		
6.4	Buildings	●		
6.5	Utilities	●		
7	**Navigation Aids**			
7.1	Navigation Aids along Channel	●		
7.2	Light Beacons along Sand Protection Dyke		●	

6.8.3 Project Scope

Based on the demarcation of work contents as above, the scope of the work for Lach Huyen Port JICA ODA Project is summarized as follows.

Table 6.8.2 Project Scope for Japan's ODA Loan

No.	Work Item	Description
1.	**Dredging**	
1.1	Access Channel & Turning Basin	Channel: Width 160m, Depth -14.0m CDL, Slope 1:15 for the depth above CDL-10m and Slope 1:10 for the depth below CDL-10m, Length 17.4 km, Turning Basin: Diameter 660m, Depth -14m CDL, Slope 1:10/1:15
2.	**Navigation Aids**	Beacon Markers on Sand protection dyke: 6 sets
3	**Reclamation**	
3.1	Land Reclamation	752mL x 750mW, Top EL +4.5m Access Road area: 200mW, Top EL +5.5m
3.2	Soil Improvement	CDM: 32,990m^2 including barge berth area PVD: 568,554m^2 including port service road area
3.3	Retaining Wall	Container Berth side: Steel Sheet Pipe Pile Wall, Length 763m, Top EL+5.5m Barge Berth side: Steel sheet pile Wall, Length 180.5m, To EL +5.5m
3.4	Inner Revetment	South side: Rubble mound, Length 709m, Top EL +5.5m
3.5	Port Service Road	Asphalt pavement, Width 53.5m, Length 1,000m
4.	**Protection Facilities**	
4.1	Outer Revetment	Top EL of Coping Concrete +6.5m, Covered by Wave Dissipation Concrete Blocks, Soil Improvement, Length 3,230m
4.2	Sand Protection Dyke	Top EL +2.0m, Length 7,600m
5.	**Public Related Facility**	
5.1	Land Reclamation	Area 170,550 m^2, V=233,708 m^3 including Port Service Road area
5.2	Dredging Berth Box	CDL-5.0m, 155,431 m^3
5.3	Service Boat Berth	347mL x 10mW x -5m Depth, Sheet Pile Wall with Berth fitting and water supply facilities
5.4	Peripheral Embankment	Sloped Rubble mound, Length 966.5 m

General Layout of JICA ODA loan Project is presented in Figure 6.8.1 to Figure 6.8.3 respectively

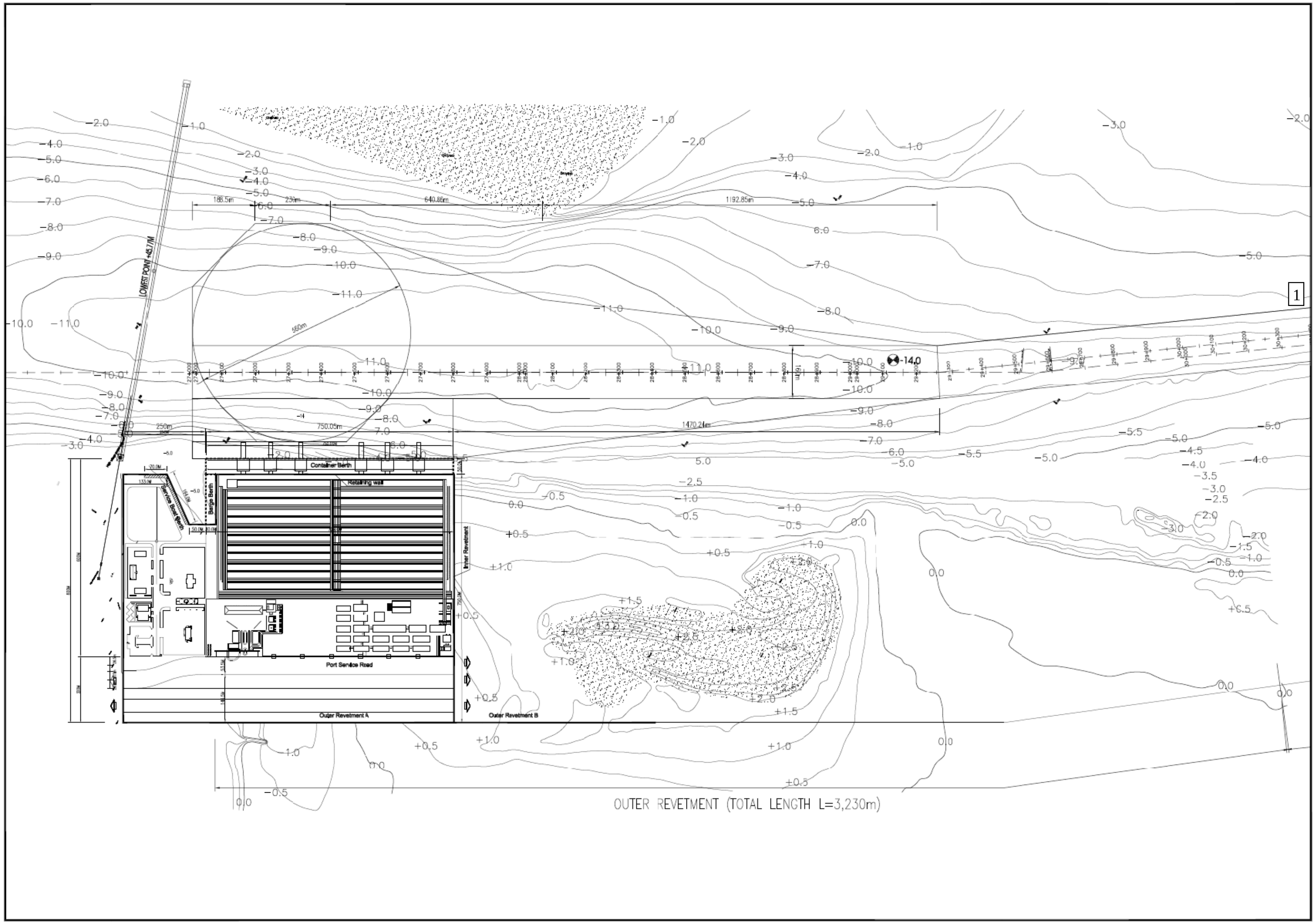


Figure 6.8.1 General Layout Plan-1

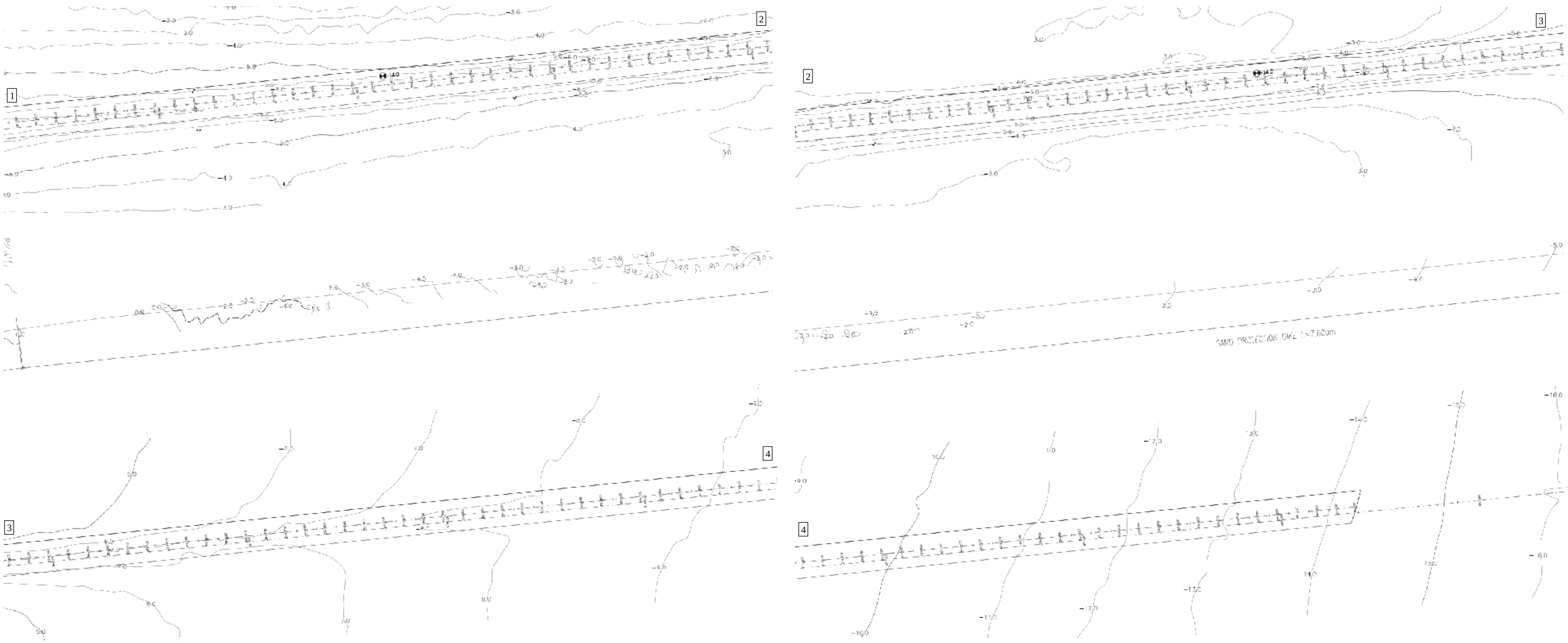


Figure 6.8.2 General Layout Plan-2

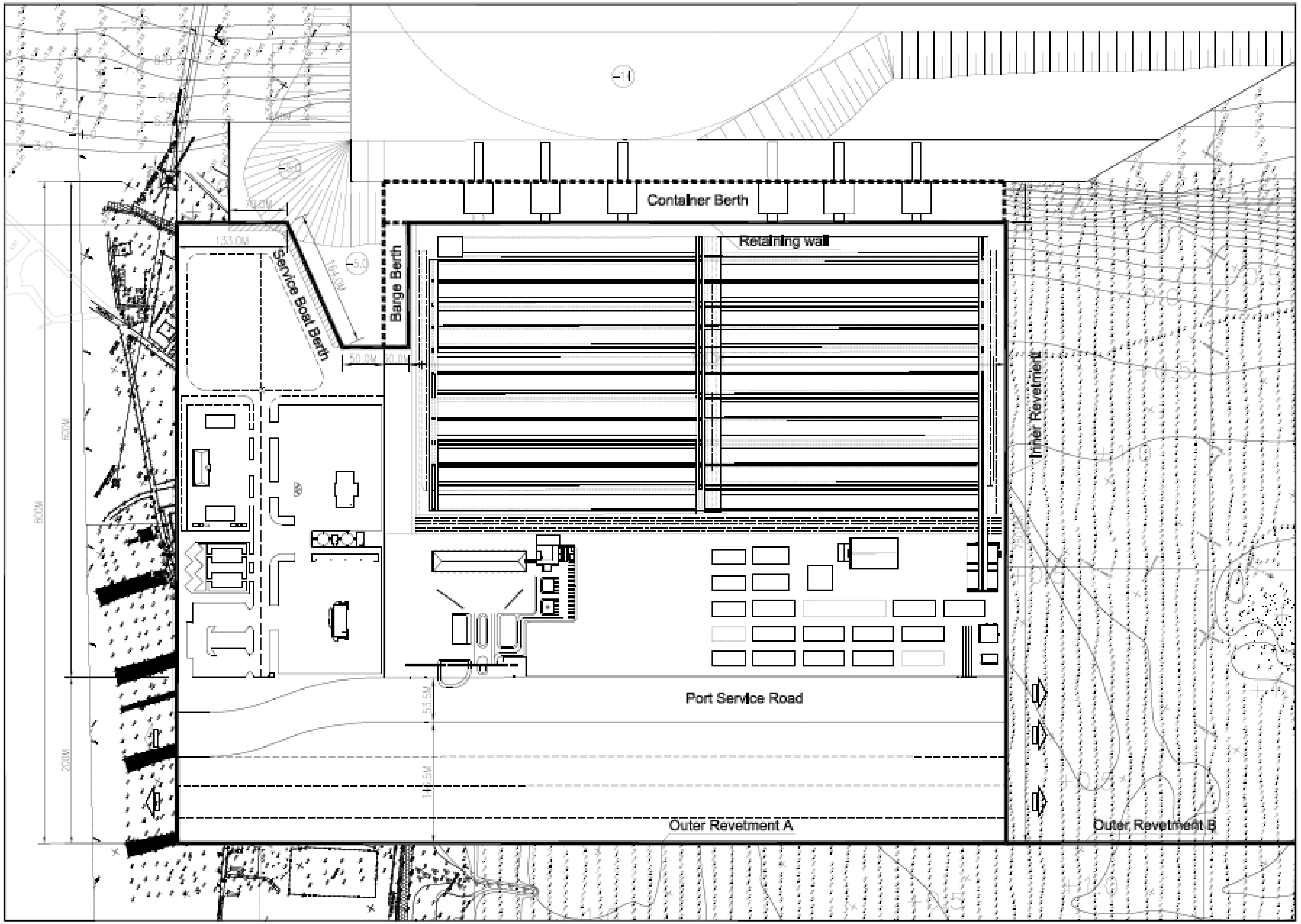


Figure 6.8.3 Layout Plan of Reclamation Area

DIVISION – II

BASIC DESIGN

7. RECLAMATION AT TERMINAL AREA AND ACCESS ROAD AREA

7.1 Design Conditions

The design conditions were determined for the purpose of executing the basic design for the Project. In the process of determination of design criteria, primary design criteria proposed by the previous studies were carefully reviewed.

The Chapter 2 of this report summarizes data and information on meteorology, oceanography and subsoil conditions that were derived from the previous study report and obtained through the site survey and investigation during this design study. Based on these data and information, and the study on the applicable design code and standards, the conditions applied to the design of port facilities were determined as discussed in the following subsections.

7.1.1 Operational Conditions

The design life of the port facilities is assumed as 50 years.

7.1.2 Natural Conditions

1) Tidal Condition

The tidal condition described in the Preparatory Survey report was presented in the TEDI's F/S report. According to the F/S report, the design tidal condition was determined by the extreme probability analysis based on historical water level observation data collected at Hon Dau Station from the year 1974 to 2004. In this Study, the extreme analysis has been conducted again by use of the data including the latest five years ones from the year 2005 to 2009. The result of the analysis conducted in this study shows that the tidal level of 100-years return period (equivalent to 1% probability of exceedance) is almost same as the previous analysis. Therefore, the same tidal conditions presented in the Preparatory Study report listed as below were applied to the design.

- HHWL : CD +4.43 m (as 100 years return period or 1% exceeded probability)
- HWL : CD +3.55 m
- MWL : CD +1.95 m
- LWL : CD +0.43 m
- LLWL : CD +0.03 m (observed on January 2, 1991)

(Note: CD refers to Chart Datum, which is nearly the level of the Lowest Astronomical Tide)

2) Wave Condition

Offshore design wave data described in the Preparatory Study report are as follows:

- Offshore Wave Height (H_0) : 5.6 m
- Wave Period (T_0) : 11.6 sec
- Predominant Wave Direction : S to E

(As offshore waves with 50 years return period)

According to the Preparatory Study report, the differences were observed between the predicted offshore waves based on the extreme wave probability analysis in the previous study results and those based on the visual observation at Hon Dau Station from the year 1956 to 1985. Therefore, the offshore design wave was analyzed again in this study through the extreme wave probability analysis based on the newly collected storm data for more than 50 years. Here, the calculated value was adjusted by using the observation data for one year at offshore area of Hai Phong, which was carried out from 2005 July to 2006 August by TEDI.

The obtained offshore wave conditions are summarized in Table 7.1.1. The details are presented in Chapter 2 of this report.

Table 7.1.1 Offshore Wave Conditions (Re-evaluated)

Return Period (years)	H_0 (m)	T_0 (sec)
1	2.30	8.3
5	4.11	11.0
10	4.72	11.8
30	5.59	12.8
50	5.96	13.3
100	6.46	13.8

3) Seismic Condition

- Horizontal Seismic Coefficient $k_h = 0.04g$
- Vertical Seismic Coefficient $k_v = 0.00g$

According to TCXDVN 375-2006, Cat Hai island area locates in the region that does not compulsorily require seismic load consideration, therefore, seismic load is not considered in the design.

4) Wind Condition

- Design Wind Velocity 60 m/sec
- Wind in Operation 20 m/sec

5) Subsoil Condition

A series of offshore boring works was carried out at the Project as presented in Chapter 2. The design property of existing subsoil for each proposed facility is determined based on the subsoil data collected from each boring works.

7.1.3 Loading Conditions

The design loads for the terminal area and access road area are as follows:

- Terminal Area (Full Container Storage Area): 30kN/m^2
- Terminal Area (Empty Container Storage Area): 10kN/m^2
- Access Road Area: 10kN/m^2

7.2 Land Reclamation

The finish elevation of reclamation at Terminal area in the Component A of the Project is 4.5m CDL. The reclamation and pavement work from +4.50m CDL to +5.50m CDL will be done under the Component B of the Project. As for the Access Road area, the area for 1st stage road construction will be reclaimed up to +4.50m CDL and the rest area will be filled up to +5.50m CDL. It is proposed that materials for reclamation fill will be sourced from both river and seabed sand dredging. The reclamation materials shall be cohesion-less, well-graded sandy materials and shall contain less than 5% in weight of particles passing sieve 74 μm and shall not contain gravel and rock. The filling materials shall be free from vegetation and roots. Suitable materials shall not have topsoil, roots, vegetation, organic matter silt, contaminating matter and other materials which are combustible or which can decay. The reclamation plan is shown in Figure 7.2.1 and typical section is shown in Figure 7.2.2.

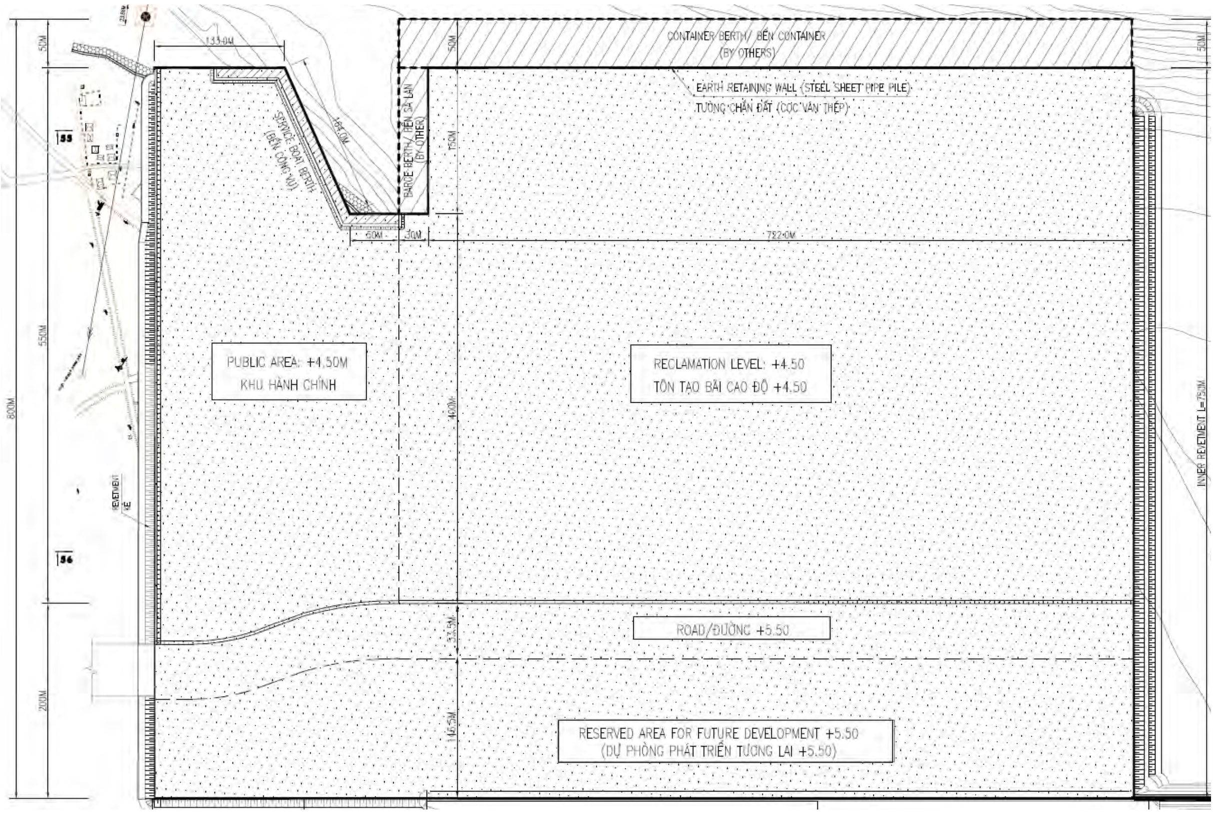


Figure 7.2.1 Plan of Land Reclamation

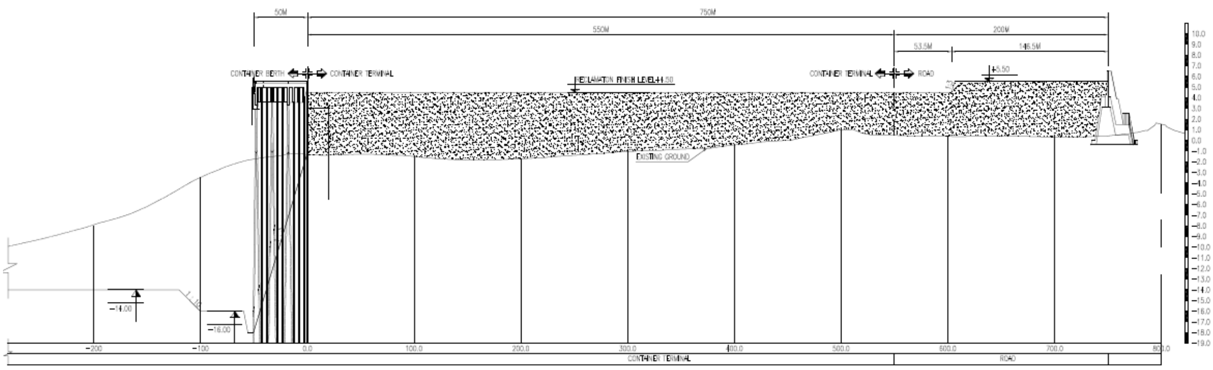


Figure 7.2.2 Typical cross section of land reclamation

7.3 Subsoil Improvement

7.3.1 Soil Improvement Methods

There are many construction methods to cope with soft subsoil conditions. The typical soil improvement techniques currently utilized are shown as follows;

- Deep Mixing Method (DMM)

- Vertical Sand Drain Method (SD) with pre-loading
- Prefabricated Vertical Drain Method (PVD) with pre-loading
- Sand Compaction Pile Method
- Sand Replacement

Among the above soil improvement techniques, the following types of basic methodology will be applicable to prepare evenly stable wide area: pre-loading, sand replacement, vertical drainage, deep chemical mixing, etc. These methods are applied independently or in some combinations.

The objectives of soil improvement at this site are to accelerate the consolidation and to reduce the residual consolidation settlement occurred by the port operation load. Considering the natural conditions and objectives, a suitable soil improvement method for Lach Huyen Port Construction site has been studied and is summarized in Appendix 7.1. The advantages and defects of some alternatives were reviewed and compared in terms of cost and construction nature. The alternatives are as follows:

- Deep Mixing Method (DMM)
- Prefabricated Vertical Drain Method (PVD) with pre-loading
- Sand Compaction Pile Method
- Replacement with Sand

In this project site, the combination of prefabricated vertical drain and pre-loading methods is recommended, since it is easy for work, low construction cost, and no hazardous impact for natural and social environment. This method is very popular but the maximum drain depth, which has ever been executed in Vietnam, is about 30 m. The effectiveness of prefabricated vertical drains of more than 30m in depth has been proved by many foreign projects, and it can be calculated as shown in Appendix 7.1. Therefore, PVD method should work in this site in case the optimal materials and equipment are selected and supervised properly.

7.3.2 Sub Soil Improvement along the Quay Wall

Other than PVD method, Cement Deep Mixing Method (CDM) is applied to the area right behind the container berth where the earth retaining wall is constructed to sustain the reclamation fill. The reasons for the CDM method introduction are as follows:

- A certain area right behind the container berth is supposed to be used as the temporary yard for construction of container berth by the Private investor. It is vital to hand over the area to the Private investor as early as practically possible so as to initiate and complete the container terminal construction.
- The earth retaining wall for berth structure needs to be designed in combination with subsoil improvement method applied to the area right behind the wall. Due to its weakness of existing subsoil, a considerable extent of active earth pressure may act on a vertical type of sheet piled earth retaining wall without subsoil improvement. Generally, the wall is not stable unless the following relationship between overburden pressure to the wall (γh+w) and the strength of clayey soil (Cohesion of Clay: C) is satisfied.

$$\Sigma(\gamma h + w) - 4C < 0$$

During the Preparatory Survey, the above relationship was calculated for the earth retaining wall behind container berth and barge berth structure. According to the calculation result shown in Table 7.3.1, it is indispensable to improve the existing subsoil in order to make vertical type of earth retaining sheet piled wall stable. As for the soil improvement method to be applied to the existing subsoil, considering that only a few increases in cohesive strength of the clayey soil by consolidation is expected by use of PVD method due to over-consolidated nature of existing subsoil, the soil improvement method other than PVD is preferable to be applied.

Table 7.3.1 Stability of Sheet Piled Vertical Wall

Surcharge Load (w) (kN/m^2)	GL Behind Wall (CDL) (m)	GL Front Wall (CDL) (m)	Cohesion (C) (kN/m^2)	Σ(γh+w)－4C (kN/m^2)	Judgment	
35	+6.0	+3.5	22	2.5x18+35-4x22=－8	<0	Stable
35		+3.0	22	3.0x18+35-4x22=+1	>0	Not Stable
35	+5.5	+3.0	22	2.5x18+35-4x22=－8	<0	Stable
35		+2.5	22	3.0x18+35-4x22=+1	>0	Not Stable

Source: The Preparatory Survey on Lach Huyen Port Infrastructure Construction in Viet Nam

Therefore, Cement Deep Mixing method (CDM) is applied to the area right behind the Container berth and Barge berth taking into account the following effects and objects of the construction.

- In order to hand over the reclaimed area right behind the berth to Private investor as early as practically possible so as to initiate and complete the succeeding construction of berth,
- In order to reduce active earth pressure acting on the vertical type of earth retaining wall installed right behind the open type of container berth structure, and
- In order to shorten the overall construction period in subsoil improvement work for the terminal construction by application of PVD and CDM method.

In the Preparatory Survey, a 50m wide area right behind the Container berth and Barge berth was divided into two areas: the 30m wide area right behind the earth retaining wall was improved by Low Improvement Ratio Cement Column Method (ALiCC method, replacement ratio 24%), the remaining 20m wide area adjacent to the PVD method area was treated by CDM method (replacement ratio 51%) in order to sustain lateral swell deformation of subsoil mass generated in the process of consolidation under the PVD preloading method (see Figure 7.3.1).

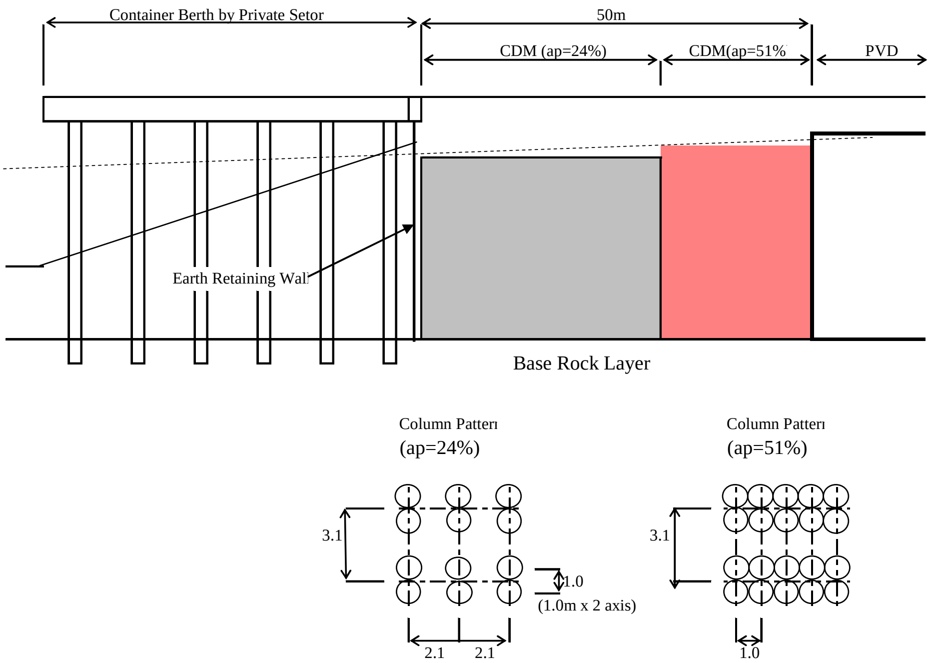


Figure 7.3.1 Arrangement of Cement Deep Mixing Method (Preparatory Survey)

The proposed arrangement of cement deep mixing method in the Preparatory Survey has possible technical risk mentioned below found in the course of this study:

- It is uncertain whether or not ALiCC columns have a great effect on reducing active earth pressure working on earth retaining wall.

Therefore, the arrangement of cement deep mixing method was re-considered, and additional wall type CDM was placed just behind earth retaining wall in order to secure the reduction of active earth pressure working on earth retaining wall as shown in Figure 7.3.2. The arrangement of CDM method is as follows:

- 13m from earth retaining wall : Wall type CDM (improvement ratio: 51%)
- 13m – 36.6m from earth retaining wall: ALiCC (improvement ratio: 24%)
- 36.6m – 50m from earth retaining wall: Wall Type CDM (improvement ratio: 51%)

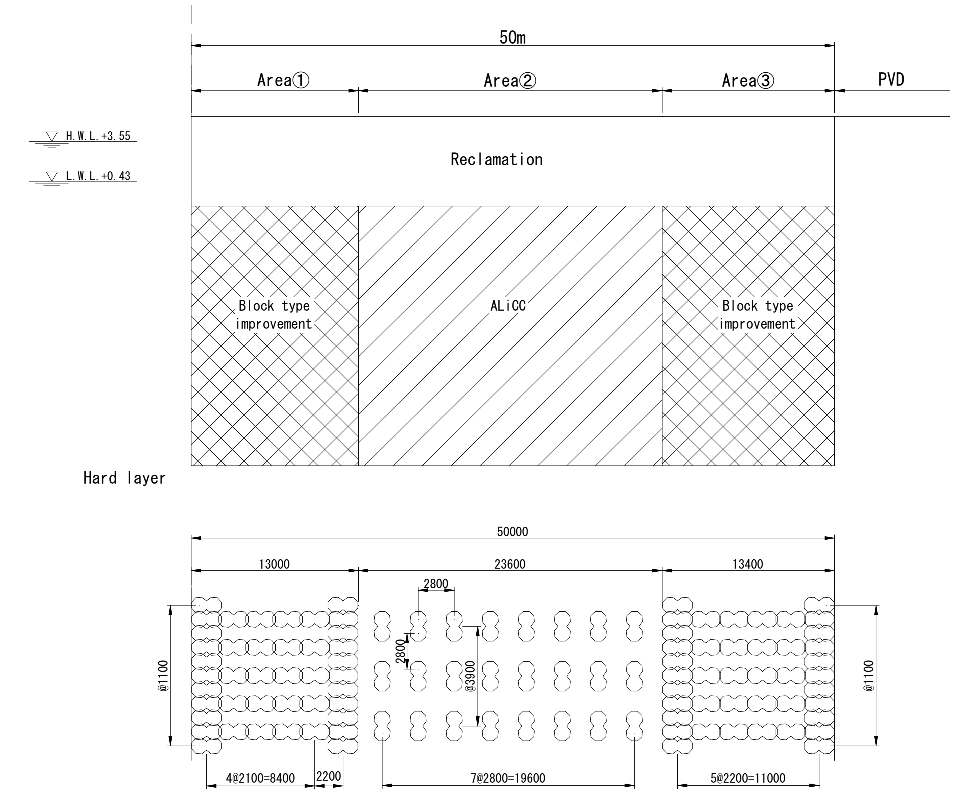


Figure 7.3.2 Proposed Arrangement of Cement Deep Mixing Method (Detailed Design Stage)

In the course of this study, a Japanese Supporting Committee headed by Dr. Asaoka was established in order to verify the soil improvement design proposed by the study team. The Committee gave experimental comments on the proposed arrangement of cement deep mixing method listed as below:

- The ratio of width to height of wall type CDM should be equal or more than 1.0.
- ALICC is not required, since there is no past experience of the combination of ALiCC and PVD method.
- The simple combination of CDM method and PVD method is preferable and has past experience.
- The consultants should re-consider the CDM method carefully with an enough safety margin.

The arrangement of Cement Deep Mixing Method was examined again in order to reflect the given by Japanese Supporting Advisory Committee headed by Dr. Asaoka and the arrangement as illustrated in Figure 7.3.3 is finally proposed in this design. The arrangement of CDM method is as follows:

- Behind earth retaining wall : Wall type CDM (improvement ratio: 51.7%)
- Width of CDM : 33.9m – 40.2m (depends on soil condition)

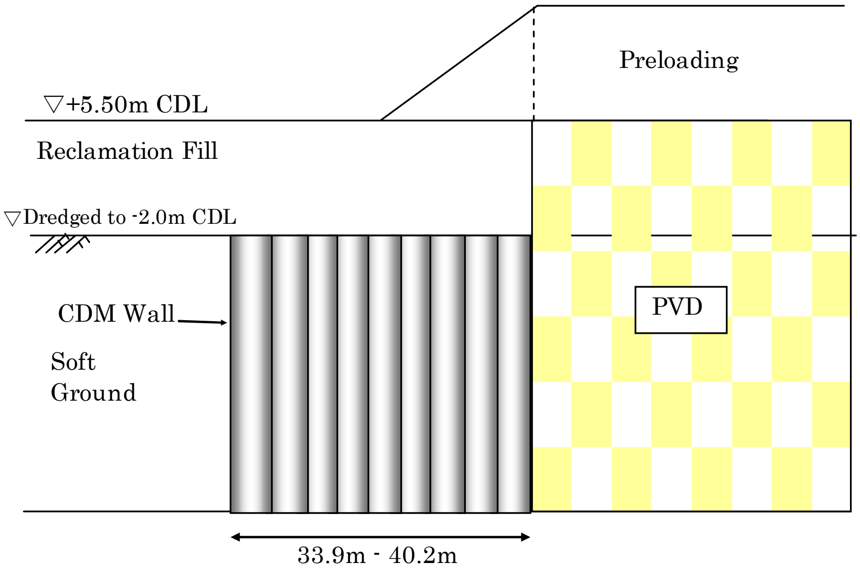


Figure 7.3.3 Proposed Arrangement of Cement Deep Mixing Method

The followings are the design of Cement Deep Mixing Method applied to the area behind earth retaining wall with the arrangement finally proposed as shown in Figure 7.3.3.

1) General

The target area to be studied is "Behind Earth Retaining Wall" area illustrated in Figure 7.3.4. In this study, the subsoil improvement design is conducted so as to realize the expected improvement effect as shown in Table 7.3.2.

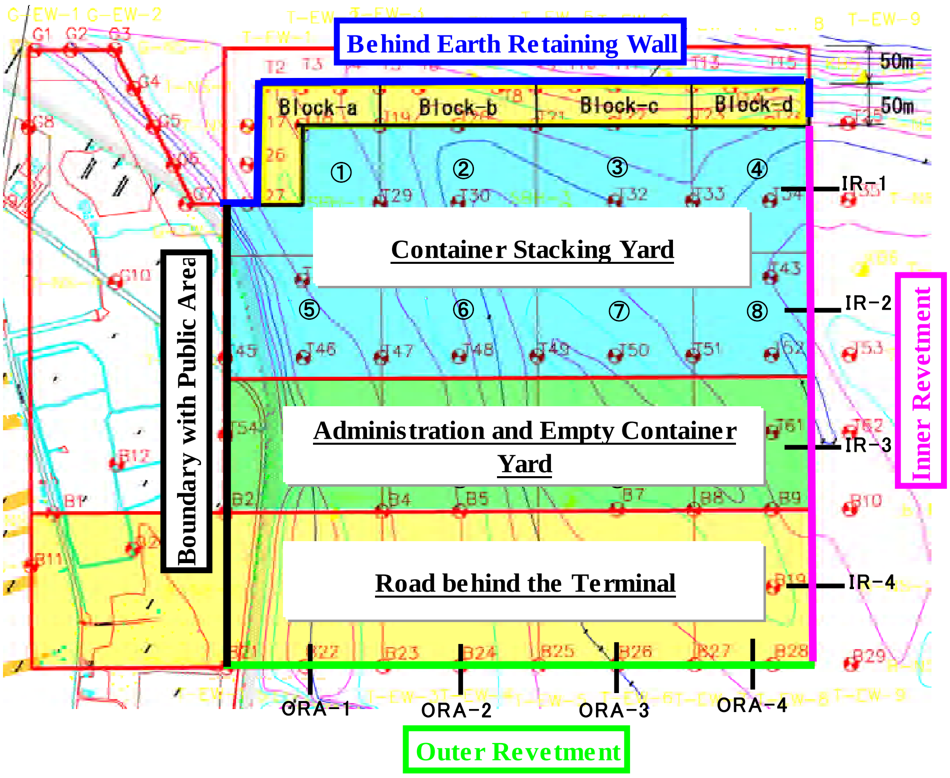


Figure 7.3.4 Plan of Examination Area for CDM Method

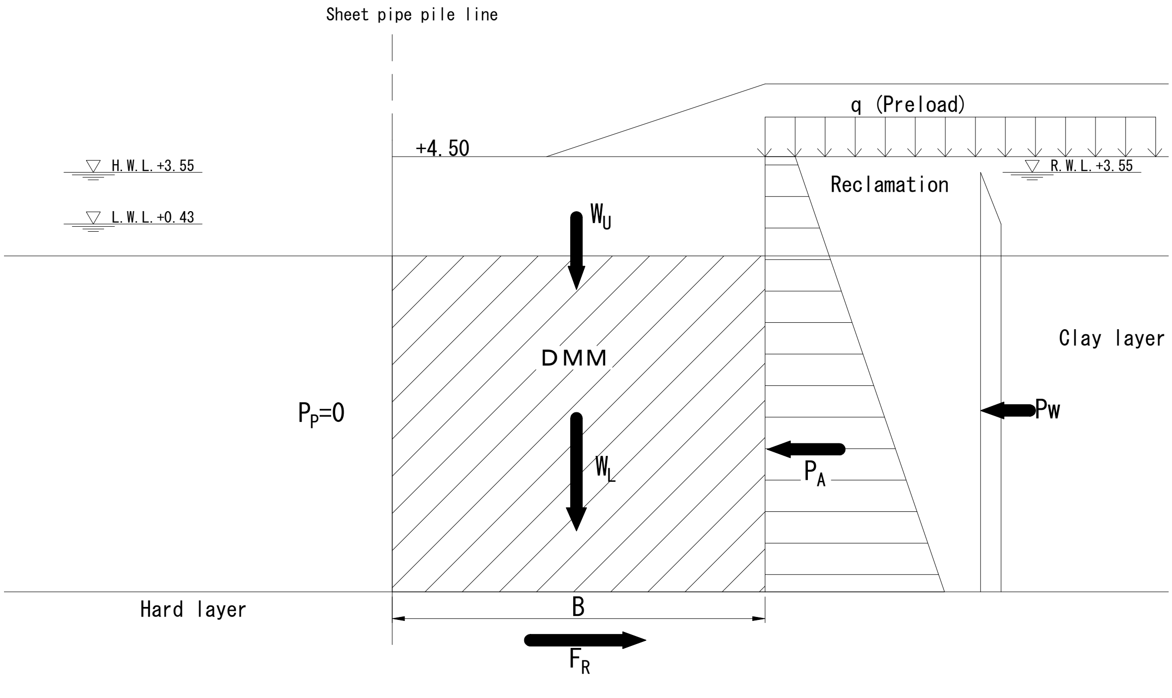
Table 7.3.2 Application Schedule of CDM method

Area	Improvement Type	Objective Effect
- Behind Earth Retaining Wall	Wall Type	- Reduce Settlement - Reduce active earth pressure on earth retaining wall

2) Examination of wall type improvement

Application purpose of the "Wall type" improvement at the area right behind the earth retaining wall is to reduce the active earth pressure acting on it. The width of improvement of "Wall type" improvement part will be calculated so as to prevent sliding failure and overturning failure under the active earth pressure acting on its behind. The Examination model is indicated in Figure 7.3.5. The basic conditions for examination are assumed as follows;

- Wall type improvement behind the earth retaining wall is installed by dedicated work vessel. The stability calculation is conducted at the time when the preloading work is in progress behind the wall type improvement after the earth retaining wall and land reclamation up to +4.50m CDL is completed.
- No passive earth pressure generated in front of the improved part is taken into account.



DMM: Deep Mixing Method, here, referring to block type improvement applied behind earth retaining wall

Figure 7.3.5 Examination Model (behind earth retaining wall)

a) Soil conditions

The soil conditions applied to this study is based on the soil investigation results conducted in the "Detailed Design Study for Lach Huyen Port Infrastructure Construction Project". The soil conditions for the Terminal area is divided into the blocks as shown in Figure 7.3.6. The soil conditions for examination of block type improvement behind the earth retaining wall are "Block a" to "Block d" and Block ① in the same figure.

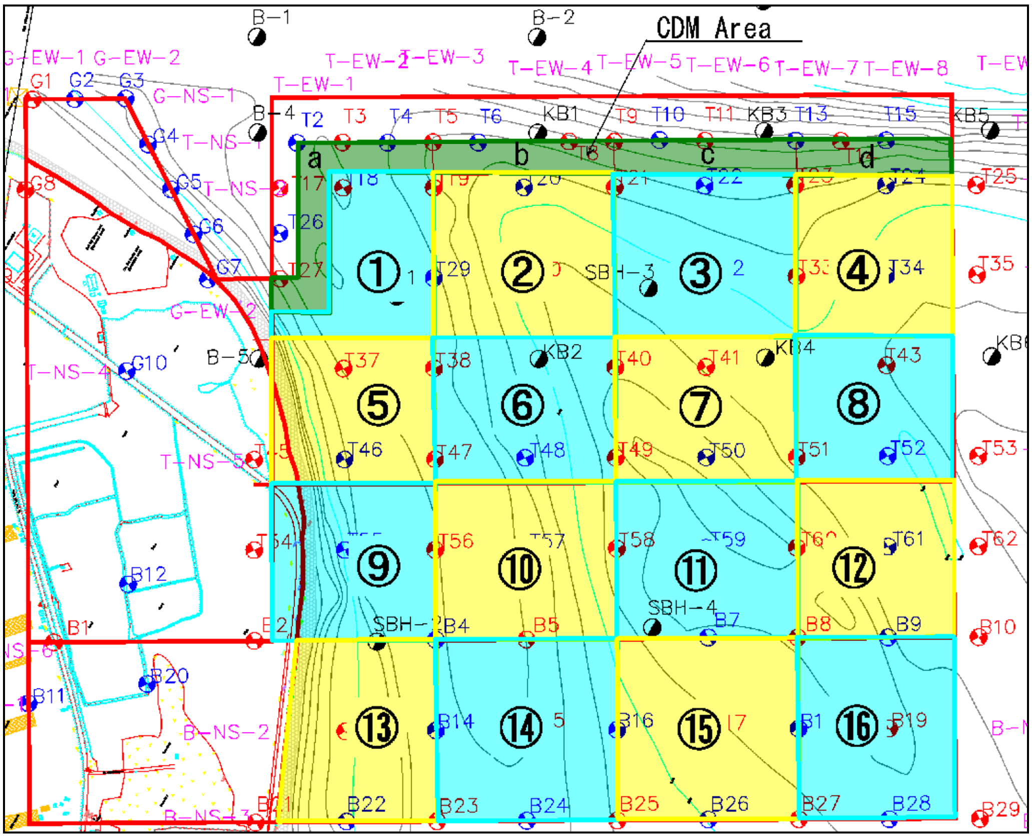


Figure 7.3.6 Plan of Examination Block for CDM Calculation

The model of soil layers for each soil condition block used in the examination is illustrated in Figure 7.3.7. The characteristics of each soil layer are tabulated in Table 7.3.3 and the soil parameters for design are summarized in Table 7.3.4.

Table 7.3.3 Soil Stratification

Layer Name		Color	Average N-Value	Distributed Depth C.D.L (m)	Distributed thickness (m)
1a	Loose sand, clayey sand (SP/SP-SC)	Grey, light grey	4.1	GL to -1.4m	0.3m to 4.5m
1b	Sandy clay (CL/SC)	blackish grey, brownish grey, grey	0.7	-0.8m to -0.4m	1.2m to 7.8m
2	Fat clay with sand (CH)	Grey, brownish and yellowish grey	1.0	-2.7m to -8.0m	2.2m to 11.3
3a	Sand (SP)	Light grey and greenish grey	4.4	-7.5m to -9.7m	1.2m to 4.8m
3b	Clayey sand/ Sandy clay (CL/SC)	Yellowish grey, grey	4.8	-8.2m to -12.2m	0.8m to 8.7m
3c	Sand (SP/SP-SC)	Yellowish grey, grey	5.8	-10.9m to -14.4m	0.5m to 7.2m
4	Sandy lean clay (CL)	Reddish brown, yellowish brown	10.3	-12.0m to -15.6m	0.5m to 9.5m
5	Fat clay with sand (CH)	Grey, yellowish grey	5.7	-15.3m to -26.2m	3.9m to 18.3m
9	Completely weathered sandstone	Reddish brown, yellowish brown	-	-26.0m to -27.9m	0.2m to 5.0m
10	Moderately weathered silt/clay stone	Reddish brown, yellowish brown	-	-26.6m to -29.7m	2.5m to 5.5m

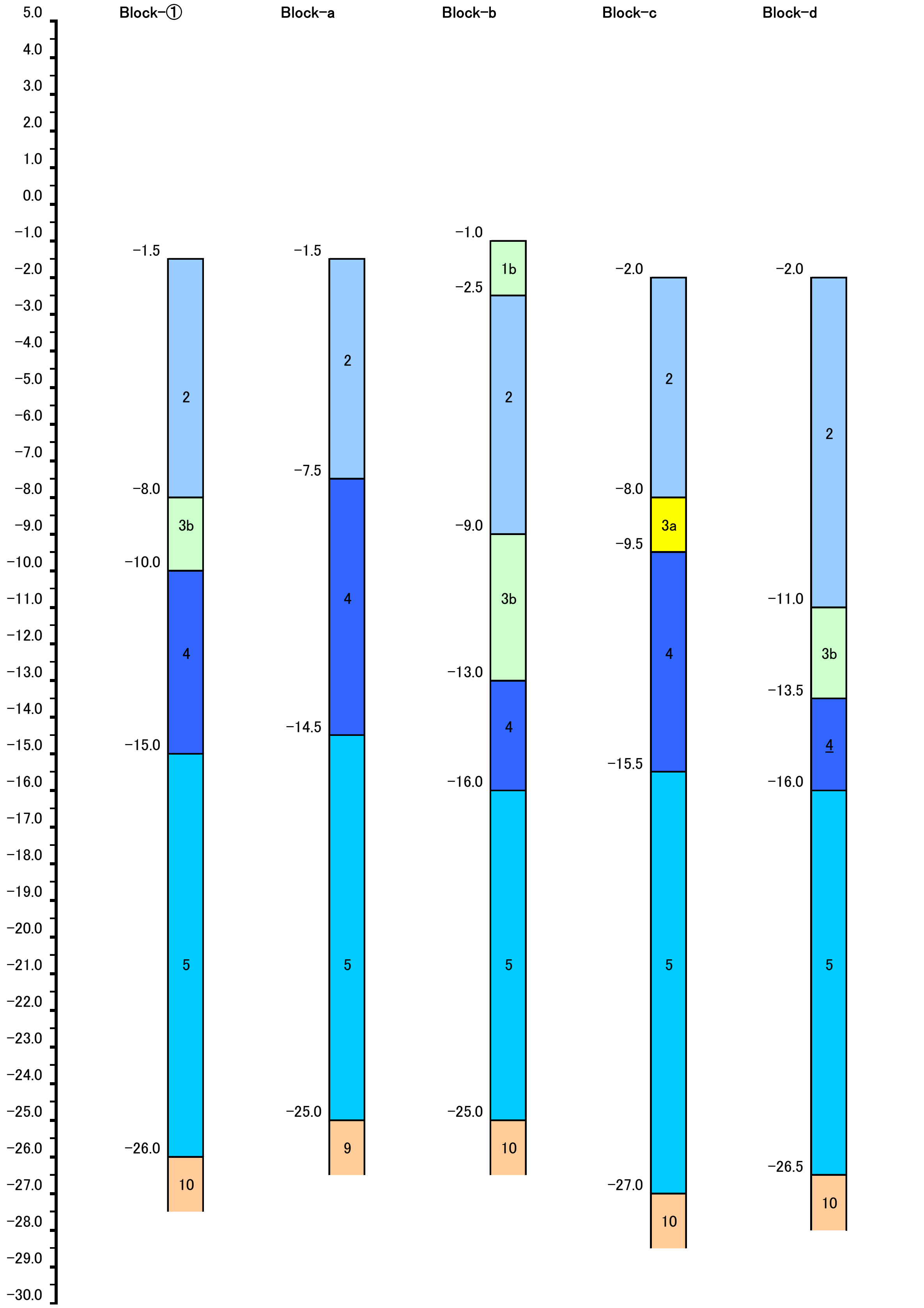


Figure 7.3.7 Model of Soil layer for Examination (behind earth retaining wall)

Table 7.3.4 Soil Parameters for CDM Method Design

Design Parameres

Layer No.	Typical Soil Type	SPT-N	γ (kN/m3)	γ' (kN/m3)	Cu (kN/m2)	ϕ (°)	Cc	Cr	$C\alpha$ (%)	Pc (kN/m2)	e0	Cv (OC) x 10^{-3} (cm2/s)	Cv (NC) x 10^{-3} (cm2/s)	Cu/P for NC
1a	SP	4	18.0	8.0	0	25.0	-	-	-	-	-	-	-	-
1b	CL	5	18.0	8.0	15	0.0	0.30	0.07	0.4	80	1.05	1.20	1.20	0.30
2	CH	1	17.0	7.0	15	0.0	0.60	0.12	0.7	80	1.45	1.00	0.60	0.30
3a	SP	4	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
3b	CL	5	19.0	9.0	25	0.0	0.25	0.05	0.4	$\Sigma\gamma'z+50$	0.80	1.20	1.20	0.30
3c	SP	6	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
4	CH, CL	10	19.0	9.0	50	0.0	0.35	0.04	0.6	$\Sigma\gamma'z+100$	0.85	1.20	0.80	0.30
5	CH	6	17.5	7.5	40	0.0	0.60	0.08	0.8	$\Sigma\gamma'z+75$	1.20	2.20	0.80	0.30
Fill,Emb	S	-	18.0	10.0	0	30.0	-	-	-	-	-	-	-	-

*NC: Normal conslidated State OC: Over consolidated State

b) Loading condition

Loads by preloading fill behind the wall type improvement are considered in the calculation. The loads by preloading fill are tabulated in Table 7.3.5 and the model of loading condition is illustrated in Figure 7.3.8.

Table 7.3.5 Loads by Preloading Fill

block	Preload Elevation	Preload Height (m)	Surcharge q (kN/m^2)
①	+8.9m CDL	4.4	79.2
a	+8.9m CDL	4.4	79.2
b	+8.4m CDL	3.9	70.2
c	+8.6m CDL	4.1	73.8
d	+8.6m CDL	4.1	73.8

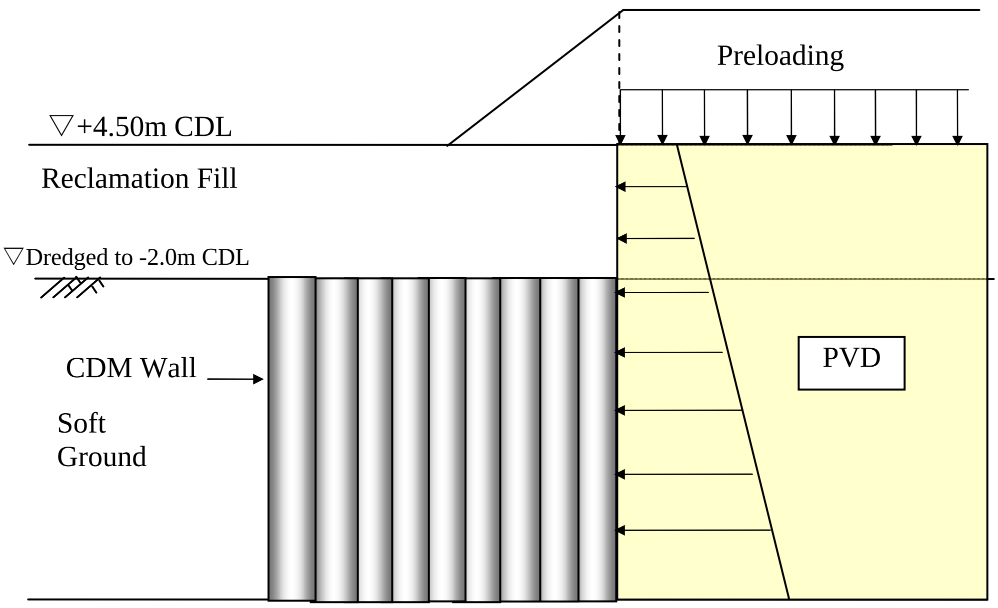
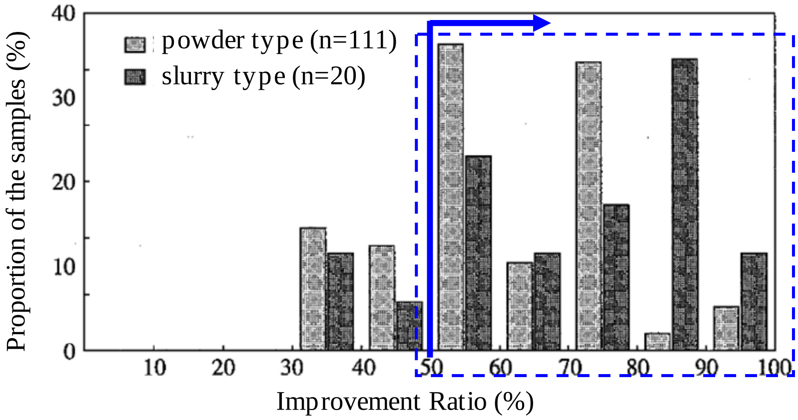


Figure 7.3.8 Model of the Loading Condition (at the time of preloading work)

c) Conditions of Calculation

i) Condition and specification of improved column

- Specific design compressive strength of Improved column: 600kN/m^2
- Bottom end of the column: Upper end of the hard soil layer of Layer 9 or Layer 10
- Diameter of column: ϕ1,300mm Lap type installed by 2-shafts.
- Improvement ratio:
  Improvement ratio of more than 50% was determined with reference of Work experience indicated in Figure 7.3.9 that CDM applied to prevent the lateral flow to Bridge abutments.



Source: "Design and Execution Manual of Deep Mixing for On-land Works (Revised Edition)"
(March 2004, Public Works Research Center) P.248

Figure 7.3.9 Improvement ratio/Work experience of CDM application for prevention of lateral flow to Bridge abutments

- Layout of Improved part:
  The layout of improvement part is basically Wall-shape and Lap type columns are applied to both longitudinal ends of the improved part in order to increase the whole strength of the improved part. In accordance with the result of calculation of minimum width of the improved part and the improvement ratio, the basic layout of improved columns is determined as shown in Figure 7.3.10.

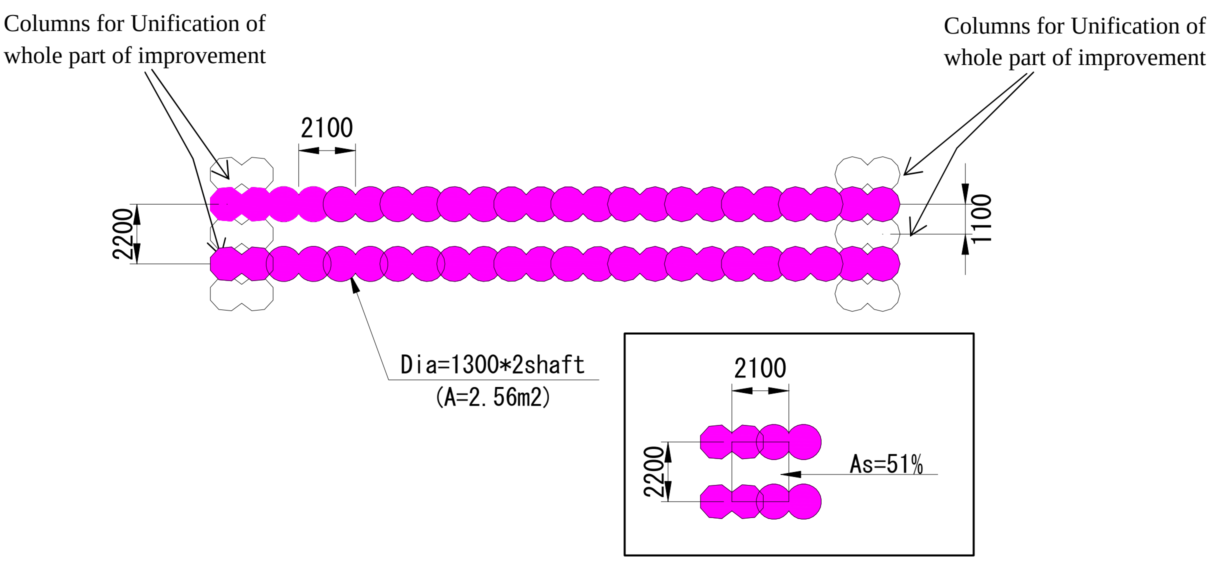


Figure 7.3.10 Typical Layout of Improved Columns for the Area behind Earth Retaining Wall

ii) Water level

The residual water level (R.W.L) is assumed the same as high water level of +3.55m CDL in this calculation.

R.W.L = H.W.L: +3.55m CDL

iii) Condition of the bottom layer

The bottom layer is assumed as a Sand layer with $\phi=35^{o}$ (μ = tanϕ = 0.57).

iv) Required factor of safety

Applied factor of safety is as follows:

- Against Sliding more than 1.10
- Against Overturning more than 1.10

d) Examination Method

The factor of safety against sliding is calculated based on the examination model shown in Figure 7.3.5 by the following formula:

$$F_s = F_R / P_A$$

where,

F_s : Safety factor against Sliding (more than 1.1 is required)
F_R : Resistance force against Sliding＝min(μ(W_U+W_L), B x τ)
P_A : Active earth pressure acting on the improved part
μ : Friction coefficient＝tanϕ (ϕ: internal friction angle of the bottom layer)
W_U : Weight of Improved part
W_L : Surcharge load acting on the improved part
B : Width of Improved part
τ : Shear strength of improved column

The factor of safety against overturning is calculated based on the examination model shown in Figure 7.3.5 by the following formula:

$$F_s = \Sigma M_R / \Sigma M_A$$

where,

F_s : Safety factor against Sliding (more than 1.2 is required)
ΣM_R : Total of Resistance Moment
ΣM_A : Total of Overturning Moment

Active earth pressure is calculated in accordance with the method indicated in “Technical Standards and Commentaries for Port and Harbor Facilities” (July 2007, The Overseas Coastal Area Development Institute of Japan).

- Earth pressure in Sand layer

$$p_{ai} = K_{ai}\left[\sum \gamma_i h_i + \frac{\omega \cos\psi}{\cos(\psi-\beta)}\right]\cos\psi$$

$$\cot(\zeta_i - \beta) = -\tan(\phi_i + \delta + \psi - \beta) + \sec(\phi_i + \delta + \psi - \beta)\sqrt{\frac{\cos(\psi+\delta)\sin(\phi_i+\delta)}{\cos(\psi-\delta)\sin(\phi_i-\beta)}}$$

$$K_{ai} = \frac{\cos^2(\phi_i - \psi)}{\cos^2\psi\cos(\delta+\psi)\left[1+\sqrt{\dfrac{\sin(\phi_i+\delta)\sin(\phi_i-\beta)}{\cos(\delta+\psi)\cos(\psi-\beta)}}\right]^2}$$

where,

p_{ai}	: Active earth pressure acting on the wall in the bottom of layer "i" (kN/m^2)
ϕ_i	: Internal friction angle in layer "i" (^{o})
γ_I	: Unit weight of soil in layer "i" (kN/m^3)
h_i	: Thickness of layer "i" (m)
K_{ai}	: Coefficient of Active earth pressure in layer "i"
ψ	: Angle of Wall from the Vertical line (^{o})
β	: Angle of Ground surface from the Horizontal line (^{o})
δ	: Angle of friction between Fill material and Wall (^{o})
ξ	: Angle of failure from the Horizontal line in layer "i" (^{o})
ω	: Load on Ground surface in Unit area (kN/m^2)

- Earth pressure in Clay layer

$$p_a = \sum\gamma_i h_i + \omega - 2c$$

where,

p_a	: Active earth pressure acting on Wall in the bottom of each layer (kN/m^2)
γ_i	: Unit weight of soil in layer "i" (kN/m^3)
h_i	: Thickness of layer "i" (m)
ω	: Load on Ground surface in Unit area (kN/m^2)
c	: Cohesion (kN/m^2)

e) Examination Results

The stability calculation results for each block are shown in Table 7.3.6. The width of wall type improvement as shown in Table 7.3.6is decided so as to satisfy the required factor of safety against sliding and overturning. The stability calculation sheets for each block in detail are compiled in Appendix 7-3.

Table 7.3.6 Stability Calculation Result against Sliding (behind Earth Retaining Wall)

Block	Specifications of DMM				Check of Sliding		Check of Over-turning	
	Improvement Length (m)	Improvement Width (m)	Design Strength (kN/m2)	Improvement Ratio (%)	Safty Factor	Judgment	Safty Factor	Judgment
①	24.0	38.1	600.0	51.7	1.109	>1.1 OK	3.049	>1.1 OK
a	23.0	33.9	600.0	51.7	1.102	>1.1 OK	2.746	>1.1 OK
b	23.0	36.0	600.0	51.7	1.103	>1.1 OK	2.844	>1.1 OK
c	25.0	38.1	600.0	51.7	1.106	>1.1 OK	3.110	>1.1 OK
d	24.5	40.2	600.0	51.7	1.141	>1.1 OK	3.206	>1.1 OK

3) Stability calculation of entire system of structure

a) Condition of Calculation

The circular slip analysis for entire system of structure was conducted at the time of preloading and at the time of operation. The conditions of calculation are set as follows:

- Factor of Safety at the time of Preloading : more than 1.10
  at the time of Operation : more than 1.30
- Operational loads : 0 at the time of preloading
  : 30kN/m^2 at the time of operation

- Strength increase of subsoil by PVD method : not considered
- Shear strength of wall type improved area is calculated by the following formula:

$$\tau = a_p \times q_{uck} / 2$$

where,

τ : Average shear strength of wall type improved area
a_p : Improvement ratio
q_{uck} : Specific design compressive strength of wall type improved column

b) Calculation Result

The result of circular slip analysis is summarized in Table 7.3.7. The results of circular slip analysis for block ① are shown in Figure 7.3.11 at the time of preloading and in Figure 7.3.12at the time of operation The analysis results for other blocks are compiled in Appendix 7-4.

Table 7.3.7 Circular Slip Calculation Result

Section	Preload		After Completion	
	Safty Factor	Judgment	Safty Factor	Judgment
①	2.464>1.10	OK	2.031>1.30	OK
a	2.391>1.10	OK	1.975>1.30	OK
b	2.498>1.10	OK	1.988>1.30	OK
c	2.531>1.10	OK	2.002>1.30	OK
d	2.506>1.10	OK	2.050>1.30	OK

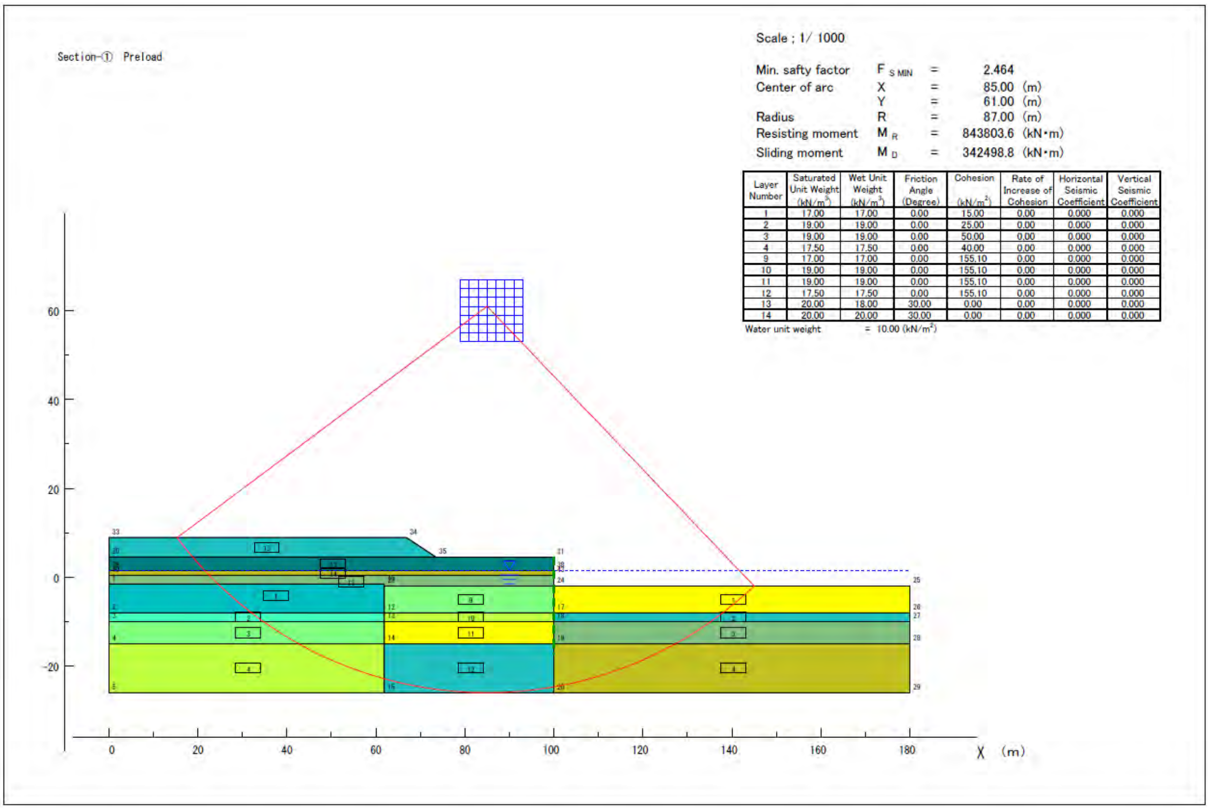
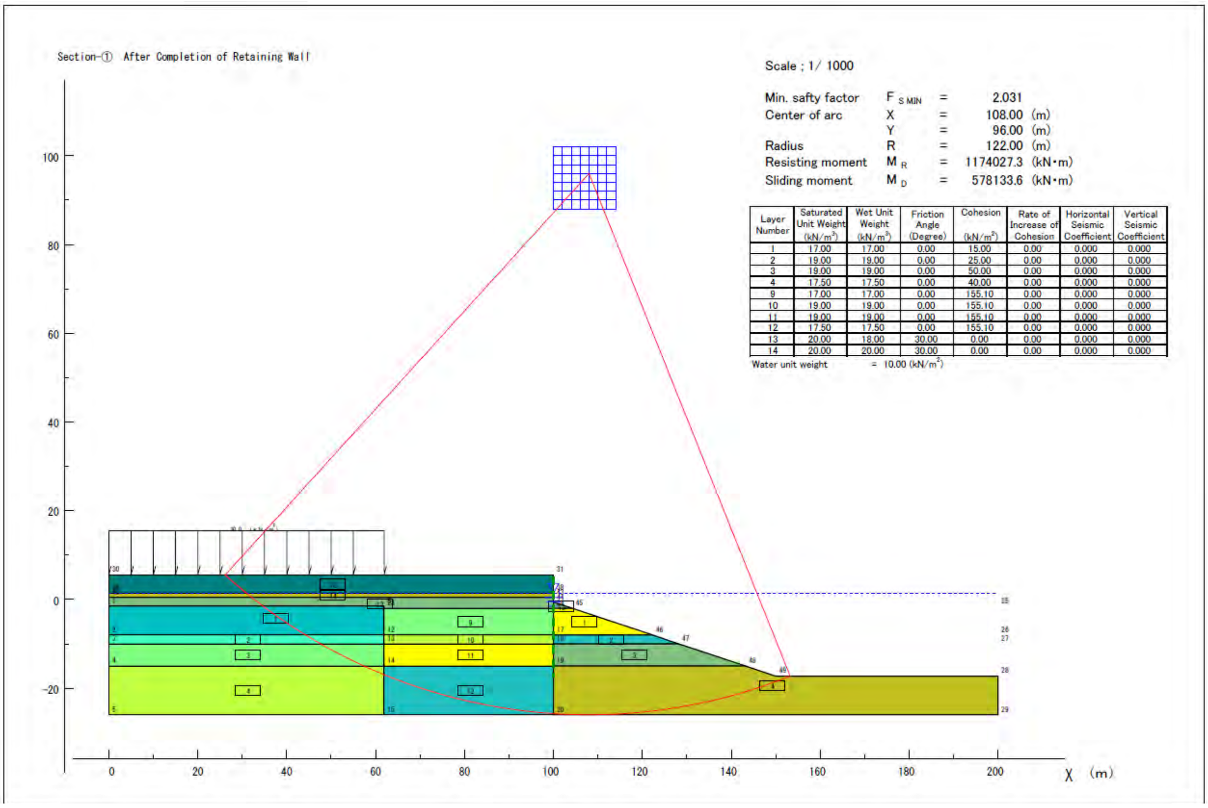


Figure 7.3.11 Result of Circular Slip Analysis for Block ① (at the time of Preloading)



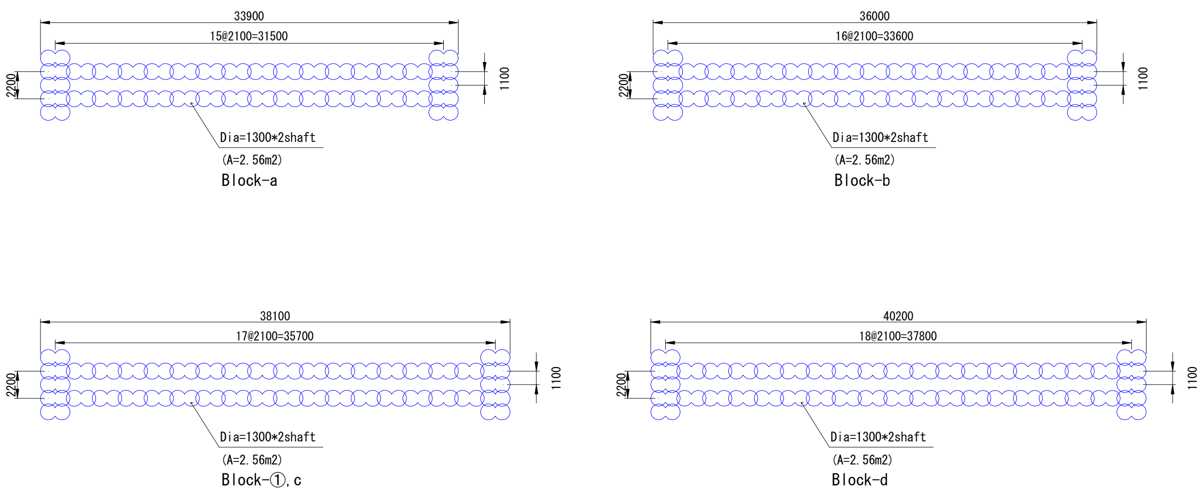
Layer Number	Saturated Unit Weight (kN/m³)	Wet Unit Weight (kN/m³)	Friction Angle (Degree)	Cohesion (kN/m²)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	17.00	17.00	0.00	15.00	0.00	0.000	0.000
2	19.00	19.00	0.00	25.00	0.00	0.000	0.000
3	19.00	19.00	0.00	50.00	0.00	0.000	0.000
4	17.50	17.50	0.00	40.00	0.00	0.000	0.000
9	17.00	17.00	0.00	155.10	0.00	0.000	0.000
10	19.00	19.00	0.00	155.10	0.00	0.000	0.000
11	19.00	19.00	0.00	155.10	0.00	0.000	0.000
12	17.50	17.50	0.00	155.10	0.00	0.000	0.000
13	20.00	18.00	30.00	0.00	0.00	0.000	0.000
14	20.00	20.00	30.00	0.00	0.00	0.000	0.000

Figure 7.3.12 Result of Circular Slip Analysis for Block ① (at the time of Operation)

4) Typical layout and work quantities of CDM method

In accordance with the calculation results, the typical improvement layout of cement column is proposed as indicated in the following figures, the total work volume of soil improvement by CDM method is tabulated in Table 7.3.8. The plan layout of cement columns behind earth retaining wall is as shown in Figure 7.3.13.

Behind Earth Retaining Wall Area



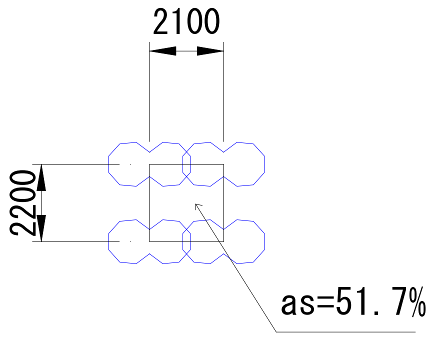


Table 7.3.8 Work Quantities of Cement Deep Mixing Method

Area	Block	Piles of improvement (piles)	Specification of improvement				Soil volume of improvement			Construction method
			Design Strength (kN/m^2)	Upper end CDL(m)	Lower end CDL(m)	Length of improvement (m)	Part of improvement (m^3)	Improbement Volume (m^3)	Cement (t)	
Retaining Wall	Block-①	746	600	-2.0	-26.0	24.0	45,834.2	45,834.2	10,083.5	Offshore φ1300×2shafts (Lap type) $2.56m^2$
	Block-a	2,485	600	-2.0	-25.0	23.0	146,316.8	146,316.8	32,189.7	
	Block-b	1,727	600	-2.0	-25.0	23.0	101,685.8	101,685.8	22,370.9	
	Block-c	1,821	600	-2.0	-27.0	25.0	116,544.0	116,544.0	25,639.7	
	Block-d	1,450	600	-2.0	-26.5	24.5	90,944.0	90,944.0	20,007.7	
Total		8,229					501,324.8	501,324.8	110,291.5	

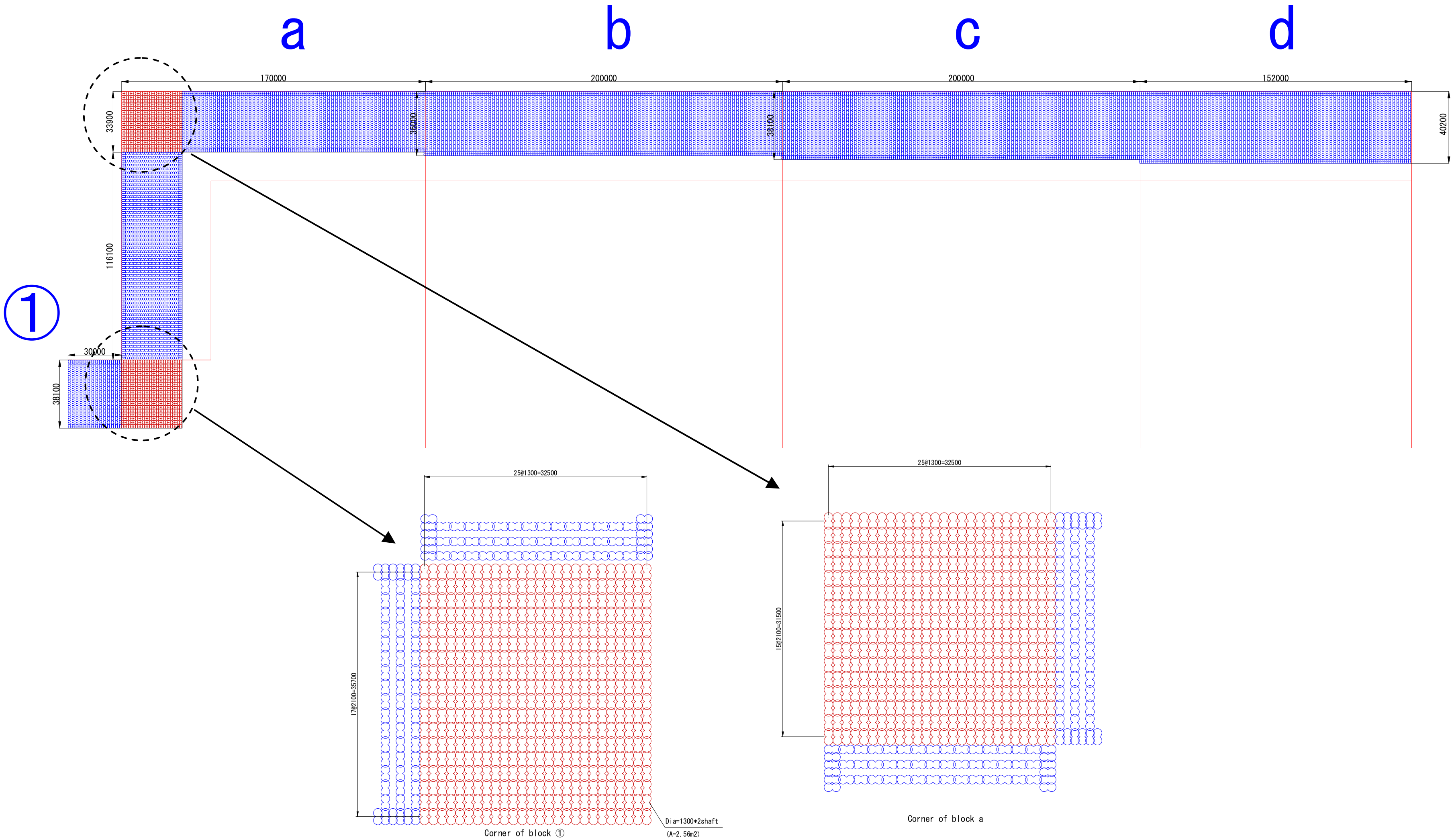


Figure 7.3.13 Layout of Cement Columns behind Earth Retaining Wall

7.3.3 Soil improvement Design for Terminal Area and Access Road Area

1) General

In this Terminal and Access Road Area, soft to medium consistency clay layers are identified in 20m to 30m thick including intermediate firm clay layer which has several meters thick. Accordingly consolidation settlement which is lasting long time and stability problem during reclamation work has been worried. And also due to tight schedule for subsoil improvement work for a reclamation block, it is considered that residual settlement cannot be retained within required range without any soil improvement works. Therefore subsoil improvement methods for Terminal Area and Access Road Area has been studied in this Section.

As main purpose of subsoil improvement in these areas is to decrease the residual settlement due to acceleration of consolidation settlement, PVD method which has many actual performance records and is very economical method has been selected as the most suitable subsoil treatment method for Terminal and Access Road Area. Furthermore preloading method has been applied together with PVD method in order to achieve the optimum improvement effect from economical point of views. Comparison table of soil improvement method is shown in Table 7.3.9.

2) Design Loads and Load Areas

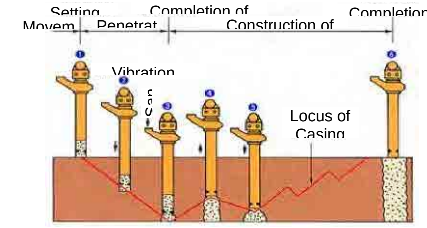
The terminal and access road area is divided into following three areas in compliance with the various operational loads anticipated during port operations:

- **Area-l**: Terminal Area (Full Container Storage Area). This area is located at the open storage yard for full containers. The operational load is defined to 30kN/m^2. (Hereinafter, Full Container Storage Yard Area)
- **Area-2**: Terminal Area (Empty Container Storage Area). This area is located at the west-end side of Terminal Area except for Area-1. This area will be used for open storage yard for empty containers. The operational load is defined to 10kN/m^2. (Hereinafter, Empty Container Storage Yard Area)
- **Area-3**: Access Road Area. This area is located at the west-end of port reclamation area. This area will be used for road. Future traffic road is defined as 10kN/m^2.

Hereinafter, above three areas to be reclaimed in the water is called as “Reclamation area”.

Each location of load area is shown in Figure 7.3.14.

Table 7.3.9 Comparison of Soft Ground Treatment Methods (PVD, ALiCC and SCP) for Reclamation Area

Comparison Items	PVD Preloading Method	Low Replacement Ratio Cement Column (ALiCC) Method	Sand Compaction Pile (SCP) Method
Photos of Each Method	  Installation of PVD Preloading	  	 
Outline of Method	This is a vertical drain method used to accelerate the consolidation in the cohesive soil ground. In this method, vertical plastic boards are installed into the cohesive soil ground as a drain material. The consolidation is accelerated by reducing the drainage distance of pore water. It can be applied together with other methods such as Sand Mat Method and Slow Surcharge Method.	ALiCC is the method which can control the settlement of embankment with low ratio of improvement due to the arch effect. Improving bodies made of high-strength cement are created in the ground in the form of pile. In the ALiCC method, since the embankment load is supported by all columns uniformly, embankment stability is kept, although consolidation settlement is expected in the unimproved ground.	Sand compaction pile (SCP) is to install the compacted sand pile in the soft ground. SCP can improve soft soil, accelerate soil consolidation, shorten settlement period and enhance shear strength. Upon completion of construction and being put into service, the post-construction settlement will not exceed the allowable designed limit.
Numbers of Work Record (For Large-Scale Port Construction)	○ Many	Δ Only in SP-PSA International Port in Vietnam	Δ Many in Japan however many for berth or revetment area.
Technical Advantages and Disadvantages	○Advantages ・Installation speed of PVD is high (7,000-8,000m/day/machine). ・Penetration depth can be achieved more than 40m in deep. ・PVD method is theoretically and practically reliable due to a lot of actual site experiences. Δ Disadvantages ・It needs preload embankment construction to accelerate consolidation settlement and removal of preload is necessary after achievement of required consolidation settlement completed. ・It is necessary to leave the preload at required height for totally 8 months to achieve the required consolidation degree. ・It is necessary to secure the quality of sand mat as a drainage layer. ・Secondary consolidation settlement between 20cm and 30cm will be left after completion of primary consolidation settlement between 1.0m and 1.5m. ・When encountered the intermediate thick hard layer (SPT>8), higher capacity PVD installation machine have to be introduced to penetrate over such layer.	○Advantages ・Deformation of ground can be reduced. ・Preload is not necessary. (Earth work can be reduced so much.) ・Leaving period is only one month for hardening of ALiCC piles. ・Almost no residual settlement come out after treatment by ALiCC piles. Δ Disadvantages ・Forming speed of ALiCC pile is low (80-100m/day/machine). ・It is necessary to secure the good working platform to support heavy ALiCC piling machine. ・Many core boring are necessary to confirm whether ALiCC piles have required strength or not. ・ALiCC method is theoretically reliable but actual performance record of ALiCC at huge reclamation area does not exist so many.	○Advantages ・SCP helps to drain pore water quickly and accelerate soil consolidation process, thus, accelerate stable settlement. ・The base ground is compacted by SCPs and water drains to SCPs. This will enhance bearing capacity of the soft soil after treatment. ・Temporary counter fill volume can be reduced due to improvement of revetment area. X Disadvantages ・Piling Speed is not so high (1,000-1,500m/day /machine). ・Large and exclusive equipments will be required. Impact on adjacent structures should be taken into consideration. ・A large amount of good quality sand will be required; therefore, transportation may cause bad effects on environment.
Construction Planning	○ (PVD interval d=1.1m- 1.6m, Preload Height H=1.5m -3.9m) Easy installation by light machine. Control Point is as follows; 1) Verticality of mandrel shall be kept. 2) Termination depth of PVD installation is easily confirmed. 3) Consolidation process shall be checked by monitoring the settlement.	Δ (ALiCC Pile 2axis ϕ=1.3m, Interval λ=3.1m, Replacement ratio Ap= 16.9%) Easy forming but quality control (many core boring of piles) is necessary. Huge quantities of cement shall be procured.	Δ (SCP ϕ=0.7m, Interval λ=2.0m, Replacement ratio, Ap= 9.6%) Easy work but a lot of sand shall be procured for SCP and Preload.
Construction Period	Δ Reasonable	○ Shorter than PVD	X Longer than PVD
Construction Cost	○ Reasonable (PVD+Preload)	X Most expensive (ALiCC)	Δ More expensive (SCP+Preload) than (PVD+Preload)
Comprehensive Evaluation	**Recommended**	**Not Recommended**	**Not Recommended**

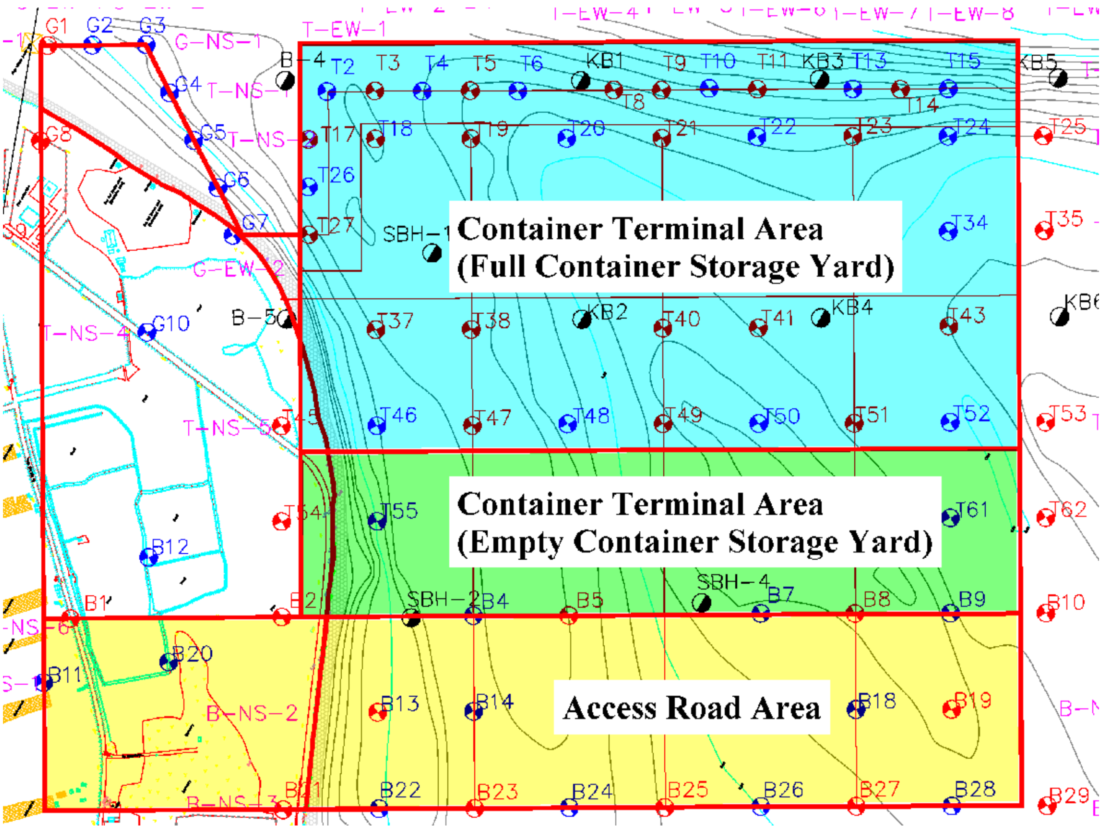


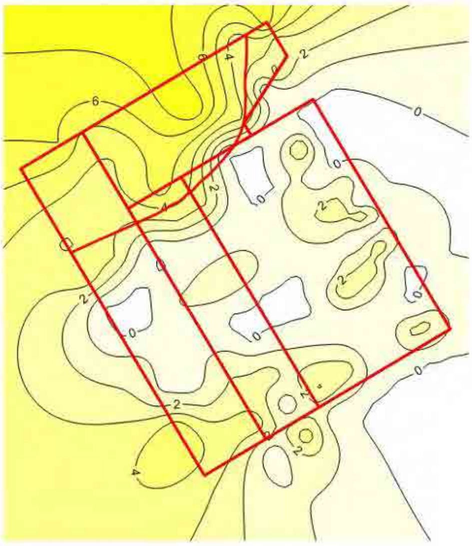
Figure 7.3.14 Load Area for Terminal Area (Full Container Storage Yard and Empty Container Storage Yard) and Access Road Area

3) Subsoil Conditions

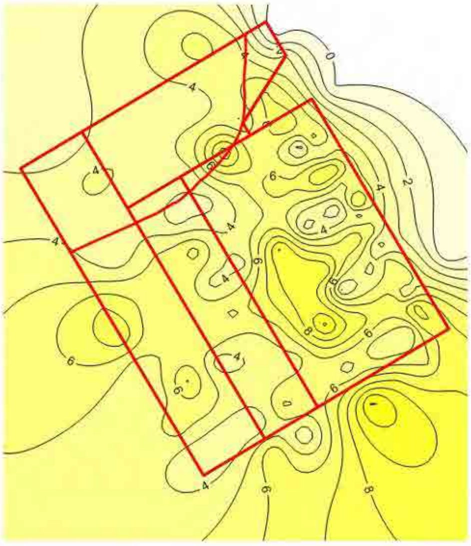
According to the result of the soil investigation at Lach Huyen Port Construction site as shown in Chapter 2.1, soil layers distributed at reclamation area are as shown in Table 7.3.10 and the clay layers to be improved are mainly two layers in principle, upper clay layer (Layer 2) and lower clay layer (Layer 5). Besides theses two layers, two sandy clay layers (Layer 1b and Layer 3b) are also to be improved. Thickness contour map for Layer 1b, Layer 2, Layer 3b, Layer 4 (Intermediate firm clay layer), Layer 5 and total thickness of these clay layers are shown in Figure 7.3.15 together with thickness of intermediate firm soil layer which has more than 8 of SPT N-value and bottom elevation contour maps. According to these contour maps for clayey soil layer thickness obtained based on this Survey result, very soft upper clay layers (Layer 2 including Layer 1b) are distributed in 6 m to 10 m thick at the port reclamation area. And also 8 m to 14 m thick medium consistency clay layer (Layer 5) is distributed as well. Intermediate firm soil layer which has more than 8 of SPT-N value is mainly distributed at the east side of Full container storage yard Area and center of Empty container storage yard Area and Access Road Area. Bottom elevation of the lower clay layer (Layer 5) varies between CD -22 m and -30 m.

Table 7.3.10 Soil Stratification at Project Site with N-value

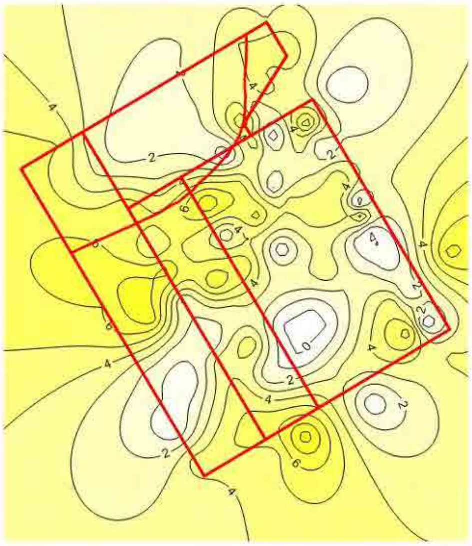
Layer Name	Color	N-Value
Layer 1a: Loose Sand (SP) - Clayey Sand (SP-SC)	Grey, Light Grey	4.1
Layer 1b: Sandy clay (CL or SC)	Blackish grey, brownish grey, grey	0.7
Layer 2: Fat Clay with Sand (CH)	Grey, brownish and yellowish grey	1.0
Layer 3a: Sand (SP)	Light grey and greenish grey	4.4
Layer 3b: Clayey Sand / Sandy clay (SC/CL)	Yellowish grey, grey	4.8
Layer 3c: Sand (SP/SP-SC)	Yellowish grey, grey	5.8
Layer 4: Stiff Sandy Lean Clay (CL)	Reddish and Yellowish Brown	10.3
Layer 5: Firm Fat Clay with Sand (CH)	Grey, Yellowish Grey	5.7
Layer 8a: Loose Silty Sand (SP-SM)	Bluish and yellowish grey, light grey	6.0
Layer 9: Completely Weathered Silt/ Sand Stone	Reddish Brown	>50
Layer 10: Highly–Moderately Weathered Silt/Clay Stone	Reddish Brown	-



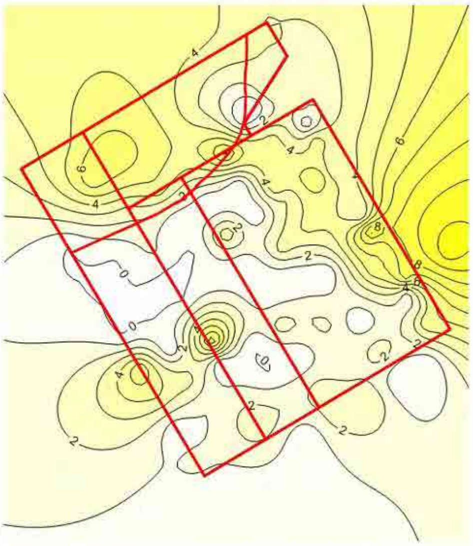
Soil layer thickness Contour Map for Layer 1b



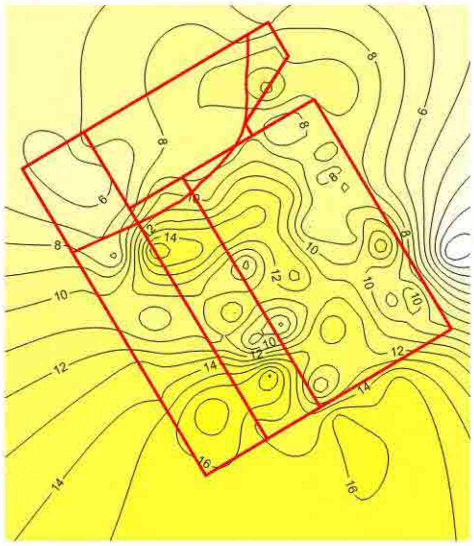
Soil layer thickness Contour Map for Layer 2



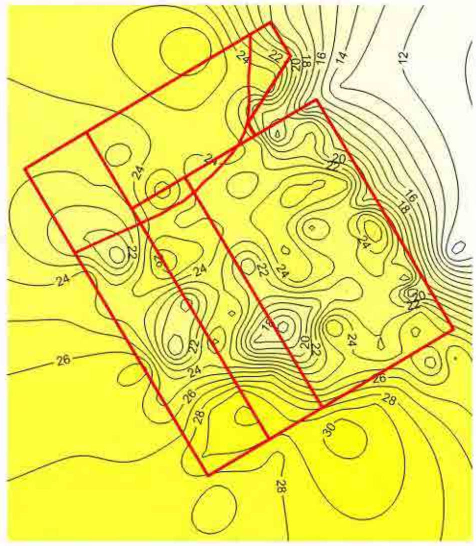
Soil layer thickness Contour Map for Layer 3b



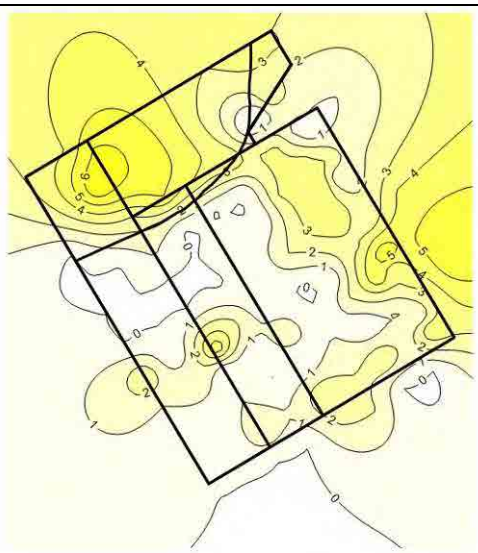
Soil layer thickness Contour Map for Layer 4



Soil layer thickness Contour Map for Layer 5



Soil layer thickness Contour Map for Total thickness of clay layers



Thickness of Intermediate firm layer (N≥8)

Bottom level of clay layer (layer 5)

Figure 7.3.15 Contour Maps for each clay layers and Bottom elevation of clay layers

There are many borings investigated at port area in this Study as shown in Figure 7.3.16. Representative soil profiles for Full container storage yard Area, Empty container storage yard Area and Access road area obtained by this Study are also shown in Figure 7.3.17 and Figure 7.3.18 respectively.

According to subsoil investigation results (refer to Chapter 2), there is no remarkable difference on those soil properties among those areas in the reclamation area. Accordingly average values of those soil properties can be used for subsoil improvement design at Container Terminal Area (Full container storage yard area and Empty container storage yard area) and Access Road Area.

Soil parameters selected for subsoil improvement design are shown in Table 7.3.11.

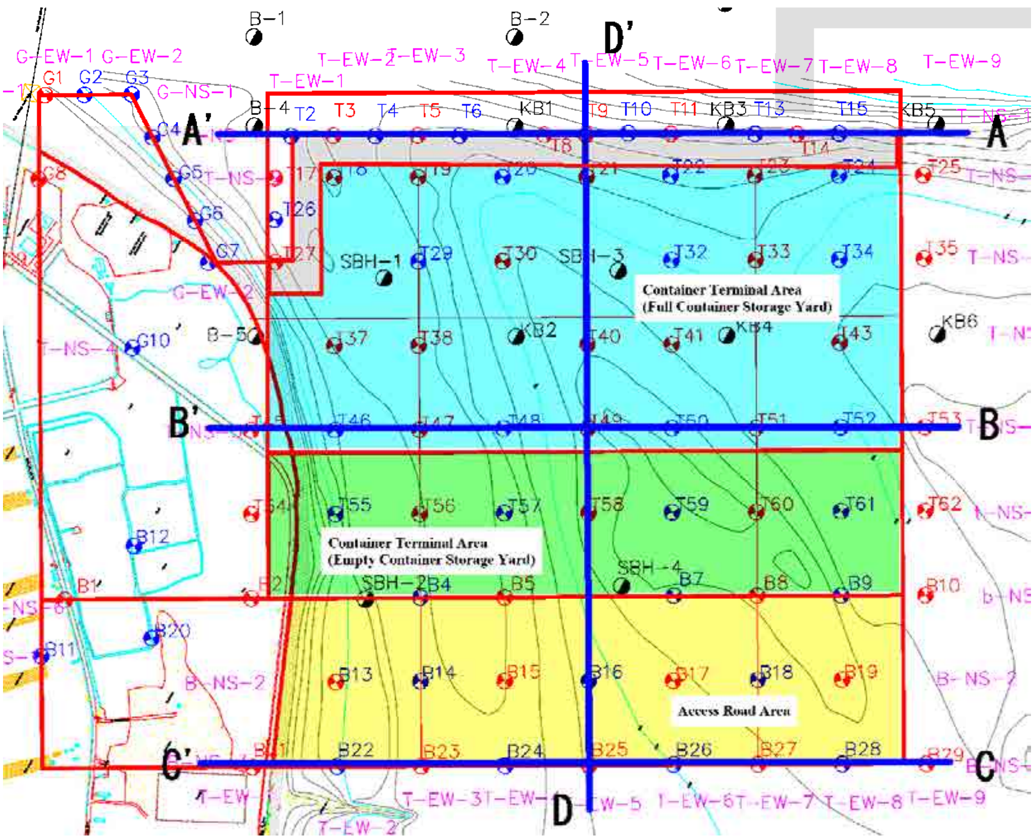


Figure 7.3.16 Borehole location map for reclamation area

Table 7.3.11 Soil Parameters Selected for Subsoil Improvement Design at Reclamation Area

Layer No.	Typical Soil Type	SPT-N	γ (kN/m³)	γ' (kN/m³)	Cu (kN/m²)	ϕ (°)	Cc	Cr	Cα (%)	Pc (kN/m²)	e0	Cv (OC) x 10^{-3} (cm²/s)	Cv (NC) x 10^{-3} (cm²/s)	Cu/P for NC
1a	SP, SP-SC	4	18.0	8.0	0	25.0	-	-	-	-	-	-	-	-
1b	CL	1	18.0	8.0	15	0.0	0.30	0.07	0.4	80	1.05	1.20	1.20	0.20
2	CH	1	17.0	7.0	15	0.0	0.60	0.12	0.7	80	1.45	1.00	0.60	0.20
3a	SP	4	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
3b	CL,SC	5	19.0	9.0	25	0.0	0.25	0.05	0.4	Σγ'z+50	0.80	1.20	1.20	0.20
3c	SP, SP-SC	6	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
4	CH, CL	10	19.0	9.0	50	0.0	0.35	0.04	0.6	Σγ'z+100	0.85	1.20	0.80	0.20
5	CH	6	17.5	7.5	40	0.0	0.60	0.08	0.8	Σγ'z+75	1.20	2.20	0.80	0.20
Fill,Emb.	S	-	18.0	10.0	0	30.0	-	-	-	-	-	-	-	-

*NC: Normal conslidated State   OC: Over consolidated State   z: Depth (m)

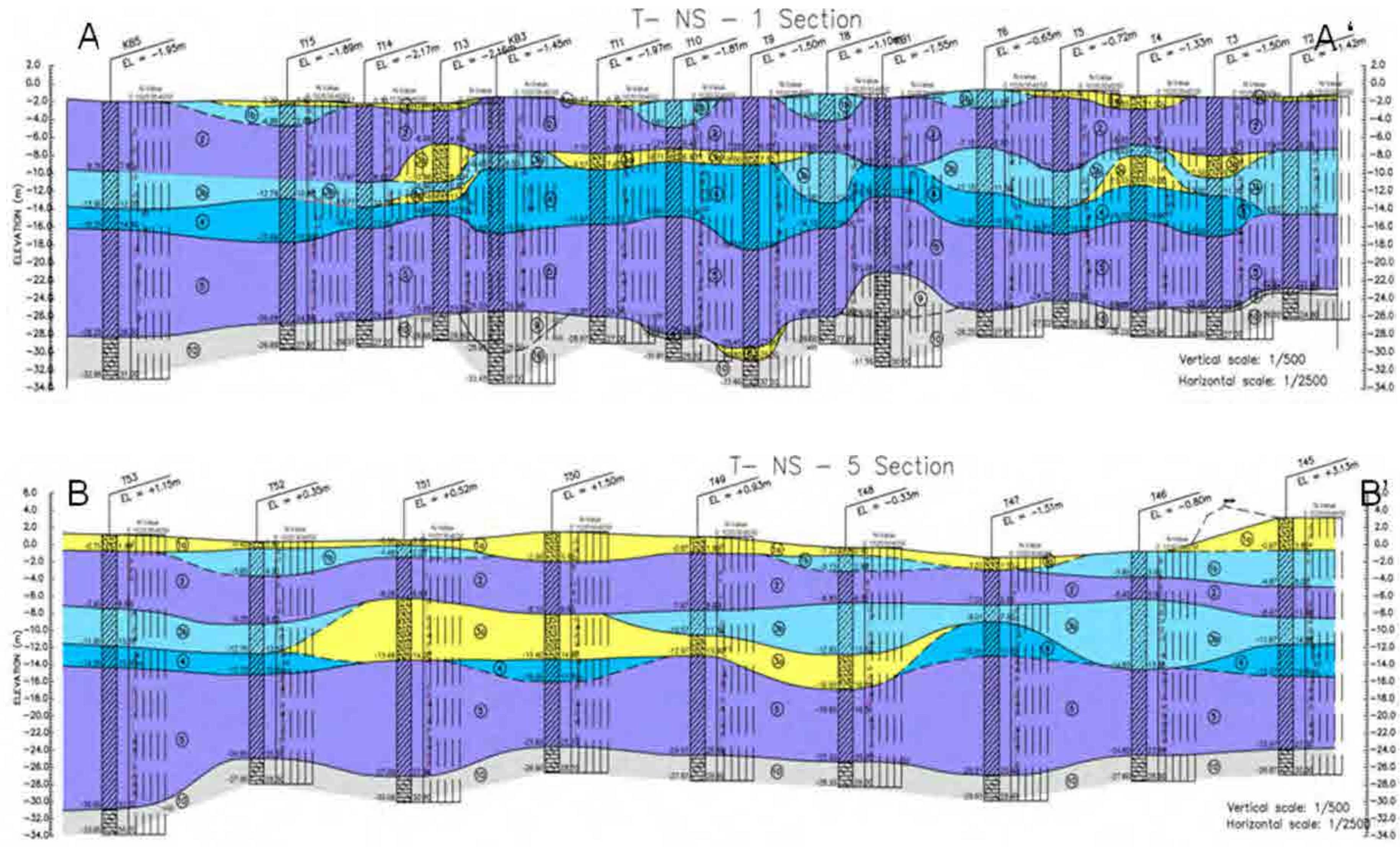


Figure 7.3.17 Soil Profiles at Terminal Area and Access Road Area (A-A' and B-B' sections)

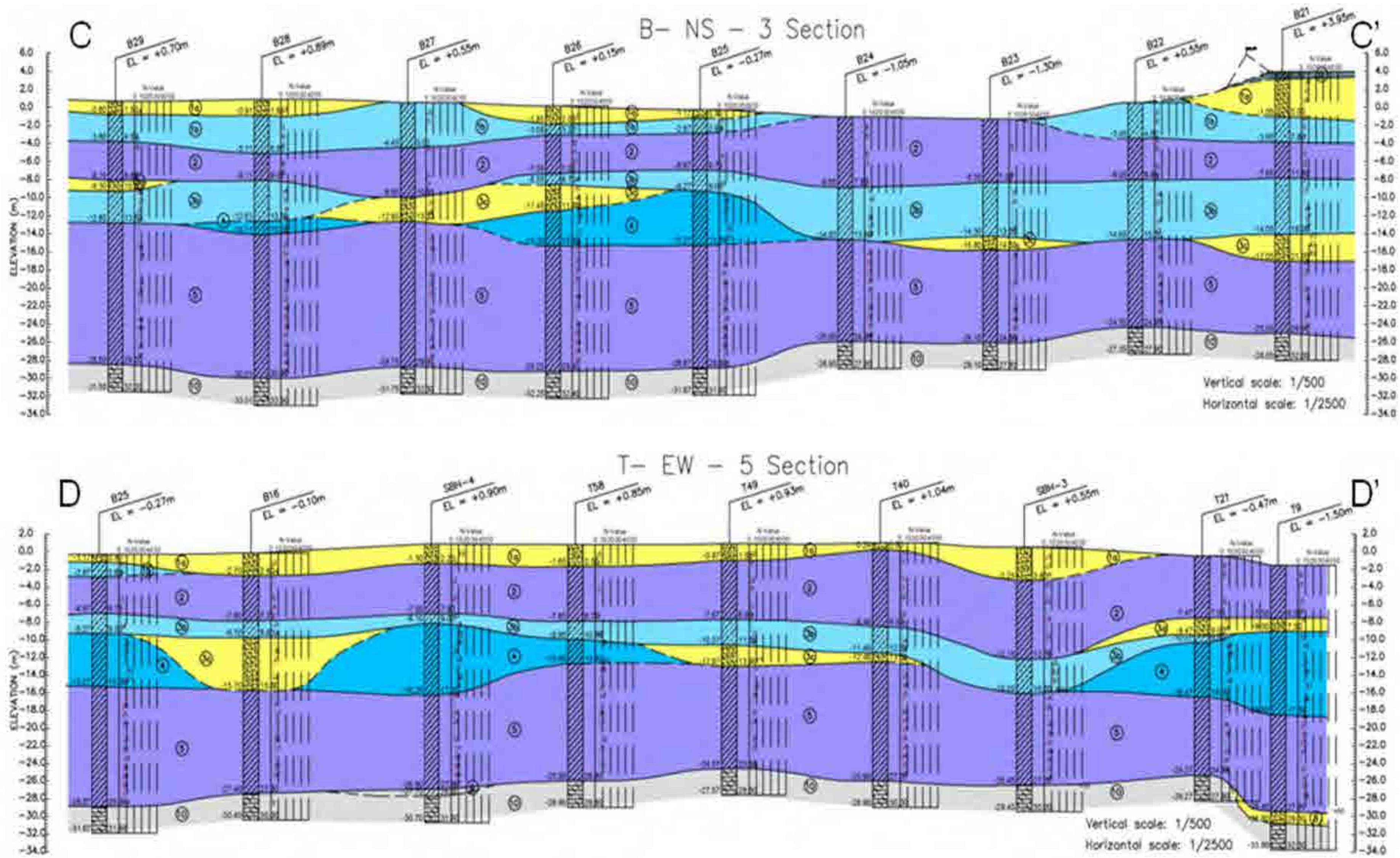


Figure 7.3.18 Soil Profiles at Terminal Area and Access Road Area (C-C' and D-D' sections)

4) Design Flow

Subsoil improvement design flow for Terminal Area and Access Road Area are shown in Figure 7.3.19.

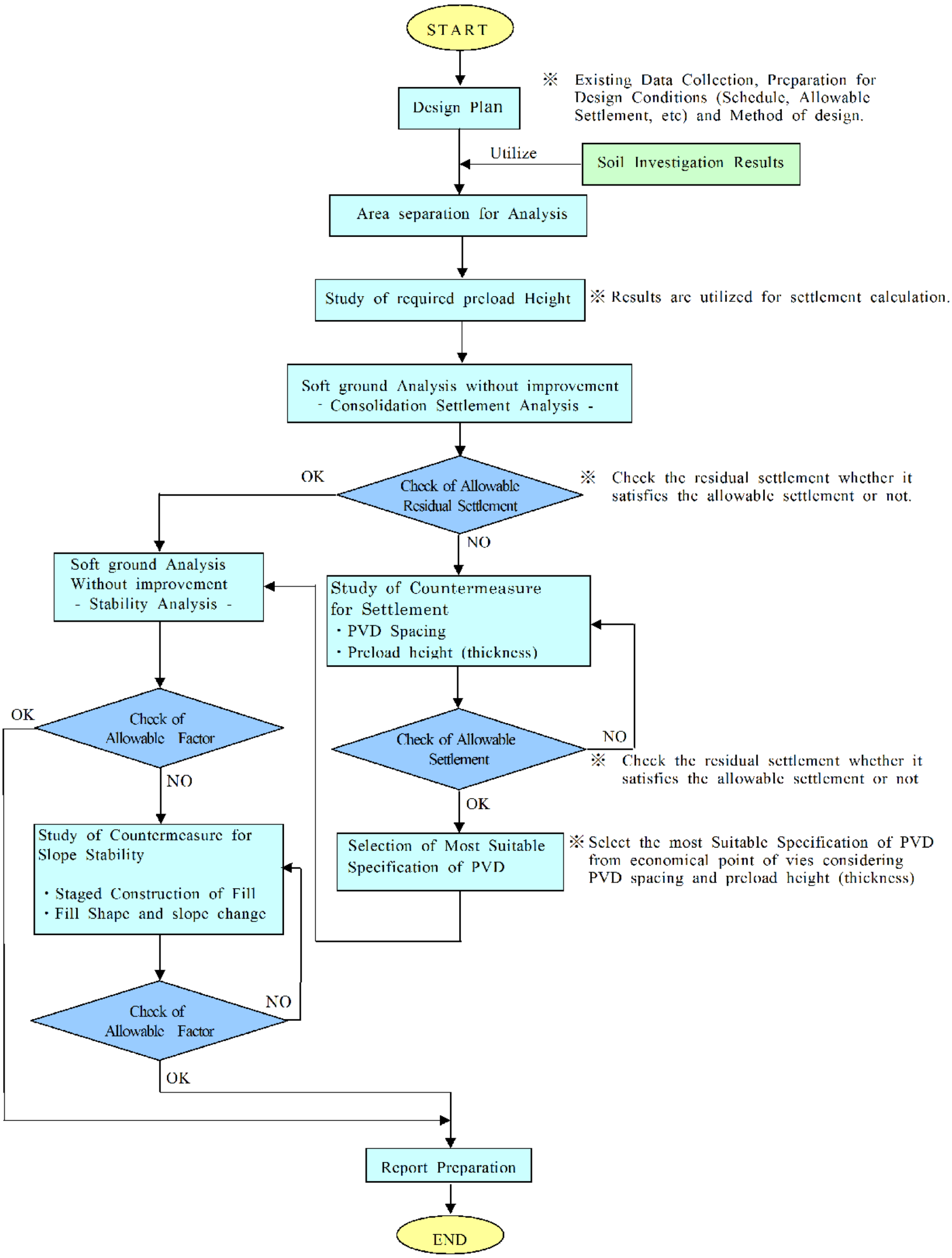


Figure 7.3.19 Subsoil improvement design flow for Terminal Area and Access Road Area

5) Design Criteria and Conditions

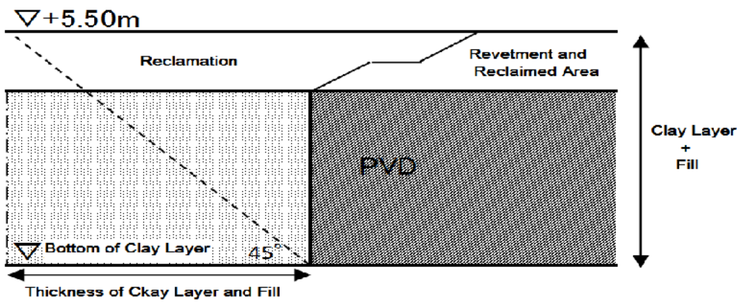
Design criteria and conditions are tabulated as shown in Table 7.3.12.

Table 7.3.12 Summary Table of Design Criteria and Conditions

Item	Design Criteria and Conditions
(a) Allowable Safety Factor for Slope Stability	･Short Term: Fsa≧1.10 (During Construction) ･Long Term : Fsa≧1.30 (Long time passed after completion of construction)
(b) Target Consolidation Degree(U) to be achieved	･U=80% to be achieved by each loading (U=90% to be achieved by final loading for Access Road Area) ･Horizontal Coefficient of Consolidation Ch=2×Cv (Cv: Vertical Coefficient of Consolidation)
(c) Residual Settlement	･Container Terminal Area (Full and empty container storage yard): At the time of 15 months later after reclamation work started: Spr= 0 cm (100% of Primary consolidation shall be completed.) ･Access Road Area: (From 22TCN262-2000) During the time of 15 years after pavement completed: S15<30cm. (30cm = Primary + Secondary consolidation. Time of pavement completion is assumed at 6months (180 days) after removal of excess Preload.)
(d) Design Load	･Container Terminal Area(Full Container Storage Yard): q＝30kN/m^2 ･Container Terminal Area(Full Container Storage Yard): q＝10kN/m^2 ･Access Road Area: q＝10kN/m^2
(e) Water Level	･HWL (High Water Level) : CD+3.55m ･MWL (Mean Water Level) : CD+1.95m (for Consolidation Settlement Analysis) ･LWL(Low Water Level) : CD+0.43m (for Slope Stability Analysis: Sea Side) ･RWL(Residual Water Level) : CD+1.47m (for Slope Stability Analysis: Reclaimed side)
(f) Design Elevation	･Design Elevation of Container Terminal Area and Access Road Area: CD +5.50m ･Required Elevation before Preloading: Higher than CD+4.50m ･Surcharge Removal Level: CD +4.50m
(g) Construction Progress Ratio	･PVD Installation : 30,000m/day with 4 parties → 60 days /construction block ･Reclamation : 10,000m^3/day with 4 parties → 1m height /week /construction block ･Preloading : 5,000m^3/daywith 4 parties → 0.5m height/week /construction block ･Removal of preload: 2,500m^3/day→ 0.25m height/week /construction block
(h) Period for Reclamation Work	･Period for Reclamation Work including Subsoil Improvement: 15 months (Retaining period for Reclamation fill and Preload per construction block: totally more than 8 months)
(i) Influence Range of settlement by loading*)	･Influence range of settlement by loading : Equivalent to thickness of clay layer (45 degree).

*) Contiguous Area to Future Site

After opening this Lach Huyen terminal, cracks and settlings of existing pavement could be formed by the looseness and settlement of subsoil that are caused by the load of reclamation at the future expansion site next to this project area. The dimensions impacted by the future reclamation works will be considered as shown in the following figure. The influence distance from the boundary of future expansion site will be about 36 m (Lowest bottom level CD-30m and Planned Elevation of Port area CD+5.5m ≈ 36m). Accordingly, this area will be improved in this project in advance.



Influence Range for Consolidation Settlement by adjacent Loading

6) Calculation Method

The calculation methods for soil improvement are described as follows;

a) Consolidation Analysis

A number of trial calculations are carried out based on variations of the following parameters under conditions shown in Table 7.3.12.

- The degree of consolidation to be more than 80 % for Terminal Area.
- The intervals of vertical drain to be between 1.0 and 2.2 meters.
- The preload established by filling materials of wet density 18 kN/m^3.
- The preload established by filling materials of saturated density 20 kN/m^3.

i) Consolidation Settlement (Primary Consolidation Settlement of Clay)

<u>Stress calculation by reclamation load and preload</u>

Stress increment by reclamation load and preload is calculated using the following Osterberg's Figure. This figure gives the stress influence factors "I" with function of a/z and b/z (refer to the following Figure 7.3.20). Vertical stress increment at depth "z" can be obtained by the following formula.

$$\sigma_z = I \times q$$

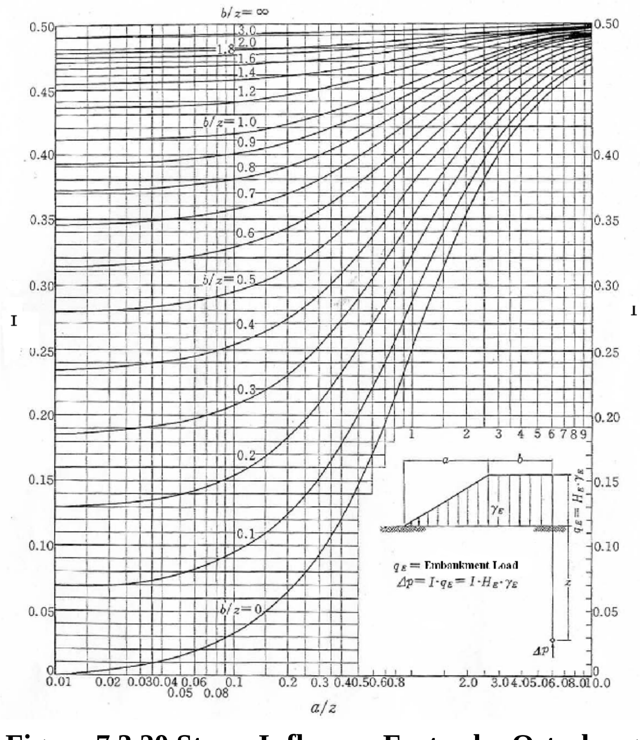


Figure 7.3.20 Stress Influence Factor by Osterberg

<u>Final Settlement Calculation</u>

Final Settlement is calculated as sum of primary consolidation settlement and secondary consolidation settlement by the following formula.

$$Sf = \frac{CrH}{e_0 + 1}\log\left(\frac{p_c}{p_0}\right) + \frac{CcH}{e_0 + 1}\log\left(\frac{p_0 + \Delta p}{p_c}\right)$$

Where,
Sf : Final Primary consolidation settlement (m)
Cc : Compression Index
Cr : Re-compression Index
e_0 : Initial void ratio
p_0 : Initial stress (Overburden pressure) (kN/m^2)
pc : Consolidation yielding stress)(kN/m^2)
Δp: Stress Increment (kN/m^2)
H : Thickness of layer (m)

ii) Time and Settlement Relation

Time and settlement relation is calculated by the followings;

Without improvement -- Terzaghi's Theory

<u>Mono Layer (Without Improvement)</u>

In case of unimproved ground, water inside the clay is discharged only to the vertical direction as shown in Figure 7.3.21. Time and settlement relation is calculated using Terzaghi's one dimensional consolidation theory which gives relation between consolidation degree and time factor as shown in Figure 7.3.22. The formula for calculations is shown as follows;

$$St = U \cdot Sc$$

$$U = 1 - \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\left(\frac{2n+1}{2}\cdot\pi\right)^2\cdot T_V\right]$$

$$T_V = \frac{C_V \cdot t}{D^2}$$

Where,
St : Settlement (m)
Sc : Final settlement by primary consolidation (m)
U : Consolidation Degree (%)
Tv :Time Factor (vertical)
Cv : Coefficient of Consolidation (vertical) (cm^2/day)
t : time (days)
D : Maximum drainage length (cm)
D=H/2 for double drainage, D=H foe single drainage

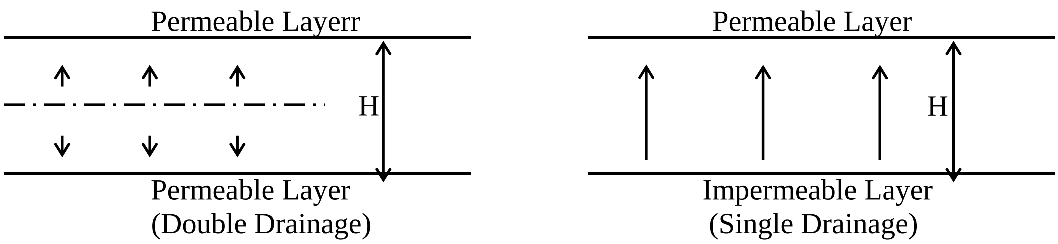
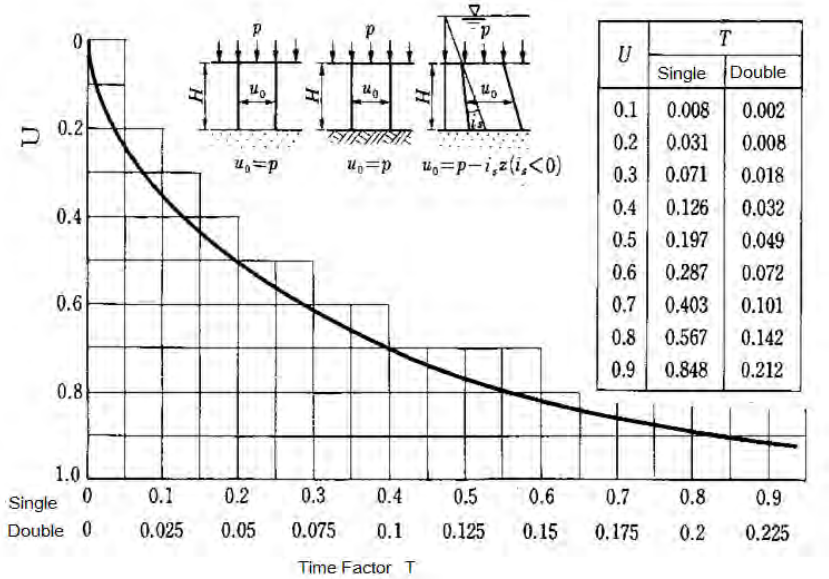


Figure 7.3.21 Concept of One Dimensional Consolidation



U	T Single	T Double
0.1	0.008	0.002
0.2	0.031	0.008
0.3	0.071	0.018
0.4	0.126	0.032
0.5	0.197	0.049
0.6	0.287	0.072
0.7	0.403	0.101
0.8	0.567	0.142
0.9	0.848	0.212

Figure 7.3.22 Relationship between Consolidation Degree U and Time Factor Tv

Multiple Layers (Without Improvement)

In case of unimproved multiple layer ground, equivalent layer thickness method is used for calculation of time and settlement relations. Equivalent layer thickness method is to calculate the time and settlement relation of multiple layers as one layer using equivalent layer thickness converted by Cv values by following formula;

$$H_0 = \sqrt{\frac{C_{V0}}{C_{Vi}}} \cdot H_i$$

Where,
- H_0 :Equivalent thickness (m)
- Hi :Thickness of each layer (m)
- Cv_0 : Representative coefficient of consolidation (cm^2/day)
- Cv_i :Coefficient of consolidation of each layer (cm^2/day)

Time and settlement relation of multilayered ground is calculated as one layer using above H_0 and Cv_0.

iii) Required Preload Height

In case of embankment works on soft ground, consolidation settlement becomes larger with increase of embankment height (load). Accordingly, extra embankment height equivalent to settlement will be necessary to retain the design elevation of the area.

In this design, required preload height is calculated to retain the design height when final settlement occurred, using relation curve between preload height and settlement.

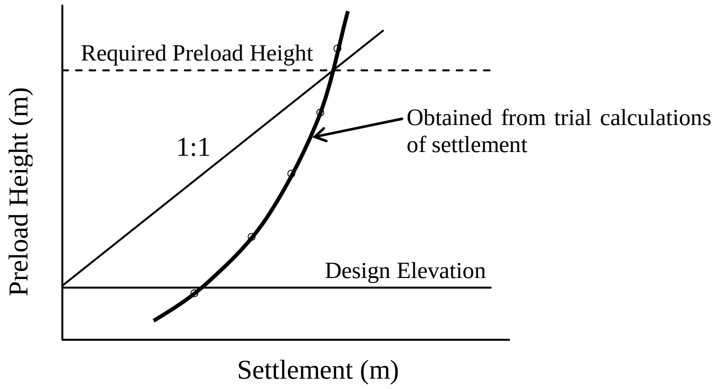


Figure 7.3.23 Required Preload Height

b) Slope Stability

i) Circular Slip Surface Method

The slope stabilities of land reclamation and preloading are examined by circular arc analysis using the modified Fellenius's method described in "Technical Standards and Commentaries for Port and Harbor Facilities in Japan (July, 2007)". The required safety factors of stability analysis shall be as follows:

For long term period; Fs = 1.3

For short term period; Fs = 1.1

To meet the requirements on safety factors, the procedure of land reclamation and the shape of surcharge are examined to ensure the slope stabilities. Inside the reclamation area, stability of preload embankment is examined using the following formula.

$$Fs = \frac{\Sigma\left[c \cdot l + (W - u \cdot b)\cos\alpha \cdot \tan\phi\right]}{\Sigma(W \cdot \sin\alpha)}$$

Where,

Fs: Safety Factor
c: Cohesion of soil (kN/m2)
l: Length of slip surface for one element of soil mass (m)
W: Weight of one element of soil mass (kN/m)
U: Porewater pressure (kN/m^2)
B: Width of one element of soil mass (m)
α: Angle between two lines, the line drawn between center of circular slip circle and center of slip surface of element of soil mass, the vertical line (degree)
ϕ: Angle of shear resistance (degree)

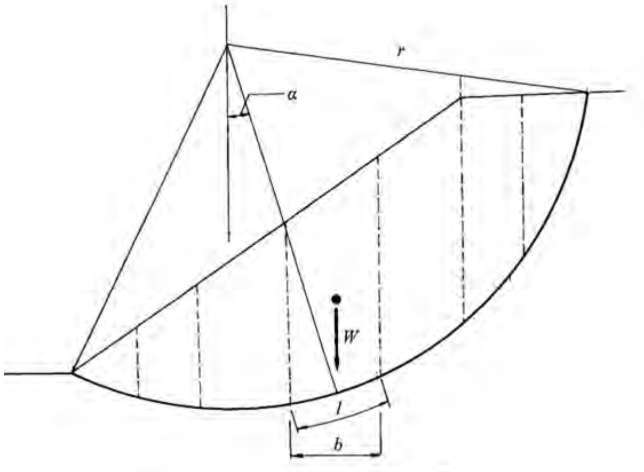


Figure 7.3.24 Slope Stability Analysis by Circular Slip Surface Method

ii) Increase of Shear Strength of Clay

In this slope stability calculation, increase of shear strength by consolidation progress is considered. Increased shear strength (cu) is calculated by the following formula;

$$cu = cu_0 + m\cdot(p_0 - pc + \Delta p)\cdot U$$
$$p_0 + \Delta p \leqq pc \rightarrow cu = cu_0$$
$$p_0 + \Delta p > pc \rightarrow cu = cu_0 + m\cdot(p_0 - pc + \Delta p)\cdot U$$

Where,
cu : Increased shear strength with consolidation progress (kN/m^2)
cu$_0$: Initial shear strength before reclamation work (kN/ m^2)
m : Increase ration of shear strength
p$_0$: Initial stress (Overburden pressure) (kN/ m^2)
pc :Consolidation yielding stress (kN/ m^2)
U : Consolidation degree (%)

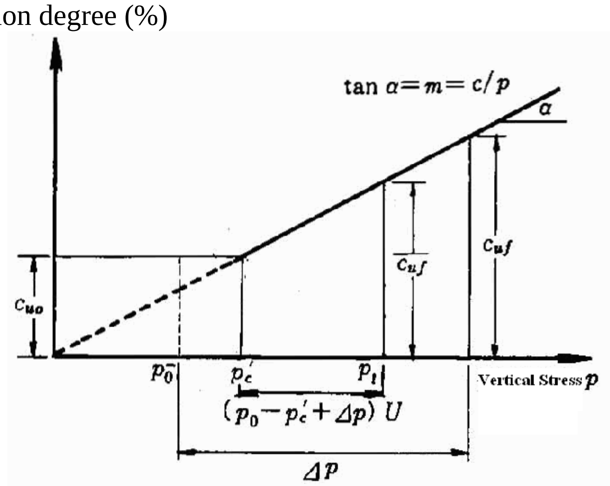


Figure 7.3.25 Increased Shear Strength with Consolidation Progress

c) Subsoil Improvement Method

i) PVD Method

Design of PVD Method is carried out according to "Technical Standards and Commentaries for Port and Harbor Facilities in Japan (July, 2007)".

PVD Method is one of vertical drain methods which install the artificial drainage in the soil to facilitate the consolidation process.

- Calculation of Primary Consolidation Settlement

Relation between time and settlement for improved ground by PVD Method is calculated by the following Barron's formula.

$$St = U \cdot Sc$$

$$U = 1 - \exp\left(\frac{-8T_h}{F(n)}\right)$$

$$T_h = \frac{C_h \cdot t}{{d_e}^2}$$

$$F(n) = \frac{n^2}{n^2 - 1} \cdot \log_e n - \frac{3n^2 - 1}{4n^2}$$

$$n = \frac{d_e}{d_w}$$

Where,

St : Settlement qt time t (m)
Sc : Final primary consolidation settlement (m)
U : Consolidation degree (%)
Th : Time Factor (Horizontal)
Ch : Coefficient of Consolidation (Horizontal) (m2/day)
t : Time (days)
d_e : Diameter of effective circle (m)
d_e=1.05d (Triangle arrangement)
d_e=1.13d (Square arrangement)
d : PVD installation interval
d_w : Diameter of PVD (Drain) (m)

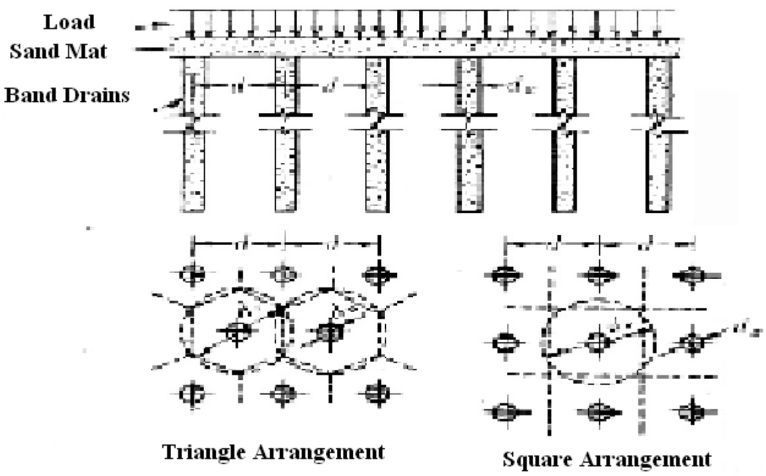


Figure 7.3.26 Effective Circle

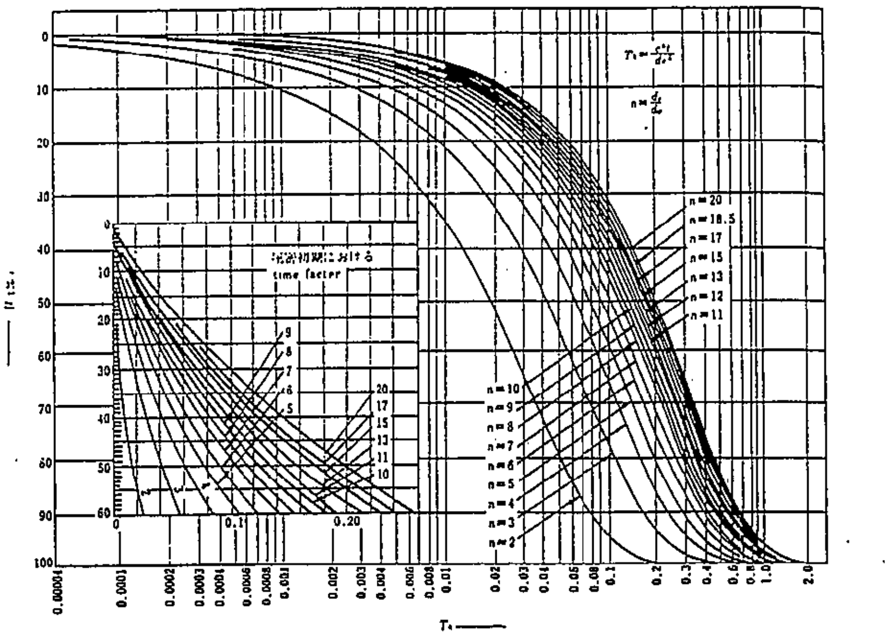


Figure 7.3.27 Consolidation Degree and Time factor Curves of Vertical Drain

- <u>Details of Vertical Drain</u>

Drain material and its installation intervals to be studied are adopted as follows;

- Drain material : Plastic board drain
- Diameter of drain : d_w=0.05m
- Drain installation interval : d=1.0m - 2.2m (Square arrangement)
- Ch = 2Cv (Ch, Cv: Coefficient of consolidation for vertical and horizontal drainage respectively.)

d) Slope Stability Analysis

Method of slope stability analysis is same as the case of without improvement. Shear strength increment with consolidation progress is to be considered.

7) Design Result

a) Area Separation and soil layer models for blocks

Terminal Area (Full container and empty container storage yards) and Access Road Area are separated into totally 17 blocks considering design load, seabed level and soil stratifications as shown in Figure 7.3.28. Settlement and stability analysis results for design of subsoil improvement methods have been carried out for the soil layer model for each block are shown in Figure 7.3.29.

As shown in Figure 7.3.29, there are found some intermediate sand layers at Terminal and Access Road Area. Actually as for the intermediate sand layers between soft clay layers might be work as drainage layers for PVD. However horizontal continuity of those sand layers has not been confirmed by boring investigation results this time. Therefore intermediate sand layers are neglected as non-drainage layers in the settlement calculations for PVD from conservative point views.

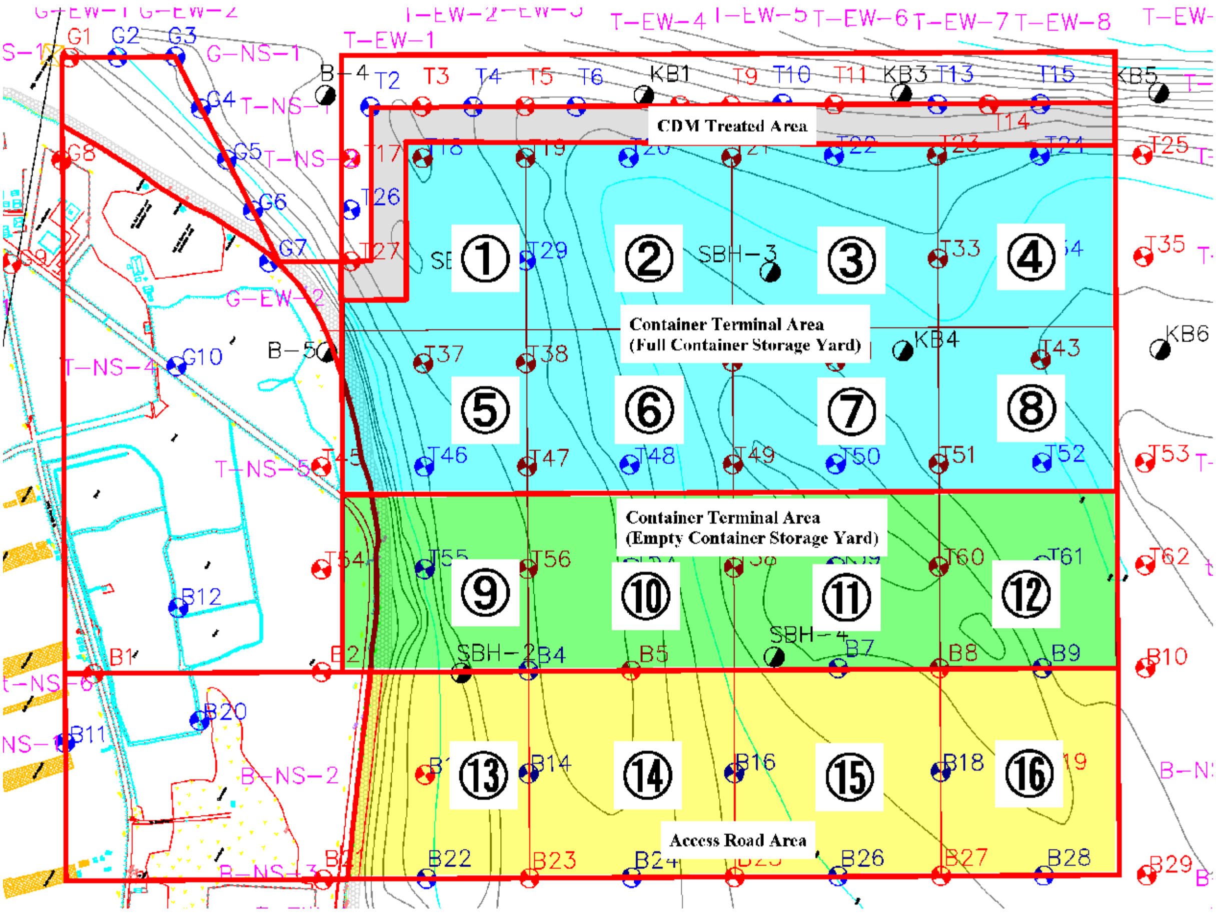


Figure 7.3.28 Blocks for subsoil improvement design

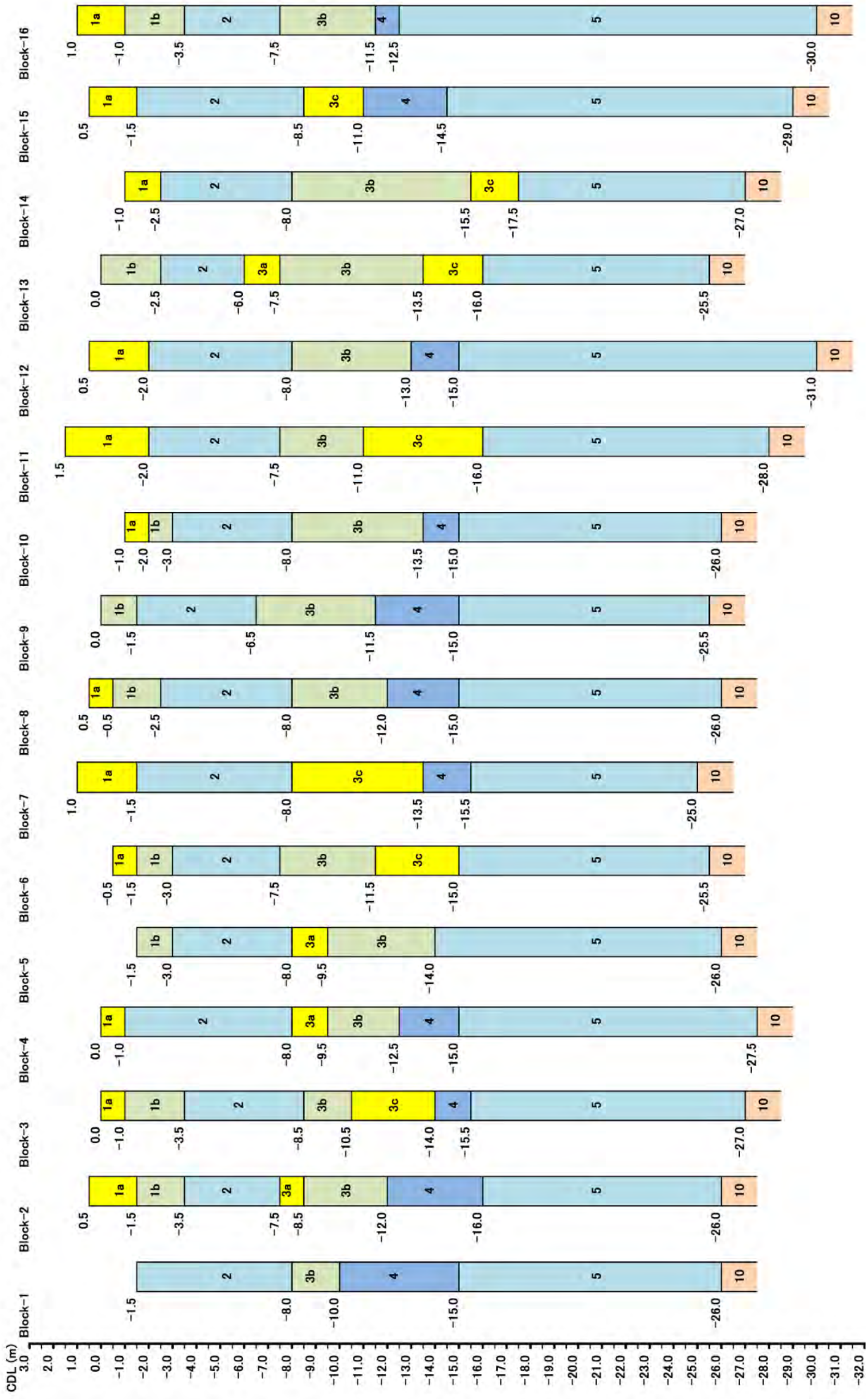


Figure 7.3.29 Soil layer model for subsoil improvement design at Reclamation Area

b) Result of consolidation Settlement calculation without subsoil improvement

i) Required embankment height

Settlement calculation has been carried out for the ground without any subsoil improvement at 16 blocks in Container Terminal Area and Access Road Area. From these calculation results, required embankment height can be estimated not to be below the design elevation (CD+5.50m) at 16 blocks as shown in Figure 7.3.30. Settlement in the estimation for required embankment height is calculated based on primary consolidation settlement.

This calculation results are tabulated as shown in Table 7.3.13. Required embankment height calculation figures are shown in the Appendix 7.1.

According to the result, required embankment height for each block is more than CD+6.0m (0.5m as thickness) to CD+7.0m (1.5m as thickness).

Table 7.3.13 Result of Required Embankment Height Calculation (without subsoil improvement)

Area	Block	Design Elevation	Required Embankment Height (Thickness)
Terminal Area (Full container storage yard)	①	CD+5.50m	CD+7.00m (1.50m)
	②		CD+6.50m (1.00m)
	③		CD+6.70m (1.20m)
	④		CD+6.80m (1.30m)
	⑤		CD+6.90m (1.40m)
	⑥		CD+6.60m (1.10m)
	⑦		CD+6.40m (0.90m)
	⑧		CD+6.70m (1.20m)
Terminal Area (Empty container storage yard)	⑨	CD+5.50m	CD+6.50m (1.00m)
	⑩		CD+6.60m (1.10m)
	⑪		CD+6.10m (0.60m)
	⑫		CD+6.50m (1.00m)
Access Road Area (On-shore)	⑬	CD+5.50m	CD+6.30m (0.80m)
	⑭		CD+6.50m (1.00m)
	⑮		CD+6.40m (0.90m)
	⑯		CD+6.40m (0.90m)

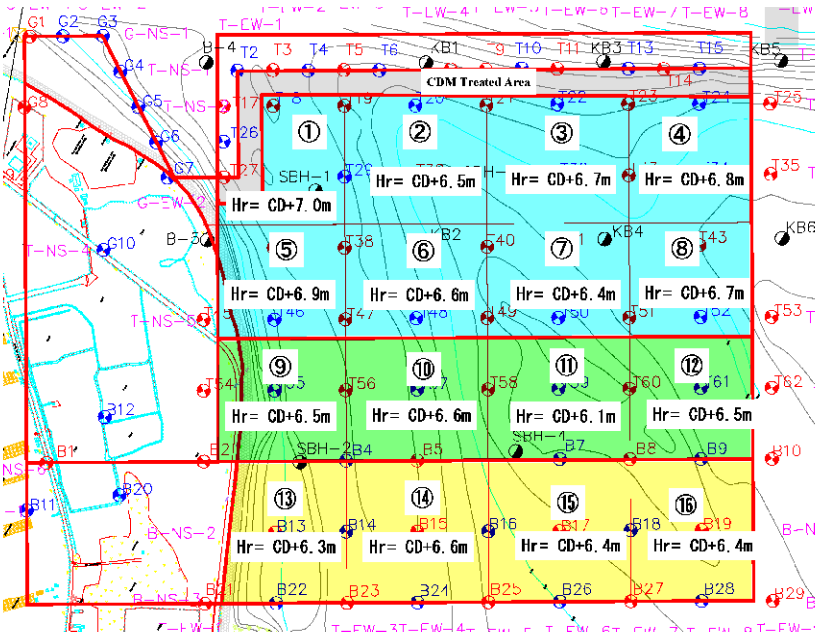


Figure 7.3.30 Required embankment height at each block

c) Result of subsoil Improvement by PVD Method

If the ground is not treated by any subsoil improvement, it takes very long time to achieve the consolidation settlement without subsoil improvement due to its thickness of clay layers. It means that harmful residual settlement will remain so much after port operation started. Accordingly, "PVD + Preload" method has been studied as suitable subsoil improvement for Terminal and Access Road Area. In this section, appropriate drain spacing and required preload elevation (thickness) for 16 blocks in Container Terminal Area and Access Road Area have been studied.

i) PVD Spacing and Required Preload Elevation (Fill Thickness)

Appropriate PVD spacing and required preload elevation have been studied for 16 blocks in Terminal Area and Access Road Area. Settlement analysis result with suitable PVD spacing and required preload elevation (thickness) are tabulated in Table 7.3.14 and Figure 7.3.31 to Figure 7.3.33.

Table 7.3.14 Settlement Calculation Result for Terminal Area and Access Road Area

Area		Block	PVD Spacing (Square) (m)	Preload Height (Thickness) (m)	Final Settlement ΣSf (m)	Settlement for each layer (m)					Residual Primary Consolidation Settlement at Port Opening Sr (m)
						1b	2	3b	4	5	
Recla-mation Area	Terminal Area (Full Container Storage Yard)	Block-1	1.1	3.9	1.458		0.727	0.102	0.147	0.482	0.000
		Block-2	1.1	3.3	0.959	0.118	0.374	0.117	0.063	0.287	0.000
		Block-3	1.1	3.5	1.134	0.161	0.492	0.078	0.028	0.375	0.000
		Block-4	1.1	3.6	1.270		0.691	0.109	0.050	0.420	0.000
		Block-5	1.1	3.8	1.389	0.126	0.547	0.189		0.527	0.000
		Block-6	1.1	3.4	1.082	0.102	0.448	0.162		0.370	0.000
		Block-7	1.1	3.1	0.841		0.571		0.025	0.245	0.000
		Block-8	1.1	3.5	1.183	0.126	0.524	0.141	0.052	0.340	0.000
	Terminal Area (Full Container Storage Yard)	Block-9	1.2	2.2	0.956	0.096	0.408	0.162	0.040	0.250	0.000
		Block-10	1.2	2.3	1.050	0.063	0.449	0.190	0.023	0.325	0.000
		Block-11	1.2	1.9	0.612		0.376	0.080		0.156	0.000
		Block-12	1.2	2.1	0.930		0.470	0.135	0.017	0.308	0.000
	Access Road Area	Block-13	1.6	1.5	0.755	0.136	0.271	0.159		0.189	0.066
		Block-14	1.6	1.5	0.944		0.477	0.229		0.238	0.107
		Block-15	1.6	1.5	0.810		0.528		0.024	0.258	0.094
		Block-16	1.6	1.5	0.776	0.109	0.296	0.095	0.006	0.270	0.081

Residual primary consolidation settlement at Access Road Area is ranging between 6cm to 11cm. Secondary consolidation settlement for 15 years after pavement completion (assumed 6months later after removal of preload = 21 months later after reclamation started) is ranging between 14cm and 21cm as shown in Table 7.3.15. Thus total residual settlement (Primary + Secondary) at Access Road Area for 15years is within required value (30cm). (Refer to Chapter 16 for calculation procedure of secondary consolidation settlement.)

Table 7.3.15 Secondary Consolidation Settlement Calculation Result for Access Road Area

Area	Block	Time of Pavement Completion tpav (days) (15months+6 months)	Time of Period for Secondary Consolidation tf (days) (15years)	Coeffi. of Secondary Consolidation $C_{\alpha\varepsilon}$					Thickness of Layer H (m)					Secondary Consolidation Settlement Ss (m)					
				1b	2	3b	4	5	1b	2	3b	4	5	1b	2	3b	4	5	Total
Access Road Area	Block-13	630	6,105	0.005	0.008	0.005	0.006	0.008	2.5	3.5	6.0	0.0	9.5	0.01	0.03	0.03	0.00	0.07	0.14
	Block-14	630	6,105	0.005	0.008	0.005	0.006	0.008	0.0	5.5	7.5	0.0	9.5	0.00	0.04	0.04	0.00	0.07	0.16
	Block-15	630	6,105	0.005	0.008	0.005	0.006	0.008	0.0	7.0	0.0	3.5	14.5	0.00	0.06	0.00	0.02	0.11	0.19
	Block-16	630	6,105	0.005	0.008	0.005	0.006	0.008	2.5	4.0	4.0	1.0	17.5	0.01	0.03	0.02	0.01	0.14	0.21

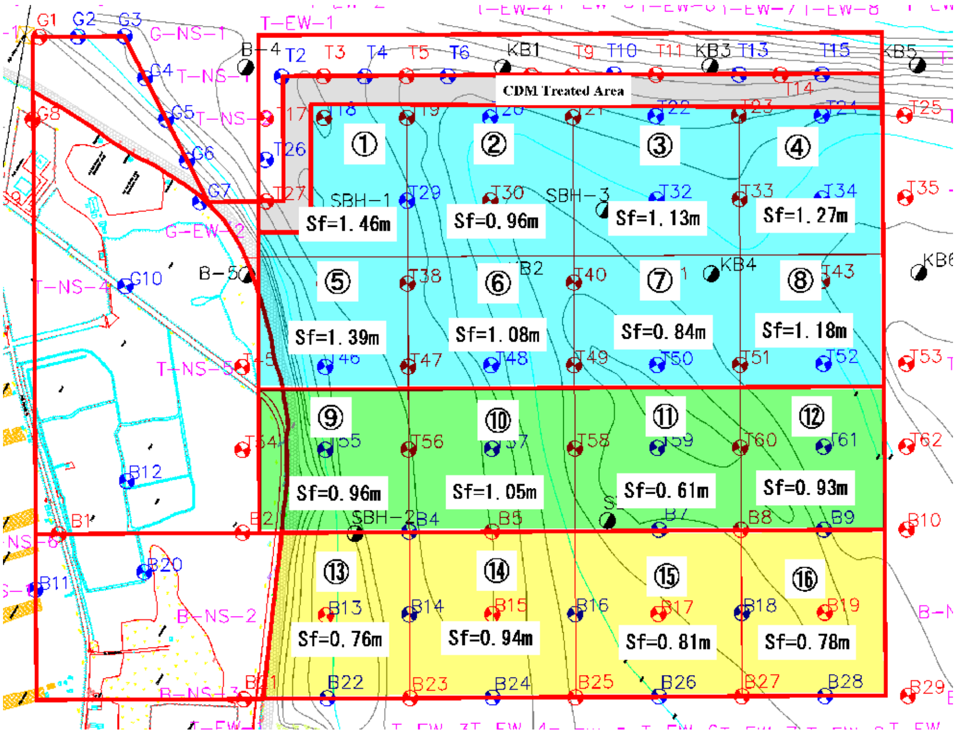


Figure 7.3.31 Final Settlement by Fill and Preload (Primary Consolidation Settlement)

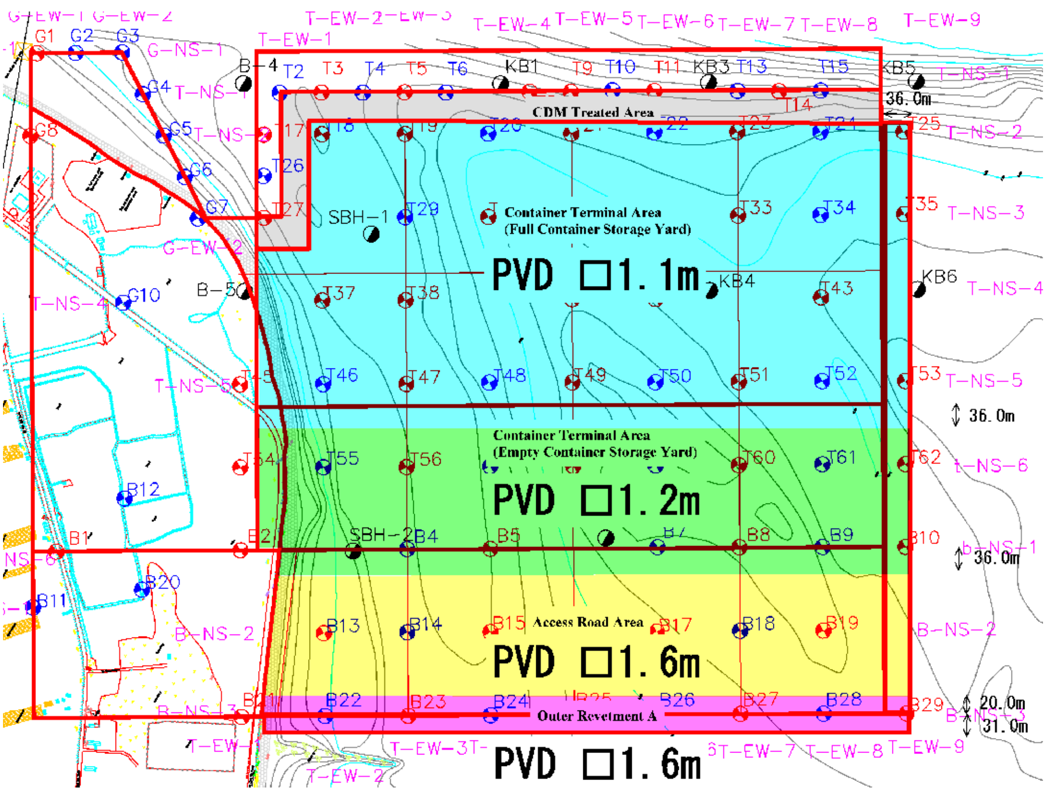


Figure 7.3.32 PVD Spacing for 16 Blocks

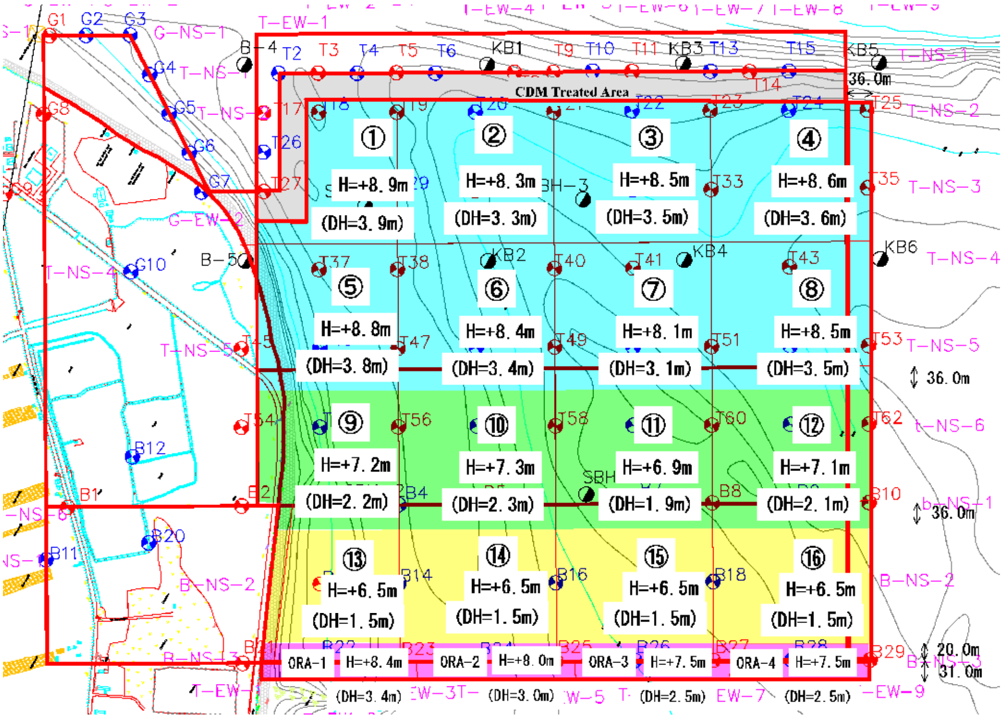


Figure 7.3.33 Required Preload Height (Thickness) for 16 Blocks

Appropriate PVD spacing has been selected from economical point of views for Block-1 to 12. PVD spacing for Access Road Area (Block-13 to 16) has been selected to achieve the required consolidation degree in assumed construction period. PVD spacing for inner Revetment Area has been selected considering continuity of PVD installation work in reclamation area. As for PVD spacing for Outer Revetment Area, it has been selected to secure the stability of preload embankment with achievement of required consolidation settlement.

PVD spacing for each area is as follows;

(1) Container Terminal Area (Full Container Storage Yard) : d= 1.1m
(2) Container Terminal Area (Full Container Storage Yard) : d= 1.2m
(3) Access Road Area : d= 1.6m
(4) Outer Revetment A Area : d= 1.6m

Extra improvement width 36m is considered at the boundary of load areas and boundary of reclamation area between the first phase and future second phase.

Representative settlement curve for each area (Terminal Area and Access Road Area) is shown in Figure 7.3.34 to Figure 7.3.36 and other settlement curves for all blocks and economical comparison by PVD spacing for Terminal Area (Block-1 to 12) are shown in the Appendix 7.1.

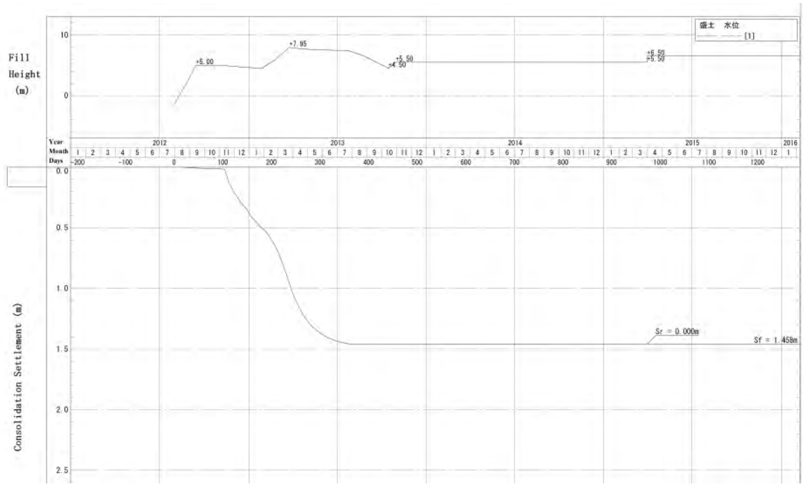


Figure 7.3.34 Settlement Curve (Full Container Storage Yard, Block-1, PVD d=1.1m)

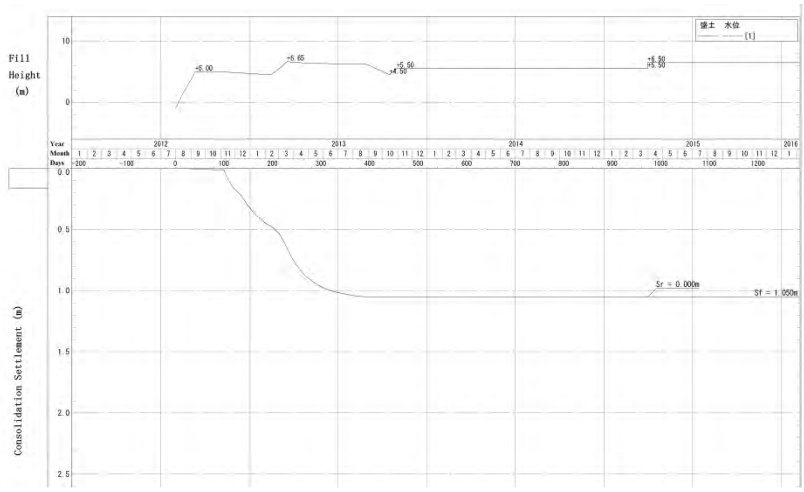


Figure 7.3.35 Settlement Curve (Empty Container Storage Yard, Block-10, PVD d=1.2m)

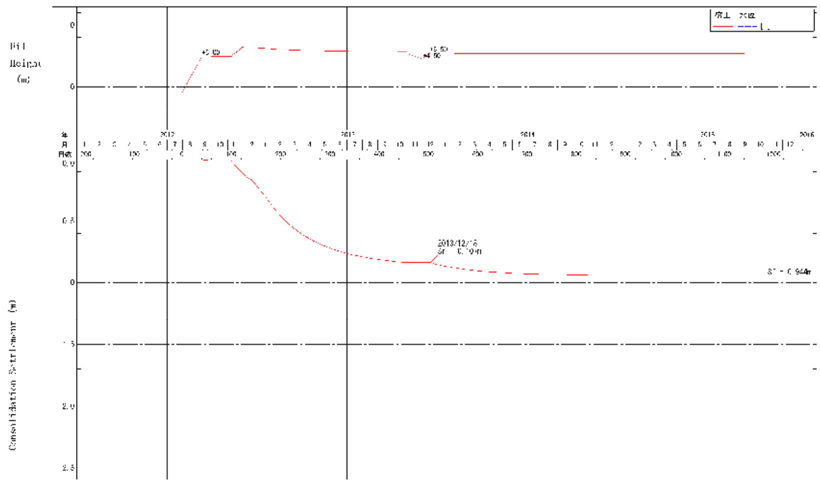


Figure 7.3.36 Settlement Curve (Access Road Area, Block-14, PVD d=1.6m)

According to above PVD spacing and preload calculation results, construction area demarcation by PVD spacing and preload height can be indicated as shown in Figure 7.3.37.

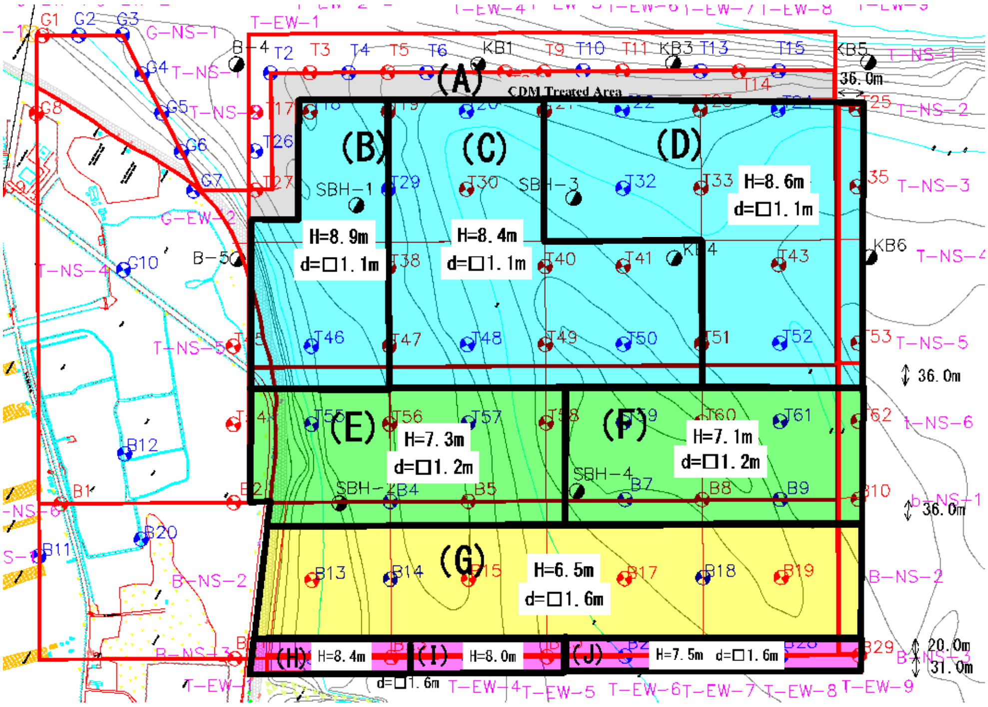


Figure 7.3.37 Construction Area Demarcation by PVD spacing and preload height

ii) Slope Stability during Filling at Reclamation Area

Slope stability analysis results during construction for the reclamation load at the 1st Step Load (CD+5.0m) has been studied for 16 blocks in the Reclamation Area.

Average slope gradient form CD+5.0m level to sea bed to satisfy the required safety factor (Fs=1.1) for slip circular analysis has been checked. Those results are shown in Table 7.3.16 and representative stability result figure for each area are shown in Figure 7.3.38 to Figure 7.3.40.

Table 7.3.16 Required Average Slope Gradient for First Step Filling (CD+5.0m)

Area		Block	Required Average Gradient	Obtained Minimum Safety Factor Fsmin	Required Safety Factor Fsa
Recla-mation Area	Terminal Area (Full Container Storage Yard)	Block-1	1:6	1.104	1.1
		Block-2	1:6	1.136	1.1
		Block-3	1:7	1.162	1.1
		Block-4	1:7	1.190	1.1
		Block-5	1:6	1.104	1.1
		Block-6	1:6	1.118	1.1
		Block-7	1:5	1.117	1.1
		Block-8	1:6	1.128	1.1
	Terminal Area (Empty Container Storage	Block-9	1:5	1.100	1.1
		Block-10	1:7	1.174	1.1
		Block-11	1:3	1.122	1.1
		Block-12	1:6	1.109	1.1
	Access Road Area	Block-13	1:5	1.124	1.1
		Block-14	1:7	1.207	1.1
		Block-15	1:7	1.175	1.1
		Block-16	1:5	1.137	1.1

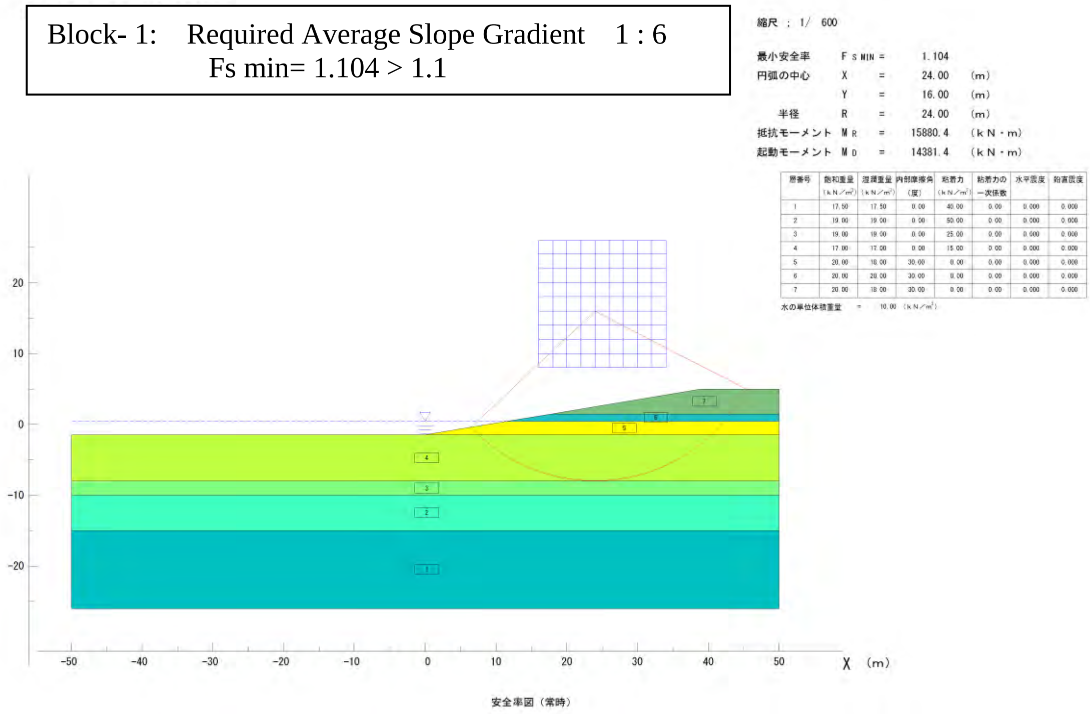


Figure 7.3.38 Stability Analysis Result for Block-1 at Full Container Storage Yard

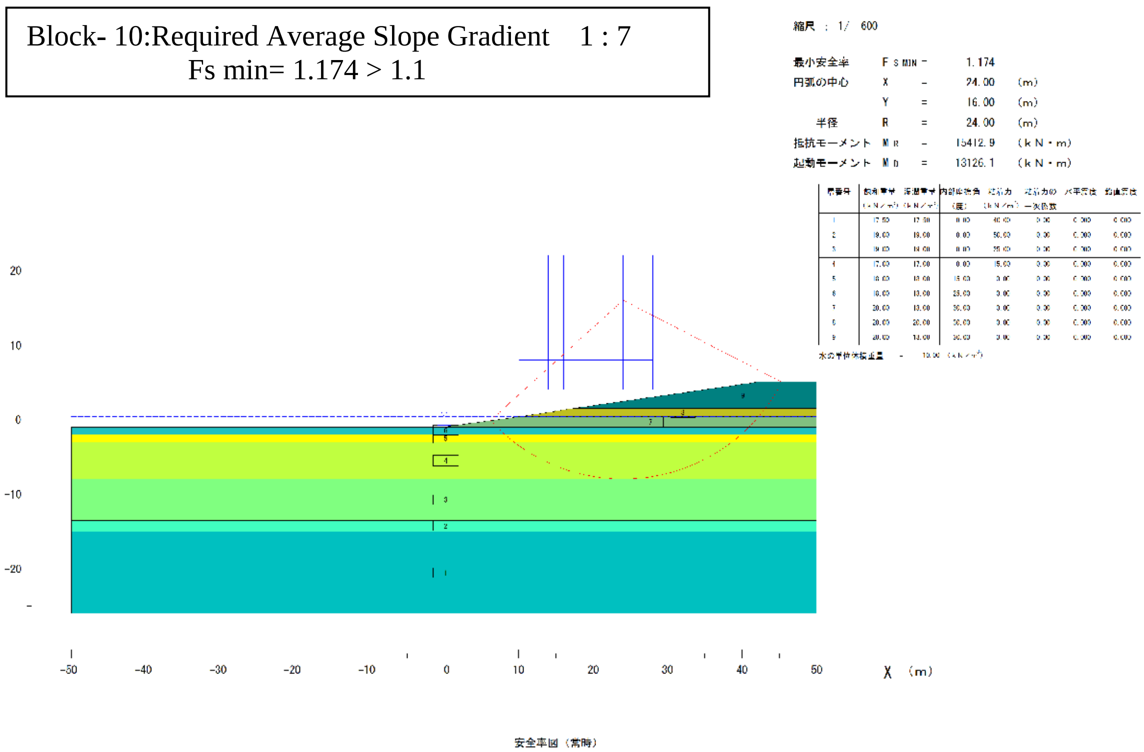


Figure 7.3.39 Stability Analysis Result for Block-10 at Empty Container Storage Yard

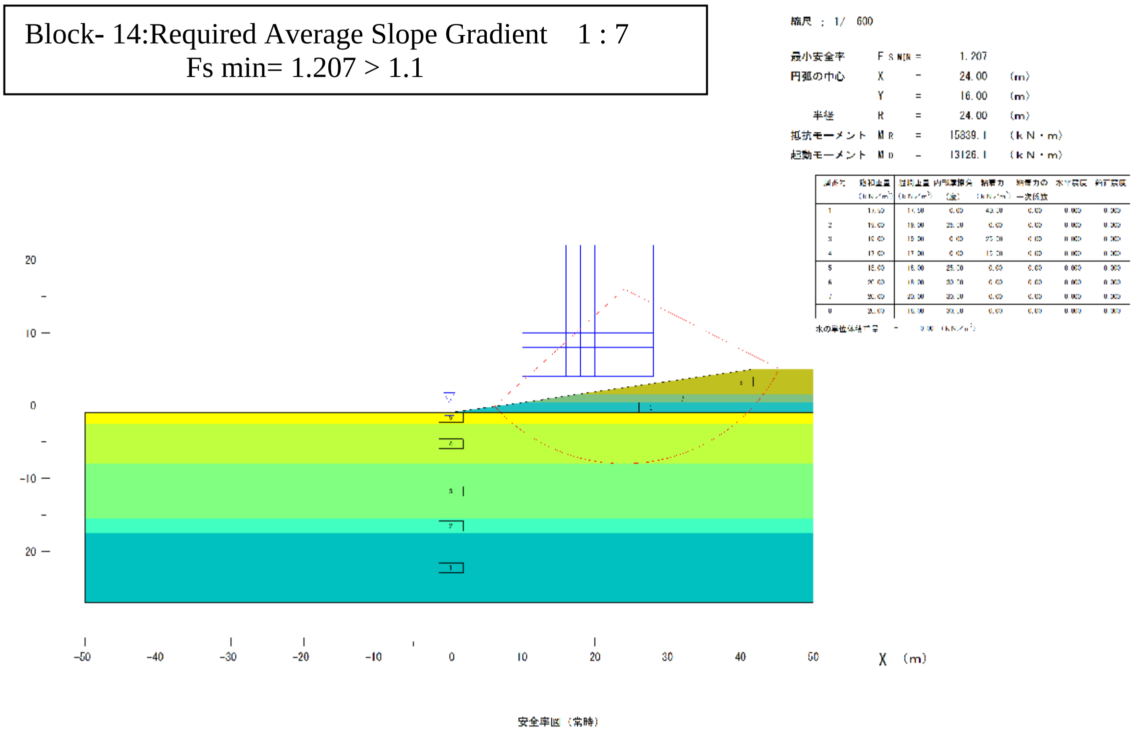


Figure 7.3.40 Stability Analysis Result for Block-10 at Empty Container Storage Yard

According to those results, average slope gradient for the first step loading up to CD+5.0m requires about 1:5 to 1:7 of very gentle one to satisfy the required safety factor during construction. As for the stability under preloading construction, required safety factor (Fs=1.1) will be satisfied when more than 20 m to 30 m buffer space between shoulder of first step fill (CD+5.0m) and toe of preload embankment is kept, according to stability analysis results at revetment area.

All slope stability analysis results for “PVD+Preload” Method at Terminal Area and Access Road Area are shown in the Appendix 7.1.

iii) Soil Improvement Procedure by PVD and Preload at Reclamation Area

Soil Improvement Procedure by PVD and Preload at Reclamation Area is shown in Figure 7.3.41. And schematic view of cross section of reclamation area improved by PVD and Preload is shown in Figure 7.3.42.

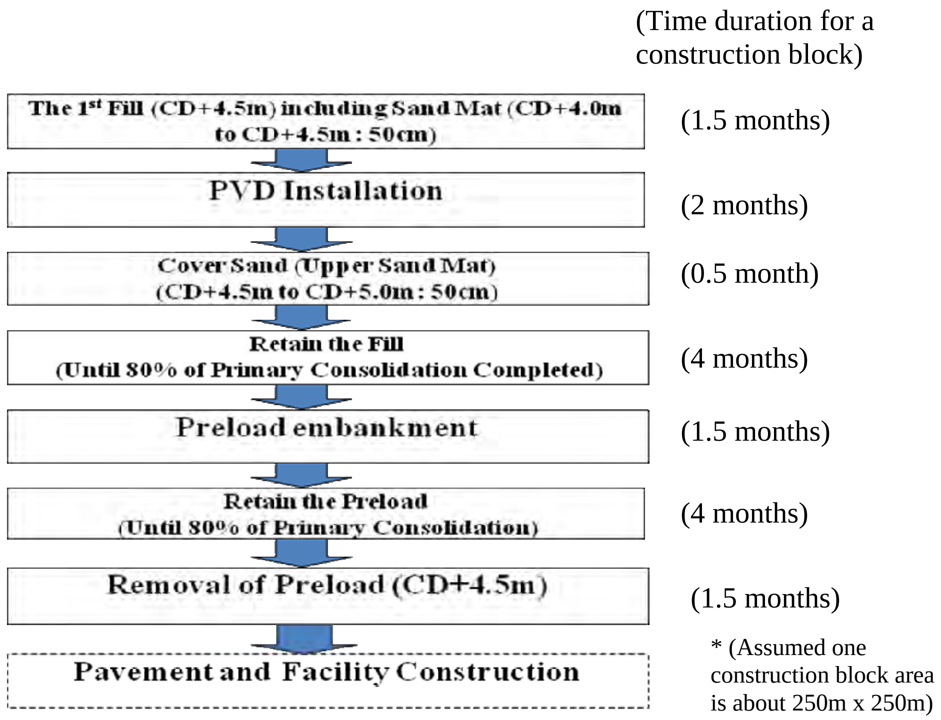


Figure 7.3.41 Soil Improvement Procedure by PVD and Preload at Reclamation Area

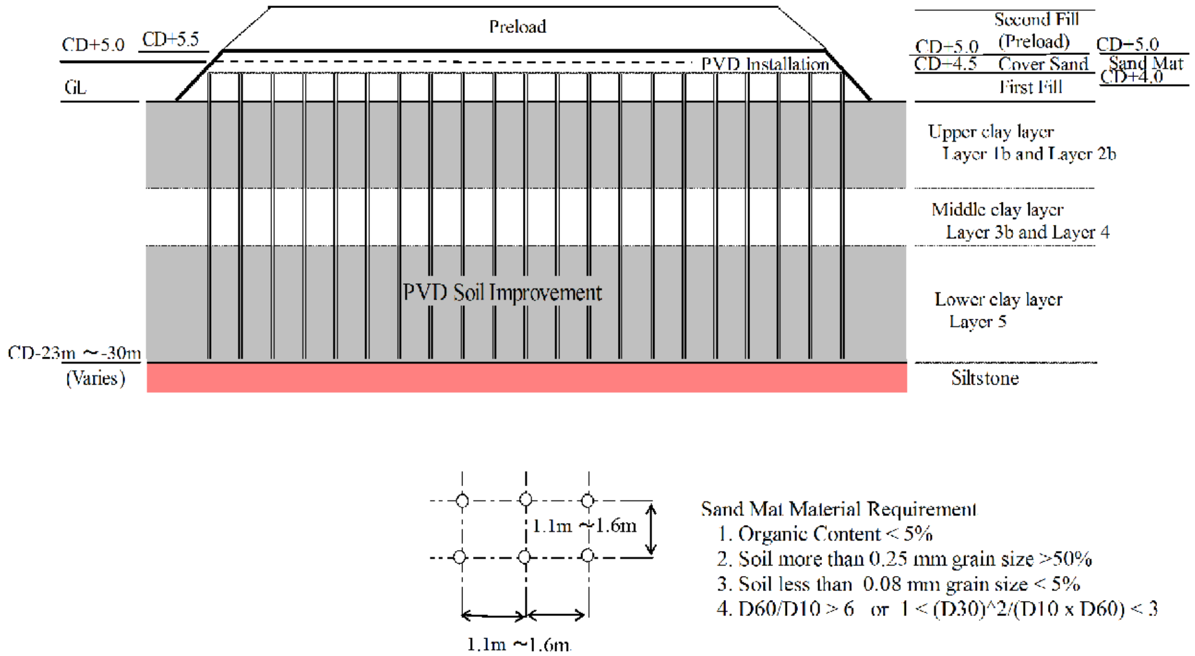


Figure 7.3.42 Schematic view of cross section of reclamation area improved by PVD and Preload

7.4 Stability for Fill and Revetment

7.4.1 Design Principle

At Inner Revetment and Outer Revetment A Area, soft to medium consistency clay layers are identified in 20m to 30m thick including intermediate firm clay layer which has several meters thick. Accordingly consolidation settlement which is lasting long time and stability problem during revetment construction has been worried. And also due to tight schedule for subsoil improvement work for a reclamation block, it is considered that residual settlement cannot be retained within required range without any soil improvement works. Therefore subsoil improvement methods for Inner Revetment and Outer Revetment A Areas have been studied in this Section.

As for the Inner Revetment, countermeasures for consolidation settlement and slope stability shall be considered, which are not only by loads due to present planned reclamation and revetment but also by future reclamation loads. Accordingly, considering the continuity of improvement method, PVD method with same spacing as applied adjacent reclamation blocks are considered as a subsoil improvement method for Inner Revetment. Furthermore preloading method has been applied together with PVD method in order to achieve the optimum improvement effect from economical point of views as well as Terminal and Access Road Area.

As for the Outer Revetment A, main purpose of subsoil improvement is to reduce the residual settlement by expedite the consolidation and to retain the slope stability. Therefore three subsoil improvement method has been studied here, PVD Method (acceleration of settlement and increase of shear strength) and Sand Replacement by excavation (decrease of settlement and increase of shear strength by replaced sand). Among the sections and specifications for two methods selected as suitable subsoil improvement methods, most suitable subsoil improvement method and specification for Outer Revetment A has been studied due to economical point of views.

7.4.2 Subsoil Improvement Design

1) Design Flow

Subsoil improvement design flows for Inner Revetment and Outer revetment A are shown in Figure 7.4.1 and Figure 7.4.2 respectively.

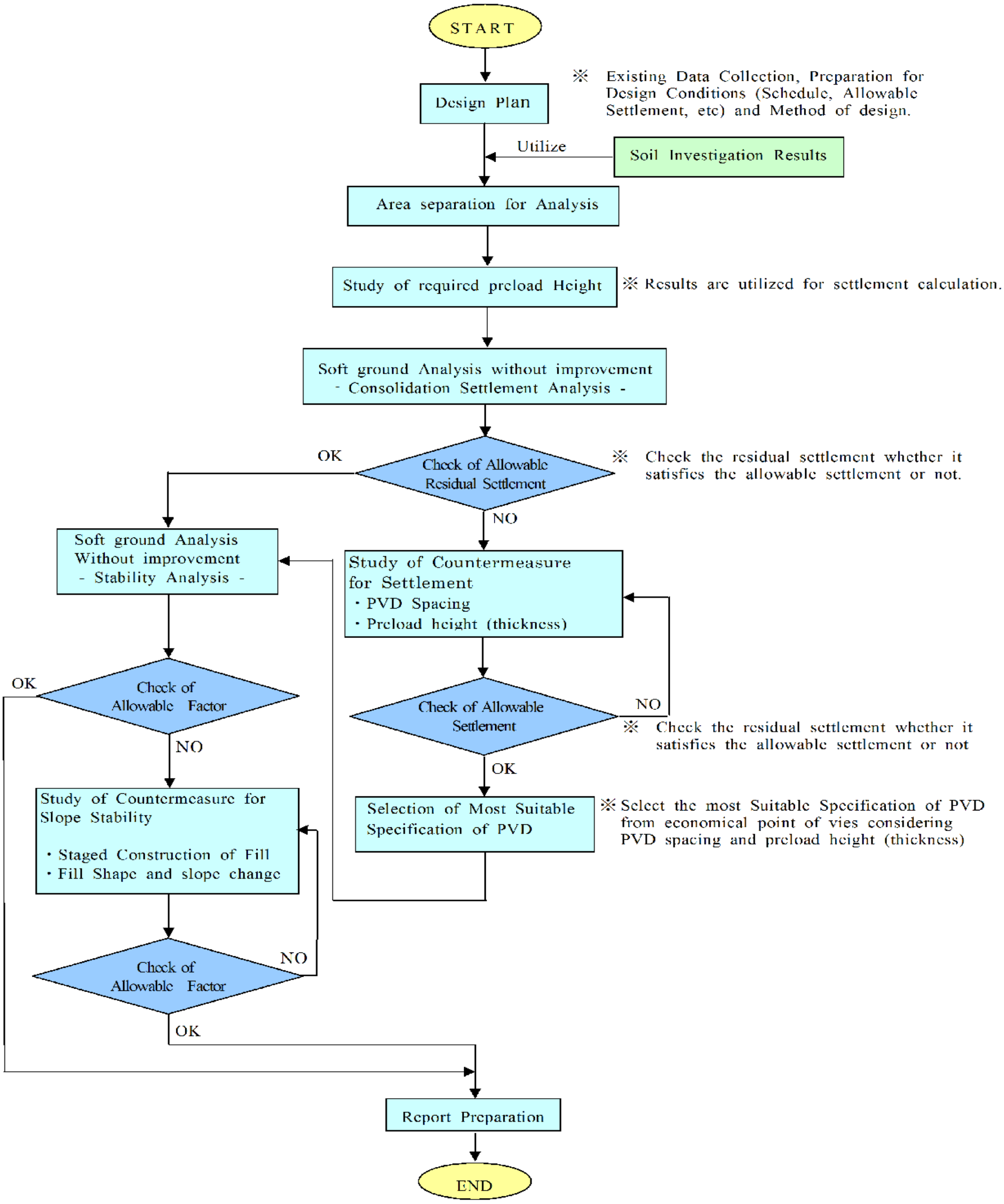


Figure 7.4.1 Subsoil improvement design flow for Inner Revetment

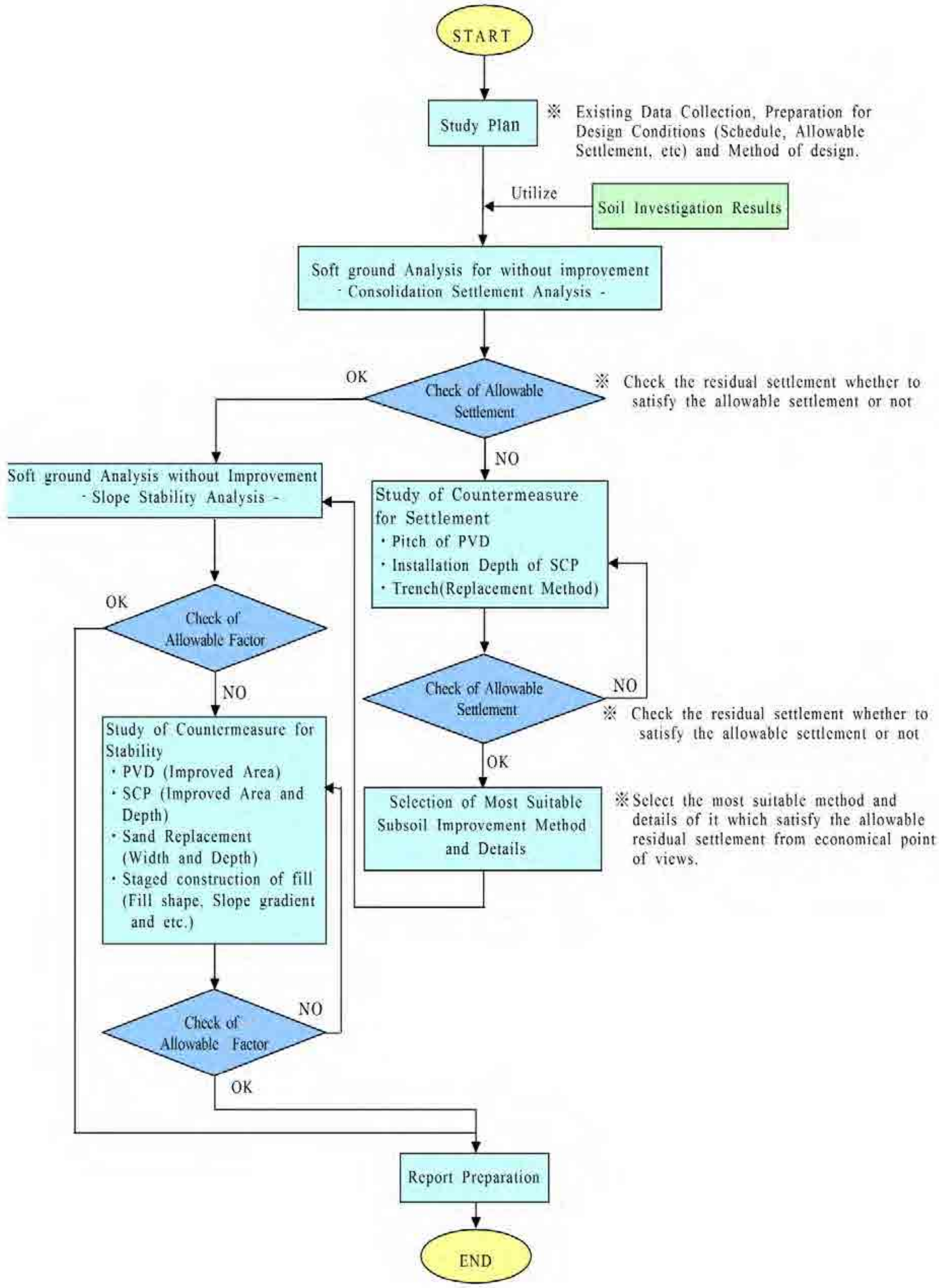


Figure 7.4.2 Subsoil improvement design flow for Outer Revetment A

2) Design Criteria and Conditions

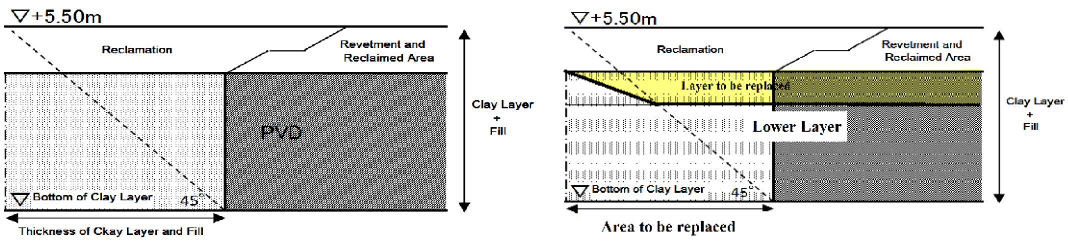
Design criteria and conditions are tabulated as shown in Table 7.4.1

Table 7.4.1 Summary Table of Design Criteria and Conditions

Item	Design Criteria and Conditions
(a) Allowable Safety Factor for Slope Stability	・Short Term: Fsa≧1.10 (During Construction) ・Long Term : Fsa≧1.30 (Long time passed after completion of construction)
(b) Target Consolidation Degree(U) to be achieved	・U=80% or more to be achieved by each loading ・Horizontal Coefficient of Consolidation Ch=2×Cv (Cv: Vertical Coefficient of Consolidation)
(c) Residual Settlement	・Inner Revetment 1) Area next to Container Terminal Area (Full and empty container storage yard): At the time of 15 months later after reclamation work started: Spr= 0 cm (100% of Primary consolidation shall be completed.) 2) Area next to Access Road Area: During the time of 15 years after pavement completed: S_{15}≤30cm (Primary consolidation) ・Outer Revetment Area next to Access Road Area: (From 22TCN262-2000)During the time of 15 years after pavement completed: S_{15}≤30cm (S15=30cm: Primary + Secondary consolidation. Time of pavement completion is assumed at 6months (180 days) after removal of excess Preload.)
(d) Design Load at Reclamation Area behind Revetment	・Container Terminal Area(Full Container Storage Yard): q＝30kN/m^2 ・Area Container Terminal Area(Full Container Storage Yard): q＝10kN/m^2 ・Access Road Area: q＝10kN/m^2
(e) Water Level	・HWL (High Water Level) : CD+3.55m ・MWL (Mean Water Level) : CD+1.95m (For Consolidation Settlement Analysis) ・LWL(Low Water Level) : CD+0.43m (For Stability Analysis : Sea side) ・RWL (Residual Water Level) : CD+1.47m (For Stability Analysis : Land side)
(f) Design Elevation	・Design Elevation of Inner Revetment Section-1, 2, 3: CD +5.50m ・Outer Revetment A: Top Level of Revetment: CD+6.50m ・Required Elevation before Preloading: Higher than CD+4.50m (HWL+1m) (Required lowest level of Sand Mat) ・Surcharge Removal Level: CD +4.50m (HWL+1m)
(g) Construction Progress Ratio	・PVD Installation : 30,000m/day with 4 parties → 60 days /construction block ・Reclamation : 10,000m^3/day with 4 parties → 1m height /week /construction block ・Preloading : 5,000m^3/daywith 4 parties → 0.5m height/week /construction block ・Removal of preload: 2,500m^3/day→ 0.25m height/week /construction block
(h) Period for Reclamation Work	・Period for Reclamation Work: Approximately 15months per construction block. (Retaining period for Reclamation fill and Preload per construction block: totally more than 8 months)
(i) Influence Range of settlement by loading*)	・Influence range of settlement by loading : Equivalent to thickness of clay layer (45 degree).

*) Contiguous Area to Future Site

After opening this Lach Huyen terminal, cracks and settlings of existing pavement could be formed by the looseness and settlement of subsoil that are caused by the load of reclamation at the future expansion site next to this project area. The dimensions impacted by the future reclamation works will be considered as shown in Figure 7.4.3. The influence distance from the boundary of future expansion site will be about 36 m (Lowest bottom level CD-30m and Planned Elevation of Port area CD+5.5m ≈ 36m). Accordingly, this area will be improved in this project in advance. In case of Sand Replacement method, replacement area to avoid the future settlement influence is also set as follows.



Incase of PVD treatment In case of Sand Replacement

Figure 7.4.3 Influence Range for Consolidation Settlement by adjacent Loading

3) Calculation Method for the ground without improvement

a) Settlement Analysis (One dimensional consolidation settlement of clay)

Same methods as Terminal Area and Access Road Area are applied.

b) Slope Stability Analysis (Slip Circular Surface Method)

Same methods as Terminal Area and Access Road Area are applied.

4) Subsoil Improvement Method

a) PVD Method

i) One dimensional consolidation settlement Analysis

Same methods as Terminal Area and Access Road Area are applied

ii) Details of Vertical Drain

Same methods as Terminal Area and Access Road Area are applied

iii) Slope Stability Analysis

Same methods as Terminal Area and Access Road Area are applied

b) Sand Replacement Method

Design of Sand Replacement Method is carried out based according to “Technical Standards and Commentaries for Port and Harbor Facilities in Japan (July, 2007)”.

i) Settlement Analysis

Settlement analysis for Sand Replacement Method is carried out for the left clay layers below the replaced sand. Calculation method is the same as ones for the ground without treatment.

ii) Slope Stability Analysis

Calculation method for slope stability is the same as ones for the ground without treatment. Details of Sand Replacement are as follows;

- Replacement Material: Sand
- Unit weight of replacement material (γ’): 10(kN/m^3)
- Friction angle of replacement sand (ϕ): 30 (^{o})
- Excavated slope gradient: 1: 3

7.4.3 Subsoil Improvement Design Result

1) Locations of sections for analysis and soil layer models

Location of sections used for design analysis is shown in Figure 7.4.4, soil layer models are also shown in Figure 7.4.7. Sections for design analysis for consolidation settlement and slope stability has been selected with totally 4 sections each for Inner Revetment and Outer Revetment A. Soil parameter as shown in Table 7.3.11 for these analysis have been used.

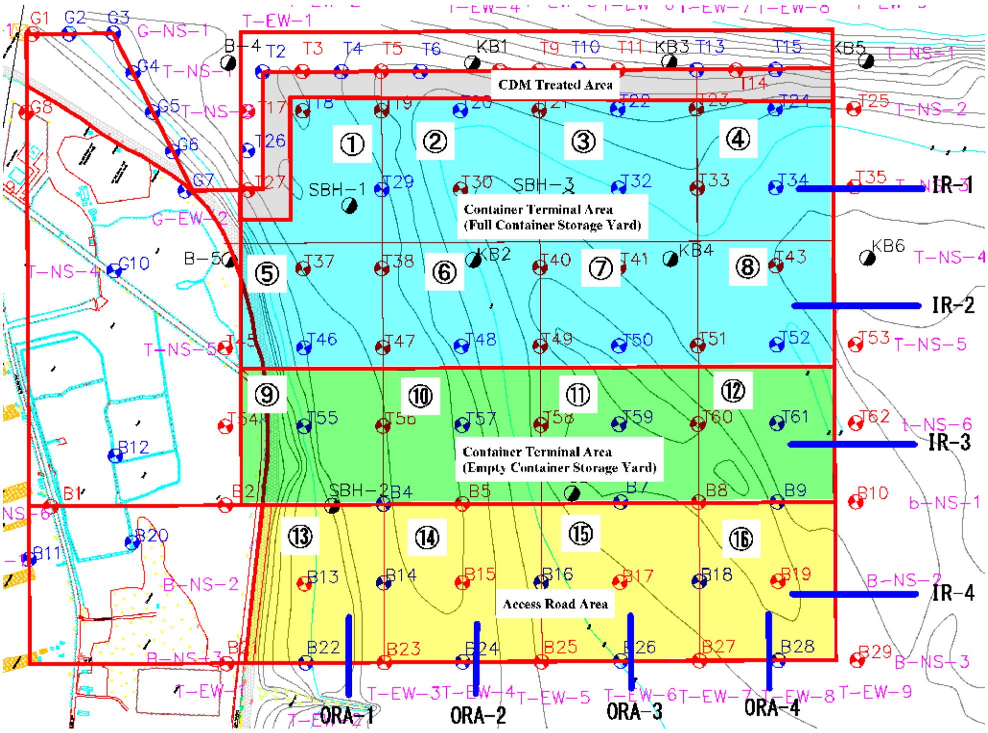


Figure 7.4.4 Sections for Analysis (Inner Revetment and Outer Revetment A)

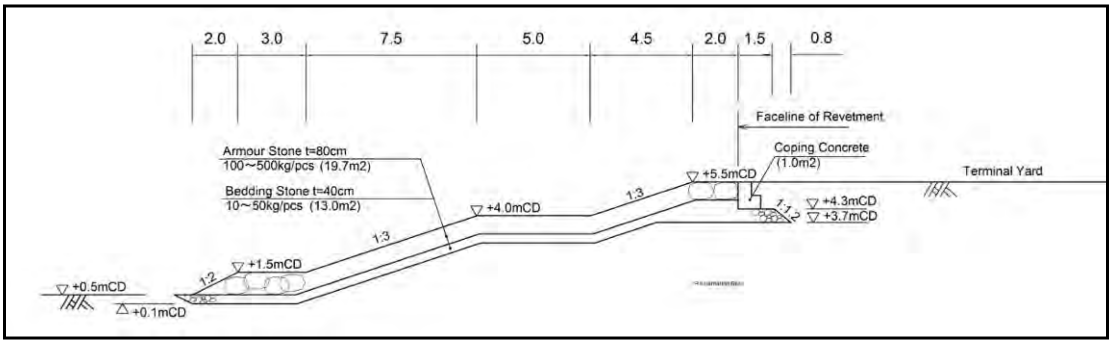


Figure 7.4.5 Cross Section of Inner Revetment

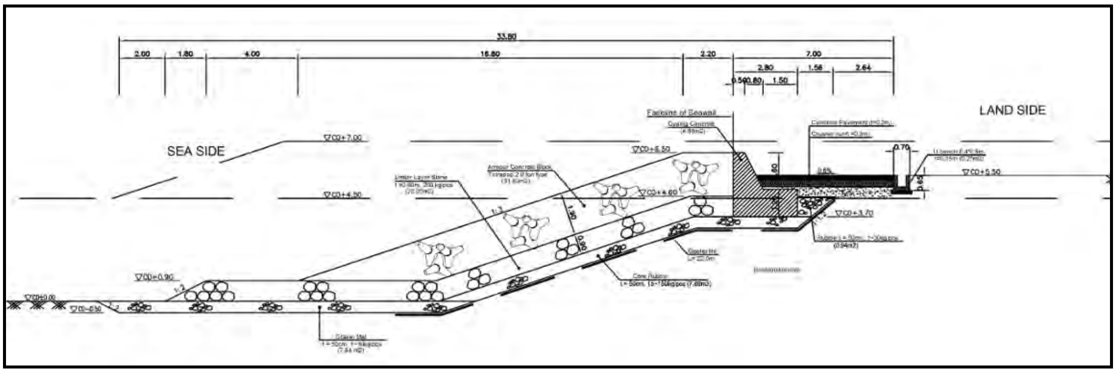


Figure 7.4.6 Cross Section of Outer Revetment A

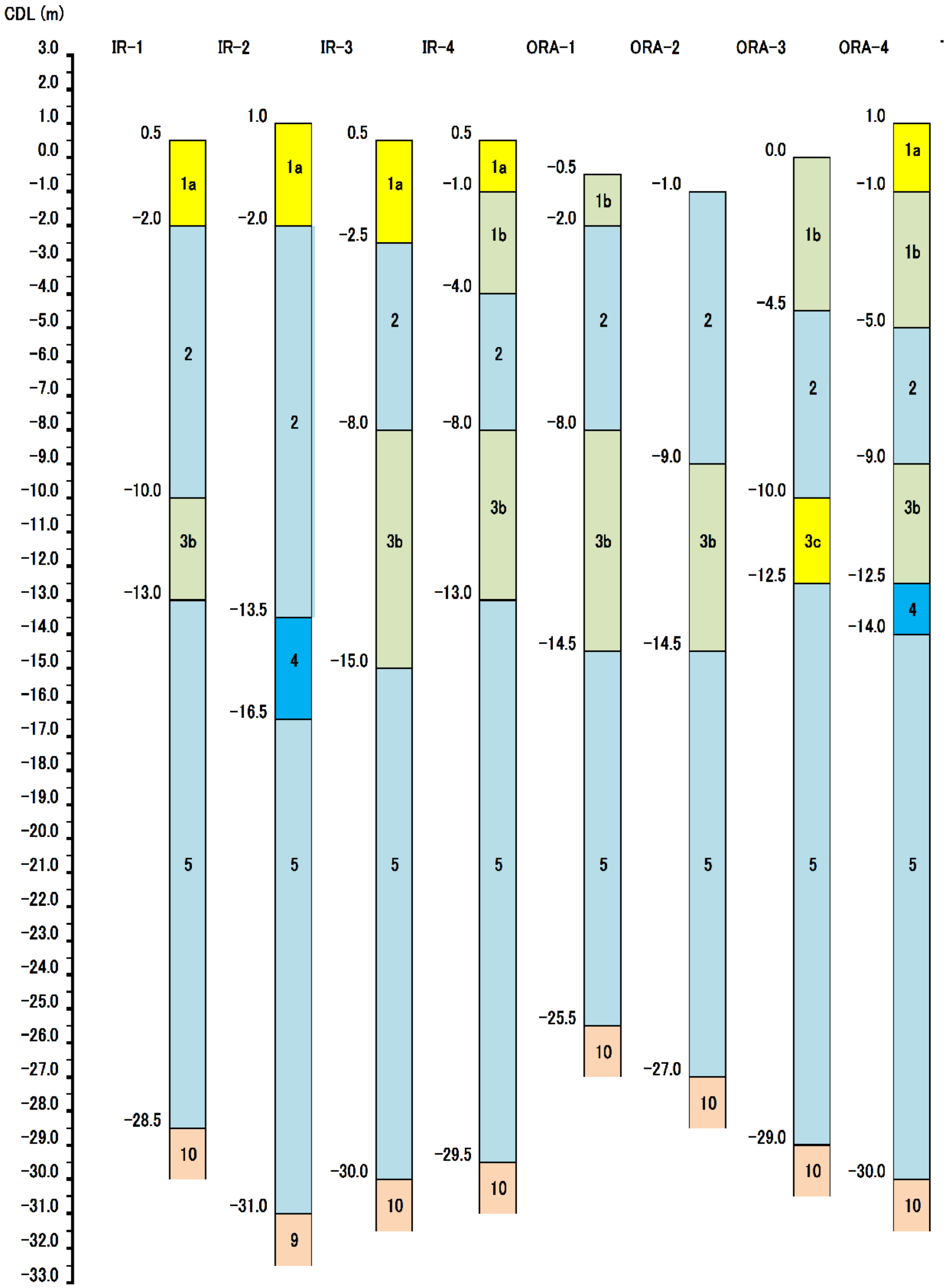


Figure 7.4.7 Soil layer models for subsoil improvement design for Inner Revetment and Outer Revetment A

2) Inner Revetment

a) Analysis without any improvement

i) Slope Stability Analysis Result

Slope stability analysis has been carried out for the ground without improvement at 4 sections (IR-1, 2, 3, and 4) along the Inner Revetment. The analysis result is tabulated as shown in Table 7.4.2 and slip circle figure of minimum safety factor at Section IL-1 is shown in Figure 7.4.8 as a representative figure. All slope stability analysis results for 4 sections along the Inner Revetment are shown in the Appendix 7.2.

According to the stability analysis results, all four sections along the Inner Revetment cannot satisfy the required safety factors (Fs = 1.3), some countermeasures for slope stability are accordingly necessary.

Table 7.4.2 Slope Stability Calculation Result (Inner Revetment without Improvement)

Analysis Sections	Areas [Adjacent Blocks]	Safety Factor obtained
Inner Revetment Section IR-1	Terminal Area (Full container storage yard) [Block-4]	$F_s$min=0.703 < Fsa=1.30 : NG
Inner Revetment Section IR-2	Terminal Area (Full container storage yard) [Block-8]	$F_s$min=0.702 < Fsa=1.30 : NG
Inner Revetment Section IR-3	Terminal Area (Empty container storage yard) [Block-12]	$F_s$min=0.876 < Fsa=1.30 : NG
Inner Revetment Section IR-4	Access Road Area [Block-16]	$F_s$min=0.885 < Fsa=1.30 NG

IR-1:Fs min= 0.703 < Fsa= 1.3

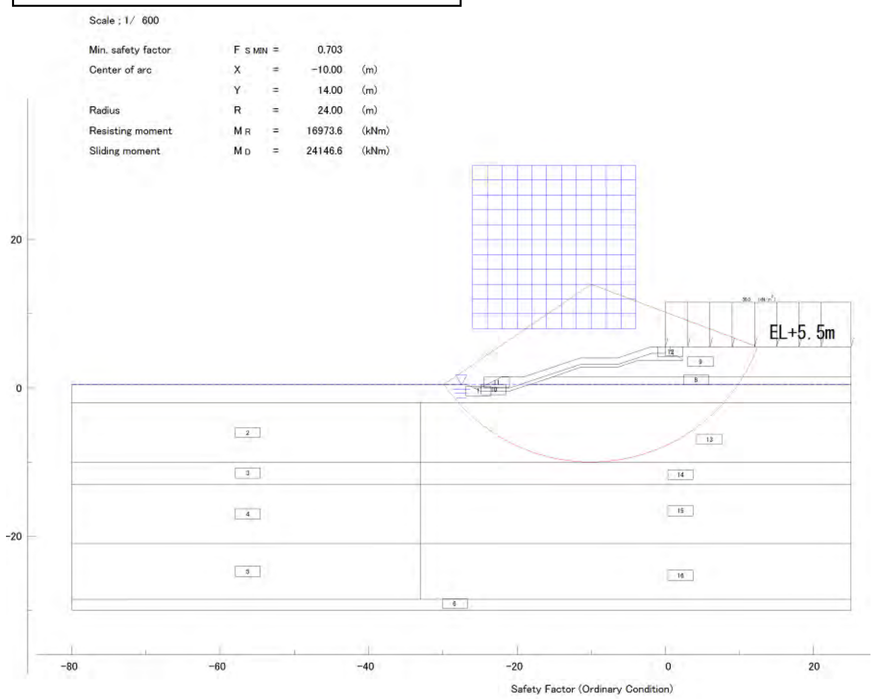


Figure 7.4.8 Stability Analysis Result at Section IR-1 (Without Subsoil improvement)

b) Result of subsoil Improvement by PVD Method

i) Slope Stability Analysis Result with PVD Method

According to slope stability analysis result for the ground without subsoil improvement, slope stability cannot be retained. Some countermeasures for slope stability are accordingly necessary. Therefore “PVD + Preload” method has been studied for Inner Revetment area because subsoil improvement method at adjacent back side of inner revetment will be improved by “PVD + Preload” method as most appropriate subsoil improvement method.

Those results are tabulated as shown in Table 7.4.3 and slip circle figure of minimum safety factor for each loading step at section IR-1 are shown in Figure 7.4.9 to Figure 7.4.13 as a representative figures. All slope stability analysis results for Section IR-1, 2, 3 and 4 along the Inner Revetment with “PVD+Preload” Method are shown in the Appendix 7.2.

As shown in Table 7.4.3, required safety factors are satisfied with staged construction of preload with PVD considering increase of shear strength by progress of consolidation.

Table 7.4.3 Slope Stability Calculation Result (Inner Revetment with PVD + Preload)

Sec.	First Fill		Second Fill (Cover Sand)			Preload			Completion
	Elevation (DL; m)	Safety Factor	Elevation (DL; m)	Counter fill Width (m)	Safety Factor	Preload Thick. (m)	Counter fill Width (m)	Safety Factor	Safety Factor
IR-1	+3.5	1.23 > 1.10 OK	+5.0	16.0	1.10 > 1.10 OK	3.6	16.0 + 22.0 (+3.5) (+5.0)	1.11 > 1.10 OK	1.32 > 1.30 OK
IR-2	+4.0	1.25 > 1.10 OK	+5.0	22.0	1.18 > 1.10 OK	3.6	22.0 + 22.0 (+4.0) (+5.0)	1.10 > 1.10 OK	1.43 > 1.30 OK
IR-3	+3.5	1.21 > 1.10 OK	+5.0	15.0	1.19 > 1.10 OK	2.1	15.0 + 10.0 (+3.5) (+5.0)	1.16 > 1.10 OK	1.33 > 1.30 OK
IR-4	+4.0	1.15 > 1.10 OK	+5.0	15.0	1.14 > 1.10 OK	0.5	15.0 + 5.0 (+4.0) (+5.0)	1.22> 1.10 OK	1.32 > 1.30 OK

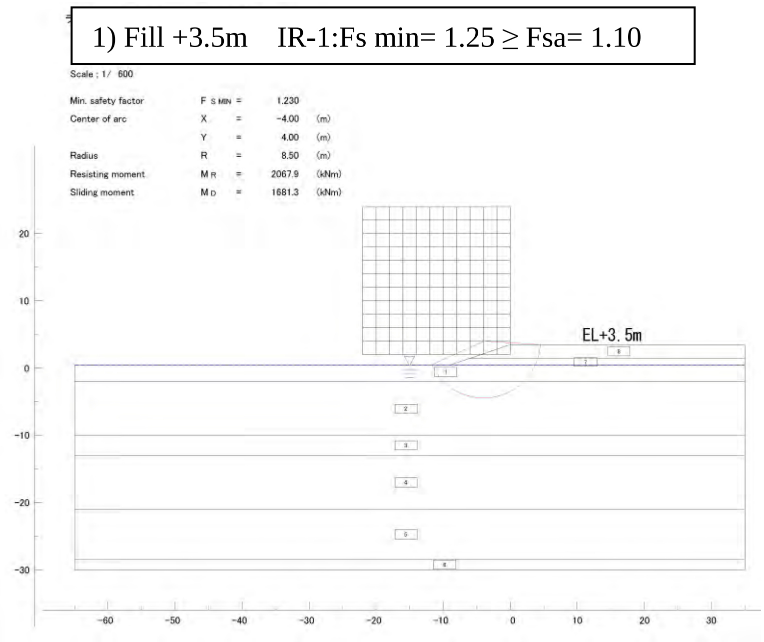


Figure 7.4.9 Stability Analysis Result at Section IR-1 (with PVD and Preload) (1/5)

2) Fill +5.0m IR-1:Fs min= 1.10 ≥ Fsa= 1.10

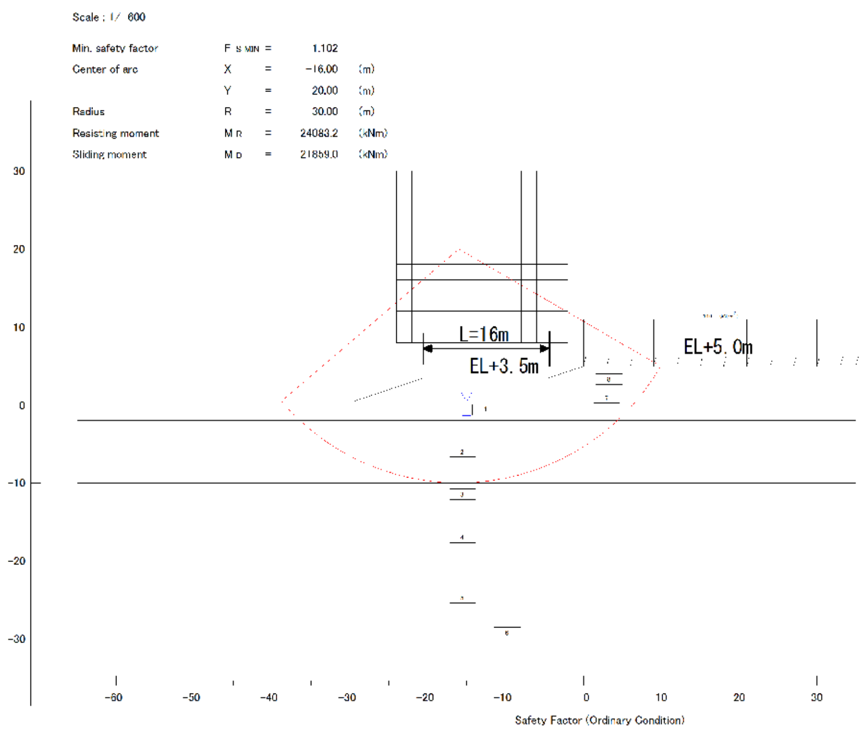


Figure 7.4.10 Stability Analysis Result at Section IR-1 (with PVD and Preload) (2/5)

3) Preload +8.6m IR-1:Fs min= 1.16 ≥ Fsa= 1.10

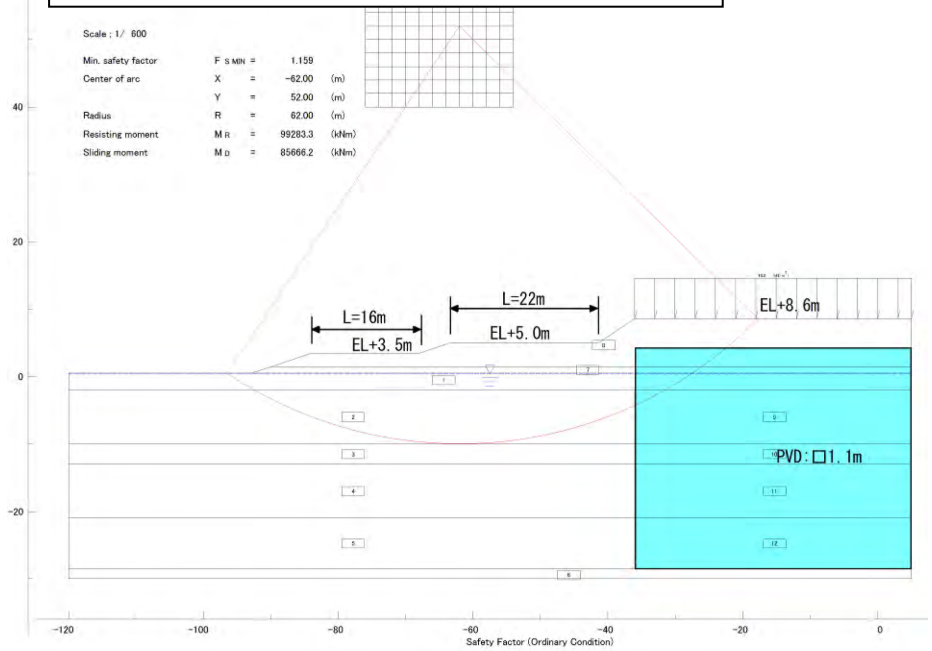


Figure 7.4.11 Stability Analysis Result at Section IR-1 (with PVD and Preload) (3/5)

4) Preload +8.6m IR-1:Fs min= 1.10 ≥ Fsa= 1.10

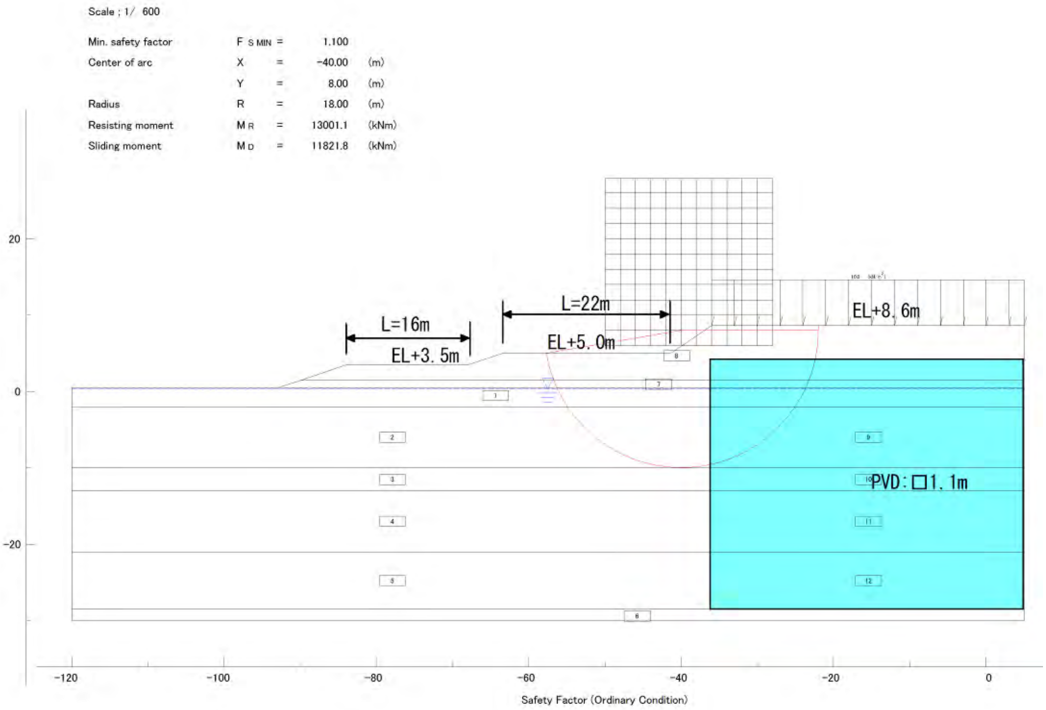


Figure 7.4.12 Stability Analysis Result at Section IR-1 (with PVD and Preload) (4/5)

5) After completion of Revetment Construction IR-1:Fs min= 1.32 ≥ Fsa= 1.30

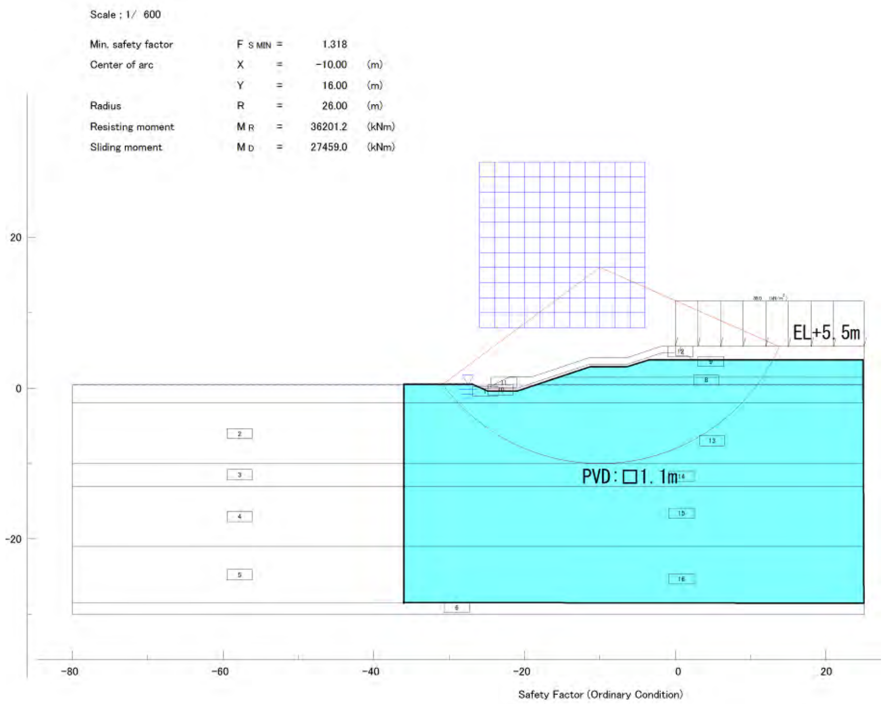


Figure 7.4.13 Stability Analysis Result at Section IR-1 (with PVD and Preload) (5/5)

ii) Consolidation Settlement Analysis Result

Considering continuity of subsoil improvement work by PVD, same PVD spacing and same preload heights with adjacent blocks are applied at all sections (IR-1, 2, 3 and 4) along the Inner Revetment.

Consolidation settlement analysis results at the face line of each section along the Inner Revetment are tabulated as shown in Table 7.4.4 and settlement curve at section IR-1 is shown in Figure 7.4.14 as a representative settlement curve among these results. All consolidation settlement curves for Section IR-1, 2, 3 and 4 along the Inner Revetment are shown in the Appendix 7.2.

According to these results, “PVD + Preload” method can satisfy the required settlement criteria even though reclamation was carried out in front of inner revetment in future.

Table 7.4.4 Consolidation Settlement Calculation Result at Face Line of Inner Revetment with PVD and Preload

Section	PVD Installation Interval	Fill Thickness (m)		Settlement (m)		Settlement Result	Remarks
		Fill	Preload	Final Sf	Residual Sr at Port Operation Started		
IR-1	d= □1.1m	CD+5.0	3.6	1.225	0.000	OK	Sr = 0
IR-2	d= □1.1m	CD+5.0	3.5	1.141	0.000	OK	Sr = 0
IR-3	d= □1.2m	CD+5.0	2.1	0.908	0.000	OK	Sr = 0
IR-4	d= □1.6m	CD+5.0	1.5	0.739	0.020	OK	Sr < 30cm for 15years after pavement completed.

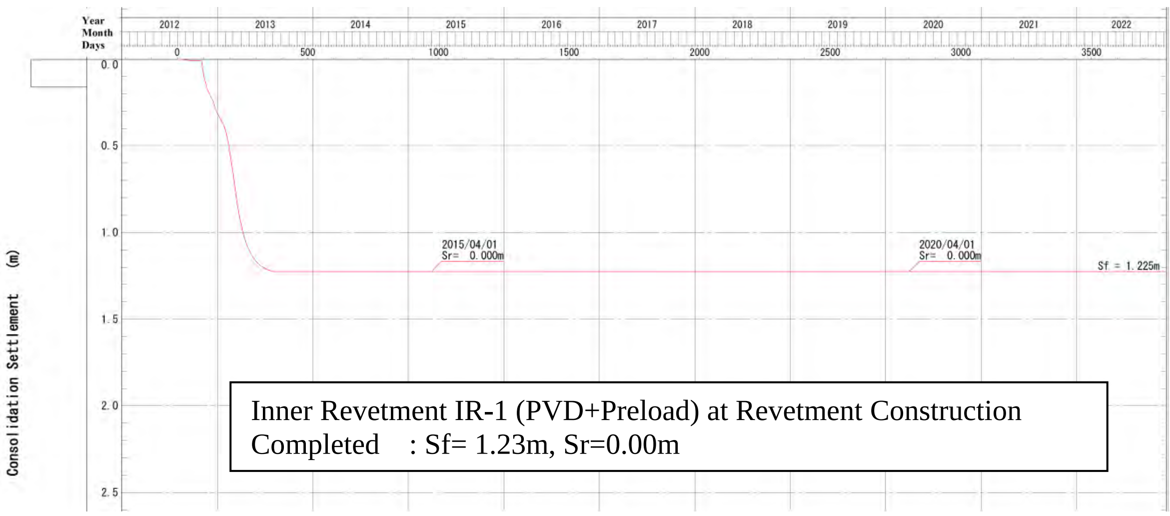


Figure 7.4.14 Consolidation Settlement Analysis Result at Section IR-1 improved with PVD and Preload

c) Soil Improvement Procedure by PVD and Preload at Inner Revetment

Soil Improvement Procedure by PVD and Preload at Section IR-1 (Inner Revetment) is shown as a representative sub soil improvement procedure figures as shown in Figure 7.4.15 and Figure 7.4.16. All procedure figures are shown in the Appendix 7.2.

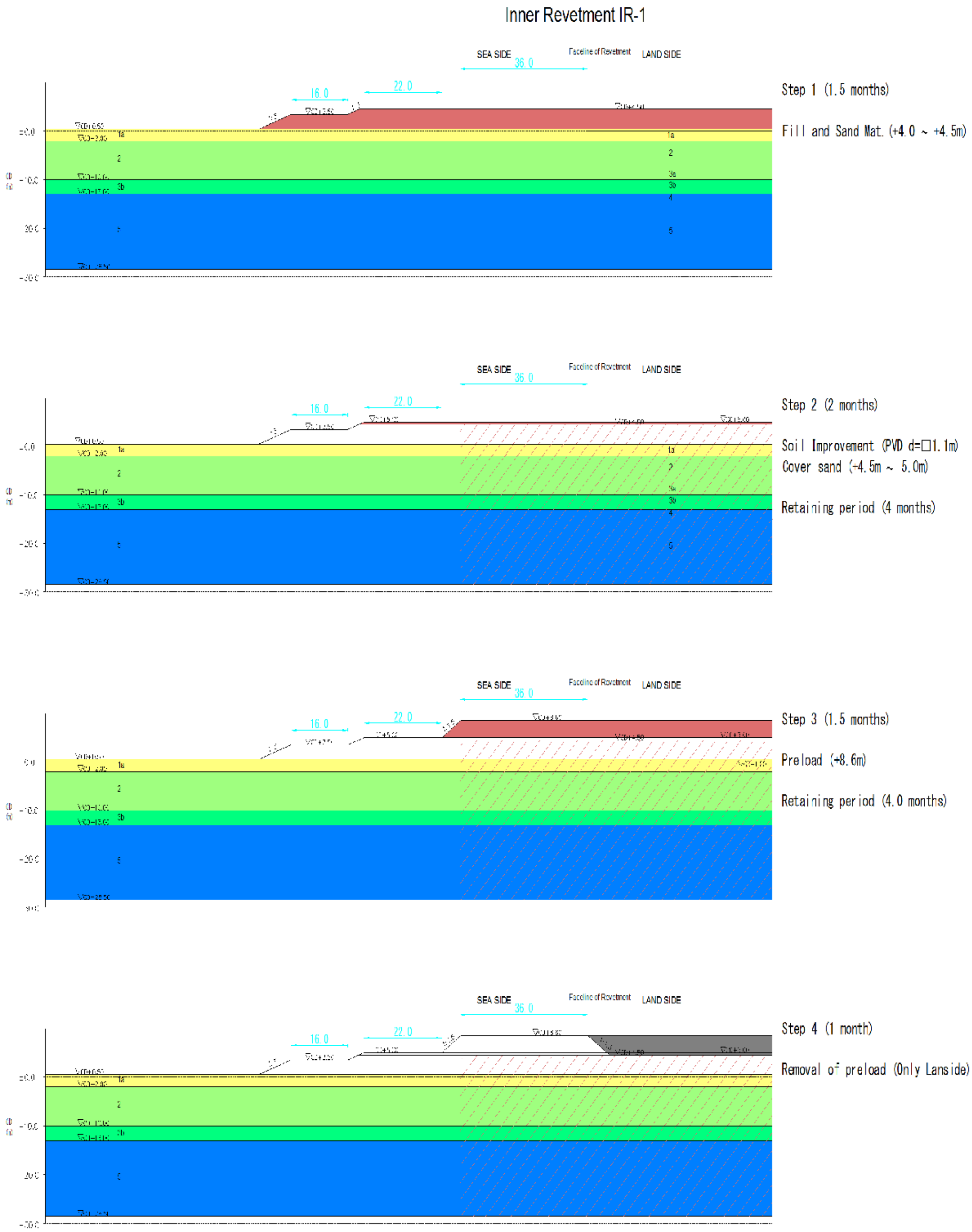


Figure 7.4.15 Subsoil Improvement Procedure with PVD+Preload at Section IR-1 (Inner Revetment) (1/2)

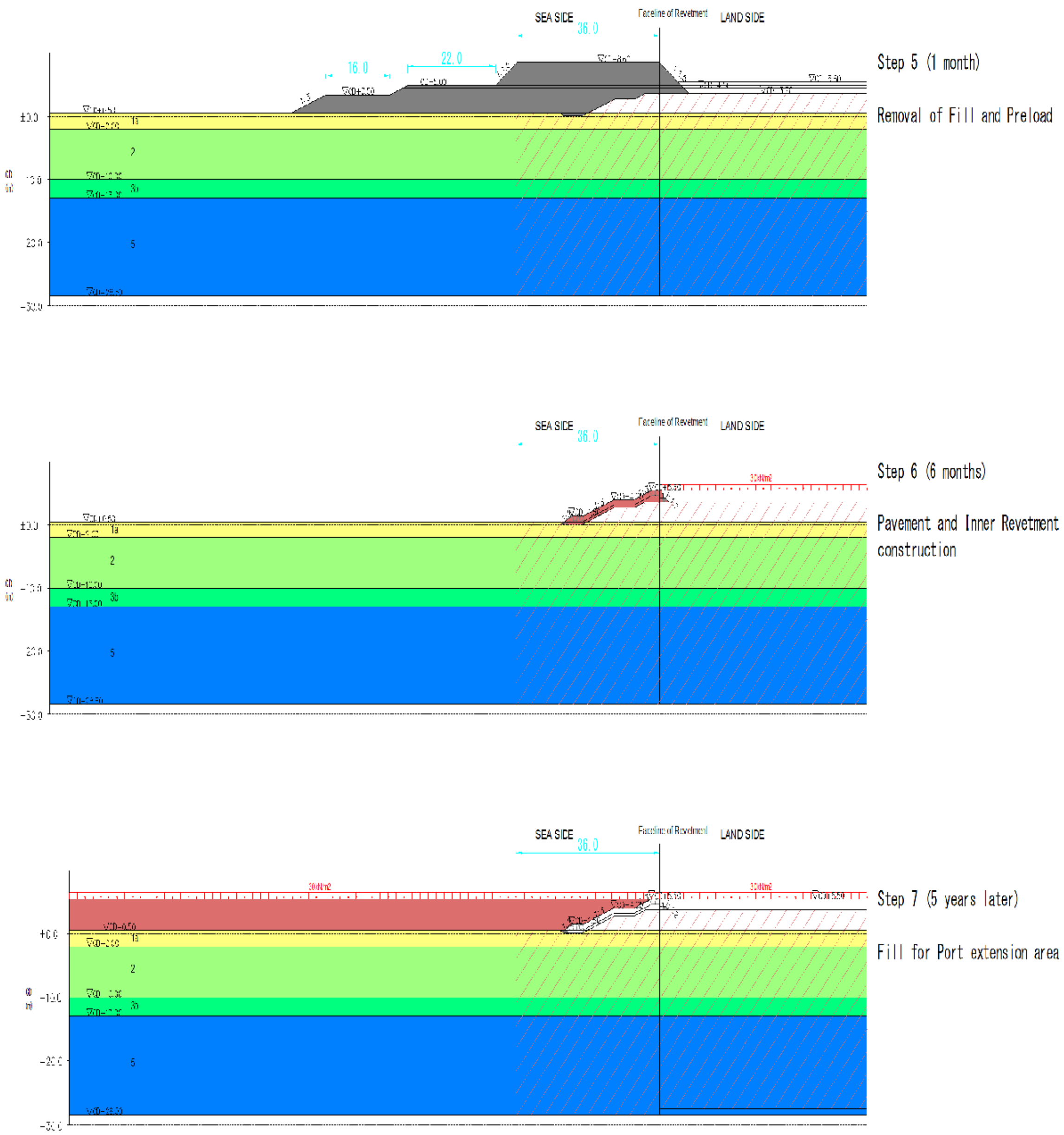


Figure 7.4.16 Subsoil Improvement Procedure with PVD+Preload at Section IR-1 (Inner Revetment) (2/2)

3) Outer Revetment A

a) Analysis without Subsoil improvement

i) Slope Stability Analysis Result

Slope stability analysis has been carried out for the ground without improvement at 4 sections (ORA-1, 2, 3, 4) along the Outer Revetment A. The analysis result is tabulated as shown in Table 7.4.5 and slip circle figure of minimum safety factor at Section ORA-1 is shown in Figure 7.4.17 as a representative figure. All slope stability analysis results for 4 sections along the Outer Revetment A are shown in the Appendix 7.2.

According to the stability analysis results, all four sections along the Outer Revetment A cannot satisfy the required safety factors (Fs = 1.3), some countermeasures for slope stability are accordingly necessary.

Table 7.4.5 Summary of Stability Analysis Result at Outer Revetment A

Section	Areas [Adjacent Block]	Safety Factor obtained
Outer Revetment A Section ORA-1	Access Road Area [Block-13]	Fsmin= 0.701 < Fsa=1.30 : NG
Outer Revetment A Section ORA-2	Access Road Area [Block-14]	Fsmin= 0.728 < Fsa=1.30 : NG
Outer Revetment A Section ORA-3	Access Road Area [Block-15]	Fsmin= 0.774 < Fsa=1.30 : NG
Outer Revetment A Section ORA-4	Access Road Area [Block-16]	Fsmin= 0.857 < Fsa=1.30 NG

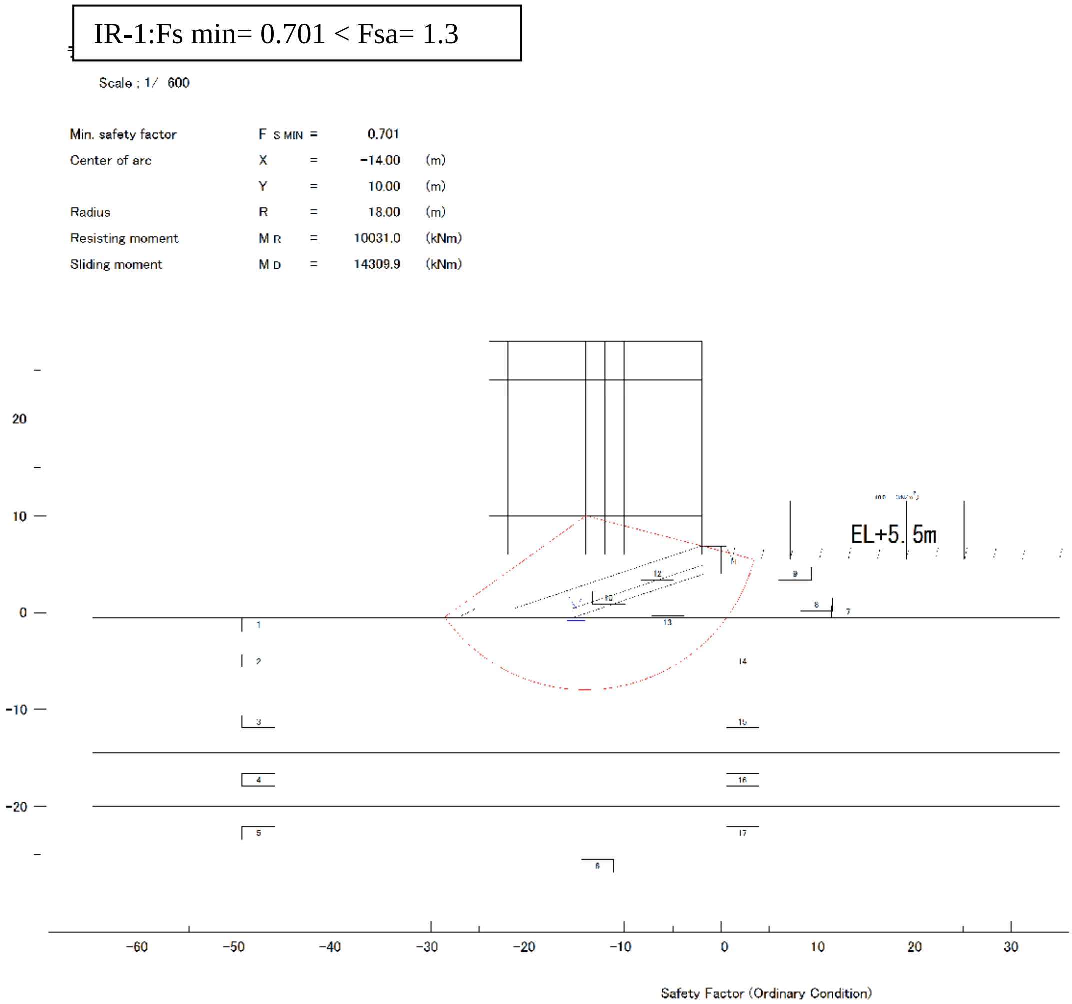


Figure 7.4.17 Stability Analysis Result at Section ORA-1 (Without soil improvement)

b) Selection of Subsoil Improvement Method for Outer Revetment A

According to stability analysis results, it cannot satisfy the required safety factor (Fs=1.3) for slope stability without subsoil improvement. Therefore countermeasures for Outer Revetment A have been studied in this section.

The following two subsoil improvements has been studied and compared to select the most suitable countermeasure for Outer Revetment A.

- **PVD Method:** PVD Method is adopted as a subsoil improvement method for back side area of revetment. Continuity of subsoil improvement method between two areas, back side area and front side area of revetment, is also important and considered. Furthermore, PVD method can contribute as a countermeasure for both of consolidation settlement and slope stability.
- **Sand Replacement:** This method is usually used as measures to retain the slope stability of revetment and etc. However it can reduce total settlement due to replacement of soft compressive clay with sand.

Details of each subsoil improvement method have been studied due to consolidation settlement and slope stability analysis. The results of analysis for settlement and stability by two subsoil improvement methods are summarized as shown in the following section.

i) Analysis Result for settlement and stability by three subsoil improvement methods

Comparison of above two subsoil improvement methods has been carried out at a representative section (ORA-2) along the Outer Revetment A from economical point of view. Analysis results of slope stability and consolidation settlement have been summarized as shown in Table 7.4.66 and Table 7.4.7 respectively. All these analysis details are shown in Appendix 7.2.

As a result of some trial calculation, each subsoil improvement method can satisfy the required values for safety factor on slope stability and residual settlement respectively with details as shown in Table 7.4.6 and Table 7.4.7.

Based on these subsoil improvement details which satisfy the required values, economical comparison study among between two methods has been carried out. It results in that PVD method is the best economical subsoil improvement method for the Revetment A (refer to Appendix 7.2.

Table 7.4.6 Slope Stability Calculation Result at Outer Revetment A with Subsoil Improvement (PVD+Preload and Sand Replacement)

Method	First Fill		Second Fill			Preload			Completion
	Elevation (CD; m)	Safety Factor	Elevation (CD; m)	Counter Fill Width (m)	Safety Factor	Preload Thick. (m)	Counter Fill Width (m)	Safety Factor	Safety Factor
PVD (d = □1.6 m)	+3.0	1.19 > 1.10 OK	+5.0	16.0	1.15 > 1.10 OK	3.4	16 + 20 (+3.0) (+5.0)	1.11 > 1.10 OK	1.30 > 1.30 OK
Sand Replacement	-	-	-	-	-	-	-	-	1.35 > 1.30 OK

Table 7.4.7 Consolidation Settlement Calculation Result at Outer Revetment A with Subsoil Improvement (PVD+Preload and Sand Replacement)

Section	Bottom level of treatment	Fill Thickness (m)				Settlement			Economical Comparison
		First Fill	Second Fill	Preload	Preload Removal	Final Settlement Sf (m)	Residual Settlement Sr (m)	Resul t	
PVD (d = □1.6 m)	CD -27.0m	CD +3.0	CD+5.0	3.4	4.0	1.163	0.00 < 0.30	OK	Economical
Sand Replacement	CD -14.5m	-	-	-	-	0.043	0.03 < 0.30	OK	(5% more than PVD method)

Stability analysis result figures at revetment construction completed for PVD+Preload and Sand Replacement methods are shown in Figure 7.4.18 and Figure 7.4.19 respectively. And also consolidation settlement curves for two methods are shown in Figure 7.4.20 and Figure 7.4.21. All stability analysis details are shown in Appendix 7.2.

Outer Revetment A (PVD+Preload) at Revetment Construction Completed : Fs min= 1.30 ≥ Fsa= 1.3

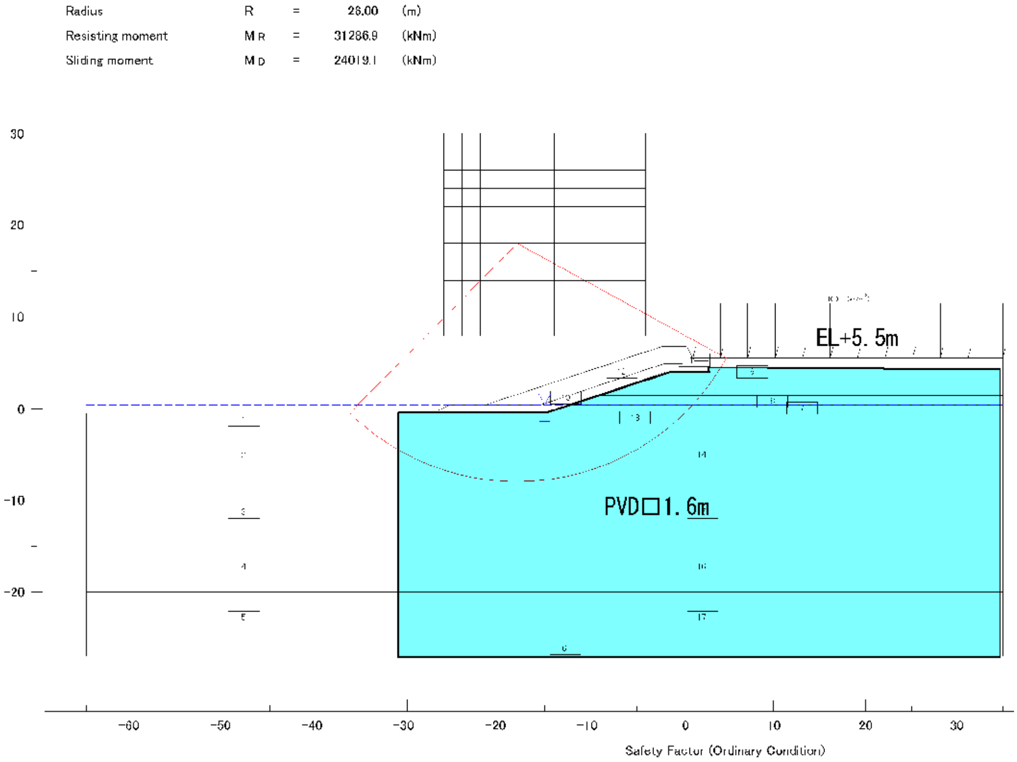


Figure 7.4.18 Stability Analysis Result (PVD+Preload) at Outer Revetment A

Outer Revetment A (Sand Replacement) at Revetment Construction Completed : Fs min= 1.35 ≥ Fsa= 1.3

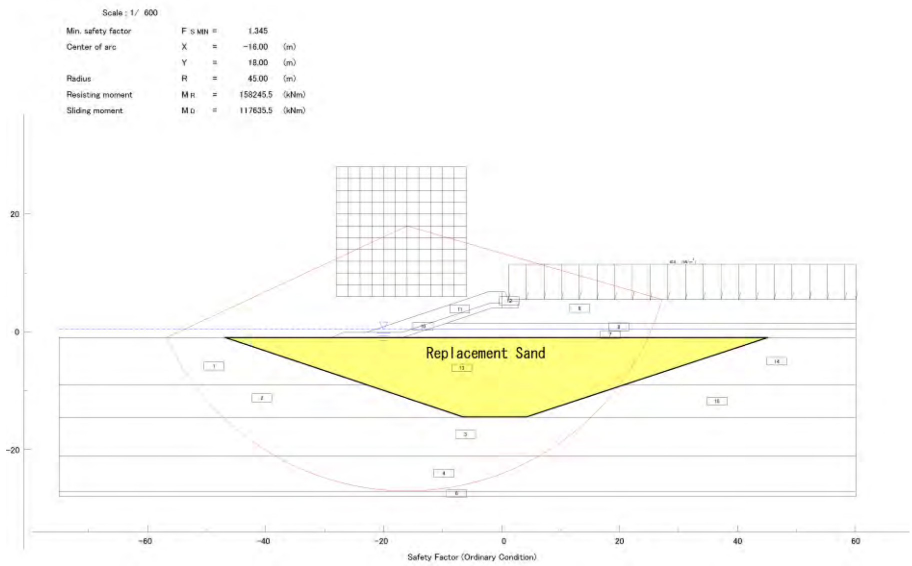


Figure 7.4.19 Stability Analysis Result (Sand Replacement) at Outer Revetment A

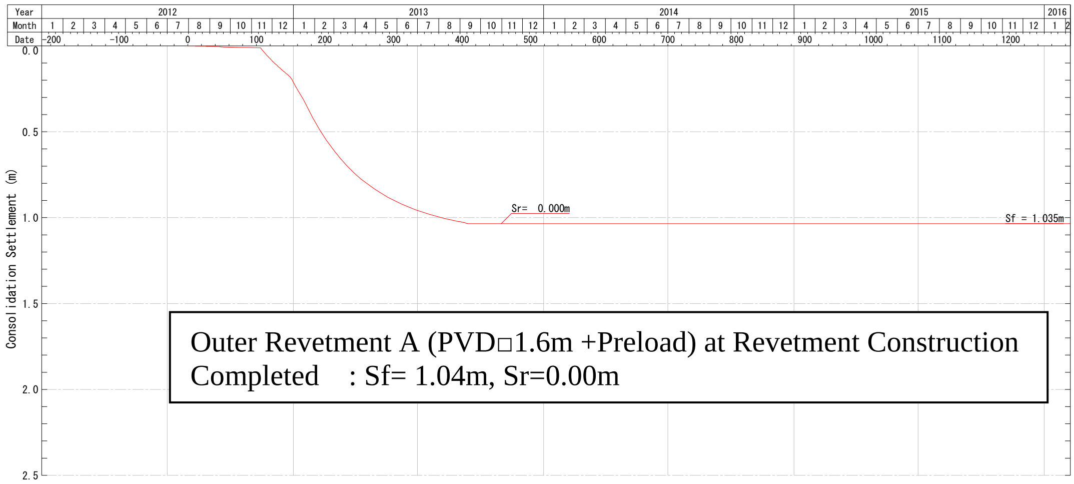


Figure 7.4.20 Consolidation Settlement Analysis Result (PVD☐1.6m +Preload) at Outer Revetment A

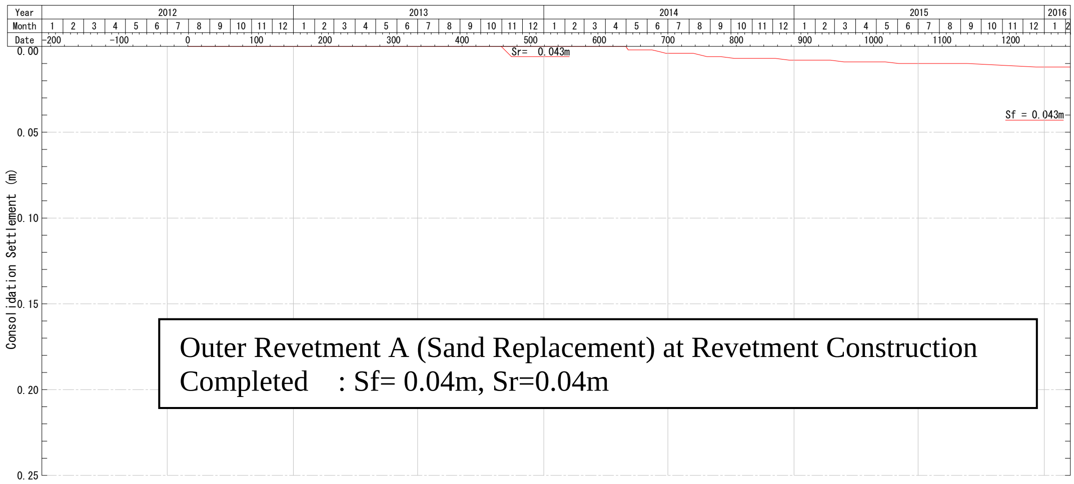


Figure 7.4.21 Consolidation Settlement Analysis Result (Sand Replacement) at Outer Revetment A

c) Analysis Result with PVD and Preload

i) Slope Stability Analysis Result

According to selection result of subsoil improvement method for Outer Revetment A, “PVD + Preload” method has been selected as most appropriate subsoil improvement method.

In this section, required spacing and preload height have been studied for four sections (ORA-1, 2, 3 and 4) along the Outer Revetment A.

Slope stability analysis results are tabulated as shown in Table 7.4.8 and slip circle figure of minimum safety factor for each loading step at section ORA-1 are shown in Figure 7.4.22 to Figure 7.4.26 as a representative figures. All slope stability analysis results for Section ORA-1, 2, 3 and 4 along the Outer Revetment A with “PVD+Preload” Method are shown in the Appendix 7.2.

As shown in Table 7.4.8, required safety factors are satisfied with staged construction of preload and counter fill with PVD considering increase of shear strength by progress of consolidation.

Table 7.4.8 Summary of Stability Analysis Result at Outer Revetment A

Section	First Fill		Second Fill			Preload			Completion
	Elevation (DL; m)	Safety Factor	Elevation (CD; m)	Counter Fill Width (m)	Safety Factor	Preload Thick. (m)	Counter Fill Width (m)	Safety Factor	Safety Factor
ORA-1	+3.0	1.19 > 1.10 OK	+5.0	16.0	1.15 > 1.10 OK	3.4	16.0 + 20.0 (+3.0) (+5.0)	1.10 > 1.10 OK	1.30 > 1.30 OK
ORA -2	+3.5	1.10 > 1.10 OK	+5.0	18.0	1.12 > 1.10 OK	3.0	18.0 + 20.0 (+3.5) (+5.0)	1.15 > 1.10 OK	1.32 > 1.30 OK
ORA-3	+4.0	1.13 > 1.10 OK	+5.0	20.0	1.13 > 1.10 OK	2.5	20.0 + 15.0 (+4.0) (+5.0)	1.12 > 1.10 OK	1.33 > 1.30 OK
ORA-4	+4.0	1.29 > 1.10 OK	+5.0	20.0	1.33 > 1.10 OK	2.5	20.0 + 15.0 (+4.0) (+5.0)	1.20 > 1.10 OK	1.42 > 1.30 OK

1) Fill +3.0m ORA-1:Fs min= 1.19 ≥ Fsa= 1.10

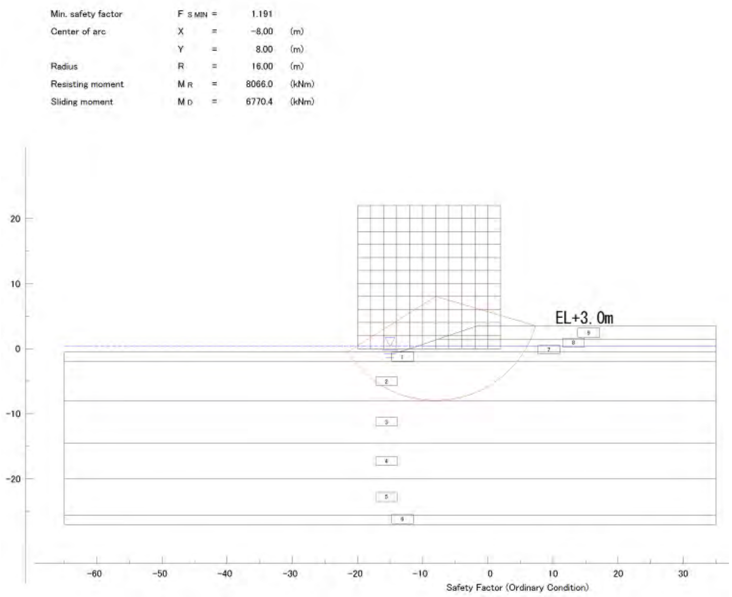


Figure 7.4.22 Stability Analysis Result at Section ORA-1 (with PVD and Preload) (1/5)

2) Fill +5.0m ORA-1:Fs min= 1.15 ≥ Fsa= 1.10

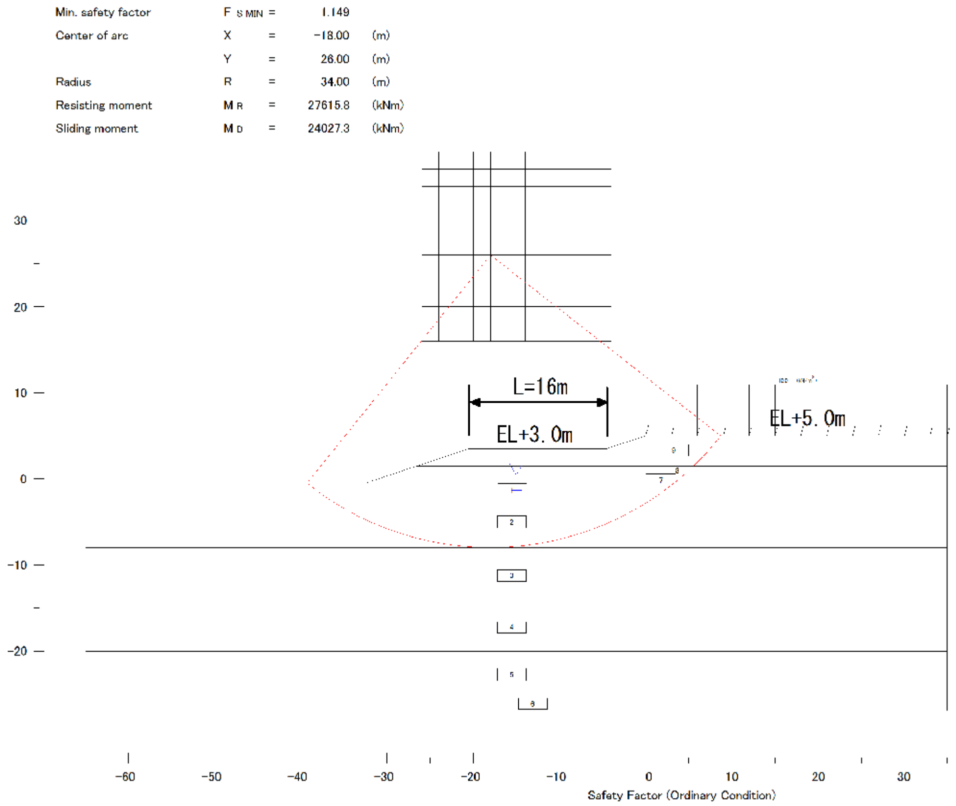


Figure 7.4.23 Stability Analysis Result at Section ORA-1 (with PVD and Preload) (2/5)

3) Preload +8.4m ORA-1:Fs min= 1.10 ≥ Fsa= 1.10

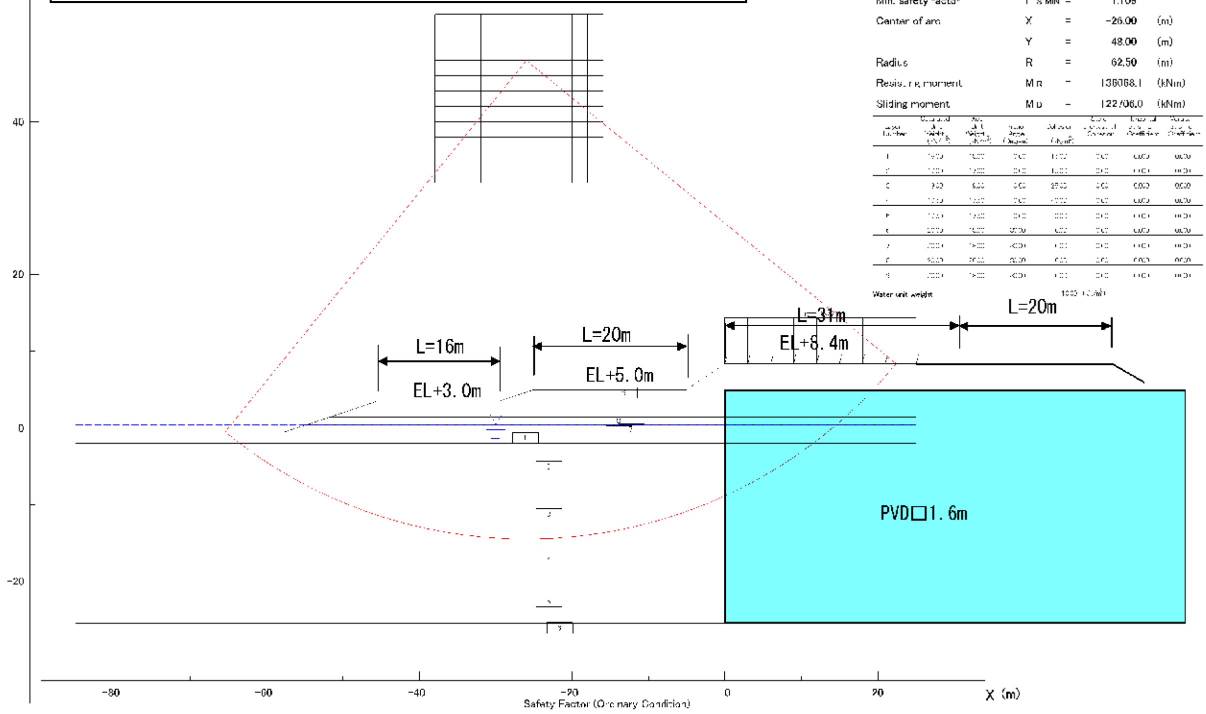


Figure 7.4.24 Stability Analysis Result at Section ORA-1 (with PVD and Preload) (3/5)

4) Preload +8.4m ORA-1:Fs min= 1.10 ≥ Fsa= 1.10

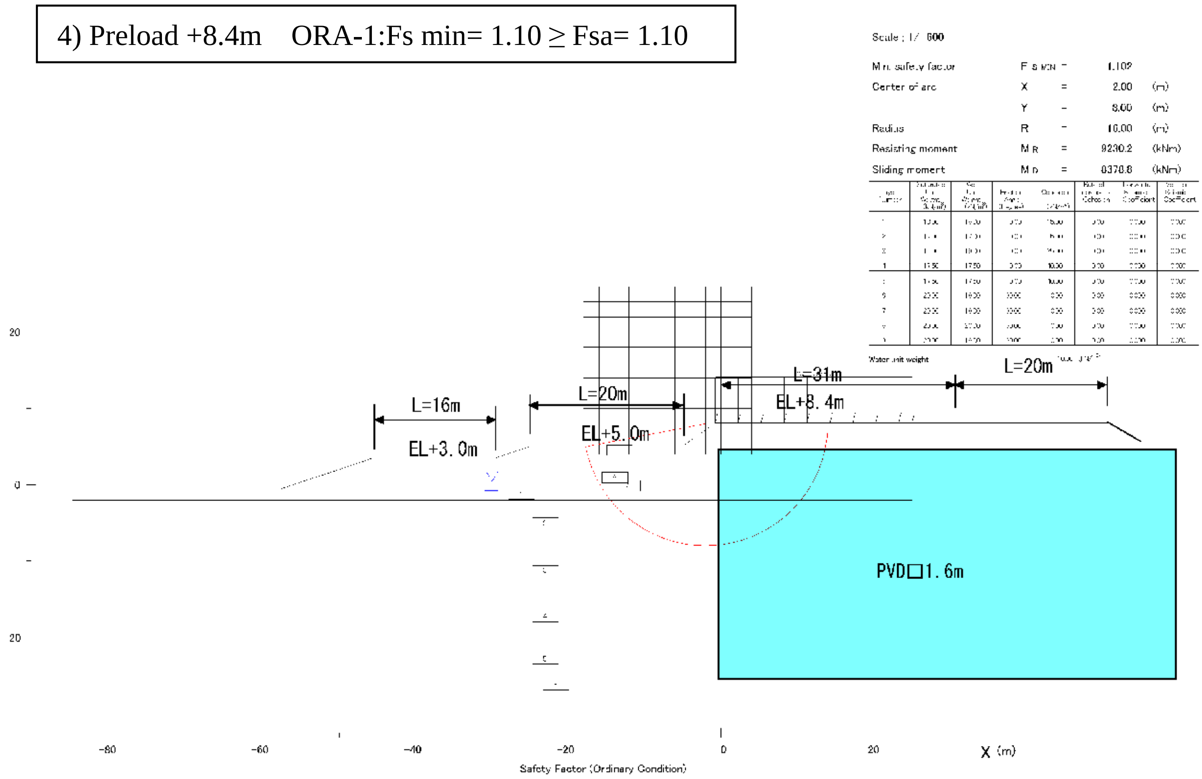


Figure 7.4.25 Stability Analysis Result at Section ORA-1 (with PVD and Preload) (4/5)

4) After completion of Revetment Construction ORA-1:Fs min= 1.30 ≥ Fsa= 1.30

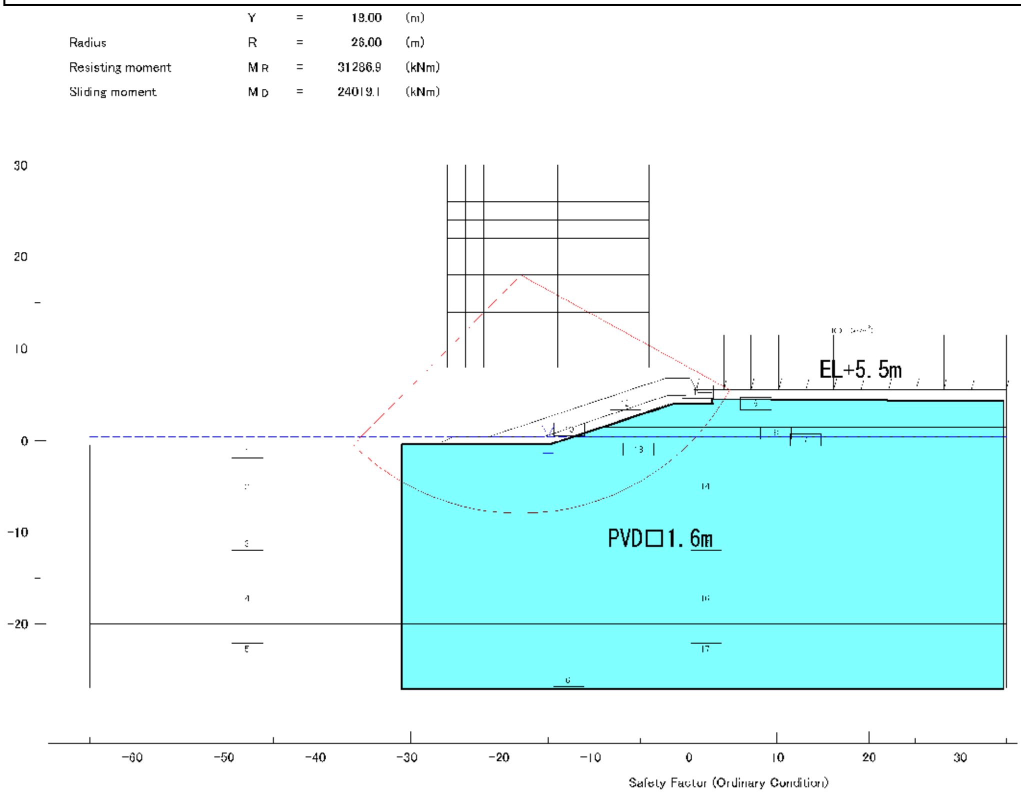


Figure 7.4.26 Stability Analysis Result at Section ORA-1 (with PVD and Preload) (5/5)

ii) Consolidation Settlement Analysis Result

Consolidation settlements at face line of revetment have calculated with preload height which can satisfy the required safety factors of stability.

Consolidation settlement analysis results at the face line of each section (ORA-1, 2, 3 and 4) along the Outer Revetment A are tabulated as shown in Table 7.4.9 and settlement curve at section ORA-1 is shown in Figure 7.4.27 as a representative settlement curve among these results. All consolidation settlement curves for Section ORA-1, 2, 3 and 4 along the Outer Revetment A are shown in the Appendix 7.2.

According to these results, “PVD(d= □1.6m)+Preload” method can satisfy the required settlement criteria.

Table 7.4.9 Consolidation Settlement Calculation Result at Face Line of Outer Revetment A with PVD and Preload

Section	PVD Installation Interval	Fill Thickness (m)		Settlement (m)		Settlement Result	Remarks
		Fill	Preload	Final Sf	Residual Sr at Compression of Pavement		
ORA-1	d= □1.6m	CD+5.0	3.4	0.975	0.00	OK	Sr < 30cm for 15years after pavement completed.
ORA-2	d= □1.6m	CD+5.0	3.0	1.035	0.00	OK	
ORA-3	d= □1.6m	CD+5.0	2.5	0.872	0.00	OK	
ORA-4	d= □1.6m	CD+5.0	2.5	0.826	0.00	OK	

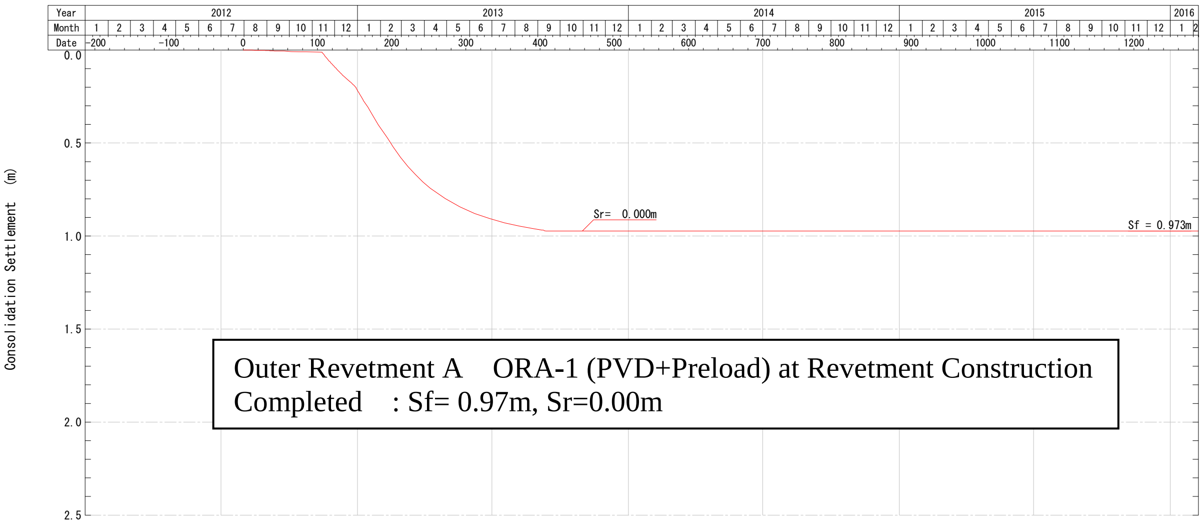


Figure 7.4.27 Consolidation Settlement Analysis Result at Section ORA-1 improved with PVD and Preload

iii) Soil Improvement Procedure by PVD and Preload at Outer Revetment A

Soil Improvement Procedure by PVD and Preload at Section ORA-1 (Outer Revetment A) is shown as a representative subsoil improvement procedure figures as shown in Figure 7.4.28. All procedure figures are shown in the Appendix 7.2.

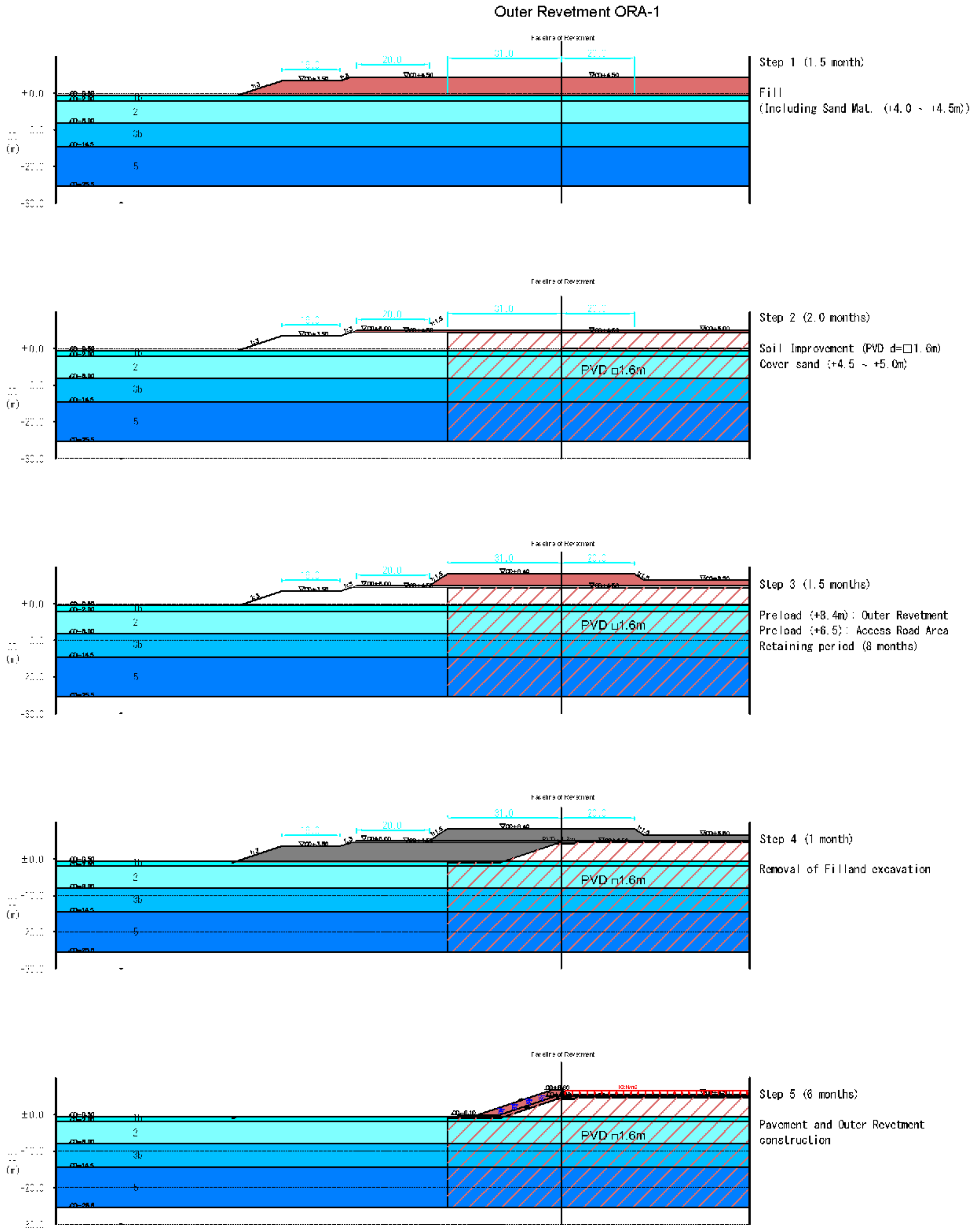


Figure 7.4.28 Subsoil Improvement Procedure with PVD+Preload at Section ORA-1 (Outer Revetment A)

7.5 Basic Design of Inner Revetment

7.5.1 General

Inner revetment for reclamation area is the revetment located alongside the south side of the Terminal area. Since the revetment is deemed as a temporary facility for the future expansion of the Project, it should be designed with consideration for possible re-use of the materials for future expansion of new container terminal to offshore.

Inner Revetment area is provided with soil improvement by application of PVD and preloading method. After completion of soil improvement work, the seaside surface slope of the reclamation fill (preloading fill for soil improvement) is formed to a slope of 1 (V) to 3 (H) along the south-side of the Terminal area. The revetment is designed in a form of sloped protection from the wave action covered by armor stones.

The total length of Inner Revetment is 709m as indicated in Figure 7.5.1.

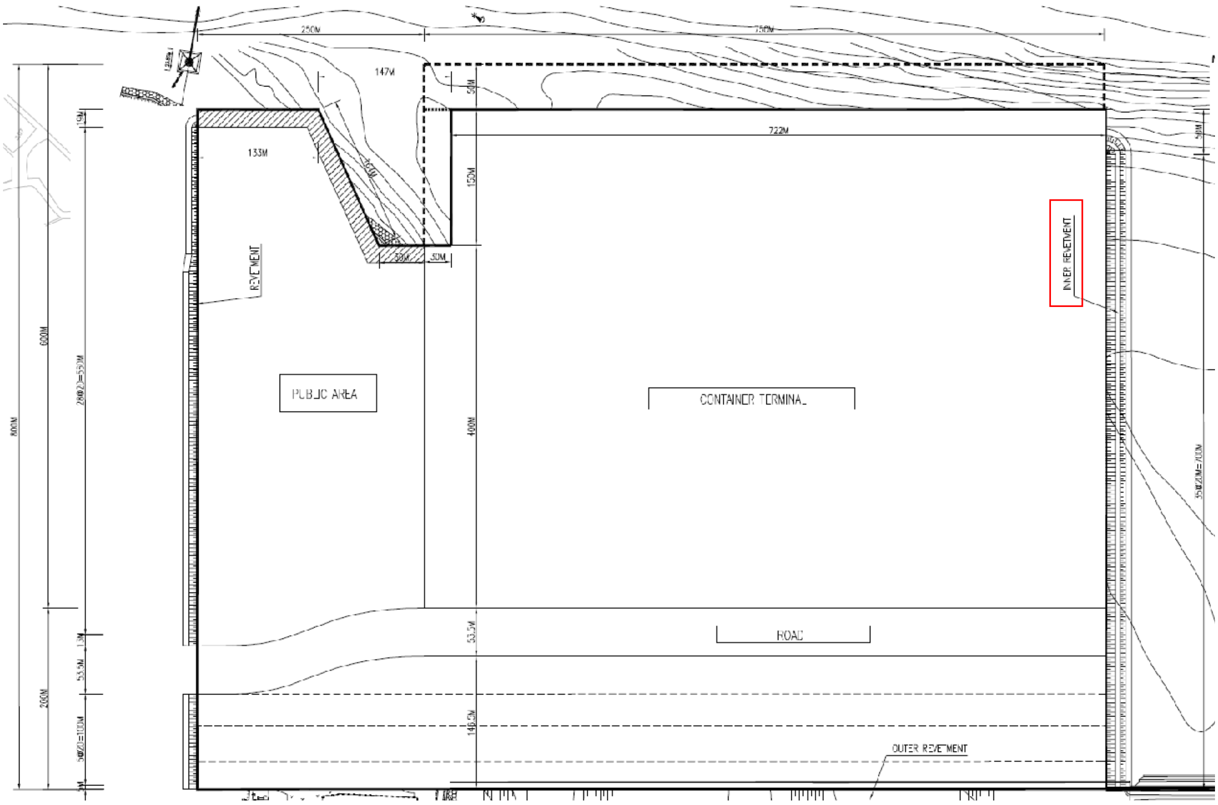


Figure 7.5.1 Location of Inner Revetment

7.5.2 Design Condition

The applied design conditions for the inner revetment are summarized as follows:

- Location of revetment : alongside the south side of the Terminal area.
- Existing seabed level : varied from +0.0m CDL to +0.8m CDL
- Tidal level : HWL : +3.55m; LWL : +0.43m
- Design wave height : according to Table 8.2.12 of this Report, the wave height of 5 years return Period, $H_{1/3}$ = 2.3m is applied
- Operational load : 30kN/m^2
- Filling sand : γ = 18kN/m^3 ; ϕ = 30^o

7.5.3 Typical Section

Typical section of Inner Revetment of Container Terminal is as shown in the figure below:

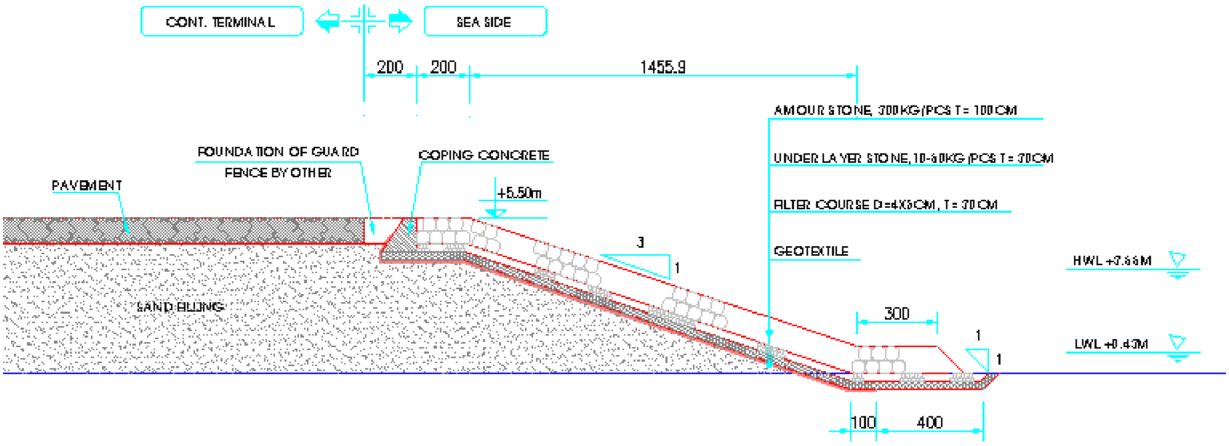


Figure 7.5.2 Typical Section of Inner Revetment

7.5.4 Slope Stability

The slope stability of inner revetment is examined as follows:

- Required Safety factor for Slope Stability is based on OCDI-2002 : Fsa ≥ 1.3
- Slope Stability Analysis (Circular Slip Surface Method): using the software: SLOPE/W) with Bishop Method.

The calculation result is shown in the figure below:

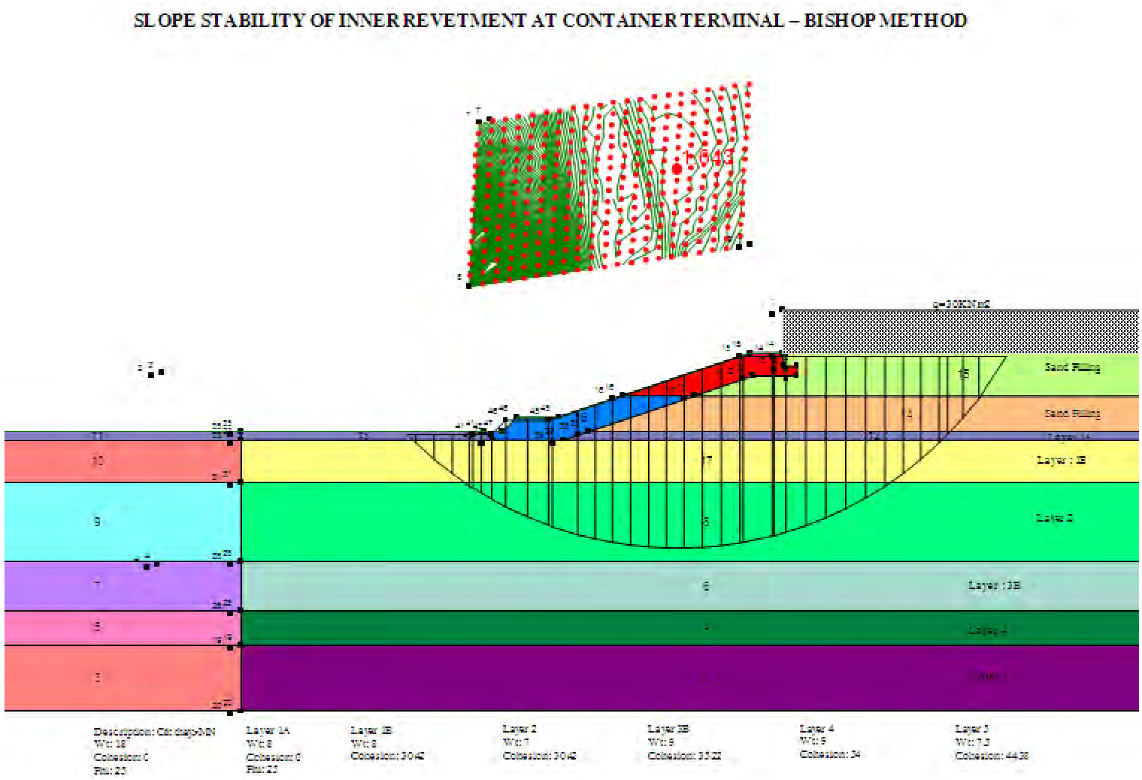


Figure 7.5.3 Result of Circular Slip Calculation for Inner Revetment

7.5.5 Weight Calculation of Armor Stone

1) Stone Weight Calculation (According to "The Rock Manual, 2nd edition" applied for Shallow water)

As presented in the figure above, it was recommended that 1:3 slope be adopted considering slope stability. Assuming this slope, the required weight of armor stone was calculated by using formula as below:

$$N_s = \frac{H_s}{\Delta D_n} = \frac{(K_D \cot \alpha)^{\frac{1}{3}}}{1.27}$$

$$W_S = D_n^3 \rho_S$$

Where:

N_s: stability parameter
H_s: significant wave height, $H_{1/3}$ of the incident waves at the toe of the structure (m)
Δ: relative buoyant density, r_s/r_w-1 (ρs: mass density of armor unit; 2.65 (t/m^3)
ρ_w: mass density of water; 1.025 (t/m^3)
W_s: necessary weight of armor stone block (t)
K_D: stability coefficient of stone
α- slope angle (^{o})

The calculation result is in the table below:

ρ_s (t/m^3)	ρ_w (t/m^3)	Δ (t/m^3)	α (^{o})	H_s (m)	$T_{1/3}$ (s)	$H_{2\%}$ (m)	T_p (s)	$T_{m-1,0}$ (s)	g (m/s^2)
2.65	1.025	1.59	18.43	2.3	5.85	3.22	6.16	5.60	9.81
P	S_d	Damage level (%)	N	$\xi_{s-1,0}$	ξ_{cr}	N_s	D_n	**W_s (t)**	
0.5	6	5-10	1000	1.54	3.01	3.06	0.47	**0.282**	

The result of calculation : W = 0.282T

Selected weight of armor stone : **W = 0.35T**

According to the calculation results of toe erosion for Outer Revetment A (Appendix 17.4), the rock of 200kg to 300 kg was selected in order to prevent toe erosion. The water depth in front of the structure and wave conditions between Inner Revetment and Outer Revetment A is quite similar, therefore, the obtained result for Outer Revetment A can be used for Inner Revetment. The weight of rock used for Inner Revetment of 350kg / pc is heavier than the calculation result for Outer Revetment A. Furthermore, it should be taken into consideration the fact that the Inner Revetment is considered as a “temporary revetment” for the future port development, therefore, the weight of rock for Inner Revetment is heavy enough for preventing toe erosion.

2) Thickness of Armor Layer

The thickness of the stone layer is calculated using the following formula:

$$r = nk_\Delta (W/W_r)^{1/3}$$

where,

r : thickness of underlayer
n : number of quarry stones
k_Δ : layer coefficient (=1 for quarry stone)
W : mass of individual armor unit
Wr : mass density per cubic meter

The required thickness of armor stone of **1.0m** is derived from the above equation.

7.5.6 Calculation of Coping Concrete

1) Design condition

- Operation load : 30kN/m^2.
- Filling sand : γ = 18kN/m^3 , ϕ = 30^o.
- Tidal Level : HWL: +3.55m, LWL: +0.43m
- Dimensions of coping concrete:
  Top level : +5.5m CDL
  Width at top : 0.4m
  Bottom level : +4.2m CDL
  Width at bottom : 1.0m

2) Calculation of earth pressure on the coping concrete

Active earth pressure of the sand filling is defined in the following Vietnamese Standard 22-TCN-207-92, equation (34):

$$\delta_a = (q + \sum \gamma_i h_i)\lambda_a - c\lambda_c$$

where :

δa : Active earth pressure (kN/m^2)
q :Operation load (kN)
γ_i : Unit weight of the i-th soil layer (kN/m^3)
h_i : Thickness of the i-th soil layer (m)
λ_a : Active earth pressure factor
c: Cohesive of soil in the i-th layer (kN/m^2)
λ_c : Cohesive factor

λ_a, λ_c is defined according to table 17 of the same Vietnamese Standard in case friction factor between sandy soil and back face wall is equal to 0.5φ (φ - internal friction angle of sandy soil).

3) Stability calculation of coping concrete

Coping concrete should be designed to stand against earth pressure and operational load acting on it. In the stability calculation, the effect of armor stone in front of the coping concrete wall is not taken into account

a) Stability calculation against sliding

The coping concrete should be designed so as to satisfy the following formula.

$$F_s = \frac{W}{H}\mu \geq 1.2$$

Where :

F_s - Safety factor against sliding

W - Total weight of a segment per unit length (the sum of sand filling weight -W_1, retaining wall weight -W_2 and operational load -W_3)

H - Total horizontal load per unit length (the sum of active earth pressure)

μ - Friction coefficient between concrete and stone

The diagram of horizontal and vertical loads is shown as figure below:

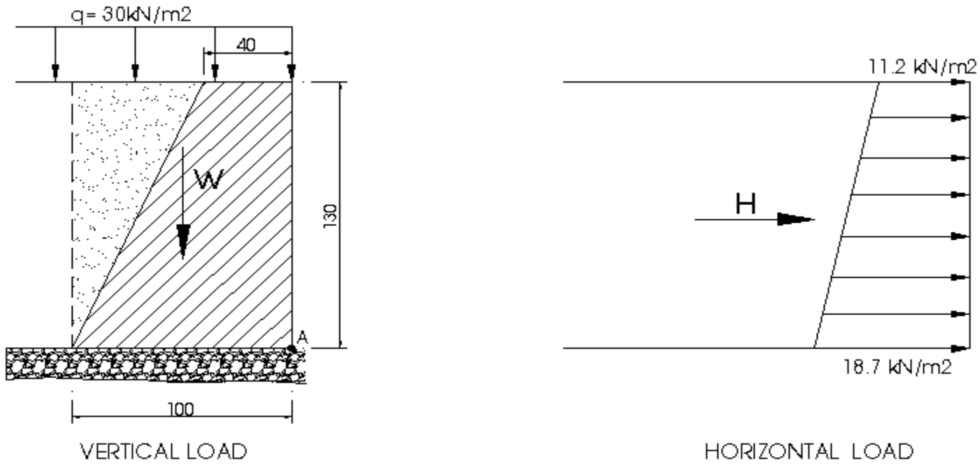


Figure 7.5.4 Load Diagram of Coping Concrete

The stability calculation result against sliding is summarized in the following table:

W (kN)				H (kN)	μ	Fs	Judgment
W_1	W_2	W_3	Total				
7.02	22.75	30.0	59.77	19.43	0.5	1.54	OK

b) Stability calculation against overturning

Overturning stability around the point A as shown in Figure 7.5.4 is examined by the following formula:

$$F_s = \frac{M_R}{M_A} \geq 1.3$$

Where :

Fs - Safety factor against overturning

M_R- Resistance moment against overturning (cause by vertical load: sand filling weight –M_{R1}, retaining wall weight –M_{R2} and operation load – M_{R3})

M_A - Moment of active earth pressure

The stability calculation result against overturning is summarized in the following table:

M_R (kNm)				M_A (kNm)	Fs	Judgment
M_{r1}	M_{r2}	M_{r3}	Total			
4.91	10.24	15.0	30.15	11.66	2.59	OK

7.6 Basic Design of Earth Retaining Walls

Container Berth is constructed by Private Sector under PPP program. The berth structure should be designed carefully in combination with earth retaining wall immediately behind the berth which is scheduled to construct by Public Sector. In this study, the structural type of “Anchored Steel Sheet Pipe Pile Wall”, recommended in the Preparatory Survey and mentioned in “Decision No. 476/ QD-BGTVT dated 13/03/2011 of the Minister of the MOT on approval for adjustment of Hai Phong international gateway port construction investment project- Starting stage”, is deemed as the target structure to be designed.

7.6.1 Design Condition

The general conditions are discussed in 7.1.

1) Natural Condition

a) Sub soil condition

According to the soil investigation results, the area for Earth retaining wall is divided into 4 blocks, namely block “a” to block “d”, by the existing soil stratification. The plan of each block with the locations of boreholes is shown in Figure 7.6.1 and the applied model of soil layer for examination is indicated in Figure 7.6.2 and Figure 7.6.3. Applied soil parameters of each layer are as shown in Table 7.6.1.

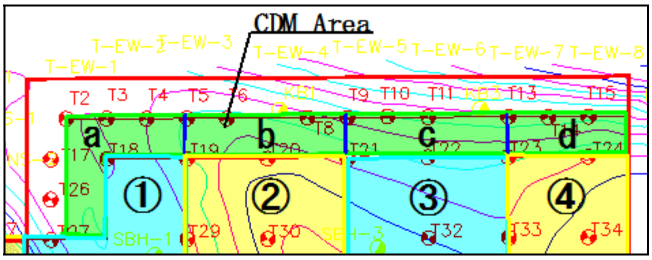
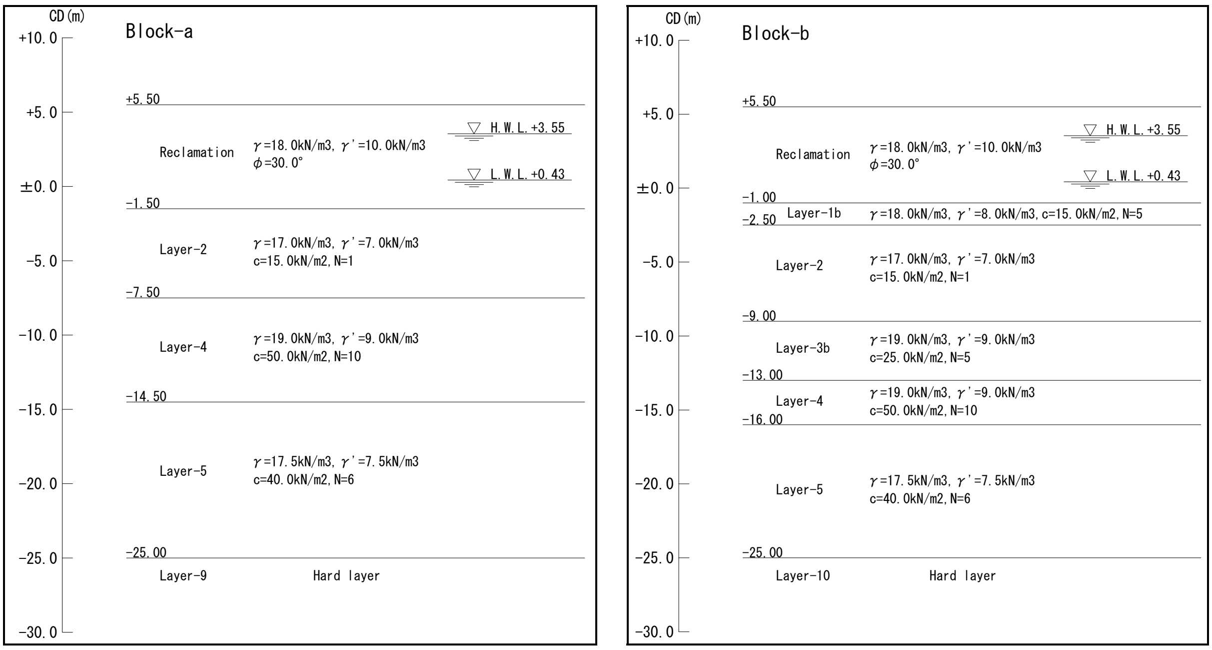
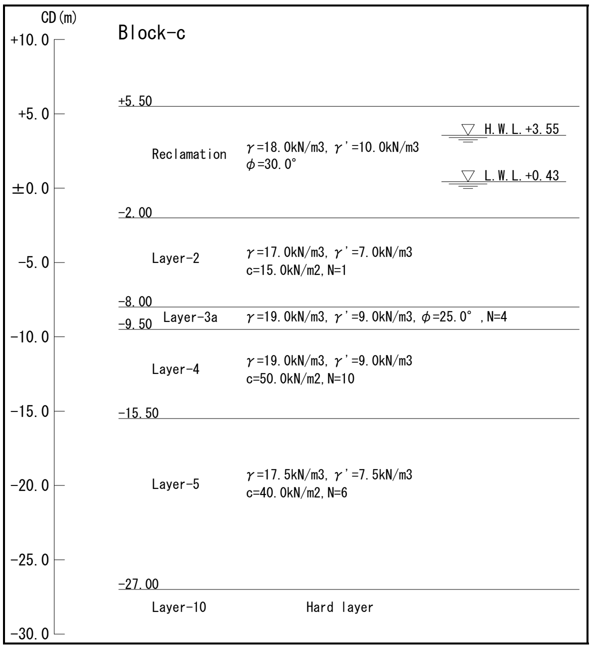


Figure 7.6.1 Plan of Examination Block for Earth Retaining Wall

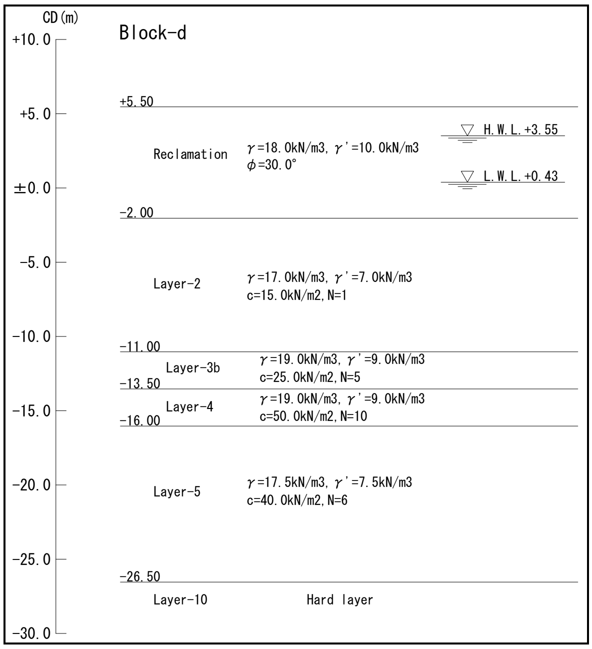


block a　　　　　block b

Figure 7.6.2 Model of Soil layer for Examination (block a and block b)



block c



block d

Figure 7.6.3 Model of Soil layer for Examination (block c and block d)

Table 7.6.1 Soil Parameters for CDM Method Design

Layer No.	Typical Soil Type	SPT-N	γ (kN/m3)	γ' (kN/m3)	Cu (kN/m2)	φ (°)	Cc	Cr	Ca (%)	Pc (kN/m2)	e0	Cv (OC) x 10^{-3} (cm2/s)	Cv (NC) x 10^{-3} (cm2/s)	Cu/P for NC
1a	SP	4	18.0	8.0	0	25.0	-	-	-	-	-	-	-	-
1b	CL	5	18.0	8.0	15	0.0	0.30	0.07	0.4	80	1.05	1.20	1.20	0.30
2	CH	1	17.0	7.0	15	0.0	0.60	0.12	0.7	80	1.45	1.00	0.60	0.30
3a	SP	4	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
3b	CL	5	19.0	9.0	25	0.0	0.25	0.05	0.4	Σγ'z+50	0.80	1.20	1.20	0.30
3c	SP	6	19.0	9.0	0	25.0	-	-	-	-	-	-	-	-
4	CH, CL	10	19.0	9.0	50	0.0	0.35	0.04	0.6	Σγ'z+100	0.85	1.20	0.80	0.30
5	CH	6	17.5	7.5	40	0.0	0.60	0.08	0.8	Σγ'z+75	1.20	2.20	0.80	0.30
Fill,Emb.	S	-	18.0	10.0	0	30.0	-	-	-	-	-	-	-	-

*NC: Normal conslidated State   OC: Over consolidated State

b) Residual Water Level

The residual water level behind the earth retaining wall is normally taken as the following formula for the sheet pile structure:

$$RWL = LWL + (HWL - LWL) \times 2/3$$

According to the design condition mentioned in 7.1, the residual water level of +2.51m CDL is derived by the above formula. However, there are cases in Vietnam that the sheet pile structure falls down due to the higher residual water level than expected in design. Therefore, in this design, the applied residual water level is equal to high water level (HWL: +3.55m CDL) in order to secure the safety of sheet pile structure.

2) Structural Condition

a) Cope elevation of Earth retaining wall

The cope elevation of Earth retaining wall is taken as +5.50m CDL.

b) Design water depth in front of Earth retaining wall

The Design water depth of -1.0m CDL is applied to the design.

The critical condition of earth retaining wall is not at "completion status" but at "during construction status" (when the slope in front of earth retaining wall is dredged so as to place the armor stone) for the following reasons:

- Since the area behind the earth retaining wall is used for the temporary yard to construct the container berth, the area load of 30kN/m^2 the same value as "completion status" should be considered.
- Since the construction of container berth requires a certain period of time, the "construction status" should be deemed as "Normal loading conditions".

Therefore, the design water depth is decided as the following steps (refer to Figure 7.6.4):

- The water level in front of earth retaining wall calculated from the water depth in front of container berth with a slope of 1:3 is +0.8m CDL.
- The thickness of armor stone is assumed as 1.2m, then the water level in front of earth retaining wall is -0.465m CDL (considering the slope of 1:3).
- The allowance for dredging work is assumed as 0.5m, finally the water level in front of earth retaining fall is calculated as -0.965m CDL → -1.0m CDL

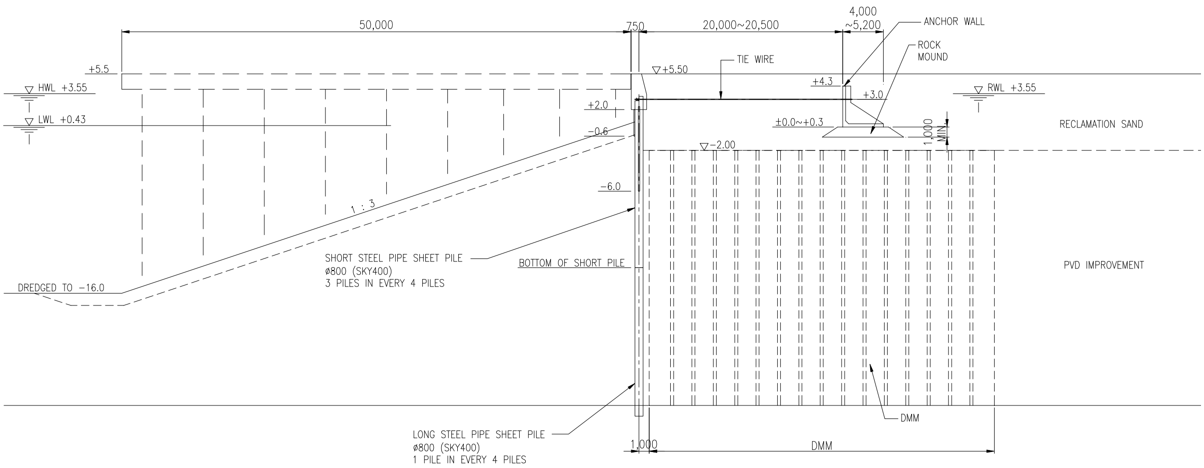


Figure 7.6.4 Determination of the Design Water Depth in front of Earth Retaining Wall

3) Loading Condition

Applied loading condition is as follows:

- Operational load : 30kN/m^2
- Seismic load : not considered
- Filling sand : γ = 18kN/m^3 ; ϕ = 30^o
- Horizontal Displacement : within 30mm

4) Material Condition

The applied materials are all in accordance with the Japanese Industrial Standard (JIS) as follows:

- Structural steel: JIS G 3101:2010 Rolled steels for general structure (SS400 etc.)

- Steel Sheet Pile: JIS A 5528: 2006 SY295 Hot rolled steel sheet piles (SY295)
- Steel Pipe Sheet Pile: JIS A 5530: 2010 Steel pipe sheet piles (SKY400)

As for the corrosion speed of steel material is assumed as follows:

- Steel sheet pile and structural steel contacting with soil: 0.03mm/year
- Seaside surface of Steel sheet pile above seabed: Appropriate corrosion protection will be applied, however, 0.03mm/year is considered in the design

7.6.2 Design of Retaining Wall (Steel Sheet Pipe Pile: SSPP)

1) Used software

Following design software was used for the analysis.

- Software : Design system for anchored sheet pile quaywall (ver.2)
- Developed by : Araise Solution Co., Ltd. (Japan)

2) Plan of retaining wall

According to the subsoil condition and the water depth in front of the retaining wall, the retaining wall is divided into 5 blocks: a, b, c ,d and 1 as shown in the figure below:

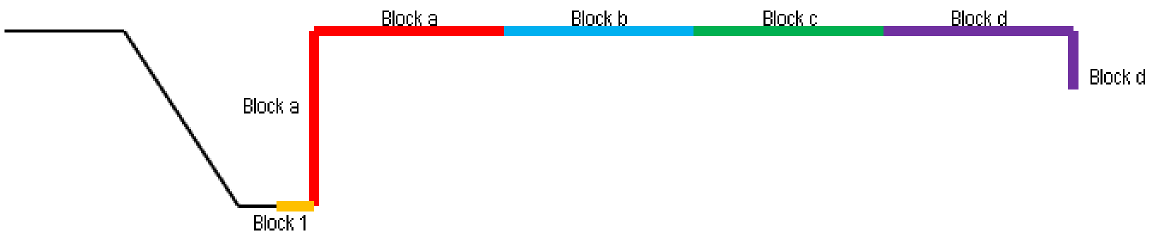


Figure 7.6.5 Plan of Retaining Wall

The length of the blocks is:

- Block 1 : 30m ; Width of DMM behind wall: 38.1m
- Block a : 150m + 170m = 320m ; Width of DMM behind wall: 33.9m
- Block b : 200m ; Width of DMM behind wall: 36.0m
- Block c : 200m ; Width of DMM behind wall: 38.1m
- Block d: 150m + 50m = 200m ; Width of DMM behind wall: 40.2m

3) Design Method

Since the SSPP will be penetrated into the soft ground, both of the following methods are employed and critical results are adopted as the input condition to determine the embedded length and section of SSSP.

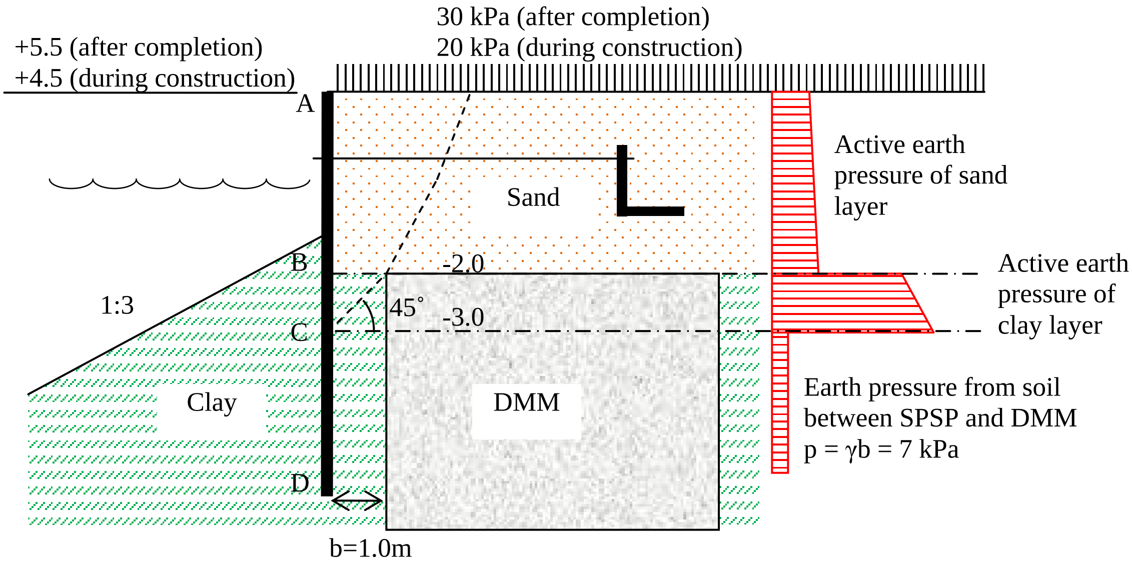
- Deflection curve method
- Free earth support method

4) Earth Pressure

a) Active earth pressure

The SSPP wall will be installed along the DMM with 1.0m offset. The DMM is regarded as a rigid structure (for the SSPP design) and will not contribute to the active earth pressure on the

SSPP. Therefore, the active earth pressure on the SSPP shown below is considered.



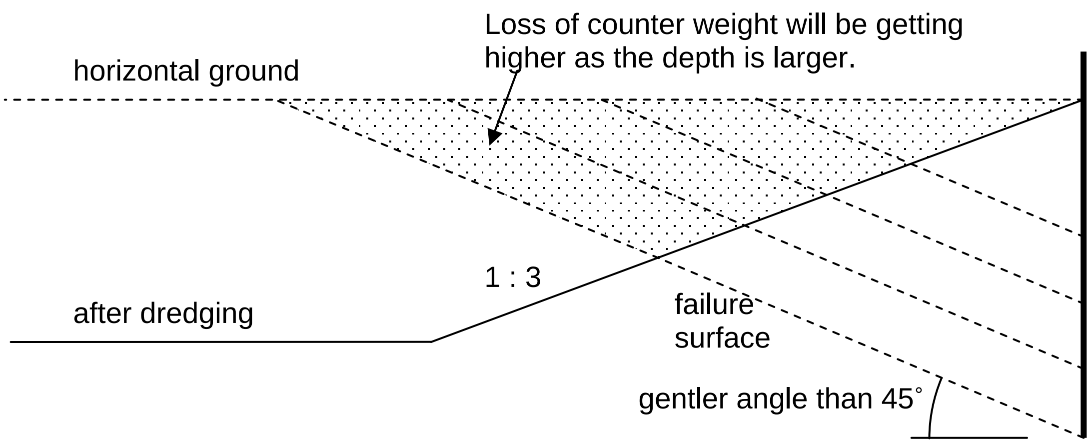
The active earth pressure on the SSPP is calculated in Appendix 7-5.

b) Passive earth pressure

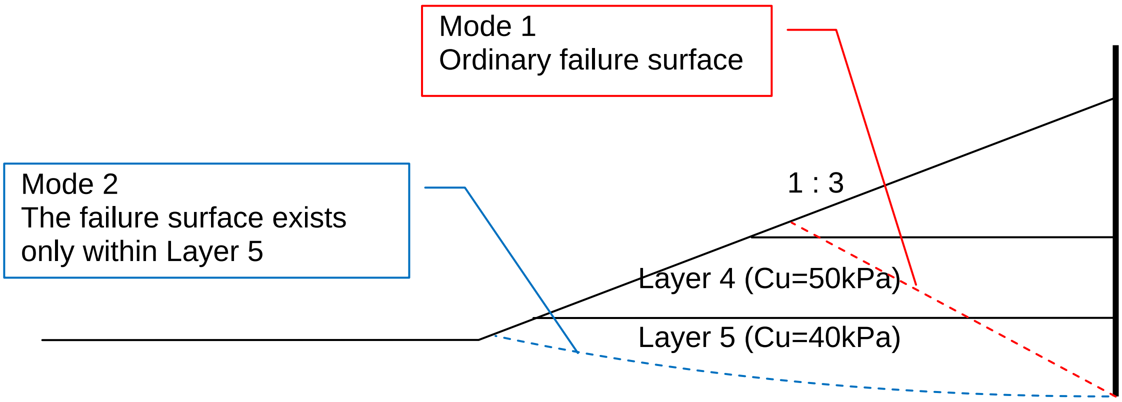
The seabed in front of the SSPP is sloped down to the berthing pocket (-16.0mCD) with a gradient of 1 in 3. Although there is no specific method shown in the Technical Standards and Commentaries for Port and Harbor Facilities in Japan – 2002 to obtain the passive resistance of the sloped cohesive ground, it is obvious that the passive earth pressure will be reduced from that for the horizontal ground.

In Appendix 7-6, the passive earth pressure for the sloped ground is estimated by the circular slip method, taking into consideration the following effects:

- Due to the loss of counter weight, failure angle would be gentler than 45˚.



- Due to the variations of shear strength of soils as well as unit weight of soils, modes of failure would vary.



The estimated passive earth pressure for the sloped ground is shown in Appendix 7-6.

5) Embedded length of Steel sheet pile and Section of SSPP

a) Deflection Curve Method

The elastic equations are solved under the external force conditions with the conditions that the displacement and deflection angle is zero at the top and the toe of the sheet pile.

For this purpose, the sheet pile is assumed to be "fix-supported" at the top of sheet pile and "pin-supported" at the tip of sheet pile and the deflection angle at the toe of sheet pile is calculated by varying the embedded length of sheet pile. Once the embedded length of sheet pile with which the deflection angle becomes zero is obtained, it is considered as the minimum embedded length. The embedded length of sheet pile shall be 1.2 times (i.e. factor of safety) of the minimum embedded length.

b) Free Earth Support Method

The embedded length of the sheet pile is obtained so that the following formula is satisfied.

$$Mp = F.S \times Ma$$

where;
Mp: Moment due to the passive earth pressure about the top of the sheet pile (kN-m/m)
Ma: Moment due to the active earth pressure and the residual water pressure about the top of the sheet pile (kN-m/m)
F.S: Factor of safety (=1.2)

The calculation result and of all blocks are summarized in the table below:

Area	Section of SPSP determined	Bottom elevation	Tie tension force TA	
			After completion	During construction
Block-1	ϕ800×14 (SKY400)	-15.5m	319.3 kN/m	246.7 kN/m
Block-a	ϕ800×10 (SKY400)	-13.5m	249.2 kN/m	180.0 kN/m
Block-b	ϕ800×10 (SKY400)	-16.5m	264.3 kN/m	191.9 kN/m
Block-c	ϕ800×10 (SKY400)	-15.0m	260.9 kN/m	189.7 kN/m
Block-d	ϕ800×11 (SKY400)	-17.5m	275.3 kN/m	201.8 kN/m

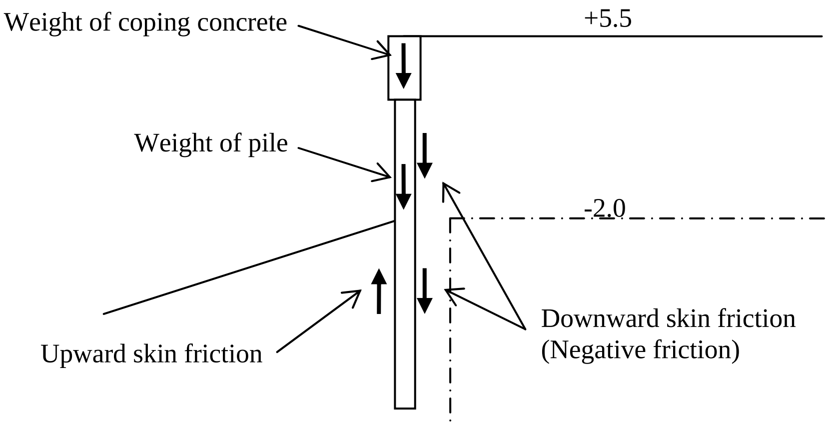
The detailed calculation results are shown in Appendix 7-7 for the time of "After Completion" and in Appendix 7-8 for the time of "During Construction", respectively.

6) Bearing capacity of steel sheet pipe pile

The location of coping concrete is between apron and container yard above which tractor head, forklift, reach stocker, etc is passing. The smooth transition on the apron is very important for the container handling operation. In order to prevent significant settlement, it is recommended that the bearing pile be provided driven up to the hard strata.

In this study, one bearing pile is provided every four SSPP considering the economical and practical reasons.

Since the settlement of the DMM itself (this is a sort of elastic settlement) and the consolidation settlement of the clay between the DMM and the SPSP are unavoidable, negative friction will occur as shown in the figure below. This downward force is greater than the upward resistance from the soil contacting the seaside surface of the SSPP which will result in a settlement of the coping concrete.



To avoid the situation mentioned above, 25% of the SSPP (i.e., one in every four piles) will be driven to the hard stratum to form bearing piles to directly support the coping concrete.

The detail of the calculation is shown in Appendix 7-9. The pile arrangement is determined as shown in the figure below.

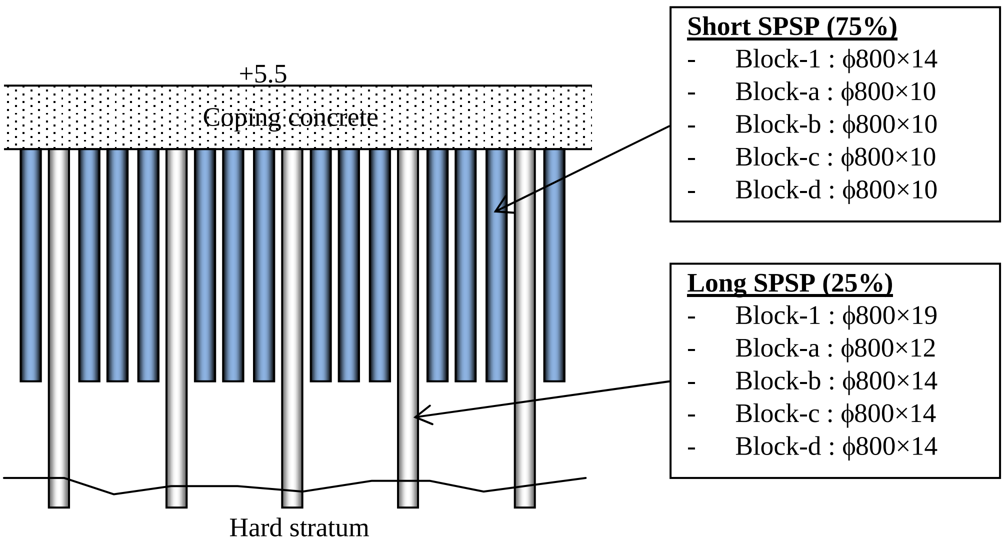


Figure 7.6.6 Arrangement of Bearing Pile

7) Slope stability in front of retaining Wall

The stability of the slope in front of the retaining wall was checked as shown below. The factor of safety of 2.29 is derived from the calculation result.

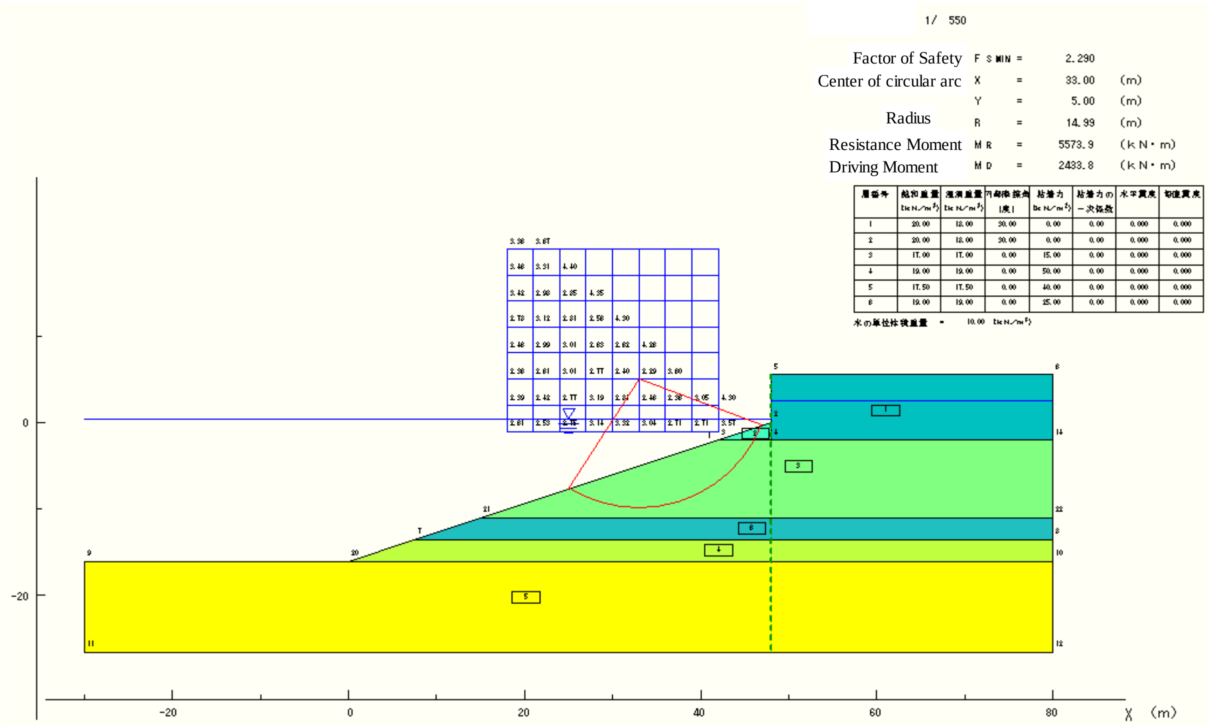


Figure 7.6.7 Slope Stability Analysis in front of the Earth Retaining Wall

8) Typical Section

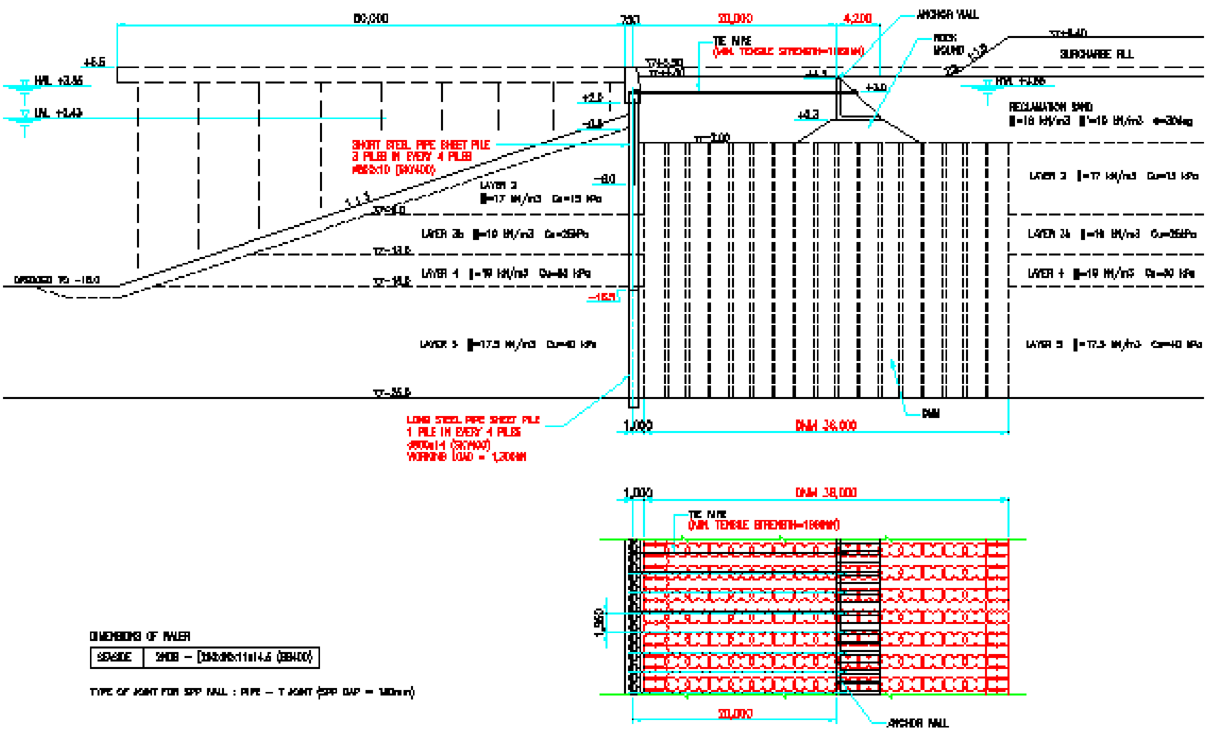


Figure 7.6.8 Typical Cross Section of Earth Retaining Wall (behind Container Berth)

7.7 Basic Design of Pavement for Access Road

7.7.1 Design Condition

1) Pavement Design Specification

Vietnamese Standard for Pavement Design, 22TCN 211-06 (hereinafter “the specification”) is applied in the design of Pavement structure in this Project.

2) Road Condition

Project Road is classified to “Public Highway” with 6-lane. Pavement type is Flexible Pavement.

3) Design Values

Summary of Design Values with reference are as following.

Table 7.7.1 Summary of Design Values

Design Input Requirements			Value	Reference (22TCN211-06)
1	Vehicle Load	Traffic Volume(Vehicles/day) in 2030	Truck=18,735 Bus=4,726	Based on the TV-LH Design
		Traffic annual growth rate(%): 2015=>2020 2020=>2030	10.35% 7.60%	
		Design Period (years)	15 (2015-2030)	
		Conversion Coefficient from 6-lane to 1-lane, f_l	0.30	D-3
		Standard calculation axle load, P_{tt}(kN)	120.0	Table 3.1
		Calculation pressure on pavement, p(Mpa)	0.60	Table 3.1
		Diameter of wheel track, D(cm)	36.0	Table 3.1
		Others (C1, C2, Pi) for each vehicle types	See Table D4-2	Table D4-2
2	Material Properties	For each materials, *Elastic Modulus, E (Mpa) *Flexural tensile strength, R_{ku} (Mpa) *Friction angle, φ (degree) *Cohesive force, C(Mpa)	See Table D6-1	Table D6-1
3	Others	Other necessary values for design are described in design sheet.		

7.7.2 Design Result

Following Pavement Structure is proposed based on the pavement calculation result by Design Sheet.

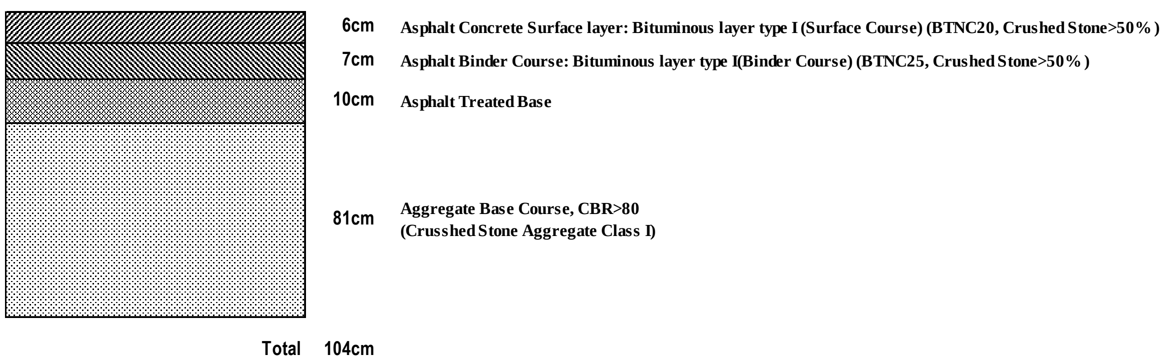


Figure 7.7.1 Pavement Structure

7.7.3 Design Sheet

Pavement Design is shown from next page. The Design was done by “Design Sheet” which is programmed by Excel based on 22TCN 211-06.

Pavement Design Sheet
for Detailed Design Study Lach Huyen Infrastructure Construction Project in Vietnam

Note: *Table No. and Figure No. is following 22TCN211-06.

D-1. Design Standard:
22TCN 211-06

D-2. Road Category:
Highway (2015 ~ 2030, 15years)

- Characteristics of Standard calculation axle load are as follwing

Table 3.1: Characteristics of Standard calculation axle load

Standard calculation axle load, P_{tt}(kN)	Calculation pressure on pavement, p(Mpa)	Diameter of wheel track, D (cm)
100	0.6	33
120	0.6	36

- From above table,

P_{tt}= 120 kN
p= 0.6 Mpa
D= 36 cm

D-3. Number of Lane:
6-lane -> f_1= 0.30 (f1; coefficient from 6-lane to 1-lane)

D-4. Calculation of Vehicle Load
*From Capter2 (Direction 3+4, Dailey Vehicle)

Table D4-1 Traffic Volume for each Vehicle type

Section: Tan Vu-Dinh Vu	MC	Car	Truck	Bus
2015	0	959	1,360	1,891
2020	0	2,892	5,549	2,740
2030	28,632	13,388	18,735	4,726

(Average annual growth rate 2015-2020) = 10.35 %
(Average annual growth rate 2020-2030) = 7.60 %

Types and Number of Trucks & Buses are spporsed as following;

		%	Number
Bus	(Total)		4,726
	- Small Bus	90.0%	4,253
	- Large Bus	10.0%	473
Truck			
	(Total)		18,735
	- Light	30.0%	5,621
	- Medium	20.0%	3,747
	- Heavy	20.0%	3,747
	- Heavy	15.0%	2,810
	- Heavy	15.0%	2,810

- Calculation of a number of axles converted into a number of standard axles (Final year of design period)

Table D4-2 Calculation of Total Number of acles, N (2030)

Type of Vehicle		P_i(kN)	C1	C2	ni	$C_1 * C_2 * n_i * (Pi/P_{tt})^{4.4}$
Small Bus	Front	26.4	1	6.4	4,253	35
	Rear	45.2	1	1	4,253	58
Large Bus	Front	56.0	1	6.4	473	106
	Rear	95.8	1	1	473	175
Light Truck	Front	18.0	0	6.4	5,621	0
	Rear	56.0	1	1	5,621	197
Medium Truck	Front	25.8	1	6.4	3,747	28
	Rear	69.6	1	1	3,747	341
Heavy Truck	Front	48.2	1	6.4	3,747	433
	Rear	100.0	1	1	3,747	1,680
Heavy Truck	Front	45.4	1	6.4	2,810	250
	Rear	90.0	2.2	1	2,810	1,744
Heavy Truck	Front	23.1	0	6.4	2,810	0
	Rear	73.2	2	1	2,810	639
Total					N=	5,684

<-(3-1)

*Ptt = **120** kN

*Values of Pi, C1, C2 are determined by refering Table E-1

Ntt= f1 *N = **0.30** * **5,684** (3-3)

= **1,705** vehicles/day (2030)

- To calculate number of standard axle accumulated in the period of 15 years

$$N_e = \frac{[(1+q)^t - 1]}{q(1+q)^{t-1}} * 365 * N_{tt} \text{ (axles)} \qquad \text{(A-3)}$$

t1=	5	(years),	q1=	0.1035	(2015-2020)
t2=	10	(years),	q2=	0.0760	(2020-2030)
Ntt1=	537	(vehicles/day), (See below calculation)			(2015-2020)
Ntt2=	1,705	(vehicles/day), (See previous page)			(2020-2030)

Table D4-3 Calculation of Total Number of acles, N (2020)

Type of Vehicle		P_i(kN)	C1	C2	ni	$C_1*C_2*n_i*(Pi/P_{tt})^{4.4}$
Small Bus	Front	26.4	1.0	6.4	2,466	20
	Rear	45.2	1.0	1.0	2,466	34
Large Bus	Front	56.0	1.0	6.4	274	61
	Rear	95.8	1.0	1.0	274	102
Light Truck	Front	18.0	0.0	6.4	1,665	0
	Rear	56.0	1.0	1.0	1,665	58
Medium Truck	Front	25.8	1.0	6.4	1,110	8
	Rear	69.6	1.0	1.0	1,110	101
Heavy Truck	Front	48.2	1.0	6.4	1,110	128
	Rear	100.0	1.0	1.0	1,110	498
Heavy Truck	Front	45.4	1.0	6.4	832	74
	Rear	90.0	2.2	1.0	832	516
Heavy Truck	Front	23.1	0.0	6.4	832	0
	Rear	73.2	2.0	1.0	832	189
Total					N=	1,790

<-(3-1)

Ntt(2020)= 1,790 * 0.30 = 537 (veh/day) (2020)

Therefore,

$$N_e = \frac{[(1+q_1)^{t1} - 1]}{q_1(1+q_1)^{t1-1}} * 365 * N_{tt1} + \frac{[(1+q_2)^{t2} - 1]}{q_2(1+q_2)^{t2-1}} * 365 * N_{tt2}$$

= 812,484 + 4,576,282 = 5,388,766 (axles)

D-5. Determination of strength coefficient for design reliability and Required elastic modulus value

$$E_{ch} \geq K_{cd}^{dv} * E_{yc} = 1.10 * 214$$
$$= \mathbf{235} \text{ (Mpa)} \qquad (3\text{-}4)$$

K_{cd}^{dv}: Strength coefficient on deflection depending on reliability
E_{yc}: Required elastic modulus value

Table 3-2: Determination of strength coefficient on deflection depending on reliability

Reliability	0.98	0.95	0.90	0.85	0.80
Strength coefficient K_{cd}^{dv}	1.29	1.17	1.10	1.06	1.02

Table 3-3 : Selection of design reliability by road type and class

Road type, class		**Design reliability**		
1. Expressway		0.90	0.95	0.98
2. Highway/road	-I, II Class	0.00	0.95	0.98
	-III, IV Class	0.85	0.90	0.95
	-V, VI Class	0.80	0.85	0.90
3. Urban road	-Expressway and urban arterial road	0.90	0.95	0.98
	-Other urban road	0.85	0.90	0.95
4. Specialized road		0.80	0.85	0.90

K_{cd}^{dv} = **1.10**

Table3-4 Required elastic modulus value

Types of standard axle load		**Required elastic modulus value Eyc(Mpa), Corresponding to a number of calculation axles (vehicle/ day/lane)**									
		10	20	50	100	200	500	1000	2000	5000	7000
10	High-grade A1			133	147	160	178	192	207	224	235
	High-grade A2		91	110	122	135	153				
	Low-grade B1		64	82	94						
12	High-grade A1		127	146	161	173	190	204	218	235	253
	High-grade A2	90	103	120	133	146	163				
	Low-grade B1		79	98	111						

E_{yc} = 204+(218-204)*(1705-1000)/(2000-1000)
= **214** Mpa

D-6. Design Condition

- Material Condition

Table D6-1 Material Properties for Each layer

Materal	E(Mpa)			R_{ku}	C	φ	t
	Sliding	Deflection	Tensil and Flexture	(Mpa)	(Mpa)	(degree)	(cm)
Surface Course	300	420	1800	2.8			6
Binder Course	350	350	1600	2.0			7
Asphalt Treated Base	350	350	800				10
Base	300	300	300				81
Embankment	50	50	50		0.028	21	-

Surface Course	:	Bituminous layer type I (Surface Course) (BTNC20, Crushed Stone>50%)
Binder Course	:	Bituminous layer type I(Binder Course) (BTNC25, Crushed Stone>50%)
Asphalt Treated Base	:	Black crushed stone mixed with compact asphalt
Base	:	Crushed Stone Aggregate Base Class I
Embankment	:	Clay and loam, CBR=8

Note: *Values of Asphalt and Base were determined by refering to Table C-1

*E of Embankment was desided by formula B-5, (CBR=8)

E=4.68*CBR+12.48=50(Mpa)

*Values of Embankment were determined by refering to Table B-3 (W/W_{nh}=0.65)

*Minimum Asphalt thickness should be 12.5cm. (N_e>4.0*10^6) (According to Table 2-2)

Therefore design condition is as following

Ntt=	**1,705**	**(vehicles/lane/day in 2030)**
Ne=	**5,388,766**	**(axle for 15 years)**
P_{tt}=	**120**	**(kN)**
p=	**0.60**	**(Mpa)**
D=	**36**	**(cm)**

E_{yc}= 214 (Mpa), K_{cd}^{dv}= 1.1

		t(cm)
Surface Course	**uminous layer type I (Surface Course) (BTNC20, Crushed Stone>5**	**6**
Binder Course	**uminous layer type I(Binder Course) (BTNC25, Crushed Stone>5(**	**7**
Asphalt Treated Base	**Black crushed stone mixed with compact asphalt**	**10**
Base	**Crushed Stone Aggregate Base Class I**	**81**
Embankment	**Clay and loam, CBR=8**	

D-7. Cheking Deflection

No.					
	$K_{cd}^{dv} * E_{yc}=$	235	Mpa		
4 Surface Course	$E_4=$	420	Mpa	6	cm
3 Binder Course	$E_3=$	350	Mpa	7	cm
2 Asphalt Treated Base	$E_{2=}$	350	Mpa	10	cm
1 Base	$E_1=$	300	Mpa	81	cm
	$E_0=$	50	Mpa		

$$E_{TB} = E_1 \cdot \left[\frac{\left(1 + k.t^{1/3}\right)}{(1+k)} \right]^3 \text{ Mpa} \qquad k = \frac{h_1}{h_2} \quad t = \frac{E_2}{E_1} \qquad (3\text{-}5)$$

The results are described in the below table:

Table D7-1 Calculation results of E_{tbi}

Layer	Material Courses	E_i (Mpa)	t $=E_2/E_1$	h_i (cm)	K $=h_2/h_1$	h_{tbi} (cm)	E_{tbi} (Mpa)
4	Surface Course	420	1.36	6	0.06	104	314
3	Binder Course	350	1.15	7	0.08	98	308
2	Asphalt Treated Base	350	1.17	10	0.12	91	305
1	Base	300		81		81	300

$E_{tb5}=$ **314** daN/cm^2

$\beta =$ **1.265** (from below)

$E_{TB}^{tt} = \beta \cdot E_{tb}$

= **1.265** * **314**

= **397** Mpa

Table 3-6 Adjustment coefficient β

H/D Ratio	0.51	0.75	1.00	1.25	1.50	1.75	2.00
β Coefficient	1.033	1.069	1.107	1.136	1.178	1.198	1.210

$\beta = 1.114*(H/D)^{0.12}$ (in case of H/D>2.0) (3-6)

Where as;

D= **36** cm (Diameter of Wheel track)

H= **104** cm (Hight of the Layer)

Therefore

H/D= **2.89**

From Table/formula 3-6,

$\beta = 1.114*(104/36)^{0.12}$

= **1.265**

E_0= **50** Mpa , E_{TB}^{tt}= **397** Mpa

E_0/E_{TB}^{tt}= **0.126**

H/D= **2.89**

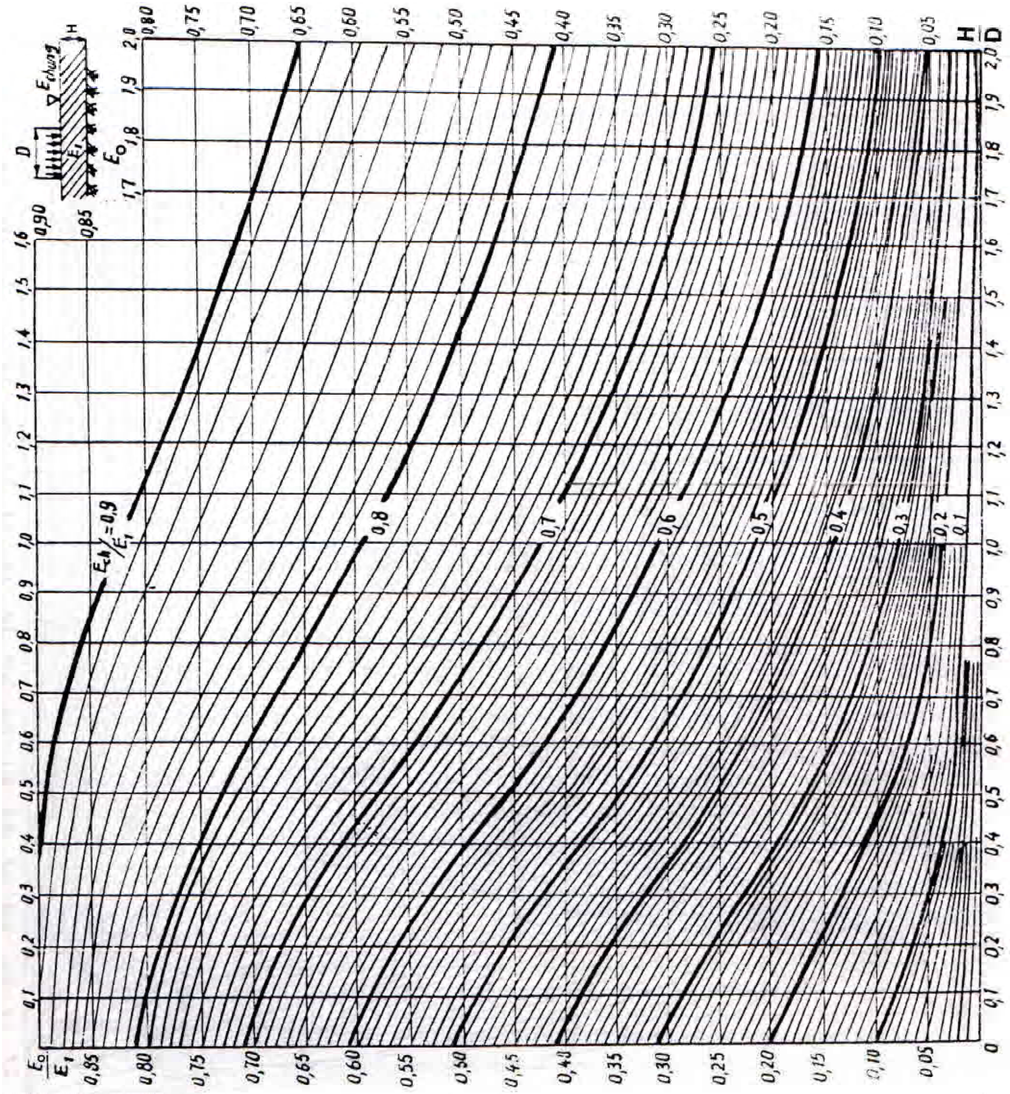


Figure 3-1. Monograph for determination of general elastic modulus of double-layer system E_{ch} (H/D<2)

$$\mathbf{E_{ch}} = \frac{1.05.E_0}{\dfrac{1+\dfrac{E_0}{E_1}}{\sqrt{1+4\left(\dfrac{H}{D}\right)^2.\left(\dfrac{E_o}{E_1}\right)^{-0.67}}}+\dfrac{E_o}{E_1}}$$

(F-1) (H/D>2)

From above Table/Formula, E_{ch}= **236** Mpa ≧ **235** **Mpa (=K_{cd}^{dv}*E_{yc})** **OK**

D-8. Cheking Sliding

$$T_{ax} + T_{av} < \frac{C_{tt}}{K_{cd}^{tr}} \qquad (3\text{-}7)$$

T_{ax} : From Table 3-2 (H/D<2.0), or From Table 3-3 (H/D >2.0)
T_{av} : From Table 3-4
C_{tt} : From formula(3-8)
K_{cd}^{tr} : From Table 3-7

- Detarmination of K_{cd}^{tr}

K_{cd}^{tr} = **0.94** (From Table 3-7)

Table 3-7 Selection of coefficient of shear strength depending on reliability

Reliability	0.98	0.95	0.90	0.85	0.80
Coef. K_{cd}^{tr}	1.10	1.00	0.94	0.90	0.87

- Calculation of Ctt

$C_{tt}= C*K_1*K_2*K_3$ = **0.0164** (Mpa)

C: **0.028** (Mpa) Cohesive force of fundation soil
K_1: **0.6** for pavement carriageway
K_2: **0.65** from Table 3-8

Table 3-8 Determination of Coefficient K2 depending on a number of design axles

A number of design axles (N_{tt}) (axle/day/lane)	Under 100	Under 1000	Under 5000	Over 5000
Coefficient K_2	1.00	0.80	0.65	0.60

*Ntt= **1,705**

K_3: **1.5** For types of cohesive soil (clay, clay loam, clay sand etc.)

No.		C_{tt}/K_{cd}^{tr}=	0.017		
4	Surface Course	E_4=	300	Mpa	6 cm
3	Binder Course	E_3=	350	Mpa	7 cm
2	Asphalt Treated Base	$E_{2=}$	350	Mpa	10 cm
1	Base	E_1=	300	Mpa	81 cm

E_0= **50** Mpa
C= **0.028** Mpa
φ= **21** degree

- Determination of T_{ax}

Table D8-1 Calculation results of E_{tbi}

Layer	Material Courses	E_i (Mpa)	t $=E_2/E_1$	h_i (cm)	K $=h_2/h_1$	h_{tbi} (cm)	E_{tbi} (Mpa)
4	Surface Course	300	0.97	6	0.06	104	308
3	Binder Course	350	1.15	7	0.08	98	308
2	Asphalt Treated Base	350	1.17	10	0.12	91	305
1	Base	300		81		81	300

E_{tb}= **308** daN/cm^2
β = **1.265** (from below)
$E_{TB}^{tt} = \beta \cdot E_{tb}$
= **1.265** * **308**
= **389** Mpa

Table 3-6 Adjustment coefficient β

H/D Ratio	0.51	0.75	1.00	1.25	1.50	1.75	2.00
β Coefficient	1.033	1.069	1.107	1.136	1.178	1.198	1.210

$\beta = 1.114*(H/D)^{0.12}$ (in case of H/D>2.0) (3-6)

Where as;
D= **36** cm (Diameter of Wheel track)
H= **104** cm (Hight of the Layer)
Therefore
H/D= **2.89**
From Table/formula 3-6,
β = 1.114*(104/36)0.12
= **1.265**

E_0= 50 Mpa , E_{TB}^{tt}= 389 Mpa

E_{TB}^{tt}/E_o= 7.79

H/D= 2.89 φ= 21 degree

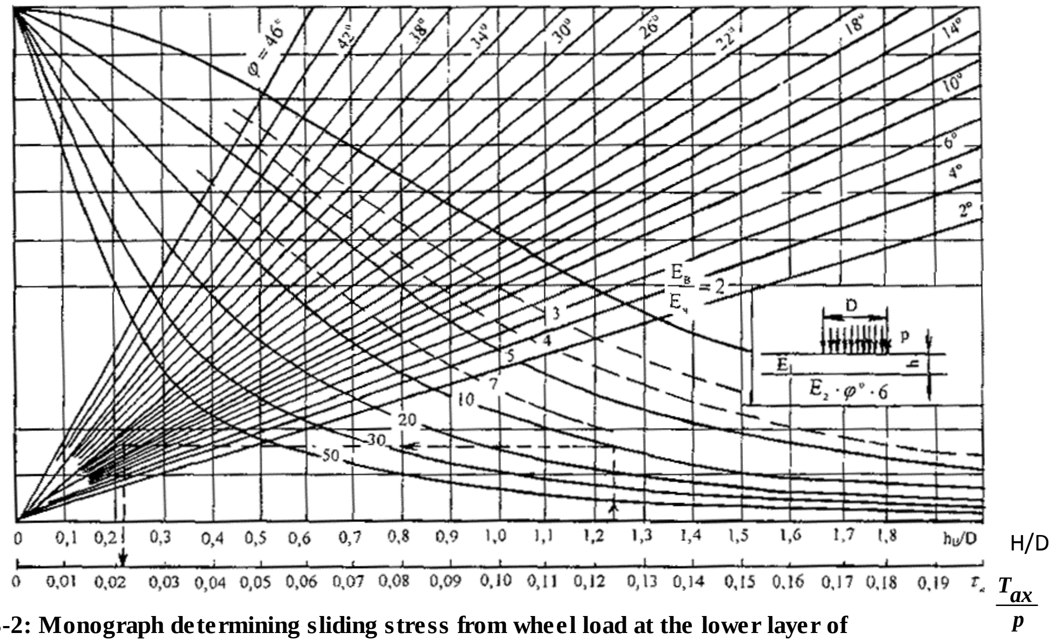


Figure 3-2: Monograph determining sliding stress from wheel load at the lower layer of the double-layer system (H/D = 0 ~ 2)

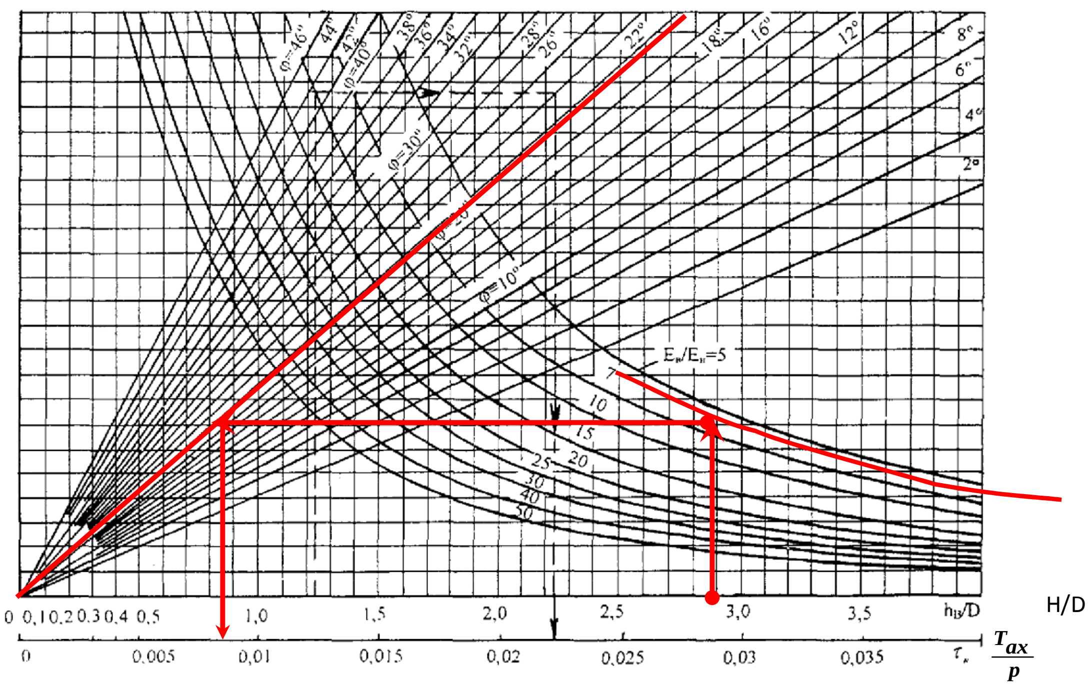


Figure 3-3: Monograph determining sliding stress from wheel load at the lower layer of the double-layer system (H/D = 0 ~ 4)

From above Figure, T_{ax}/p= 0.008 , p= 0.60 Mpa

Therefore T_{ax}= 0.0048 Mpa

- Determination of T_{av}

H= **104** cm
φ= **21** degree

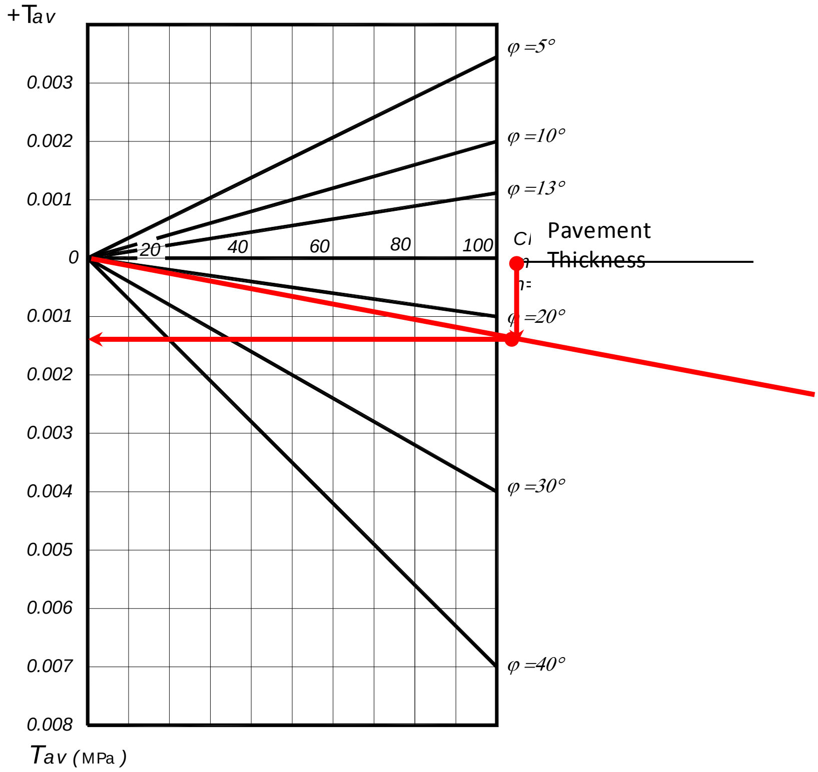


Figure 3-4. Monograph for finding active shearing stress T_{av} by self waight of pavement

From above Figure,

T_{AX}= <u>**-0.0013**</u> Mpa

- Cheking Sliding

$$T_{ax} + T_{av} < \frac{C_{tt}}{K_{cd}^{tr}} \qquad (3\text{-}7)$$

T_{ax} =	0.0048	Mpa
T_{av} =	-0.0013	Mpa
C_{tt} =	0.0164	Mpa
K_{cd}^{tr} =	0.94	Mpa

$T_{ax} + T_{av}$ =	0.0048	+	-0.0013	=	0.0035
C_{tt}/K_{cd}^{tr}=	0.01638	/	0.94	=	0.0174

$T_{ax} + T_{av} < C_{tt}/K_{cd}^{tr}$ <u>**OK**</u>

D-9. Cheking Flexural Strength

$$\sigma_{ku} \le \frac{R_{tt}^{ku}}{K_{cd}^{ku}} \quad (3\text{-}9)$$

$$\sigma_{ku} = \overline{\sigma_{Ku}} * p * K_b \quad (3\text{-}10)$$

$\overline{\sigma}$ ku: the value shall be determined by Figure 3-5, 3-6, (See after)

p: = **0.60** Mpa

Kb= **1.00** (for the heaviest special axle load)

$$R_{tt}^{ku} = k_1 * k_2 * R_{ku} \quad (3\text{-}11)$$

$k_1 = 11.11/N_e^{0.22}$ (for asphalt concrete material) (3-12)

= 11.11/ **5,388,766** $^{0.22}$ = **0.37**

N_e = **5,388,766** (axle for 15 years)

k_2 = **1.00** (for material consolidated with inorganic material)

R_{ku} = **2.80** (for Surface Course, See D-7 Design Condition)

2.00 (for Binder Course, See D-7 Design Condition)

K_{cd}^{ku} = **0.94** (From Table 3-7)

- Design Condition

No.				
4 Surface Course	E_4=	1800	Mpa	6 cm
3 Binder Course	E_3=	1600	Mpa	7 cm
2 Asphalt Treated Base	$E_{2=}$	800	Mpa	10 cm
1 Base	E_1=	300	Mpa	81 cm
	E_0=	50	Mpa	

Table D9-1 Calculation results of E_{tbi}

Layer	Material Courses	E_i (Mpa)	t $=E_2/E_1$	h_i (cm)	K $=h_2/h_1$	h_{tbi} (cm)	E_{tbi} (Mpa)
4	Surface Course	1800	4.60	6	0.06	104	438
3	Binder Course	1600	4.71	7	0.08	98	392
2	Asphalt Treated Base	800	2.67	10	0.12	91	340
1	Base	300		81		81	300

A) Cheking of Surface Course

h_1= 6 cm, E_1= 1800 Mpa

Etb4= 392 Mpa (from Table D9-1)

β = 1.256 (from below)

$E_{TB}^{tt} = \beta \cdot E_{tb}$

= 1.256 * 392

= 492 Mpa

Table 3-6 Adjustment coefficient β

H/D Ratio	0.51	0.75	1.00	1.25	1.50	1.75	2.00
β Coefficient	1.033	1.069	1.107	1.136	1.178	1.198	1.210

$\beta = 1.114*(H/D)^{0.12}$ (in case of H/D>2.0) (3-6)

Where as;

D= 36 cm (Diameter of Wheel track)

H= 98 cm (Hight of the Layer)

Therefore

H/D= 2.72

From Table/formula 3-6,

$\beta = 1.114*(98/36)^{0.12}$

= 1.256

E_0= **50** Mpa , $E_{TB}{}^{tt}$= **492** Mpa

$E_0/E_{TB}{}^{tt}$= **0.102**

H/D= **2.72**

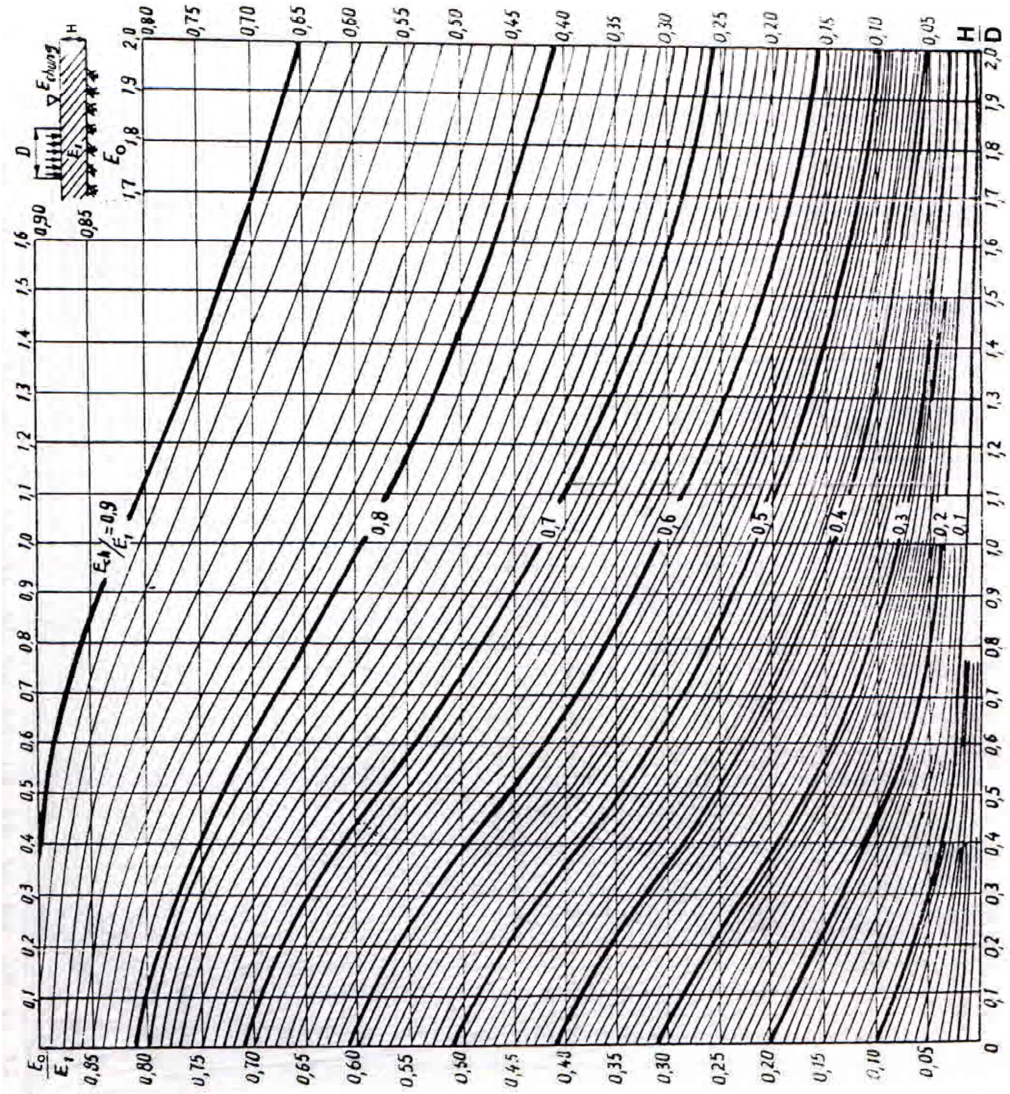


Figure 3-1. Monograph for determination of general elastic modulus of double-layer system E_{ch} (H/D<2)

$$\mathbf{E_{ch}} = \frac{1.05.E_0}{\dfrac{1+\dfrac{E_0}{E_1}}{\sqrt{1+4\left(\dfrac{H}{D}\right)^2\left(\dfrac{E_o}{E_1}\right)^{-0.67}}}+\dfrac{E_o}{E_1}} \qquad \text{(F-1)} \qquad \text{(H/D>2)}$$

From above Table/Formula, E_{ch}= **269** Mpa

h_1=	6	cm	⇨ H/D=	0.1667
E_1=	1800	Mpa	⇨ E_1/E_{ch}=	6.6999

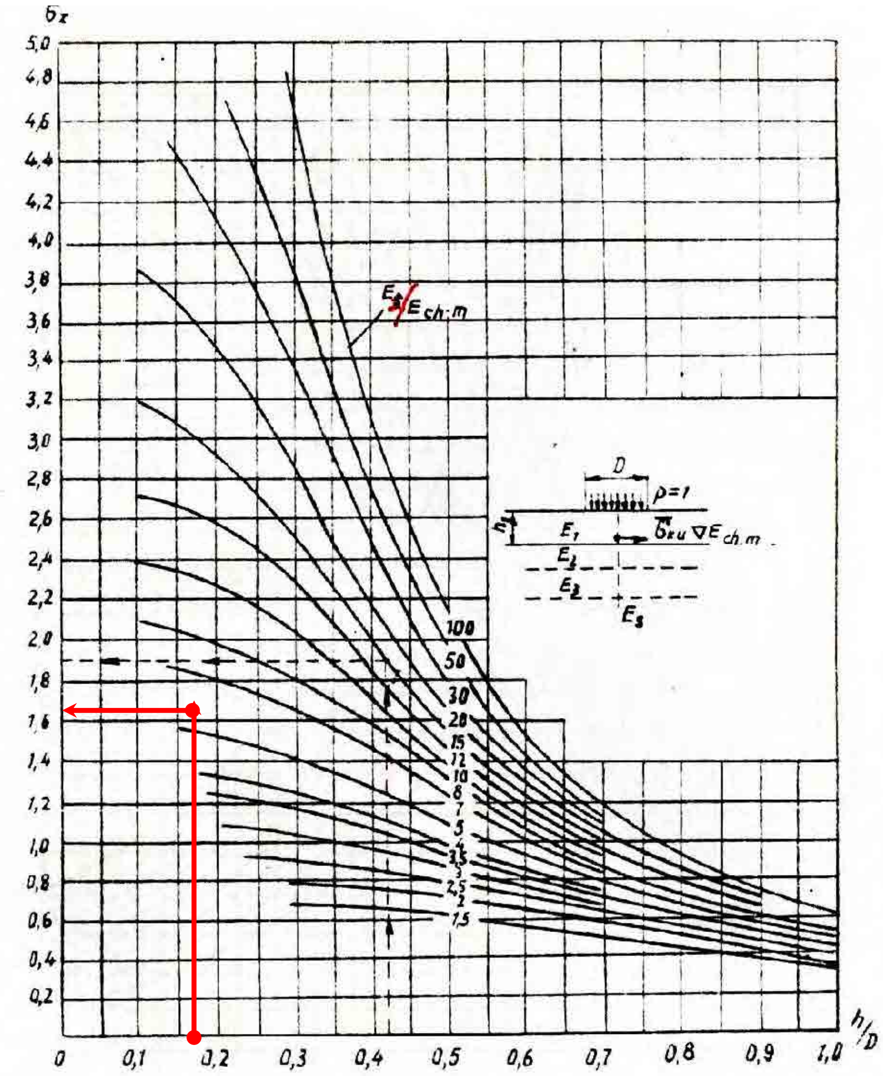


Figure 3-5: Monograph determining unit bending and tensile stress σ_{ku} in layers of surface layer

From above Figure,

$\overline{\sigma}_{ku}$ = 1.65

Terefore,

$\sigma_{ku} = \overline{\sigma}_{Ku} * p * K_b$ = 1.65 * 0.60 * 1.00

= 0.99

And,

$R_{tt}^{ku} = k_1 * k_2 * R_{ku}$ = 0.37 * 1.00 * 2.80

= 1.03

K_{cd}^{ku} = 0.94

$$\sigma_{ku} \leq \frac{R_{tt}^{ku}}{K_{cd}^{ku}} = \frac{1.03}{0.94} = 1.09$$

OK

B) Cheking of Binder Course

h_1= 6 + 7 = 13 cm

$$E_1 = \frac{1800 * 6 + 1600 * 7}{6 + 7}$$

= 1692 Mpa

Etb4= 340 Mpa (from Table D9-1)

β = 1.245 (from below)

$E_{TB}^{tt} = \beta \cdot E_{tb}$

= 1.245 * 340

= 423 Mpa

Table 3-6 Adjustment coefficient β

H/D Ratio	0.51	0.75	1.00	1.25	1.50	1.75	2.00
β Coefficient	1.033	1.069	1.107	1.136	1.178	1.198	1.210

$\beta = 1.114*(H/D)^{0.12}$ (in case of H/D>2.0) (3-6)

Where as;

D= 36 cm (Diameter of Wheel track)

H= 91 cm (Hight of the Layer)

Therefore

H/D= 2.53

From Table/formula 3-6,

$\beta = 1.114*(91/36)^{0.12}$

= 1.245

E_0= **50** Mpa , E_{TB}^{tt}= **423** Mpa

E_0/E_{TB}^{tt}= **0.118**

H/D= **2.53**

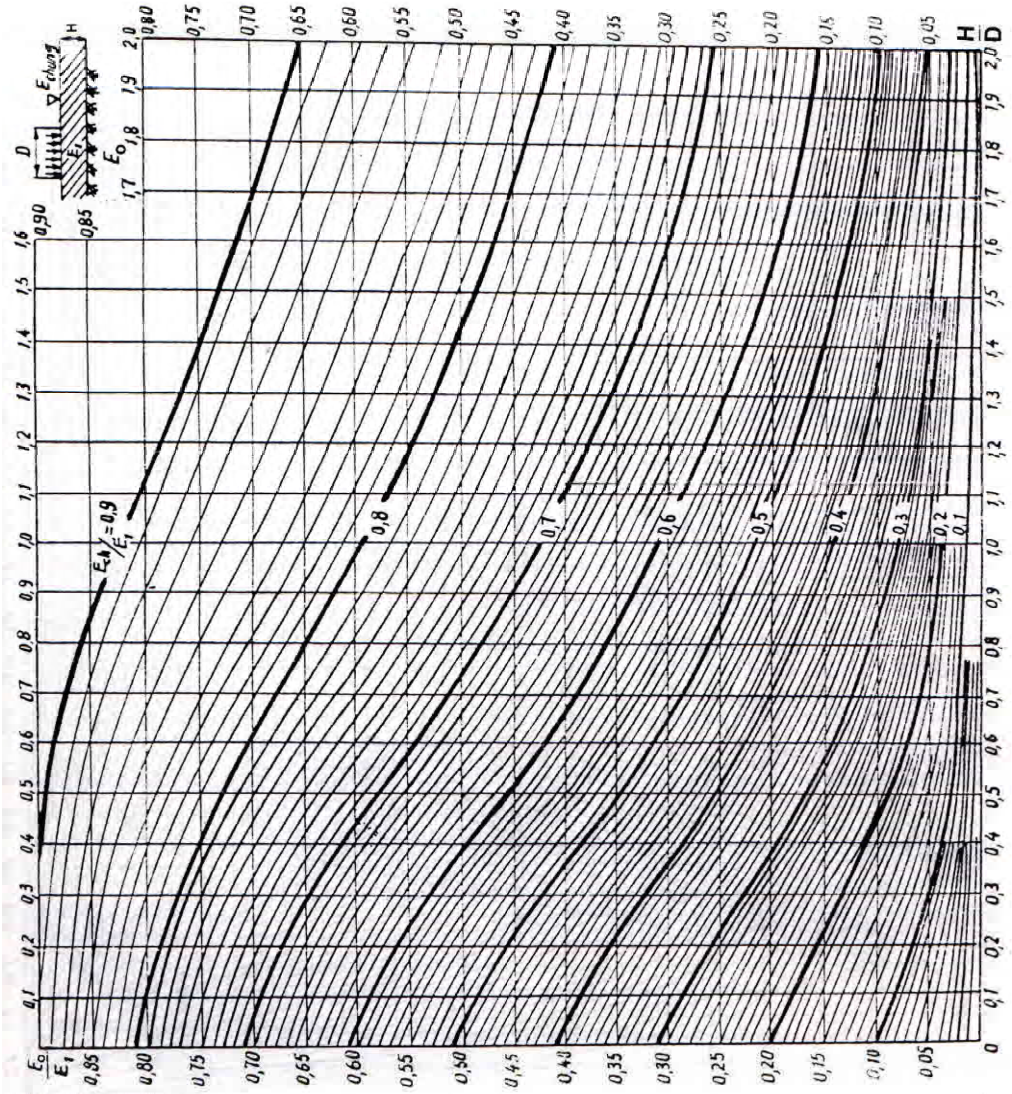


Figure 3-1. Monograph for determination of general elastic modulus of double-layer system E_{ch} (H/D<2)

$$\mathbf{E_{ch}} = \frac{\dfrac{1.05.E_0}{1+\dfrac{E_0}{E_1}}}{\sqrt{1+4.\left(\dfrac{H}{D}\right)^2.\left(\dfrac{E_o}{E_1}\right)^{-0.67}}+\dfrac{E_o}{E_1}} \qquad \text{(F-1)} \qquad \text{(H/D>2)}$$

From above Table/Formula, E_{ch}= **233** Mpa

h_1=	13	cm	⇨	H/D=	0.36
E_1=	1692	Mpa	⇨	E_1/E_{ch}=	7.28

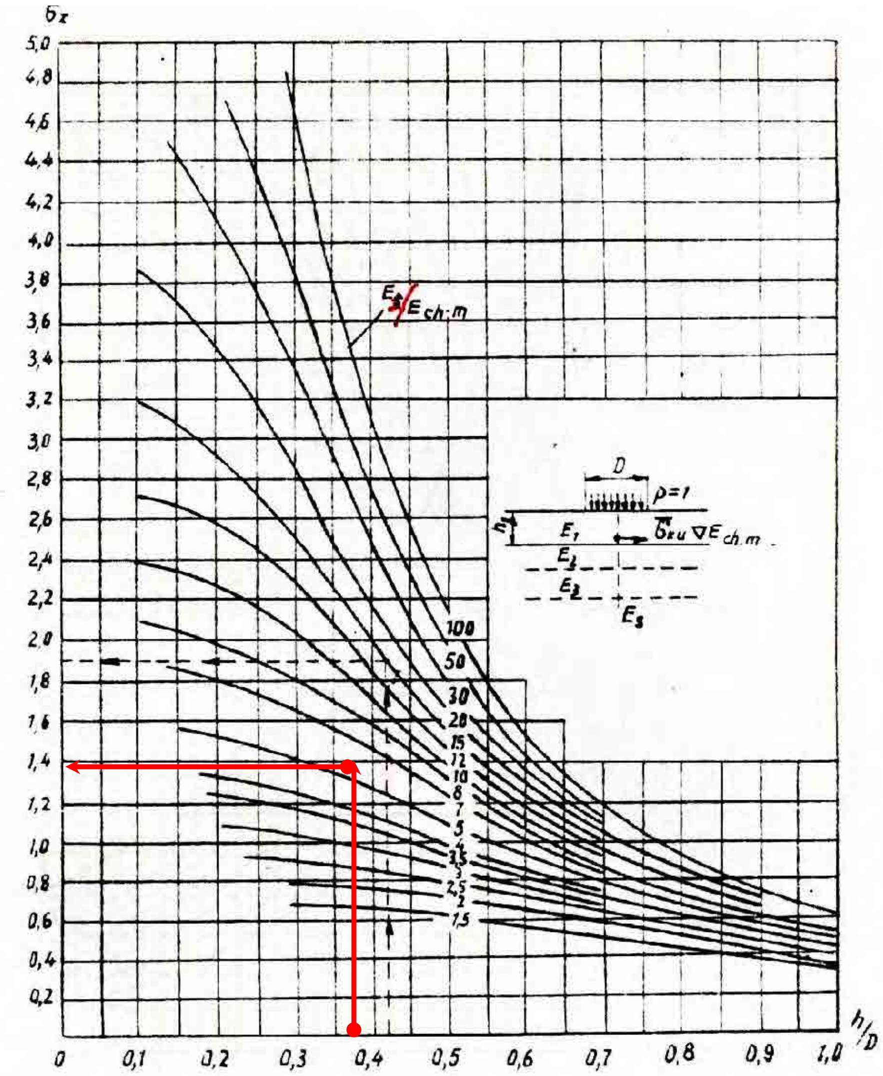


Figure 3-5: Monograph determining unit bending and tensile stress σ_{ku} in layers of surface layer

From above Figure,

$\overline{\sigma_{ku}}$ = <u>1.40</u>

Terefore,

$\sigma_{ku} = \overline{\sigma_{Ku}} * p * K_b$ = 1.40 * 0.60 * 1.00

= <u>0.84</u>

And,

$R_{tt}^{ku} = k_1 * k_2 * R_{ku}$ = 0.37 * 1.00 * 2.80

= 1.03

K_{cd}^{ku} = 0.94

$$\sigma_{ku} \leq \frac{R_{tt}^{ku}}{K_{cd}^{ku}} = \frac{1.03}{0.94} = \underline{1.09}$$

<u>**OK**</u>