# CHAPTER 12

# STUDY OF TIDE OBSERVATION SYSTEM

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## 12.1 TIDE OBSERVATION SYSTEM

### 12.1.1 CURRENT SITUATION OF TIDAL OBSERVATION IN MYANMAR

It is said that the tidal range is about 2 to 4 m in the coastal areas of Myanmar and exceeds 6 m in Yangon Port. Since slopes of the riverbed in the delta area are extremely gentle, tidal fluctuation reaches far upstream. Therefore, the influence of tide reaches a wide range on the coastal area and along the rivers in Myanmar.

Tidal observation has been carried out in Yangon Port near the junction of the Yangon River and Bago River called Monkey Point, as shown in Figure 12.1.2. However, the observation is only conducted in diurnal period.

There are several ports scattered along the coastal area in Myanmar, but tidal observation has not been conducted. Though some ports for inland water transport have established the water gauge stations, these are not being operated.

### 12.1.2 CHART DATUM AND TIDE TABLE OF YANGON PORT

In the current tide tables, not only the tide levels of Yangon Port but also that of the river mouth point called Elephant Point are predicted. Each of the chart datum levels, which are LWST in the dry season, are shown in Table 12.1.1. The chart datum levels were determined based on the results of the observations conducted from the late 1980s till the early 1990s. The mean water level was 3.5 m at Elephant Point and 3.2 m in Yangon Port. The storm tide recorded 6.644 m in Yangon Port (1899) and 7.35 m at Elephant Point (1930).

The data corresponding to average high water level and low water level at the spring tide, which are HWL and LWL, respectively, are not described.

The tide table currently used in Myanmar are not the only one that is used by MPA (hereinafter referred as MPA Tide Table); another one is predicted by the navy independently (hereinafter referred as Navy Tide Table). However, it is often the case that the values in these tide tables are different from the actual values in Yangon Port.

The methods of calculation of these tide tables are not known. As shown in Figure 12.1.1, tide levels in the MPA Tide Table tend to be lower than that in the Navy Tide Table during low or high tide.

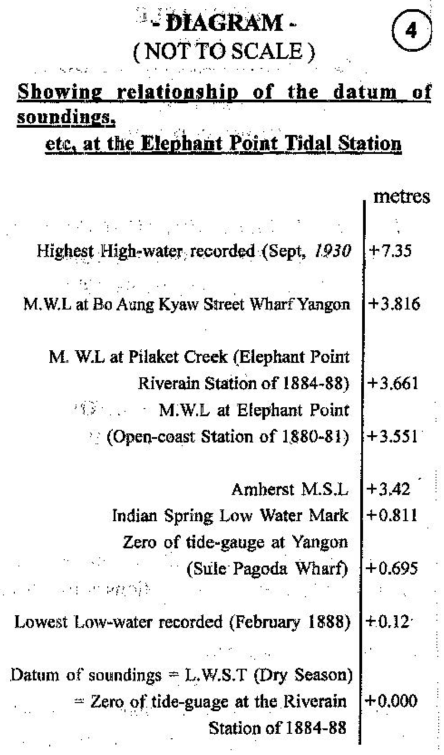
### 12.1.3 INTRODUCTION OF TIDE OBSERVATION EQUIPMENT IN YANGON PORT

The accurate records of high water levels are not retrievable when a disaster such as Cyclone Nargis occurs. This makes the restoration plan difficult.

Moreover, since the tide table currently used by MPA was predicted by India, the basic data for prediction is old and its analysis technique is unclear. Also it is known that the actual tide levels of Yangon Port may differ from the tide table by several dozen cm, and the tidal times sometimes delay for more than 30 min. This is attributed to the fact that the values in the tide tables have been predicted by using insufficient data. Therefore, it is considered desirable to carry out long-term observation and prepare the environment for accurate tidal prediction.

In view of these present conditions, two sets of tidal gauges with digital recording systems were supplied through JICA funding in 2009. The JICA Project Team installed one at Monkey Point, which was regarded as the upper river basin of the Yangon River, and the other at MITT of Thilawa which was regarded as the middle part of the river. The type of the tide gauge was selected such that the observation period is 1 to 2 years. Obtained data were analyzed, and the characteristics of the Yangon River were defined. Proposal for the tide observation system in Myanmar was made in the study.

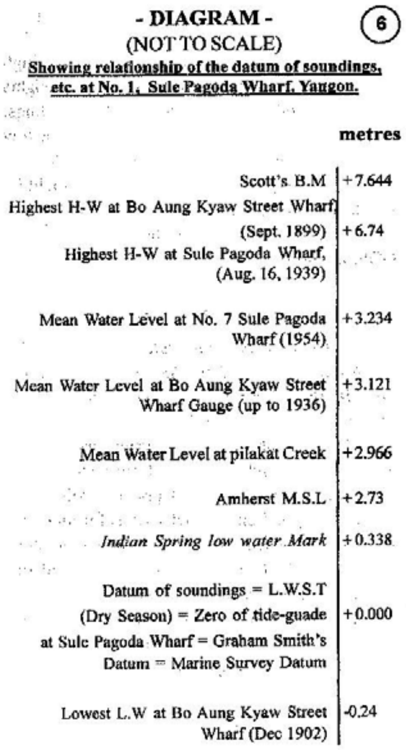
Table 12.1.1 Existing Chart Datum



**- DIAGRAM -** ④
(NOT TO SCALE)

**Showing relationship of the datum of soundings,**
**etc, at the Elephant Point Tidal Station**

| | metres |
|---|---|
| Highest High-water recorded (Sept, *1930* | +7.35 |
| M.W.L at Bo Aung Kyaw Street Wharf Yangon | +3.816 |
| M. W.L at Pilaket Creek (Elephant Point Riverain Station of 1884-88) | +3.661 |
| M.W.L at Elephant Point (Open-coast Station of 1880-81) | +3.551 |
| Amherst M.S.L | +3.42 |
| Indian Spring Low Water Mark | +0.811 |
| Zero of tide-gauge at Yangon (Sule Pagoda Wharf) | +0.695 |
| Lowest Low-water recorded (February 1888) | +0.12 |
| Datum of soundings = L.W.S.T (Dry Season) = Zero of tide-guage at the Riverain Station of 1884-88 | +0.000 |

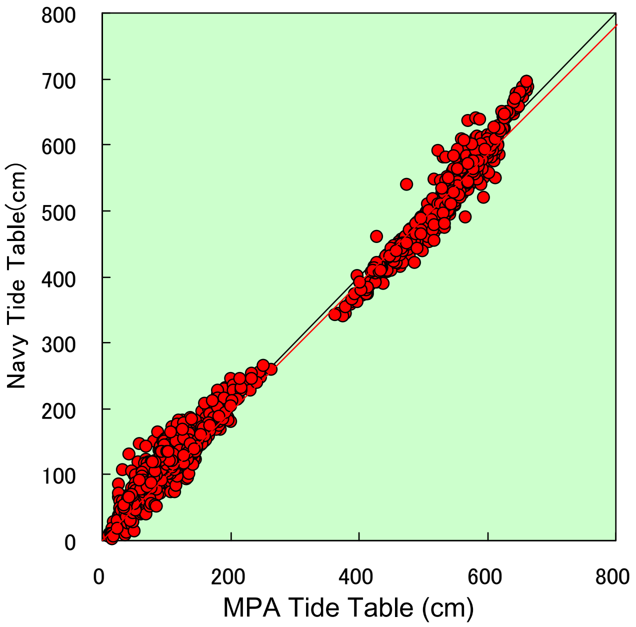


**- DIAGRAM -** ⑥
(NOT TO SCALE)

**Showing relationship of the datum of soundings,**
**etc. at No. 1, Sule Pagoda Wharf, Yangon.**

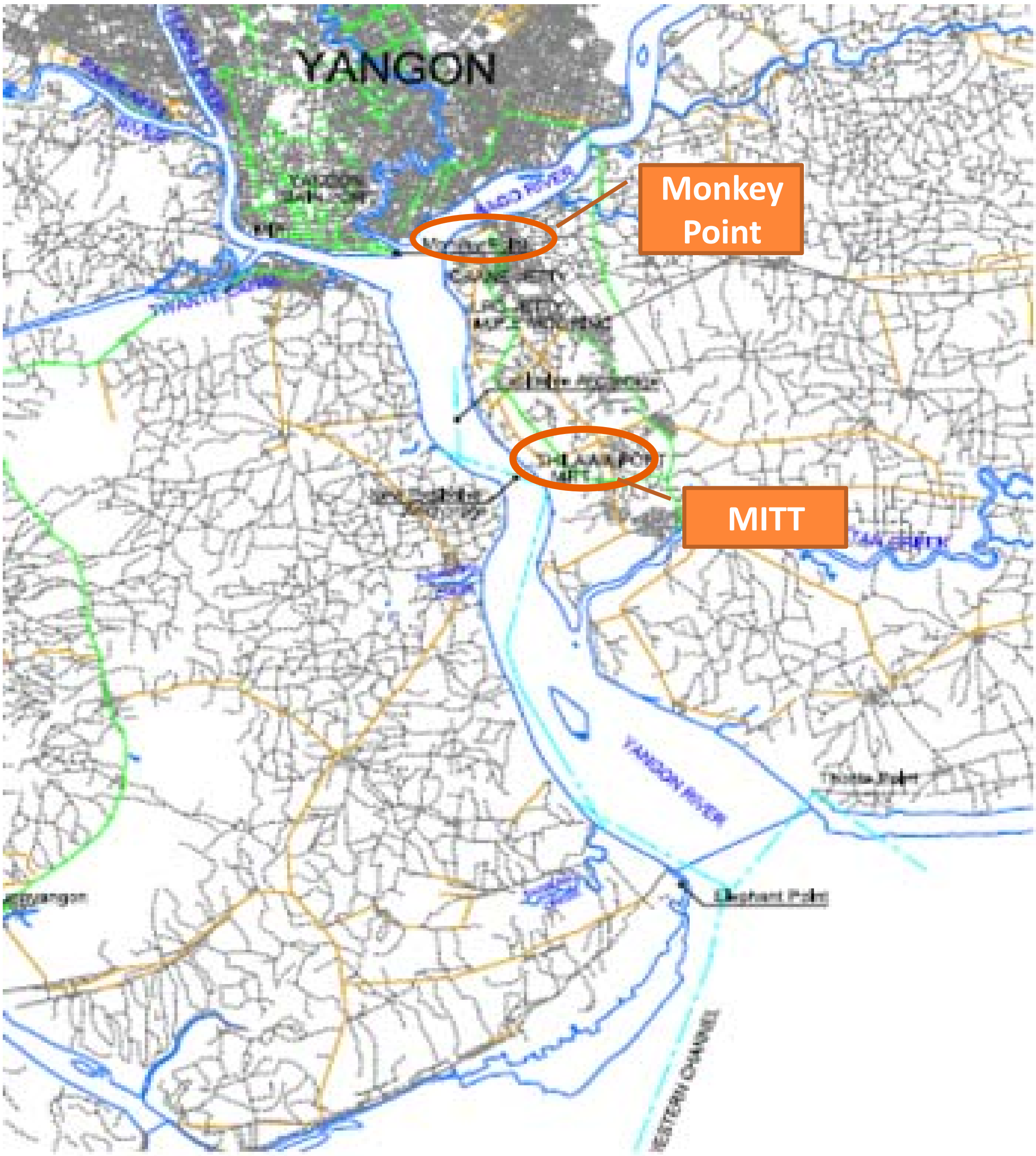
| | **metres** |
|---|---|
| Scott's B.M | +7.644 |
| Highest H-W at Bo Aung Kyaw Street Wharf (Sept. 1899) | +6.74 |
| Highest H-W at Sule Pagoda Wharf, (Aug. 16, 1939) | |
| Mean Water Level at No. 7 Sule Pagoda Wharf (1954) | +3.234 |
| Mean Water Level at Bo Aung Kyaw Street Wharf Gauge (up to 1936) | +3.121 |
| Mean Water Level at pilakat Creek | +2.966 |
| Amherst M.S.L | +2.73 |
| *Indian Spring low water Mark* | +0.338 |
| Datum of soundings = L.W.S.T (Dry Season) = Zero of tide-guade at Sule Pagoda Wharf = Graham Smith's Datum = Marine Survey Datum | +0.000 |
| Lowest L.W at Bo Aung Kyaw Street Wharf (Dec 1902) | -0.24 |

Source: Myanma Port Authority 2013



Source: MPA and JICA Project Team

Figure 12.1.1 Comparison of Tide Table Height



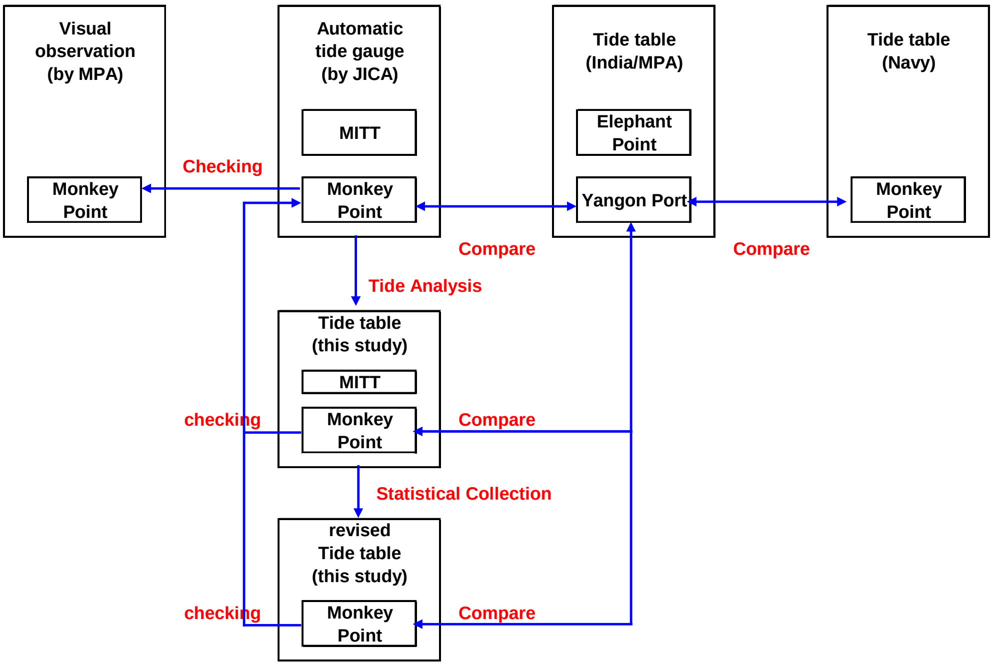
Source: JICA Project Team

Figure 12.1.2 Location Map of Tidal Gauges Installed by the JICA Project Team

## 12.2 TIDAL OBSERVATION DATA ANALYSIS

### 12.2.1 FLOW OF ANALYSIS

The flow of analysis using the observation data of tide levels obtained at Monkey Point and MITT is shown in Figure 12.2.1. First, the characteristics and accuracy of the MPA and Navy Tide tables were checked by comparing with the observation data. Second, the tide levels during the observation periods were predicted with the harmonic analysis of observation data, and then the accuracy of predicted tide levels were checked with the observation data. In the course of analysis, the errors considered as influence of the river were discovered. The errors were collected, and the accuracy of collected prediction of tide levels were checked with the observed data.



Source: JICA Project Team

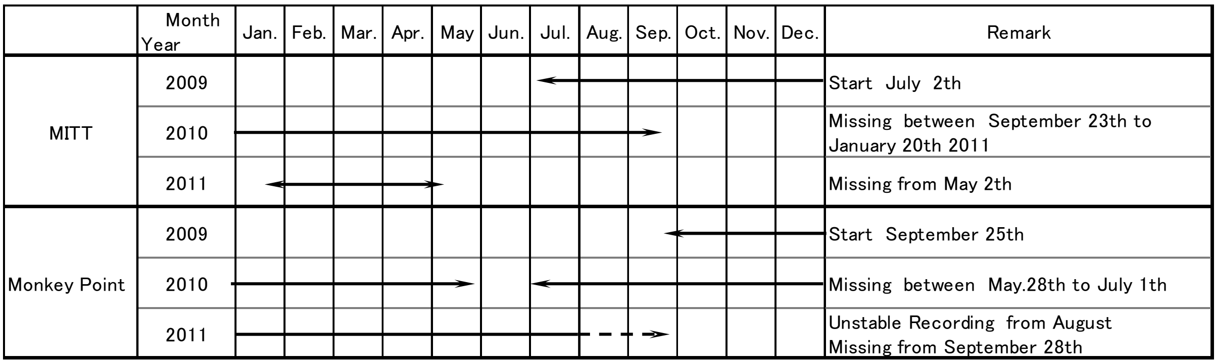
Figure 12.2.1 Flow of Analysis

## 12.2.2 SUMMARY OF TIDAL OBSERVATION

The data acquisition period is shown in Figure 12.2.2. The solid line represents the period applied for analysis.

Tidal observation at MITT was started in July 2009, and data was satisfactorily acquired till September of the following year. However due to faults of equipment and repair, there are missing observation data till January 2011. The tidal observation at MITT was terminated in May 2011.

On the other hand, tidal observation at Monkey Point was started in September 2009. Since the waveform of the data acquired from around August 2011 became unstable, the observation had missing data since October 2011. In addition, missing data of one month in June 2010 was due to a cable problem.

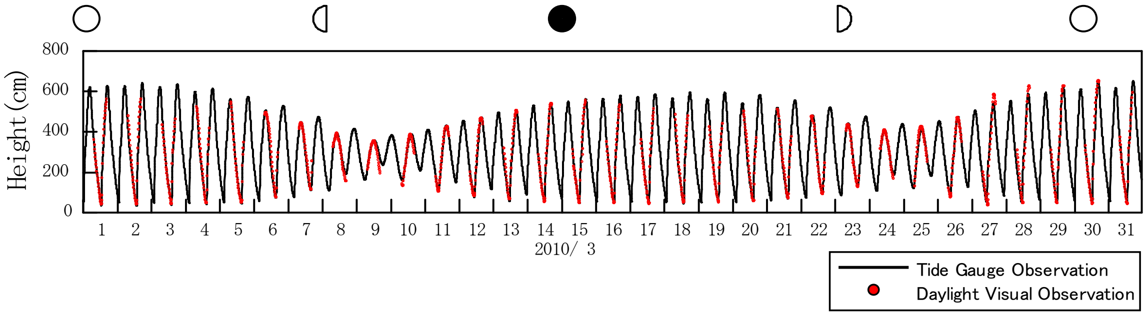


| | Month<br>Year | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MITT | 2009 | | | | | | | | | | | | | Start July 2th |
| | 2010 | | | | | | | | | | | | | Missing between September 23th to January 20th 2011 |
| | 2011 | | | | | | | | | | | | | Missing from May 2th |
| Monkey Point | 2009 | | | | | | | | | | | | | Start September 25th |
| | 2010 | | | | | | | | | | | | | Missing between May.28th to July 1th |
| | 2011 | | | | | | | | | | | | | Unstable Recording from August<br>Missing from September 28th |

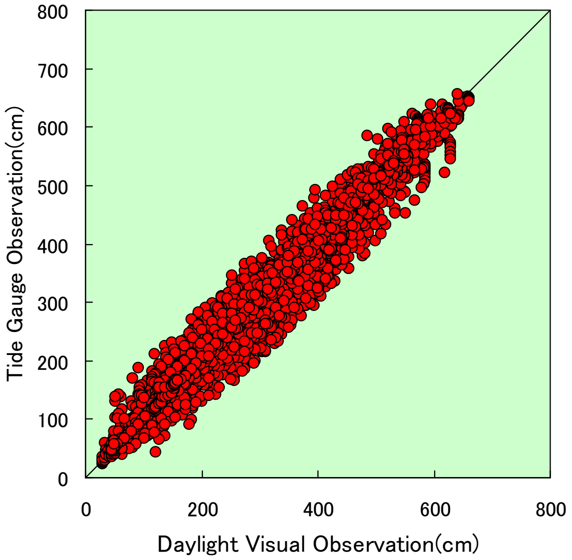
Source: JICA Project Team

Figure 12.2.2 Observation Period of Tidal Gauges Installed by the JICA Project Team

The sampling interval of data was 0.5 sec and the average values for the last 10 sec were recorded on the recorder every 5 min. Comparison between tide gauge observation and visual observation at Monkey Point is shown in Figure 12.2.3. Although around 50 cm differences of tide levels were identified, both water level and tidal times nearly coincided with each other.



Note: The ● in the figure means new moon, while the ○ means full moon.



Source: JICA Project Team

Figure 12.2.3 Comparison between Tide Gauge and Visual Observation at Monkey Point

Monkey Point

MITT

Source: JICA Project Team

Photo 12.2.1 Tide Observation Facilities at Monkey Point and MITT

### 12.2.3 CHARACTERISTICS OF TIDE LEVELS

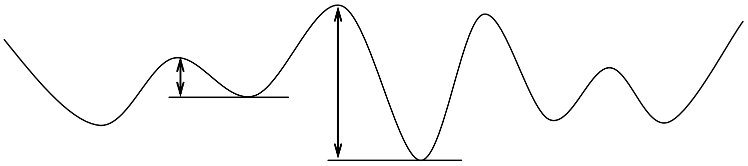
According to the observation data, normally, tide goes up and down twice a day and the tidal range at the spring tide exceeds 6 m under normal condition, while the tidal range is small in neap tide from February to April. The highest and lowest levels of observation data for nearly a year are shown in Table 12.2.1.

Table 12.2.1 Highest and Lowest Levels of Observation Data

| Observation Site and Period | Level | Height (cm) | Date Time |
|---|---|---|---|
| Monkey Point<br>Sep. 25, 2009 - Jul. 31, 2010 | Highest | 702 | Oct. 8, 2010 03:35 |
| | Lowest | 19 | Feb. 23, 2011 15:15 |
| MITT<br>Jul. 2, 2009 – May 5, 2010 | Highest | 711 | Apr. 18, 2011 15:45 |
| | Lowest | 10 | Jan. 3, 2010 13:30 |

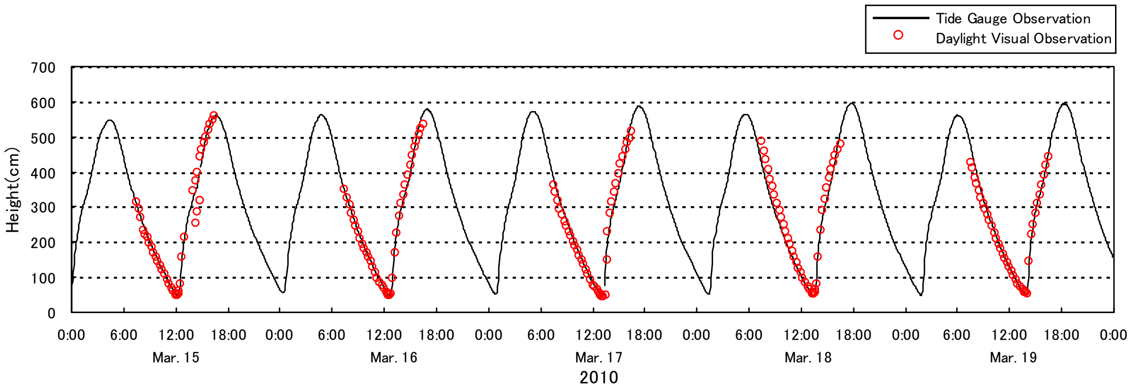
Source: JICA Project Team

In the area from medium to high latitudes, the continuing tide range of ebb and flow may differ remarkably, which is called diurnal inequality. Diurnal inequality in Yangon Port is small.



As seasonal characteristics, the mean water levels are high from July to October including rainy season, about 1 m higher than the one in January of the dry season. According to the observation data, spring tide appears 2 or 3 days after new moon and full moon. Moreover, this is one of the features where differences between spring tide and neap nap are little in November and December.

Although it is hard to grasp in the time-sequence diagram, the downward speed of ebbing tide becoming slow when the tide level reaches the middle, while conversely upward speed of rising tide is fast till the tide level reaches the middle. In addition, tide curves become sawtooth waveforms. This phenomenon was also seen in the recorded visual observation data at Monkey Point.



Source: JICA Project Team

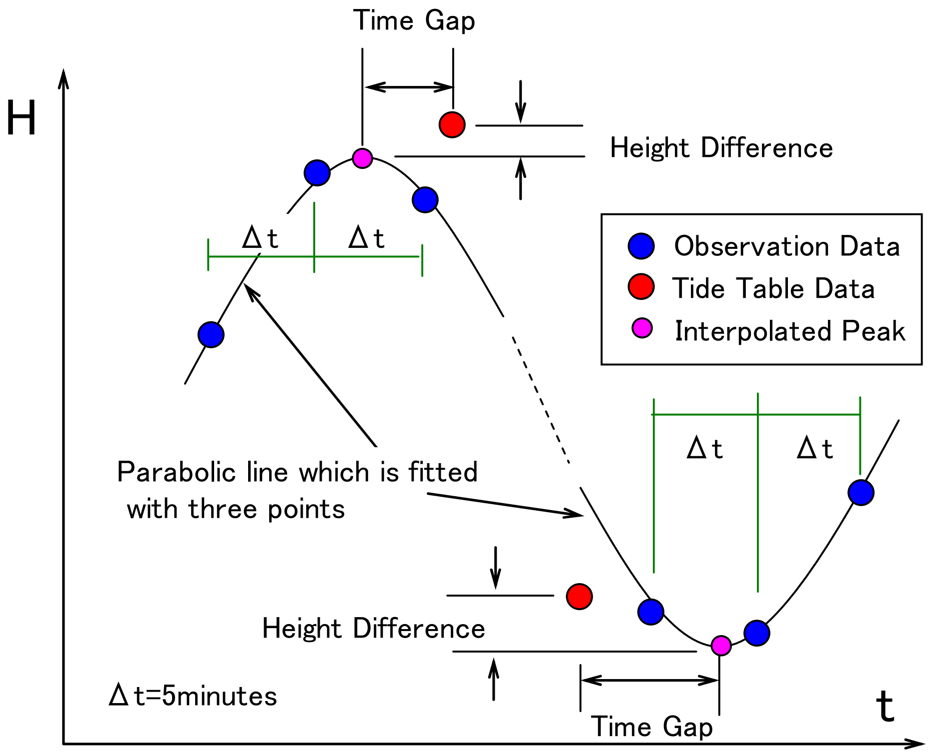
Figure 12.2.4 Wave Distortion (Example of Monkey Point)

### 12.2.4 COMPARISON WITH THE CURRENT TIDE TABLES

As discussed previously, there are two tide tables used in Myanmar, one has been purchased from India and the other has been published by the Navy. Here, the characteristics and the accuracy of these tide tables were determined by comparing each of these tide tables in Yangon Port with the observation data.

#### (1) Difference of Tide Level

Accuracy of the tide tables were determined by comparing the data of tide tables in Yangon Port with the observation data at Monkey Point near the prediction point. Since observation data was in 5-min intervals, the tide levels of high tide and low tide were calculated by utilizing a parabolic approach, as shown in Figure 12.2.5.



Source: JICA Project Team

Figure 12.2.5 Parabolic Approach by Tidal Observation

Figure 12.2.6 shows the correlation between tide levels in the tide tables and that of the observation data. The horizontal axis shows the observation value, while the vertical axis shows the tide levels in the tide tables. The red line shows the regression line that represents the relation between them. According to the correlation diagram with the MPA Tide Table, the plots were scattered around the diagonal line, which means that the values of the observation data nearly coincide with the values in the MPA Tide Table. However, the tide levels in the tide table tended to become low when the tide levels exceeded 600 cm. Moreover, the tide levels in the tide table tended to be low as a whole when the tide levels were LWL plotted 300 cm or less.

Tide levels in the Navy Tide Table varied more widely than that in the MPA Tide Table. Tide levels in the Navy Tide Table had some periods that the levels exceed actual observation data, as shown in Figure 12.2.7, though the tide levels in the Navy Tide Table tended to be lower than the actual data as a whole. For this reason, the plots in the high tide were split into two cases in Figure 12.2.6; that is when high water levels in the Navy Tide Table were higher than the observation data, and when they were lower.

It is considered that the tide levels at Monkey Point are subject to the influence of the rainy season and dry season. Therefore, the data in Figure 12.2.6 was divided into two cases, the dry season and rainy season as shown in Figure 12.2.10. According to the monthly precipitation in Yangon, as shown in Table 12.2.2, the rainy season is considered from May to October.

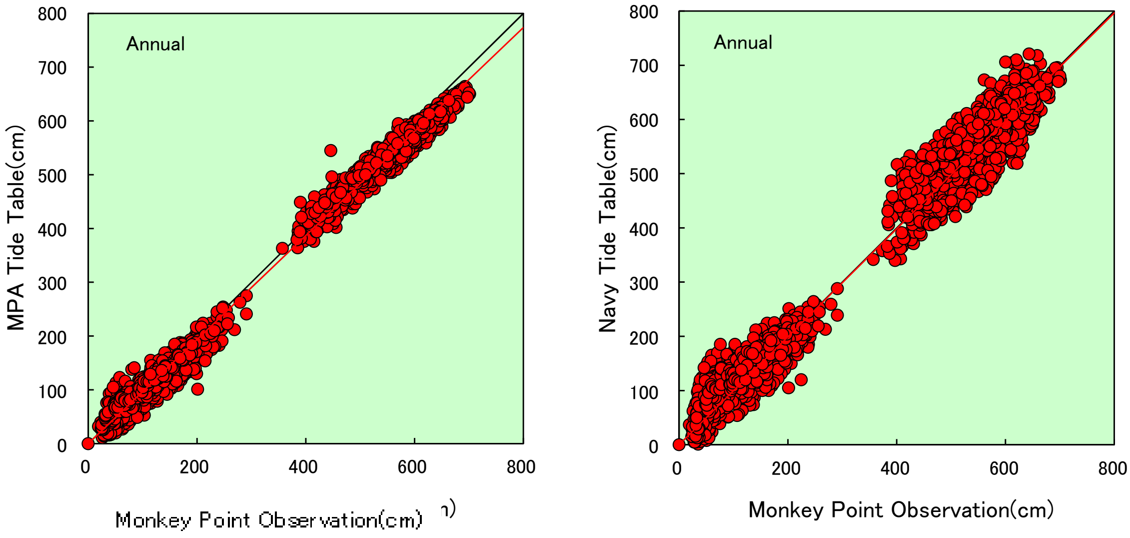
According to Figure 12.2.10, the gaps between the low water levels from observation data and that in the tide table were larger in the dry season than that in the rainy season. This is because the tide levels at the neap tide in the tide table have little correspondence with the observation data in the dry season as shown in Figure 12.2.11. On the other hand, a clear tendency related to high tide was not identified.

Table 12.2.2 Monthly Rainfall (mm)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | **TOTAL** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 0 | 0 | N/A | 156 | 341 | 411 | 780 | 634 | 366 | 147 | N/A | 0 | **2,835** |
| 2007 | 0 | 0 | 0 | N/A | 837 | 559 | 700 | 446 | 774 | 260 | 16 | 0 | **3,592** |
| 2008 | 5 | 7 | 25 | 169 | 656 | 431 | 541 | 474 | 448 | 301 | 6 | 0 | **3,063** |

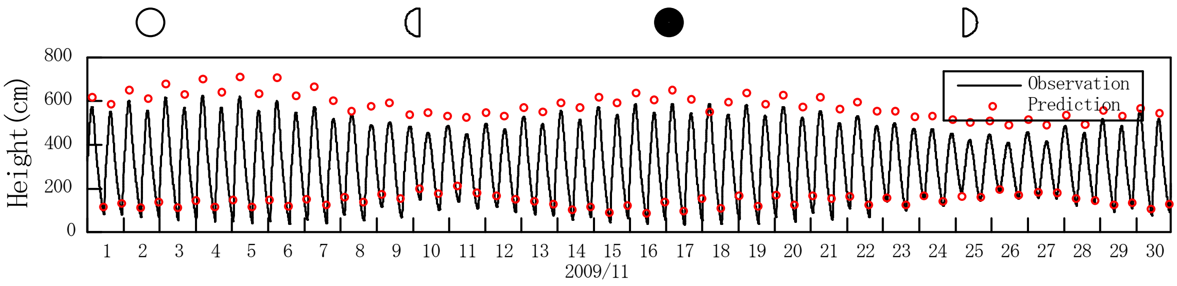
Note: "N/A" The amount of rainfall which cannot be measured.

Source: Department of Meteorology and Hydrology, Ministry of Transport



Source: JICA Project Team

Figure 12.2.6 Tide Level Comparison between Observation Data and Tide Table (Annual)

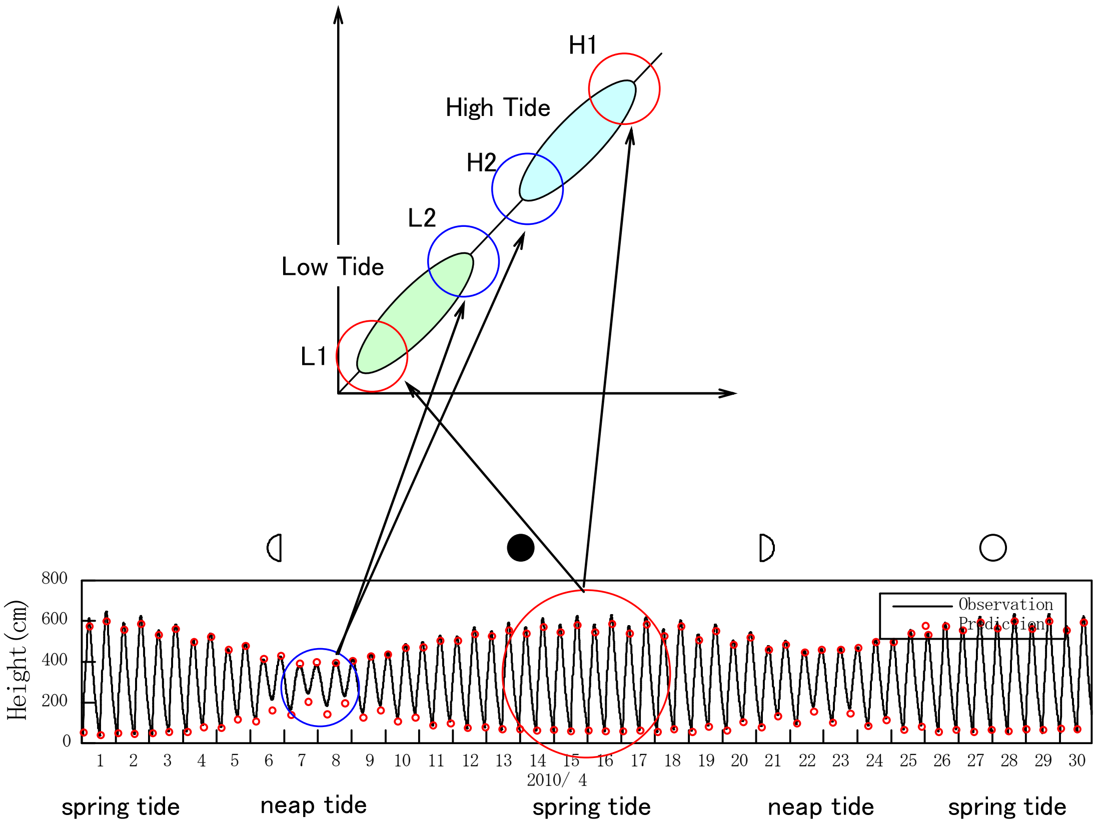


Note: The ● in the figure means new moon, while the ○ means full moon.

Source: JICA Project Team

Figure 12.2.7 Difference between Observation Data and Navy Tide Table

The relation between the plotted position in a correlation diagram and age of tide are explained again in Figure 12.2.8. In the correlation diagram, the lower left is the area of low tide, while the upper right is the area of high tide. The data of spring tide when the tidal range was large was plotted near L1, while the date of neap tide was plotted near L2. Similarly, the data of high tide at the spring tide was plotted in H1, while the data of high tide at the neap tide was plotted H2 since the tide level did not become high at that time.



Source: JICA Project Team

Figure 12.2.8 Relation between Plotted Position in Correlation Diagram and Age of Tide

The highest levels at high tide during spring tide were low from January to July. Moreover, high water levels at low tide during neap tide also tended to be low. However, since amplitude at neap tide was large in July, such plots were not identified. From August to October, the tide levels in the MPA Tide Table tended to be low at high tide during spring tide and high during neap tide. In November, tide levels at high tide comparatively matched with the observation data, but tide levels as a whole were calculated higher. In December, the tide levels at high tide during spring tide tended to be low.

Next, in regard to the Navy Tide Table, the high water levels tended to be lower from January to July regardless of tidal cycle. Low water levels at spring and neap tides in the Navy Tide Table coincided comparatively with the observation data, while low water levels at the middle of tidal cycle tended to be high. In January, tide levels at spring tide in the Navy Tide Table tended to be higher. Tide levels in August and September in the Navy Tide Table most closely matched with the observation data in a year, however the Navy Tide Table had high dispersions relative to the MPA Tide Table. In addition, low water levels at the spring tide tended to be low and accuracy of high water levels at neap tide was low in September. Both high water levels and low water levels in the Navy Tide Table were remarkably higher than that of observation data from October to December, as shown in Figure 12.2.7, so plots were scattered and separated from the diagonal line.

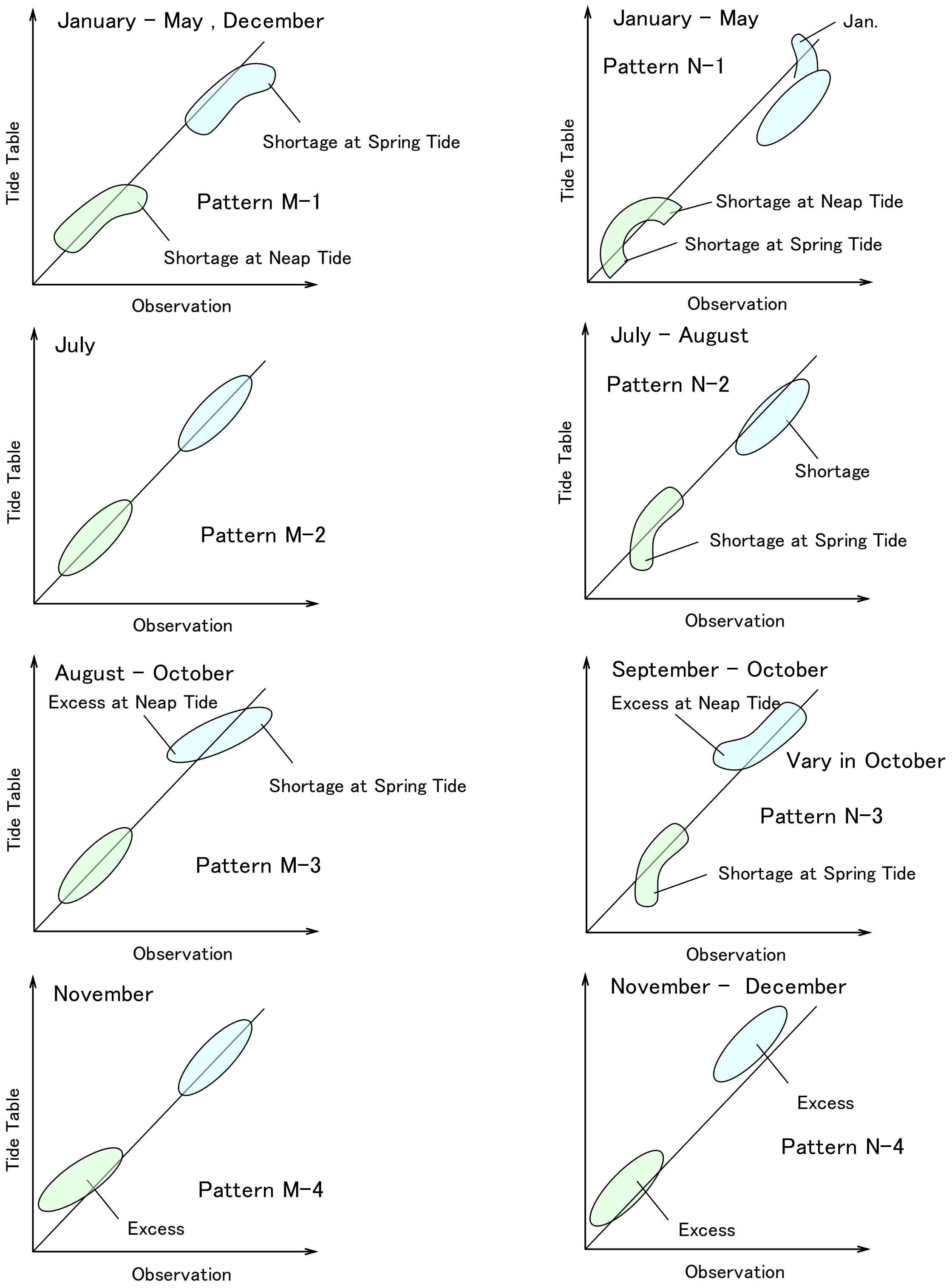
By organizing the above condition, there is a relation, which is illustrated in Figure 12.2.9

The left side figures show the patterns regarding the MPA Tide Table, while the right side figures show the patterns regarding the Navy Tide Table. The relevant month is written in the upper left side of each figure.

In regard to the MPA Tide Table, Pattern M-1 describes that both high water levels and low water levels at spring tide tend to be low, while Pattern M-2 describes that levels of two cases matched comparatively. Pattern M-3 has unique tendency that tide levels in the MPA Tide Table are lower at spring tide than that of the observation data and higher at neap tide. Pattern M-4 describes that most of low water levels in the MPA Tide Table were higher than that of the observation data.

In regard to the Navy Tide Table, Pattern N-1 describes that high water levels are constantly low and low water levels are not stable. Pattern N-2 describes that low water levels at spring tide are low, that is also common in Pattern N-3. However, Pattern N-3 also has tendency to show that tide levels of high tide at neap tide in the Tide Table tend to be high. On the other hand, Pattern N-4 that has similar tendency with Pattern M-3, has tendency that low water levels in the Navy Tide Table are constantly higher than that of the observation data and also shares similar feature with Patter M-4.

While amplitudes of tide become fairly small at neap tide, the tide levels in tide tables do not match the observation data. Since the amplitude did not become small at neap tide in Patterns M-2 and M-3, the gap with the observation data was still small. It was thought that the reason why the tide levels would not match at spring tide or neap tide is because amplitudes of harmonic constants used for prediction was small. Moreover, the reason why both low water levels and high water levels were constantly high was because it did not correspond to variation of mean water level at the point.

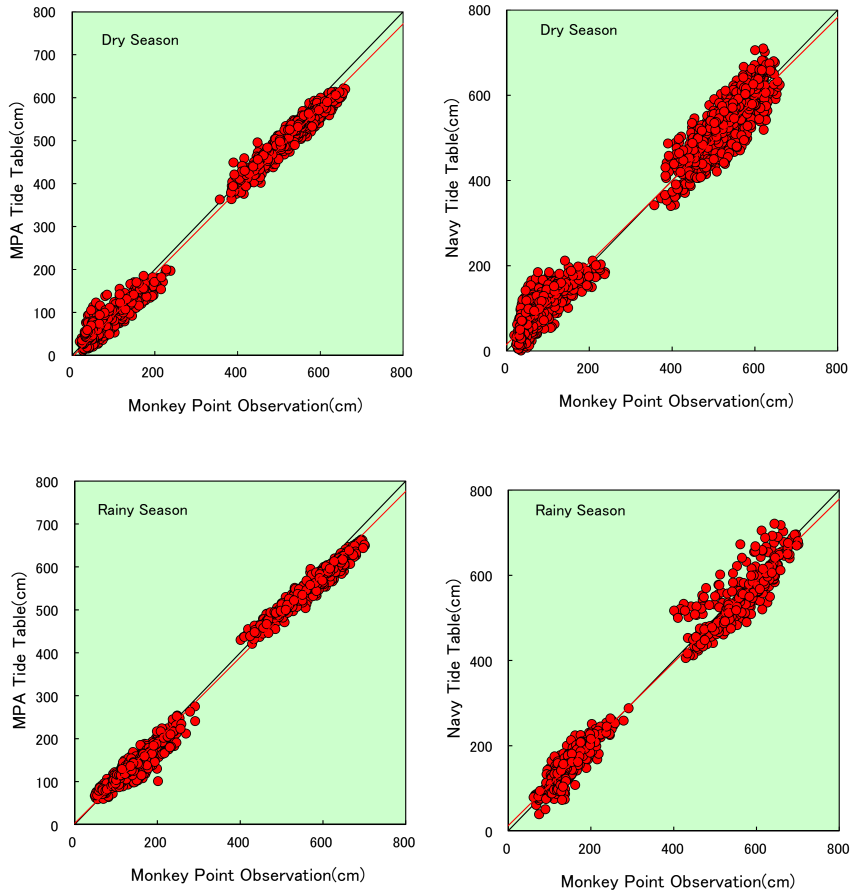


MPA Tide Table

Navy Tide Table

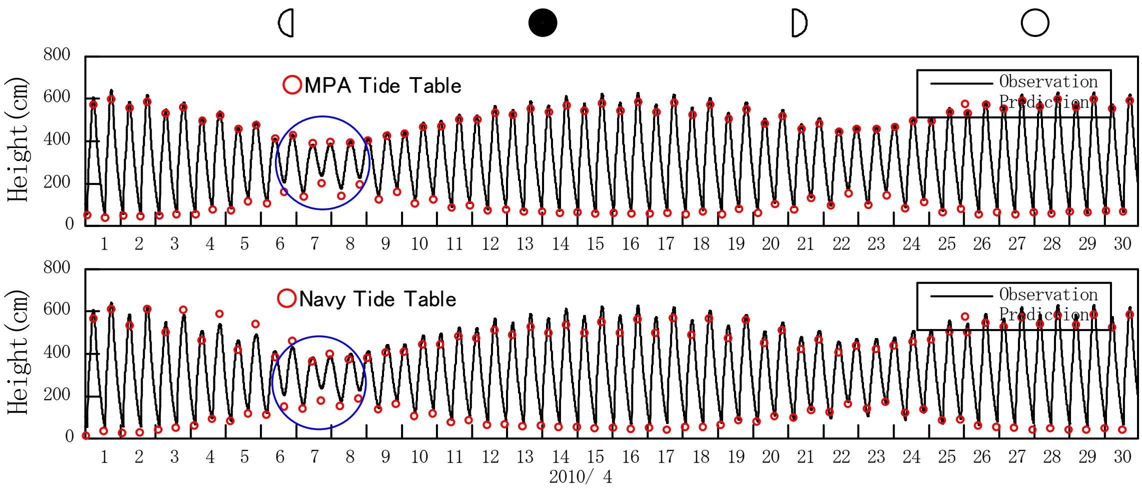
Source: MPA, Navy and JICA Project Team

Figure 12.2.9 Relation Patterns between Observation Data and Tide Table



Source: MPA and JICA Project Team

Figure 12.2.10 Tide Level Comparison between Observation Data and Tide Table (Seasonal)



Source: MPA and JICA Project Team

Figure 12.2.11 Differences with the Observation Data during Neap Tide

The average of differences and standard deviation of differences between the observation data and the data in tide tables are shown in Table 12.2.3. The value in yellow box includes statistical value of both low tide and high tide, while statistical value of high tide and that of low tide are shown in green box and orange box, respectively.

Even if each value of differences is large, the average of differences might be small since plus and minus value can cancel each other out. Therefore, evaluation was focused on the standard deviation of differences that indicate the degree of variation.

First, in regard to the MPA Tide Table, the standard deviation of dry season was larger than that of rainy season. On the other hand, the monthly standard deviation in the dry season was smaller than that in the rainy season as a whole. The reason why the standard deviation of the dry season was larger than that of the rainy season is that the standard deviation was large in November and December which was the beginning of the dry season, while the rainy season was considered from May to October. As with the comparison between low tide and high tide, the standard deviation of low tide is larger than that of high tide on the average, while smaller in rainy season. In the dry season when water levels are low, it might have a certain effects when tide levels become low.

In regard to the comparison between the Navy Tide Table and the MPA Tide Table, the standard deviation of differences of the Navy Tide Table was more than double of that of MPA Tide Table. Especially, the gaps were large in the dry season. On the other hand, the Navy Tide Table has similar seasonal trends with the MPA Tide Table, for example, the standard deviation of differences was larger in the dry season than in the rainy season and was large from October to December. The different point from the MPA Tide Table was that the values around August were small. A possible reason was that the harmonic constants used for the prediction were based on the data of the same season. Furthermore, since there were comparatively many differences from the observation data except around August, it was assumed that the data was obtained from short-term observation.

Table 12.2.3 Comparison between the Observation Data and Tide Tables

| Unit: cm | | Comparison with the MPA Tide Table | | | | Comparison with the Navy Tide Table | | | | DATA NUMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ave. | | S.D. | | Ave. | | S.D. | | | |
| Annual | | 11.5 | 16.1 | 19.0 | 17.7 | -3.3 | 2.9 | 35.8 | 41.7 | 2366 | 1174 |
| | | | 6.9 | | 19.0 | | -9.4 | | 27.6 | | 1192 |
| Dry Season | | 13.5 | 18.3 | 18.8 | 16.7 | -1.8 | 10.1 | 42.1 | 47.0 | 1326 | 655 |
| | | | 8.8 | | 19.5 | | -13.2 | | 33.0 | | 671 |
| Rany Season | | 7.2 | 11.3 | 15.9 | 17.3 | 2.3 | 9.8 | 32.9 | 39.7 | 618 | 310 |
| | | | 3.0 | | 13.2 | | -5.0 | | 22.1 | | 308 |
| Dry Season | January | 26.6 | 28.6 | 12.5 | 11.6 | 6.1 | 13.9 | 26.9 | 30.8 | 237 | 119 |
| | | | 24.6 | | 13.2 | | -1.7 | | 19.5 | | 118 |
| | February | 17.3 | 19.3 | 14.2 | 15.7 | 1.1 | 8.3 | 27.6 | 32.0 | 206 | 103 |
| | | | 15.4 | | 12.2 | | -6.0 | | 20.3 | | 103 |
| | March | 8.4 | 12.7 | 15.9 | 16.2 | -3.9 | 1.4 | 33.3 | 39.0 | 234 | 115 |
| | | | 4.2 | | 14.6 | | -9.1 | | 25.9 | | 119 |
| | April | 8.3 | 16.0 | 17.2 | 15.6 | 1.0 | 8.4 | 35.0 | 42.3 | 222 | 109 |
| | | | 0.8 | | 15.3 | | -5.8 | | 24.9 | | 113 |
| Rainy Season | May | 4.3 | 12.8 | 16.0 | 12.5 | -1.6 | 9.9 | 37.4 | 44.9 | 220 | 109 |
| | | | -4.0 | | 14.7 | | -13.3 | | 22.6 | | 111 |
| | June | 5.8 | 10.7 | 19.1 | 22.9 | -25.8 | -28.1 | 20.8 | 19.8 | 114 | 57 |
| | | | 0.8 | | 12.8 | | -23.5 | | 21.6 | | 57 |
| | July | 8.1 | 12.8 | 13.3 | 13.7 | -4.8 | 1.8 | 30.0 | 36.7 | 225 | 113 |
| | | | 3.5 | | 11.1 | | -11.3 | | 19.4 | | 112 |
| | August | 6.7 | 9.5 | 14.5 | 16.5 | 8.9 | 18.6 | 20.3 | 16.5 | 117 | 58 |
| | | | 3.9 | | 11.6 | | -0.4 | | 19.3 | | 59 |
| | September | 4.2 | 6.2 | 14.8 | 16.5 | 0.0 | 1.6 | 23.1 | 28.3 | 130 | 66 |
| | | | 2.2 | | 12.8 | | -1.5 | | 16.9 | | 64 |
| | October | 19.1 | 21.8 | 25.0 | 24.0 | -1.8 | -6.9 | 45.0 | 51.2 | 233 | 115 |
| | | | 16.5 | | 25.8 | | 3.1 | | 37.7 | | 118 |
| Dry Season | November | 2.3 | 8.9 | 22.8 | 15.6 | -20.5 | -13.1 | 44.0 | 47.8 | 225 | 111 |
| | | | -4.1 | | 26.6 | | -27.9 | | 38.7 | | 114 |
| | December | 18.3 | 24.3 | 17.3 | 17.1 | -2.2 | 12.6 | 45.4 | 54.8 | 202 | 98 |
| | | | 12.6 | | 15.7 | | -15.9 | | 28.4 | | 104 |

Difference means subtraction of the Tide Table height from the observation value.
Ave.:Average of Differences
S.D.:Standard Deviation of Differences

| | |
|---|---|
| High and Low Tide | High Tide |
| | Low Tide |

Source: MPA, Navy and JICA Project Team

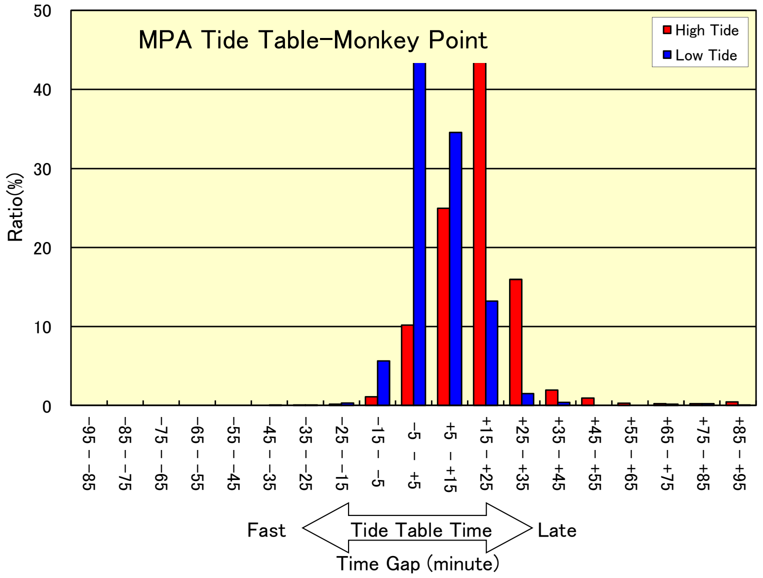
### (2) Gaps of Tidal Times

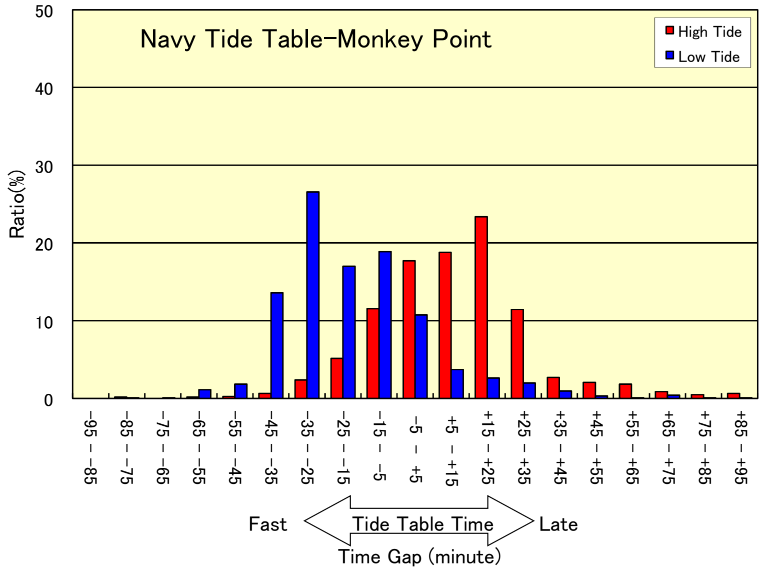
Figure 12.2.12 shows the aggregation of gaps of tidal times between the observation data and tide tables. The right half of the horizontal axis showing the gaps of tidal times indicates that the times for tides in the tide table come late.

Tidal times in the MPA Tide Table tend to be delayed. Actual high tides arrived about 10 to 20 min earlier than the tidal times in the MPA Tide Table, even the gap between them frequently reached 30 min.

The gaps at low tide were smaller than that at high water but actual low tide frequently comes 20 min earlier.

On the other hand, times for high tides in the Navy Tide Table deviate by ±5 min from the actual times and the rate of delay and early arriving was almost the same. In fact, no certain tendency was found. Times for low tides in the Navy Tide Table became 30-40 min earlier than those of actual tide.





Source: MPA and JICA Project Team

Figure 12.2.12 Tidal Time Gap between the MPA Tide Table and Observation Data at MP

### (3) Chart Datum

According to the definition of datum level, the tide level components were identified by using observed tide level data for one year.

There are differences in the type and calculation method of the datum level by country. Here, the Nearly Highest High Water (hereinafter referred to as “NHHW”), Nearly Lowest Low Water (hereinafter referred to as “NLLW”), Mean Monthly Highest Water Level (hereinafter referred to as “HWL”), Mean Monthly Lowest Water Level (hereinafter referred to as “LWL”), and Mean Sea Level (equivalent to Mean Water Level, and hereinafter referred to as “MSL”), all of which are used in Japan, are to be targeted.

NHHW is defined as the value which is calculated by adding mean water level to major four tidal components, while NLLW is defined as the value which is calculated by subtracting major four tidal components from mean water level.

$$NHHW = MSL + HM2 + HS2 + HK1 + HO1$$

$$NLLW = MSL - (HM2 + HS2 + HK1 + HO1)$$

Here, HM2, HS2, HK1, and HO1 are amplitudes of major four tidal components (amplitude of the harmonic constants). NHHW corresponds to the value called the Indian Spring Low Water in England. By substituting amplitudes of major four tidal components shown in Table 12.3.1 and MSL (A0 in Table 12.3.1) for the above equation, the following were calculated:

Monkey Point: NHHW = 338.4＋181.9＋67.9＋20.8＋9.8 = 618.8 (cm)
NLLW = 338.4－(181.9＋67.9＋20.8＋9.8) = 58.0 (cm)
MITT: NHHW = 328.5＋188.7＋74.0＋22.4＋10.3 = 623.9 (cm) ※no change at MITT
NLLW = 328.5－(188.7＋74.0＋22.4＋10.3) = 33.1 (cm)

HWL and LWL are the yearly average of highest tide level and lowest tide level, respectively, that appear in five days at the maximum after new moon or full moon, respectively. Table 12.2.4 shows the calculated values according to this definition.

Table 12.2.4 Calculated Results of HWL and LWL

Monkey Point

| Month | yyyymmdd | Highest (cm) | yyyymmdd | Lowest (cm) |
|---|---|---|---|---|
| Sep. | 20090930 | 518.1 | 20090930 | 161.8 |
| Oct. | 20091005 | 666.4 | 20091020 | 92.0 |
| Nov. | 20091104 | 624.0 | 20091117 | 34.0 |
| Dec. | 20091204 | 621.4 | 20091207 | 44.0 |
| Jan. | 20100131 | 622.3 | 20100103 | 22.8 |
| Feb. | 20100201 | 628.0 | 20100201 | 26.0 |
| Mar. | 20100331 | 652.1 | 20100303 | 34.8 |
| Apr. | 20100401 | 644.7 | 20100401 | 50.1 |
| May | 20100525 | 626.3 | 20100517 | 61.4 |
| June | | | | |
| July | 20100713 | 667.3 | 20100714 | 101.0 |
| Aug. | 20100812 | 693.1 | 20100811 | 123.6 |
| Sep. | 20100910 | 695.3 | 20100910 | 117.9 |
| Oct. | 20101008 | 701.4 | 20101009 | 128.3 |
| Nov. | 20101107 | 660.0 | 20101125 | 54.4 |
| Dec. | 20101207 | 630.0 | 20101226 | 46.7 |
| Jan. | 20110122 | 630.9 | 20110121 | 32.9 |
| Feb. | 20110220 | 648.2 | 20110223 | 18.8 |
| Mar. | 20110320 | 636.1 | 20110321 | 23.7 |
| Apr. | 20110418 | 654.4 | 20110419 | 30.7 |
| May | 20110517 | 634.4 | 20110505 | 48.8 |
| June | 20110617 | 652.0 | 20110603 | 60.6 |
| July | 20110731 | 663.0 | 20110705 | 94.4 |
| | H.W.L.(mean) | 644.1 | L.W.L.(mean) | 64.0 |

MITT

| Month | yyyymmdd | Highest (cm) | yyyymmdd | Lowest (cm) |
|---|---|---|---|---|
| Sep. | 20090723 | 667.4 | 20090724 | 63.3 |
| Oct. | 20090822 | 673.4 | 20090822 | 50.0 |
| Sep. | 20090920 | 676.2 | 20090920 | 58.0 |
| Oct. | 20091005 | 665.1 | 20091020 | 59.7 |
| Nov. | 20091104 | 635.6 | 20091105 | 33.5 |
| Dec. | 20091204 | 632.0 | 20091231 | 42.0 |
| Jan. | 20100102 | 625.3 | 20100103 | 10.6 |
| Feb. | 20100201 | 629.3 | 20100202 | 12.6 |
| Mar. | 20100331 | 659.2 | 20100302 | 17.0 |
| Apr. | 20100401 | 648 | 20100401 | 36.9 |
| May | 20100528 | 630.0 | 20100517 | 46.6 |
| June | 20100613 | 636.0 | 20100615 | 51.8 |
| July | 20100713 | 660.3 | 20100714 | 60.0 |
| Aug. | 20100812 | 700.1 | 20100813 | 90.0 |
| Sep. | 20100910 | 710.2 | 20100910 | 82.0 |
| Oct. | | | | |
| Nov. | | | | |
| Dec. | | | | |
| Jan. | 20110122 | 646.2 | 20110121 | 37.7 |
| Feb. | 20110220 | 664.6 | 20110221 | 21.7 |
| Mar. | 20110321 | 692.7 | 20110321 | 44.9 |
| Apr. | 20110418 | 711.2 | 20110421 | 59.8 |
| May | | | | |
| | H.W.L.(mean) | 661.2 | L.W.L.(mean) | 46.2 |

Source: JICA Project Team

Table 12.2.5 shows the tide level components of Monkey Point described in the current MPA Tide Table and that of the observation results.

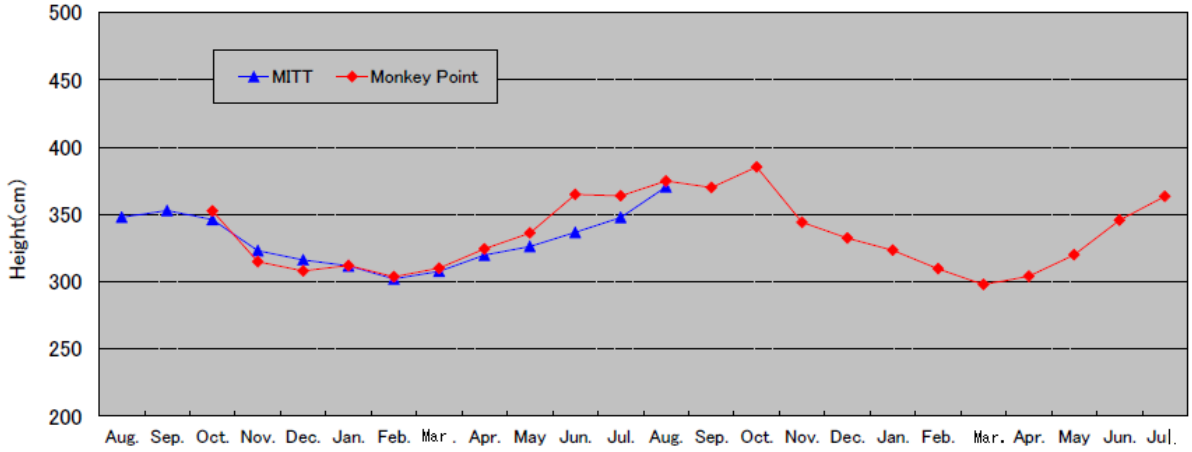
Table 12.2.5 Comparison of Datum Level

| Datum | MPA Tide Table | Monkey Point Observation |
|---|---|---|
| Highest H-W at Sule Pagoda Wharf (1899) | +6.74 | |
| Highest H-W at Bo Aung Kyaw Street Wharf (1939) | +6.664 | |
| HWL | | +6.441 |
| NHHW | | +6.188 |
| MSL(Mean Water Level) | | +3.384 |
| Mean Water Level at No.7 Sule Pagoda Wharf (1954) | +3.234 | |
| Mean Water Level at Bo Aung Kyaw Street Wharf (1936) | +3.121 | |
| Mean Water Level at Pilakat Creek | +2.966 | |
| Amherst MSL | +2.73 | |
| LWL | | +0.640 |
| NLLW ( Indian Spring Low Water Mark) | +0.338 | +0.58 |
| Datum of soundings = LWST (Dry season) | +0.000 | |
| Lowest L.W at Bo Aung Kyaw Street Wharf (1902) | -0.24 | |

Source: MPA and JICA Project Team

Here, there are only mean water level (MSL) and NLLW (Indian Spring Low Water Mark) which can be compared directly. The NLLW of observation data is 0.24 m higher than that of the MPA Tide Table. On the other hand, the MSL of the observation data is higher than all of the four components shown in the MPA Tide Table.

Figure 12.2.13 shows the monthly average of MSL calculated from the observation data at Monkey Point and MITT. The average of MSL was high from August to October in the rainy season and the gap with the average in February in the dry season, which was the lowest value, was 0.7-0.9 m.



Source: JICA Project Team

Figure 12.2.13 Variation of Mean Water Level

## 12.3 PREDICTION OF TIDE LEVEL

### 12.3.1 HARMONIC CONSTANT

The harmonic constants of 60 component tides were calculated from the observation data. Tidal forecasting from 2009 to 2011 was calculated based on the harmonic constants and calculation accuracy was checked. Since the data used for harmonic analysis should be consecutive, the data from August 2009 to July 2010 was used for MITT. As for Monkey Point, the data from October 2009 to July 2011 was used. One month of missing period, which was June 2009, was interpolated by the predicted values from the harmonic constants of 40 component tides that were calculated from stable short-period data. The list of harmonic constants is shown in Table 12.3.1. The contents of main component tides are as follows:

| | |
|---|---|
| M2 | Principal lunar semidiurnal constituent (speed: 28.984 degrees per mean solar hour) |
| S2 | Principal solar semidiurnal constituent (speed: 30.000 degrees per mean solar hour) |
| N2 | Larger Lunar elliptic semidiurnal constituent (speed: 28.440 degrees per mean solar hour) |
| K1 | Luni-solar declinational diurnal constituent (speed: 15.041 degrees per mean solar hour) |
| O1 | Lunar declinational diurnal constituent (speed: 13.943 degrees per mean solar hour) |
| M4 | First overtide of M2 constituent (speed: 2 x M2 speed) |
| M6 | Second overtide of M2 constituent (speed: 3 x M2 speed) |
| S4 | First overtide of S2 constituent (speed: 2 x S2 speed) |
| MS4 | A compound tide of M2 and S2 (speed: M2 + S2 speed) |

S2, M2, K1, and O1 are called major four tidal components. Although these major four tidal components are dominant tidal components in most marine waters, it is characterized that N2 component tide next to S2 component tide dominates at both MITT and Monkey Point.

Table 12.3.1 Harmonic Constants

| Tide | Monkey Point(no rainy) | | MITT | |
|---|---|---|---|---|
| Component | H(cm) | κ(° ) | H(cm) | κ(° ) |
| Sa | 36.6 | 151.6 | 24.5 | 146.8 |
| Ssa | 4.3 | 294.8 | 2.1 | 353.3 |
| Mm | 4.4 | 35.3 | 1.8 | 29.9 |
| Msf | 14.8 | 45.9 | 9.5 | 38.8 |
| Mf | 4.5 | 41.4 | 3.6 | 50.3 |
| 2Q1 | 0.4 | 71.4 | 0.4 | 350.3 |
| σ1 | 1.5 | 86.3 | 1.7 | 76.7 |
| Q1 | 0.6 | 16.6 | 0.6 | 20.6 |
| ρ1 | 0.6 | 314.7 | 0.6 | 346.9 |
| O1 | 9.8 | 20.2 | 10.3 | 12.6 |
| MP1 | 4.7 | 97.6 | 5.1 | 92.1 |
| M1 | 0.6 | 252.9 | 0.1 | 244.8 |
| χ1 | 0.6 | 286.0 | 0.3 | 216.2 |
| π1 | 0.9 | 76.3 | 1.2 | 81.0 |
| P1 | 5.0 | 51.9 | 5.6 | 48.9 |
| S1 | 3.4 | 123.3 | 3.5 | 121.9 |
| K1 | 20.8 | 31.1 | 22.4 | 25.3 |
| ψ1 | 1.0 | 172.4 | 1.0 | 166.3 |
| φ1 | 0.8 | 120.7 | 0.9 | 101.7 |
| θ1 | 0.7 | 0.9 | 0.5 | 300.9 |
| J1 | 0.8 | 82.2 | 0.8 | 69.5 |
| SO1 | 3.9 | 196.2 | 3.8 | 184.4 |
| OO1 | 0.7 | 97.1 | 0.7 | 53.0 |
| OQ2 | 2.0 | 90.3 | 1.6 | 76.3 |
| MNS2 | 6.3 | 271.2 | 6.4 | 262.9 |
| 2N2 | 0.4 | 96.1 | 3.9 | 151.4 |
| μ2 | 15.1 | 278.6 | 13.4 | 273.2 |
| N2 | 34.7 | 110.5 | 34.5 | 99.7 |
| ν2 | 9.9 | 100.7 | 9.1 | 100.1 |
| OP2 | 3.4 | 110.2 | 2.4 | 140.8 |
| M2 | 181.9 | 124.9 | 188.7 | 115.6 |
| MKS2 | 5.7 | 275.6 | 5.2 | 262.8 |
| λ2 | 7.5 | 159.4 | 7.6 | 145.7 |
| L2 | 15.9 | 142.7 | 12.3 | 125.5 |
| T2 | 6.4 | 167.7 | 5.2 | 160.8 |
| S2 | 67.9 | 163.3 | 74.0 | 153.9 |
| R2 | 3.5 | 128.8 | 2.6 | 135.5 |
| K2 | 18.6 | 160.2 | 20.5 | 152.5 |
| MSN2 | 3.5 | 25.8 | 3.9 | 5.0 |
| KJ2 | 0.4 | 214.5 | 0.4 | 293.1 |
| 2SM2 | 5.9 | 39.6 | 5.7 | 26.1 |
| MO3 | 3.9 | 41.2 | 3.5 | 22.3 |
| M3 | 1.9 | 351.3 | 1.5 | 345.9 |
| SO3 | 3.7 | 71.8 | 3.7 | 55.1 |
| MK3 | 5.4 | 74.2 | 4.8 | 56.4 |
| SK3 | 2.2 | 122.1 | 2.4 | 103.8 |
| MN4 | 8.5 | 155.8 | 6.6 | 139.9 |
| M4 | 22.7 | 168.0 | 17.8 | 148.4 |
| SN4 | 2.3 | 221.5 | 2.5 | 202.9 |
| MS4 | 20.6 | 211.5 | 17.1 | 189.0 |
| MK4 | 5.1 | 207.9 | 4.5 | 186.6 |
| S4 | 3.4 | 267.4 | 3.4 | 243.4 |
| SK4 | 2.0 | 256.9 | 2.0 | 235.7 |
| 2MN6 | 3.4 | 76.8 | 3.4 | 31.0 |
| M6 | 6.2 | 92.2 | 6.4 | 50.8 |
| MSN6 | 1.3 | 118.0 | 1.8 | 72.8 |
| 2MS6 | 7.8 | 135.8 | 8.1 | 93.7 |
| 2MK6 | 1.6 | 139.8 | 1.8 | 95.3 |
| 2SM6 | 1.2 | 168.7 | 2.0 | 130.3 |
| MSK6 | 1.0 | 169.8 | 1.3 | 120.0 |
| A0 | 338.4 | | 328.5 | |

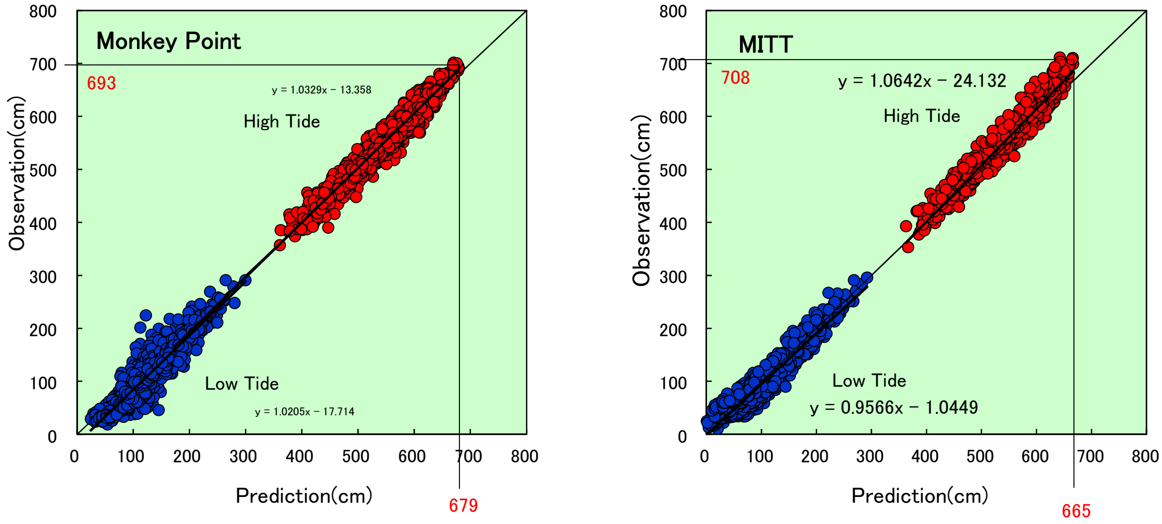
Source: JICA Project Team

## 12.3.2 ACCURACY CONFIRMATION

### (1) Accuracy of Tide Level

Figure 12.3.1 shows the comparison between tide level during high tide and tide level during low tide. There is a good correlation between the predicted value and observation value since plots of both points were concentrated in a diagonal line. Moreover, it can be said that variation was smaller than that in Figure 12.2.6, in which the current tide tables were compared with the observation data. Even the accuracy in small tide was higher in this result, since the current tide tables in small tide was much less accurate.

However, the predicted high water level at the spring tide tends to be low as it can be seen in the current tide tables. When compared around the highest tide level, the predicted tide level was 50-60 cm lower, which reached about 10% of the tidal level range. In Japan, where the tidal level range reaches 200-300 cm, it is recognized that 30 cm of deviation commonly happens. Therefore, it may be said that the gap here was within the margin of error.



Source: JICA Project Team

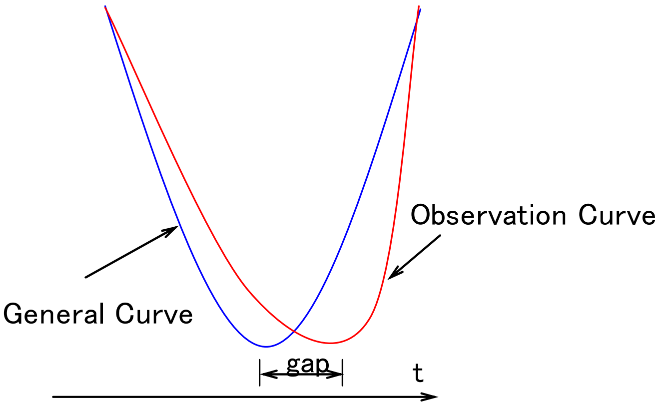
Figure 12.3.1 Comparison of Predicted and Observed Tide Levels

### (2) Accuracy of Tidal Times

The difference of high tide time or low tide time between prediction value and observation data is shown in Figure 12.3.3 and Figure 12.3.4.

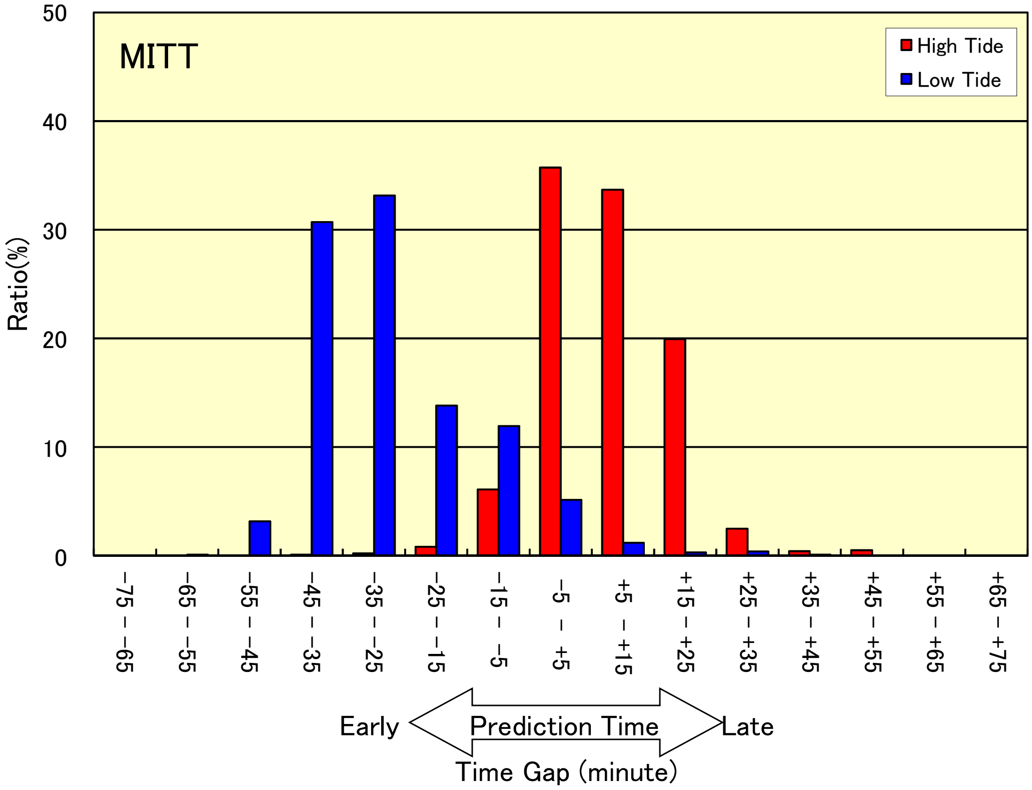
Most of the times for high tides at MITT deviated by ±5 min. Since 23% of the predicted data was delayed more than 15 min to the observation data, predicted times tend to delay in general. On the other hand, the times for low tides by prediction became 25-35 min earlier than those of observation data and 90% of the predicted data advanced over 5 min. Since there must be fluctuation near the peak of observation data, more than 50 min of time gap might be influenced by the uncertainty of arrival time of tide.

On the other hand, most of the times for high tides at Monkey Point deviated ±5 min and 75% of the predicted data were within ±15 min deviation. Meanwhile, times for low tides by prediction became 35 to 45 min earlier than the observation, similar to MITT. Actually, 86% of the predicted data became 15 to 55 min earlier. Namely, the arrival time of low tide by prediction was earlier than that from the observation data. The reason of error is that the tidal fluctuation near the low tide deviated from the general curve as shown in the figure below. Such phenomenon may be seen near the mouth of a river but is considered to be affected by non-tidal phenomenon.



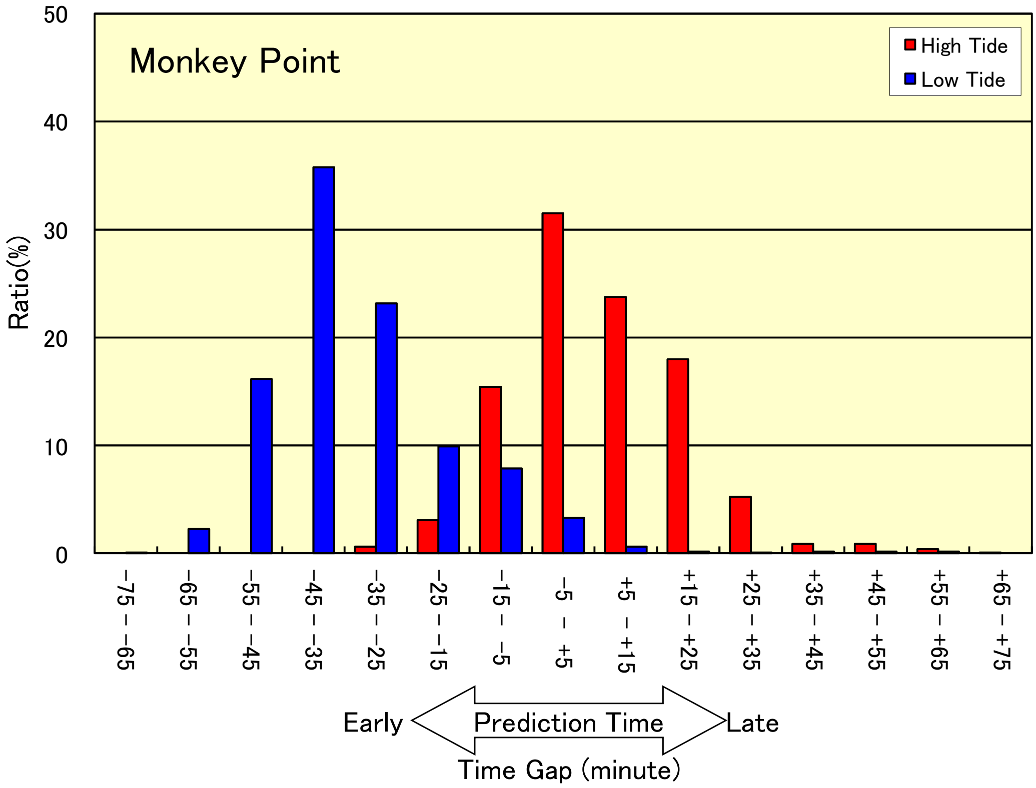
Source: JICA Project Team

Figure 12.3.2 Tide Curves during Low Tide



Source: JICA Project Team

Figure 12.3.3 Tidal Time Gap at MITT between Predicted Value and Observation Data

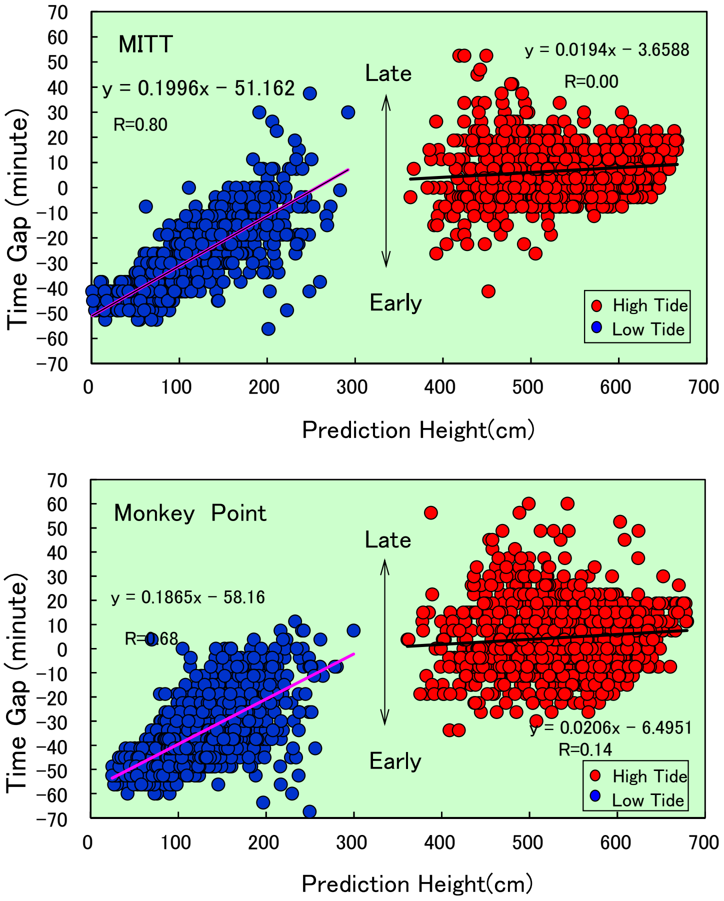


Source: JICA Project Team

Figure 12.3.4 Tidal Time Gap at MP between Predicted Value and Observation Data

### 12.3.3 STUDY OF DATA CORRECTION

As shown in Figure 12.3.1, tide level during high tide predicted by using harmonic constants described in Table 12.3.1 was slightly lower than the observation value. Although it is considered to be influenced by change of mean water level, it was difficult to find the factor due to limited observation data. Therefore, at this moment, the tide level was corrected by using the regression formula shown in Figure 12.3.1. Moreover, since there are time gaps during high tide and low tide which reached more than 30 min, the tidal time was corrected also. Figure 12.3.5 shows the relation between time gaps during high and low tides and tide level. No relation between time gaps and tide level during high tide was identified. Since the gap at MITT was 7 min and 10 min at Monkey Point, correction for these gaps was considered. On the other hand, since the relation between time gaps and tide level during low tide was clearly identified, the correction value calculated by using regression formula was deducted from the predicted value.

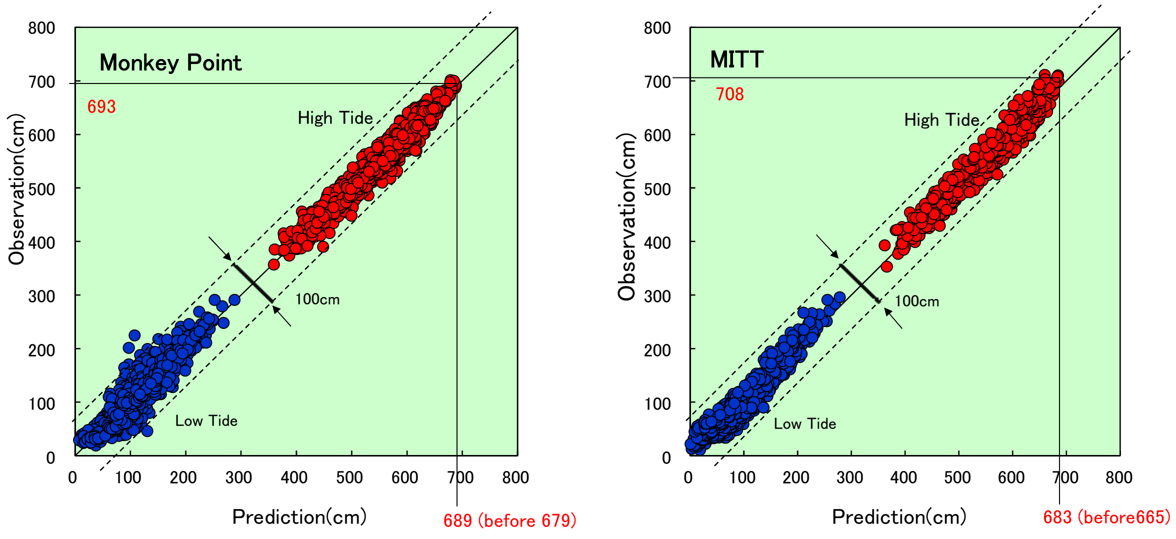


Source: JICA Project Team

Figure 12.3.5 Relation between Time Gaps during High and Low Tides and Tide Levels

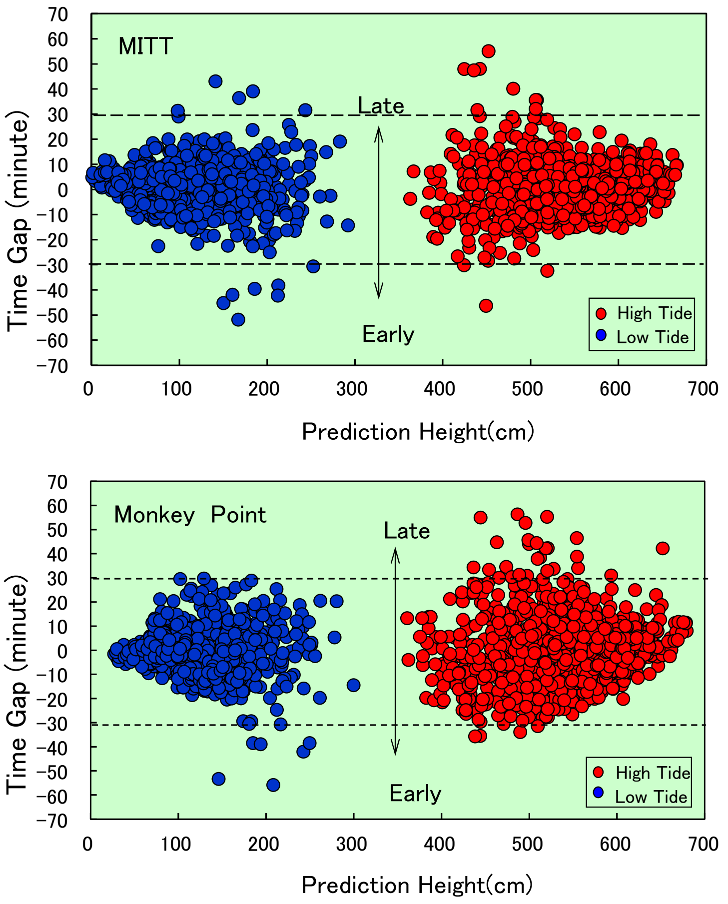
Figure 12.3.6 shows the corrected tide levels from the predicted data shown in Figure 12.3.1. For example, when comparing the high water level, the corrected value at Monkey Point and that at MITT improved at 10 cm and 15 cm, respectively. In addition, it can be identified from the figure that the maximum gap of the predicted value at MITT was ±40 cm, while that at Monkey Point was about ±50 cm.

The corrected tidal times are shown in Figure 12.3.7. The gaps at MITT were within ±20 min, and that at Monkey Point were within ±30 min. Dispersion at high tides remained.



Source: JICA Project Team

Figure 12.3.6 Corrected Tide Level



Source: JICA Project Team

Figure 12.3.7 Corrected Tidal Times

### 12.3.4 COMPARISON BETWEEN THE CURRENT TIDE TABLES AND PREDICTED VALUES

Table 12.3.2 shows the gaps between tide levels in tide tables/the predicted results and the observation data. The average of gaps might be around zero since plus and minus values can cancel each other out. Therefore, the standard deviation of gaps must be an important indicator. In comparison among three cases at Monkey Point, the gaps of the MPA Tide Table were almost same as that of this analysis result.

However, the accuracy of this analysis result can be improved if it is corrected. On the other hand, the Navy Tide Table had big gaps with the observation data.

Table 12.3.2 Errors in the Tide Tables

(Unit: cm)

| Site | Tide Table | Average | Standard Deviation |
|---|---|---|---|
| MITT | Tide table based on the observation data in the Project (with correction) | 2.2<br>(-1.1) | 19<br>(15.5) |
| Monkey Point | MPA Tide Table | 11.5 | 19 |
| | Navy Tide Table | -3.3 | 36 |
| | Tide table based on the observation data in the Project (with correction) | -6<br>(0.0) | 20<br>(17.4) |

Ave.: Prediction－Observation Data

Source: JICA Project Team

## 12.4 CURRENT TIDE TABLES AND APPLICABILITY OF THE PREDICTED TIDE LEVEL

### 12.4.1 CHARACTERISTICS OF CURRENT TIDE TABLES AND ITS APPLICABILITY

#### (1) Tide Level and Tidal Times

In regard to the MPA Tide Table, high water levels at spring tide were calculated low. Moreover, the accuracy at neap tide cannot be judged to be high. Margin of the gap and its feature vary with the season. The time gaps were within about 30 min during high tides, while about 50 min during low tides.

Although, the Navy Tide Table had similar tendency with the MPA Tide Table, the gaps of the Navy Tide Table were large throughout the year. According to the comparison in 2009 to 2010, there were some periods recognized when the data of the Navy Tide Table was remarkably different from the observation data. Tidal time for high tides showed averagely the actual tidal time in Yangon Port, but as for low tides, the time gaps reached about one hour. These gaps will easily pose a big issue in cargo handling plan, etc.

As mentioned above, it is thought that the MPA Tide Table would give higher applicability than the Navy Tide Table in Yangon Port. However, it is necessary to recognize that high water level at spring tide was set lower and the arrival time of it may be delayed for more than 30 min. It should be taken into consideration that the gaps of the tide level vary with the seasons. Moreover, comparison with the observation data should be made again when a longer-term observational data can be acquired.

#### (2) Mean Water Level and Tide Level Components

The mean water level even in an open ocean varies with the seasons. For example, the gap of mean water level is at 0.2-0.4 m in seas around Japan, while its gap reaches 0.7 m in Yangon Port. This is clearly caused by the difference in precipitation by season. For this reason, it is necessary to calculate the mean water level in the Yangon River including Yangon Port from the observation data for at least one year.

Although some tide level components were shown in the current tide tables, the observation data to generate them has not been clarified.

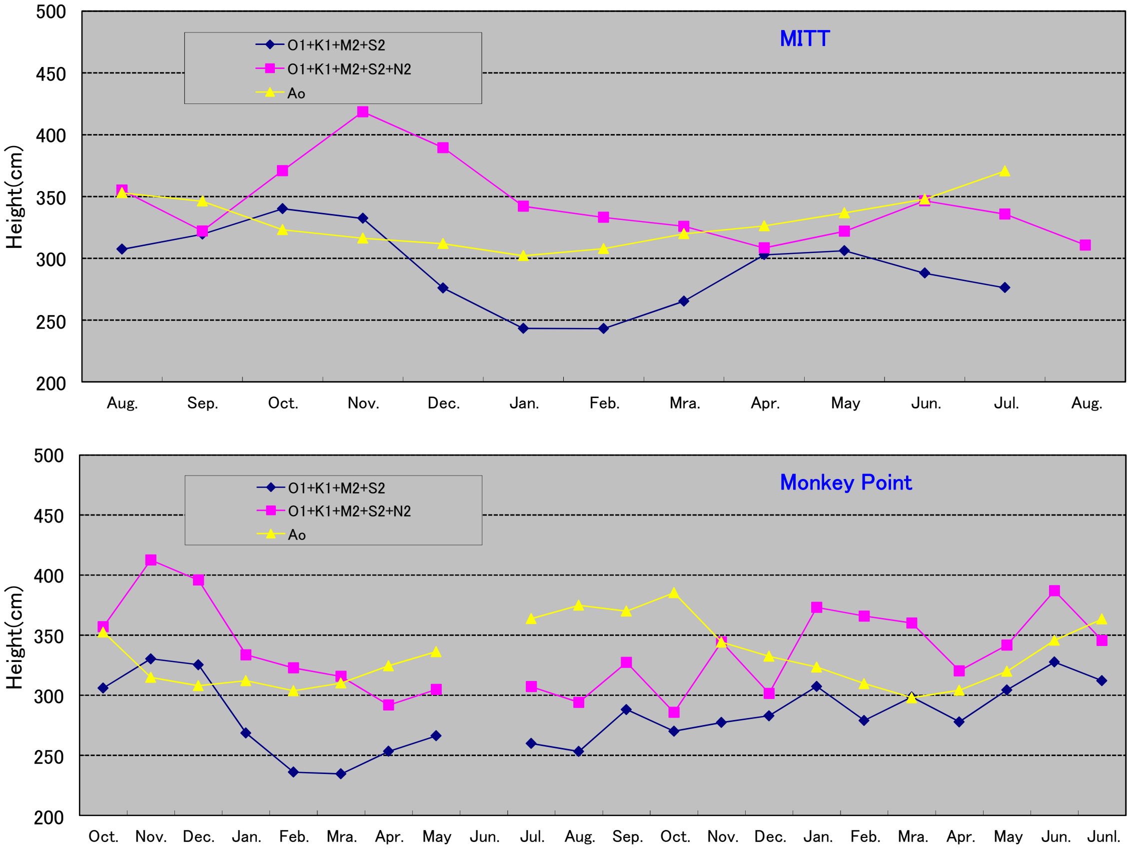
Although the tide level components of high water were calculated based on the old record of data, it is considered that the quality of data, i.e., how the data was observed, will become vitally important in the future. Therefore, it is thought that the time has come to review them by using the statistical technique. For this purpose, a long-term tidal observation is indispensable. For example, at least one year is needed to get the mean water level, while theoretically 19 years of observation data is needed. On the other hand, the Hydrographic Department of the Japan Coast Guard and the Japan Meteorological Agency have used the recent five-year data to calculate the mean water lever.

### 12.4.2 APPLICABILITY OF PREDICTED TIDE LEVEL

It was confirmed that the predicted tide level by harmonic constants calculated from the data of tide observation started from 2009 had equivalent level of accuracy or more as the tide levels in the MPA Tide Table. The accuracy had few differences by seasons, and also the tidal fluctuation at neap tide was more accurate than the one in the existing tide tables. However, there was still an issue that the tidal times for low tides deviated from the actual state. The time gaps reached to 60 min. The errors were corrected by the regression analysis to be less than 30 min. Continuous observation and further update of analysis for practical use are recommended.

One major reason why the high water level at spring tide is undervalued must be because the situation of water area varies with the season. Figure 12.4.1 shows the amplitude change of component tides by month. The total of main four tidal components in a year reached over 1 m. In regard to Yangon Port, since the N2 component tide is large, the total fluctuation of main four tidal components and N2 component might reach over 1 m. It is necessary to investigate such characteristics by using the longer term data in order to raise the accuracy of tidal prediction.

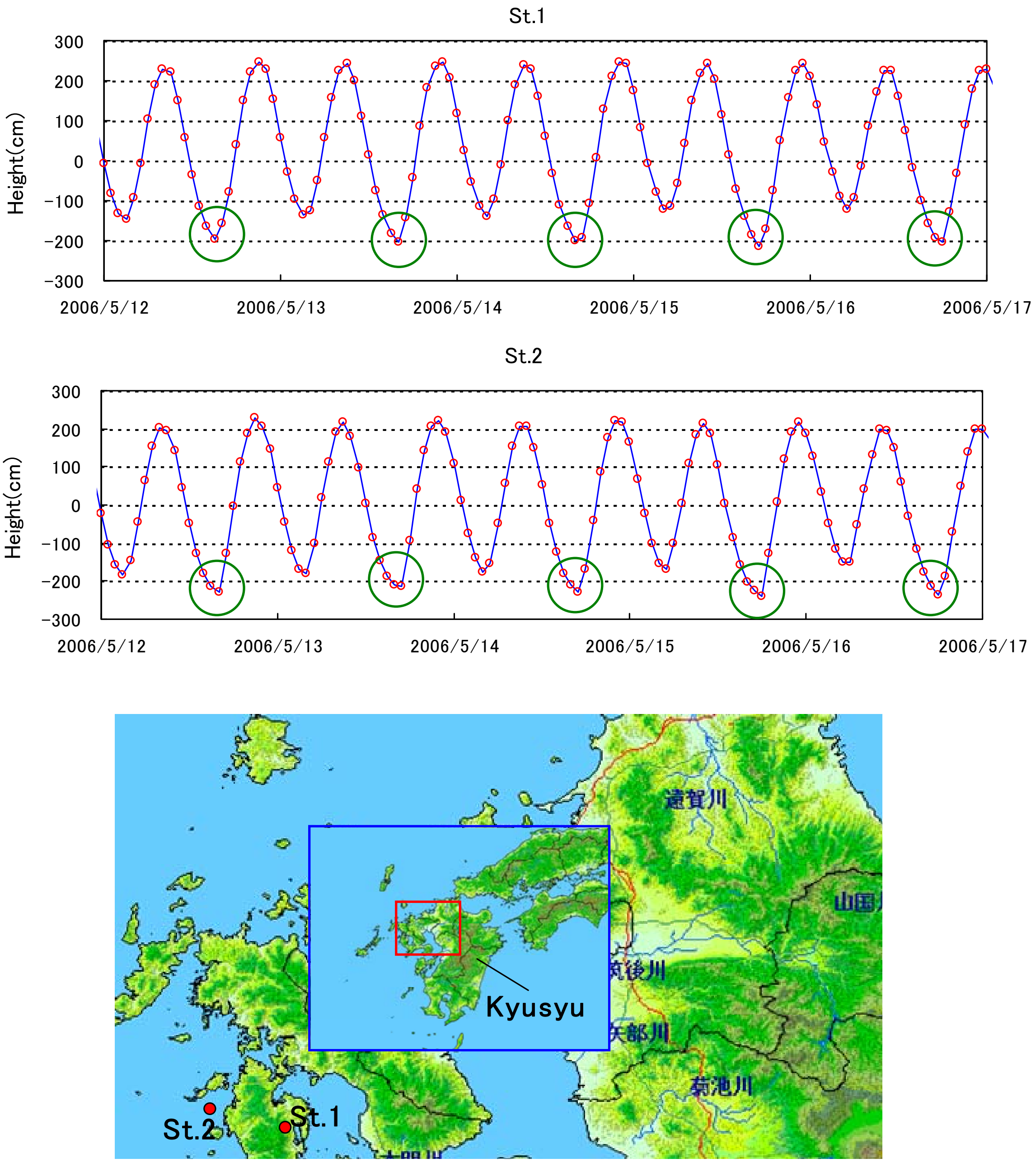
A phenomenon that the downward speed of water level at the spring tide decreases was taken as the reason of time deviation for low tide in tidal prediction. This phenomenon happens easily at the river mouth. The example of this phenomenon in Japan is shown in Figure 12.4.2. In this small river, the downward speed of tide became slow when the water level almost fell to the bottom. It was said that the reason is the flow of ebbing tide retained at the very bottom of low tide. Before the tide falls to the bottom, the tide rises. Therefore, when the tide starts flowing, the water level might go up rapidly for a while after low tide. Figure 12.2.4 indicates such kind of waves. Since this kind of tidal fluctuation has a great impact on Yangon Port, it is important to devise a new method not by means of correction method. In predicting tide level, this might not be given little consideration, in general.



Source: JICA Project Team

Figure 12.4.1 Amplitude Change of Component Tides

In case of using harmonic constants that subtract the rainy season, the predicted values were much less than the observation data as seen in October and November. Therefore, as for the tidal fluctuation in Yangon Port, it is necessary to conduct the harmonic analysis, wherein the period should include the seasonal level fluctuation in the river, and it is important to predict tide levels by using the harmonic constants based on the observation results for one year.



Source: JICA Project Team

Figure 12.4.2 Example of Tidal Fluctuation near the River Mouth in Japan

### 12.4.3 IMPORTANCE OF TIDAL OBSERVATION IN YANGON PORT

Table 12.4.1 shows the qualitative comparison between the current tide tables and the observation data of this study. Tide levels were judged not only from the error of prediction accuracy by standard deviation but also from the comparison scatter diagram with the observation data.

In regard to the tide tables, the MPA Tide Table seems better. However, there are also many points to be considered. On the other hand, the prediction value by harmonic constants based on the observation data is almost at equivalent level as the MPA Tide Table. Although it is expected that the accuracy of the prediction value can be raised by rectifying, it is hard to say that the correction coefficient calculated in this study is of universal value. For this purpose, tidal observation should be continued.

Table 12.4.1 Comparison of Observation Data and Various Prediction Value

| Site | Comparison Object | Tidal Division | Comparison with the Observation | |
|---|---|---|---|---|
| | | | Tidal Level | Tidal Hour |
| MITT | This Analysis Result | High Tide | Lower | Accurate ±5minutes(Dominant)<br>(-5)-(+25)minutes(90%) |
| | | Low Tide | Accurate | Earlier (-35)-(-25)minutes(Dominant)<br>(-45)-(-5)minutes(90%) |
| Monkey Point | MPA Tide Table | High Tide | Higher | Later (+15)-(+25)minutes(Dominant)<br>(-5)-(+25)minutes(70%) |
| | | Low Tide | Accurate | Accurate ±5minutes(Dominant)<br>(-5)-(+25)minutes(90%) |
| | Naval Tide Table | High Tide | Vary | Later ±5minutes(Dominant)<br>(-15)-(+25)minutes(70%) |
| | | Low Tide | Vary | Later (-35)-(-25)minutes(Dominant)<br>(-45)-(-5)minutes(80%) |
| | This Analysis Result | High Tide | Lower | Accurate ±5minutes(Dominant)<br>(-15)-(+25)minutes(90%) |
| | | Low Tide | Accurate | Earlier (-45)-(-35)minutes(Dominant)<br>(-55)-(-15)minutes(85%) |

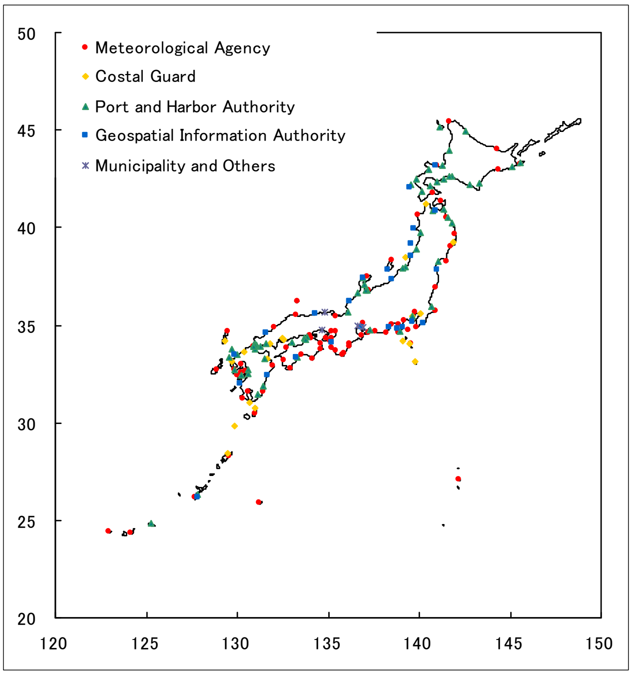
Source: JICA Project Team

## 12.5 ENHANCEMENT OF TIDE OBSERVATION SYSTEM IN MYANMAR

### 12.5.1 TIDE OBSERVATION SYSTEM IN JAPAN

### (1) Observational Organization

In Japan, there are several organizations which carry out tidal observation, namely, the Geospatial Information Authority of Japan (GSI), the Japan Metrological Agency, the Japan Coast Guard, and the Ministry of Land, Infrastructure, Transport and Tourism. Major points of tidal observation are shown in Figure 12.5.1 below. Although all points are not shown in the figure, automatic tide-gauge stations have already been installed in all major ports and harbors in Japan.



Source: Prepared by JICA Project Team based on data from Coastal Movements Data Center, Japan

Figure 12.5.1 Major Points of Tidal Observation by Organization

The purpose of tidal observation of each organization is as follows:

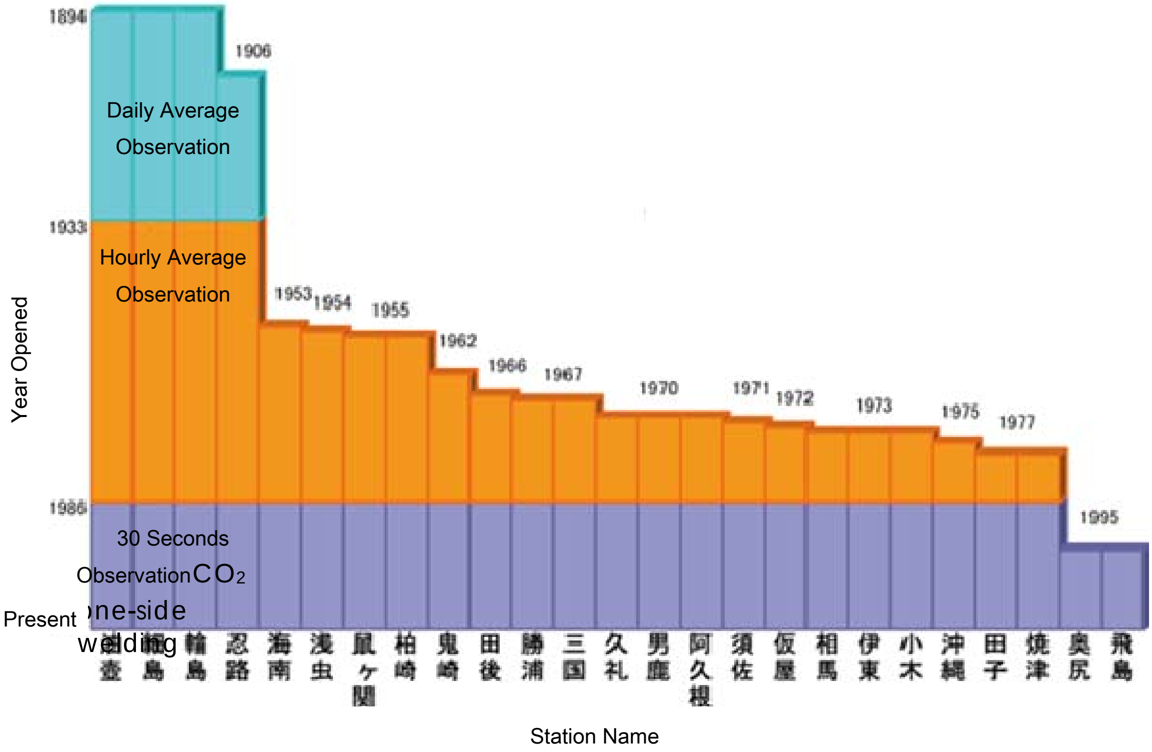
The Geospatial Information Authority of Japan (GSI): GSI decides the standard of height of land. The tide level data has been continuously stored for a long period of time and has played an important role in disaster prevention, such as surveillance of diastrophism, and detection of tsunami.

The Japan Metrological Agency (JMA): JMA has been observing the tide level as one of the meteorological data, and has set the key point especially on the abnormal sea level.

The Japan Coast Guard (JCG): JCG has drawn the sea chart, which provides necessary information for safety voyage, and has observed tide levels for prediction. Since many observation points are located in major ports, this information has also been utilized for port construction or port plan preparation.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (Ports and Harbors, River): In order to set the standard level for construction, to check the tide level under construction and after construction, and to acquire the tide level of every moment that is required for the depth sounding, regular observation stations have been established.

GSI is the oldest organization which has been conducting tidal observation in Japan, and there are some points where tidal observation has continued for more than 100 years.

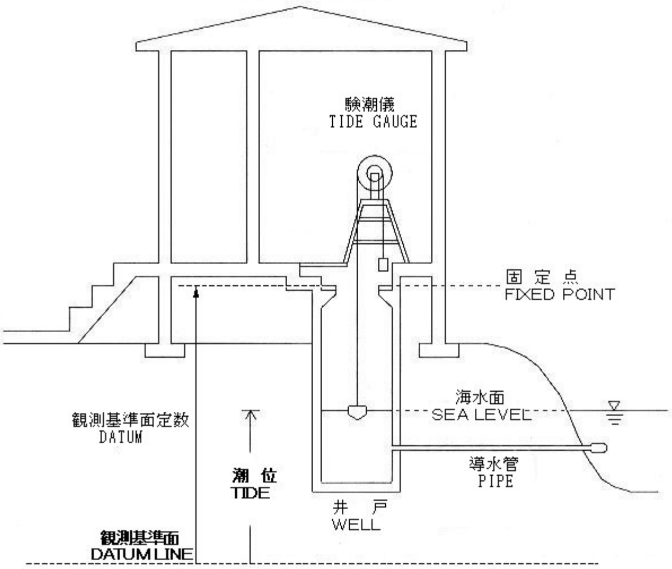


Source: Geospatial Information Authority of Japan

Figure 12.5.2 Accumulated Data of the Geospatial Information Authority of Japan

### (2) Observation Method

Tidal observation has been conducted in a tightly fixed facility. A Japanese standard type of tide gauge station is illustrated in Figure 12.5.3.



Source: Geospatial Information Authority of Japan

Figure 12.5.3 Japanese Standard Type of Tide Gauge Station

The basic equipment of the tide gauge station consists of a well, water pipe, and observation (tide gauge) room. The principle of the tidal observation is to observe seawater rise and fall which is caused by the water coming through the water pipe with a certain diameter by measuring the position of a buoy. The pipe can remove a short cycle of water surface fluctuation.

Source: Geospatial Information Authority of Japan

Photo 12.5.1 Tide Gauge with Float System

There is another type of tide gauge that measures the change of water pressure using a sensor sunk below the sea.

Source: Geospatial Information Authority of Japan

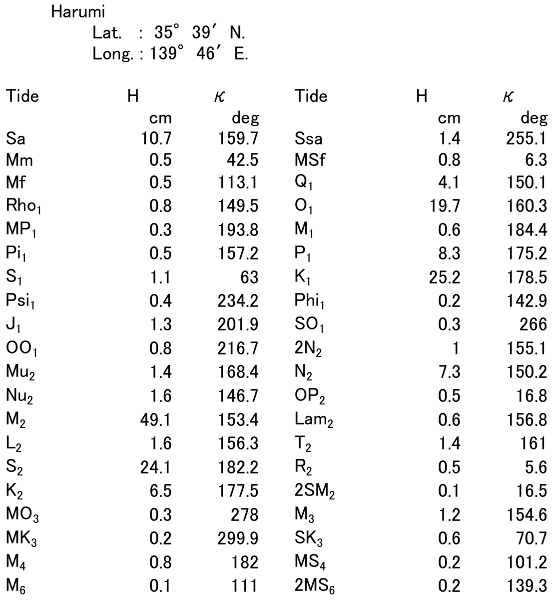
Photo 12.5.2 Tide Gauge with Float System

The height of the tide gauge is required to be checked from a nearby level point. However, it is not easy to see the changes of the level point by ground transformation. Therefore, this point should be kept in mind when dealing with long-term data. In the future, this issue might be solved by using new technology for measurement, such as GPS.

## (3) Observation Results

The Japan Coast Guard published harmonic constants obtained from results of observation of tide levels in Japan, which can be purchased by anyone.

Moreover, the tide table is published every year by the Japan Coast Guard and the Japan Meteorological Agency. In recent years, it became possible to browse the tide level under observation and predicted value through its website (see Figure 12.5.5).

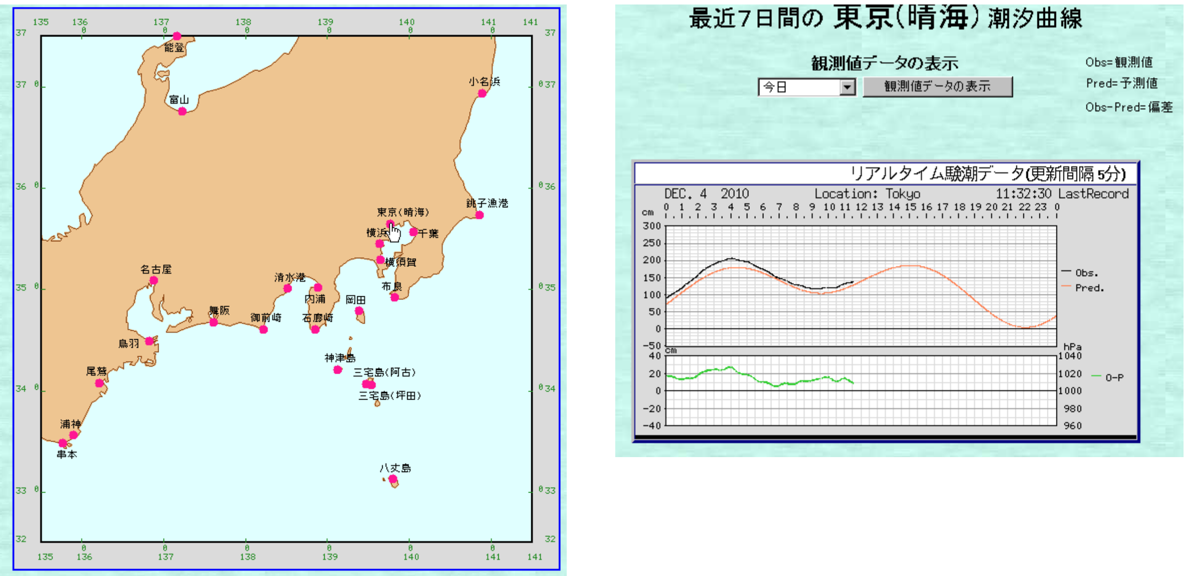


Harumi
Lat. : 35° 39′ N.
Long. : 139° 46′ E.

| Tide | H | $\kappa$ | Tide | H | $\kappa$ |
|---|---|---|---|---|---|
| | cm | deg | | cm | deg |
| Sa | 10.7 | 159.7 | Ssa | 1.4 | 255.1 |
| Mm | 0.5 | 42.5 | MSf | 0.8 | 6.3 |
| Mf | 0.5 | 113.1 | $Q_1$ | 4.1 | 150.1 |
| $Rho_1$ | 0.8 | 149.5 | $O_1$ | 19.7 | 160.3 |
| $MP_1$ | 0.3 | 193.8 | $M_1$ | 0.6 | 184.4 |
| $Pi_1$ | 0.5 | 157.2 | $P_1$ | 8.3 | 175.2 |
| $S_1$ | 1.1 | 63 | $K_1$ | 25.2 | 178.5 |
| $Psi_1$ | 0.4 | 234.2 | $Phi_1$ | 0.2 | 142.9 |
| $J_1$ | 1.3 | 201.9 | $SO_1$ | 0.3 | 266 |
| $OO_1$ | 0.8 | 216.7 | $2N_2$ | 1 | 155.1 |
| $Mu_2$ | 1.4 | 168.4 | $N_2$ | 7.3 | 150.2 |
| $Nu_2$ | 1.6 | 146.7 | $OP_2$ | 0.5 | 16.8 |
| $M_2$ | 49.1 | 153.4 | $Lam_2$ | 0.6 | 156.8 |
| $L_2$ | 1.6 | 156.3 | $T_2$ | 1.4 | 161 |
| $S_2$ | 24.1 | 182.2 | $R_2$ | 0.5 | 5.6 |
| $K_2$ | 6.5 | 177.5 | $2SM_2$ | 0.1 | 16.5 |
| $MO_3$ | 0.3 | 278 | $M_3$ | 1.2 | 154.6 |
| $MK_3$ | 0.2 | 299.9 | $SK_3$ | 0.6 | 70.7 |
| $M_4$ | 0.8 | 182 | $MS_4$ | 0.2 | 101.2 |
| $M_6$ | 0.1 | 111 | $2MS_6$ | 0.2 | 139.3 |

Source: Japan Coast Guard

Figure 12.5.4 Table of Harmonic Constants



Source: Hydrographic and Oceanographic Department, Japan Coast Guard

Figure 12.5.5 Website Providing Tide Level Data in Japan

## (4) Utilization of Tidal Observation

The objectives of accumulating tide level data are as follows:

- To set up a chart datum level for construction at a newly developed point.
- To detect changes of mean water level, a datum plane for construction, etc., at the existing point.
- To acquire tide level data per hour under investigation and construction.

The above objectives are for construction. As for port and harbor works or disaster prevention planning, the following are the objectives:

- To calculate harmonic constants, and to predict the tide level.
- To acquire records of high tide, tsunami, and abnormal sea level phenomenon.
- To grasp long-term water level fluctuation trend.

In regard to the tide level, HHWL is being updated, while LWL and HWL are stable specifications. In addition, the harmonic constants based on the local data enable more accurate tidal prediction, and are provided for port and harbor works. Statistical analysis of tide level deviation predicts how much high tide generates in a certain period. For example, if the observation would continue more than ten years, high water level which might occur once per 10-30 years can be predicted by a statistical method. Long-term water level fluctuation trend might be useful for future disaster prevention planning, although its necessity varies from place to place.

Furthermore, accumulation of tide level data can be expected for the use of conditions of tidal current simulation. Tidal current simulation calculates repeatedly the tide level of computational grid and flow between grids. The calculation method gives some tidal fluctuation in a region, and tide level data is also utilized for such occasion. By utilizing this method, tidal prediction in the entire Ayeyarwady Delta is theoretically possible.

There are more than 400 of varying size of ports and harbors scattered in Myanmar. It is expected to install tide observation equipment in respective place from the viewpoint of port and harbor management.

However, it must be impossible to realize early installation of them. Therefore, it would be reasonable to consider how to cover the thin observation network by numeric simulation.

### 12.5.2 PROPOSAL OF TIDE OBSERVATION SYSTEM IN MYANMAR

#### (1) Medium/Long-Term Plans

The tide observation is important not only for the establishment of chart datum, but also for the disaster prevention information system. Continuous observations are necessary in major ports. Therefore, the JICA Project Team proposed medium/long-term plans for improvement of the tide observation system in Myanmar as follows:

- Tide stations, which can regularly observe tide levels, with the function of disaster prevention are installed. The function of disaster prevention means automatic measuring, recording, and transmission of meteorological and hydrographic data on disasters such as tsunamis, storm surges, and floods.
- The tide fluctuations can be different among neighboring points due to topography or the resonance phenomenon in inner bays or rivers. Dense installation of supplemental stations on the coast line or the Ayeyarwady Delta and continuous observation for more than one year at each point are proposed.

Tide observation for 19 years is theoretically required for tide analysis. On the other hand, the chart datum is practically prepared based on five years of observation, in the case of the Japan Meteorological Agency. Updating of tide tables of major ports through the analysis of the five-year records of the above proposed stations is recommended.

#### (2) Short-Term Plan

**1) Yangon Port**

Yangon Port, which deals 90% of cargo, is the most important port among the nine international ports in Myanmar. The implementation of a tide observation system in Yangon Port should be prioritized. In the Project, the temporal tide stations at Monkey Point and MITT, located upstream and midstream of the Yangon River respectively, were installed, and tide observation by automatic gauges, granted by the Project, was conducted. Consequently, the existing tide tables were verified with the observation data, and the comparison revealed the characteristics of the tide in Yangon Port. The importance of tide observation systems was also recognized.

**2) Other Ports**

In the Project, Yangon Port was mainly studied due to the limitation of the study area and transfer to rural areas. However, the JICA Project Team recognized the importance of tide observation system in the other ports as described in the proposal of medium/long-term plans. As a first step for the establishment of tide observation system, temporal observations for one month at each port in sequence with the automatic gauge granted by the Project is proposed. The importance of ports, construction costs, and accuracy of existing data compared with the observed data are analyzed. The installation priority order of each station is finally studied.

Table 12.5.1 Proposal of Tide Observation System

| | | |
|---|---|---|
| Yangon Port | Short-Term | Construction of tide station (MP and EP) |
| | Medium-Term | Update of tide table with 5-year data |
| | Long-Term | Update of tide table with 19-year data |
| Other Ports | Short-Term | Temporal observation for one month |
| | Short-Term | Study of construction sites<br>Priority order for construction of stations |
| | Medium-Term | Construction of stations in studied sequence |
| | Long-Term | Update of tide table with 5-year data |
| | Long-Term | Update of tide table with 19-year data |

Source: JICA Project Team

# CHAPTER 13

# DESIGN AND IMPLEMENTATION OF PILOT PROJECT FOR JETTY RESTORATION

# CHAPTER 13 DESIGN AND IMPLEMENTATION OF PILOT PROJECT FOR JETTY RESTORATION

## 13.1 GENERAL

During the steering committee meeting on the 22nd of July 2009, restoration work on Botahtaung Jetty was selected as a pilot project to be implemented in Phase 2 within the framework of technical assistance concept to be extended by the Japanese government. The aims of the pilot project are to introduce advanced technology or to apply some technology not common in Myanmar, but it will also be effective for MPA in implementing their further recovery work. The points of technology transfer will cover aspects of port planning, design, and construction.

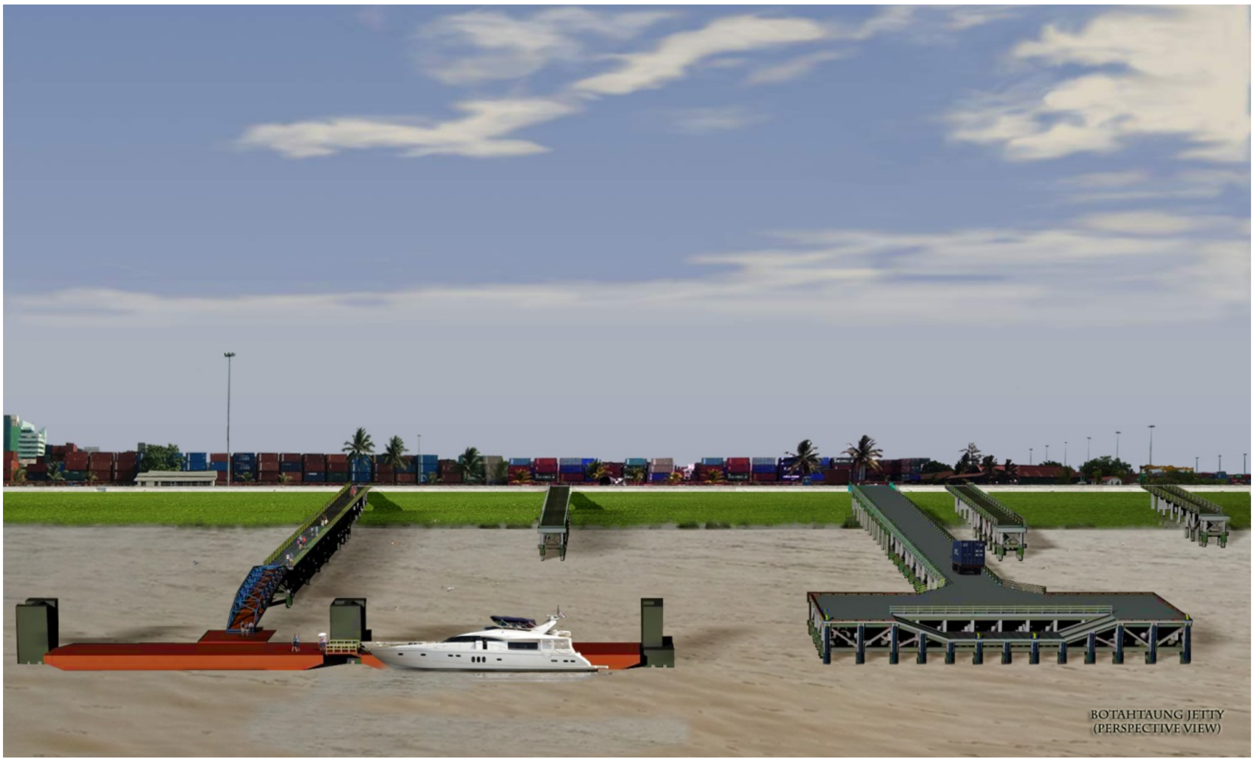
The location of the pilot project was changed from Botahtaung Jetty to Dalla Ferry Terminal at the 3rd steering committee meeting on the 31st of March 2013 through the process shown in Section 13.4.

The name of the pilot project is “Restoration Works of the Dalla Ferry Terminal Jetty at Dalla Side” (hereinafter called the “pilot project”). IWT ferries carry around 30,000 passengers per day between Dalla and Pansodan Ferry Terminal Jetty.

This chapter describes the design of the port facilities in Botahtaung and Dalla (Section 13.2 and 13.3), tender process (Section 13.4), construction of Dalla Jetty (Section 13.5) and seminars for the pilot project (Section 13.6).

Source: JICA Project Team

Figure 13.1.1 Location of Botahtaung Jetty and Dalla Ferry Terminal Jetty



Source: JICA Project Team

Figure 13.1.2 3D View of Planed Botahtaung Jetty

Source: JICA Project Team

Figure 13.1.3 3D View of the Dalla Ferry Terminal

## 13.2 NATURAL CONDITIONS

### 13.2.1 METEOROLOGICAL CONDITIONS

### (1) Rainfall, Temperature, Humidity and Wind

Myanmar is located between the latitude of 10º and 28º N and between the longitude of 92º and 100º E. The port of Yangon is situated at latitude 16º47' N and longitude 96º15' E on the Yangon River and about 32 km from the Elephant Point on the Gulf of Martaban.

Statistical data of monthly rainfall, monthly mean temperature, and humidity from 2006 to 2008 are shown in Table 13.2.1, Table 13.2.2 and Table 13.2.2, respectively. These data are recorded at Kaba Aye Station, which is located at the head office of the Department of Meteorology and Hydrology, Ministry of Transport.

Table 13.2.1 Monthly Rainfall (mm)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 0 | 0 | N/A | 156 | 341 | 411 | 780 | 634 | 366 | 147 | N/A | 0 | 2,835 |
| 2007 | 0 | 0 | 0 | N/A | 837 | 559 | 700 | 446 | 774 | 260 | 16 | 0 | 3,592 |
| 2008 | 5 | 7 | 25 | 169 | 656 | 431 | 541 | 474 | 448 | 301 | 6 | 0 | 3,063 |

Note: “N/A” refers to the amount of rainfall which cannot be measured.

Source: Department of Meteorology and Hydrology, Ministry of Transport

Table 13.2.2 Monthly Mean Temperature (°C)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 23.8 | 26.1 | 28.5 | 28.8 | 26.7 | 26.0 | 25.1 | 26.4 | 27.5 | 29.3 | 29.0 | 26.0 | 26.9 |
| 2007 | 25.9 | 27.3 | 29.2 | 31.9 | 28.1 | 27.7 | 26.6 | 26.7 | 26.1 | 27.0 | 27.2 | 25.0 | 27.4 |
| 2008 | 25.5 | 26.1 | 29.2 | 29.9 | 27.1 | 26.6 | 26.0 | 25.8 | 26.1 | 27.0 | 26.4 | 24.5 | 26.7 |

Source: Department of Meteorology and Hydrology, Ministry of Transport

Table 13.2.3 Monthly Mean Relative Humidity (%) at 9:30 hrs M.S.T

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 84 | 75 | 77 | 75 | 84 | 91 | 95 | 93 | 92 | 84 | 78 | 75 | 83.6 |
| 2007 | 74 | 67 | 70 | 69 | 89 | 91 | 92 | 91 | 94 | 87 | 81 | 92 | 83.1 |
| 2008 | 78 | 68 | 71 | 78 | 87 | 89 | 90 | 97 | 92 | 85 | 76 | 72 | 81.9 |

Source: Department of Meteorology and Hydrology, Ministry of Transport

### (2) Wind

Statistical data of mean and maximum wind velocity and direction from 2006 to 2008 are shown in Table 13.2.4 and Table 13.2.5, respectively. These data are recorded at Kaba Aye Station which is located at the head office of the Department of Meteorology and Hydrology, Ministry of Transport. Interval of record for wind velocity at Kaba Aye is four times a day at 6:30 a.m., 9:30 a.m., 12:30 p.m., and 6:30 p.m.

Regarding wind direction, from March to October including monsoon season, wind comes from the southwest while for other months, it comes from various directions.

Maximum wind recorded by Cyclone Nargis before landfall in the delta area was 59 m/s (132 mph) of sustained wind and 72 m/s (161 mph) of wind gust. Maximum wind speed was reduced after landfall and recorded winds in Yangon Airport on May 3, 2008 were 31 m/s (111 km/hr) of maximum sustained wind and 62 m/s (222 km/hr) of maximum wind gust.

Table 13.2.4 Monthly Mean Wind Velocity (m/s) and Direction

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 0.49 | 0.49 | 0.63 | 0.63 | 0.76 | 0.67 | 0.67 | 0.76 | 0.67 | 0.58 | 0.67 | 0.67 |
| | NE | W | SE | SW | SW | SW | SW | SW | SW | SW | NW | N |
| 2007 | 0.49 | 0.58 | 0.67 | 0.98 | 0.94 | 0.85 | 0.76 | 0.76 | 0.63 | 0.58 | 0.63 | 0.58 |
| | NW | W | NW | SW | SW | SW | SW | SW | SW | W | NW | NW |
| 2008 | 0.54 | 0.54 | 0.72 | 0.72 | 1.56 | 1.03 | 1.07 | 0.85 | 0.76 | 0.58 | 0.72 | 0.67 |
| | NE | SE | SW | SW | SW | SW | SW | SW | SW | SW | E | NE |

Source: Department of Meteorology and Hydrology, Ministry of Transport

Table 13.2.5 Monthly Maximum Wind Velocity (m/s) and Direction with Date

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 Date | 2.15 | 2.15 | 2.15 | 3.22 | 3.22 | 3.22 | 2.15 | 2.68 | 4.83 | 2.15 | 4.29 | 3.22 |
| | N | N | S | SE | E | NW | SW | SW | E | SW | SE | SE |
| | 5 | 8 | 30 | 26 | 17 | 30 | 8 | 8 | 27 | 8 | 7 | 21 |
| 2007 Date | 3.22 | 4.29 | 3.22 | 4.29 | 6.44 | 2.15 | 3.22 | 3.22 | 2.15 | 2.15 | 3.22 | 3.22 |
| | S | E | S | SW | SW | SW | W | SW | E | E | SE | E |
| | 28 | 1 | 1 | 28 | 14 | 29 | 5 | 10 | 21 | 15 | 14 | 2 |
| 2008 Date | 2.68 | 1.61 | 2.15 | 2.15 | 42.91 | 3.22 | 3.22 | 3.22 | 2.15 | 2.15 | 2.15 | 2.15 |
| | SE | SE | S | SE | 99 | SW | W | SW | W | SW | E | SE |
| | 1 | 22 | 15 | 18 | 3 | 17 | 30 | 10 | 12 | 4 | 21 | 1 |

Source: Department of Meteorology and Hydrology, Ministry of Transport

### 13.2.2 HYDRAULIC CONDITIONS

#### (1) Tide Level

The tide levels in Yangon Port at No.1 Berth, Sule Pagoda Wharf, which were published by the MPA in 2007, 2008, and 2009, are shown in Table 13.2.6, Table 13.2.7 and Table 13.2.8, respectively.

From the tide level data in the last three years, the average high and low water spring levels at Yangon Port are estimated at around 6.2 m and 0.7 m, respectively.

Table 13.2.6 Tide Level at Yangon Port (2007)

| Year / Month | 2007 | | | | | | | | | | | | Annual Ave. | Annual Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | | |
| HWSL | 5.75 | 5.92 | 6.13 | 6.19 | 6.12 | 5.99 | 6.32 | 6.55 | 6.60 | 6.43 | 6.07 | 5.68 | 6.15 | 6.60 |
| MSL | 3.01 | 3.06 | 3.20 | 3.30 | 3.38 | 3.47 | 3.69 | 3.89 | 3.90 | 3.67 | 3.33 | 3.04 | 3.41 | 3.40 |
| LWSL | 0.27 | 0.20 | 0.27 | 0.40 | 0.64 | 0.94 | 1.06 | 1.22 | 1.20 | 0.90 | 0.59 | 0.40 | 0.67 | 0.20 |

Source: MPA

Table 13.2.7 Tide Level at Yangon Port (2008)

| Year / Month | 2008 | | | | | | | | | | | | Annual Ave. | Annual Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | | |
| HWSL | 5.63 | 5.73 | 5.95 | 6.12 | 6.14 | 6.09 | 6.22 | 6.39 | 6.47 | 6.40 | 6.15 | 5.86 | 6.10 | 6.47 |
| MSL | 2.93 | 2.97 | 3.13 | 3.27 | 3.39 | 3.49 | 3.63 | 3.82 | 3.81 | 3.68 | 3.39 | 3.13 | 3.39 | 3.34 |
| LWSL | 0.23 | 0.21 | 0.31 | 0.42 | 0.63 | 0.88 | 1.04 | 1.25 | 1.15 | 0.96 | 0.62 | 0.40 | 0.68 | 0.21 |

Source: MPA

Table 13.2.8 Tide Level at Yangon Port (2009)

| Year/ Month | 2009 | | | | | | | | | | | | Annual Ave. | Annual Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | | |
| HWSL | 5.81 | 5.85 | 5.94 | 6.02 | 6.08 | 6.26 | 6.51 | 6.58 | 6.50 | 6.31 | 6.12 | 5.91 | 6.16 | 6.58 |
| MSL | 3.01 | 3.00 | 3.07 | 3.21 | 3.39 | 3.59 | 3.9 | 3.93 | 3.84 | 3.65 | 3.42 | 3.15 | 3.42 | 3.37 |
| LWSL | 0.20 | 0.15 | 0.20 | 0.40 | 0.69 | 0.92 | 1.10 | 1.25 | 1.17 | 0.99 | 0.71 | 0.38 | 0.68 | 0.15 |

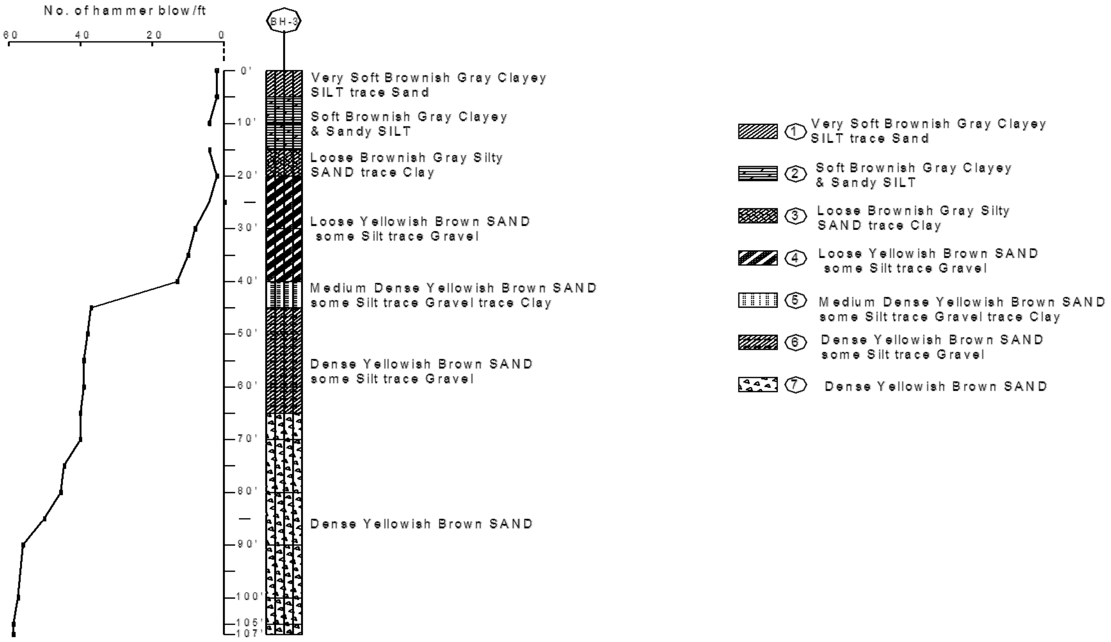
Source: MPA

### (2) Tidal Currents

Maximum river current at Yangon Port is estimated at around 3.1 m/s (6 knots), according to the information obtained from MPA.

## 13.2.3 SOIL CONDITIONS

From the result of soil investigation at Boaungkyaw Container Wharf near Botahtaung, it has alluvial soil deposits in the upper layer and sandy soil deposits encountered at deeper depths.



Source: Report on Subsurface Soil Investigation of Boangkyaw Container Wharf Project, June 1996, Public Works, Ministry of Construction

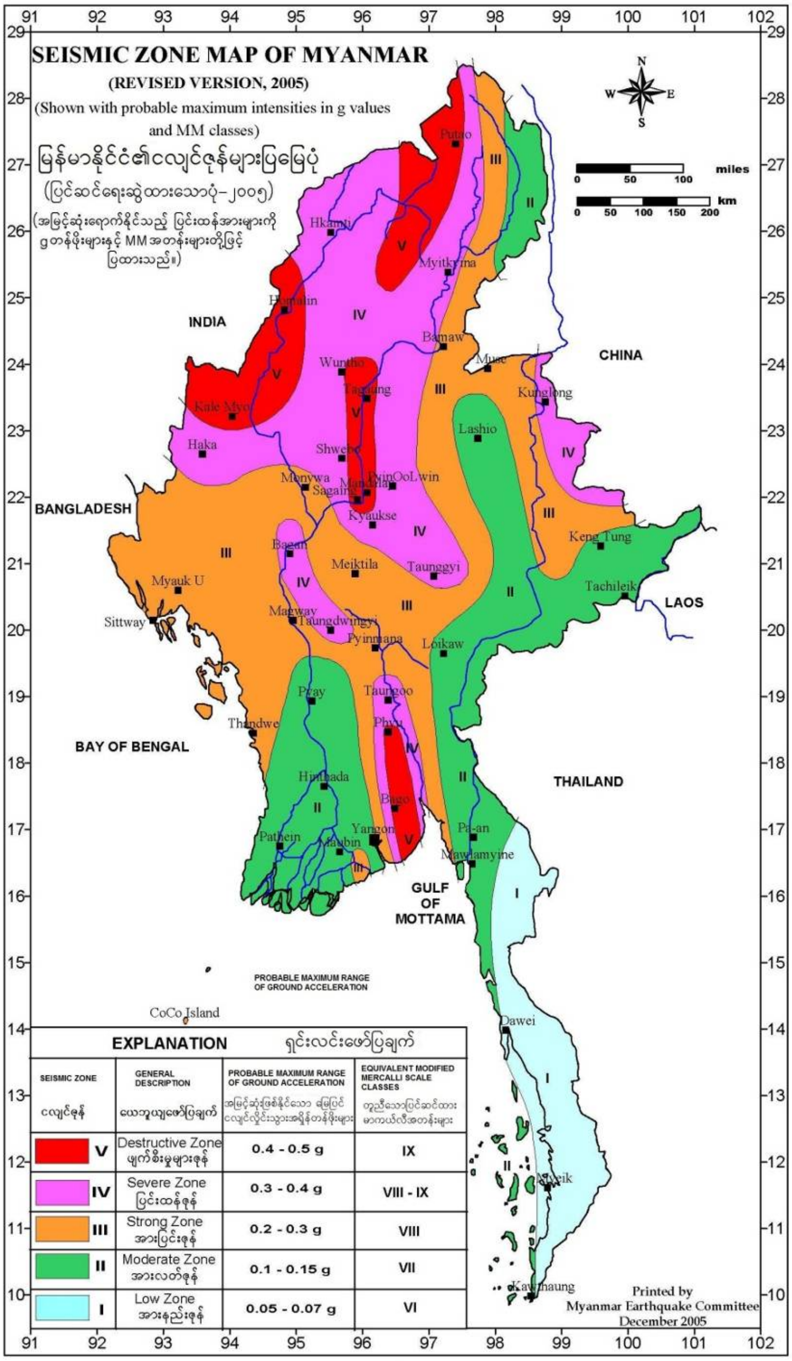
Figure 13.2.1 Soil Profile of Borehole at Boaungkyaw Container Wharf

The soil layer at a depth of 6 m below the ground surface is formed by clayey silt and loose silty sand. The layer at a depth between 6 m and 12 m is formed by loose sand, and dense sand layer can be found at a depth between 12.5 m to 32 m. An N-value of more than 20 is measured at depths between 12.5 m and 32 m.

The soil profile of borehole at Boaungkyaw Container Wharf is shown in Figure 13.2.1. The JICA Project Team carried out geological investigation at three points in the Botahtaung Jetty site to obtain the geotechnical condition of the site which is needed for the design of the pilot project. The results of the survey were presented in Section 13.3.3 6 "Soil Condition of Botahtaung Jetty site".

### 13.2.4 EARTHQUAKE

The seismic zone map of Myanmar is shown in Figure 13.2.2.



Revised by Dr. Maung Thein, U Tint Lwin Swe and Dr. Sone Han (December 2005)

Source: Myanmar Earthquake Committee

Figure 13.2.2 Seismic Zone Map of Myanmar

In Myanmar, most of the earthquakes occur in the northwest region (mainly in Sagain Division). Earthquakes occurring near Yangon are not frequent. The earthquakes that occurred from 1900 to 2009 in the Yangon area (within 600 km) are shown in Table 13.2.9. During this period of 110 years, Yangon experienced six large earthquakes with magnitude of more than 5.0. Among these earthquakes, Bago earthquake in 1930 caused large damage in Bago which was also felt in Yangon due to its close proximity.

Table 13.2.9 Past Earthquakes Recorded in Myanmar

| Year/Month/ Date | Latitude | Longitude | Magnitude (Richter Scale) | Distance from Yangon | Remarks |
|---|---|---|---|---|---|
| 1912.05.23 | 21° 00' 00"N | 97° 00' 00"E | 8.0 | 475 km | Mandalay, Mogok |
| 1930.05.05 | 17° 00' 00"N | 96° 30' 00"E | 7.3 | 68 km | Bago, casualty: 500 |
| 1930.12.03 | 18° 12' 00"N | 96° 24' 00"E | 7.3 | 159 km | Pyu |
| 1943.10.23 | 21° 30' 00"N | 93° 30' 00"E | 7.2 | 592 km | Swa |
| 1975.07.08 | 21° 29' 00"N | 94° 42' 00"E | 6.5 | 542 km | Pagan |
| 2003.09.21 | 19° 55' 01N" | 95° 40' 19"E | 6.6 | 351 km | |

(Period: 1900 – 2009, Magnitude: over 5.0, Distance from Yangon: less than 600 km)

Source: Department of Meteorology and Hydrology, MOT

Myanmar has been divided into five categorized levels based on the earthquake factors and Yangon region is classified as Level II. From this classification, the horizontal seismic coefficient of the Yangon region is estimated between 0.10 and 0.15.

## 13.3 BOTAHTAUNG JETTY RESTORATION (ONLY PLAN, DESIGN AND TENDER)

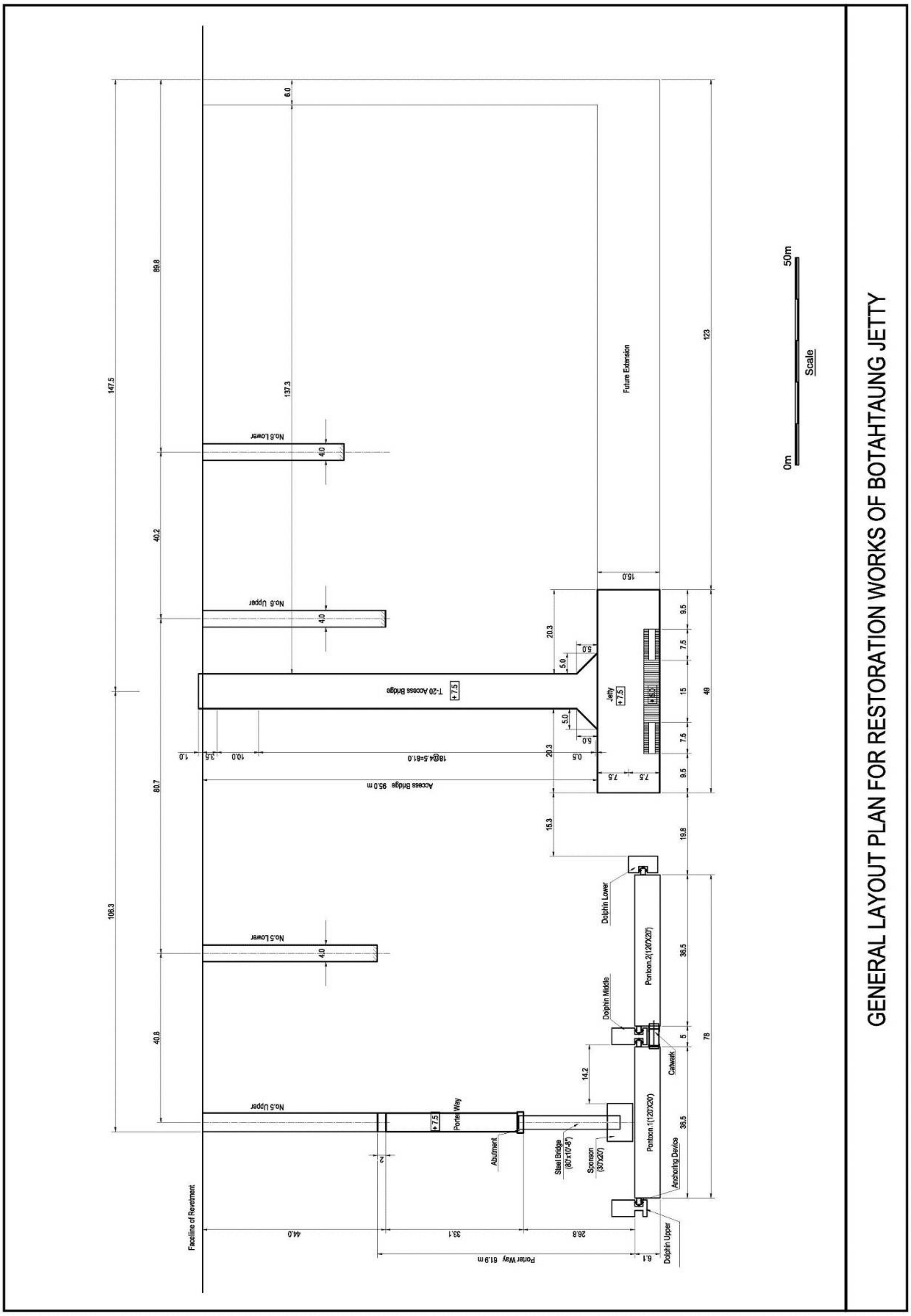
### 13.3.1 DESCRIPTION OF BOTAHTAUNG JETTY RESTORATION

Main features of the Pilot Project of Restoration Work of Botahtaung Jetty include:

Mooring pier of basically rigid concrete piled pier type with total length of 127 m and in which three types of landing facilities are involved;

- A 78 m long pontoon section composed of two units of 120 ft x 20 ft pontoon (to be provided by MPA). Three dolphins for anchoring two pontoons;
- A 15 m long reinforced concrete landing platform section at 5.0 m above sea level;
- A 49 m long reinforced concrete landing platform section at 7.5 m above sea level;
- A 95 m long and 8.4 m wide access bridge for laborers, passengers, and vehicles;
- Porter way access which is 35.1 m long and 4.5 m wide as the pontoon jetty section;
- Movable steel truss access bridge (80 ft x 10 ft) with sponson (30 ft x 20 ft) which are expected to be provided and installed by MPA; and
- Pier accessories such as mooring bollards, fenders, and other miscellaneous items.

Layout plan of the pilot project was arranged as shown in Figure 13.3.1.



Source: JICA Project Team

Figure 13.3.1 Layout Plan of the Planed of Botahtaung Jetty

### 13.3.2 APPLICABLE STANDARDS, CODES AND SPECIFICATIONS

The structures of the pilot project were designed in accordance with the following standards and codes:

- Technical Standards and Commentaries for Port and Harbor Facilities in Japan 1999 edition (TS), which is the primary standard applied for the design;
- Japanese Industrial Standards (JIS);
- Standard Specifications for Concrete in Japan;
- Specifications for Highway Bridges V: Japan Road Association, Jan 2004;
- Standards of Japanese Geotechnical Society; and
- Guideline for the Design of Fenders Systems (2002).

All dimensions and weights used for the design and detailing of all items are in international system of units (S.I.), unless specified otherwise.

### 13.3.3 DESIGN CRITERIA

### (1) Natural Condition

Design criteria covers various items of natural condition and are described hereinafter.

**1) Tide**

Design tidal levels are defined as shown below, based on the available tide table and information obtained from MPA.

- Extremely High Water Level: +7.10 m (Nargis estimate)
- Highest High Water Level: +6.74 m (Sule Pagoda Wharf on 16 Aug. 1939)
- HWLS: +6.20 m
- Mean Water Level: +3.23 m (Sule Pagoda Wharf in 1954)
- LWLS: +0.34 m
- Low Water Spring Tide: ±0.00 m
- Lowest Low Water Level: -0.24 m (Bo Aung Kyaw Wharf in Dec. 1902)

**2) Tidal Current**

Maximum current speed is estimated at 6 knots (3 m/s) based mainly on the hearing from MPA.

**3) Wind**

The sustained maximum wind speed recorded at Yangon Airport was 30 m/s during Cyclone Nargis. The design wind speed was assumed by converting landside wind to river surface wind by multiplying a coefficient of 1.3. Based on the record at Yangon Airport, the design wind speed is assumed at 40 m/s (30 m/s x 1.3 = 40 m/s).

The design wind speed was applied for the wave hindcast analysis and estimation of wind pressure acting on the ships and pontoon.

**4) Wave**

Wave height is estimated by applying the SMB method. Design wind speed is assumed at 40 m/s for all directions.

Design wave heights were estimated for three directions as shown in Table 13.3.1 below.

Table 13.3.1 Design Wave Height at Botahtaung Point

| Direction | Effective Fetch | Wave Height ($H_{1/3}$) | Wave Period |
|---|---|---|---|
| SE | 3.9 km | 1.9 m | 3.5 s |
| SSE | 2.3 km | 1.5 m | 3.2 s |
| S | 1.6 km | 1.3 m | 2.7 s |

Source: JICA Project Team

### 5) Earthquakes and Seismic Condition

Historically, there was a big earthquake on the 5th of May 1930 in Bago area. The earthquake, called Bago Earthquake, had an estimated magnitude of 7.3 and the distance from the epicenter to the pilot project site was 68 km. The horizontal ground acceleration of the Bago Earthquake was estimated at 0.13g.

Yangon area is in the Category II region having seismic coefficient of 0.10 to 0.15 as mentioned in Chapter 9. Judging from the intensity estimated for Bago Earthquake and seismic zone map shown in Figure 9.4.1, design horizontal seismic coefficient (Kh) was determined at 0.15.

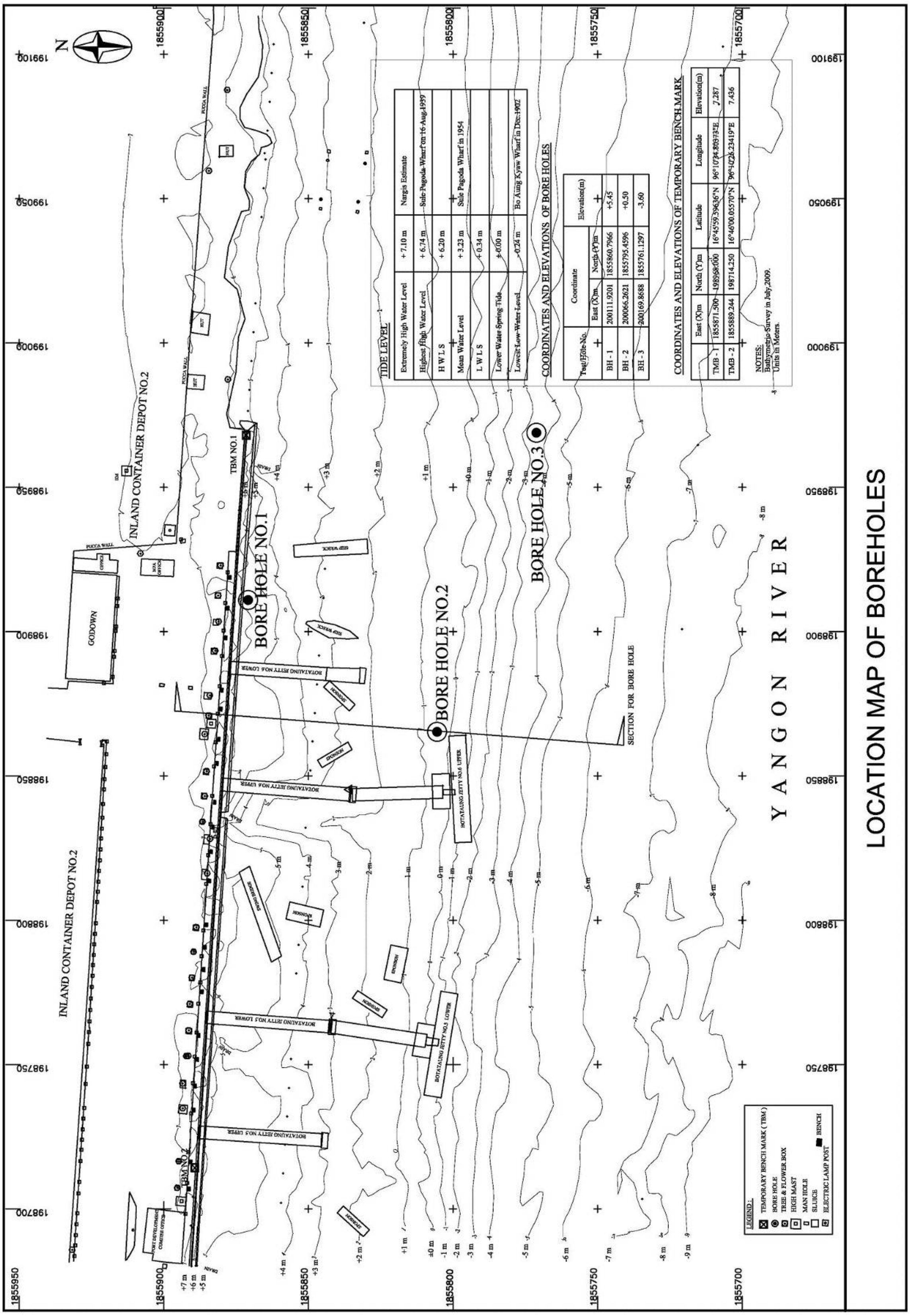
### 6) Soil Condition of Botahtaung Jetty Site

As mentioned in Chapter 9, there is only one existing soil investigation data for Boaunggyaw Container Wharf near the Botahtaung Jetty. It was useful for the conceptual design, but not enough for the basic and detailed designs of the pilot project. Therefore, soil investigation (3 boreholes) and topographic survey (land area = 2.0 ha, river area = 6.0 ha) were carried out in July and August 2009 by the JICA Project Team.

Three borings were conducted at the locations shown in Figure 13.3.2 in the Botahtaung area. The boring logs are shown in Figure 13.3.3.

According to the logs, soil condition at the planned site is as follows:

- At 0 m ~ 5~7 m from the river bed: clayey silt and with SPT of about 0~5.
- At 5~7 m ~ 12~13 m from the river bed: silty sand with SPT of about 10~30.
- Deeper than 12~13 m from the river bed: dense silty sand or sand with gravel with SPT over 30.



TIDE LEVEL

| | | |
|---|---|---|
| Extremely High Water Level | + 7.10 m | Nargis Estimate |
| Highest High Water Level | + 6.74 m | Sule Pagoda Wharf on 16 Aug.1939 |
| H W L S | + 6.20 m | |
| Mean Water Level | + 3.23 m | Sule Pagoda Wharf in 1954 |
| L W L S | + 0.34 m | |
| Lower Water Spring Tide | ± 0.00 m | |
| Lowest Low Water Level | -0.24 m | Bo Aung Kyaw Wharf in Dec.1902 |

COORDINATES AND ELEVATIONS OF BORE HOLES

| Test/Hole No. | Coordinate | | Elevation(m) |
|---|---|---|---|
| | East (X)m | North (Y)m | |
| BH - 1 | 200111.9201 | 1855860.7966 | +5.45 |
| BH - 2 | 200066.2621 | 1855795.4596 | +0.50 |
| BH - 3 | 200169.8688 | 1855761.1297 | -3.60 |

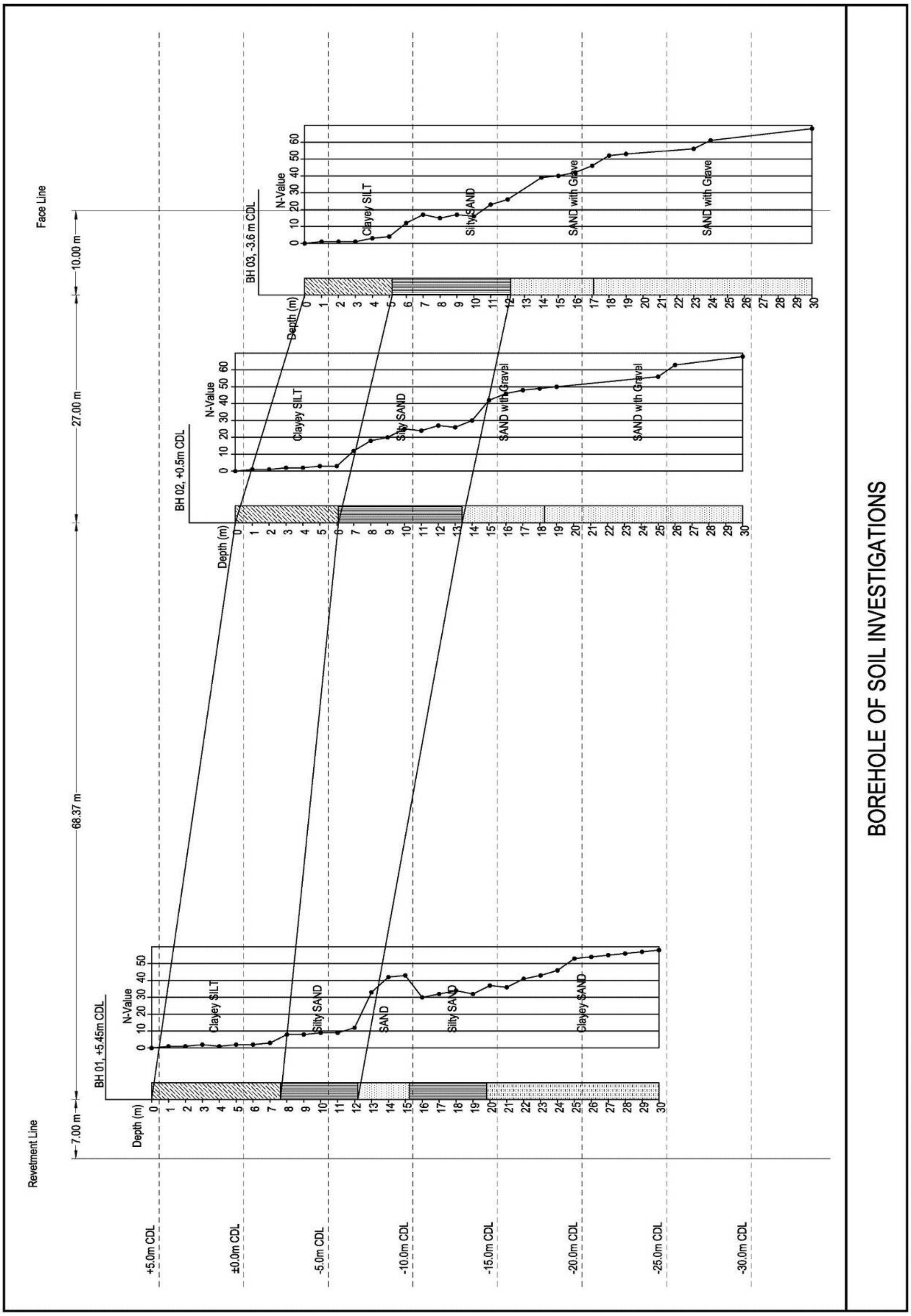
COORDINATES AND ELEVATIONS OF TEMPORARY BENCH MARK

| | East (X)m | North (Y)m | Latitude | Longitude | Elevation(m) |
|---|---|---|---|---|---|
| TMB - 1 | 1855871.500 | 198968.000 | 16°45'59.59636"N | 96°10'34.80373"E | 7.287 |
| TMB - 2 | 1855889.244 | 198714.250 | 16°46'00.05570"N | 96°10'26.23419"E | 7.436 |

NOTES:
Bathymetric Survey in July,2009.
Units in Meters.

Source: JICA Project Team

Figure 13.3.2 Location Map of Boreholes



Source: JICA Project Team

Figure 13.3.3 Profile of Soil Investigations

### (2) Coordinates and Elevation

Coordinates and elevation system for the pilot project should be referred to the standard benchmark located at Nanthidar Park in front of the MPA office (Kyauktada Township, Yangon) and well coordinated to WGS-84 as well as UTM projection. The position of the standard benchmark is set as shown in Table 13.3.2 below.

Table 13.3.2 Position of the Standard Benchmark in Yangon

| | |
|---|---|
| Latitude | 16°46’05.9301” N |
| Longitude | 96°9’46.73597” E |
| UTM (X) | 1856086.667 m |
| UTM (Y) | 197546.333 m |
| Elevation (C.D.L) | 7.644 m |

Source: JICA Project Team

### (3) Operation Conditions

#### 1) Ships Subject to the Design

The description of works for the related port facilities extracted from “the scope of work” is as follows:

- To make the recovery plan of facilities in Yangon Port;
- To make the basic concept to recover the facilities in order to restore capacities before Cyclone Nargis;
- To make the recovery plan of the port facilities based on the basic concept and prioritization of the project(s); and
- To estimate the cost and design of the priority project(s).

In accordance with the above, ships subject to the project shall be mainly IWT market ship and cargo ships.

Table 13.3.3 Dimensions of Target Ship for the Pilot Project

| | **Target Ship 1** | **Target Ship 2** |
|---|---|---|
| Structure | For jetty berth | For pontoon berth |
| Type of ship | Coastal cargo ship | Delta ship (bazaar ship) with two barges abreast |
| Dead weight tonnage | 1,200 DWT | 400 + 300 x 2 = 1,000 DWT |
| Length overall | 200 feet (60 m) | 200 feet (60 m) |
| Width | 32 feet (9.6 m) | 32 feet (9.6 m) |
| Full load draft | 16 feet (4.8 m) | 1.7 m |
| Depth | N/A | 2.9 m |

Source: JICA Project Team

#### 2) Berthing Speed

Both the market ship and the coastal cargo ship do not use tug boats at the Yangon Port. The berthing speed for design is assumed at 15 cm/s based on the Japanese standard and hearing results from MPA.

#### 3) Live Load

Design load is assumed at 20 tons of truck load on full load condition for the access bridge and jetty. The design live load is not considered for the porter way.

#### 4) Surcharge

Design load of surcharge is assumed at 1.0 ton under normal conditions and 0.0 ton under seismic conditions.

## 13.3.4 DESIGN OF FACILITIES

### (1) Design Concept

Basic concepts of the implementation of the pilot project are as follows:

- To introduce new technology to the traditional system without large investment cost for the construction facilities, and
- To utilize newly introduced technology to adopt for further recovery work as much as possible.

In this context, the following considerations were taken into account in selecting structural type and materials:

- In selecting materials, locally available materials are given priority.
- Traditionally manufactured concrete piles (square pile) with maximum size of 40 cm x 40 cm were considered to be selected; and special piles like steel pipe pile, special featured concrete pile, and pre-stressed concrete piles were avoided.
- It was considered that pile driving barges of MPA can be utilized for new structural design.

Design concept of the pilot project facilities is described below.

#### 1) Structural Composition

The design ship (IWT market ship) has very small freeboard of only about 2 ft (0.6 m). In addition, cargo handling for this ship is performed manually.

In order to allow manual cargo handling, taking into consideration the high tidal range of about 6 m, the berthing facility shall be a structure such as a pontoon which can move vertically in accordance with the tidal fluctuation. However, anchoring system for the pontoon shall not be an anchor and chain system used for the existing pontoon jetties. The reason is that this system will not have sufficient pontoon holding capacity at a place where natural conditions are supposed to be severe like in Botahtaung area.

An anchoring dolphin system is considered appropriate to secure sufficient anchoring capacity for the pontoon portion. The anchoring dolphin system is composed of steel frames made up of anchoring devices with four rubber rollers inside each to allow smooth movement of the supporting columns that penetrate inside them.

A lower concrete floor with length of 15 m to accommodate manual cargo handling ships and cargo ships with gears during low tide conditions is provided in the concrete pier.

#### 2) Water Depth

The water depth at the pier shall allow the design ships to berth in the pier at any tidal condition.

The maximum draft of the design ships is estimated at 4.2 m. In consideration of possible siltation near the pier which is supposed to increase due to the effect of piles driven for the pier, the design water depth is determined at about 5.0 m.

Length of the Jetty

Previously, there were three tank pontoon jetties, each 200 ft (60 m) long, at this location over a total length of 920 ft (270 m).

The particular configuration of the pier is as follow:

- A set of pontoons approximately 75 m in length which accommodates IWT ships such as market ships;
- A 7.5 m high concrete floor portion with length of 145 m (inclusive of margin for mooring) which accommodates two cargo ships with length of 200 ft (60 m) which are expected to use this jetty; and
- A 15 m (30 m inclusive of stairs portion) long lower floor which accommodates fully loaded IWT cargo ships during low tide conditions.

The total length required for the concrete pier is 250 m (= 75 m + 145 m + 30 m).

Out of the 250 m long pier, the length subject to JICA’s pilot project is approximately 130 m.

### 3) Width of the Jetty

The width of the pier is determined taking into account the surface area utilization for cargo handling. To allow for mechanical cargo handling including truck traffic in the future, a width of 15 m at the concrete jetty section is determined.

### 4) Structure and Elevation of the Jetty

Considering the elevation of the existing pier at Botahtaung of about 7.2 m above CD and an anticipated extremely high water level of about 7.1 m during cyclones, an elevation of 7.5 m is determined for the concrete jetty.

Due to limited cargo hoisting height of cargo ships of about 5.4 m, a 7.5 m elevation pier could not be appropriate for cargo handling at lower tide situation. In order to accommodate cargo handling at lower tide situation, a lower elevation floor of 5.0 m above CD is determined.

The lower elevation floor will be submerged in water for several hours a day due to tide. As a result, soil particles in the river water are expected to be deposited on the floor. The deposited soil may create a slippery layer on the floor and this will result in danger to laborer activities. Grating structure for the lower floor section is adopted to avoid accumulation of soil particle deposits on the floor.

### 5) Pontoon

The pontoons are to be provided by MPA. In order to accommodate IWT market ships or similar ships, two pontoons will be installed. The pontoon available for the jetty is 120 ft (36 m) in length, 20 ft (6 m) in width, and 6.5 ft (2 m) in depth.

As indicated in above item “(1) Structural Composition”, the pontoons should be equipped with special anchoring devices. In addition, aluminum anodes are to be attached to the pontoons for cathodic protection.

#### 6) Access to the Pier and Pontoons

A 95 m long access way to the pier shall allow 20 ton truck traffic. For securing smooth truck traffic, one access way should have a width of 8 m to allow two-way traffic. The remaining concrete pier section of the former jetty pier (No. 5 upper) is to be connected to the new pier for manual handling only without spending costs for the construction. The access way shall be constructed using concrete beams.

An 80 ft long steel truss bridge owned by MPA is provided for pedestrian access and gangway from the concrete pier portion to the pontoon portion.

#### 7) Fender System and Bollards

Rubber fenders are to be installed on frames of the concrete pier. Large used rubber tires are to be hanged on the river side hulls of the pontoons as substitute fender.

Pontoons will be equipped with bollards, but additional bollards shall be installed on the concrete pier as necessary.

### (2) Design of Pier Structures (Jetty, Access Bridge and Porter Way)

#### 1) General

Based on the design criteria described in the previous section, the design work was carried out. For some works or structures, alternative methods and techniques are compared in order to determine the most suitable type.

#### 2) Alternatives

The following alternative structures were considered:

- Alternative 1 - Concrete block type quay wall and reclamation,
- Alternative 2 - Sheet pile type quay wall and reclamation,
- Alternative 3 - Pile deck type.

The pile deck type is the most suitable in Yangon Port because of the soft soil condition, very high speed of river current, materials and construction equipment. Pile deck type is selected for the pilot project.

#### 3) Design Conditions for the Jetty

Summary of design conditions for the jetty is shown in Table 13.3.4 below.

Table 13.3.4 Design Conditions for the Jetty

| | |
|---|---|
| Tide | HHWL = +7.1 m, HWL = +6.20 m, MSL = +3.23 m, LWL = +0.34 m |
| Maximum current | 6 knots (3 m/s) |
| Wave significant height | 1.90 m |
| Wave period | 3.5 s |
| Ship size | 1 General Cargo Ship (1,200 DWT) |
| Berthing speed | 0.15 m/s |
| Fender size | H = 300 mm |
| Bollard size | 25 ton |
| Live load | T20 Truck |
| Surcharge | 1.0 ton/m$^2$ for ordinal condition and<br>0 ton/m$^2$ for seismic condition |
| Crown level | +7.5 m and +5.0 m |
| Existing riverbed level | -5.0 m ~ -2.4 m CDL |
| Subsoil conditions | Soft clayey SILT, N average = 2 (riverbed ~ -7.6 m CDL)<br>Silty SAND, N average = 15 (-7.6 m ~ -16 m CDL)<br>SAND with Gravel, N average = 30 (below -16 m CDL) |
| Seismic Coefficient | Kh = 0.15 |

Source: JICA Project Team

Table 13.3.5 Design Conditions for the Access Bridge and Porter Way

| | |
|---|---|
| Tide | HHWL = +7.1 m, HWL = +6.20 m, MSL = +3.23 m, LWL = +0.34 m |
| Live load | T20 Truck (only for Access Bridge) |
| Surcharge | 0.5 ton/m$^2$ for ordinal condition, and<br>0.0 ton/m$^2$ for seismic condition |
| Crown level | +7.5 m |
| Existing riverbed level | -3.0 m ~ +5.0 CDL |
| Subsoil conditions | Soft clayey SILT, N average = 2 (riverbed ~ 6 m from the riverbed level)<br>Silty SAND, N average = 15 (6 m ~ 12 m)<br>Silty SAND or SAND with Gravel, N average = 30 (12 m ~ 18 m)<br>Dense SAND or SAND with Gravel, N average > 50 (below 18 m) |
| Seismic Coefficient | Kh = 0.15 |

Source: JICA Project Team

### 4) Calculation

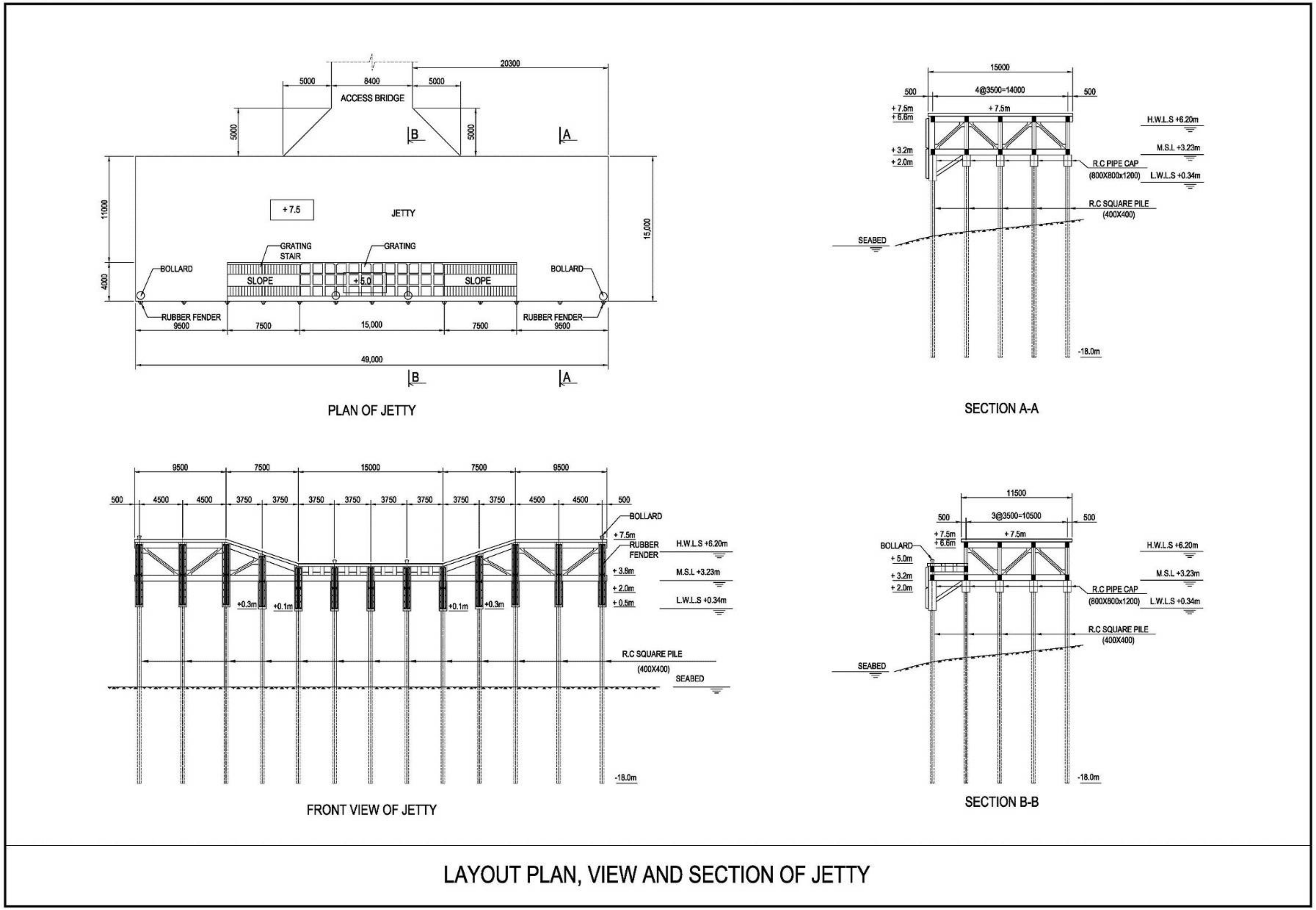
Pier structures were designed by three dimensional frame analysis method. From the results of structural calculations, the following dimensions were determined.

Table 13.3.6 Dimension of Superstructures

| | |
|---|---|
| Pile | 400 x 400 mm |
| Pile Head | 800 x 800 mm |
| Pillar | 400 x 400 mm |
| Beam | 400 x 600 mm |
| Diagonal | 300 x 300 mm |
| Slab | Thickness 300 mm |

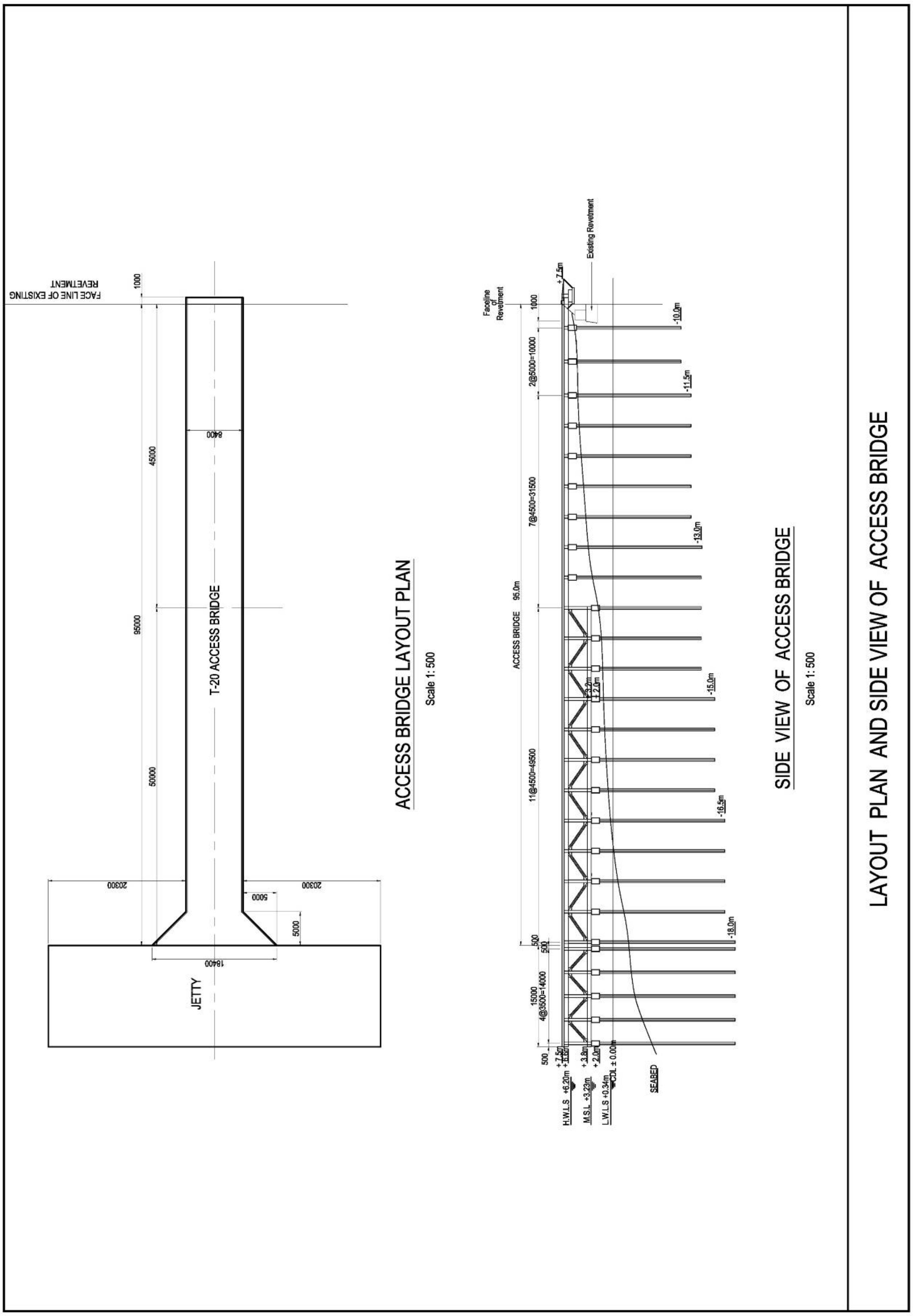
Source: JICA Project Team

The pile arrangement and superstructure are determined as shown in the following Figures 13.3.4 to 13.3.6.



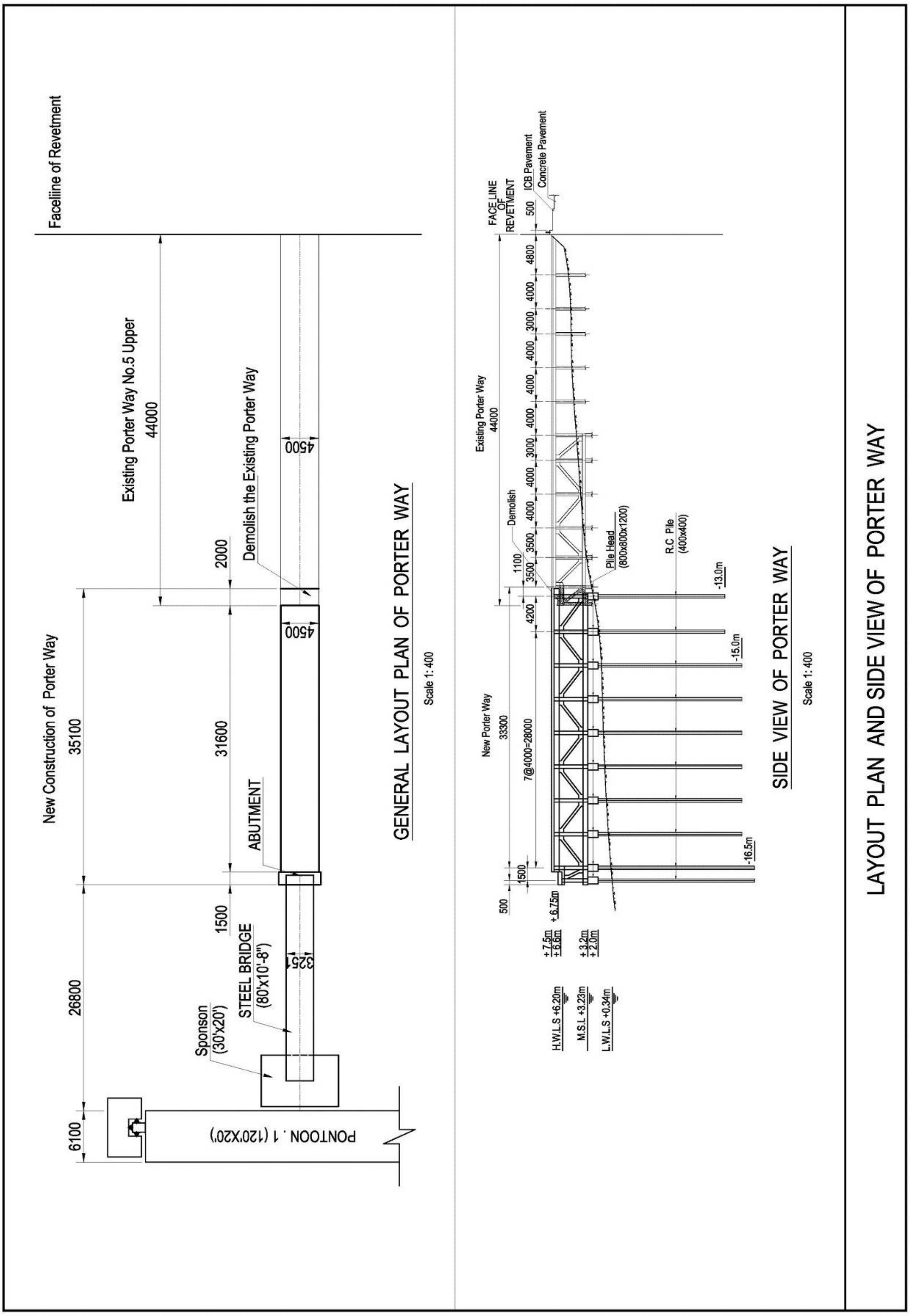
Source: JICA Project Team

Figure 13.3.4 Plan, Front View and Sections of Jetty



Source: JICA Project Team

Figure 13.3.5 Plan and Side View of Access Bridge



Source: JICA Project Team

Figure 13.3.6 Plan and Side View of Porter Way

## (3) Design of Dolphins

### 1) Method of Calculation Analysis

Dolphin structure was designed through the structural calculation by three dimensional Radosavljevic analysis method.

### 2) Design Conditions

Summary of design conditions is shown in Table 13.3.7 below.

Table 13.3.7 Design Conditions of the Dolphin

| | |
|---|---|
| Tide | HHWL = +7.1 m, HWL = +6.20 m, MSL = +3.23 m, LWL = +0.34 m |
| Maximum current | 6 knots (3 m/s) |
| Significant wave height | 1.90 m |
| Wave period | 3.5 s |
| Ship size | 3 marketing ships, 400 DWT + 300 DWT + 300 DWT |
| Berthing speed | 0.15 m/s |
| Pontoon size | Width = 6.10 m x Height = 2.00 m x Length = 36.50 m |
| Existing riverbed level | -5.0 m ~ -2.0 m |
| Subsoil conditions | Soft clayey SILT, N average = 2 (riverbed ~ 5 m from the riverbed level)<br>Silty SAND, N average = 15 (5 m ~ 12 m)<br>SAND with Gravel, N average = 30 (12 m ~ 17 m) |
| Seismic coefficient | Kh = 0.15 |

Source: JICA Project Team

### 3) Design Force of Wave and Current

Design forces of wave and current acting on the dolphin are estimated in Table 13.3.8 below.

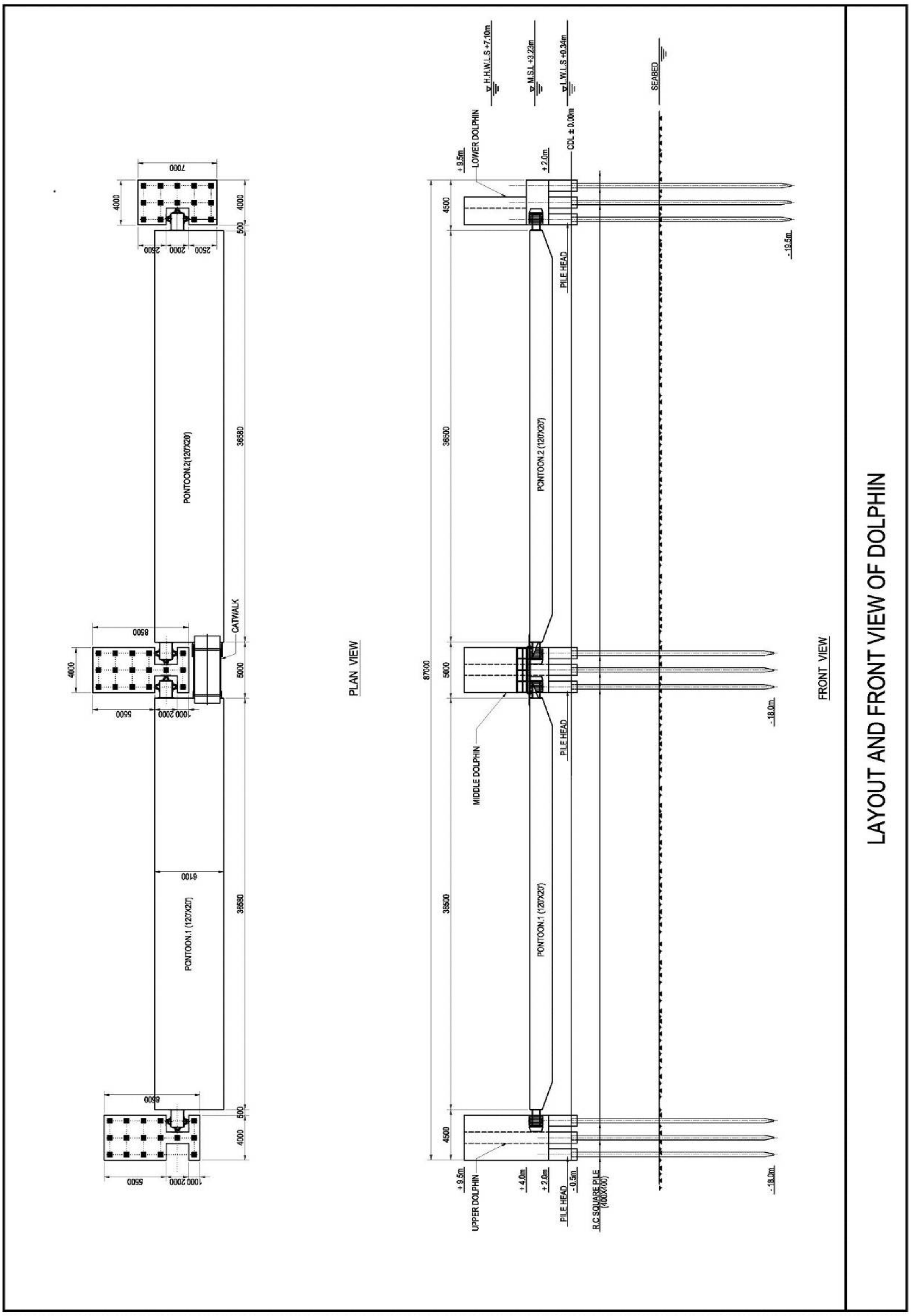
Table 13.3.8 Design Force Acting on the Dolphins

| | | Upper Dolphin | Middle Dolphin | Lower Dolphin |
|---|---|---|---|---|
| Wave | Force | 310 kN | 620 kN | 310 kN |
| | Direction | River to land | River to land | River to land |
| Current | Force | 82 kN | ±164 kN | 164 kN |
| | Direction | Downstream to upstream | Downstream to upstream and vice versa | Upstream to downstream |

Source: JICA Project Team

### 4) Structural Design of Dolphins

From the results of structure analysis, the pile arrangement, pile head and coping are designed as shown in the following Figure 13.3.7.



Source: JICA Project Team

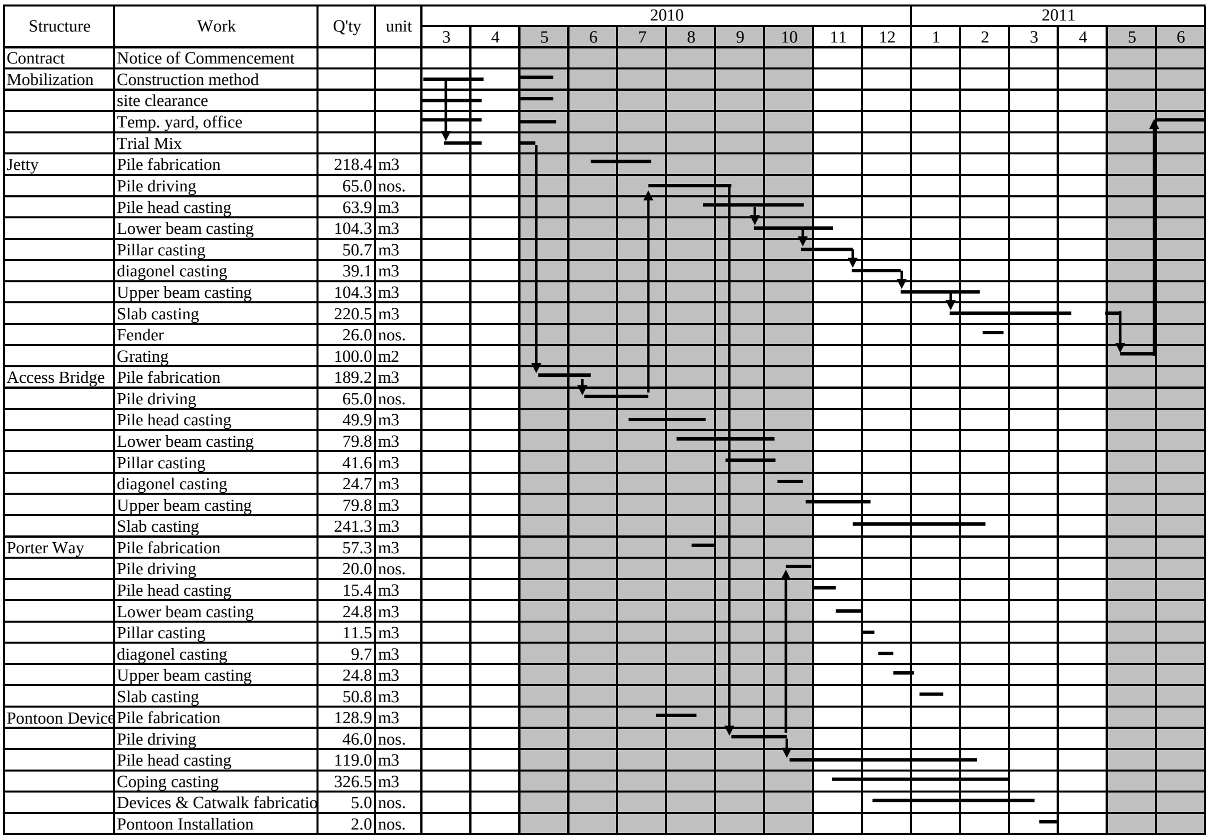
Figure 13.3.7 Plan and Front View of Dolphin

## 13.3.5 CONSTRUCTION METHOD

### (1) Overall Implementation Program

Construction work schedule was estimated as shown in Figure 13.3.8. The total construction period is estimated at 16 months from the notice of the commencement of work.

The gap of around three weeks in April is a long vacation for the New Year holiday (water festival) in Myanmar. The rainy season is from May to October, so a slower construction speed during the rainy season was applied.



| Structure | Work | Q'ty | unit |
|---|---|---|---|
| Contract | Notice of Commencement | | |
| Mobilization | Construction method | | |
| | site clearance | | |
| | Temp. yard, office | | |
| | Trial Mix | | |
| Jetty | Pile fabrication | 218.4 | m3 |
| | Pile driving | 65.0 | nos. |
| | Pile head casting | 63.9 | m3 |
| | Lower beam casting | 104.3 | m3 |
| | Pillar casting | 50.7 | m3 |
| | diagonel casting | 39.1 | m3 |
| | Upper beam casting | 104.3 | m3 |
| | Slab casting | 220.5 | m3 |
| | Fender | 26.0 | nos. |
| | Grating | 100.0 | m2 |
| Access Bridge | Pile fabrication | 189.2 | m3 |
| | Pile driving | 65.0 | nos. |
| | Pile head casting | 49.9 | m3 |
| | Lower beam casting | 79.8 | m3 |
| | Pillar casting | 41.6 | m3 |
| | diagonel casting | 24.7 | m3 |
| | Upper beam casting | 79.8 | m3 |
| | Slab casting | 241.3 | m3 |
| Porter Way | Pile fabrication | 57.3 | m3 |
| | Pile driving | 20.0 | nos. |
| | Pile head casting | 15.4 | m3 |
| | Lower beam casting | 24.8 | m3 |
| | Pillar casting | 11.5 | m3 |
| | diagonel casting | 9.7 | m3 |
| | Upper beam casting | 24.8 | m3 |
| | Slab casting | 50.8 | m3 |
| Pontoon Device | Pile fabrication | 128.9 | m3 |
| | Pile driving | 46.0 | nos. |
| | Pile head casting | 119.0 | m3 |
| | Coping casting | 326.5 | m3 |
| | Devices & Catwalk fabricatio | 5.0 | nos. |
| | Pontoon Installation | 2.0 | nos. |

Source: JICA Project Team

Figure 13.3.8 Construction Work Schedule

### (2) Construction Equipment in Myanmar

Construction method was assumed considering the site conditions and construction methods commonly applied in Myanmar.

#### 1) Piling Barge

Local construction companies in Myanmar do not own any floating piling barge. It is owned by government organizations only. There are two types of piling barge as shown in the following Table 13.3.9. The maximum limit of pile dimension to be driven by the piling barge is 21 m for a 400 mm x 400 mm square pile.

Table 13.3.9 Specifications of Piling Barge (K35 Model)

| Description | Unit | K35 model |
|---|---|---|
| Overall length | mm (ft) | 4.55 (14' 11") |
| Diameter of anvil | mm (ft) | 700 (2'-3 9⁄16") |
| Distance between center of hammer and lead pipe | mm (ft) | 490 (1'-7 5⁄16") |
| Max: width of hammer | mm (ft) | 881 (2'-10 ¾") |
| Total weight | ton (lbs) | 7.5 (16,500) |
| Weight of ram | ton (lbs) | 3.5 (7,700) |
| No. of blows | blow/min | 39-60 |
| Energy output per blow | ton m (ft. lbs) | 10.5 (75,900) |
| Explosion pressure on pile | ton (lbs) | 150 (330,700) |
| Fuel consumption (light oil) | L/h (gal/h) | 12-16 (2.75-3.5) |
| Lube oil consumption | L/h (gal/h) | 2 (0.5) |
| Fuel tank capacity | L (gal) | 48 (10.5) |
| Lube oil chamber capacity | L (gal) | 9.5 (2.1) |
| Cooling water tank capacity | L (gal) | 140 (30.8) |
| Lubricant for ram | - | Motor oil SAE 40-50 |
| Lubricant for anvil | - | Superheated steam cylinder oil |
| Bearing capacity for piles (long term) | ton (lbs) | 50-150 (110,200-330,600) |
| Maximum batter angle | degrees | 20 |

Source: JICA Project Team

### 2) Crane Barge

Local construction companies do not own any crane barge in Myanmar. They could rent from abroad or use a crawler crane mounted on a barge. The operating radius of the crawler on a barge in Myanmar is 9 m and the hanging capacity is 10 ton only, because of the limited capacity of the crawler crane and barge.

### 3) Diver Equipment

Local construction companies do not have enough experience of working in water because diving equipment is not enough in quantity and quality in Myanmar and because of the very high turbidity level of Yangon River. Underwater construction shall be avoided as much as possible while the construction method of the pilot project is being formulated.

### 4) Construction Equipment Overall

Construction equipment such as cranes, backhoes, and dump trucks are quite few and old in the construction market in Myanmar. Construction equipment is not used so much and the use of manual labor prevails.

## (3) Construction Method

### 1) Pile Fabrication, Driving and Pile Top Treatment

Square precast 400 mm x 400 mm RC pile is the most commonly used for pier structures catering to the inland waterway ships in Yangon, because there are only a few piling barges in Myanmar. The piling barge does not have sufficient capacity to handle piles larger than 400 mm x 400 mm x 21 m. In this project, the construction method and design were formulated based on the above size of square piles.

Piling shall start from the access bridge for T20 due to the narrow area of the construction site and the construction sequence, and continue on to the jetty, dolphins for anchoring and finally to the porter way. The pile numbers and length are shown in the following Table 13.3.10.

Table 13.3.10 Summary of Pile Numbers and Length

| Structures | Length (m) | Numbers | Total Length (m) |
|---|---|---|---|
| Jetty | 21.0 | 65 | 1365 |
| Access Bridge | 21.0 | 5 | 105 |
| | 19.5 | 12 | 234 |
| | 18.0 | 12 | 216 |
| | 16.0 | 9 | 114 |
| | 19.4 | 6 | 116.4 |
| | 17.9 | 15 | 268.5 |
| | 16.4 | 6 | 98.4 |
| Porter Way | 19.5 | 4 | 78 |
| | 18.0 | 12 | 216 |
| | 16.0 | 4 | 64 |
| Dolphin | 20.5 | 3 | 61.5 |
| | 20.0 | 3 | 60 |
| | 19.0 | 14 | 266 |
| | 17.0 | 8 | 136 |
| | 16.0 | 12 | 192 |
| | 15.0 | 6 | 90 |
| **TOTAL** | **----** | **196** | **3680.8** |

Source: JICA Project Team

### 2) Concrete Frame Members and Slab

Because of the pile dimension’s limitation and the depth of soil bearing layer, the pile top level does not reach the crown level of +7.5 m CDL taking into consideration the tide and wave conditions as mentioned above. Because of the distance between the pier slab and pile head construction, which is five meters, concrete frame members for the pile head, lower beam, pillar, and diagonal were designed. Contractors in Myanmar have no experience in driving precast concrete piles for the port project in Yangon. In accordance with generally accepted practice, the precast concrete method was not selected but in-situ concrete casting method was adopted.

After completion of the pile driving work, the construction process below was assumed to follow.

- Concrete breaking of the top of pile to expose the rebar
- Establishment of support and formwork for the pile head,
- Rebar arrangement for the pile head and connection with the pile rebar,
- In-situ concrete casting of the pile head,
- Establishment of support and formwork for the lower beam,
- Rebar arrangement and in-situ concrete casting for the lower beam,
- Establishment of support and formwork for the pillar and diagonal,
- Rebar arrangement and in-situ concrete casting for the pillar and diagonal,
- Establishment of support and formwork for the upper beam,
- Rebar arrangement and in-situ concrete casting for the upper beam
- Establishment of support and formwork for the slab, and
- Rebar arrangement and in-situ concrete casting for the slab.

Table 13.3.11 Summary of Superstructure Concrete Volumes

| **Structures** | **Concrete Volume ($m^3$)** |
|---|---|
| Jetty | 583 |
| Access Bridge | 517 |
| Porter Way | 137 |
| Dolphin | 446 |
| **TOTAL** | **1,682** |

Source: JICA Project Team

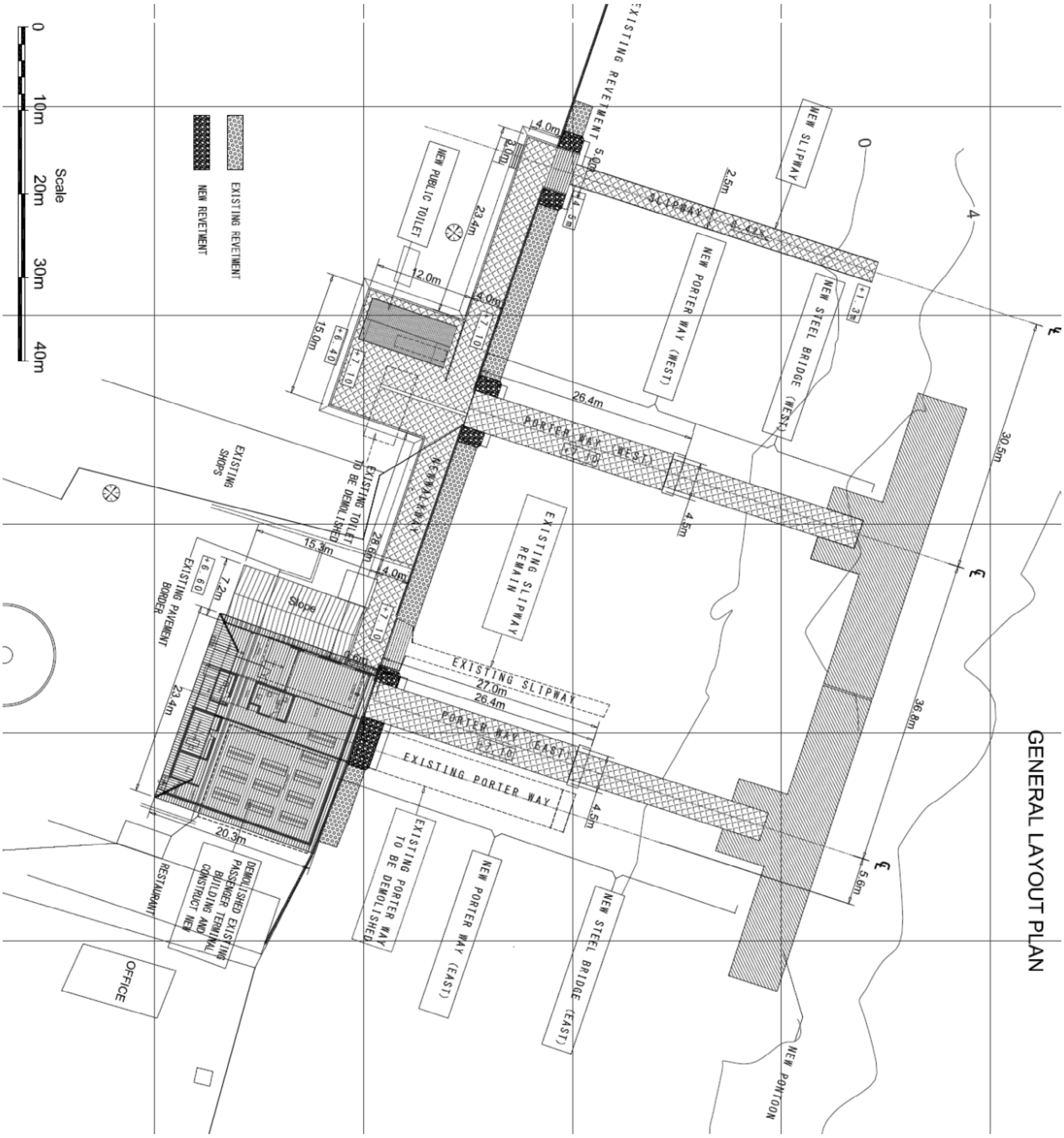
### 3) Anchoring Devices, Catwalk and Slip Panel

Four anchoring devices, one catwalk, twelve slip panels for two pontoons, and three dolphins, will be fabricated. The anchoring devices and slip panels will be made of stainless steel and the catwalk will be made of steel and painted.

## 13.4 THE PILOT PROJECT (DALLA FERRY TERMINAL)

### 13.4.1 DESCRIPTION OF THE PILOT PROJECT OF DALLA

Main features of the final plan for the pilot project shown in Figure 13.4.1 include:



Source: JICA Project Team

Figure 13.4.1 Layout Plan and Project Components of the Restoration Works at Dalla

- Two units of 22.5 m long movable steel bridges,
- Two concrete-coated pontoons (36.8 m long, 6 m wide, and 2.5 m deep),
- Two porter ways on rigid concrete pile foundation,
- Walkway with interlocking concrete pavement,
- Slipway on pile foundation and staircase, and
- Passenger terminal and other buildings.

### 13.4.2 APPLICABLE STANDARDS, CODES AND SPECIFICATIONS

The structures of the pilot project for Dalla are mainly the same as for Botahtaung. Please refer to Section 13.2.2.

### 13.4.3 DESIGN CRITERIA

### (1) Natural Condition

Design criteria covers various items of natural condition and are described hereinafter.

**1) Tide**

Same as for Botahtaung.

**2) Tidal Current**

Same as for Botahtaung.

**3) Wind**

There is no wind velocity observation record of the site when Cyclone Nargis passed.

Wind record of Cyclone Nargis in Yangon is adopted instead which indicates the following:

Maximum wind velocity: 59.2 m/s

Maximum instantaneous wind velocity: 72 m/s

Therefore, it is considered that 60 m/s wind is the maximum wind velocity, and 72 m/s wind is the maximum instantaneous wind velocity.

**4) Wave**

Wave height is estimated applying the Sverdrup Munk Bretschneider (SMB) method. Design wind speed is assumed at 60 m/sec for all directions.

Design wave heights were estimated for three directions as shown in Table 13.4.1 below.

Table 13.4.1 Design Wave Height at Botahtaung Point

| Direction | Effective Fetch | Wave Height ($H_{1/3}$) | Wave Period |
|---|---|---|---|
| NE | 0.9 km | 0.9 m | 2.4 s |
| NNE | 0.8 km | 0.9 m | 2.4 s |
| N | 0.8 km | 0.9 m | 2.4 s |
| NNW | 0.9 km | 0.9 m | 2.4 s |
| NW | 1.4 km | 1.2 m | 2.6 s |

Source: JICA Project Team

**5) Earthquakes and Seismic Condition**

In Myanmar, most of the earthquakes occur in the northwest region (mainly in Sagain Division). Earthquakes occurring in close proximity to Yangon are not frequent. Earthquakes that occurred from 1900 to 2009 in Yangon area (within a radius of 600 km) are shown in Table 13.4.2 below. During the last 110 years, Yangon experienced six large earthquakes which had a magnitude of more than 5.0. Among these earthquakes, Bago Earthquake in 1930 caused large damage in Bago.

Table 13.4.2 Past Earthquakes Recorded in Myanmar

| Year/Month/ Date | Latitude | Longitude | Magnitude (Richter Scale) | Distance from Yangon | Remarks |
|---|---|---|---|---|---|
| 1912.05.23 | 21° 00' 00" N | 97° 00' 00" E | 8.0 | 475 km | Mandalay, Mogok |
| 1930.05.05 | 17° 00' 00" N | 96° 30' 00" E | 7.3 | 68 km | Bago, casualty = 500 |
| 1930.12.03 | 18° 12' 00" N | 96° 24' 00" E | 7.3 | 159 km | Pyu |
| 1943.10.23 | 21° 30' 00" N | 93° 30' 00" E | 7.2 | 592 km | Swa |
| 1975.07.08 | 21° 29' 00" N | 94° 42' 00" E | 6.5 | 542 km | Pagan |
| 2003.09.21 | 19° 55' 01" N | 95° 40' 19" E | 6.6 | 351 km | |

(Period: 1900 – 2009, Magnitude: over 5.0, Distance from Yangon: less than 600 km)
Source: Department of Meteorology and Hydrology, MOT

The earthquake called Bago Earthquake had a magnitude of 7.3 and the distance from the epicenter to the pilot project site is 68 km. The horizontal ground acceleration due to the Bago Earthquake was estimated at 0.13g.

Myanmar has been divided into five categorized levels of seismic coefficient and Yangon region is classified as Level II. From this classification, the horizontal seismic coefficient of Yangon region is estimated to be between 0.10 to 0.15.

Judging from the estimated intensity of Bago Earthquake as well as seismic zone category indicated in the zone map, design horizontal seismic coefficient (Kh) was assumed at 0.15.

### 6) Soil Condition of Botahtaung Jetty Site

There is no existing soil investigation data around Dalla Jetty; therefore, soil investigation (two boreholes) and topographic survey (land area = 0.9 ha, river area = 1.2 ha) were carried out in 2013 by the JICA Project Team.

The borings were conducted at locations in the Dalla Jetty area shown in Figure 13.4.2. The boring logs are shown in Figure 13.4.3. Table 13.4.3 provides the design source conditions established from the boring results.

From the result of soil investigation of the two boreholes at Dalla Ferry Terminal in 2013, the project area is generally classified as “River Filled Deposit, Alluvium Holocene”. According to the SPT test, subsoil can be mainly defined as follows:

#### (a) Clayey Silt

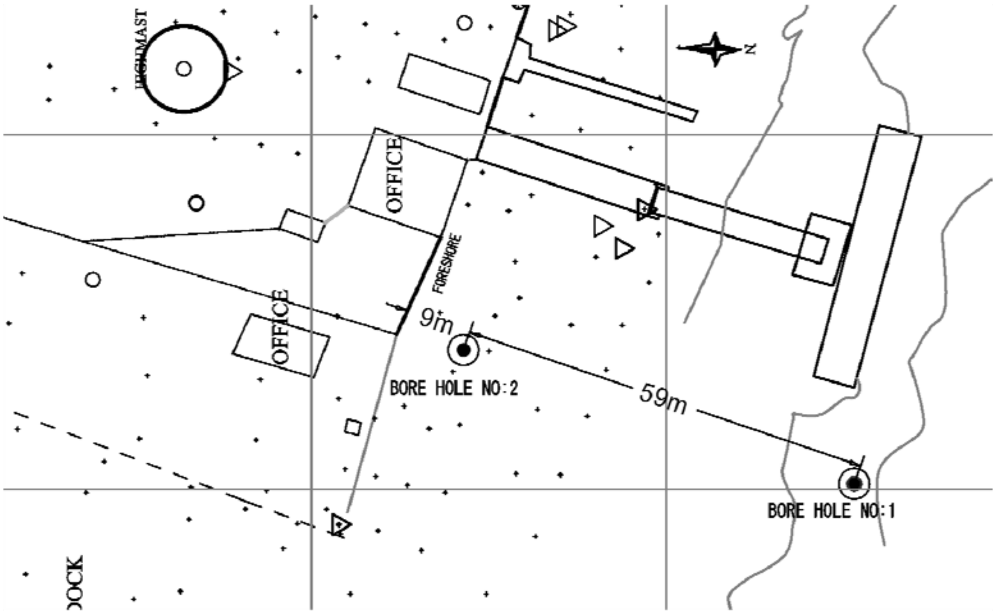
This is the top soil layer at every borehole with a thickness of approximately 0-12 m. This is known as river filled deposit. It contains little black peat soil, medium plasticity, soft to firm, cohesive and moist. The blow count is between 2 to 12. The color is bluish grey.

#### (b) Silty Sand

This layer is under the top soil layer of BH.2 at the depth between 8.2-10.3 m.This layer is medium dense to dense, with fine to medium grained sand and contains mica flake. The color is yellowish and the blow count ranges from 19 to 28.

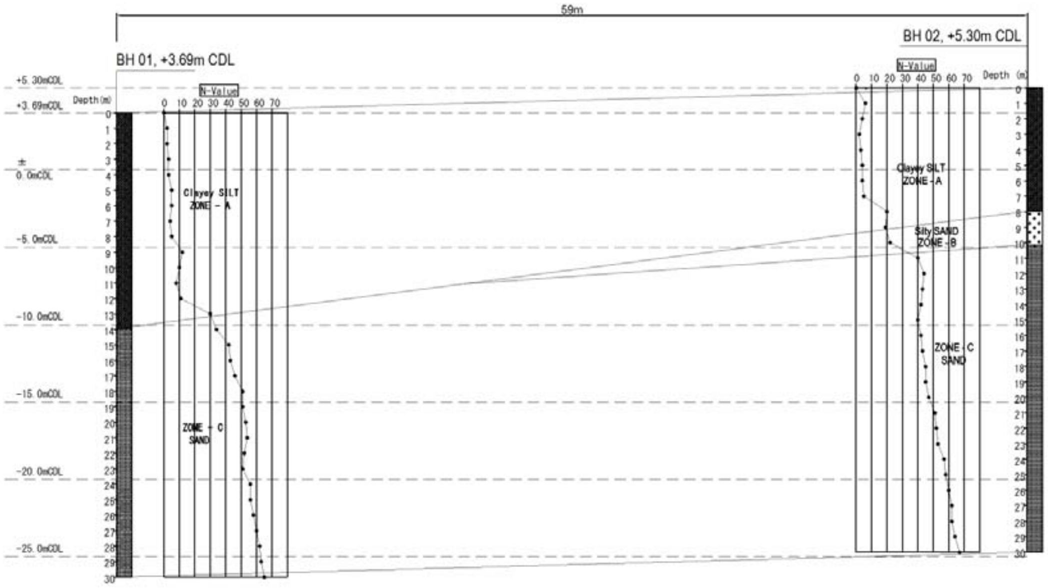
### (c) Sand with Gravel

This layer is under the second layer of BH.1 at the depth between 12.5-13.5 m. This layer is dense to very dense, with medium to coarse grain. The color is yellowish brown and the blow count is between 45 to > 60. The consistencies of plastic soils are soft to firm. For this plastic soil layer, liquid limit (LL) and plastic limit (PL) range between 42% to 46% and 24% to 29%, respectively. The plasticity index (PI) is between 16% and 17%.



Source: JICA Project Team

Figure 13.4.2 Location Map of Boreholes



Source: JICA Project Team

Figure 13.4.3 Profile of Soil Investigations

Table 13.4.3 Design Soil Condition

| Soil | Mean N Value | Cohesion C (kN/m$^2$) | Internal Friction Angle $\phi$ (° ) | Unit Weight $\gamma$ (kN/m$^3$) |
|---|---|---|---|---|
| Clayey SILT | 5 | 47.6 | | 18 |
| Silty SAND | 20 | - | 29 | 20 |
| SAND | 40 | - | 35 | 20 |

Source: JICA Project Team

### 7) Coordinate and Elevation

The basis of the coordinates and elevation is the same as that of Botahtaung. Location and elevation of temporary benchmark and two boreholes for this project are shown in Table 13.4.4 below.

Table 13.4.4 Location and Elevation of Temporary Benchmark and Boreholes

| Test/Hole No. | Coordinates | | Elevation (m) |
|---|---|---|---|
| | East (X) (m) | North (Y) (m) | |
| BH - 1 | 196899.26 | 1855476.57 | 3.69 |
| BH - 2 | 196880.391 | 1855421.46 | 5.30 |
| TMB - 1 | 196860.50 | 1855446. 98 | 7.10 |

Source: JICA Project Team

## (2) Operation Conditions

### 1) Ships Subject to the Design

The ships using the project site shall be mainly IWT's passenger and cargo ships. Dimensions of those ships are summarized in Table 13.4.5 below.

Table 13.4.5 Dimensions of Target Ship for the Pilot Project

| Structure | For Pontoon Berth | Slipway |
|---|---|---|
| Type of ship | Passenger / Cargo | Small Passenger Boat |
| Reg. tonnage | 257.14 | N/A |
| Length overall | 41.3 m | 9.1 m |
| Width | 9.0 m | 1.8 m |
| Full load draft | 1.0 m | N/A |
| Depth | 1.8 m | 0.9 m |

Source: JICA Project Team

### 2) Berthing Speed

The ferry boats do not use any tug boats at Yangon Port. The berthing speed for design is assumed at 15 cm/s based on the Japanese standard and hearing results from MPA.

Private Note: Ships, especially ferries, do not follow standards. You should assume berthing speeds will be 2-3 times the standard at adverse conditions.

#### 3) Live Load

Design live load is not considered for the porter way. The design live load of the movable steel bridge and pontoon are 5.0 kN/m$^2$.

#### 4) Surcharge

Design surcharge load is assumed at 5 kN/m$^2$ under normal conditions and 0.0 tons under seismic conditions.

### (3) Material Conditions

#### 1) Steel

- Steel material constants
- Modulus of elasticity E 2.0 x 105 N/mm$^2$
- Shear modulus G 7.7 x 104 N/mm$^2$
- Poisson's ratio v 0.3
- Coefficient of linear thermal elongation α 12 x 10-6 m/m°C

#### 2) Structural Steel

- Type of steel: SS400, SM400, SMA400
- Tensile, compressive stress 140 N/mm$^2$
- Shearing stress 80 N/mm$^2$
- Bearing stress 210 N/mm$^2$

#### 3) Allowable Tensile Stresses of Steel Reinforcements

Table 13.4.6 Allowable Tensile Stresses of Steel Reinforcement

(Unit: N/mm$^2$)

| Type of steel reinforcement (available material) | SD295 A,B |
|---|---|
| (a) Allowable stress in normal cases | 176 |
| (b) Allowable stress determined by figure strength | 157 |
| (c) Allowable stress determined by yield strength | 176 |

SD345 is not popular in Myanmar
Source: JICA Project Team

### 4) Concrete

Table 13.4.7 Allowable Stresses of Reinforced Concrete

(Unit: N/mm$^2$)

| Type of stress | | | Standard concrete strength | |
|---|---|---|---|---|
| | | | 24 | 40 |
| | | | Structural Concrete | Concrete Pile |
| Allowable bending compressive stress (σca) | | | 9 | 14 |
| Allowable shearing stress | No calculating diagonal | For beam | 0.45 | 0.55 |
| | | For slab | 0.9 | 1.1 |
| | Diagonal RC | Shearing F | 2.0 | 2.4 |
| Allowable bond stress | Shape steel | | 0.7 | 0.9 |
| | Plain bars | | 0.8 | 1.0 |
| | Deformed bars | | 1.6 | 2.0 |
| Allowable bearing stress | | | 0.3fck’ | |

Source: JICA Project Team

### 5) Covering for Reinforcement

Table 13.4.8 Standard Value of Covering for Reinforcement

| Location | Covering Depth |
|---|---|
| Portion directly washed by seawater and portions subjected to severe sea breeze | 70 mm |
| Portions other than above | 50 mm |

Source: JICA Project Team

### 6) Unit Weight

Table 13.4.9 Unit Weight of Material

| Materials | Unit Weight (kN/m$^3$) |
|---|---|
| Steel | 77.0 |
| Reinforced concrete | 24.0 |
| Plain concrete | 22.6 |
| Stone | 26.0 |
| Sand, gravel, rubble (dry condition) | 16.0 |
| Sand, gravel, rubble (wet condition) | 18.0 |
| Sand, gravel, rubble (saturated condition) | 20.0 |
| Sand, gravel, rubble (effective weight in water) | 10.0 |

Source: JICA Project Team

### 13.4.4 SOUNDNESS OF THE EXISTING PORTER WAY

#### (1) General

The existing porter way of Dalla Ferry Terminal Jetty was very old and seems without sufficient maintenance. The damage to the structure was apparent. It may be dangerous to use the existing porter way without repair and/or reconstruction. The JICA Project Team implemented the study of the soundness of the porter way and the recoverability.

#### (2) Program

1) On-site investigation (October 2013): Japanese experts inspected the jetties.
2) Laboratory test in Japan (November 2013): Core samples were taken from the jetties. Laboratory test was carried out in Japan.

#### (3) Test Items

- Visual test (cracking, corrosion of rebar)
- Hammering test (spalling and delamination)
- Strength of concrete
- Location of rebar (covering concrete thickness)
- $CO_2$ attack (carbonation )
- Salt attack (chloride )
- Corrosion of rebar

#### (4) Survey Result

**1) Visual Test (Cracking, Corrosion of Rebar)**

Visual test for jetty

(How to find, measure and record damages to concrete and rebar)

**(a) Whole View of the Jetty**

**(b) Damages (Deterioration) to Structural Members**

- Cracks
- Spalling of concrete cover
- Delamination of concrete cover
- Rebar corrosion

**(c) Record**

#### (5) Whole View of the Jetty

Check obvious settlement, leaning and deformation of concrete structure by taking a whole view of the jetty.

Source: JICA Project Team

Photo 13.4.1 Whole View of Dalla Port Jetty

### (6) Damages (Deterioration) to Structural Members

Check for obvious damages.

#### 1) Cracks

- Find cracks with width over 0.3 mm.
- Check a typical crack width at the widest point.
- Measure the crack width with a crack scale or measure.

Source: JICA Project Team

Photo 13.4.2 Cracks

#### 2) Spalling of Concrete Cover

- Check spalling (measure length and width).

### 3) Delamination of Concrete Cover

- Check for loss and concrete member with a decreasing cross section.
- Check the rebar diameter of the exposed part (measure length and width).

Source: JICA Project Team

Photo 13.4.3 Spalling and Delamination of Concrete Cover

### 4) 2.4 Rebar corrosion

- Check exposed rebar for corrosion (condition of rust).
- Measure length, width, and rebar diameter.

Source: JICA Project Team

Photo 13.4.4 Spalling and Delamination of Concrete Cover

## (7) Record

### 1) Record Cracks and Other Damages by Freehand Drawing

- Make a photo record at the measured locations and number the photos.

Source: JICA Project Team

Photo 13.4.5 Freehand Drawing and Taking Photo

### 2) Hammering Test (Spalling and Delamination)

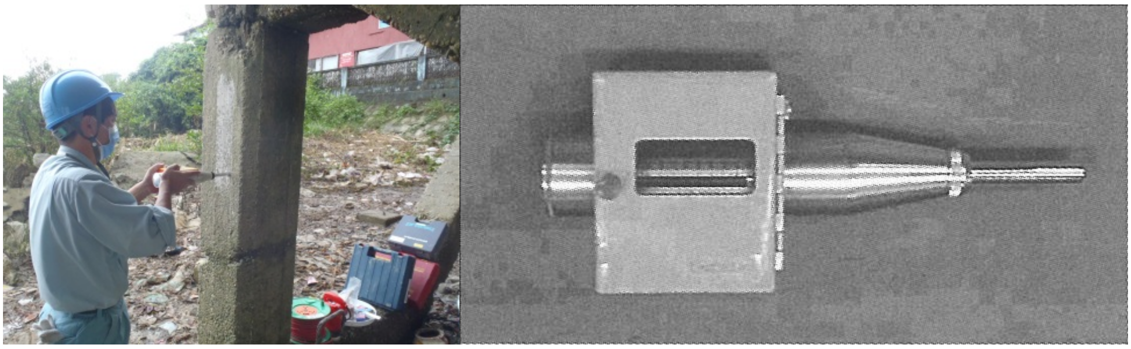
- Subsurface defects inside concrete, such as voids, can be found by hammering test.
- Sound of hammering of concrete surface would be different between good part and deteriorated part.

Source: JICA Project Team

Photo 13.4.6 Hammering Test (Spalling and Delamination)

### 3) Strength of Concrete

- Rebound hammer (schmidt hammer) is used to estimate concrete strength by measuring rebound hardness of concrete surface.
- Rebound hardness is influenced by condition of concrete surface (roughness and gravel, etc.)
- Core Samples

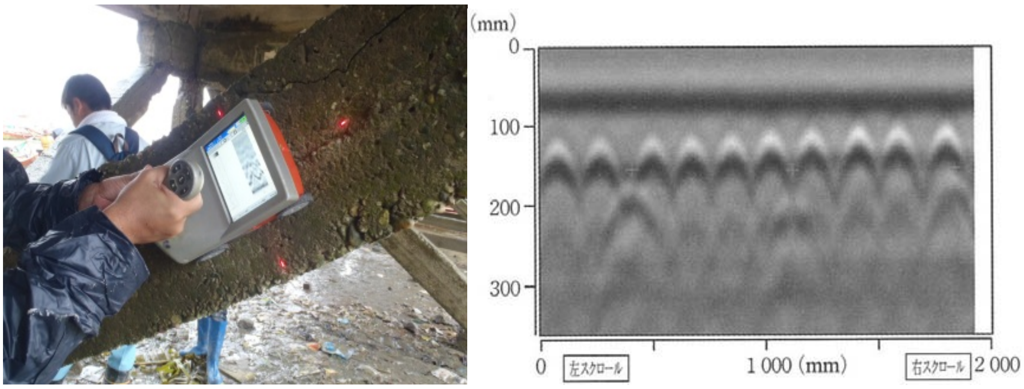


Source: JICA Project Team

Photo 13.4.7 Estimating Strength of Concrete Using Rebound Hammer

### 4) Location of Rebar (Concrete Cover Thickness)

- Electromagnetic wave is used as “radar method”.
- Electromagnetic waves reflect from the rebar in the concrete. This provides information regarding the inner concrete.
- Location of rebar and cover thickness.



Source: JICA Project Team

Photo 13.4.8 Location of Rebar

### 5) $CO_2$ Attack (Carbonation)

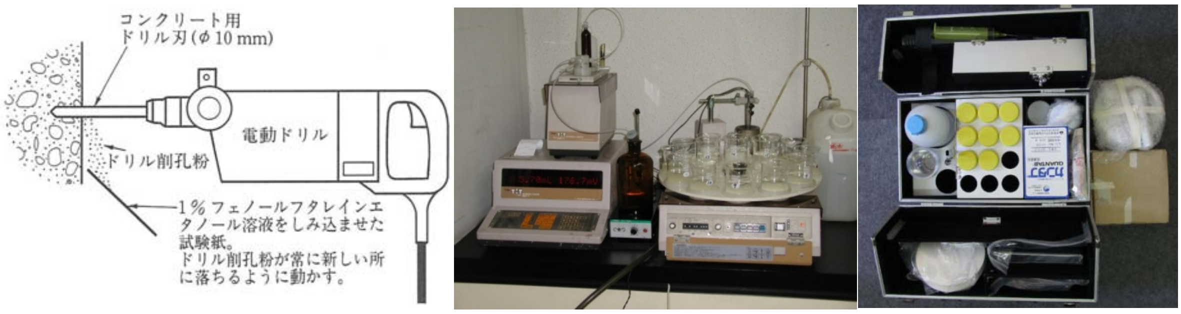
- Carbonation depth in concrete is measured by core sampling or chipping concrete using 1% Phenolphthalein liquid solution.
- High alkaline part would change to red color; carbonated part would not change color.

Source: JICA Project Team

Photo 13.4.9 Core Sample and Chipping Concrete

### 6) Salt Attack (Chloride)

- Concrete core sample or drilling sample (powder) of concrete are used to measure chlorides contained in concrete.
- Using “Qantabu” or “Lab. Experiment” to analyze Chlorides in concrete.



Source: JICA Project Team

Photo 13.4.10 Drill Sample and Laboratory Test

### 7) Corrosion of Rebar

- When rebar is exposed by delamination, degree of corrosion is inspected using visual test.
- Before delamination, by chipping the concrete cover out and exposing the rebar, the degree of corrosion of the rebar in the concrete can be inspected.

Source: JICA Project Team

Photo 13.4.11 Chipping Concrete Cover and Exposing Rebar

## (8) Summary of Results of Inspection

### 1) Concrete Strength

- 16 to 19 $N/mm^2$ (Core sample)
- 29 to 37 $N/mm^2$ (Schmidt hummer test)
  ⇒ effect of gravel on concrete surface

### 2) Carbonation Depth

- 6 to 20 mm (smaller than cover depth)

### 3) Salt ($Cl^-$) at Rebar

- 2 to 5 $kg/m^3$ (over 1.2 $kg/m^3$)

### 4) Rebar Corrosion

- Spotted rust (good area)
- Much rust and breaking (poor area)

## (9) Characteristic of Jetty's Deterioration

- Area of high water level is in poor condition.
- Because of too much salt, $CO_2$, water and $O_2$.

Source: JICA Project Team

Photo 13.4.12 Area in Poor Condition (Dalla Jetty)

- Area of low to high water level is in good condition.
- Because of too much salt, $CO_2$ and water.
- Because of shortage of $O_2$.

Source: JICA Project Team

Photo 13.4.13 Area in Good Condition (Dalla Jetty)

- Some parts are in poor condition.
- Because of shock and load.

Source: JICA Project Team

Photo 13.4.14 Area in Poor Condition (Dalla Jetty)

## (10) Evaluation and Judgment

Classification of Evaluation Results

(Guidelines on Strategic Maintenance for Port Structures)
http://www.pari.go.jp/unit/kozo/guidelines.html

Table 13.4.10 Classification of Evaluation

| Evaluation | Condition of Facility |
|---|---|
| A | Facility performance has been degraded. |
| B | Facility performance degradation could occur if left unattended. |
| C | No deformations related to facility performance were found but continuous observation is necessary. |
| D | No major deformation was found and sufficient performance is being maintained. |

Source: JICA Project Team

Considering the degree of performance degradation, importance of the structure, and life-cycle cost, facility performance has been degraded (A) (Deterioration stage).

Considering the degree of performance degradation and importance of the structure, Dalla Port Jetty should be reconstructed.

## (11) Technical Transfer to Counterpart

The JICA Project Team conducted the workshop for the maintenance of reinforced concrete in 2013. It is described in Section 10.6.4.

### 13.4.5 DESIGN OF FACILITIES

#### (1) Design Concept

Basic concepts of the implementation of the pilot project are as follows:

- To introduce new technology to the traditional system without large investment cost for the construction facilities, and
- To utilize newly introduced technology to be adopted in further recovery work as much as possible.

In this context, the following were taken into account in selecting the structural type and materials:

- In selecting materials, locally available materials are given priority.
- Traditionally manufactured concrete square piles with size of 40 cm x 40 cm was considered to be the best option, whereas special piles like steel pipe pile and prestressed concrete piles were avoided. It was considered that pile driving barges of MPA can be utilized for new structural design.
- For earthquake-resistance and to simplify the jetty structure, concrete octagonal-shaped piles with pile size of 50 cm x 50 cm to be driven by the existing piling barge in Myanmar was considered.
- For the reduction of maintenance cost of pontoons, some upgrading measures were considered.

The design concept of the pilot project facilities is described below.

##### 1) Porter Way

Existing porter way is composed of 40 cm x 40 cm square piles and truss braces as shown in the photos in Section 13.4.4.

Square piles are not strong against seismic force. Also, the 400 mm x 400 mm x 21 m pile will easily crack during lifting operations prior to piling.

Because of the 400 mm square pile, pile length above ground could not be longer so truss brace shall be needed to maintain the strength of the structure. But it is not a simple structure. It will require a long construction period including difficult underwater construction work.

The JICA Project Team proposed octagonal-shaped piles of 500 mm x 500 mm and simple upper structure without truss bracing for the pilot project.

##### 2) Movable Steel Bridge

The following three points had been devised in this project:

**(a) Strength Calculations**

After Cyclone Nargis, the design condition for wind speed in Yangon was changed. It became necessary to apply wind speed of 60 m/s in the design requirements for corresponding infrastructures and buildings. In addition, the seismic loads subject to kh = 0.15 shall be considered as well. Therefore, the design strength calculations and analysis of each member were carried out in three dimensional models of the structural forms.

### (b) Change of Structure Type

The roof coverage is required for this movable steel bridge. If an arch type like the existing is used, roof construction cannot be simplified due to different distances to the roof. Therefore, considering the construction simplification and precision improvement, the roof had to be a linear structure.

### (c) Installation of Center Pin

By placing the center pin on the pontoon side, the curvature of the saucer of the roller and chain will not be required, and the structure was simplified. In addition, it is possible to reduce the misalignment towards the normal parallel direction. However - as with the existing pontoon, pin or the like - in order to reduce the impact to the joints of the pontoon side and porter way side, it is important to regularly check the tension in the anchor chains of the pontoon.

### 3) Pontoon

The pontoon was constructed at IWT Dalla Dockyard to accomplish the technical transfer of the design and construction by the JICA Project Team. The following new technologies were selected. The details are shown in Section 11.7.

The pontoon structure type was studied. The characteristics of each type of pontoon structure are shown in Table 13.4.11. Because it is difficult to construct prestressed concrete for pontoons in Myanmar, RC hybrid type was selected. Almost all pontoons in Myanmar are of the steel type. The initial cost for steel pontoons in Myanmar is cheap because they are built with thin steel plates and have poor paint application. However, frequency of maintenance is as little as two years and the cost is high. On the other hand, in Japan, steel type pontoons have thick steel plates, good quality marine paint and furthermore, are provided with anode protection, where the initial cost is expensive but the maintenance frequency and cost are low.

Table 13.4.11 Characteristics of Pontoon Structure Type

| Type | Anti -corrosion | Anchor Size | Draft | Possibility of Big Size | Cost (in Japan) |
|---|---|---|---|---|---|
| Steel | poor | small | small | Best | 1.3 |
| RC concrete | good | big | big | Poor | 1.0 |
| PC concrete | good | middle | big | Good | 1.2 |
| PC hybrid (PC concrete + steel beam) | good | small | middle | Good | 1.0 |
| RC hybrid (RC concrete + steel plate) | good | small | middle | Poor | 1.2 |

Source: JICA Project Team

The mooring type for the pontoons was studied. The characteristics of each type of anchor are shown in Table 13.4.12. Based on the site conditions, cost, and impact on passengers, the anchor chain (taut) type was selected. The anchor chain (taut) type is commonly used in Myanmar.

Table 13.4.12 Characteristics of Mooring System

| Type | System | Water Depth | Wave Height | Ground Condition | Movement (Approx.) |
|---|---|---|---|---|---|
| Pile | Pile and rubber roller | shallow | small | solid | 0.1 m |
| Chain (taut) | Anchor chain and block | shallow | small | solid | 1.0 m |
| Chain (catenary) | Anchor chain and block | deep | big | soft | over 1.0 m |
| Dolphin | Dolphin with fender | --- | middle | --- | 0.1 m |

Source: JICA Project Team

There are four kinds of anti-corrosion systems for steel pontoons, namely: corrosion allowance, paint system, concrete cover, and anode protection. It was decided for the pontoons of the pilot project that the side walls and top lobe will be covered by concrete and the bottom to be protected by anode. Paint systems were not selected because in Myanmar, normal paint (not marine) and corrosion allowance are commonly used for anti-corrosion systems which results in the disadvantage of needing frequent maintenance.

### 4) Slipway

The existing slipway was not supported by piles; the concrete pavement was placed on brick basement only. As the ground is very soft, the slipway will be settling. In order to reduce maintenance cost, the JICA Project Team proposed piles for the slipway instead of brick basement.

### 5) Walkway and Revetment

#### (a) Walkway

There are four kinds of major pavement type as shown in Table 13.4.13. Interlocking concrete block (ICB) was selected for the pavement of the walkway of the pilot project because ICB is a major type for walkway and terminal yard in the port.

Table 13.4.13 Pavement Types

| Type | Durability | Comfort | Cost | Maintenance | Equipment |
|---|---|---|---|---|---|
| RC Concrete | Very Good | Good | Expensive | Difficult | Needed |
| Asphalt | Fare | Good | Expensive | Fare | Needed |
| ICB | Fare | Very Good | Fare | Easy | Not needed |
| Macadam | Poor | Poor | Cheap | Fare | Not needed |

Source: JICA Project Team

#### (b) Revetment

There are some kinds of revetment type as shown in Table 13.4.14. Stone masonry with mortar was selected for the revetment of the pilot project because it is cheapest and is the same type as the existing revetment.

Table 13.4.14 Revetment Types

| Type | Durability | Cost | Maintenance | Equipment |
|---|---|---|---|---|
| Concrete block | Very Good | Expensive | Fare | Needed |
| Steel sheet pile | Good | Very Expensive | Difficult | Needed |
| Stone masonry | Fare | Cheep | Easy | Not needed |

Source: JICA Project Team

## (2) Design of Pier Structures (Porter Way)

### 1) General

Based on the design criteria described in the previous section, the design work was carried out. For some works or structures, alternative methods and techniques are compared in order to determine the most suitable type.

### 2) Design Conditions for the Porter Way

Summary of the design conditions for the porter way is shown in Table 13.4.15 below.

Table 13.4.15 Design Conditions for the Porter Way

| | |
|---|---|
| Tide | HHWL = +7.1 m, HWL = +6.20 m, MSL = +3.23 m, LWL = +0.34 m |
| Live load | 0.0 (not considered) |
| Surcharge | 5 kN/m$^2$ for normal condition and<br>0.0 tons for seismic condition |
| Crown level | +7.1 m |
| Existing river bed level | +2 m ~ +4.1 m CDL |
| Subsoil conditions | Clayey SILT, N average = 5 (riverbed 8 m~10 m from the riverbed level)<br>Silty SAND, N average = 20 (8 m ~ 10 m)<br>SAND, N average = 40 (below 10 m) |
| Seismic coefficient | Kh = 0.15 |

Source: JICA Project Team

### 3) Calculation

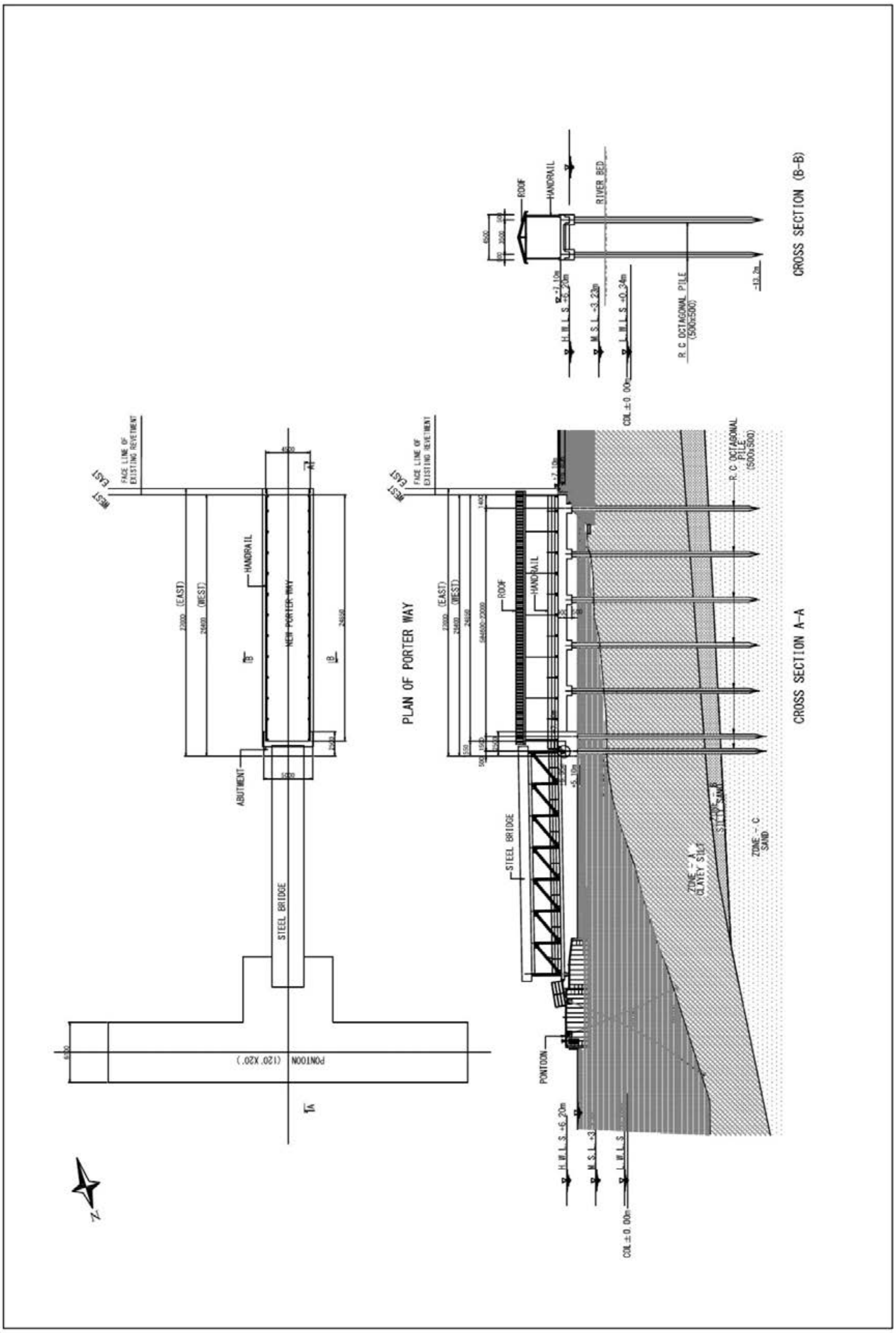
Pier structures were designed in two-dimensional frame analysis method. From the results of structural calculations, the dimensions in Table 13.4.16 were determined.

Table 13.4.16 Dimension of Superstructures

| | |
|---|---|
| Pile | 500 x 500 mm |
| Pile Head | 1000 x 1000 mm |
| Beam | 600 x 600 mm |
| Slab | Thickness of 300 mm |

Source: JICA Project Team

The pile arrangement and superstructure were determined as shown in the following Figure 13.4.4.



Source: JICA Project Team

Figure 13.4.4 Plan and Cross Section of Porter Way

## (3) Design of Movable Steel Bridge

### 1) Design Basis

The following specifications, handbook, and rules were applied:

- Specifications for Highway Bridge (from Japan Road Association)
- Handbook of Shipbuilding (from Kansai Shipbuilding Association)
- Rules for Steel (from Classification Society Nippon Kikai)

Steel grade applied: JIS SS400 (or equivalent)

Load combinations applied were:

| Load Type / Load Condition | Dead Load | Live Load | Wind Load | Seismic Load |
|---|---|---|---|---|
| Stationary Load | X | X | X | |
| Seismic Load | X | X | X | X |
| Wind Load | X | X | X | |

Source: JICA Project Team

#### (a) Applied Loads

| Load Type | Load Description | Value |
|---|---|---|
| Dead Loads | Steel Weight | 77.0 kN/$m^3$ |
| | Wooden Floor (t = 50 mm) | 0.25 kN/$m^2$ |
| Live Load | for Floor Design | 5.0 kN/$m^2$ |
| | for Main Framing | 3.5 kN/$m^2$ |
| Seismic Load | | 0.15 x g |
| Wind Load | Continuous Velocity | 60 m/s |

Source: JICA Project Team

#### (b) Check Items

- Stress check: To be checked for combined stress (bending stress + axial stress).
- Deformation check: Deformation to be not larger than L/600 (Specifications for Highway Bridge).
- Local buckling check for compression members.

#### (c) Method of Calculation

- Local floor strength: To be confirmed by simple beam theory.
- Main Framing Strength: By three-dimensional framing calculation using structural analysis program “NX/NASTRAN”.

## 2) Local Strength of Floor Member

Floor Load: Live Load + Wooden Deck Load = $5.0\ \text{kN/m}^2 + 0.25\ \text{kN/m}^2 = 5.25\ \text{kN/m}^2$

L. Beam H100x100x6/8 with strength:

$Z_L = 75{,}600\ \text{mm}^3$

Moment: $M_L = w_L \bullet L_L^2/8 = 5.25\ \text{kN/m}^2 \bullet 0.8125\ \text{m} \bullet (3.23\ \text{m})^2/8 = 5.56\ \text{kN}\bullet\text{m}$

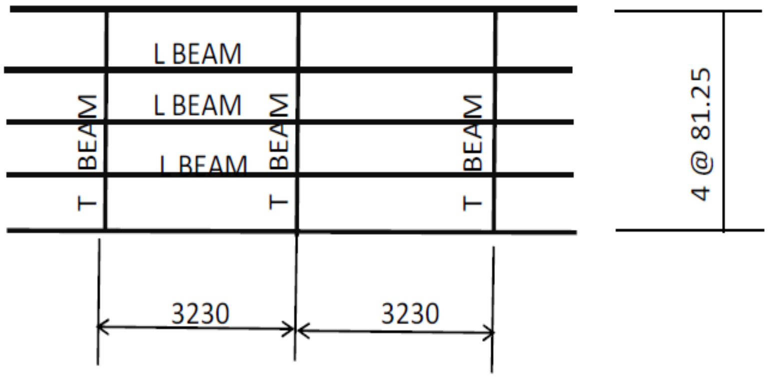
Tension: $\sigma_L = M_L/Z_L = 5.56\bullet10^6\ \text{kNmm}/75{,}600\ \text{mm}^3 = 73.6\ \text{N/mm}^2 < 140\ \text{N/mm}^2$ OK

T. Beam H250x150x5.5x8:

$Z_T = 181{,}000\ \text{mm}^3$

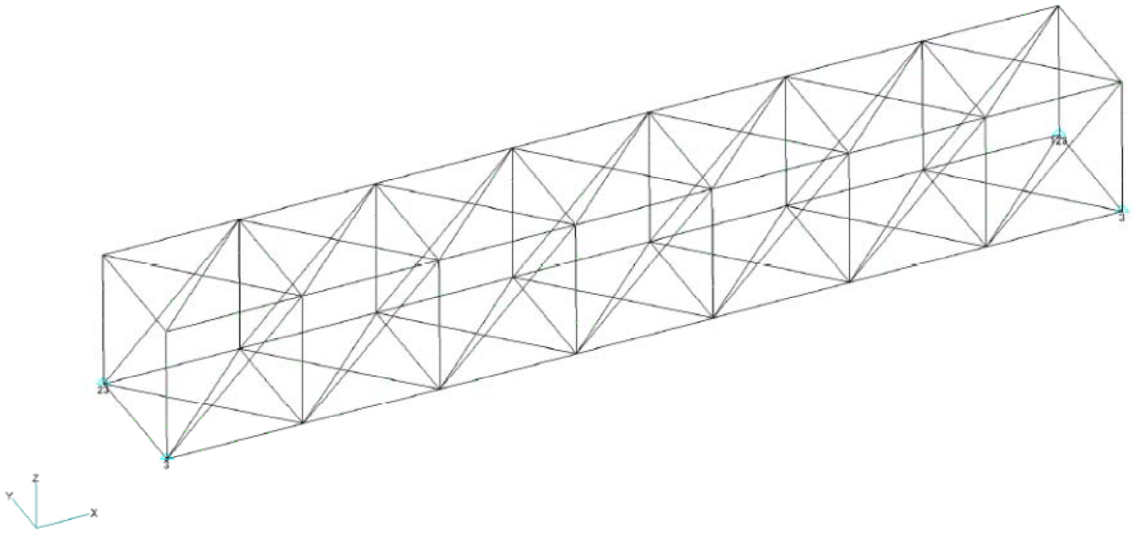
Moment: $M_T = w_T \bullet L_T^2/8 = 5.25\ \text{kN/m}^2 \bullet 3.23\ \text{m} \bullet (4\bullet0.8125\ \text{m})^2/8 = 22.4\ \text{kN}\bullet\text{m}$

Tension: $\sigma_T = M_T/Z_T = 22.4\bullet10^6\ \text{kNmm}/181{,}000\ \text{mm}^3 = 123.7\ \text{N/mm}^2 < 140\ \text{N/mm}^2$ OK



## 3) 3D Framing Analysis

### 3D Model and Constraint



## Structural Member

| Member | Type | A (mm$^2$) | I1 (mm$^4$) | I2 (mm$^4$) | J (mm$^4$) |
|---|---|---|---|---|---|
| UPPER CHORD | H300x150x6.5/9 | 4,533 | 69,330,000 | 5,068,954 | 102,075 |
| LOWER CHORD | H300x150x6.5/9 | 4,533 | 69,330,000 | 5,068,954 | 102,075 |
| VERTICAL MEMBER | H200x150x6/9 | 3,792 | 5,065,776 | 27,660,000 | 86,992 |
| VERTICAL MEMBER (END) | □200x200x8 | 5,076 | 16,890,000 | 16,890,000 | 26,060,000 |
| DIAGONAL MEMBER | H200x100x5.5/8 | 2,612 | 17,610,000 | 1,335,884 | 44,875 |
| UPPER BRACE | L90x90x6 | 1,044 | 825,869 | ,825,869 | 12,484 |
| LOWER BRACE | L90x90x6 | 1,044 | 825,869 | ,825,869 | 12,484 |
| UPPER BEAM | H200x100x5.5/8 | 3,792 | 5,065,776 | 27,660,000 | 86,992 |
| LOWER BEAM | H200x100x5.5/8 | 2,612 | 17,610,000 | 1,335,884 | 44,875 |

*PROPERTIES TO BE CAL. BY PROGRAM

Source: JICA Project Team

## Applied Load

| DEAD LOAD, STEEL WEIGHT | | UNIT WEIGHT kg/m | LENGTH m | Q'TY | WEIGHT kg | WEIGHT N |
|---|---|---|---|---|---|---|
| UPPER CHORD | H300x150x6.5/9 | 36.7 | 22.78 | 2 | 1,672.1 | 16,721 |
| LOWER CHORD | H300x150x6.5/9 | 36.7 | 23.48 | 2 | 1,723.4 | 17,234 |
| VERTICAL MEMBER | H200x150x6/9 | 29.9 | 3.2 | 12 | 1,148.2 | 11,482 |
| VERTICAL MEMBER (END) | □200x200x8 | 46.9 | 3.2 | 4 | 600.3 | 6,003 |
| DIAGONAL MEMBER | H200x100x5.5/8 | 20.9 | 4.2 | 14 | 1,228.9 | 12,289 |
| UPPER BRACE | L90x90x6 | 8.28 | 4.2 | 14 | 486.9 | 4,869 |
| LOWER BRACE | L90x90x6 | 8.28 | 4.2 | 14 | 486.9 | 4,869 |
| UPPER BEAM | H200x100x5.5/8 | 20.9 | 3.25 | 8 | 543.4 | 5,434 |
| LOWER BEAM | H200x100x5.5/8 | 20.9 | 3.25 | 8 | 543.4 | 5,434 |
| FLOOR BEAM | H100x100x6/8 | 16.9 | 22.58 | 3 | 1,144.8 | 11,448 |
| ROOF BEAM (TR) | L75x75x6 | 6.85 | 7.99 | 15 | 821.0 | 8,210 |
| ROOF BEAM (LG) | L75x75x6 | 6.85 | 23.28 | 1 | 159.5 | 1,595 |
| ROOF BEAM | □25x25x106 | 1.2 | 22.58 | 10 | 271.0 | 2,710 |
| HAND RAIL | ϕ42x6.25 | 5.51 | 23.48 | 6 | 776.2 | 7,762 |
| HAND RAIL STANCHION | L75x75x6 | 6.85 | 1.1 | 30 | 226.1 | 2,261 |
| BRICKET etc. | t = 8 | 5.65 | − | 63 | 356.0 | 3,560 |

| DEAD LOAD, OTHERS | | UNIT WEIGHT kg/m | L m | B m | WEIGHT kg | WEIGHT N |
|---|---|---|---|---|---|---|
| WOODEN FLOOR | (t = 50) | 25 | 22.58 | 3.25 | 1,834.6 | 18,346 |
| CORRUGAT. GALV. ROOF | (Bxh)130x44.3 | 2.157 | 23.48 | 4.8 | 243.1 | 2,431 |
| | TOTAL | | | | 14,260 | 142,597 |
| | TOTAL (rounded) | | | | | 150,000 |

| LIVE LOAD | UNIT LOAD kN/m | L m | B m | WEIGHT kg | WEIGHT kN |
|---|---|---|---|---|---|
| LIVE LOAD | 3.50 | 22.68 | 3.25 | 25,798.5 | 258.0 |

## WIND PRESSURE

$P = - S\ C_x = 1/2 \bullet \rho \bullet A \bullet V \bullet C_x$ ,

where $\rho$ is the air density (0.123 kg•s$^2$/m$^4$), A is the area subject to the wind load, V is the wind velocity (60.0 m/s) and $C_x$ is the resistance coefficient of the area (shape) subject to the wind; in this case $C_x = 1.5$ is applied.

On this basis, the design wind pressure is calculated as follows:

P = 1/2 x 0.123 x 41.61 x 60.0 x 1.5 = 13,864 kg (=13,864 kg/22.58 m = 614 kg/m)

## PROJECTED AREA

| | H (m) | L (m) | N | A (m$^2$) |
|---|---|---|---|---|
| ROOF | 0.700 | 23.48 | 1 | 16.44 |
| UPPER CHORD | 0.300 | 22.78 | 1 | 6.83 |
| LOWER CHORD | 0.300 | 23.48 | 1 | 7.04 |
| DIAGONAL MEMBER | 0.200 | 4.30 | 7 | 6.02 |
| HAND RAIL | 0.042 | 23.28 | 3 | 2.95 |
| HAND RAIL POST | 0.075 | 1.10 | 7 | 0.58 |
| BRACKET | 0.300 | 0.30 | 21 | 1.89 |
| **TOTAL** | | | | **41.75** |

Source: JICA Project Team

## Checking of Results
## Stress Check

| LOAD CASE | COMBINED STRESS*) | | Allowable Stress σ II N/mm$^2$ | σ < σ II |
|---|---|---|---|---|
| | MAX σ N/mm$^2$ | MIN σ N/mm$^2$ | | |
| Stationary Load | 75.8 | 72.9 | 140.0 | OK |
| Seismic Load | 88.4 | 84.5 | 210.0 | OK |
| Wind Load | 124.6 | 114.1 | 168.0 | OK |

Notes: *) combined stress = axial stress + bending stress

## DEFORMATION CHECK (At Stationary Load)

ALLOWABLE DEFORMATION $\delta_{all}$ = L/600 = 22,580/600 = 37.63 mm

Max. DEFORMATION $\delta_{act}$ = 12.07 mm OK

**BUCKLING STRENGTH**

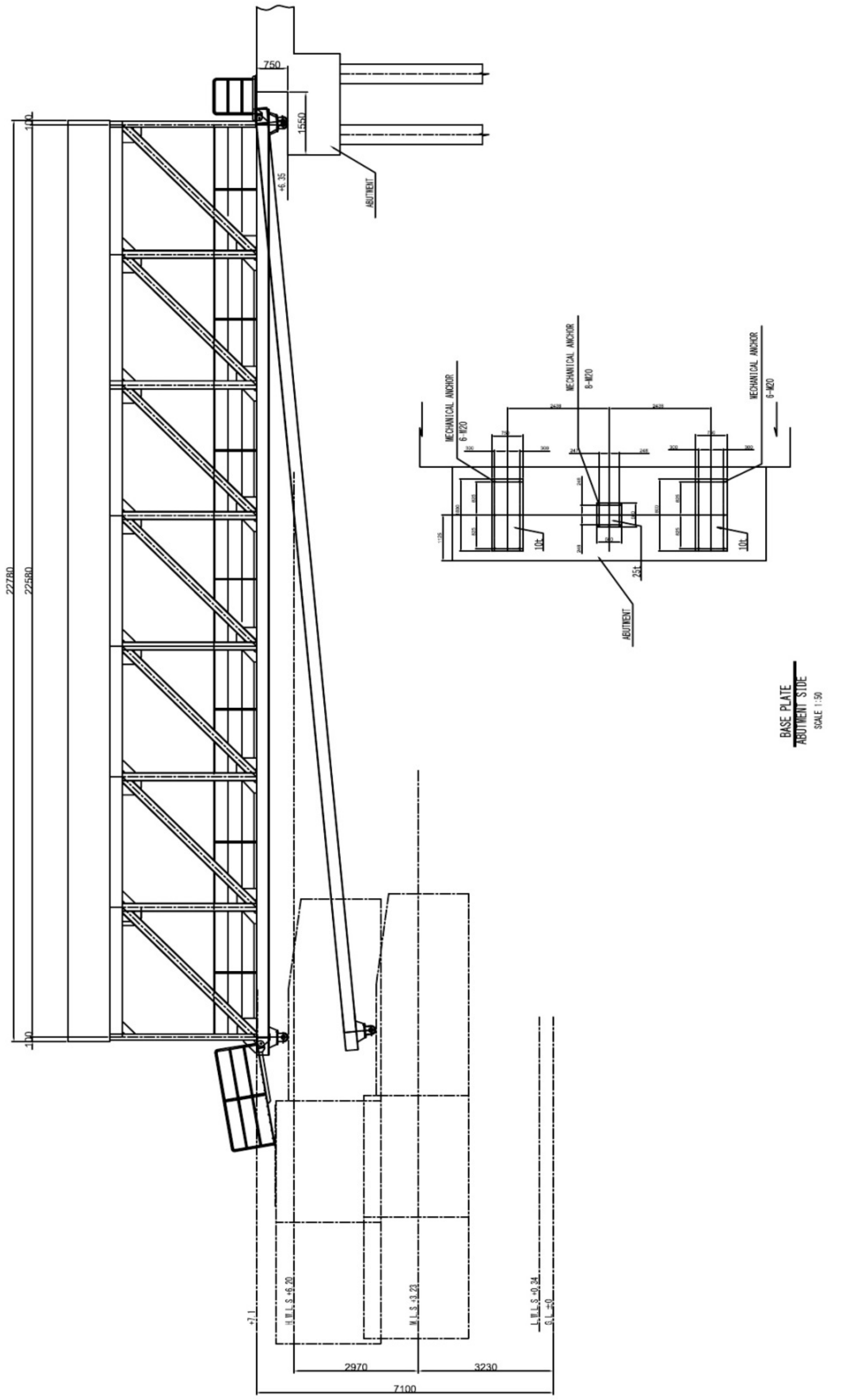
| | L cm | k cm | I $cm^4$ | N | L/k | FORMULA*) | S.F | Wall (N) | Wact (N) | Wall >Wact |
|---|---|---|---|---|---|---|---|---|---|---|
| UPPER CHORD | 323 | 3.3 | 508 | 4 | 48.9 | EULER | 5 | 3,844,576 | 156,106 | OK |
| LOWER CHORD | 323 | 3.3 | 508 | 4 | 48.9 | EULER | 5 | 3,844,576 | − | OK |
| VERTICAL MEMBER | 320 | 3.65 | 507 | 4 | 43.8 | EULER | 5 | 3,909,289 | 61,896 | OK |
| DIAGONAL MEMBER | 350 | 2.24 | 134 | 4 | 78.1 | EULER | 5 | 863,691 | 116,445 | OK |
| BRACE | 170 | 1.77 | 93 | 4 | 48.0 | EULER | 5 | 2,540,825 | 15,054 | OK |

Notes: *) Formulas applied are: for L/k > 40 EULER and for L/k < 40 RANKHINE

Source: JICA Project Team

### 4) Structure Design of Movable Steel Bridge

From the results of structure analysis, the superstructures were designed as shown in the following Figure 13.4.5.



Source: JICA Project Team

Figure 13.4.5 Side View of Movable Steel Bridge

## (4) Design of Pontoon

### 1) Method of Calculation Analysis

Pontoon was calculated using Japanese standards.

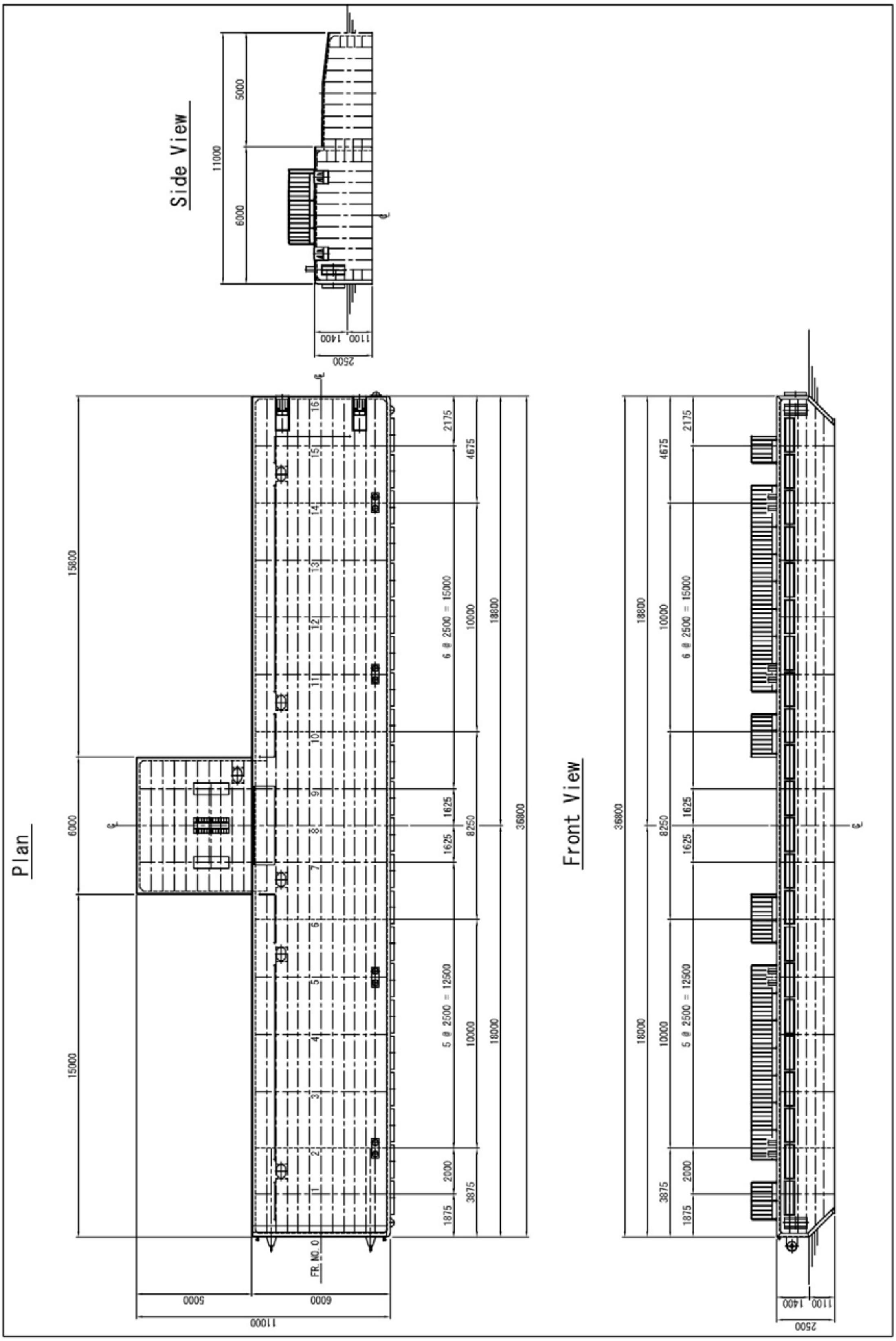
### 2) Design Conditions

Summary of the design conditions is shown in Table 13.4.17 below.

Table 13.4.17 Design Conditions of the Pontoon

| | |
|---|---|
| Tide | HWL = +6.20 m, LWL = +0.00 m |
| Maximum current | 4 knots (2.06 m/s) |
| Wave significant height | 1.00 m |
| Wave maximum | 1.86 m |
| Wind speed | 30 m/s |
| Ship size | 400 (G.T.) |
| Pontoon size | W: 6.00 m x H: 2.50 m x L: 36.80 m, Air draft =1.4 m |
| Surcharge | 5.0 kN/$m^2$ for structure calculation<br>3.0 kN/$m^2$ for stability analysis |
| Riverbed condition | Clay |

Source: JICA Project Team

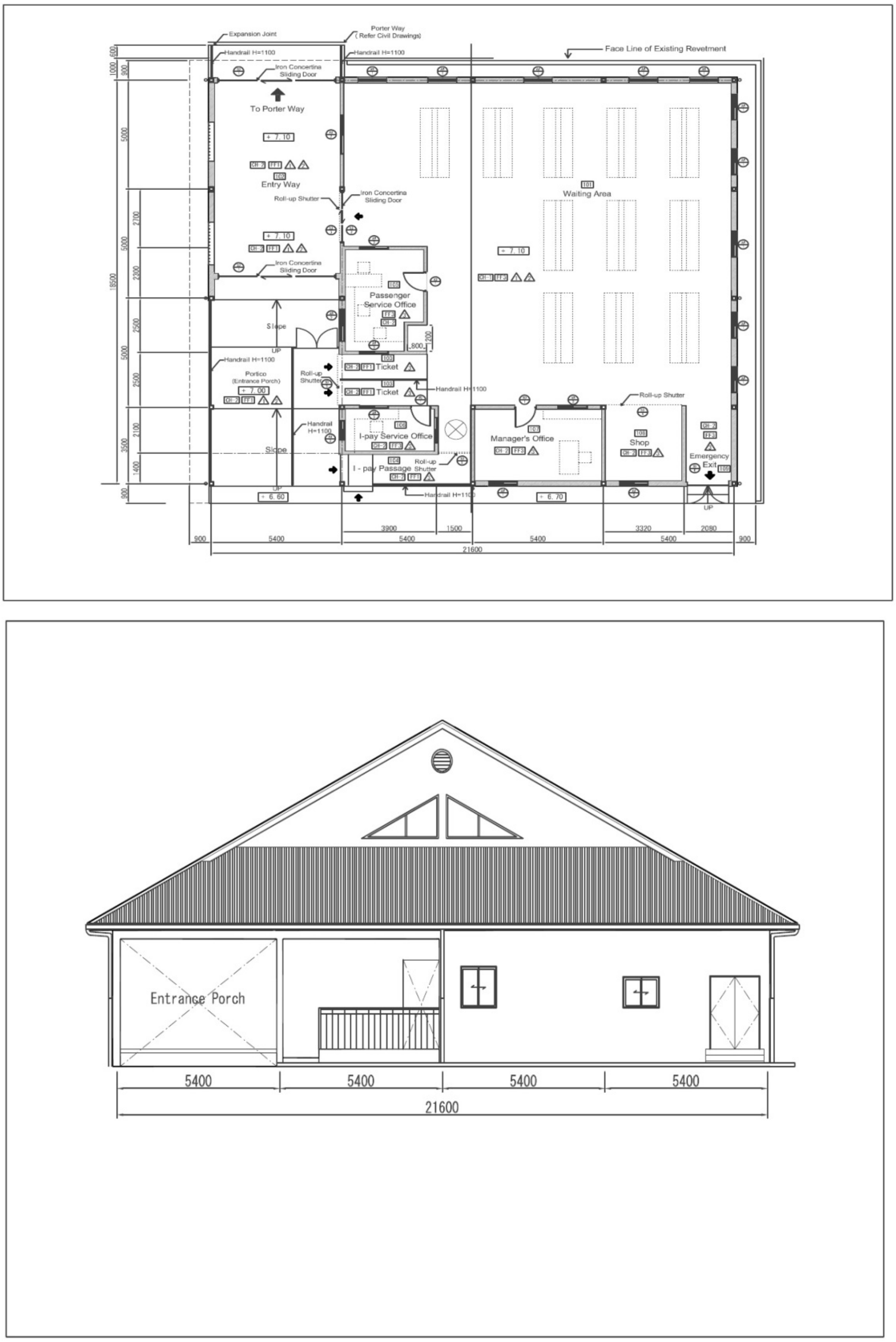


Source: JICA Project Team

Figure 13.4.6 Plan, Front and Side View of Pontoon

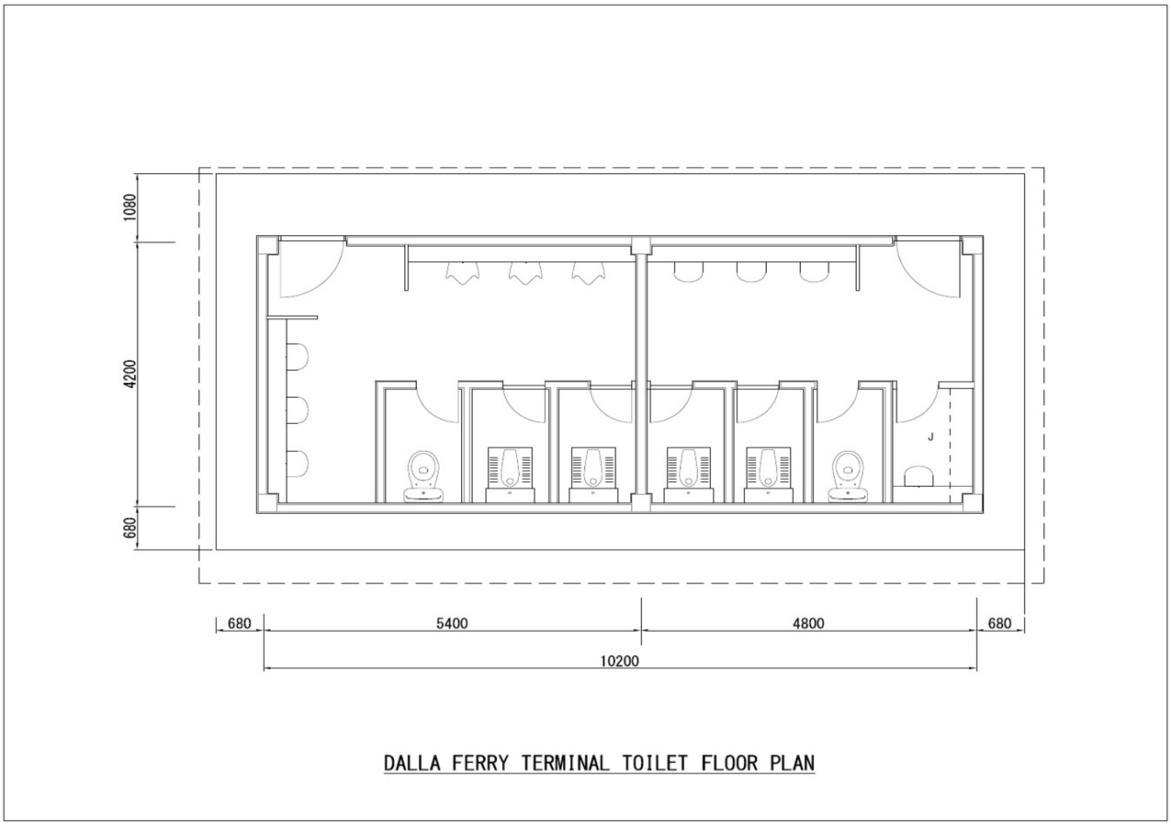
### (5) Design of Terminal Building and Toilet Building

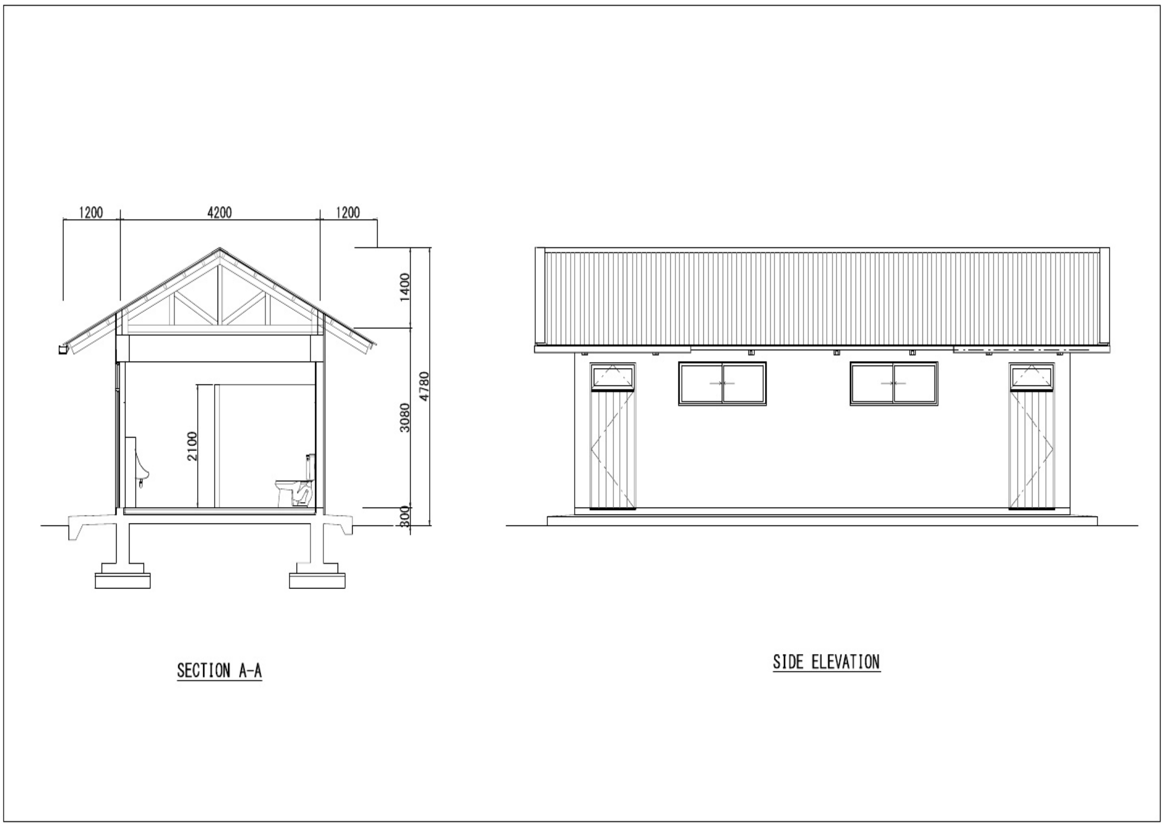
The facilities of the terminal building and toilet building were designed based on the building code in Myanmar. The code is not yet official but it is used widely in Myanmar.



Source: JICA Project Team

Figure 13.4.7 Plan and Front View of Terminal Building



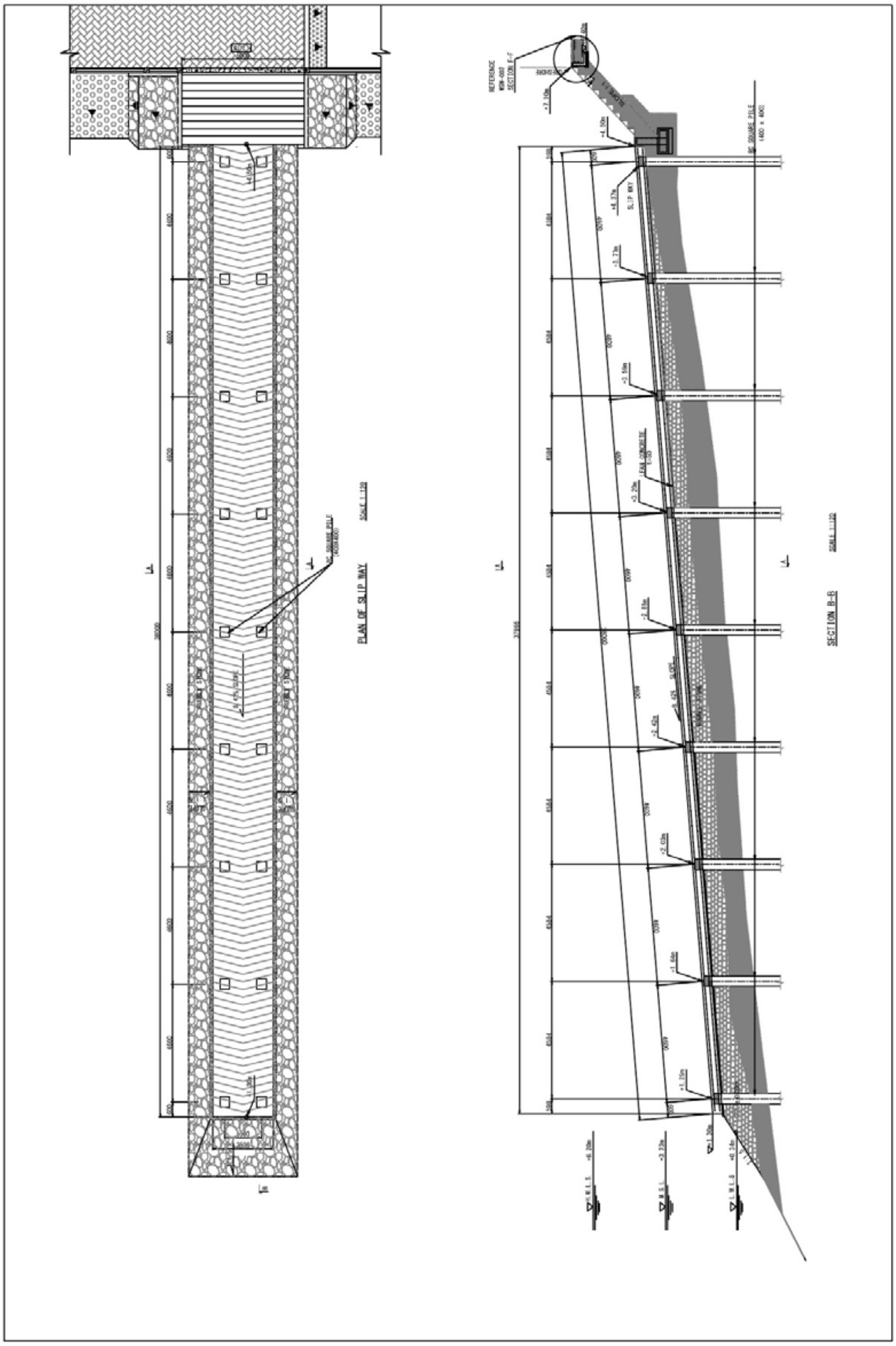


Source: JICA Project Team

Figure 13.4.8 Plan and Front View of Toilet Building

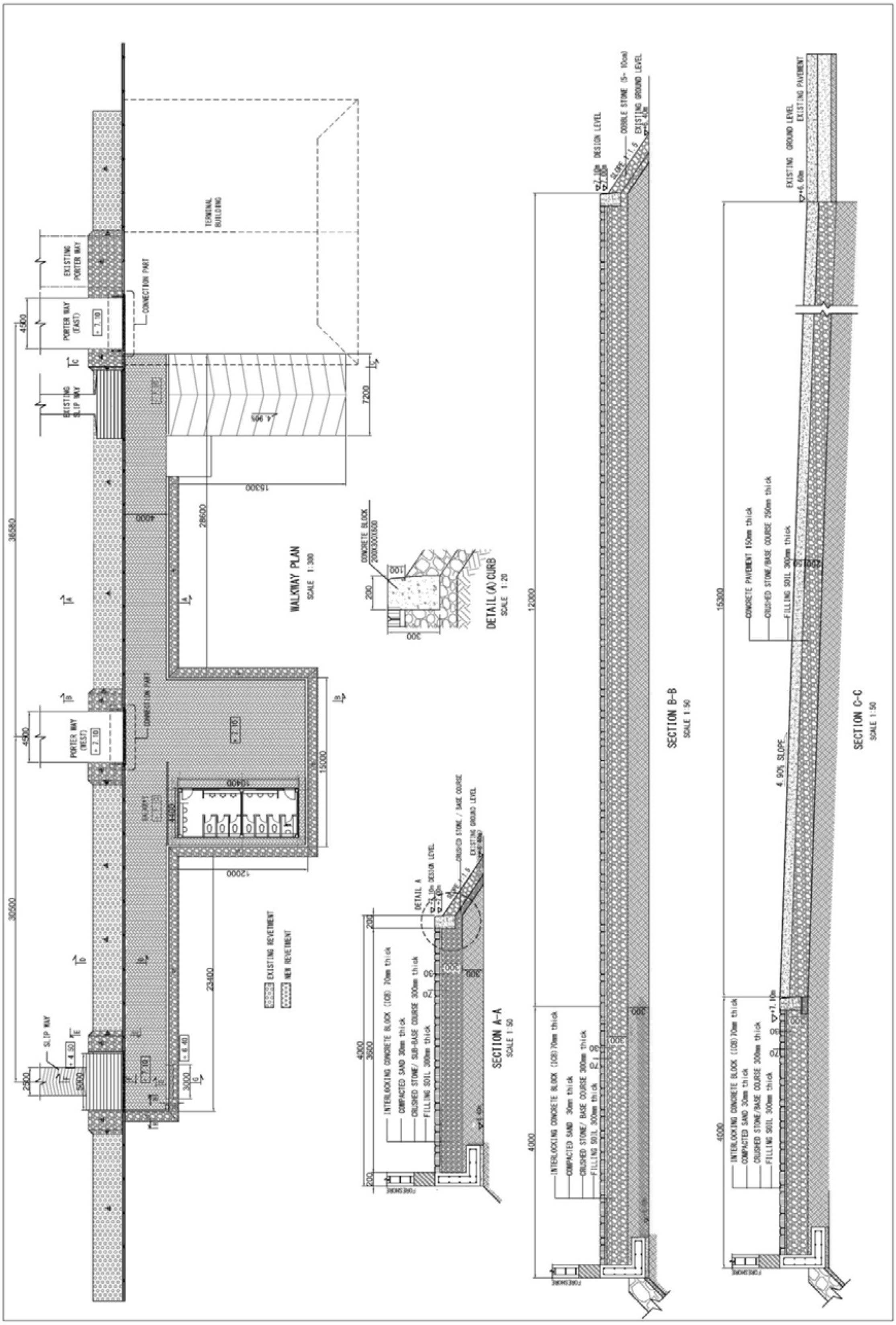
### (6) Design of Other Civil Structures

Other civil structures such as slipway, walkway, and revetment were designed based on Japanese standards.



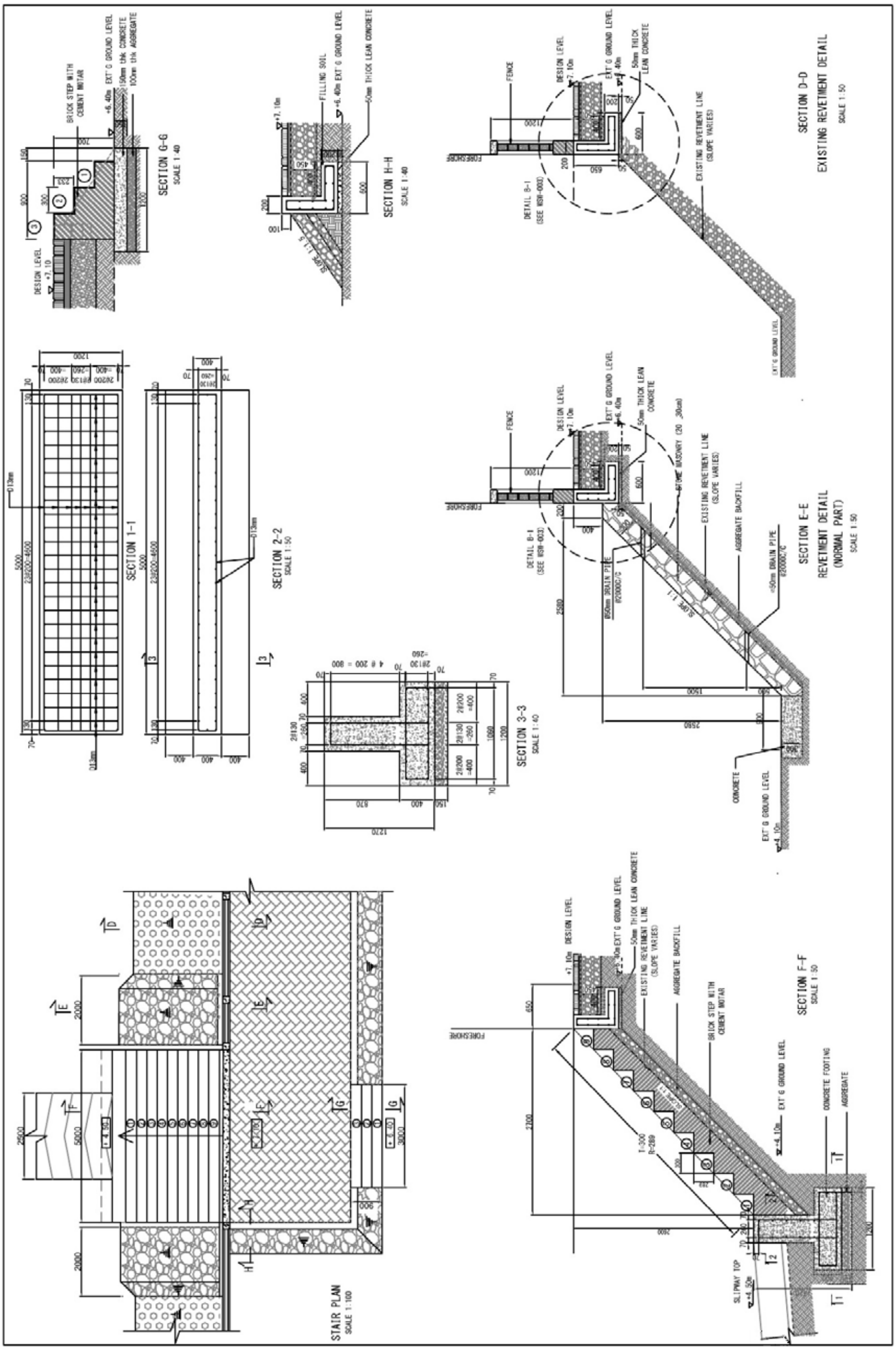
Source: JICA Project Team

Figure 13.4.9 Plan and Front View of Slipway



Source: JICA Project Team

Figure 13.4.10 Plan and Cross Section of Walkway



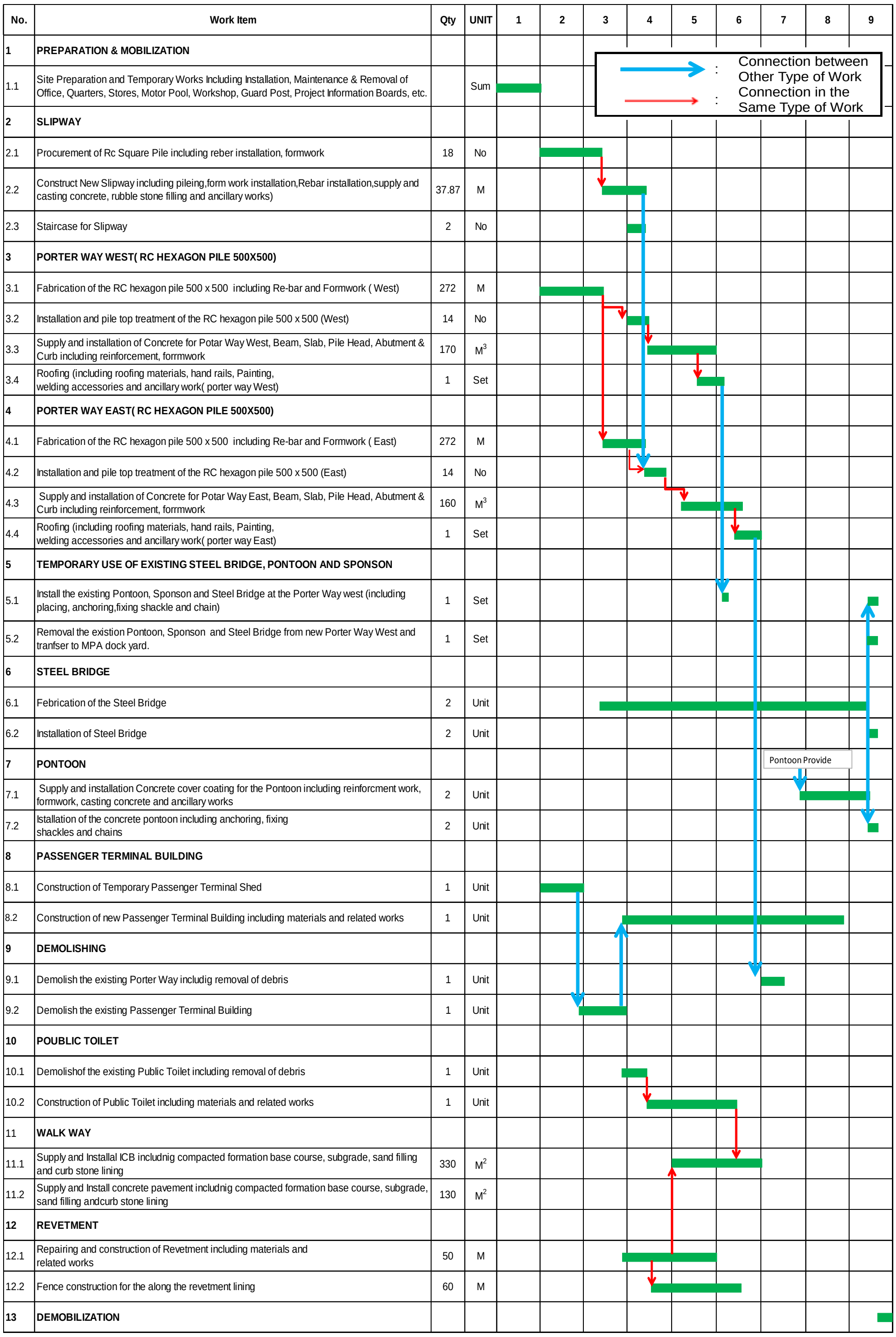
Source: JICA Project Team

Figure 13.4.11 Plan and Front View of Revetment

## 13.4.6 CONSTRUCTION METHOD

### (1) Overall Implementation Program

Construction work schedule was estimated as shown in Figure 13.4.12. The total construction period is estimated at nine months from the notice of the commencement of work.



| No. | Work Item | Qty | UNIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **PREPARATION & MOBILIZATION** | | | | | | | | | | | |
| 1.1 | Site Preparation and Temporary Works Including Installation, Maintenance & Removal of Office, Quarters, Stores, Motor Pool, Workshop, Guard Post, Project Information Boards, etc. | | Sum | 🟩 | | | | | | | | |
| 2 | **SLIPWAY** | | | | | | | | | | | |
| 2.1 | Procurement of Rc Square Pile including reber installation, formwork | 18 | No | | 🟩 | 🟩 | | | | | | |
| 2.2 | Construct New Slipway including pileing,form work installation,Rebar installation,supply and casting concrete, rubble stone filling and ancillary works) | 37.87 | M | | | 🟩 | 🟩 | | | | | |
| 2.3 | Staircase for Slipway | 2 | No | | | | 🟩 | | | | | |
| 3 | **PORTER WAY WEST( RC HEXAGON PILE 500X500)** | | | | | | | | | | | |
| 3.1 | Fabrication of the RC hexagon pile 500 x 500 including Re-bar and Formwork ( West) | 272 | M | | 🟩 | 🟩 | | | | | | |
| 3.2 | Installation and pile top treatment of the RC hexagon pile 500 x 500 (West) | 14 | No | | | | 🟩 | | | | | |
| 3.3 | Supply and installation of Concrete for Potar Way West, Beam, Slab, Pile Head, Abutment & Curb including reinforcement, forrmwork | 170 | $M^3$ | | | | 🟩 | 🟩 | | | | |
| 3.4 | Roofing (including roofing materials, hand rails, Painting, welding accessories and ancillary work( porter way West) | 1 | Set | | | | | 🟩 | 🟩 | | | |
| 4 | **PORTER WAY EAST( RC HEXAGON PILE 500X500)** | | | | | | | | | | | |
| 4.1 | Fabrication of the RC hexagon pile 500 x 500 including Re-bar and Formwork ( East) | 272 | M | | | 🟩 | 🟩 | | | | | |
| 4.2 | Installation and pile top treatment of the RC hexagon pile 500 x 500 (East) | 14 | No | | | | 🟩 | | | | | |
| 4.3 | Supply and installation of Concrete for Potar Way East, Beam, Slab, Pile Head, Abutment & Curb including reinforcement, forrmwork | 160 | $M^3$ | | | | | 🟩 | 🟩 | | | |
| 4.4 | Roofing (including roofing materials, hand rails, Painting, welding accessories and ancillary work( porter way East) | 1 | Set | | | | | | 🟩 | | | |
| 5 | **TEMPORARY USE OF EXISTING STEEL BRIDGE, PONTOON AND SPONSON** | | | | | | | | | | | |
| 5.1 | Install the existing Pontoon, Sponson and Steel Bridge at the Porter Way west (including placing, anchoring,fixing shackle and chain) | 1 | Set | | | | | | 🟩 | | | 🟩 |
| 5.2 | Removal the existion Pontoon, Sponson and Steel Bridge from new Porter Way West and tranfser to MPA dock yard. | 1 | Set | | | | | | | | | 🟩 |
| 6 | **STEEL BRIDGE** | | | | | | | | | | | |
| 6.1 | Febrication of the Steel Bridge | 2 | Unit | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |
| 6.2 | Installation of Steel Bridge | 2 | Unit | | | | | | | | | 🟩 |
| 7 | **PONTOON** | | | | | | | | | | | |
| 7.1 | Supply and installation Concrete cover coating for the Pontoon including reinforcment work, formwork, casting concrete and ancillary works | 2 | Unit | | | | | | | 🟩 | 🟩 | 🟩 |
| 7.2 | Istallation of the concrete pontoon including anchoring, fixing shackles and chains | 2 | Unit | | | | | | | | | 🟩 |
| 8 | **PASSENGER TERMINAL BUILDING** | | | | | | | | | | | |
| 8.1 | Construction of Temporary Passenger Terminal Shed | 1 | Unit | | 🟩 | | | | | | | |
| 8.2 | Construction of new Passenger Terminal Building including materials and related works | 1 | Unit | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | |
| 9 | **DEMOLISHING** | | | | | | | | | | | |
| 9.1 | Demolish the existing Porter Way includig removal of debris | 1 | Unit | | | | | | | 🟩 | | |
| 9.2 | Demolish the existing Passenger Terminal Building | 1 | Unit | | | 🟩 | | | | | | |
| 10 | **POUBLIC TOILET** | | | | | | | | | | | |
| 10.1 | Demolishof the existing Public Toilet including removal of debris | 1 | Unit | | | | 🟩 | | | | | |
| 10.2 | Construction of Public Toilet including materials and related works | 1 | Unit | | | | 🟩 | 🟩 | 🟩 | | | |
| 11 | **WALK WAY** | | | | | | | | | | | |
| 11.1 | Supply and Installal ICB includnig compacted formation base course, subgrade, sand filling and curb stone lining | 330 | $M^2$ | | | | | 🟩 | 🟩 | | | |
| 11.2 | Supply and Install concrete pavement includnig compacted formation base course, subgrade, sand filling andcurb stone lining | 130 | $M^2$ | | | | | | | | | |
| 12 | **REVETMENT** | | | | | | | | | | | |
| 12.1 | Repairing and construction of Revetment including materials and related works | 50 | M | | | | 🟩 | 🟩 | | | | |
| 12.2 | Fence construction for the along the revetment lining | 60 | M | | | | 🟩 | 🟩 | 🟩 | | | |
| 13 | **DEMOBILIZATION** | | | | | | | | | | | 🟩 |

Source: JICA Project Team

Figure 13.4.12 Construction Work Schedule

### (2) Construction Equipment in Myanmar

Construction method was assumed considering the site condition and construction method commonly applied in Myanmar as shown in the design of Botahtaung Jetty (Section 13.3).

### 13.4.7 INITIAL ENVIRONMENTAL EXAMINATION

An initial environmental examination (IEE) was carried out based on the execution plan for “The Pilot Project for the Urgent Project for Rehabilitation of Yangon Port and Main Inland Water Transportation in the Union of Myanmar”. The IEE report was prepared according to the screening and scoping methodology using existing data and results from a site survey conducted by the JICA Project Team. The full IEE report is in the appendix.

Yangon Port is located on the northern side of the Andaman Sea and faces the Yangon River. The proposed project site is situated in the existing Yangon Port in Yangon City. Yangon Port is a river port located 32 km upstream from the Yangon Estuary.

To ensure the effectiveness of environmental management, it is necessary to appoint an institution to be responsible for the coordination and implementation of the environmental management. Environmental management shall be conducted based on environmental legislations and policies with the support of concerned government authorities. An environmental management institution shall be established in the project execution organization in the MPA project management section that will be responsible for the coordination of the environmental management plan.

The main sources causing air pollution are expected to come from transportation activities for construction materials and the equipment required in this project. As a result, transportation activities will be considered the main sources of air pollution. The following activities are foreseen to contribute to the increase in dust/particulate levels during the construction stage:

- Material transportation
- Earthwork activities required for construction
- Construction equipment (pile driver, crane, truck)
- Concrete batching plant for freshly mixed concrete

In this project, only small-scale facilities are included and it is expected that the construction work which will have an environmental impact will only take a short period of time. In the case of the construction works, it is estimated that the environmental impact on the riverbank zone will be relatively small. However, it is recommended that construction methods which will minimize the environmental impact on the riverbank and river area be adopted.

The screening/scoping process and the subsequent analysis of potential social and environmental impacts (adverse effects) and mitigation measures show that although there is potential for some significant adverse effects due to the port project, all potential adverse effects are still manageable, and could be mitigated with well-known, tested, and feasible mitigation methods. Most of the anticipated negative impacts caused by the project can be managed and minimized through proper project planning, design, construction, and operational management of the port.

## 13.5 CONSTRUCTION

### 13.5.1 GENERAL

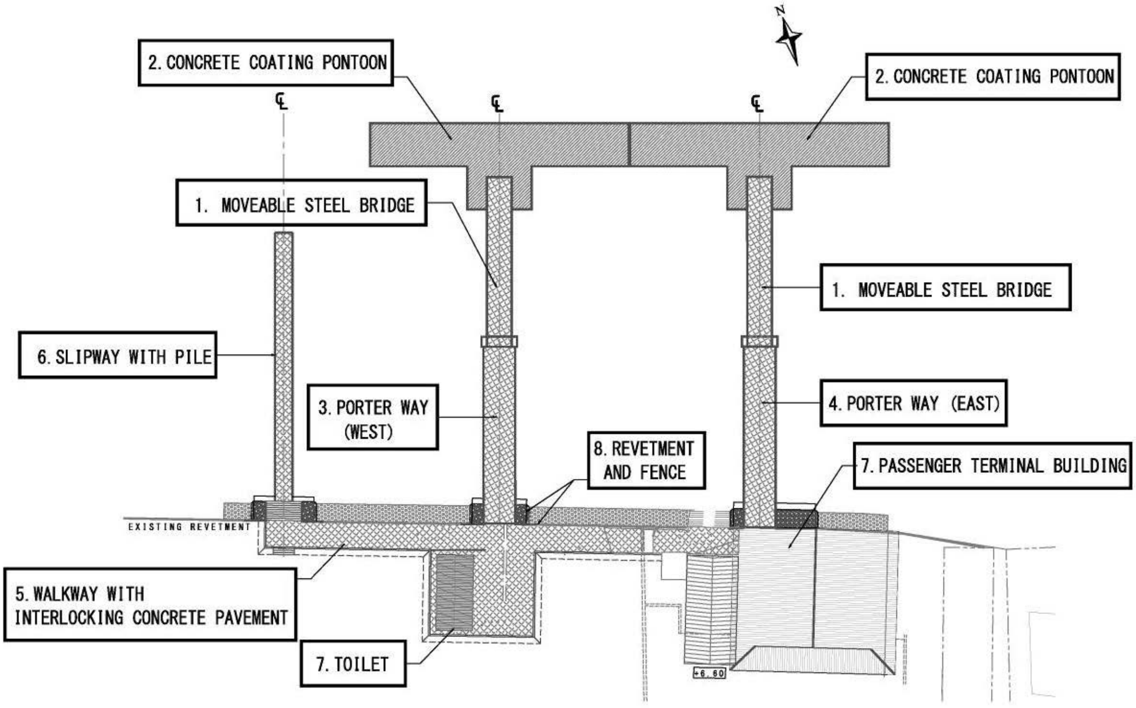
The scope of the project has been summarized in the following Table 13.5.1 and Figure 13.5.1.

Table 13.5.1 Major Scope of Project

| No. | Item | Dimension |
|---|---|---|
| 1 | Two moveable steel bridges | Truss Type Steel Bridge<br>(Length: 22.78 m, Width: 3.25 m) |
| 2 | Concrete coating of two pontoons | Side and top of 2 nos. of steel pontoons |
| 3 | Porter way (West) | 14 nos. of concrete piles (0.5 m x 0.5 m x 19.4 m)<br>Concrete deck slab (24.85 m x 4.5 m x 0.3 m) |
| 4 | Porter way (East) | 14 nos. of concrete piles (0.5 m x 0.5 m x 19.4 m)<br>Concrete deck slab (25.45 m x 4.5 m x 0.3 m) |
| 5 | Walkway with interlocking concrete pavement | Length of pavement = 67 m (Area = 448 m2) |
| 6 | Slipway with pile | 18 nos. of concrete piles (0.4 m x 0.4 m x 11.5 m)<br>Concrete deck slab (2.5 m x 38 m x 0.4 m) |
| 7 | Passenger terminal building and toilet | Single story building (18.5 m x 21.6 m)<br>Single story building (4.2 m x 10.2 m) |
| 8 | Revetment and fence | Length: about 50 m and 70 m each |
| 9 | Demolition works | Same as existing porter way, terminal building, and toilet |
| 10 | Supply of material for pontoons | Steel plate, welding rod, paint, anode |

Note: Fabrication of two steel pontoons was carried out by IWT Dalla Dockyard.

Source: JICA Project Team



Source: JICA Project Team

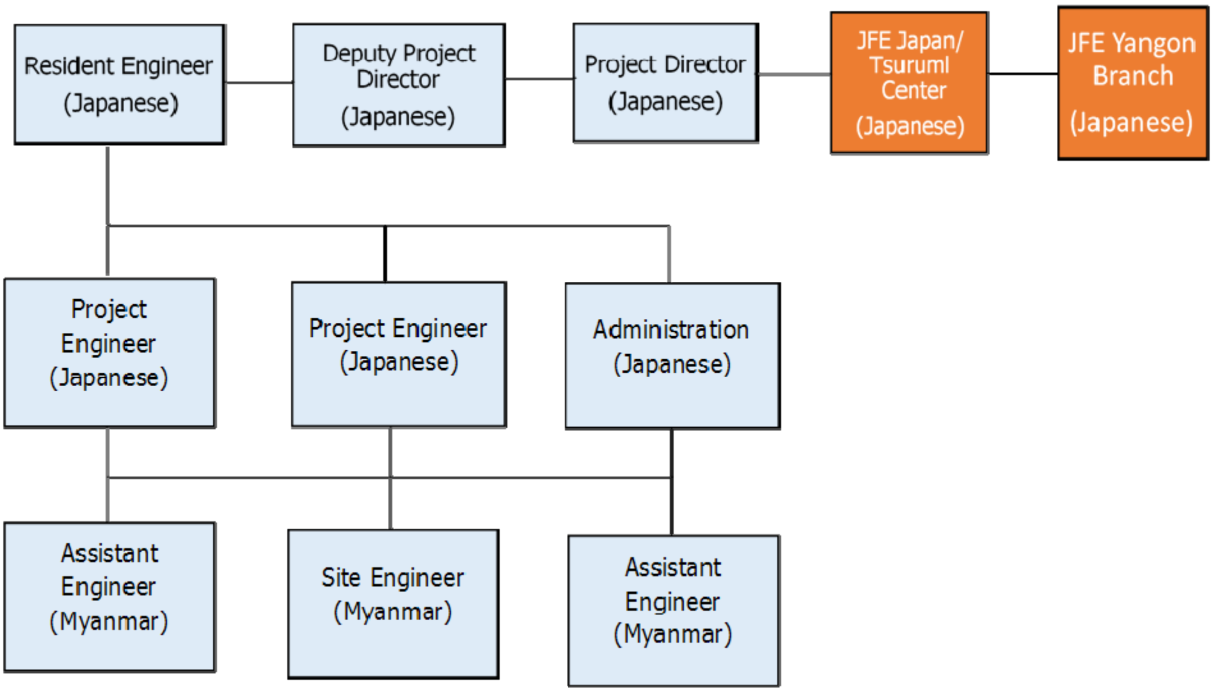
Figure 13.5.1 Project Facilities

### 13.5.2 CONSTRUCTION OF DALLA JETTY

#### (1) Project Organization

**1) Contractor**

JFE Engineering Cooperation was selected as the result of tender. The Contractor's organization is depicted in the organizational chart in Figure 13.5.2. As seen in the chart, four Japanese staff (Deputy Project Director, Resident Engineer, and two Project Engineers) were stationed at the site office thoughout the construction period.



Source: JICA Project Team

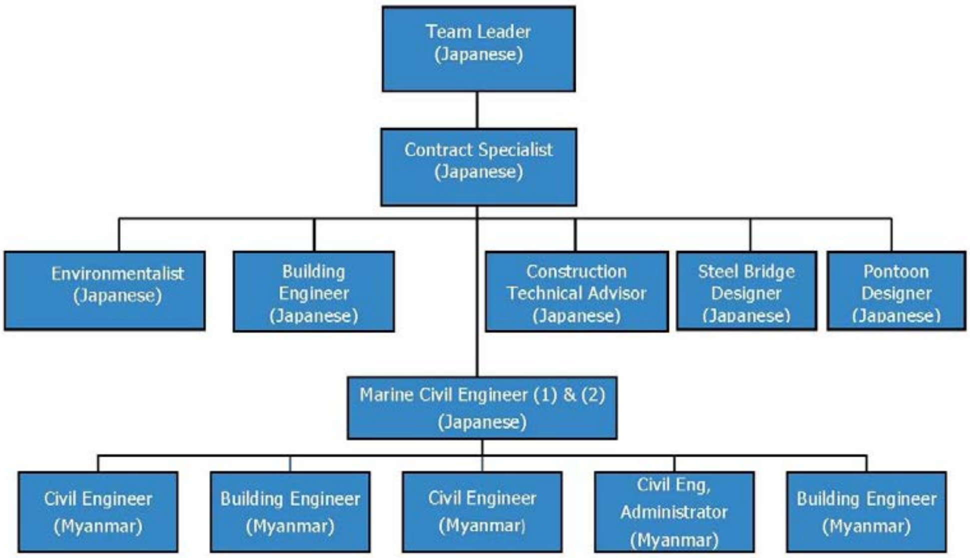
Figure 13.5.2 Contractor's Organization

**2) Consultant[1]**

The Consultant's organization is depicted in the following Figure 13.5.3. The Marine Civil Engineer acted as the resident engineer and oversaw the supervision team. The specialist engineers such as Building Engineer, Construction Specialist, Environmental Specialist, Steel Bridge Specialist, and Pontoon Specialist were mobilized in accordance with the progress of the Work.

---

[1] Under this pilot project, JICA Myanmar Office was the client of the project who signed the construction contract with the contractor. Unlike the normal construction supervision, the duty of the consultant was mainly the schedule monitoring. As for the quality control, the consultant provided the appropriate technical guidance to the contractor and inspects the completed works, but did not directly supervise the ongoing works.

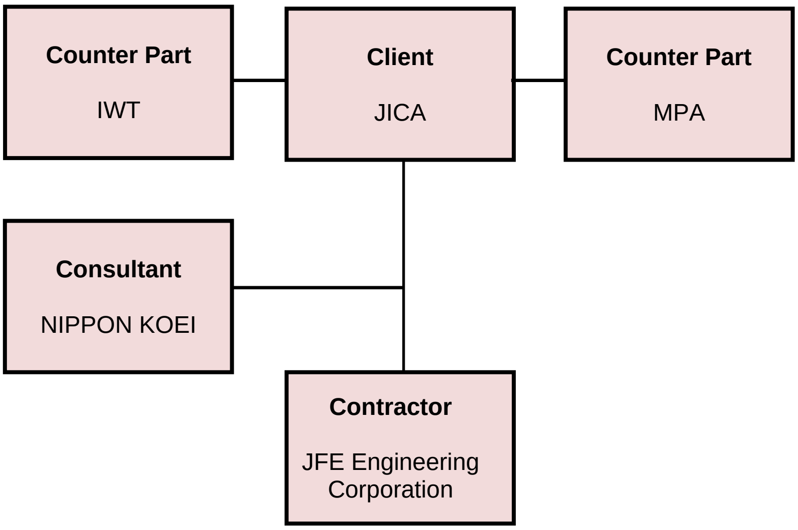


Source: JICA Project Team

Figure 13.5.3 Consultant's Organization

### 3) Overall

Overall project organization is depicted in the chart in Figure 13.5.4. IWT and MPA are also involved as project counterparts. Since IWT and MPA are the recipients of the project facilities (land facilities by IWT, and riverside facilities by MPA), they have participated in many aspects of the project proactively.

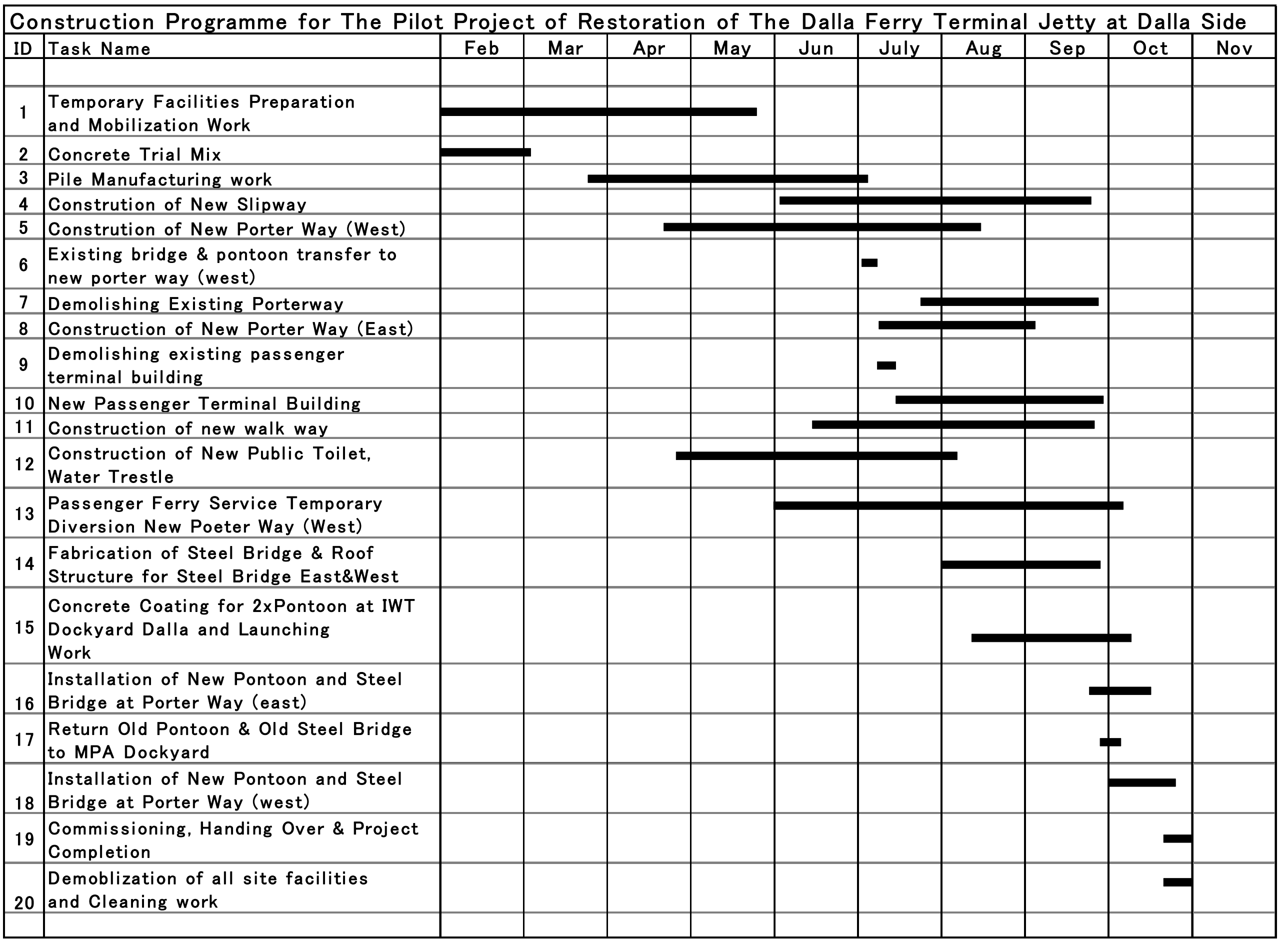


Source: JICA Project Team

Figure 13.5.4 Overall Organization

## (2) Construction Progress

The actual progress of the Work is depicted in the bar chart in Figure 13.5.5.



Source: JICA Project Team

Figure 13.5.5 Actual Progress Bar Chart

The Work commenced on February 1, 2014, and was completed on October 28, 2014, which is within the stipulated construction duration.

## (3) Construction Activities

Major construction activities are explained with pictures in this subsection.

### 1) Concrete Pile Fabrication

| | |
|---|---|
|  | The concrete piles for the porter way (500 x 500 mm hexagonal) and slipway (400 x 400 mm square) were manufactured at the Hi-Tech Concrete's Shwe Pyi Thar Plant. |

### 2) Piling Work

| | |
|---|---|
|  | The picture shows the piling work at the west porter way. First, a temporary sand mount was constructed on the riverbed for accessing a pile driving crawler crane. A diesel hammer was connected to a short section of a leader guide and lifted by a crane to act as a flying hammer.<br>The concrete piles were set into the steel guide frame, and driven by the flying hammer to the required depth. |

### 3) Porter Way Concreting

| | |
|---|---|
|  | The contractor procured the ready-mix concrete from Hi-Tech Concrete located at the Yangon side. The contractor, in an attempt to shorten the concrete delivery time, cast the large volume concrete at night.<br>The picture shows the slab concrete casting at the west porter way. |

### 4) Passenger Terminal Building

| | |
|---|---|
|  | The contractor manufactured the steel members at its own factory (J&M Steel Solutions) at Yangon side. |

### 5) Public Toilet

| | |
|---|---|
|  | The foundation type is isolated footing type with brick retaining wall. Roof is timber truss structure. |

## 6) Pontoon Concrete Coating

| | |
|---|---|
|  | The steel pontoons were manufactured at the IWT's Dalla Dockyard by IWT with technical assistance by JICA. The contractor then cast the 15 cm thick concrete coating on the sides and 10 cm thick on the top of the pontoons.<br>The picture shows the pontoon just after launch at the IWT Dalla Dockyard. |

## 7) Movable Steel Bridge

| | |
|---|---|
|  | The contractor manufactured the steel members at its own factory (J&M Steel Solutions) at Yangon side. Assembly of the bridge was carried out at MPA's Botahtaung Maintenance Yard.<br>The completed steel bridges were towed to the site on a pontoon, and positioned in between the porter way and the new pontoon during high tide, and set to position when the tide went down. |

## 8) Pavement

| | |
|---|---|
|  | The subbase of the pavement is crushed stone and sand, and the surface is made of interlocking concrete blocks. |

## 9) Slipway

| | |
|---|---|
|  | Concrete square piles (400 x 400 mm) were used for the slipway foundation. The thickness of the slab concrete is 400 mm, and the concrete near the tip of the slipway was cast during low tide.<br>The picture was taken during low tide of the spring tide. |

### 10) Completion Overview

| | |
|---|---|
|  | Two new pontoons were connected by pins, and two steel bridges were installed. The building on the left is the new passenger terminal building. The new slipway is to the west of the west porter way (right), but is not visible because of high tide. |

## (4) Construction Equipment

Major construction equipment deployed (monthly average) is summarized in the following Table 13.5.2.

Table 13.5.2 Construction Equipment (Monthly Average)

| Year | 2014 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov |
| AG Trucks | 3 | | | | | | | | | |
| Generator 10 kVA | 1 | | | | | | | | | |
| Generator 65 kVA | 1 | | 1 | 1 | 1 | | | | | |
| Generator 25 kVA | | | 1 | | | | | | | |
| Generator 85 kVA | | 1 | | | | | | | | |
| Generator 240 kVA | | | | 2 | 2 | 3 | 3 | 3 | 1 | |
| Compressor | 1 | 1 | | | | | | | | |
| Electric Saw | 1 | | | | | | | | | |
| Cutting Machine | | 1 | | | | | | | | |
| Rammer Compactor | | 1 | | 1 | 1 | | | | | |
| Excavator (0.75 $m^3$) | | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | |
| Welding Machine | | | 1 | 2 | 3 | 5 | 5 | 5 | 2 | |
| 2.5 ton Diesel Hammer | | | | 1 | 2 | 1 | | | | |
| 55 ton Crawler Crane | | | | 1 | 1 | | | 1 | | |
| 25 ton Mobile Crane | | | | 1 | | | | | | |
| Vibro Hammer | | | | 1 | 1 | 1 | | | | |
| Concrete Mixer | | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| Gas Cutter (O2+Acetylene) | | | | 1 | 2 | 2 | 2 | 2 | 1 | |
| Concrete Cutter | | | | 1 | | | | | | |
| Rebar Cutting Machine | | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| Submersible Pump | | | | 1 | | 1 | 1 | 2 | | |
| Drilling Machine | | | | | | 1 | 1 | 1 | 1 | |
| Hammer Drill | | | | | | 1 | 1 | 1 | 1 | |
| Concrete Vibrator | | | | | | 4 | 4 | 4 | 1 | |
| Water Pump | | | | | | 3 | 3 | 3 | 3 | |
| Grinder | | | | | | 5 | 5 | 5 | 2 | |
| Pilling Machine | | | | | | 1 | 1 | | | |
| Crawler Crane | | | | | | 1 | 1 | | | |
| Dump Truck | | | | | | | | | 1 | |

Source: JICA Project Team

### (5) Manpower

Manpower deployed by the contractor (man-day) is summarized in Table 13.5.3 below.

Table 13.5.3 Manpower (man-day)

| Year | 2014 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov |
| JFE | | | | | | | | | | |
| Project Director (Japanese) | 24 | 18 | 25 | 27 | 23 | 31 | 50 | 47 | 49 | |
| Resident Engineer (Japanese) | 11 | 24 | 25 | 31 | 28 | 35 | 23 | 27 | 25 | |
| Engineers (Japanese and Myanmar) | 57 | 96 | 90 | 187 | 171 | 196 | 169 | 158 | 106 | |
| Administrator | 20 | 20 | 17 | 22 | 22 | 23 | 21 | 22 | 22 | |
| Staff | | | | 45 | 180 | 111 | 134 | 67 | | |
| **Total** | **112** | **158** | **157** | **312** | **424** | **396** | **397** | **321** | **202** | |
| **Sub-con** | | | | | | | | | | |
| Managers | 41 | 24 | | 16 | 59 | 93 | 93 | 90 | 37 | |
| Safety/Security | 37 | 25 | 3 | 30 | 37 | 31 | 31 | 30 | 30 | |
| Admin | 34 | 36 | 3 | 27 | 29 | 31 | 31 | 30 | 30 | |
| Engineer | 71 | 130 | 42 | 165 | 174 | 187 | 217 | 210 | 135 | |
| Surveyor | 23 | 27 | 29 | 136 | 121 | 151 | 124 | 120 | 20 | |
| Supervisor | 23 | 36 | 2 | | | | | | | |
| Surveyor Helper | 46 | 37 | 2 | | | | | | | |
| Worker | 536 | 412 | 21 | 1216 | 1976 | 2825 | 3435 | 3655 | 844 | |
| Guard | | 58 | 90 | 93 | 135 | 124 | 124 | 120 | 120 | |
| Storekeeper | | | 6 | 58 | 149 | 125 | 155 | 150 | 75 | |
| **Total** | **811** | **785** | **198** | **1,741** | **2,680** | **3,567** | **4,210** | **4,405** | **1,291** | |
| **Grand Total** | **923** | **943** | **355** | **2,053** | **3,104** | **3,963** | **4,607** | **4,726** | **1,493** | |

Source: JICA Project Team

## (6) Meetings

Weekly meetings between the consultant and the contractor were held on Tuesdays throughout the construction period. Other major meetings are summarized in the following Table 13.5.7.

Table 13.5.4 Major Meetings

| No. | Meeting Title | Date | Attendance |
|---|---|---|---|
| 1. | Kick-off Meeting | 7th February.2014 | JICA, IWT, MPA, NK & JFE |
| 2. | Monthly meeting No.1 | 4th March,2014 | JICA, IWT, MPA, NK & JFE |
| 3. | Monthly meeting No.2 | 2nd April ,2014 | JICA, IWT, MPA, NK & JFE |
| 4. | Monthly meeting No.3 | 7th May ,2014 | JICA, IWT, MPA, NK & JFE |
| 5. | Monthly meeting No.4 | 4th June ,2014 | JICA, IWT, MPA, NK & JFE |
| 6. | Monthly meeting No.5 | 4th July,2014 | JICA, IWT, MPA, NK & JFE |
| 7. | Meeting for Quality Management | 17th July ,2014 | JICA, IWT, MPA, NK & JFE |
| 8. | Seminar for Safety in JICA Myanmar Office | 22nd July ,2014 | JICA, IWT, MPA, NK & JFE |
| 9. | Monthly meeting No.6 | 6th August,2014 | JICA, IWT, MPA, NK & JFE |
| 10. | Monthly meeting No.7 | 10th September,2014 | JICA, IWT, MPA, NK & JFE |
| 11. | Monthly meeting No.8 | 1st October,2014 | JICA, IWT, MPA, NK & JFE |
| 12. | Monthly meeting No.9 | 28th October,2014 | JICA, IWT, MPA, NK & JFE |
| 13. | Monthly meeting No.10 | 13th November, 2014 | JICA, IWT, MPA, NK & JFE |
| 14. | Warranty period meeting | 20th November, 2014 | IWT, MPA, NK & JFE |

Source: JICA Project Team

### 13.5.3 PROCUREMENT OF MATERIAL FOR PONTOONS

Two pontoons were constructed at IWT Dalla Dockyard with technical support from the experts of the JICA Project Team for training. Based on the 3rd steering committee meeting on the 31st of March 2013, it was decided that not only technical transfer but also materials and consumable items were to be provided for the pontoons by JICA. Sand blasting was also executed in Theinphyu Dockyard because of the time constraint. The procurement is included in the contract between JICA Myanmar Office and the contractor for the construction of the jetty. The maximum allowable amount of the procurement was USD 800,000 including the 5% profit of the contractor.

The contractor ordered the work including transport from an agent in Myanmar. The major items are shown below. The contractor procured materials from the 1st of February up to the end of the project in conformity with the instructions of the JICA Project Team to Dalla Dockyard and MPA Theinphyu Dockyard.

### 13.5.4 ENVIRONMENTAL MONITORING

#### (1) Project Description

Port development project was implemented by JICA and Inland Water Transport (IWT), an entity directly under the Ministry of Transport (MOT). As for the initial development plan of this project, construction work for the project was planned to be conducted with a timeframe of nine months starting from the 1st of Feburuary 2014.

The five major components of the construction project are summarized below.

| Component | Notes |
|---|---|
| 1) Porter Way of Rigid Concrete Pile Foundation | 2 sets |
| 2) Slipway with Pile Foundation and Staircase | 1 set |
| 3) Movable Steel Bridge | 2 sets |
| 4) Passenger Terminal Building | 1 building |
| 5) Concrete Coating Pontoon | 2 sets |

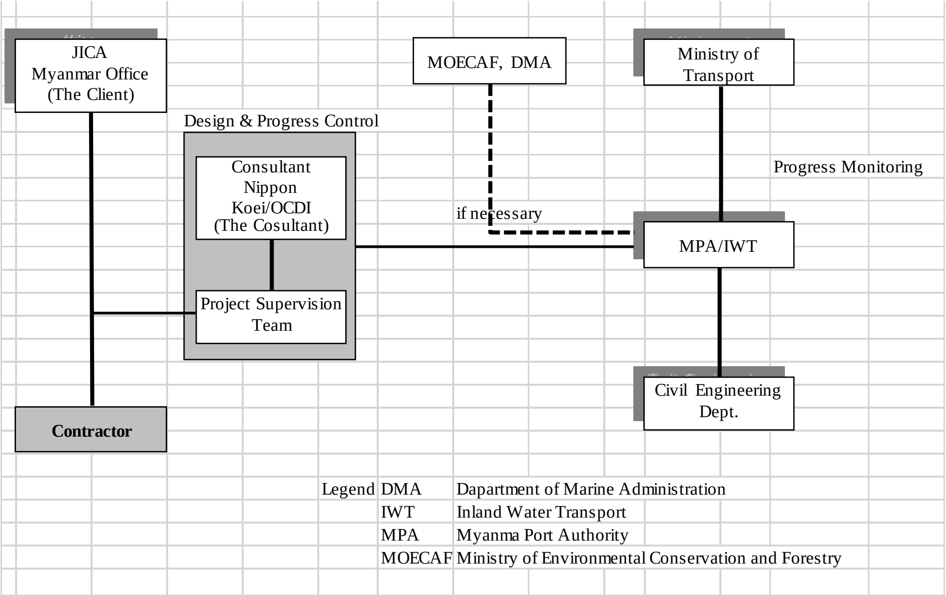
Source: JICA Project Team

Source: JICA Project Team

Figure 13.5.6 Bird’s-eye View

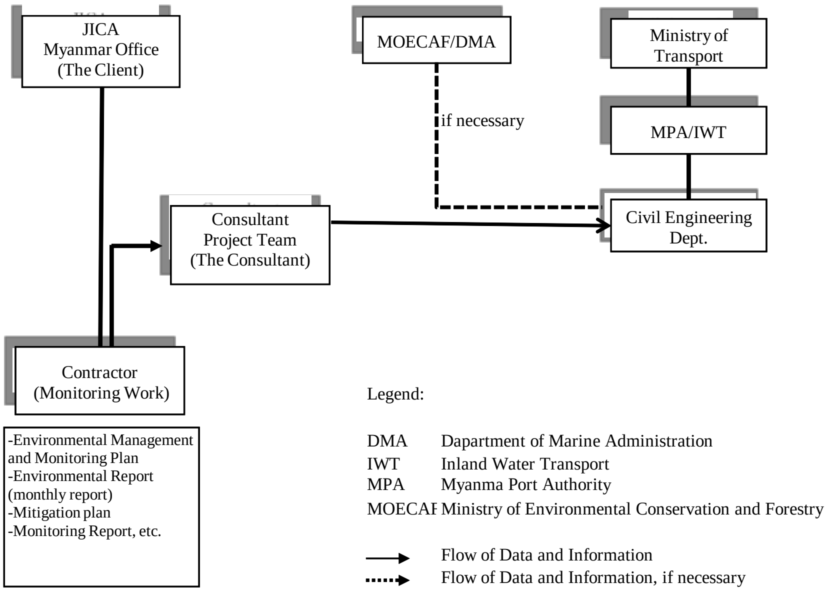
### (2) Organization and Structure of Environmental Management

The organizational structure of environmental management during the construction phase for the restoration of Dalla Ferry Terminal is shown in Figure 13.5.7 and Figure 13.5.8. The project proponent was responsible for the construction work of the jetty and related facilities. The contractor (JFE) established a project office where the implementation of the construction work took place. The consultant was responsible for the progress management of the construction work, environmental and social consideration, and so on. The overall project management was done by JICA as the responsible organization.



Source: JICA Project Team

Figure 13.5.7 Project Organization



Source: JICA Project Team

Figure 13.5.8 Organization of Environmental Monitoring and Management

### (3) Environment Management and Monitoring Plan

The purpose of environmental management is to ensure that the project activities are planned and carried out during the preconstruction and construction phases of the project in a manner that avoids or minimizes impacts on the social and natural environment, in order to maintain the status of the environment in and around the ferry port under satisfactory condition and conform to the requirements of the new JICA Guideline and other environmental laws, rules, and regulations in Myanmar.

The environment management and monitoring plan (EMMP) prepared for the implementation of the project was approved by the consultant. All of the environmental management and monitoring work were conducted by the contractor based on this approved EMMP. Table 13.5.5 shows the monitoring conditions carried out by the contractor.

Table 13.5.5 Monitoring Conditions

| Monitoring Element | Location | Monitoring Done During | | Remarks |
|---|---|---|---|---|
| | | Baseline | Construction | |
| Water Quality of Yangon River | Designated sites | √ | √ | |
| Water Quality of Surface Drainage | Designated sites | √ | √ | Monitoring carried out at the construction site. |
| Soil Erosion of Earthwork Site | Construction site | - | √ | |
| Air Quality | Air quality at construction site | √ | √ | Construction equipment/ vehicles : visual inspection |
| Compliance with HSE | Construction site | √ | √ | |
| Solid Waste Accumulation at Site | Solid waste dumping sites allocated to the contractor, and any other vacant areas where the contractor is depositing the debris | - | √ | |
| Accidents at Site | Every site under contract | - | √ | |
| Noise and Vibration | Every site under contract | √ | √ | Construction equipment/vehicles, close to the housing area which may be affected |
| Traffic and Public Facilities | Access road to construction area, detour road and any other temporary construction works related to road | √ | √ | |

√ : Items completed by the contractor
Source: JICA Project Team

The key elements in the environmental management plan were the proposed mitigation measures that were incorporated in the detailed design. The contractor completed the monitoring of the environmental impact during the execution of the Works as well as applied the necessary mitigation measures in order to keep to an absolute minimum level any adverse impact on the surrounding areas.

Environment management institution was established in the project execution organization that was responsible for the coordination of the EMMP.

Basically, the supervision of environmental management and monitoring required for EMMP was carried out by the consultant and the project executing organization. All of the activities were managed and controlled by the project executing organization as shown in Figure 13.5.7 and 13.5.11.

Mitigations and monitoring activities during the construction phase are shown in Table 13.5.6. During the construction phase, the environmental impact caused by construction work was not observed through any kind of monitoring, and no serious troubles on safety and health matters occurred during the construction stage. The contractor has conducted sufficient proper countermeasures for the prevention of any troubles. Treatment and control of environmental impact were carried out through mitigation and countermeasures. The obtained data and information were reported in the weekly meetings and submitted to each concerned environmental organization.

Table 13.5.6 Mitigations and Monitoring Activities

| Issue | Impact to be Mitigated | Monitoring Activities |
|---|---|---|
| Traffic and public facilities | Nuisance or danger of traffic accidents caused to local residents near the port access road due to construction vehicular traffic. | • Speed control of construction vehicles.<br>• Timing/scheduling of construction vehicles.<br>• Traffic control and site attention signs/traffic flag man.<br>• Visual inspection |
| Air pollution | Dust and air pollutant emission due to construction equipment, vehicles, and activities like land clearing, transport/storage of dust-prone materials at the site. | • Monitoring of proper operational functioning of all heavy equipment/vehicles, transport/storage of materials and regular water sprinkling of site.<br>• Regular ambient air quality monitoring at site.<br>• Visual inspection |
| Noise and vibration | Nuisance caused to nearby residences due to construction equipment and heavy vehicles, and construction activities. | • Check of heavy vehicles and construction equipment and timing of high noise/vibration activity.<br>• Visual inspection |
| Water quality monitoring | Pollution caused to water. The procedures for sampling, storage and transport of samples and analysis were according to the Standard Methods for Examination of Water approved by MOECAF. Water quality monitoring was completed by the following two organizations: Laboratory Technical Consultant and the National Health Laboratory (Department of Health, Ministry of Health). | • Water Temperature, ºC<br>• Turbidity, NTU<br>• Total Suspended Solids (TSS), mg/L<br>• pH Value at Ambient Temperature<br>• Biochemical Oxygen Demand (BOD5), mg/L<br>• Dissolved Oxygen (DO), mg/L<br>• Chemical Oxygen Demand (COD), mg/L<br>• Nitrate (N), mg/L |

Source: JICA Project Team

### (4) Water Quality Monitoring

During the preconstruction phase, the contractor was responsible for ensuring the baseline conditions, and formal environmental monitoring of water quality was carried out by a qualified laboratory approved by the consultant. Water quality monitoring was completed by the following two organizations:

- Laboratory Technical Consultant
- National Health Laboratory (Department of Health, Ministry of Health)

#### 1) Parameters

During the construction phase, in addition to visual inspection, the following parameters were monitored at the monitoring point of Yangon River water:

- Water Temperature, °C
- Turbidity, NTU
- Total Suspended Solids (TSS), mg/L
- pH Value at Ambient Temperature
- Biochemical Oxygen Demand ($BOD_5$) mg/L
- Dissolved Oxygen (DO), mg/L
- Chemical Oxygen Demand (COD), mg/L

- Nitrate (N), mg/L

### 2) Methodology

The procedures for sampling, storage, and transport of samples and analysis were according to the Standard Methods for Examination of Water approved by MOECAF.

### 3) Weekly Environmental Check Sheet

As required in the contract, the contractor carried out site inspection of the environmental conditions for the construction works, and submitted inspection report (check list) which included the following items:

- Water quality of surface drainage
- Soil erosion of earthworks
- Air quality of site
- Solid waste accumulation
- Compliance with HSE plan
- Noise and vibration
- Traffic congestion

### (5) Reporting

The environmental monitoring program during the preconstruction and construction phase was carried out by the contractor and consultant, and the existing baseline data, test results, and other data were compiled into an environmental management report.

The contractor submitted copies of all laboratory reports and site inspection reports according to the contract.

## 13.5.5 SAFETY

### (1) Safety Records

The contractor's safety record during the construction period is summarized in the following Table 13.5.10:

Table 13.5.7 Safety Record

| MONTH | MAN-DAYS | | ACCIDENTS | | No. of ACCIDENTS RELATED TO JOB | | ACCIDENT RATIO | |
|---|---|---|---|---|---|---|---|---|
| | CURRENT | ACCU-MULATED | CURRENT | ACCU-MULATED | CURRENT | ACCU-MULATED | (a) | (b) |
| FEB | 923 | 923 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 880 | 1,803 | 0 | 0 | 0 | 0 | 0 | 0 |
| APR | 348 | 2,151 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 2,338 | 4,489 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUN | 3,156 | 7645 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUL | 3,852 | 11,497 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 4,607 | 16,104 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 4,726 | 20,830 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 1,493 | 22,323 | 0 | 0 | 0 | 0 | 0 | 0 |

(a): INJURED, DEATH CASE/ ACCUMULATED MAN-HOUR X 1,000,000 (I/A)
(b): LOST DAYS/ ACCUMULATED MAN-HOUR X 1,000(L/A)
As seen in the table, there were no accidents throughout the construction period.

Source: JICA Project Team

### (2) Safety Activities

Major safety activities are summarized in this subsection.

#### 1) Toolbox Meeting

| | |
|---|---|
|  | The contractor conducted toolbox meetings before the start of the daily works.<br>At the meeting, daily work items were confirmed, and the safety precautions were explained to the workers. |

#### 2) Weekly Housekeeping

| | |
|---|---|
|  | On Saturdays, the contractor, including managerial staff, conducted cleaning (collecting garbage) at the site and site office areas. |

#### 3) Monthly Safety Meeting/Patrol

| | |
|---|---|
|  | After the regular monthly meetings, monthly safety meetings were held among JICA, IWT, MPA, JFE, and NK, agenda of which includes last month's safety review and the current month's safety precautions.<br>Managerial safety patrol (see picture) followed the monthly safety meeting. |

## 13.6 SEMINAR AND WORKSHOP

### 13.6.1 GENERAL

The seminars and workshops for port engineering was planned with the aim of transferring engineering knowhow in planning and design of port facilities which is required for the proper development and maintenance of the MPA-owned port facilities under any future changes in the socioeconomic and natural conditions.

The seminars and workshops covered the following topics:

**1) Port Facility Design Seminar (1)**

- Date and Time: 25th March 2010, 9:00 AM to 2:30 PM
- Presenter: Dr. T. Yagyu, Co-team Leader of the project

**2) Port Facility Design Seminar (2)**

- Date and Time: 15th July 2010, 1:00 PM to 2:30 PM
- Presenter: Mr. Y. Ando, Port Engineer

**3) Port Facility Construction Seminar**

- Date and Time: 15th July 2010, 2:30 PM to 4:30 PM
- Presenter: Me. H. Otani, Senior Civil Engineer

**4) Workshop about Maintenance of Reinforced Concrete**

- Date and Time: 26th December 2014, 1:00 PM to 4:30 PM
- Lector: Dr. Kimitoshi Matsuyama, Senior Civil Engineer

**5) Workshop on Environment and Social Considerations**

- Date and Time: 3rd November 2014, 10:00 AM to 11:30 AM
- Lector: Mr. Shigeru Kanaya, Environmentalist

### 13.6.2 PORT FACILITY DESIGN SEMINAR (1)

#### (1) Contents of the Seminars

The first seminar was composed of two sections, namely, “design criteria” and “planning and design of a pilot project facility” and was attended by about 40 MPA staff.

The seminar on design criteria included the difference between a specification-based and performance-based design, a state-of-the-art technology which has been applied recently to the design of port facilities around the world.

The seminar on planning and design of a pilot project facility included the following topics:

- design conditions,
- planning parameters,
- design parameters,
- construction, and
- maintenance.

#### (2) Evaluation of the Seminars

In order to fulfill the aim of the seminar, an appropriate post evaluation of the performance of the seminar is inevitable.

The evaluation has been performed by the participants to indicate their knowledge about the seminar topics prior to the seminar and after taking the seminar in narrative as well as qualitative forms regarding the following items:

"Please answer the following questions in English."

1) What kind of items shall be determined in planning and design of port facilities?
2) What is the difference between a specification-based design and a performance-based design?
3) What interesting topics have you learned during the seminar?
4) Any other comments on the seminar or others?

Twenty one participants submitted the response forms after the seminar. Particular points to be noted are as follows:

#### 1) Understanding of the Design Criteria

Eleven participants among the 21 who responded seem to understand the concept of the performance-based design criteria although they still need some time to understand it completely because a performance-based design criteria is a new and difficult technology adopted only starting from 2008, even in Japan.

#### 2) Understanding of the Planning and Design of the Pilot Project Facility

Most participants were interested in the seminar and understood the design conditions and the planning and design parameters of the facility quite well as well as the concept of construction and maintenance of the facility which were the most important part of the seminar.

#### 3) Other Comments

Participants appreciated the seminar given to them which enabled them to learn about new technology in port engineering. Some participants indicated that they want to have more opportunities like taking seminars on planning and design of port facilities or similar topics in the future.

### (3) Overall Evaluation

A six-hour seminar seems not enough to provide complete understanding of the whole subject of the seminar. However, the trainees were only supposed to understand the new concept of performance-based design criteria and the planning and design of the pilot project facility which was the main subject of the seminar aiming at transfer of technology.

For further improvement of MPA engineers' knowledge, it can be suggested to give more specific engineering seminars in connection with the construction of the pilot project facility before and during the construction period.

## 13.6.3 PORT FACILITY DESIGN SEMINAR (2)

### (1) Purpose of the Seminar

The purpose of the seminar is to make Myanmar engineers understand "the general work procedure and content of quay design" and "the content of the design of pilot project facility.

### (2) Contents of the Seminar

In the seminar, the design process of a pilot project facility was explained as an example to understand the procedure and the content of general quay design.

The seminar covered the following topics:

1) Flow of design work,
2) Setting of design condition,
3) Establishment of acting force,
4) Examination of structural,
5) Examination of material, and
6) Design drawing.

### (3) Evaluation of the Seminar

After the seminar, the level of understanding of the participants with regard to the seminar was reviewed using a questionnaire.

Unfortunately, the level of understanding with regard to the general content of quay design could not be regarded as “good” according to the answers. It seems that the short duration of the seminar for the explanation and the questionnaire session was the cause.

However, they likely understood well how the structures of the pilot project were designed through the handouts and explanations at the seminar.

The Myanmar engineers also showed interest about the content of individual design works such as "how to settle the design condition", "structural type and feature of the quay", and "structural analysis method".

Since it will take a considerably longer time to explain these individual contents in detail, it is practically impossible to make a proper lecture in the framework of the short seminar for this project and it is necessary to perform this under another scheme such as JICA special training.

## 13.6.4 PORT FACILITY CONSTRUCTION SEMINAR

### (1) Contents of the seminar

This seminar covers two sections, namely, “concrete” and “piling”.

Due to the limited time, only important items were picked up for the seminar. The subjects on technical skill and knowledge were mainly explained in the seminar.

<Section-1 CONCRETE>

- Characteristics of concrete such as materials, water cement ratio, strength of concrete, slump and workability of concrete were explained. Relationship between each characteristic was explained.
- Procedure of making mix design in accordance with abovementioned concrete characteristics is explained.
- Procedure of the trial mix and its relation with mix design were explained.
- Daily control of concrete quality such as material test, site test, and strength test were explained.

<Section-2 PILING>

- Important points on survey for pile position, pile verticality, and pile elevation were explained.
- Method of piling completion (final setting) was explained based on the pile penetration and bearing capacity.
- Characteristics of each element of piling such as ram weight, ram height, penetration, and rebound, and their relationship were explained.

- Mechanism, procedure and important points on the PDA test were explained.

### (2) Evaluation of the Seminar

In order to evaluate the effectiveness of the seminar, an evaluation was performed among the participants to indicate their understanding of the seminar contents. Questions were prepared in the form of “Is the following sentence correct or not correct?” and answers are to be shown as ○ or X. The evaluation results of the participants’ level of understanding of each content are as follows:

<Section-1 CONCRETE>

- Participants understood about concrete generally. However, many participants did not understand about the relationship between the water content (W/C) and concrete strength.

<Section-2 PILING>

- Participants understood piling work comparatively well. They are interested in final setting and PDA test more because the final setting method is still not popular in Myanmar.

### (3) Conclusion of the Seminar

Many participants attended the lecture with high interest and concentration. Many questions were raised during the lecture which shows that they require more technical knowledge.

On the other hand, their technical knowledge is not sufficient according to the evaluation of the seminar mentioned above and technical discussion during the study. In particular, knowledge about quality control on site is necessary for them in properly controlling the construction project.

It is recommended to give a more specific engineering seminar on the basic technical skill of construction supervision.

## 13.6.5 WORKSHOP ABOUT MAINTENANCE OF REINFORCED CONCRETE

### (1) Purpose

In Yangon Port, many jetties are made of reinforced concrete and have been used for a long time. Some of the jetties need maintenance because they have deteriorated. Japanese experts investigated them and enhanced Myanmar engineer’s technologies of investigation, evaluation, repair, and maintenance for reinforced concrete jetties through training.

### (2) Effects

On-site investigation and lecture will enhance Myanmar engineer’s technologies regarding deterioration of reinforced concrete as follows:

- How to investigate them,
- How to evaluate the deterioration,
- How to repair them, and
- How to maintain them.

### (3) Schedule

- On-site investigation: October 2013

| | |
|---|---|
| ➢ Laboratory test in Japan: | November 2013 |
| ➢ Lecture: | 26 December 2013, 13:00-16:30, 23 trainees (18 from MPA and 5 from IWT) |

## (4) Contents of On-site nvestigation and Laboratory Test

- Visual test (cracking, corrosion of rebar)
- Hammering test (peeling of concrete)
- Carbonation ($CO_2$ attack)
- Chloride (salt attack)
- Concrete cover (thickness of concrete cover, depth of rebar)
- Evaluation of deteriorated concrete

## (5) Contents of Lecture

- Characteristics of Reinforced Concrete and Maintenance
- Inspection and Evaluation of Reinforced Concrete
- Results of Inspection and Evaluation of Jetties (Wadan Jetty 6 and Dalla Port Jetty)
- Repair and Maintenance of Reinforced Concrete (showing examples of Kaindan Jetty and Dalla Port Jetty)
- Display (in the Meeting Room)
  - Equipment for Inspection of Reinforced Concrete
  - Materials of Concrete
  - Materials for Repair

Explanation by Mr. Kimura

Explanation by Dr. Matsuyama

Trainees

Group Photo

Result of On-site Survey

Test Material and Instrument

Source: JICA Project Team

Photo 13.6.1 State of Worshop (RC Maintenance)

### 13.6.6 WORKSHOP ON ENVIRONMENT AND SOCIAL CONSIDERATIONS

#### (1) Summary of the Lecture

The lecture was held on the 3rd of January 2015. The outline of the lecture is shown in Table 13.6.1.

Table 13.6.1 Outline of the Lecture on Environmental and Social Consideration

| Date / Time | Venue | Participants |
|---|---|---|
| 3rd November, 2014 / 10:15am to 11:15am | Meeting Room, IWT, No.50 Pansoedan Street Kyauktada Township, Yangon | - U Zaw Maung Maung: Assistant Manager of IWT<br>- U Than Htay: Assistant Command Engineer of IWT<br>- U Thant Zin: Divisional Engineer of MPA<br>- U Sung Thein: Deputy Divisional Engineer |

Source: JICA Project Team

#### (2) Contents of the Lecture

The following contents were presented in the lecture:

**1) JICA's Environmental Policy**

- Explanation of new environmental and social guidelines including categorization, public consultation and information disclosure.

**2) Current Situation of Legislation for Environmental Law and Regulation in Myanmar**

- Introduction of the related laws and rules for port development project.
- Explanation of draft environmental impact assessment (EIA) procedure.

**3) Environmental Consideration for Port Project**

- Explanation of items of environmental monitoring during operation stage.
- Explanation of environmental management including mitigation measures.

### (3) Question and Answer

Table 13.6.2 shows the record of questions and answers during the lecture on environmental and social consideration. Photo 13.6.2 shows the state of the lecture.

Table 13.6.2 Record of Questions and Answers during the Lecture

| No. | Question (from participant) | Answer (Nippon Koei) |
|---|---|---|
| 1 | After the enforcement of EIA procedure, how will the categorization of IEE and EIA be carried out? | For the categorization, the project proponent has to submit the proposal to the Ministry of Environmental Conservation and Forestry. Based on the proposal, MOECAF will categorize the IEE or EIA requirement. |
| 2 | According to the draft of environmental law in Myanmar, if the project proponent violates the law, the operation will be suspended for 60 days for the first time violation of the law. And for the second time, the operation will be suspended for five years.<br>What do you think about this penalty as compared to environmental law in Japan? | In Japanese environmental law, there is no long penalty period like the five year suspension of the operation. Therefore, Myanmar's environmental law penalty is strict. |

Source: JICA Project Team

Photo 13.6.2 State of Workshop (Environment)

### (4) Conclusion of the seminar

In order to confirm the effectiveness of the lecture, questionnaire survey was conducted among participants to confirm their understanding of the lecture contents. As a result, all of the participants attended the lecture with high interest and concentration. They have understood the necessity of EIA, and the requirement of EIA or IEE in future projects.

It is recommended to hold a meeting for the discussion of more practical issues during the operation stage such as the scrutiny of monitoring items, frequency for each monitoring item, and the cost for the monitoring.

# CHAPTER 14

# SUMMARY
# (OUTPUT AND EVALUATION)

# CHAPTER 14 SUMMARY (OUTPUT AND EVALUATION)

## 14.1 REPORT OUTLINE

This Project consists of two parts: Establishment of recovery plan from the damages caused by Cyclone Nargis (Part 1) and Capacity development of counterparts through the recovery measures (Part 2). This chapter delineates the output and evaluation of the capacity development.

### 14.1.1 PART 1

The organizations that are involved in the waterway transport in Myanmar and the services were explained in Chapter 2. Characteristics of Cyclone Nargis were indicated in Chapter 3. Details of the facilities operated by MPA and IWT, and the damages caused by Nargis were explained in Chapter 4 to 6. In each chapter, present state analysis, definition of problems, listing of recovery plan, and prioritization of recovery projects (urgent, short-term, and long-term) were listed.

| | |
|---|---|
| Chapter 4: | Measure for Safe Navigation in Yangon Port |
| Chapter 5: | Recovery Plan for Yangon Port |
| Chapter 6: | Recovery Plan of Main Inland Waterway Transport |

### 14.1.2 PART 2

In Chapter 7, procedures for selecting the project packages depending on the urgency and the necessity by the counterpart for capacity development were depicted in Chapter 7. At the second steering committee, the following five packages (two trainings, and one pilot project) were decided, shown below. In Chapter 8, environmental consideration investigation was summarized, which was carried out in accordance with the Myanmar laws.

| | |
|---|---|
| Chapter 9: | Capacity Development for Ship Crew and Navigation |
| Chapter 10: | Capacity Development for Repairing Ships and Metal Structures |
| Chapter 11: | Study on Maritime Disaster Risk Management |
| Chapter 12: | Study of Tide Observation System |

## 14.2 ENVIRONMENTAL AND SOCIAL CONSIDERATION (CHAPTER 8)

When JICA study team commenced the services in 2009, there was no environmental law and the public perception of environmental and social consideration was scarce. During the course of implementation of the investigation and the preparation of the interim report, the counterparts had acquired such knowledge. Furthermore, during the execution of the pilot project, which started after the Myanmar environmental law had been introduced in 2014, environmental issues including Myanmar law and JICA’s guidelines were lectured in the seminar. Judging from the interests that the counterparts showed in the regular progress meetings of the pilot project, the perception of environmental and social consideration seems to have increased.

## 14.3 CAPACITY DEVELOPMENT FOR SHIP CREW AND NAVIGATION (CHAPTER 9)

Trainings for safety navigation include Capacity Development for Ship Crew of IWT Ships, Capacity Development on Ship Navigation Training, and Capacity Development of Ship Crew of IWT Ships. Through these trainings, the safety of inland waterway transport was improved. Also it is believed that the perception of importance of statistical data such as tidal elevations has increased.

When JICA's granting a leading light, the counterparts initially requested a low-cost China made model. However, after negotiation between the counterparts and the study team, a Japan made leading light was finally selected. After four-year operation of the leading light without breakdown, it was proved that the life cost of such equipment could be economized, resulted in the eradication of MPA's financial burden.

In Japan where road and railway transportation have well developed, surprisingly about 40% of the domestic cargo transportation is handled by waterway transport. In Myanmar, where there are over 6,500km waterway network and about 300 inland ports, the waterway transport will be still the major mode of the transport. However, the present state is that the navigation channels are not maintained properly and the navigating is depended on the captain's experience and intuition. As for the passenger and cargo transportation, punctuality, speed, safety, and reliability are the important factors. Thus, for future, establishment of navigation channel maintenance management including safe navigation system will be necessary.

## 14.4 CAPACITY DEVELOPMENT FOR REPAIRING SHIPS AND METAL STRUCTURES (CHAPTER 10)

This Project conducted four trainings for capacity development of repairing ships and metal structure.

As of 2008, IWT owned 476 vessels, which were deployed for inland waterway transport for passenger and cargo. Cyclone Nargis inflicted damages on 121 vessels, and the repair works were conducted at the Dalla and Ahlone dockyards. By 2009 repair for 84 vessels had been completed, but the repair of remaining 25 vessels, which had suffered severe damages, was expected for a long time.

When the study team commenced the services in 2009, the IWT dockyards were fully occupied with the repairing vessels. Regular checkup and repair for the operating vessels became a backlog, since the priority was given to the repair of vessels. Furthermore, IWT had to deploy the retired vessels to supplement the shortage of vessels. There were imminent concerns about the service and safety conditions.

According to the IWT's records and schedules, the regular repair of a large cargo-passenger vessel took as long as three to four months. The cause of this long repair time was, apart from the slow procurement of the materials and equipment, the inefficiency of the work due to the lack of skills of the IWT employees. Especially, it was evident in the welding and steel cutting skills. IWT had no systematic technical training schemes to the employees then. The employees had learned the skills only through the on-the-job trainings, resulted in limited abilities of the employees.

Training of the techniques of ship repair and welding started as "Capacity Development of Repairing and Metal Structure" in October 2009. The objectives of the training were to guide the skills of welding, steel structure manufacturing, and quality assurance to IWT. Especially, during the pontoon manufacturing as a part of the pilot project, the skills acquired in the trainings were fully utilized. In addition, the pilot project offered a precious opportunity to learn actual application of the block method.

The capacity development of the project started to aim the improvement of technical knowledge and skill for the IWT employees. The trainings were such a style that problems encountered at dockyard were highlighted and sought the solutions during the seminar.

Welding training started with lecture and practice of arc welding, which was the basic of the welding. Then, the study team assisted IWT to establish the education system. Finally, CO2 welding techniques were guided in the seminar. The knowledge and skill acquired in the trainings were applied to the manufacturing of steel cradles at slipway and Japanese-design hybrid steel pontoon at jetty.

Transferring the new welding skills was highly appreciated by the counterpart. Furthermore, the study team assisted the counterpart in the improvement of the management capabilities. Knowledge about “mold loft”, which is an interface of design and construction site, was introduced in the seminars. Detailed technical standards were set and this information was put into “mold loft” at each stage of foldout marking, cutting, assembling, welding, and assembling, rigging, and painting. Making of the construction plan was also stressed in the seminars. Construction plan was decided based on the condition of work space and capacity of facilities. In the construction plan, overall procedures, such as block division, built-up order of block, and joint geometry were described. Making of effective construction schedule was also transferred in the project. In manufacturing of pontoons in the pilot project, master and breakdown schedules were made to control the construction process. It is believed that IWT has understood the importance of making effective construction schedule, and IWT’s management skill has improved.

Through this capacity development, IWT has understood the importance of implementing the construction under the detailed construction plan and schedule. IWT learned that effective plan and schedule defined the construction ability and efficiency, confirmed the delivery time of materials and equipment, defined the delayed activities, defined the critical path of the activities, and shared the information by the people involved in the construction. It is believed that the lessons learned will enable IWT to manage the construction effectively.

As for quality management, IWT had not enough knowledge of quality standards and understanding of the troubleshooting method. However, IWT passively followed the error treating method, and up skilling in error treating technique was recognized. IWT did not carry out any air tightness test until it was introduced in the project and so inspection related to air leakage could not be done. It caused poor verification of quality control. In this technical transfer, the air leak test was introduced, thus the quality management awareness of IWT was improved. IWT learned the importance of conducting the manufacturing inspections through the trainings about general inspection methods or nondestructive test like coloring welding test. IWT also learned in the pilot project the techniques to construct less-maintenance pontoon such as the painting method, and the concrete coating method including manufacturing of its steel formwork. As a result, IWT has recognized the importance of reduction of life cycle cost through the proper quality management.

Trainings were especially appreciated by the participants: attendance ratio was more than 99%. The proactive learning attitudes of the participants were observed in all training courses. This is believed to contribute the improvement of work efficiency and quality thus the IWT’s profitability, and the safety navigation.

Through the training IWT’s work efficiency was improved to a certain extent. For further improvement of efficiency, planning and equipping of infrastructure equipment such as lifting crane to be used for block manufacturing method will be necessary. By doing so, the productivity will be increased more than 50%, which will result in increasing profitability and securing safe navigation.

## 14.5 STUDY ON MARITIME DISASTER RISK MANAGEMENT (CHAPTER 11)

The study results were unveiled to the public in the three seminars, and the number of the participants were 80 (first), 114 (second), and 138 (third). The large number of the participants indicated the high appreciations by the Myanmar side. Among the participated organizations were Department of Meteorology and Hydrology, Myanmar Maritime University, Yangon Institute of Technology, Myanmar Economic Corporation, private port operators, and shipping companies. Judging from many questions raised by the participants during the seminars, their interests were very high.

The studies were carried out by the Research and Development Center of Nippon Koei in cooperation with Hiroshima University (Cyclone and High Tide), Tohoku University (Tsunami), Kyoto University (Disaster Prevention), as well as Myanmar Maritime University and Department of Meteorology and Hydrology in Myanmar. Cooperation with many universities enabled the study results at high technological level. Especially, it was the first attempt to forecast the degrees of high tide and Tsunami in the Delta region such that the extent of disaster damages could be estimated. It is expected that the study results are published in the academic papers and utilized for the establishment of disaster prevention and reduction plans.

In this study, simulation of the propagation of Tsunami and high tide in the Delta was carried out. Since there was no information about the river bed configurations in the Delta region, the sounding surveys were carried out at the Ywe River system. The type of the river configurations was classified into several patterns by use of the survey results, and these patterns were applied to the rivers in the Delta for the simulation. This newly established method will be able to be applied to other countries that have vast delta areas. Furthermore, the study team carried out short-term tidal observations at various locations in the Delta region to grasp the tidal characteristics in this region. Understanding the tidal characteristics is very important for establishment of disaster prevention plan, and the method used in the study will be utilized in the future similar studies.

Damages caused by the 2011 Tohoku Earthquake Tsunami were delineated in the seminar. The participants appeared to have understood that if there were no education or evacuation drill for disaster, the damages could be more severe. The counterparts and the seminar participants have understood the importance of education and drill as well as establishment of disaster prevention and reduction plans. It is expected that this study results and the weather radar, which was provided and installed by JICA grant, will improve the methods of collecting and analyzing the weather data and then will be utilized for establishment of Business Continuity Plan (BCP).

## 14.6 STUDY OF TIDE OBSERVATION SYSTEM (CHAPTER 12)

As a technological transfer of the improvement of the ability for utilization of the tide gauge, automatic recording tide gauges were installed for establishing the future tide gauge installation plan. Tide levels had been observed visually prior to installation of tide gauges. Two sets of tide gauges with digital recording systems were supplied by the JICA fund in 2009. The JICA Project Team installed one at Monkey Point, where the Yangon River, the Bago River, and the Pazundan Creek converged, and the other at Thilawa Area Port.

Unlike rivers in Japan, the characteristics of tide vary by seasons (rainy and dry). Also the specific tidal characteristics in river make the tide level forecast and its correction difficult. After tidal observations in the Delta region, it was learned that the each river in Myanmar possesses unique characters.

In this project, due to limitations of budget and time and restriction of import custom clearance, pressure type automatic tide gauges were selected. However, due to the turbidity, current, and salinity of the Yangon River, the deterioration at the sensor part was obvious. For the future permanent observation, the type of the tide gauge shall be selected to meet the natural conditions.

Since the tidal constituents used in the published “Tide Table” appear to have become obsolete, these shall be revised by use of statistical method. The Study Team proposes to conduct continuous tidal observations, and revise the tide tables at major ports in Myanmar. Theoretically, 19-year observation data are recommended, however five year observation will suffice to produce a reliable tidal forecast. For example, in Japan to obtain the mean water level, average of five year tidal levels is used.

Tidal observation is used not only to determine the chart datum level, but also to establish the disaster prevention plan. Making of the tide tables at major ports are currently being outsourced to the Indian Government, though there are drawbacks in terms of national security. In short-term, continuous tidal observations at major ports are necessary. For the mid-term and long-term, there will be a need for establishing the observation plan including observations at local ports in addition to Yangon Port. The Study Team has explained to the counterpart the data analysis and management in order to obtain the accurate tidal forecast. Though the counterpart has understood the importance of establishing the observation plan, the observation system has not yet been established. In the near future, mid-term and lone-term as well as short-term observation system shall be established.

During the disaster prevention seminars, the topic about the tidal observation was also raised in order to develop capacity of the counterpart and to disseminate the knowledge to the related government authorities. As stated in Chapter 11, the tidal observations were conducted at various locations in the Delta region, and the tidal characteristics, which were not known well, were characterized by use of the observed data.

## 14.7 DESIGN AND IMPLEMENTATION OF PILOT PROJECT FOR JETTY RESTORATION (CHAPTER 13)

At the steering committee meeting held on July 22, 2009, restoration of Botahtaung jetty was selected as the pilot project. Preparation of detailed design and tender documents were conducted under the project. Though the tender was conducted, the tender was nullified partly due to the sudden change of exchange rate between Myanmar kyat and US dollar. MPA, then, requested the change of the project site. Among the alternative locations, Dalla ferry terminal was selected, and the steering committee accepted the location at the meeting held on March 31, 2013. The Study team made new designs, and tender was conducted and the contractor was selected. The construction work was commenced on February 1, 2014 and completed on the prescribed date of October 28, 2014.

The objective of the pilot project was to apply a new technology in Myanmar, which can contribute to the efficient maintenance of the jetty facilities.

It was intended that the construction materials could be procured in Myanmar, so that the counterpart can apply the same technology for future. For example, the steel pipe pile was not designed, though the robust jetty structure can be constructed. This was due to the fact that the maintenance was difficult, and the import of the piles was costly. Within the limitation of the materials, the structure type was determined such that the maintenance cost is minimal, which resulted in lowering the life cycle cost.

Various new technologies were applied in the pilot project. For example, the splicing method of concrete pile was introduced. In Myanmar proper splicing method had not been applied for the concrete piles. Also, concrete pile with octagonal cross-section was applied, which could save the volume of concrete without sacrificing the strength of the piles. The porter way structure was designed such that the structures withstand the severe earthquakes. Slipway was designed to be a piling foundation type. Due to the rigid foundation, settlement of the slipway could be avoided, thus the maintenance cost would be minimal. In the terminal building, the applied roof type enabled large space, which kept comfortable temperature in the hall. The floor tiles made the maintenance easy and added the beauty of the building. As for the operation aspect, two-way pedestrian access to the jetty enabled the smooth exchange of the passenger. The interval of ferry service reduced from 20 to 15 minutes after the completion of pilot project. Not only efficiency of the ferry service was improved, but also the safety for the passengers became secured.

As mentioned above, new technologies but could be constructed locally was applied. The counterparts participated in construction stage proactively. Upon requests, new technologies were transferred to the counterparts. The official seminars and workshops are listed below.

### 1) Port Facility Design Seminar

In order to improve the design capability, by using the Japan's port design standard, the seminars for design of port facilities were conducted. The content of the seminar included design flow, determination of design conditions, determination of external forces, structure inspection, material inspection, making and reading of drawings. The design calculations of the jetty design were provided to MPA for future use.

### 2) Port Facility Construction Seminar

In order to improve the construction supervision skills, seminar about the port facility construction was conducted. Major supervision items for concreting, such as characteristics and mix design of concrete, trail concrete mix, and quality control, were lectured in the seminars. As for the piling, which required high technical skills, lecture items included piling method, pile penetration confirmation, and piling monitoring.

### 3) Workshop about Maintenance of Reinforced Concrete

Most jetties in Yangon Port were made of reinforced concrete, which had been made as old as 70 years ago. Deterioration of the structure is at the critical stage, and most jetties need urgent rehabilitation. The Study Team conducted the jetty soundness investigation. In the workshop, trainings to MPA staff were made on the subject of inspections (appearance, hammer knocking, carbonation, chloride, thickness of concrete cover), evaluation method of deteriorated concrete, characteristics and repairs of reinforced concrete, and maintenance method.

### 4) Workshop on Environment and Social Conditions

Topics of environmental seminars conducted during the pilot project contained (i) JICA's environmental policy, (ii) Current situation of legislation for environmental law and regulation in Myanmar, and (iii) Environmental consideration for the port project.

The counterparts have increased the understandings in various aspects through the abovementioned seminars and workshops.

As for the construction safety, the counterparts have learned the safety management skills thorough the weekly and monthly safety meetings and the safety patrols. The safety awareness had gradually been increased during the course of the project: wearing ratio of PPE (Personal Protective Equipment) was satisfactory level at the end.

Through this project it was found out that Yangon Port was susceptible to disaster. Since the Yangon Port handles 90% of import and export cargos in Myanmar, it is imminent to reinforce the deteriorating facilities. It would be desirable that the port facility soundness investigations would be carried out, and targeted facilities be selected. Selection of the targeted facilities would be utilized for MPA's Business Continuity Plan (BCP). Japanese assistance to establish BCP is highly expected.