APPENDIX F CIVIL WORK DESIGN

APPENDIX F CIVIL WORK DESIGN

F.1 Design Criteria

F.1.1 Natural Conditions

(1) Meteorological Conditions

1) Temperature

The highest maximum and lowest minimum temperature recorded in La Unión between 1996 and 2000 are listed in Table F.1.1. These temperatures shall be considered in design.

Table F.1.1 Temperature Changes

	Absolute Temperature
Highest Maximum	38.7 °C
Lowest Minimum	20.2 °C

2) Rainfall

The recorded annual precipitation from 1996 to 2000 ranges from 1,272 mm (1997) to 2,123 mm (1998).

The average number of rainy days during the above period is 118 and the average monthly number of rainy days during the rainy season (May-October) is 17.3.

The rainfall intensity for the duration between 5 minutes to 60 minutes covering the period from 1970 to 2000 is shown in Table F.1.2. The data for the years between 1982 and 1994 was not reported due to damage of the instruments.

Table F.1.2 Annual Maximum Rainfall Intensity in La Unión

(unit: mm/min)

Duration of	5 min.	10 min.	15 min.	20 min.	30 min.	45 min.	60 min.
1970	2.24	1.98	1.78	1.58	1.24	1.12	0.88
1971	2.88	2.20	2.00	1.79	1.47	1.07	0.89
1972	3.38	2.52	2.03	1.67	1.29	1.08	1.02
1973	2.56	2.23	1.95	1.82	1.44	1.07	0.94
1974	2.78	2.25	1.99	1.69	1.24	0.96	1.07
1975	4.00	3.59	3.20	3.33	2.43	1.80	1.40
1976	2.74	2.22	1.94	1.76	1.55	1.23	0.97
1977	2.42	2.28	1.86	1.58	1.29	1.02	0.87
1978	2.80	2.30	1.87	1.65	1.20	0.89	0.81
1979	2.90	2.24	1.80	1.62	1.28	1.01	0.97
1980	3.28	2.10	1.83	1.67	1.55	1.32	1.17
1981	2.60	2.00	1.83	1.77	1.85	1.62	1.42
1983	2.02	1.97	1.99	1.98	1.81	1.34	0.78
1995	3.02	2.42	2.15	1.95	1.53	1.16	0.90
1996	3.80	3.00	2.40	2.05	1.63	1.26	1.17
1997	3.20	2.10	1.60	1.32	0.79	0.54	0.42
1998	2.50	2.40	2.20	2.00	1.60	1.20	1.00
1999	1.90	1.60	1.30	1.20	1.00	0.90	0.70
2000	3.62	2.74	2.29	1.99	1.41	1.03	0.82

[Source: Ministry of Agriculture and Cattle]

According to "Design Guide of Drainage for Road and Pavement in Japan", the design rainfall intensity is calculated based on the probable rainfall intensity of 60 minutes.

Based on "Annual Maximum Rainfall Intensity in La Unión", the probable rainfall intensity of 60 minutes has been computed and indicated in Table F.1.3.

Table F.1.3 Probable Rainfall Intensity of 60 minutes in La Unión

(Unit: mm/hour)

Return period	5 years	10 years	20 years	30 years	40 years	50 years
Probable Rainfall Intensity (mm/hour)	57	70	76	81	84	86

[Notes: Analyzed by JICA Study Team]

The design rainfall intensity of each culvert is described in Chapter 4.5

3) Winds

The highest instantaneous wind velocity observed in the past (from 1970 to 1984) is 29.3 m/sec. recorded in December 1970 as shown in Table F.1.4.

Table F.1.4 Maximum Instantaneous Wind Velocity in La Unión (1970-1984)

(Unit: m/sec)

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Max.
1970	NA	NA	NA	NA	NA	NA	NA	NA	NA	11.5	26.2	29.3	9.3
1971	12.8	16.0	19.1	18.6	14.0	24.1	21.5	23.1	19.0	16.0	13.5	14.0	24.1
1972	13.1	20.3	13.6	16.9	16.1	14.4	24.3	20.7	22.1	17.0	12.1	17.4	24.3
1973	19.0	19.4	16.0	14.1	15.7	21.8	23.9	26.6	15.6	15.5	14.0	15.9	26.6
1974	13.7	20.1	15.2	14.9	18.0	19.4	21.1	19.3	20.0	16.8	14.4	13.8	21.1
1975	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
1976	19.5	21.5	15.6	14.0	16.5	16.2	13.1	20.7	26.0	20.1	17.0	17.1	26.0
1977	16.1	21.0	13.0	16.6	16.5	18.5	20.8	16.4	17.0	16.0	18.1	20.1	21.0
1978	20.1	21.0	19.5	15.0	14.4	17.5	14.9	NA	NA	-	NA	NA	21.0
1979	14.2	15.0	15.8	15.5	15.3	14.4	10.6	13.2	11.0	17.8	10.6	12.0	17.8
1980	12.0	12.0	12.5	15.5	16.3	9.5	NA	NA	NA	NA	NA	NA	16.3
1981	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
1982	NA	NA	NA	NA	NA	NA	11.9	20.2	14.8	12.0	12.6	14.4	20.2
1983	19.0	12.0	15.5	13.1	13.0	20.0	19.0	20.0	19.6	NA	NA	NA	20.0
1984	12.8	14.0	10.3	13.8	13.4	15.0	NA	NA	NA	NA	NA	NA	15.0
Absolute Max. Wind	20.1	21.0	19.5	18.6	18.0	24.1	24.3	26.6	22.1	20.1	26.2	29.3	29.3

[Source: Ministry of Agriculture and Cattle]

The probable maximum wind velocity with a return period from 1 to 75 years has been computed as shown in Table F.1.5.

Table F.1.5 Probable Maximum Instantaneous Wind Velocity

(Unit: m/sec)

Return period (year)	1 Year	5 Years	10 Years	20 Years	30 Years	50 Years	75 Years
Probable maximum wind velocity (m/sec)	16	20	23	26	28	30	31

[Source: Analyzed by JICA Study Team]

El Salvador is affected by hurricanes, tropical storms and tropical dep ressions. During the period from 1911 to 2000, a total of at least 14 storms occurred around El Salvador and about 5 storms passed nearby the country as shown in Table F.1.6.

Some typical hurricanes routes that passed around the country are shown in Figure F.1.1.

The maximum wind velocity of those storms reached the country was in the range of 17.9 m/sec to 22.4 m/sec, in spite that those absolute max. wind velocity were in the range of 35 m/sec to 80 m/sec as shown in Table F.1.6. It means that the wind velocity of Hurricanes are reduced before reaching to the country.

Judging from these wind velocity records, it was considered that the probable maximum instantaneous wind velocities (Table F.1.5) are proper values, therefore, the design maximum instantaneous wind velocity in storm condition has been set as 31 m/sec for a probability of 75 years.

Table F.1.6 Recorded Max Wind Speeds of Hurricanes Storms (from 1911 to 2000)

Year	Storm Name	Max. Wind Speed Data of Hurricane				Max. Wind Speed recorded at/around El Salvador			
		Month/day	Latitude N	Longitude W	Wind speed (m/sec)	Month / day	Latitude N	Longitude W	Wind speed (m/sec)
2000	KEITH	10/01	18.0	87.3	60.33				
1999	BRET	8/22	25.5	95.5	64.80				
1999	KATARINA	10/29	13.2	82.9	17.88				
1998	MITCH	10/26	16.9	83.1	80.44	10/31	14.7	87.0	22. 4
1998	JOAN	10/19	11.3	78.9	64.80	7/23	13.1	87.9	17.9
1996	CESAR	7/28	12.3	84.2	35.75				
1995	OPAL	10/04	27.3	88.5	67.03				
1995	ROXANNE	10/11	20.0	87.0	51.39				
1993	GERT	9/20	21.3	97.0	44.69				
1974	FIFI	9/19	16.1	87.5	49.16				
1971	IRENE	9/18	11.4	82.3	35.75	9/20	12.5	87.9	17.9
1949	10	10/4	29.1	95.4	60.33	9/27	12.5	89.5	17.9
1933	21	11/17	12.2	84.3	17.88				
1911	3	9/10	13.0	82.3	44.69	9/11	13.4	87.9	20.1

[Note: Area around to El Sarvador is the extent within Latitude N12-15 degree, Longitude W87-90 degree]

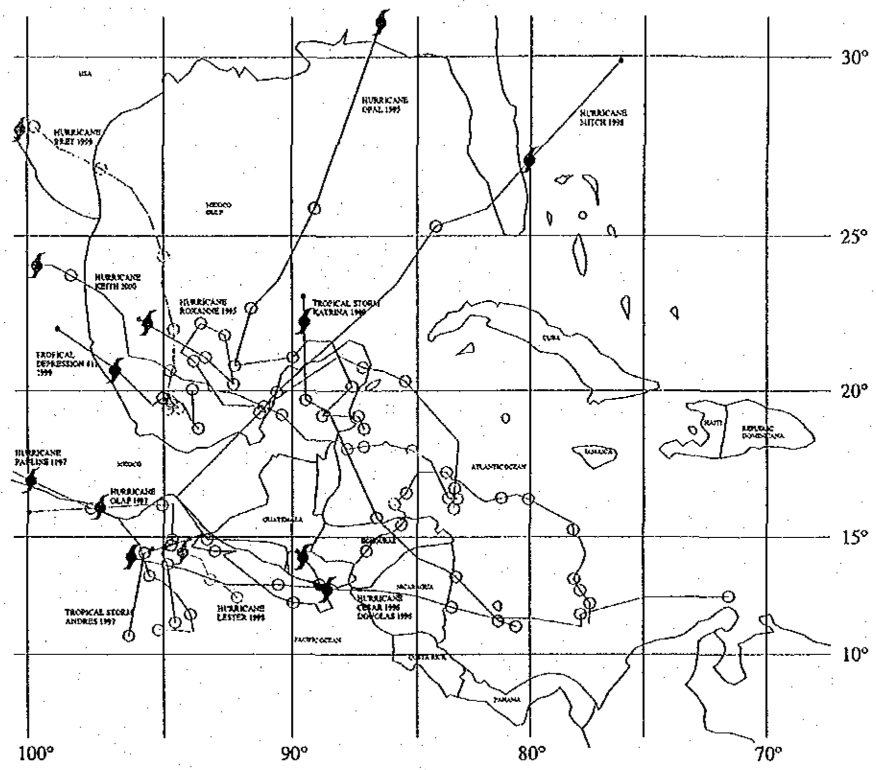


Figure F.1.1 Route of Representative Hurricanes

(2) Oceanographic Conditions

1) Tides

A harmonic analysis was carried out on the data gained through the tide measurements done in the period from 1 September 2001 to 30 September 2001, and the results are summarized as follows.

Four major tidal components

M2 (principal lunar semidiurnal tidal component)	123.2cm
S2 (principal solar semidiurnal tidal component)	26.9cm
K1 (luni-solar diurnal tidal component)	9.3cm
O1 (principal lunar diurnal tidal component)	5.8cm

According to the Technical Standards for Port and Harbor Facilities in Japan, Edition 1999 issued by the Port and Harbors Bureau of the Ministry of Transport of Japan, the Zo is calculated by adding those 4 major tidal components and the Chart Datum Level is below the Mean Sea Level by a range of Zo. Accordingly the following tide levels are applied for the project.

Mean Springs High Water Level (HWL)	3.374m

High Water Level of Ordinary Spring Tide (HWOST)	3.153m
High Water Level of Ordinary Neap Tide (HWONT)	2.615m
Mean Sea Level (MSL)	1.652m
Low Water Level of Ordinary Neap Tide (LWONT)	0.689m
Low Water Level of Ordinary Spring Tide (LWOST)	0.151m
Chart Datum Level (CDL)	0.000m
Mean Springs Low Water Level (LWL)	-0.128m

The HWL and LWL are established from the average of the HWL and LWL which are calculated by every harmonic constant of every month during 10 years. The design tidal level in La Unión Port has been set up as follows:

Mean Springs High Water Level (H.W.L)	+3.37m
Mean Sea Level (M.S.L)	+ 1.65 m
Mean Springs Low Water Level (L.W.L)	-0.13m

2) Currents

According to the current measurement survey carried out in September 2001 by the JICA Study Team, the maximum observed current velocity was 1.78 m/sec at the upper layer in the inner channel area with a direction of southeast during the ebb tide as shown in Table F.1.7.

Table F.1.7 Observed Fastest Current Speeds

Observation Layer		Ebb Tide			Flood Tide		
		M/D/H/M	Speed (cm/s)	Direction	M/D/H/M	Speed (cm/s)	Direction
B-1	L	9/20/8/50	133.1	120	9/21/2/20	84.6	301
	M	9/20/8/50	148.3	124	9/20/1/20	96.6	303
	U	9/19/20/10	159.5	128	9/19/0/50	97.4	307
B-2	L	9/19/8/30	118.4	137	9/20/1/20	80.0	309
	M	9/20/8/50	142.0	138	9/19/14/30	98.2	314
	U	9/19/20/30	178.9	136	9/19/1/20	115.8	324
B-3	L	9/21/21/10	128.7	222	9/19/12/00	102.9	30
	M	9/21/21/10	139.1	218	9/20/1/40	111.3	41
	U	9/21/21/10	155.7	215	9/20/1/40	112.3	50
B-4	L	9/18/6/30	87.1	206	9/19/11/40	81.7	44
	M	9/19/20/20	101.3	191	9/19/1/20	85.4	37
	U	9/19/7/50	116.8	194	9/21/3/50	66.0	36
B-5	L	9/17/17/10	55.2	223	9/19/0/30	46.2	54
	M	9/21/8/40	48.5	262	9/19/13/50	45.3	80
	U	9/21/20/40	68.1	259	9/20/13/00	43.1	6

L: Lower Layer, M: Middle Layer, U: Upper Layer

M/D/H/M: Month/Day/Hour/Minute

Based on the observation results, a harmonic analysis has been conducted and the fastest currents and the constant currents have been predicted. The results are indicated in Table F.1.8. Details of the analysis results are shown in Appendix C.

Table F.1.8 Fastest Current Predicted at Each Station

Station	Predicted Fastest Current		Constant Current	
	Speed (cm/sec.)	Direction	Speed (cm/sec.)	Direction
B-1	119	124	10.0	125
B-2	136	137	13.9	130
B-3	145	214	11.0	196
B-4	78	196	8.1	155
B-5	34	265	8.0	317

3) Waves

La Unión Gulf is well sheltered by islands and capes, consequently, it is expected that offshore waves will be attenuated to a minimal thus no consideration has been made.

Instead, locally generated wind waves have been estimated based on the fetch of La Unión Gulf, and the following wave characteristics are obtained;

a) Fetch

Fetch length:	10.13 km
Direction:	East

b) Operational Condition

Wind Velocity:	V= 15 m/sec
Wave Height:	H1/3 = 1.0 m
Wave Period:	T1/3 = 3.4 sec

c) Stormy Condition (75 years return period)

Wind Velocity:	V = 31 m/sec
Wave Height:	H1/3 = 2.2 m
Wave Period:	T1/3 = 4.5 sec

(3) Geological and Geotechnical Conditions

Geological and geotechnical conditions of the Cutuco Port site were studied by means of core drilling, standard penetration tests (SPT) and laboratory tests. The purpose of these investigations was to obtain geological and foundation engineering information as follows:

The subsurface geological conditions such as thickness and distribution of soil deposit, depth to bedrock, grain size distribution, Mechanical characteristics, etc.

Geotechnical data was collected for the subsurface conditions of the sites proposed for port structures, reclamation, dredging, construction materials and other important structures of the project.

Site geological investigation started in early September 2001 and ended in late November 2001. Appendix D.1 shows the locations of the core drilling and Appendix D.2 gives the coordinates of each drilling location.

1) Soil characteristrics and profiles

Geological sections are shown in Figures F.1.2 to F.1.6, more detailed drilling logs and laboratory test results are compiled in the geotechnical investigation report.

a) Land Area

Three layers were identified by correlating the stratigraphic profiles obtained from the on land boreholes BL-1 to BL-10. They are as follows:

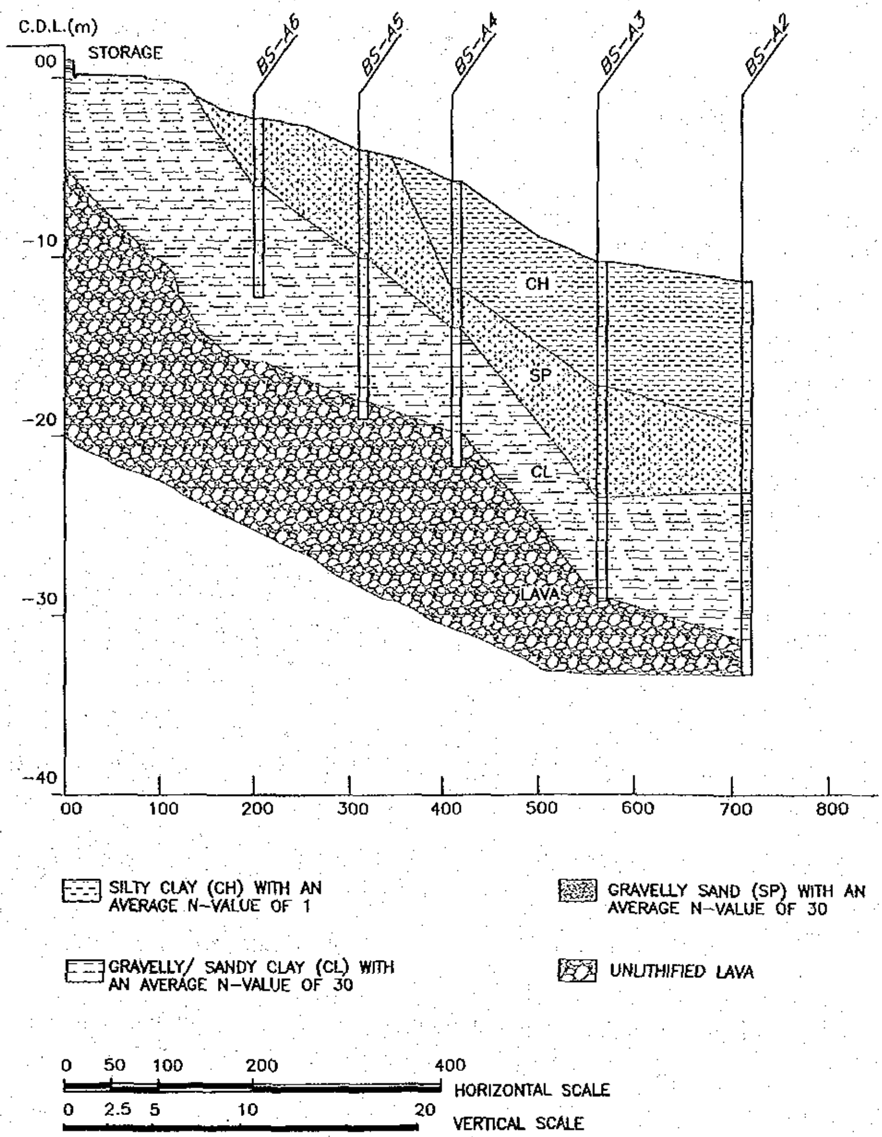
- Layer 1 – Top soil (CL): The layer is brown to brownish red and 0 to 3.0 m thick, and consists of silty CLAY with roots and some gravel s.
- Layer 2 – Silty/clayey SAND (SM): The layer followed by alluvial and colluvial pyroclastic deposits, is composed mainly of silty/clayey SAND, with medium angular to subangular gravel content of andesite, basalt and so on. The soil layer, unconsolidated to subconsolidated, has low to medium stiff, low water content, and somewhat consistent. The expected N values of the layer are about 50 except in the upper part.
- Layer 3 – ANDESITE: The layer is made up mainly of ANDESITE at drilled depth. In the upper part after the soil-rock contact, the rock is highly weathered into brown loose gravelly sand and attains a thickness of 1.0 to 3.0 m. Below the weathered part, only joints and cracks are slightly oxidated, the rock remains the original dark color and has a high strength of 50 to 150 Mpa. Moreover, the drilled cores have 80 to 100% RQD.

b) *Offshore Area (Port Area)*

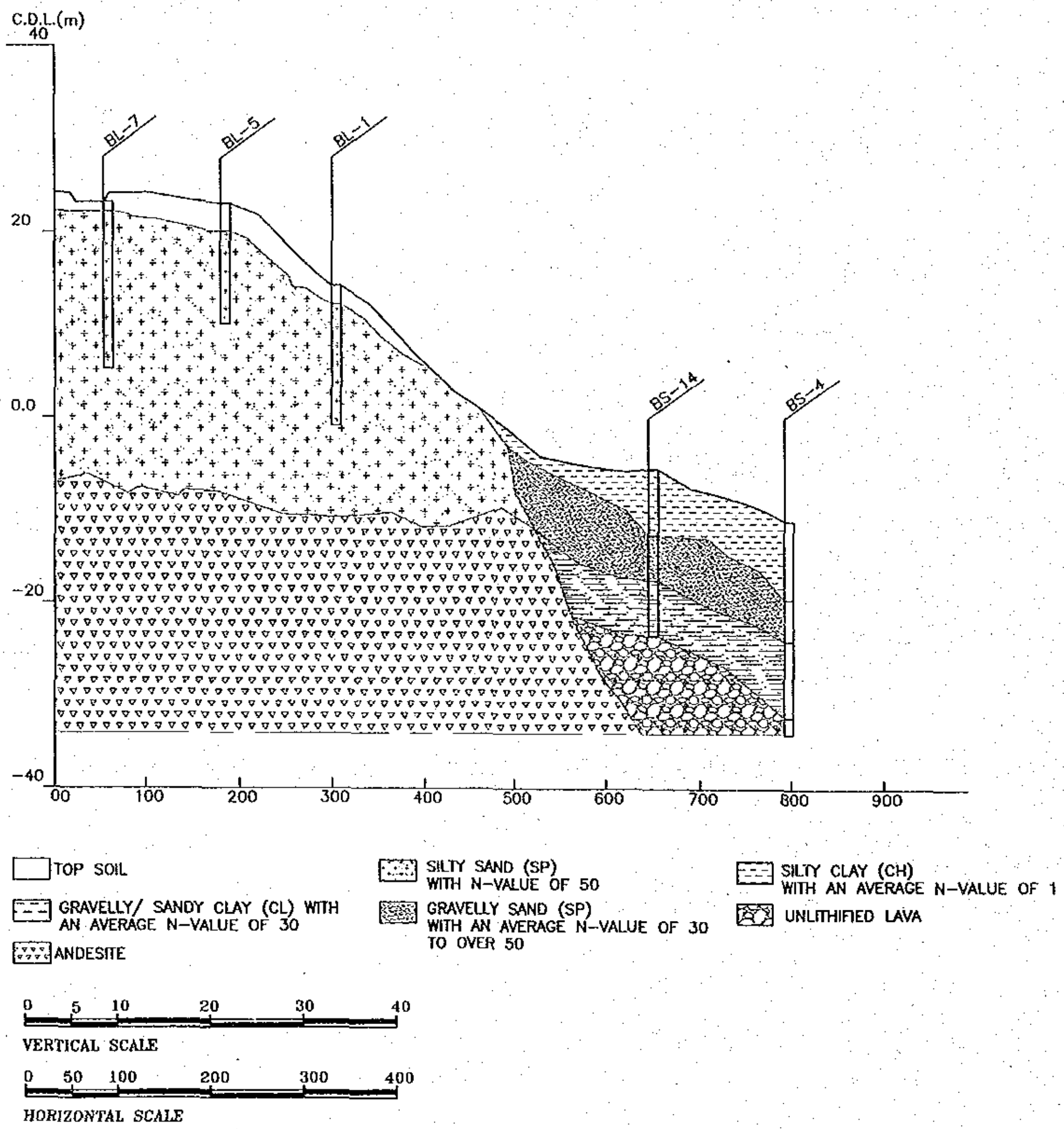
From the correlation of stratigraphic profiles obtained from the off shore boreholes BS-1 to BS-20, four layers were determined as follows:

- Layer 1 - Silty CLAY (CH): The silty clay is gray to dark and 5 to 10 m deep, consists of silt and clay with some sand and fine gravel. The layer has high plasticity and low strength. The N values of the layer show almost 1 to maximum 5.
- Layer 2 - Gravelly SAND (SP): The layer is loose dark fine to coarse gravelly SAND, with occasional cobbles of andesite. The gravel is mostly between 0.2 to 5.0 cm in size with the maximum of 50 to 100 cm. The gravel content is 20 to 40%. The N values of the layer range from 11 to 46 with an average of 30.
- Layer 3 - Gravelly/sandy CLAY (CL): The layer, brown to brownish red, consists of mainly is silty CLAY, with some coarse sands and fine gravels. The layer has low water content and low plasticity. The N values of the layer range from 11 to 36 with an average of about 30.
- Layer 4 – Unlithified LAVA: The layer, light brown to dark, is unlithified LAVA and strongly weathered into gravelly sand at some depth.
- In Layers 2 and 3, the N values have no clear and continuous tendency of increasing in the depth direction. The measured N values in the two layers range from the minimum of 11 to the maximum of over 50. The N value of over 50 is due presumably to the resistance of coarse gravel. The

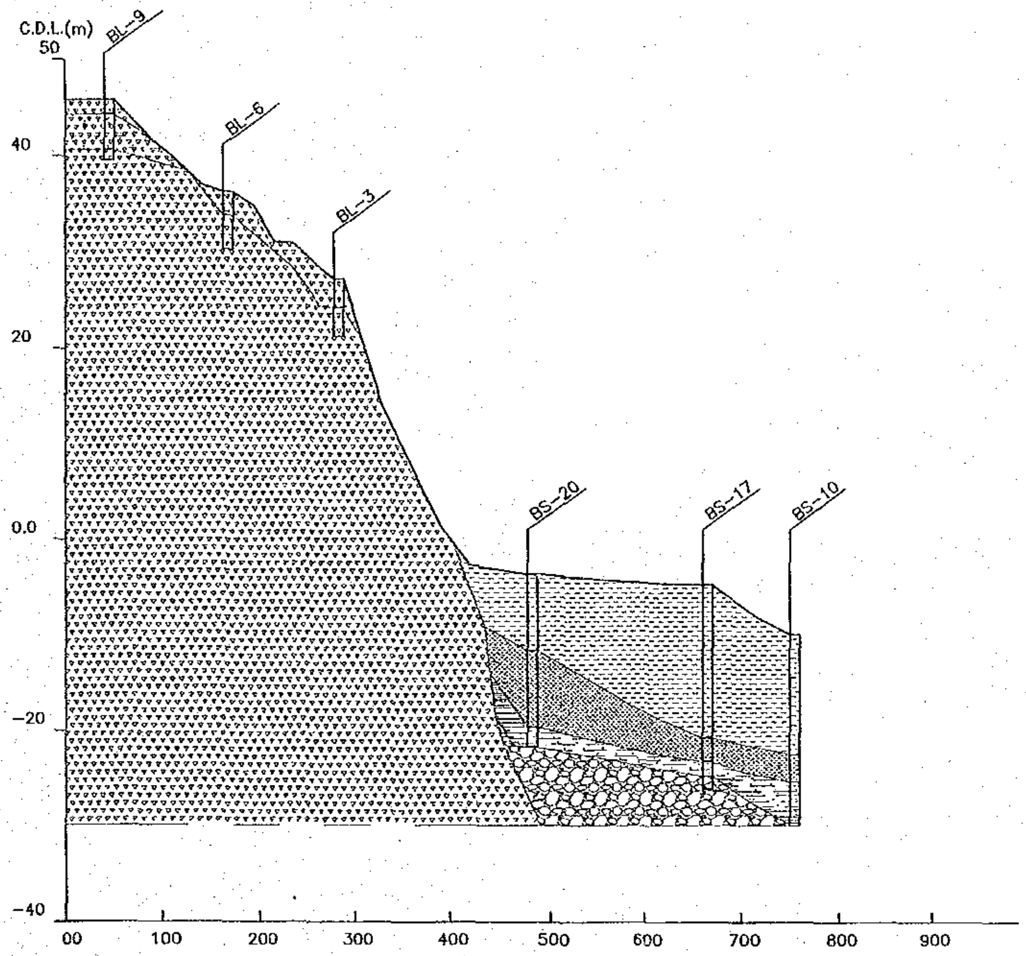
strength of these layers is thus evaluated by using the average N value except for N value of over 50.



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.1.2	Geological Section (1)



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.1.3	Geolgical Section (2)



TOP SOIL

SILTY SAND (SP) WITH N-VALUE OF 50

SILTY CLAY (CH) WITH AN AVERAGE N-VALUE OF 1

GRAVELLY/ SANDY CLAY (CL) WITH AN AVERAGE N-VALUE OF 30

GRAVELLY SAND (SP) WITH AN AVERAGE N-VALUE OF 30 TO OVER 50

UNLITHIFIED LAVA

ANDESITE

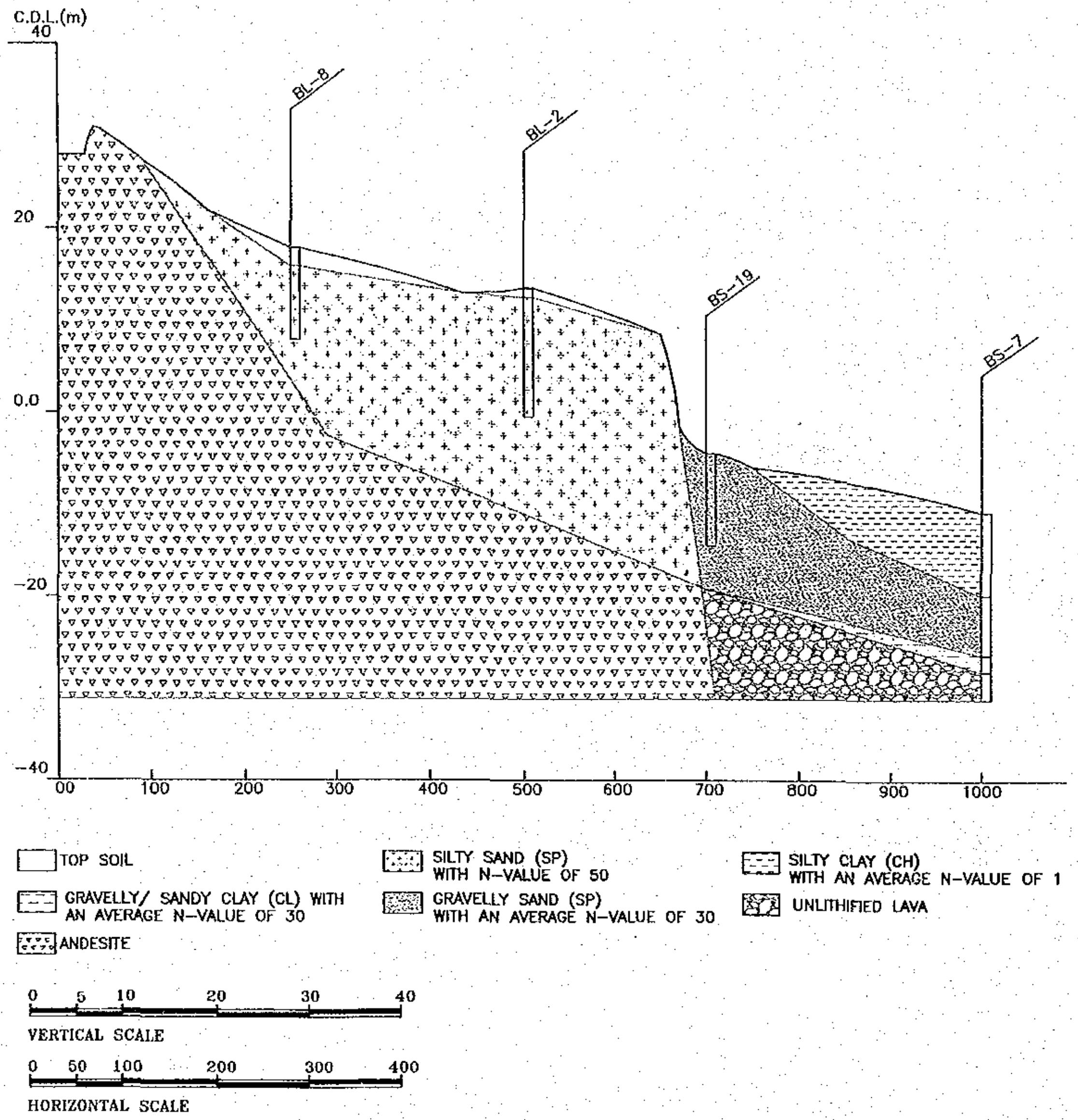
0 5 10 20 30 40

VERTICAL SCALE

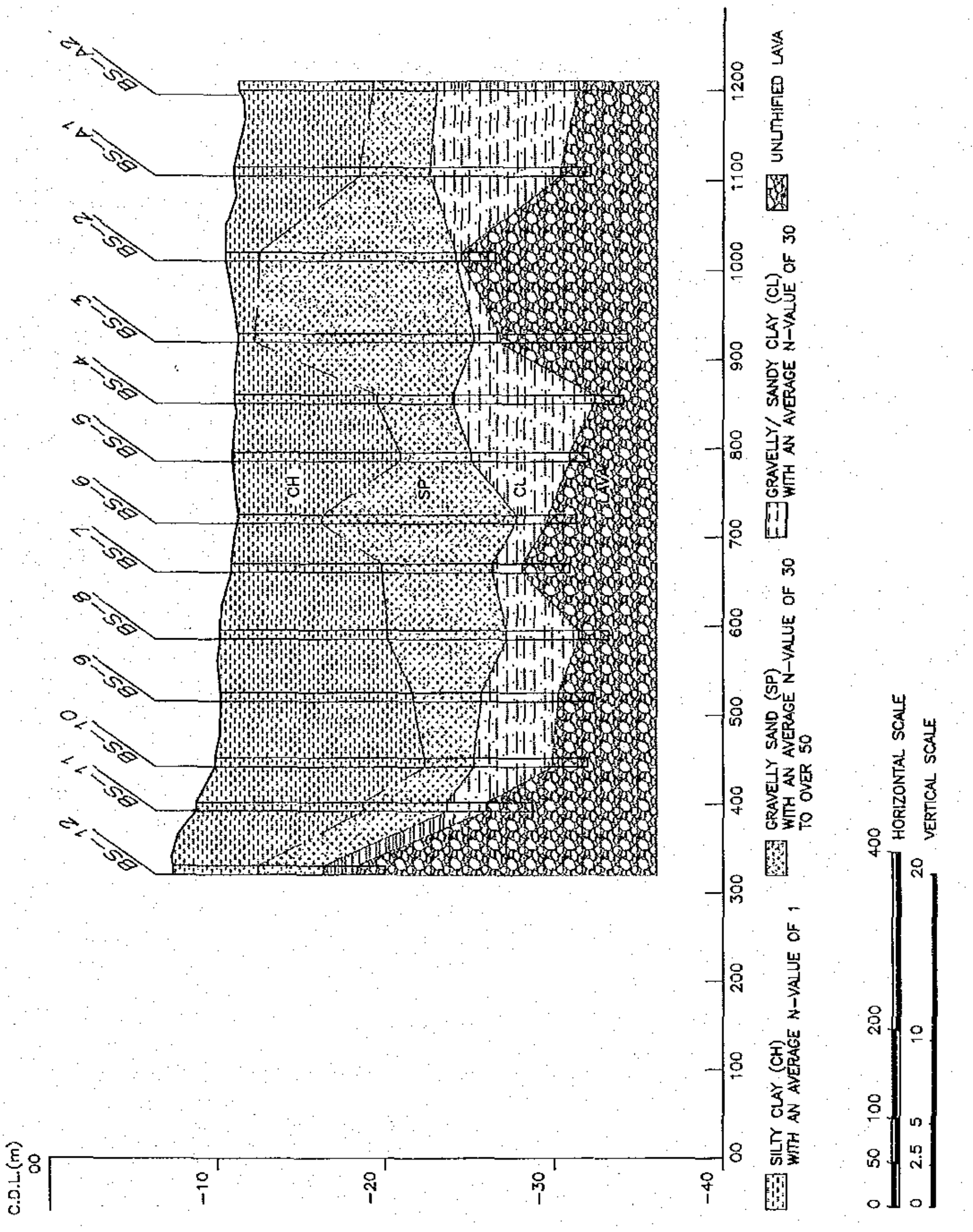
0 50 100 200 300 400

HORIZONTAL SCALE

Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.1.4	Geological Section (3)



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.1.5	Geological Section (4)



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province *of the Republic of El Salvador*	F.1.6	Geological Section (5)

2) Grain size distribution and index properties

a) Land samples (Borrow soil)

The physical properties of borrow soil obtained from the laboratory soil tests were used to evaluate its suitability for reclamation materials, while the mechanical properties of rock were done to select the appropriate excavation technique for rock slope.

Figures F.1.7 and F.1.8 respectively give the representative grading curves for Layer 1 and Layer 2 at borrow area. The soils below the surface layer (Layer 1), in its natural form, is mostly classified as SAND (SW to SM) by the Unified Soil Classification System of ASTM. The sand-gravel fraction (grain size larger than 0.074 mm) ranges from 60% to 90%, indicating that Layer 1 is suitable as fill material for the reclamation. Moreover, the natural water content was in range of 10% to 20% and the specific gravity varied from 2.50 to 2.70, indicating it is a normal soil.

The rock mass (Layer 3) for the excavation area, corresponding to the class CL to CH has unconfined compressive strength of 50 to 130 Mpa and an average of 85 Mpa.

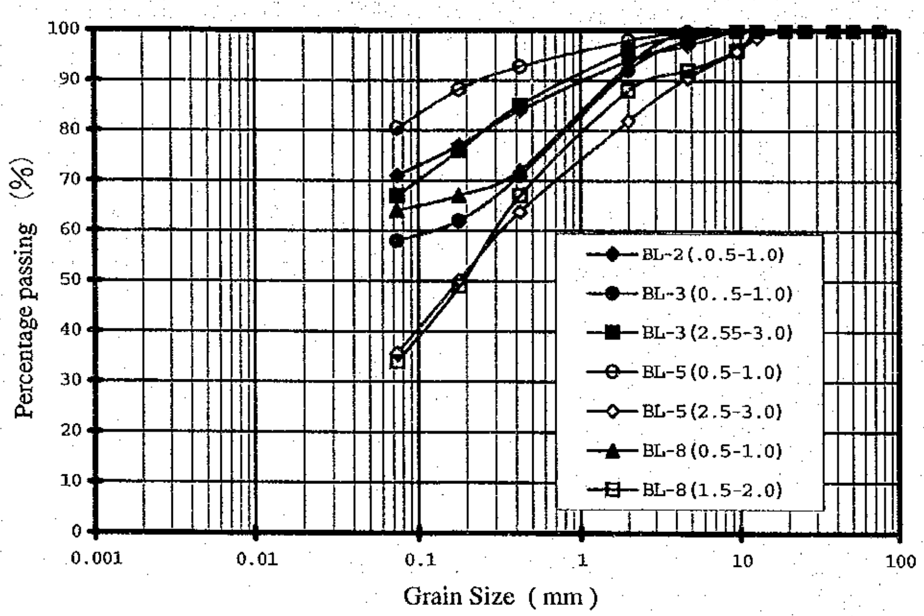


Figure F.1.7 Grain Size Distribution Curve of Layer 1

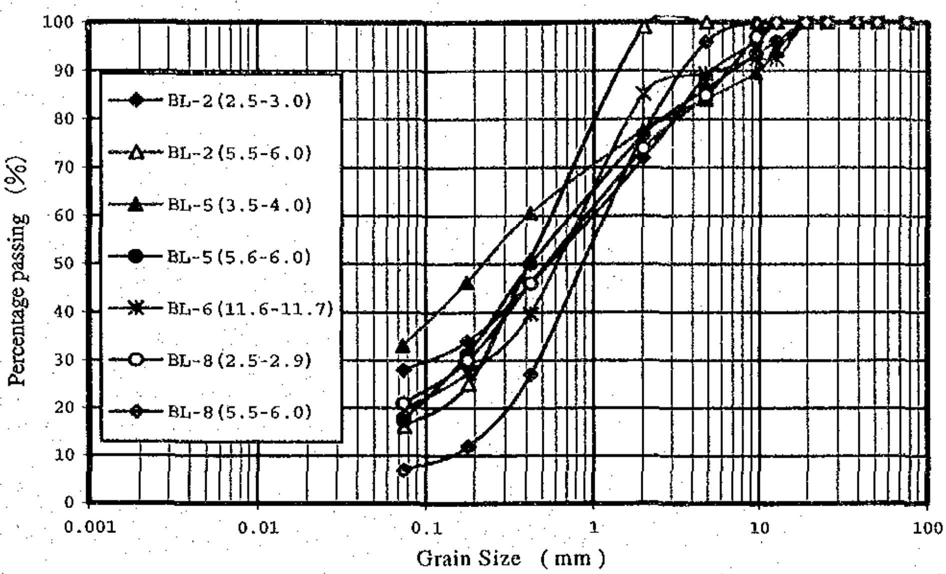


Figure F.1.8 Grain Size Distribution Curve of Layer 2

b) Offshore samples (Port Area)

All samples for Layer 1 were classified as fine soil by the unified soil classification criteria of ASTM (Figure F.1.9). The sand gravel fraction (grain size larger than 0.074 mm) ranges from 70% to 99%. The natural water content was in range of 30% to 200%, and the unit weight varied from 11.6 kN/m^3 to 19.3 kN/m^3. The liquid limit was in range of 26% to 243%, and Plastic Limit varied from 16.9% to 153.8%. Its unit weight and natural moisture are 14 kN/m^3 and 119 % on average, respectively (Figure F.1.10). These index properties indicates Layer 1 is very soft and compressible clay soil (peat) with high plasticity.

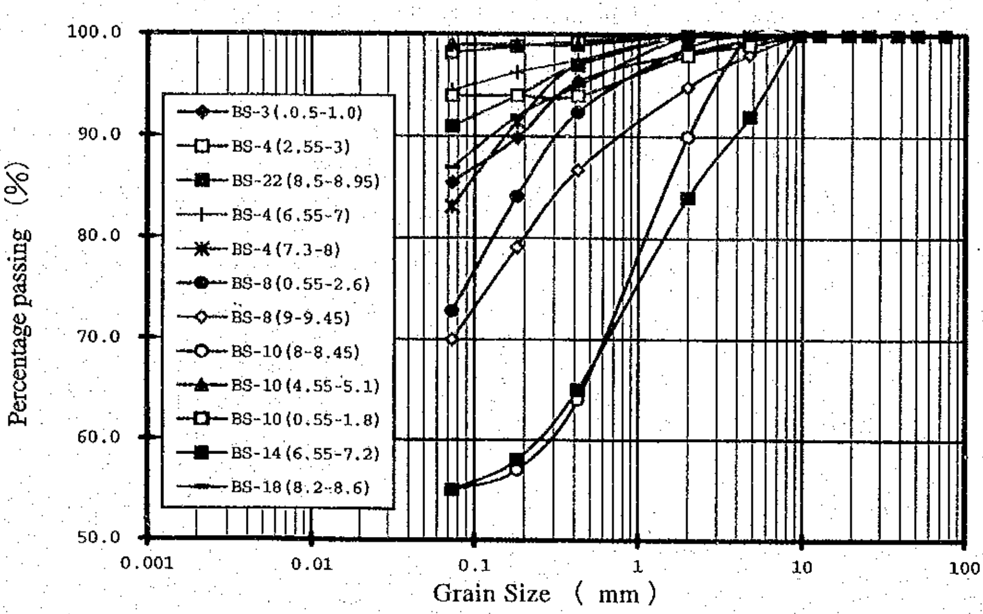


Figure F.1.9 Grain Size Distribution Curve of Layer 1

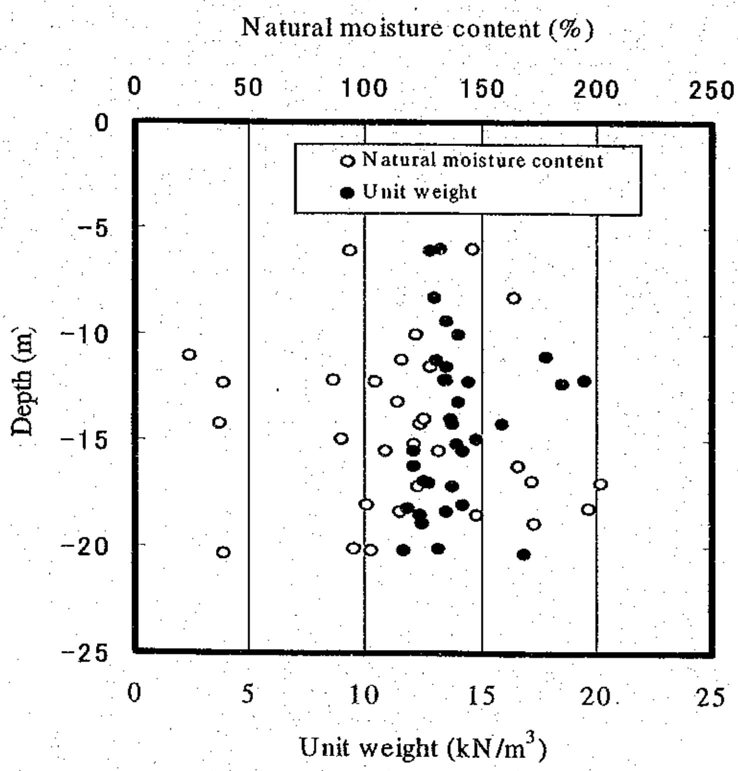


Figure F.1.10 Depth Versus Unit Weight

On the other hand, almost all samples for Layer 2 and Layer 3 have the fine-grained content (less than 0.075 mm) of 10% to 50% and were classified into SP or SM soil group of ASTM (Figures F.1.11 and F.1.12). The unit weight and natural moisture content ranges respectively from 12 to 20 kN/m^3 and from 20 to 30 %.

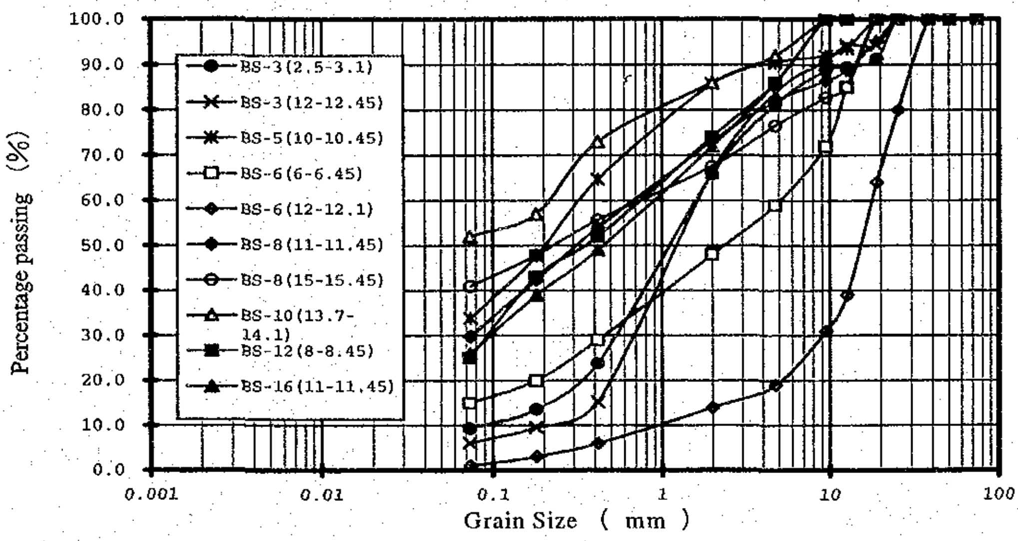


Figure F.1.11 Grain Size Distribution Curve of Layers 2

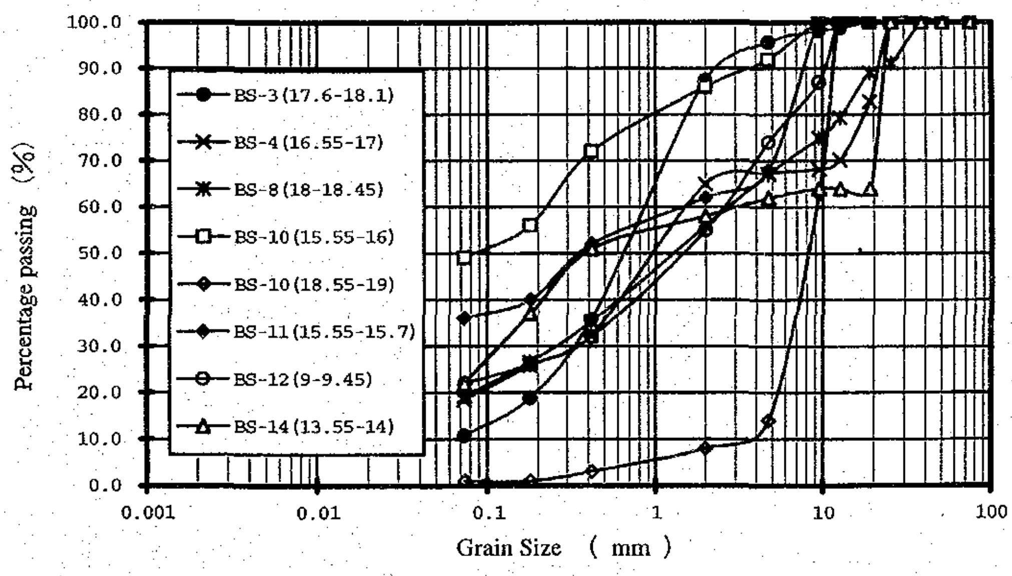


Figure F.1.12 Grain Size Distribution Curve of Layers 3

3) Strength Characterics

Figure F.1.13 illustrates the relation between depth and unconfined compressive strength of the layer 1. The unconfined compression test results were summarized in Appendix D.3. The unconfined compressive strength ranges from 0.9 kPa to 32.5 kPa with an average of 10.3 kPa, showing a big dispersion.

Therefore, the strength parameter (c) is determined from the average value of the test results measured for all test samples. The estimated shear strength parameter is presented below.

$c_u = q_u/2 = 5.15$ kPa

Moreover, the cohesion, c, of cohesive soil can be determined from the following empirical relation with N value.

$c_u = (0.6 \text{ to } 1.0)\ 10N$ (kPa)

The N value of the layer 1 is about 1, and therefore, the cohesion of the layer 1 is estimated to be c_u = 6 to 10 kN/m^2, on the basis of the above relation. The estimated value gave most agreement with the test results, showing that the obtained results are reasonable and reliable.

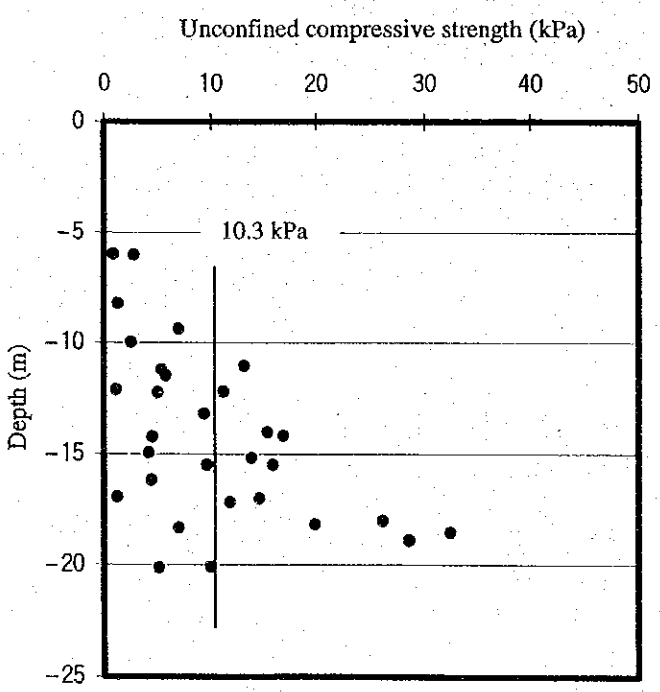


Figure F.1.13 Distribution of Unconfined Compressive Strength

Layers 2 and 3 consist mainly of gravel and sand with some fines (silt and clay) and correspond to sandy soil ground. In case of no laboratory test data, the shear strength (.) of sandy soil ground is generally determined from N-value by Dunham Equation.

$$\phi = \sqrt{12N} + 20 \text{ (degree)}$$

As previously stated, Layers 2 and 3 have an average N-value of about 30. The estimated strength parameters of Layers 2 and 3 are 39 degree on the basis of Dunham equation above.

4) Consolidation characteristics

The consolidation characteristics of Layer 1 are plotted with void ratio versus the log of pressure curve (Figure F.1.14), the logs of coefficient of consolidation versus average pressure curve (Figure F.1.15) and the logs of coefficient of volume compression versus the average pressure curve (Figure F.1.15).

The slope of compression line after yield pressure stress on e~logP curve is expressed as compression index Cc and frequently used to evaluates compressibility of soft soil ground. The compression index in Layer 1, ranging from 0.2 to 2.0, shows typical values of sensitive clay. Because of scatter in measured values, the mean void ratio versus the log of pressure curve is also shown in Figure F.1.16.

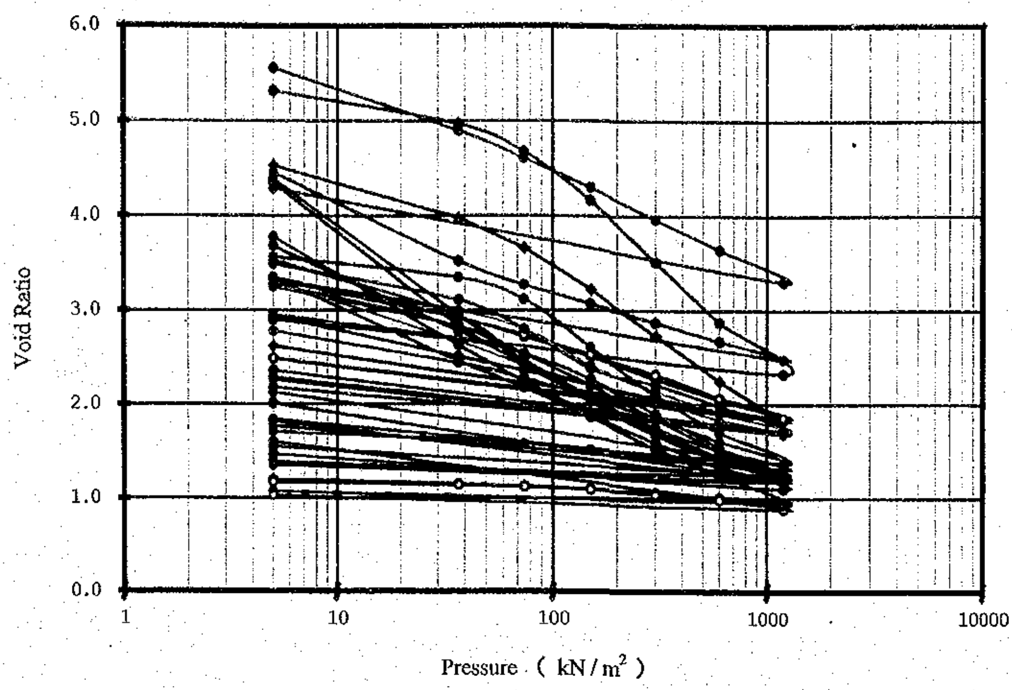


Figure F.1.14 Void Ratio Versus Pressure

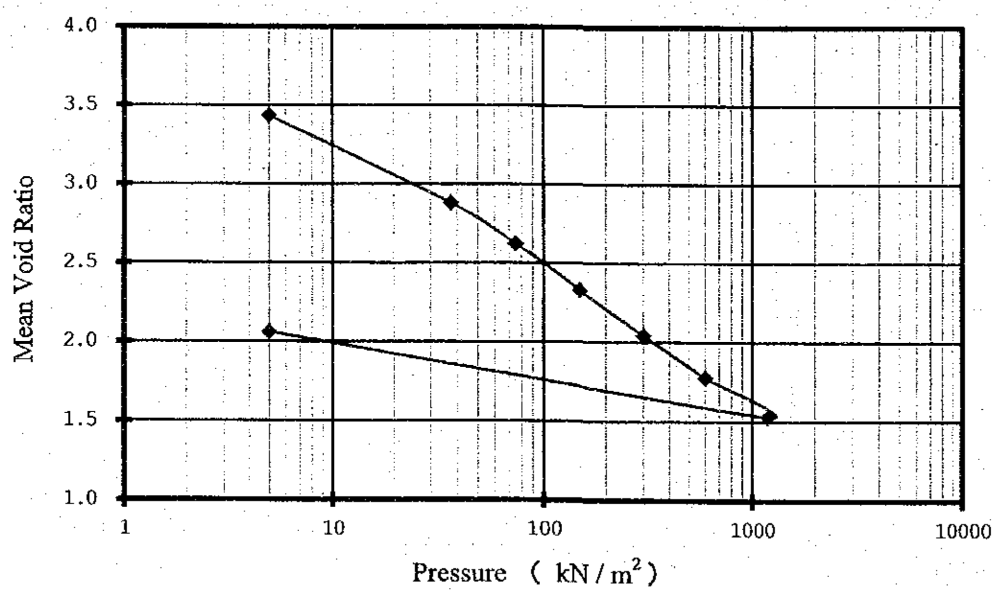


Figure F.1.15 Mean Void Ratio Versus Pressure

Furthermore, the change in volume strain $((e_0-e)/(1+e_0))$ versus pressure is illustrated in Figure F.1.16 on the basis of the above mean void ratio. There is a linear variation in volume strain increase with the pressure increment.

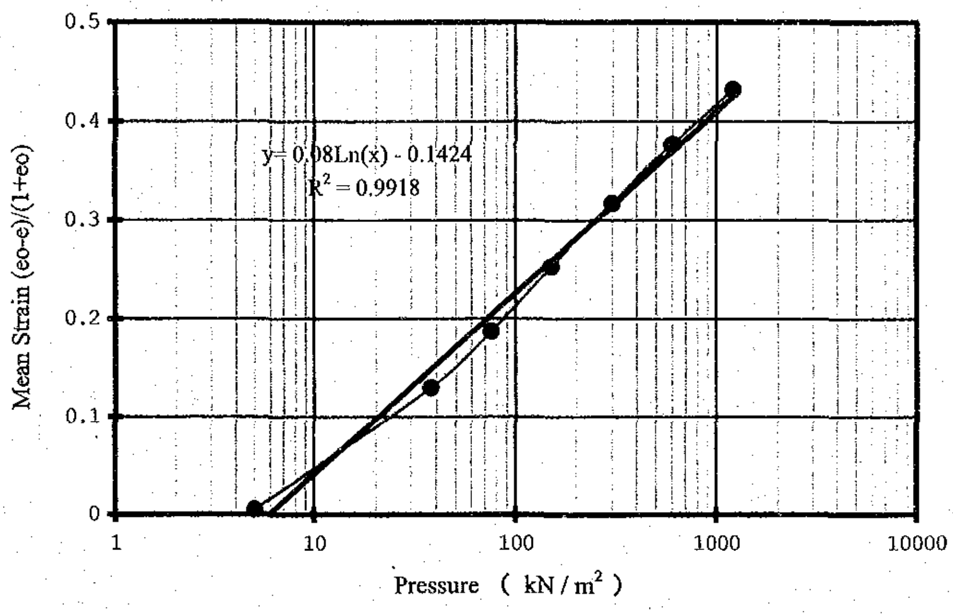


Figure F.1.16 Mean Strain Versus Pressure

The coefficient of consolidation, Cv, of Layer 1 is remains constant at each pressure stage with an average value of about 0.1162 cm^2/min (Figures F.1.17 and F.1.18). On the other hand, the coefficient of volume compression tends to decrease with the increased average pressure (Figures F.1.19 and F.1.20).

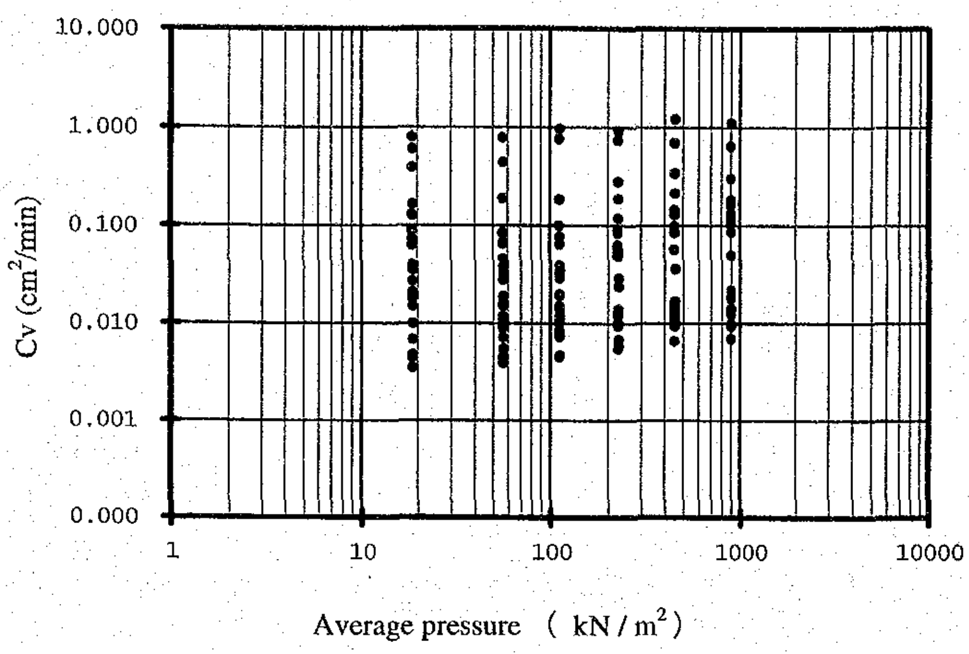


Figure F.1.17 Coefficient of Consolidation Versus Average Pressure

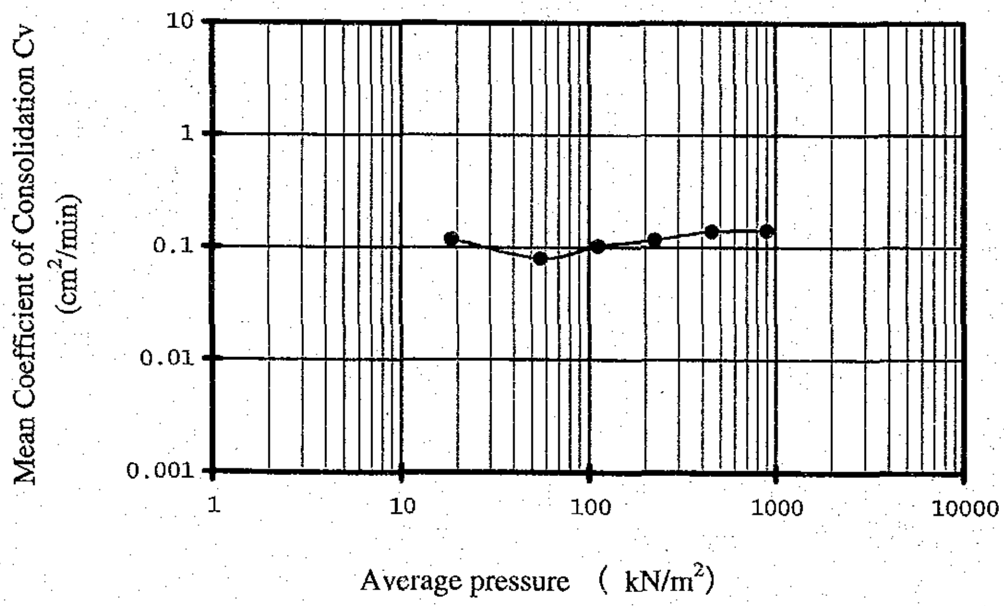


Figure F.1.18 Mean Coefficient of Consolidation Versus Average Pressure

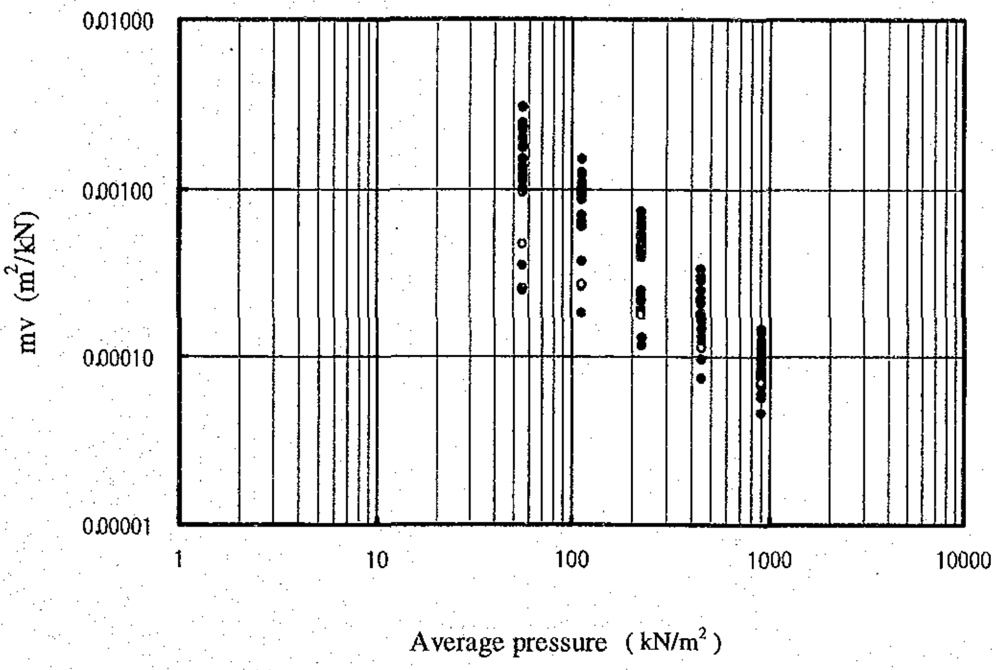


Figure F.1.19 Coefficient of Volume Compression Versus Average Pressure

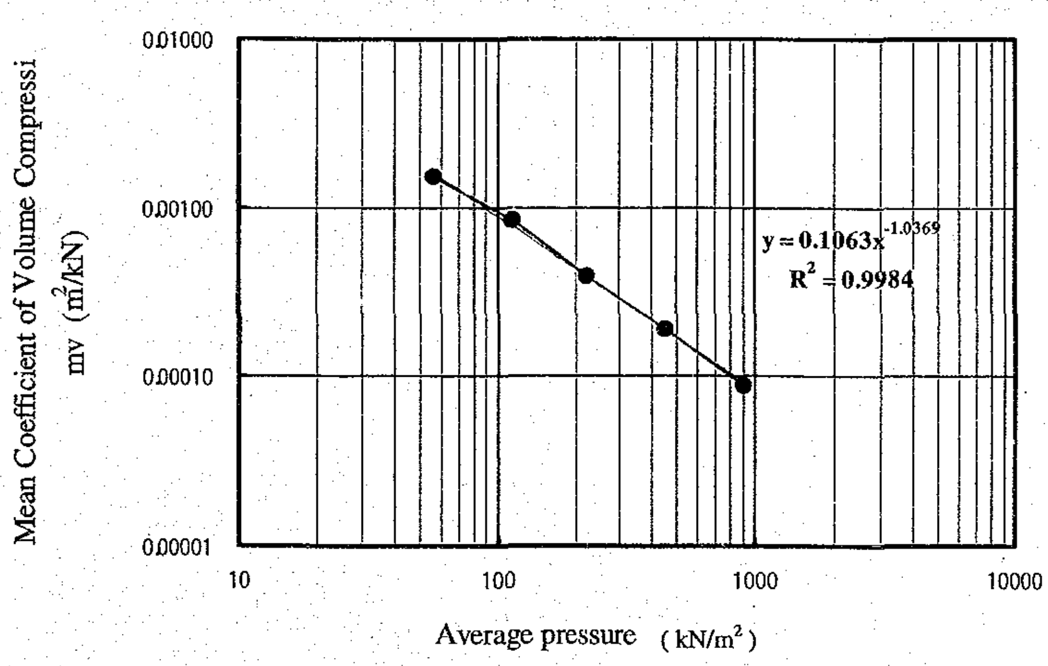


Figure F.1.20 Mean Coefficient of Volume Compression Versus Average Pressure

5) Summary of geological and geotechnical conditions

a) Selection of design parameters for port structure

Ground conditions at berth front comprise:

- Layer 1: Silty clay (CH), 5.0 to 10.0m deep
- Layer 2: Gravelly sand (SP), 5.0 to 10.0m deep
- Layer 3: Gravelly/sandy clay (CL), 2.0 to 5.0m deep

The parameters of shear strength in Layer 1 were based on the laboratory test results. The cohesion c was determined from the average unconfined compression strength because of its dispersion. Similarly, the unit weight in Layer was obtained by averaging the test results. The buoyant (submerged) unit weight was calculated directly after buoyancy.

The internal friction in Layers 2 and 3 was estimated at 39 degrees from the N-value and thus set up with 35 degrees for the safety design. Moreover, in the case of sandy or gravelly soil ground, unit weights, . =18 kN/m^3 and . '=10 kN/m^3 are usually used.

The proposed design parameters for port structures are summarized in Table F.1.9.

Table F.1.9 The Proposed Design Parameters for Port Structures

LAYER 1: Silty CLAY $\gamma' = 4$ kN/m^3 $\gamma = 14$ kN/m^3 $c_u = 5.0$ kN/m^2
LAYER 2: Gravelly SAND $\gamma' = 10.0$ kN/m^3 $\gamma = 18.0$ kN/m^3 $\phi = 35$ degree
LAYER 3: Sandy CLAY $\gamma' = 10.0$ kN/m^3 $\gamma = 18.0$ kN/m^3 $\phi = 35$ degree

b) Reclamation and soil improvement

In reclamation area, silty clay (layer 1), is characterized by high water content, high plasticity and high compression, and should be thus improved for stable foundation.

The engineering properties of the layer is as follows:

- N-value: 1 - 5
- Moisture content: 38% – 200%
- Mean unit weight: 14 kN/m^3
- Shear strength, c: 5.0 kN/m^2
- Mean initial void ratio e_o: 3.46
- Compression index C_c: 0.2 to 2.0
- *Coefficient of consolidation C_v: 0.1162 cm^2/min*

Coefficient of volume compression m_v:0.9×10^{-4} to 15.4×10^{-4} kN/m^2

(4) Seismic Condition

El Salvador has suffered from calamities by big earthquakes in the past. Consideration of the earthquake-proof design in the structure is an essential and important factor.

The seismic force to the berth structures will be calculated by the seismic coefficient method. The horizontal seismic loads will be considered with the vertical seismic loads, which are 1/2 of the horizontal seismic loads.

The design earthquake coefficient will be selected by the relationship between the characteristic factor and usage of the structure in terms of its cost performan ce.

The design seismic coefficient will be determined considering three scenarios as follows.

Building Standards of El Salvador

Mercalli seismic Intensity of Past Large Earthquake

Past Earthquake Data in El Salvador for the last 32 years

1) The standard building calculation of El Salvador "Reglamento para la Seguridad Estructural de las Construcciones El Salvador, 1997", published by Ministry of Public Work.

In the building standard of El Salvador, the seismic force is calculated by the following formula.

$V = 0.5 \times A \times I \times W$

Where; V : seismic force, A : Factor of zone , I : Factor of importance, W : Weight of structure

Table F.1.10 Factor of "A" According to the Zone

Zone	Factor A
I	0.40
II	0.30

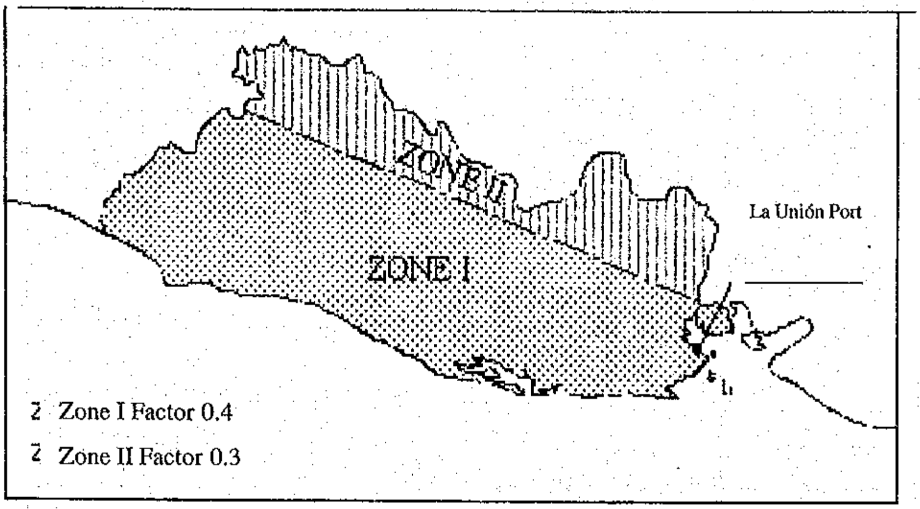


Figure F.1.21 Seismic Zone El Salvador

Table F.1.11 Factor of Importance

Category of Occupation	Importance of Facilities	Factor
I	Essential or dangerous facilities	1.5
II	Buildings of special occupation	1.2
III	Building of normal occupation	1.0

From these parameters, the seismic coefficient can be calculated as follows.

Importance factor: 1.0 for Category III

V = 0.5 x 0.4 x 1.0 x W = 0.20 x W (for Category III)

The seismic coefficient is given as 0.20 in the area of La Unión, according to the building standards in El Salvador.

2) Calculation of the Mercalli Seismic Intensity according to past records.

The Mercalli seismic intensity records of the larger earthquakes in El Salvador are shown in from Figure F.1.22 to F.1.25.

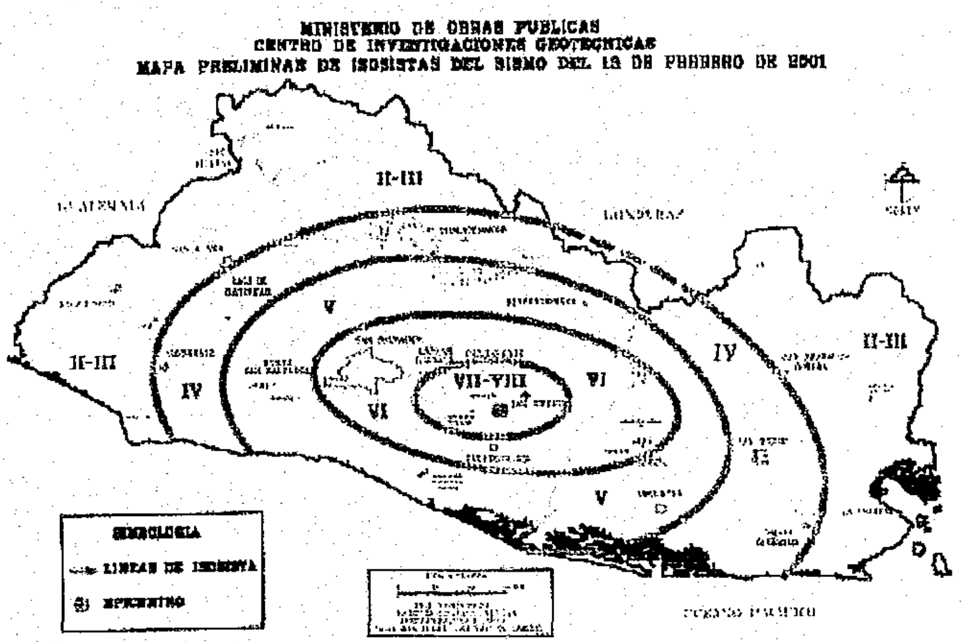


Figure F.1.22 Isometric Map of Earthquake on 13th February, 2001 in El Salvador

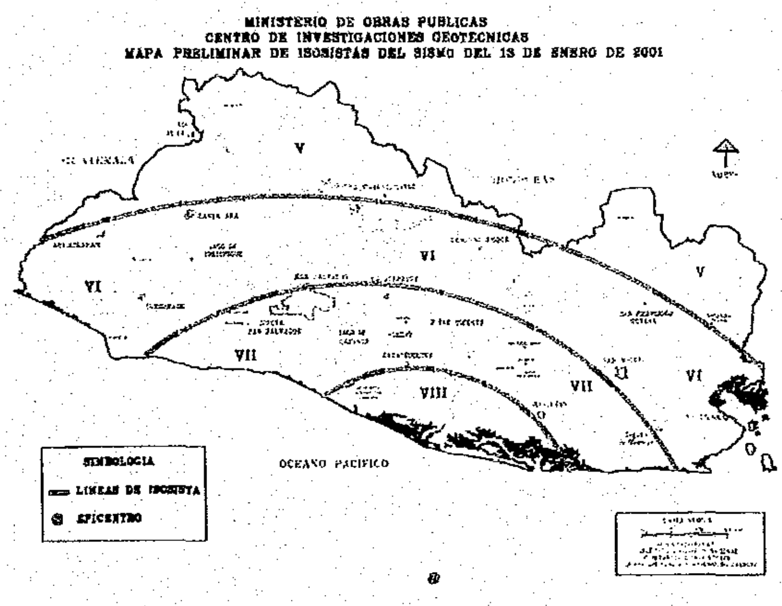


Figure F.1.23 Isometric Map of Earthquake on 13th January, 2001 in El Salvador

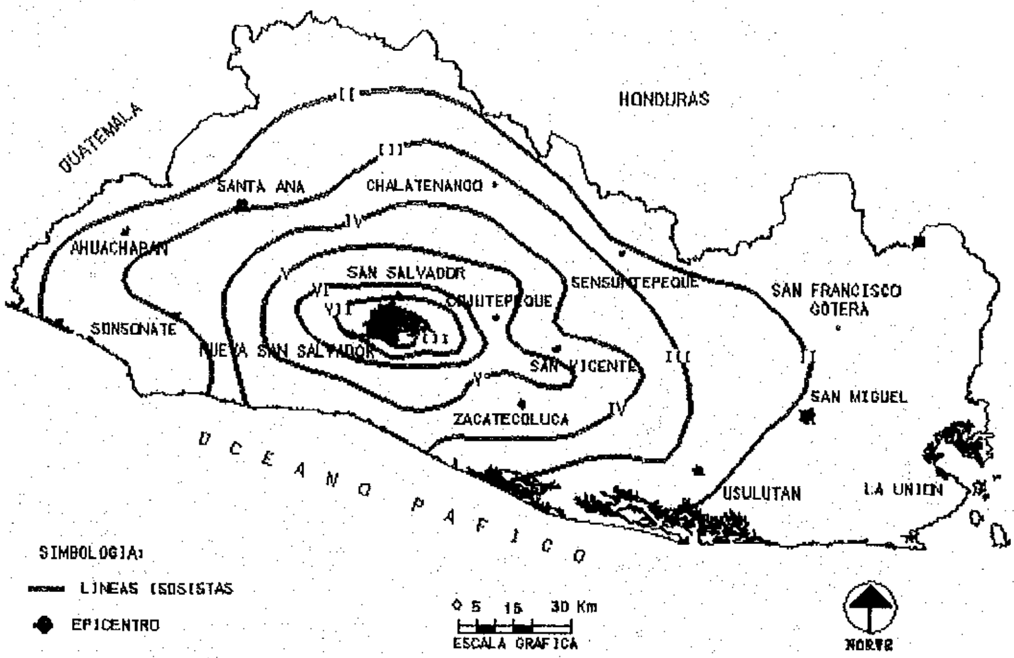


Figure F.1.24 Isometric Map of Earthquake on 10th October, 1986 in El Salvador,

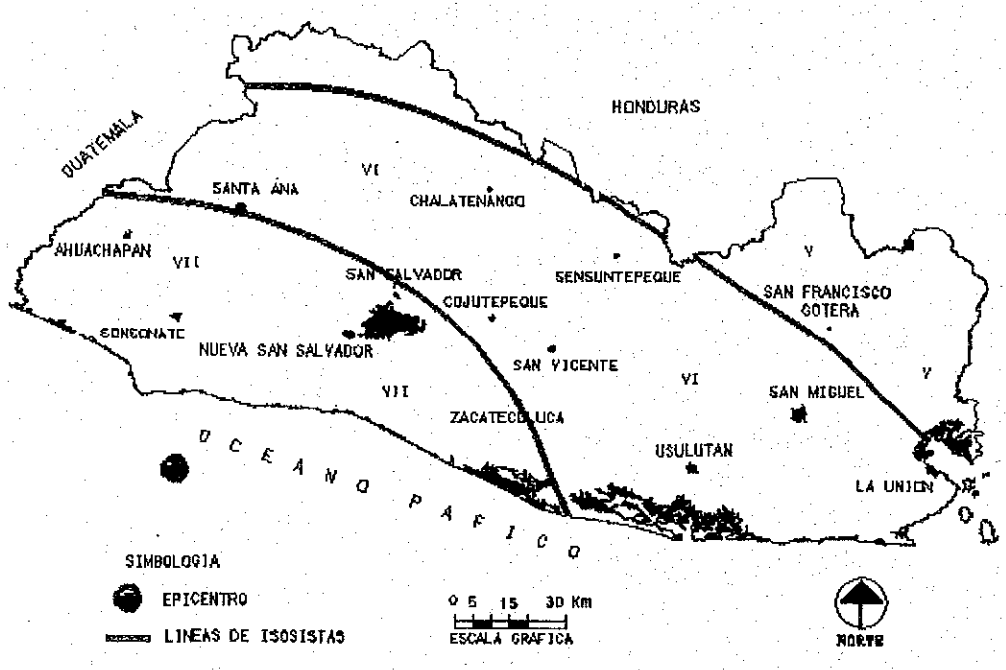


Figure F.1.25 Isometric Map of Earthquake on 19th June, 1982 in El Salvador

Based on these Mercalli seismic intensities, the maximum level is given in La Unión as VI. Table F.1.12 shows the relationship between the Mercalli seismic intensity and the seismic acceleration.

Table F.1.12 Relation Between Mercalli Seismic Intensity and Acceleration

MM (Mercalli seismic intensity)	I	II	III	IV	V	VI	VII	VIII	IX	X
Acceleration (gal)	0.8	2.5	2.5-8.0	8.0-25	25	25-80	80	250	400	>400

The Mercalli Seismic intensity VI is equivalent to 25~ 80 gal. From the following formula that correlates the seismic coefficient with seismic acceleration, the seismic coefficient is 0.08 at 80 gal.

Thus, the seismic coefficient is given as 0.20 by the following formula:

i) $Kh = A / g$ $A \leq 200$ gal

ii) $Kh = 1/3\,(A/g)^{1/3}$ $A > 200$ gal

Kh: Seismic Coefficient

A : Seismic Acceleration

g : Acceleration of Gravity

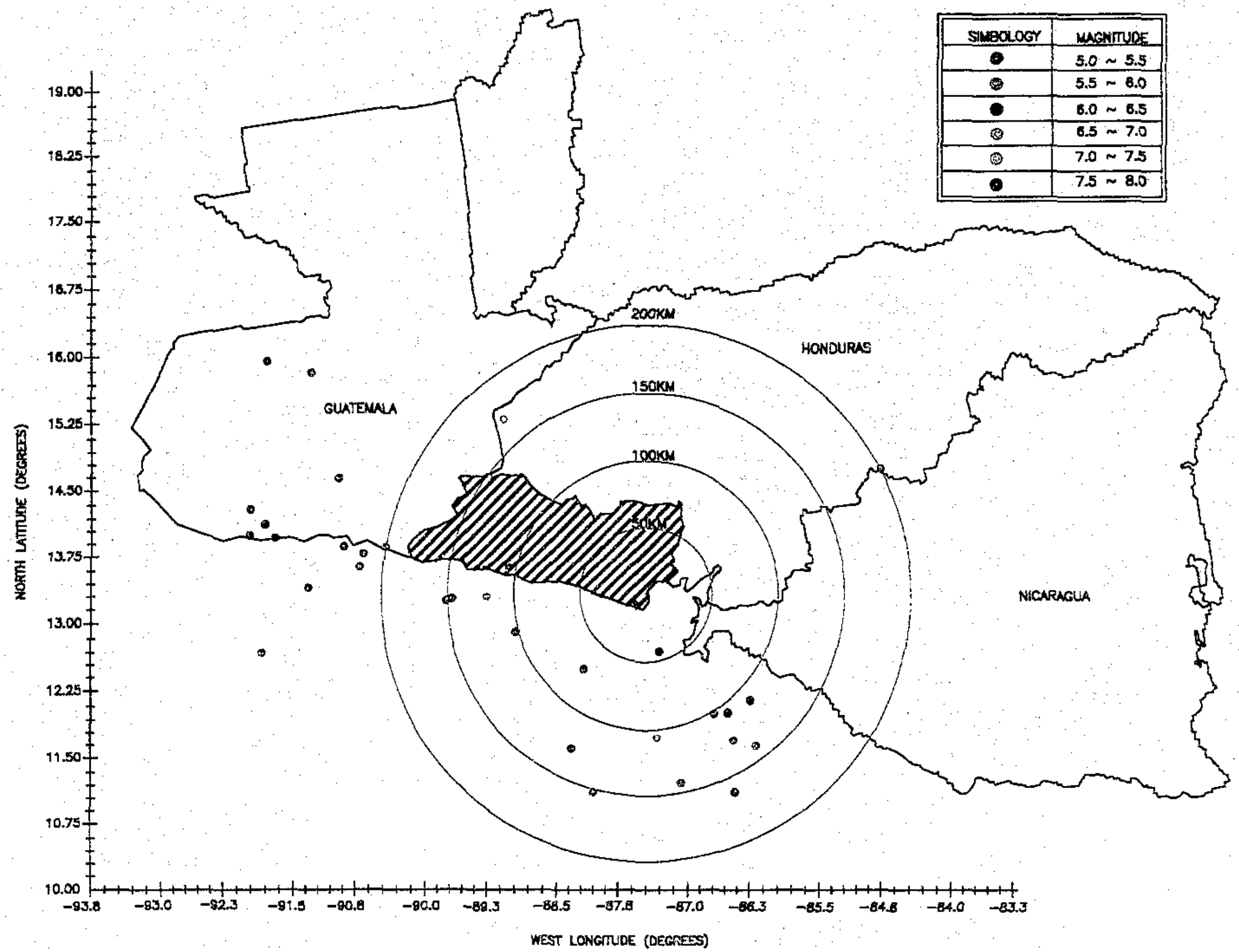
3) Past Earthquake Data in El Salvador for the last 32 years.

The annual maximum earthquake and the calculated seismic acceleration at La Unión for the period of 1970 to 2001 is shown in Table F.1.13 and Figure F.1.26.

The seismic intensity at La Unión site is calculated based on the magnitude and distance from the epicenter of each earthquake.

Table F.1.13 Estimate Seismic Intensity at La Unión 1970 - 2001

Year	Month	Day	Latitude (Degrees)	Longitude (Degrees)	Distance from La Unión (Km)	Depth (Km)	Recorded Magnitude	Seismic Intensity (Gal)
1970	8	12	12.015	-86.542	107	33	6.3	56.6
1971	10	12	15.833	-91.300	303	-	5.7	14.2
1972	12	23	12.150	-86.283	111	10	6.2	52.0
1973	6	7	14.295	-91.988	305	72	5.4	12.2
1974	12	31	14.126	-91.824	486	39	6.1	10.2
1975	3	25	13.647	-90.737	217	33	5.5	18.5
1976	2	4	15.300	-89.100	169	5	7.5	65.2
1977	9	10	13.974	-91.712	284	72	5.3	12.5
1978	8	19	12.962	-87.343	26	33	7.2	263.3
1979	10	27	13.800	-90.700	216	65	5.8	21.6
1980	11	4	13.876	-90.928	231	83	5.4	16.5
1981	9	17	14.000	-92.000	303	33	5.4	12.3
1982	6	19	13.300	-89.300	121	82	7.0	71.2
1983	7	3	12.000	-86.700	102	33	5.9	48.5
1984	11	2	13.632	-89.037	106	218.3	5.8	44.5
1985	12	2	12.697	-87.316	43	185.5	6.3	121.8
1986	8	9	12.502	-88.183	72	230.6	6.3	81.1
1987	4	8	11.220	-87.070	142	30	5.9	35.2
1988	11	3	13.880	-90.450	200	69	5.6	21.3
1989	4	28	13.280	-89.690	146.5	65	5.1	23.0
1990	7	20	15.956	-91.802	381	157.6	5	7.8
1991	9	18	14.650	-90.983	248	5	6.1	21.6
1992	9	2	11.740	-87.340	105	45	7.2	90.1
1993	11	22	11.710	-86.470	126	36.9	5.6	34.1
1994	3	15	11.110	-88.080	152	15	5.9	32.8
1995	6	14	11.660	-88.390	126	34.6	5.7	35.8
1996	3	27	11.620	-88.320	126	30.2	6.1	43.7
1997	12	4	13.404	-91.329	255	27.8	5.4	14.8
1998	10	9	11.124	-86.459	161	31	6.3	37.8
1999	4	3	13.225	-87.603	11	12.5	5.8	191.8
2000	7	6	11.647	-86.209	143	34.8	5.9	34.9
2001	1	13	12.915	-88.968	102	32.1	7.7	118.8



Japan International Cooperation Agency (JICA)	Figure No.	Title
The Detailed Design on Port Reactivation Project in La Union Province *of the Republic of El Salvador*	**F.1.26**	**EPICENTER OF EARTHQUAKE IN AND AROUND EL SALVADOR**

Table F.1.14 Probable Seismic Intensity

Return period	5 Years	10 Years	30 Years	50 Years	75 Years	100 Years
Probable Seismic Intensity (gal)	91	122	170	191	208	221

[Notes: Term of data 31 years (1970-2001), Number of data 31]

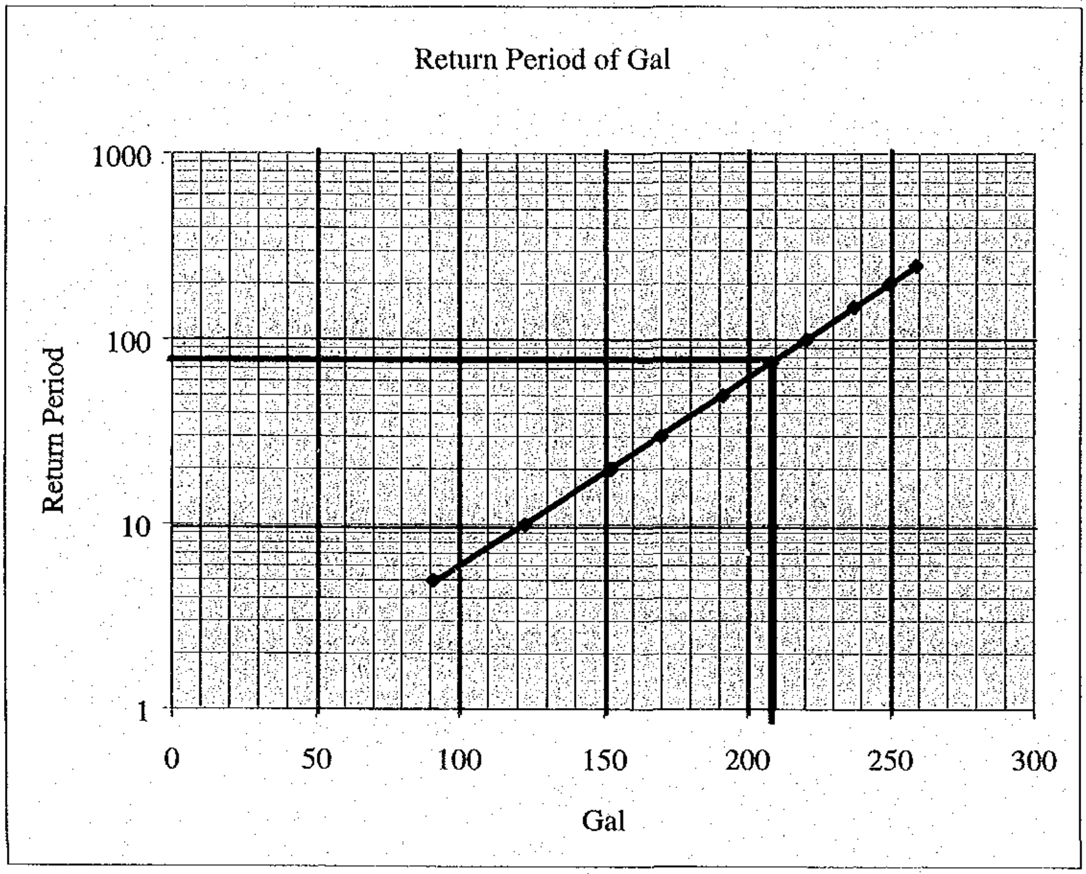


Figure F.1.27 Return Period of Gal

Based on the above 32 records, the seismic acceleration with a 75-year return period is calculated to be 208 gal using the Weibull Distribution Model.

4) Conclusion

From the above consideration results, it is concluded that the design seismic coefficient to be adopted in the design should be 0.20 as shown in Table F.1.15. Figure F.1.26 shows that a seismic coefficient 0.20 has a 75 years return period.

Table F.1.15 Design Seismic Coefficient

	Seismic Coefficient for General Seismic Resistance
1) Building Standard	0.20
2) Mercalli Seismic Intensity	0.08
3) Estimate based on the Past Earthquake Data	0.20
Design Seismic Coefficient	0.20

F.2 Berth Structure

F.2.1 Berth Requirements

(1) Required Berths and Design Vessels

As discussed in Chapter 3 Planning, three (3) berths are required in the Project. The design vessels for each berth have also been discussed and determined as the base of the berth design as shown in Table F.2.1.

Table F.2.1 Required Berths and Design Vessels

Berth	Design Vessels					
	Type	DWT	LOA (m)	Breadth (m)	Draft (m) Max.	Draft (m) Sailing
1.Container Berth	Container Ship	55,000	294.0	32.2	13.1	13.1
2.Multi-purpose Berth	Bulk Carriers	43,000 ~ 50,000	185.0	32.2	12.0	11.8
3.Passenger Berth	Passenger Ship	25,000	195.0	27.0	8.5	8.0
	Car Carrier	25,000	200.0	32.2	10.0	8.5

[Source: JICA Team research]

(2) Berth Dimensions

1) Berth Length

The berth length is determined from the design ship length and bow and stern mooring space. Normally the mooring angle of ship varies from 30 to 45 degrees considering that the berth line is continuous and straight. (See Figure F.2.1)

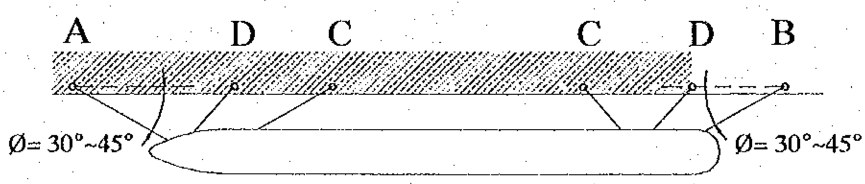


Figure F.2.1 Arrangement of Mooring Line

A : Bow mooring line C : Spring line

B : Stern mooring line D : Breast line

Design berth length = Design Ship length

+ 2 {(Design Ship Beam/2 + 1.0m (Fender)+1.0m (Bollard)) / tan (30° ~ 45°)}

a) Container berth

L = 294.0 m + 2 {(32.2 m/2 + 2.0m) / (0.577 ~ 1.00)} = 330.2 ~ 356.7 m

Thus, L= 340 m be used

b) Multi-Purpose Berth

L = 185.0 m + 2 {(30.5 m/2 + 2.0m) / (0.577 ~ 1.00)} = 219.5 ~ 244.8 m

Thus, L=220 m be used

c) Passenger Berth

- Passenger Ship

L = 185.0 m + 2 {(27.5 m/2 + 2.0m) / (0.577 ~ 1.00)} = 216.5 ~ 239.6m

- Car Carrier

L = 200.0 m + 2 {(32.2 m/2 + 2.0m) / (0.577 ~ 1.00)} = 236.2 ~ 262.7

Thus, L=240 m be used

2) Design Depth

The design water depth of berths is determined based on the design ship draught and the required underkeel clearance.

a) Container Berth and Multi purpose Berth

Design water depth = 13.1 m + (0.75~0.85)= 13.85~13.95 m, thus 14 m

b) Passenger Berth

Design water depth = 8.5 m x 1.1 = 9.35m, thus 9.5m

3) Crown Height

The design crown height of berth is determined taking the exising berth conditions, tidal range, design ship size and operational aspects, etc. into consideration.

a) Existing Berth Conditions

The crown heights of the existing berths in La Unión are as follows,

Cutuco Pier	+ 5.08 m
Punta Gorda Berth	+ 5.34 m

Acćoding to the interview made to the CEPA staff and Punta Gorda Port, the present height of both berths have caused no problem in technical and operational aspects.

b) Crown height determined from tidal range and design ship

The recommended crown height of berths above H.W.L. by the Technical Standards for Port and Harbour Facilities in Japan, are shown in Table F.2.2

Table F.2.2 Crown Height of Berth

Tidal Range 3.0 m or more	Tidal Range 3.0 m or more	Tidal Range less than 3.0 m
Berth for Large Ship(with a water depth of 4.5m or more)	0.5 – 1.5 m	1.0 – 2.0 m
Berth for Small Ship(with a water depth of less than 4.5m)	0.3 – 1.0 m	0.5 – 1.5 m

From the above table, the berth crown height above H.W.L. is recommended to be 0.5 m – 1.5 m

Thus, the crown height of the berth is calculated as follows:

Crown Height = HWL + (0.5 m ~ 1.5 m) = +3.87 m ~ +4.87 m where, HWL is +3.37 m

c) Examination of wave conditions

The design wave height at the berth front is estimated at 2.2 m ($H_{1/3}$) in the stormy condition.

In order to prevent the berth from excessive overtopping of waves, the crown height should be not lower than the following height:

Crown Height = HML + 0.7x $H_{1/3}$

$$= +3.37 + 0.7 \times 2.2\text{ m} = +4.91\text{ m}$$

d) Operational Aspects

There would be no particular operational restriction on crown height of the container berth and multi-purpose berth.

As to the appropriate berth height for Car Carrier, it should be lower than the ramp height in any tide condition. Normally Car Carrier has three ramps, one for stern and two for middle position. At least two ramps shall be made available for smooth operation. The heights of each ramp for Car Carrier s calling Acajutla Port are indicated in Table F.2.3.

Table F.2.3 Height of Ramps for Car Carrier

LOA	Draft	Height of Stern Ramp (m)	Height of Side Upper Ramp (m)	Height of Side Lower Ramp (m)
199m class	9.7 – 10.1m	5.2 – 5.4m	5.2 – 5.4m	1.9 – 3.6m
185m class	8.8 – 9.2m	5.2 – 5.3m	5.2 – 5.3m	2.3 – 3.5m
180m class	8.5 – 9.0m	5.2 – 5.5m	5.2 – 6.8m	1.1 – 4.2m

As can be seen above, it is quite difficult to adjust for lower side ramp during low tide. However, the crown height of +5.0m can allow to use two ramps in the same time.

e) Conclusion

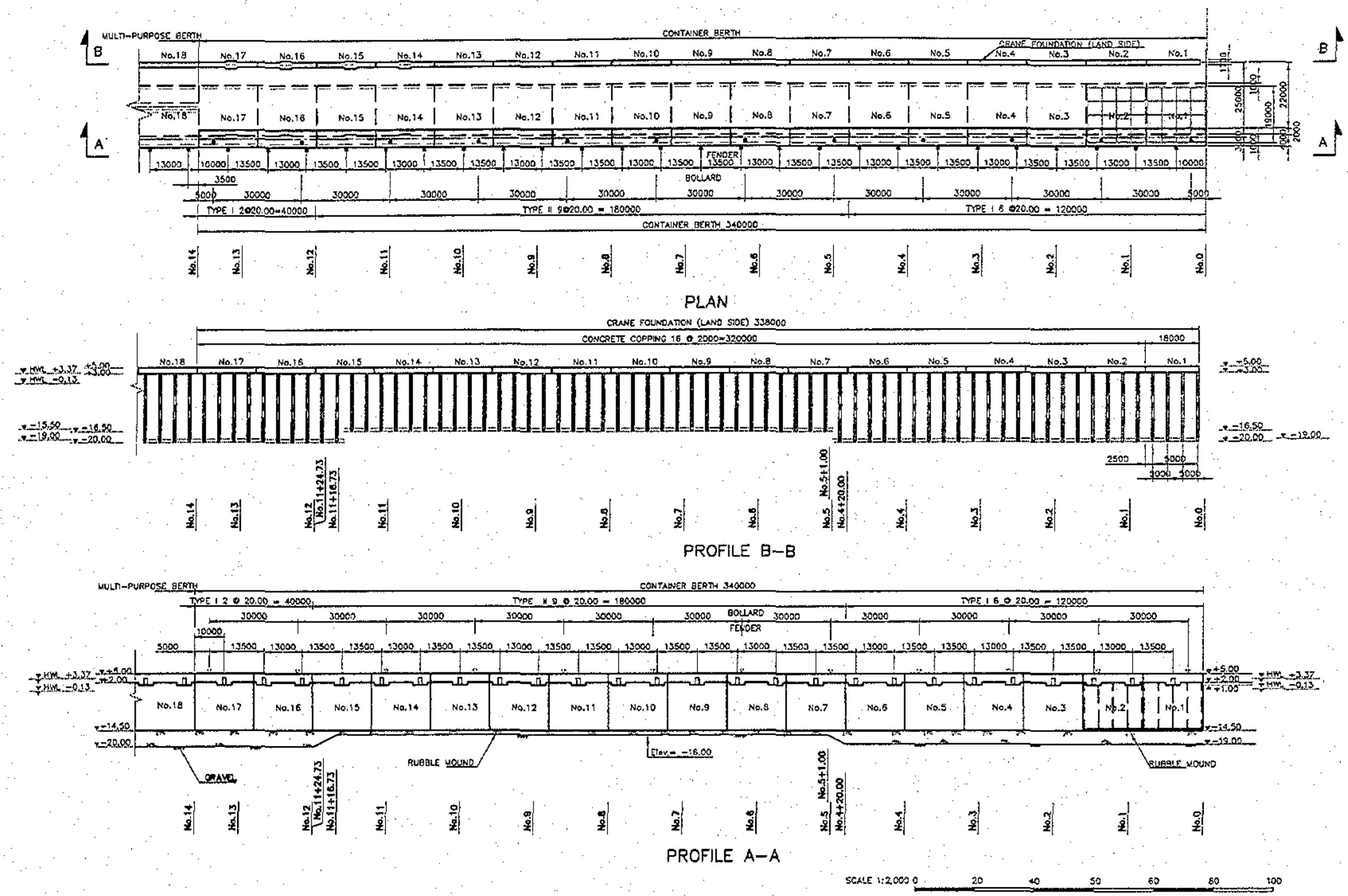
From the above examination and considerations, the crown height is set at +5.0 m for all three berths.

Table F.2.4 Berth Dimensions

	Length (m)	Water Depth (m)	Crown Height (m)
Container Berth	340.0	-14.0	+5.0
Multi-Purpose Berth	220.0	-14.0	+5.0
Passenger / Car Carrier Berth	240.0	-9.5	+5.0

F.2.2 Berth Drawings

Berth drawings are shown in Figures from F.2.2 to F.2.11



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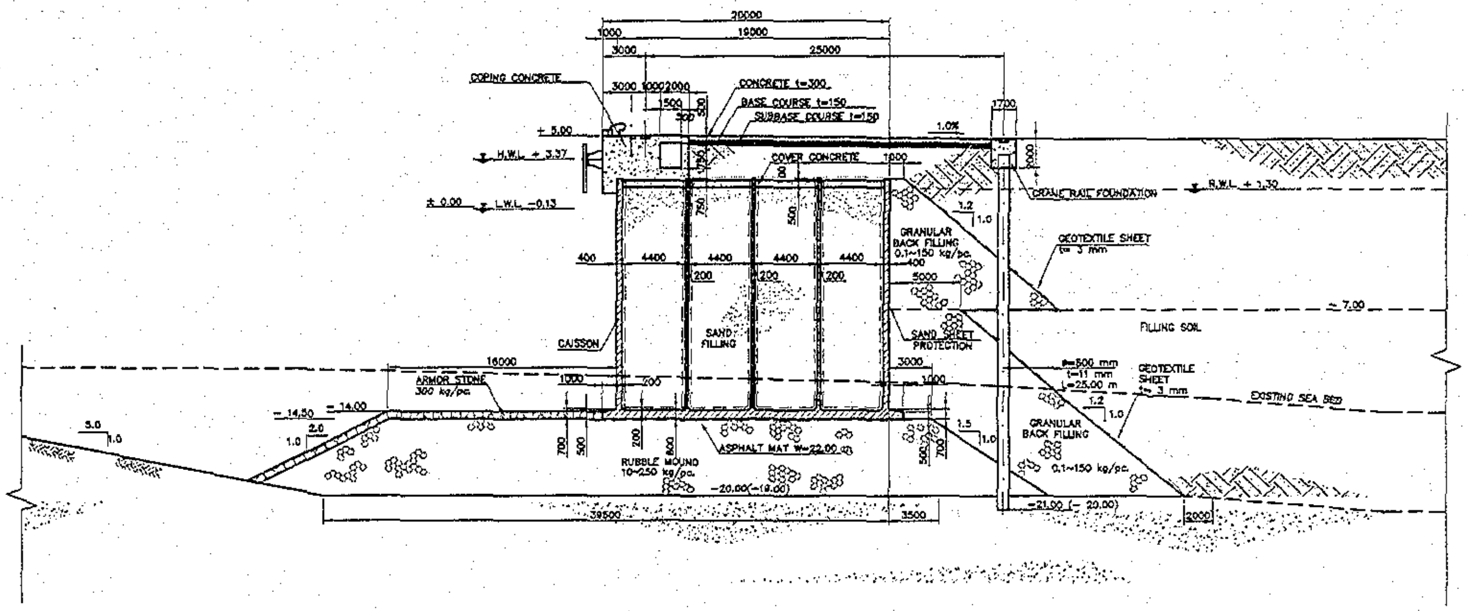
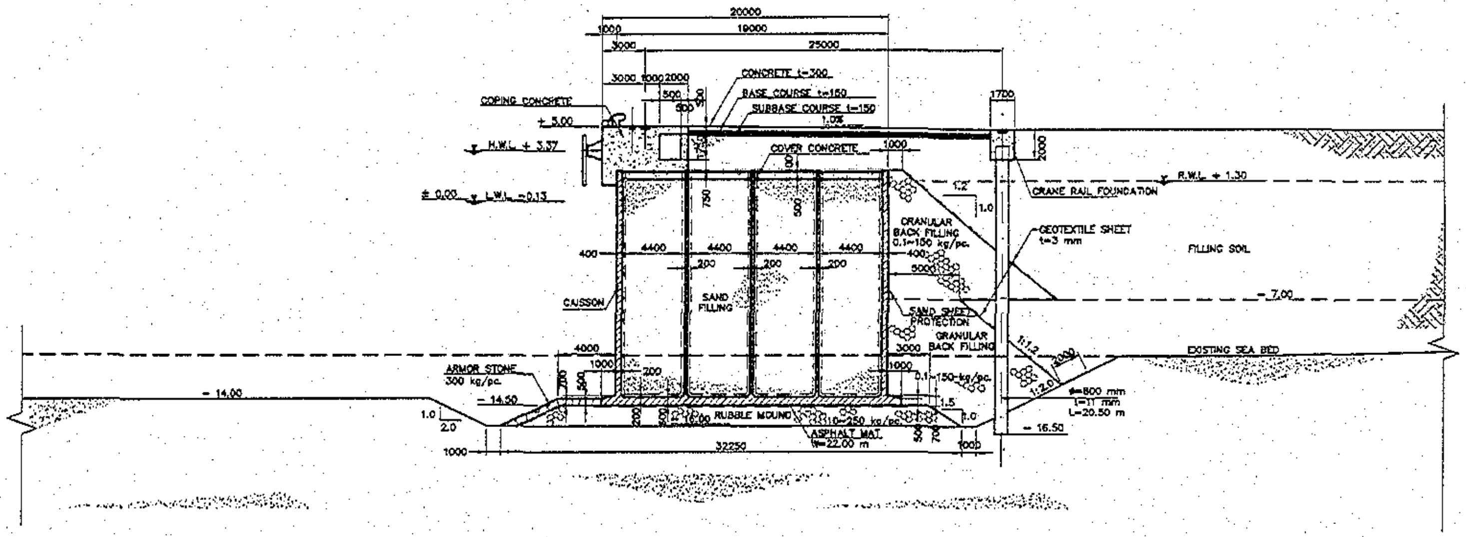
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador

Figure	F.2.2
Title	PLAN AND PROFILE CONTAINER BERTH



TYPICAL CROSS SECTION TYPE I
CONTAINER BERTH (−14.0 m)

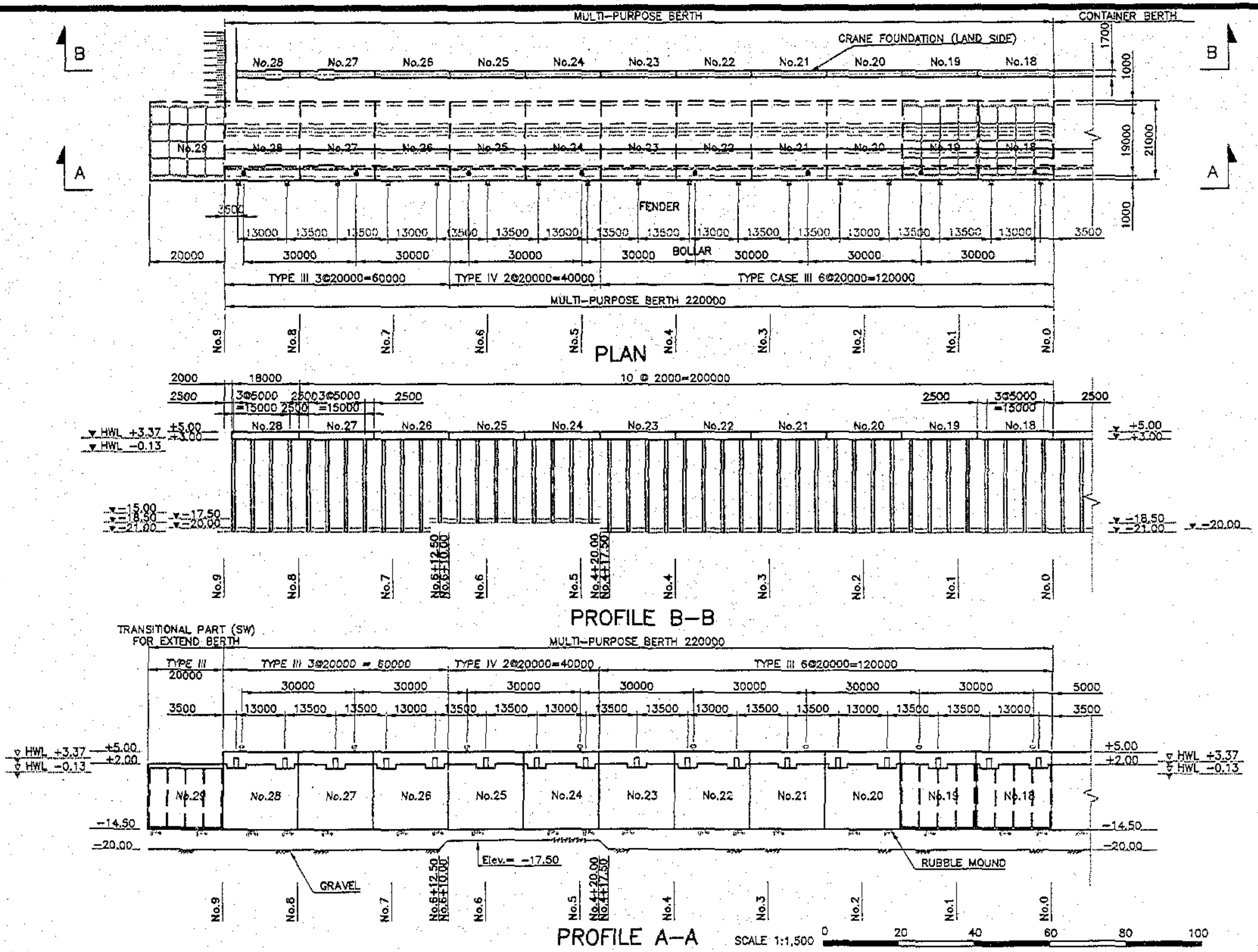
Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.3	TYPICAL CROSS SECTION TYPE I CONTAINER BERTH (-14.0 m)



TYPICAL CROSS SECTION TYPE II
CONTAINER BERTH (−14.0m)

SCALE 1:500 0 5.0 10.0 15.0 20.0 25.0 30.0

Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.4	TYPICAL CROSS SECTION TYPE II CONTAINER BERTH (−14.0m)

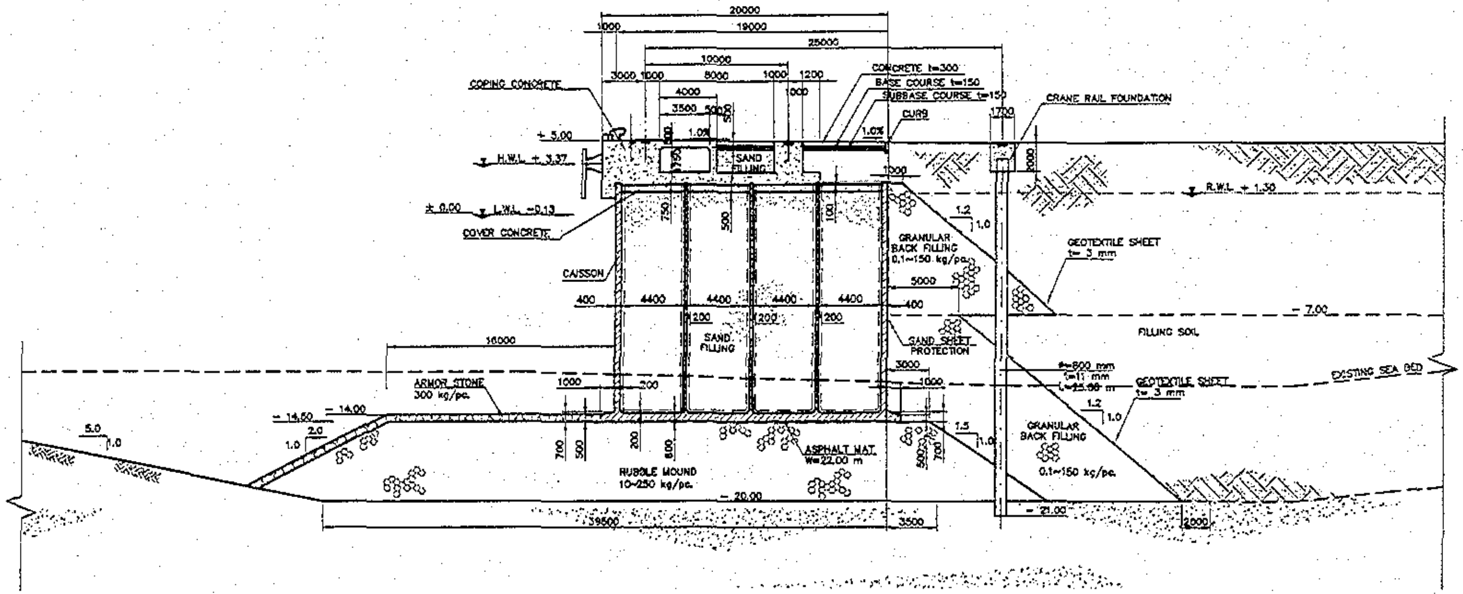


Japan International Cooperation Agency (JICA)

The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador

Figure F.2.5

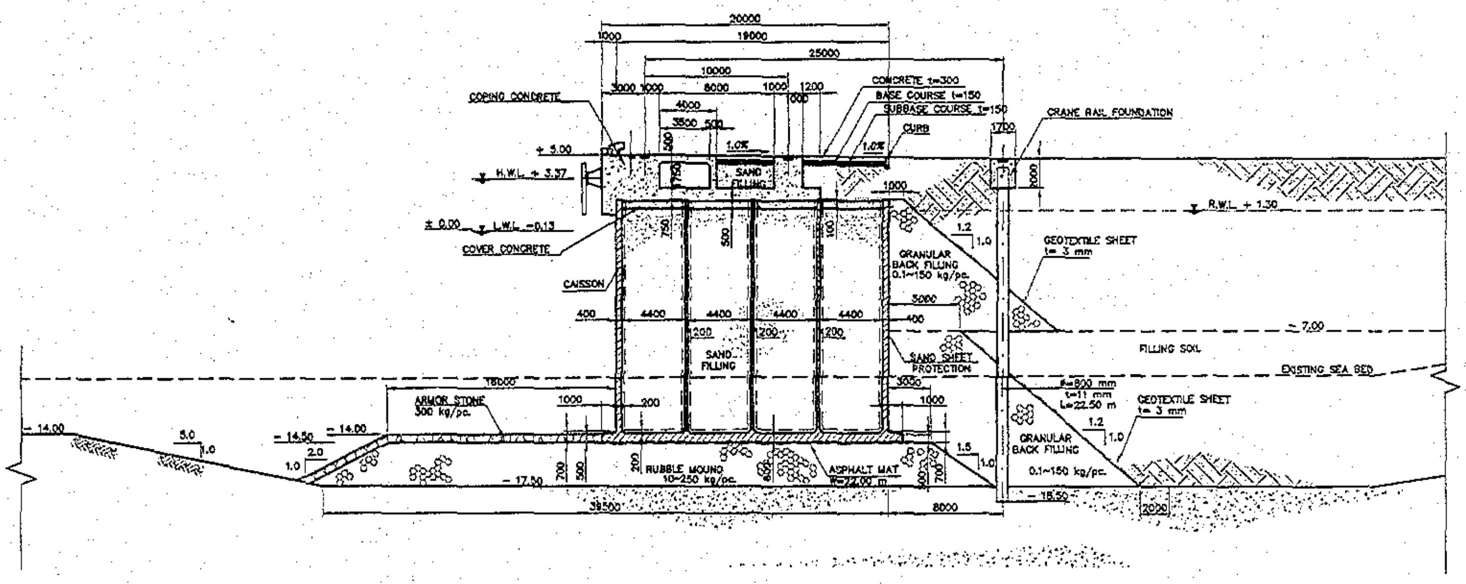
Title: PLAN AND PROFILE FOR MULTIPURPOSE BERTH



TYPICAL CROSS SECTION TYPE III
MULTI-PURPOSE BERTH (-14.0m)

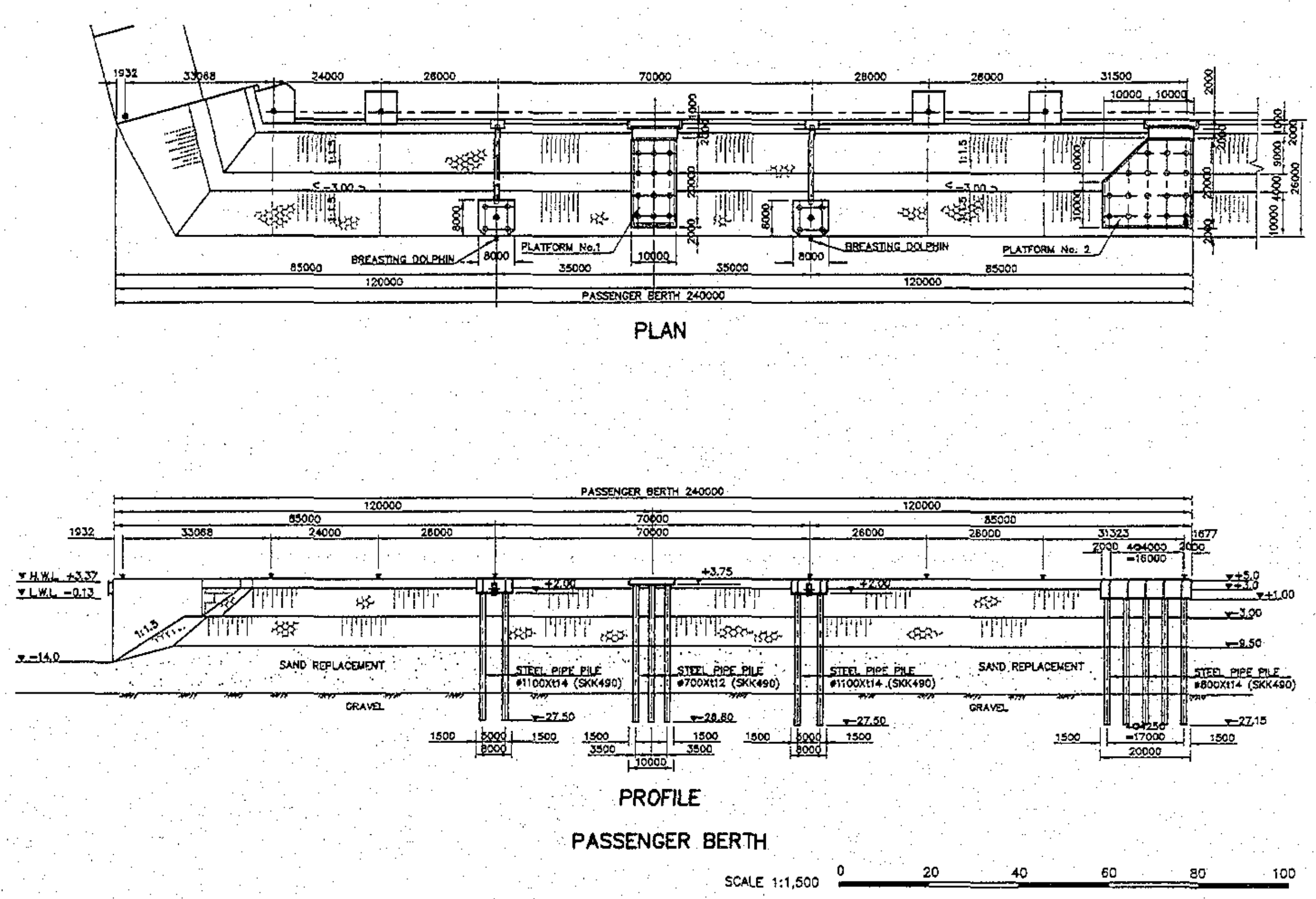
SCALE 1:300 0 5.0 10.0 15.0 20.0 25.0 30.0

Japan International Cooperation Agency (JICA)	Figure
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.6
Title	TYPICAL CROSS SECTION TYPE III MULTI-PURPOSE BERTH (-14.0m)



TYPICAL CROSS SECTION TYPE IV
MULTI-PURPOSE BERTH (-14.0m)

Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.7	TYPICAL CROSS SECTION TYPE IV MULTI-PURPOSE BERTH (-14.0m)

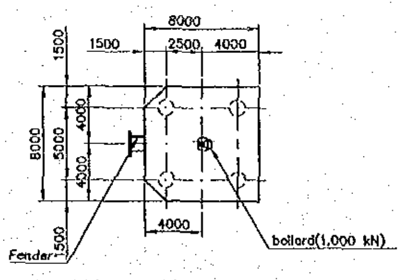


Japan International Cooperation Agency (JICA)

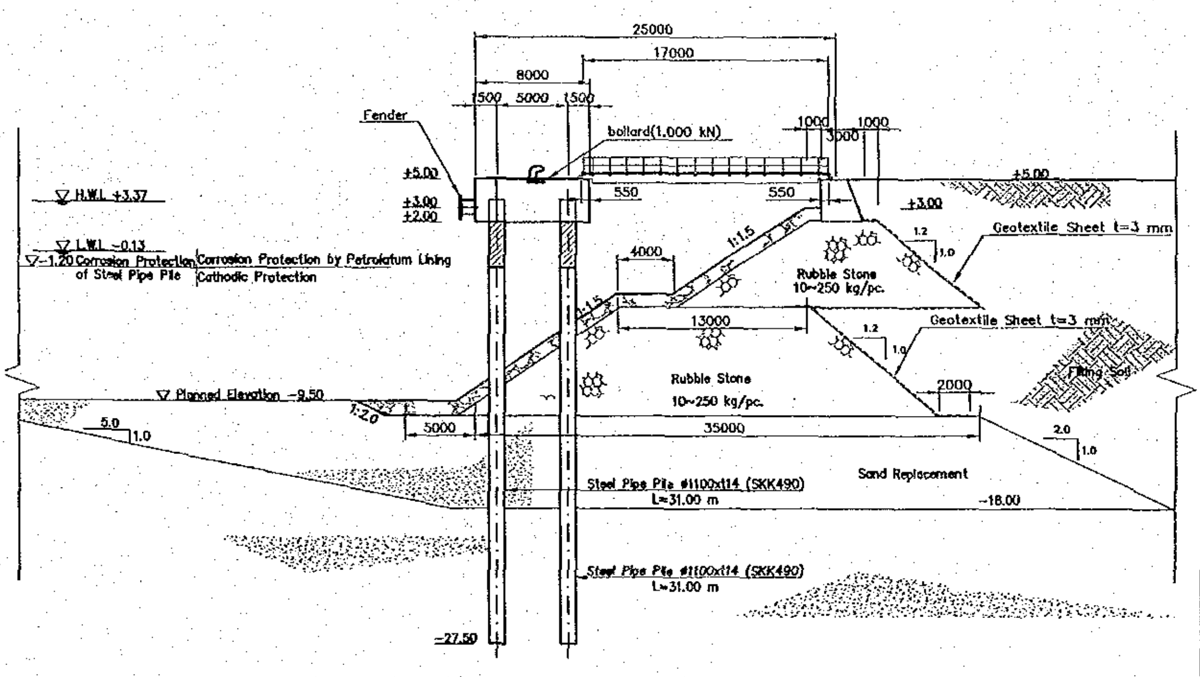
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador

Figure: F.2.8

Title: PLAN AND PROFILE OF PASSENGER BERTH



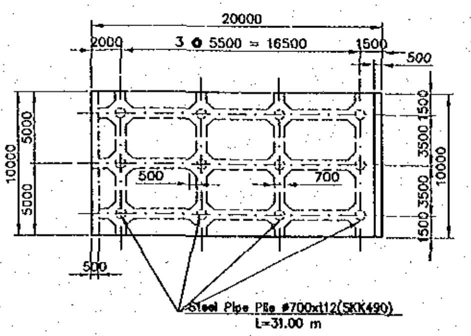
PLAN BREASTING DOLPHIN



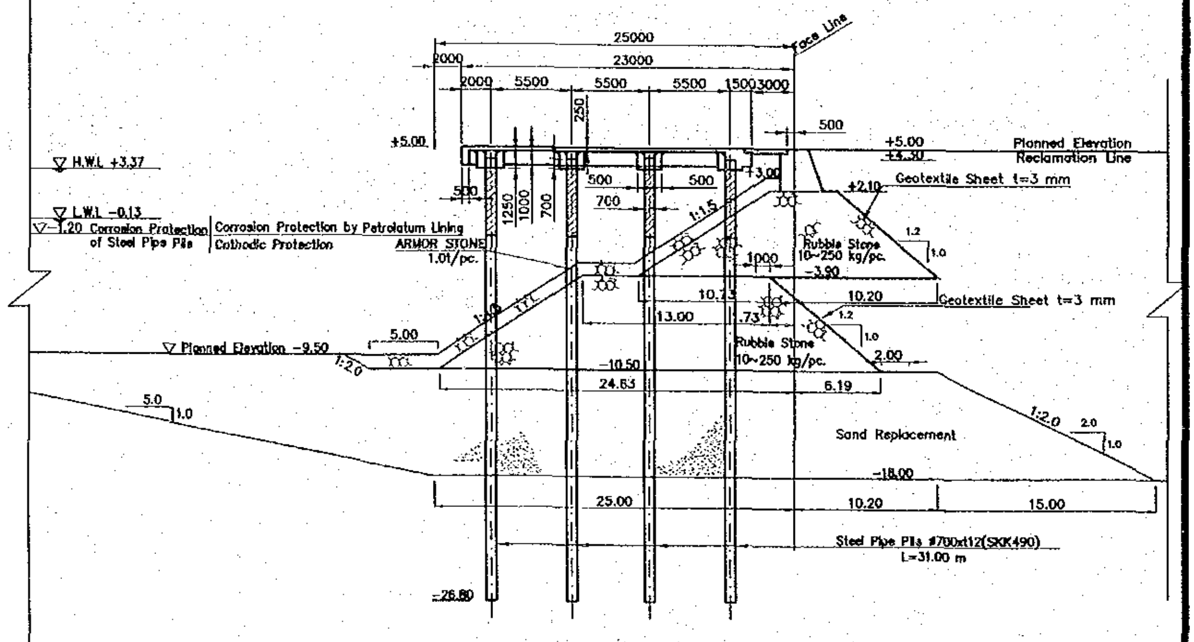
TYPICAL CROSS SECTION

SCALE 1:500 0 5.0 10.0 15.0 20.0 25.0 30.0

Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.9	PASSENGER BERTH BRESTING DOLPHIN PLAN & TYPICAL CROSS SECTION



PLAN PIER 1



TYPICAL CROSS SECTION

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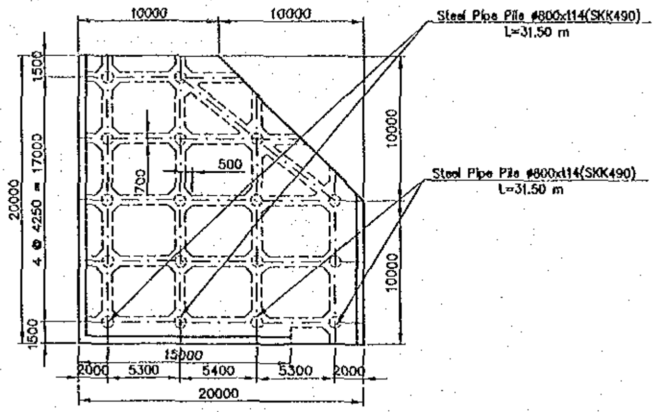
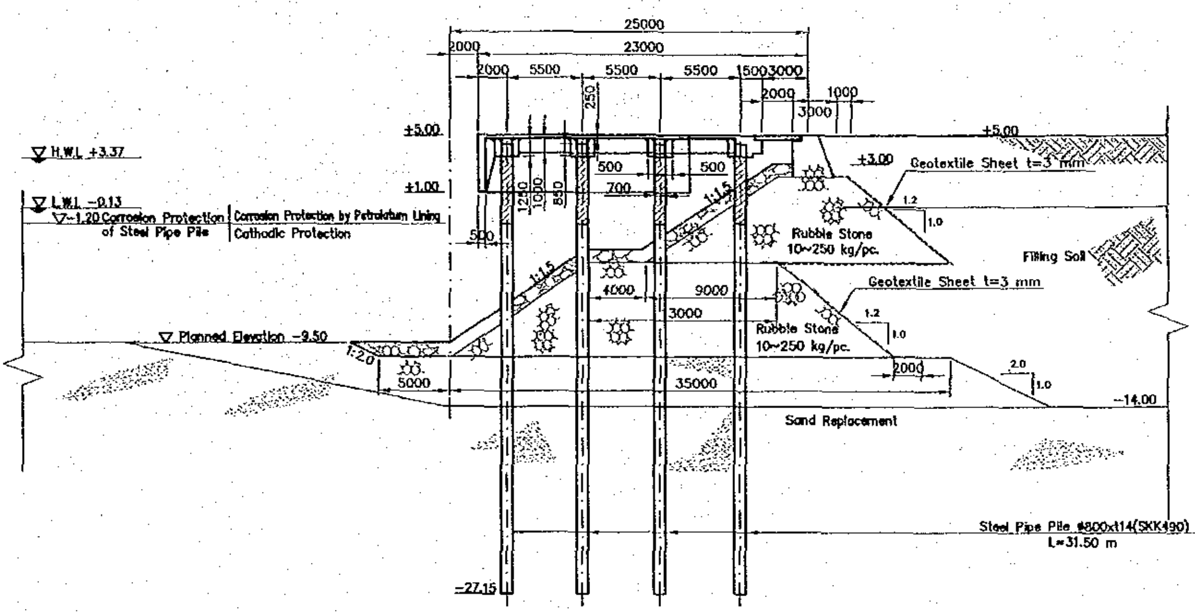
Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.10	PASSENGER BERTH PIER 1 PLAN & TYPICAL CROSS SECTION



PLAN PIER 2



TYPICAL CROSS SECTION

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Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	F.2.11	PASSENGER BERTH PIER 2 PLAN & TYPICAL CROSS SECTION