CHAPTER VIII DESIGN AND COST ESTIMATION FOR THE MASTER PLAN

CHAPTER VIII DESIGN AND COST ESTIMATION FOR MASTER PLAN

VIII-1 General

The high capital cost of port facilities requires that they should be storongly constructed and be able to withstand severe operating conditions. It is also desirable that they remain operational with minimum maintenance costs over a long useful life. This demands careful design of port facilities to obtain the optimum balance between capital cost and operational effeciency. The basic design concept of port facilities, therefore, should be selected through:

- better understanding the effects of such meterological conditions as waves, winds, etc.
- evaluation of subsoil conditions to be considered in designing individual port facilities.
- investigation of seismic risk to determine the appropriate level of aseismicity of structures.
- clarification of berth requirements for berth utilization in the framework of future development plans.
- choice of a basic design concept most suited to the site conditions and economical in construction.
- review of the availability of such construction inputs as materials, manpower and heavy equipment.

VIII-2 General Considerations

(1) Meteorological Conditions

Winds and waves are two of the major factors governing the port development planning of the ports. These factors may necessitate restraint of port operations under severe conditions, resulting in the inefficient utilization of the port facilities.

A guideline for port development planning is presented in Table VIII-2-1; the table shows the maximum wind speed and wave height under which cargo handling at ports is normally operational.

Table VIII-2-1 Max. Conditions for Cargo Handling

Item	max. condition
Wind	15 m/s
Wave (H1/3)	0.5 ∿ 0.7 m

1) The Port of Valparaiso

The port of Valparaiso is well sheltered from the southwesterly waves which prevail along the coast of Valparaiso throughout the year. Waves affecting the port are northerly to norhwesterly waves. The waves from these directions are generally frequent only in winter, but are sometime strong.

A wide range of shoreline in Valparaiso Bay is available for the future development of the port. However, special attention should be paid to the northerly to northwesterly waves, particularty in planning port expansion to the western part of Valparaiso. Moreover, very deep water offshore from the port makes the extension of port facilities offshore prohibitively expensive.

Based on the wind and wave data collected, the harbour calmness of the water area of the port is roughly estimated. The restraint of cargo handling due to wind at the port is niminal because winds over 30 knots occur in frequency of approx. 1%. Fig. VIII-2-1 indicats the average frequency (%) of wave occurence of not more than 0.5 m wave hight. Fig. VIII-2-1 (1) and (2) are prepared for the selected master plan with and without the extension of the existing breakwater.

The study concludes that the extension of the existing breakwater is unnecessary as far as the port development is envisioned at the waterfront east of berth 8. Since the extension of the existing breakwater would require a high capital cost, it is recommended that wave data be collected and a detailed investigation by model test on harbour calmness be carried out so that the optimum solution between capital cost and operational eficiency can be determined . The recommended guidline for the operational frequency of port cargo handling is 90 - 95% on an annual basis.

2) The Port of San Antonio

The port of San Antonio is well protected from the prevailing waves by an artificial breakwater, Molo Sur. Thus, vessels can remain alongside the existing berths and work cargo handling in all weather.

However, since the port opens to the Pacific Ocean westward, the water basin between Espigon de Atraque and Molo Norte is subject to westerly waves. This water basin is also very deep. Thus, the allocation of berthing facilities alongside this water basin will have to be restrained unless the port breakwater is properly extended.

Cargo handling operations at the port of San Antonio will very rarely be restrained by winds of more than 30 knots speed: less than 1% of the time on the average. The study results on the harbour calmeness are presented in Fig. VIII-2-2 which shows the average frequency (%) of the occurence of waves not more than 0.5 m in wave hieght.

(2) Subsoil Conditions

The ports of Valparaiso and San Antonio appear suitable for the construction of port facilities in view of the subsoil conditions. In practice, the type of berth structures is largely determined by the prevailing foundation conditions. Therefore, the subsoil conditions must be locally examined for designing each individual berth structure. Following are our general overall views on the subsoils at the ports of Valparaiso and San Antonio.

1) The Port of Valparaiso

According to subsoil data obtained by our boring works, the natural soils (sea bed soils) were found at 11.0 m below the datum at borings 1 and 2 (existing berths 1 to 3) as shown in Fig. II-2-12. The sea bed soils appeared to be comprised of very dense silty sands of not less than 35 N-value. At existing berths 1 to 3, the natural rock level is relatively shallow, -16 m to -17 m below datum.

No boring was carried out in the slip between berths 4 and 6 by our soil investigation. But, the existing subsoil data[1] show that weak subsurface clays exist in the water area. The existing jetty wharves (Espigon Atraque) of berths 6 to 8 appear to have been constructed upon the weak clayey soils.

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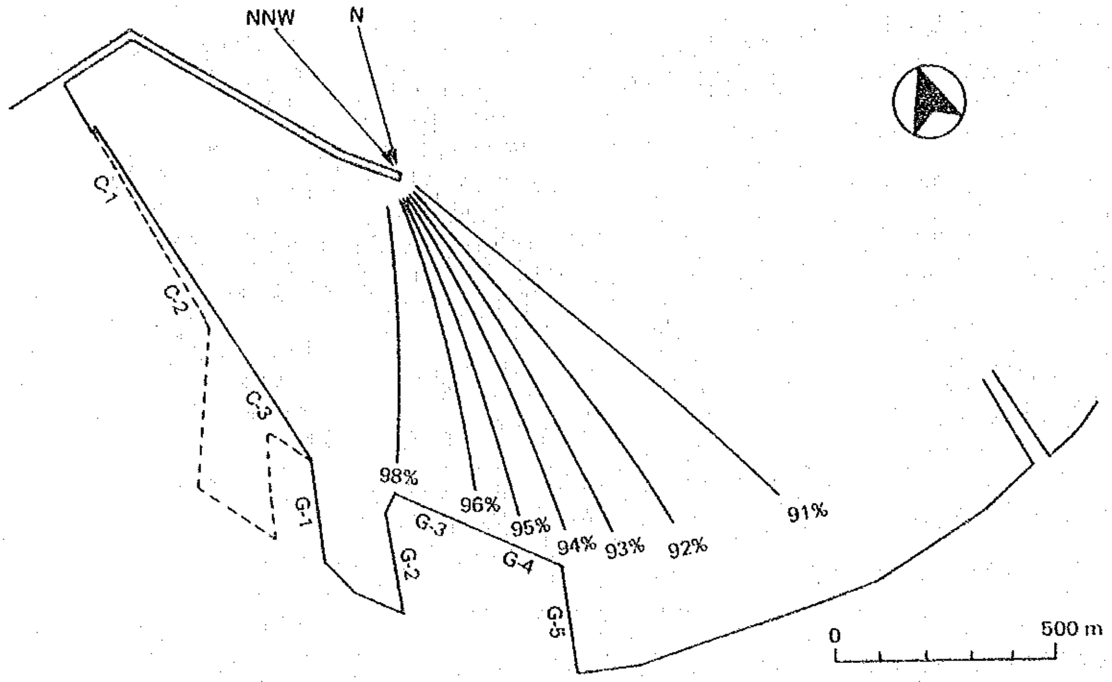
1) Source: Drawing of Puerto de Valparaiso, Sondajes Geologicos en el Sitio del Espigon Atraque, Drawing No. V.O. 192, 20 Augest 1913.



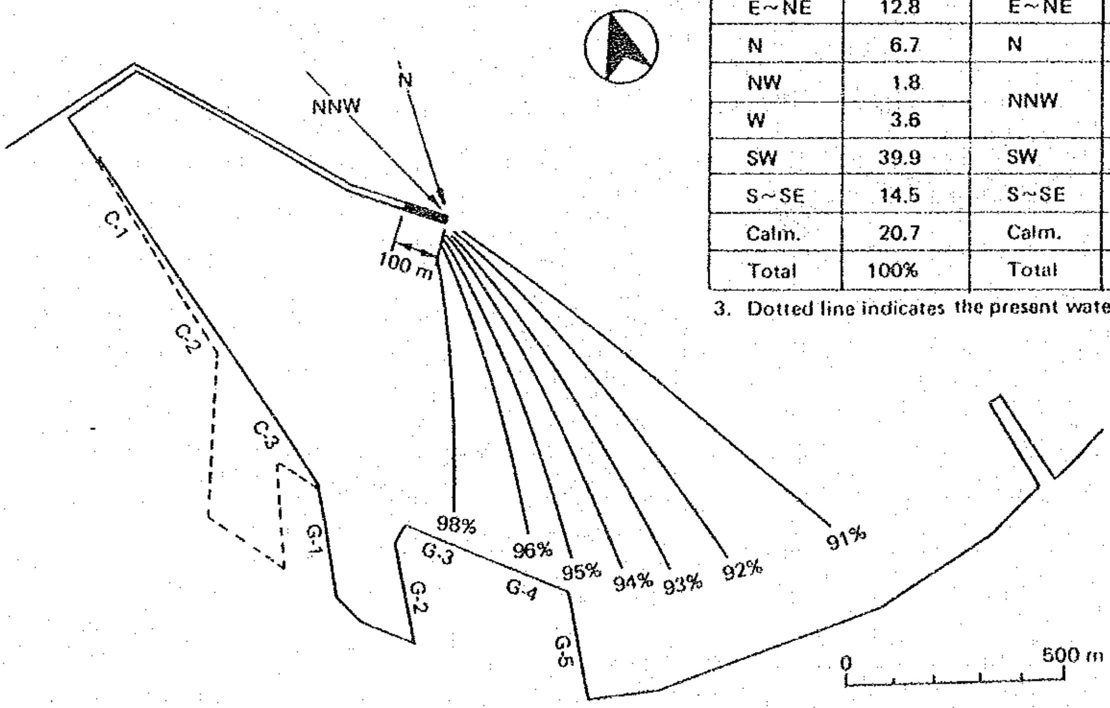
(1) Without Extension of the Breakwater.

Notes 1. Conditions of cargo handling
Operation H⅓ ≦ 0.5 m

2. Average Frequency of Wind and Wave Directions

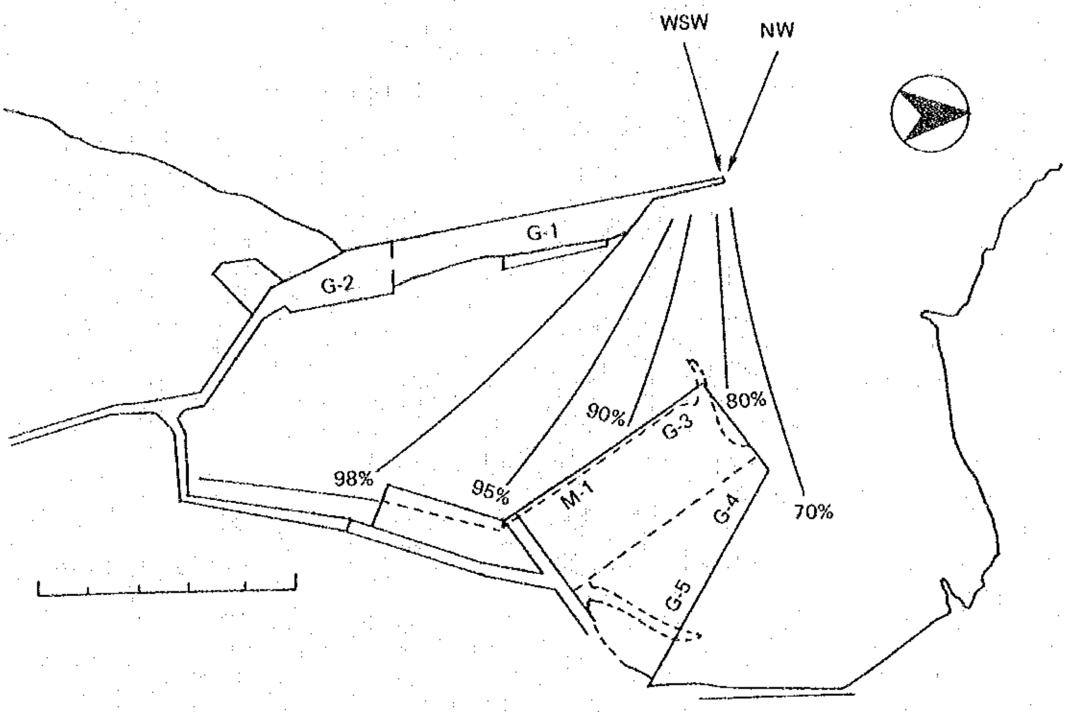
Winds in total		Frequency of wave occurence affecting the harbour claimness	
Direction	Frequency (%)	Direction	Frequency (%)
E～NE	12.8	E～NE	Neglect
N	6.7	N	6.7
NW	1.8	NNW	5.4
W	3.6		
SW	39.9	SW	Neglect
S～SE	14.5	S～SE	Neglect
Calm.	20.7	Calm.	Neglect
Total	100%	Total	

3. Dotted line indicates the present waterfront.



(2) With a 100 m long Extension of the Breakwater.

Fig. VIII-2-1 Operational Frequency (%) of Cargo Handling for the Selected Master Plan at Valparaiso



Notes 1. Conditions of cargo handling
Operation $H^{1}/_{3} \leq 0.5$ m
2. Average Frequency of Wind and Wave Direction.

Winds in total		Frequency of wave occurence affecting the harbour claimness	
Direction	Frequency (%)	Direction	Frequency (%)
NE~N	7.2	NE~N	Neglect
NW	12.7	NW	12.7
W	10.8	WSW	33.2
SW	22.4		
S~E	26.3	S~E	Neglect
Calm.	20.6	Calm.	Neglect
Total	100%	Total	

3. Dotted line indicates the present waterfront
4. Wave data at Quintero is used for the study

Source: Institute Hidrografico de la Armada.

Fig. VIII-2-2 Operation Frequency (%) of Cargo Handling for the Selected Master Plan at San Antonio

In close proximity to Baron pier, there is a soft clayey soil approx. 5 m thick. Despite this soft layer, it appears that port expansion in this zone may be possible.

2) The Port of San Antonio

The subsurface natural soils (sea bed) appear to be comprised of alternate soil layers of medium plastic clays of 15 N-value in average and medium to very dense silty sands. In particular, the subsurface sand layer at the water area between berths 3 and 4 will be the deposits coming from the south beach of the port. Very dense gravel formations vary by location of boring, but are mostly found at -22 m below datum.

The backfill soils at berths 1 to 3 are loosely deposited fine sands and are probably supplied by the dredging operation from the outside seabed of the port. There is a high possibility of soil liquefaction during strong earthquake vibrations.

(3) Seismic Risk

The country of Chile lies in the eastern region of the Pan-Pacific Earthquake Belt of volcanic activities. The tectonic plate theory indicates that the Chilean coast is located along the border between the South American plate and the Nazca oceanic plate which have important significance for volcanic and earthquake activities.

The cause of interplate earthquakes is the diastrophism along the border of the tectonic plates, where the dip subduction of the plates takes place. This dip subduction follows the displacement of the crust which finally yields and produces seismic waves perceptible as earthquakes on the sufrace ground.

The country of Chile lies in a highly frequent zone of earthquake activity and, therefore, port structures in the framework of the future development plan should be designed giving consideration to future earthquakes and their effects on the structures.

A detailed evaluation of future seismic risk is carried out in the succeding subsection. The study results provide a basis to determine the appropriate level(s) of seismic resistance of the port structures.

(4) Study on the Type of Sructures

The alternative types of berth structure are:-

- open piled construction with suspended decks
- quaywalls such as sheet pile walls, concrete walls, caissons and diaphragm walled cells

The factors for selection of the type of structure are ground conditions, water depth of berth, durability, availability of materials and construction equipment, cost and maintenance requirements, etc. In order to provide an optimum solution, practical judgement must be exercised in evaluation of all the factors, but some of these cannot be measured precisely.

(5) Availability of Construction Materials

The use of locally available materials provides such distinct advantages as minimal foreign currency requirments, and enhances the country's economic activities which are sluggish at present. The maximum utilization of locally available materials will therefore benefit the people of Chile in accordance with the national economic policy.

(6) Availability of Construction Equipment and Possible Participation of Local Contractors

This project requires the implementation of construction by contractors capable of handlingoffshore as well as onshore activities. At present, not a few local contractors have some skills and technology in this field, but local contractor with adequate experience in offshore works are limited. The participation of local contractors together with foreign contractors will facilitate and ensure the necessary transfer of skills and technology in this field of construction activities.

Generally, such on-land equipment as hoisting cranes, transportation vehicles and earth-moving equipment are locally available although the quantity of these machines is relatively limited, particularly the larger size heavy equipment.

There are very few floating crafts locally available in Chile. Floating crafts are essential for the proper execution of marine works for the project and, therefore, should be mobilized from other countries.

VIII-3 Seismic Risk

(1) General

Seismic risks at the ports of Valparaiso and San Antonio are evaluated based on the statistics of earthquakes which have occurred in central Chile. The seismic risk evaluated in this study is defined as the probability that a certain intensity of earthquake affecting both ports will occur in an objective period. The following seismic risks are evaluated in this study report:

① probability of very large scale earthquake occurrence to be used for evaluation of the high seismic resistance berth concept.

② probability of earthquake occurrence which would cause a certain intensity of earthquake vibrations (maximum ground accelerations) to be used for determining the appropriate seismic resistance levels of new structures and the remaining useful life expectancy of existing structures.

The procedures of the seismic risk evaluation are shown as a flow chart in Fig. VIII-3-1.

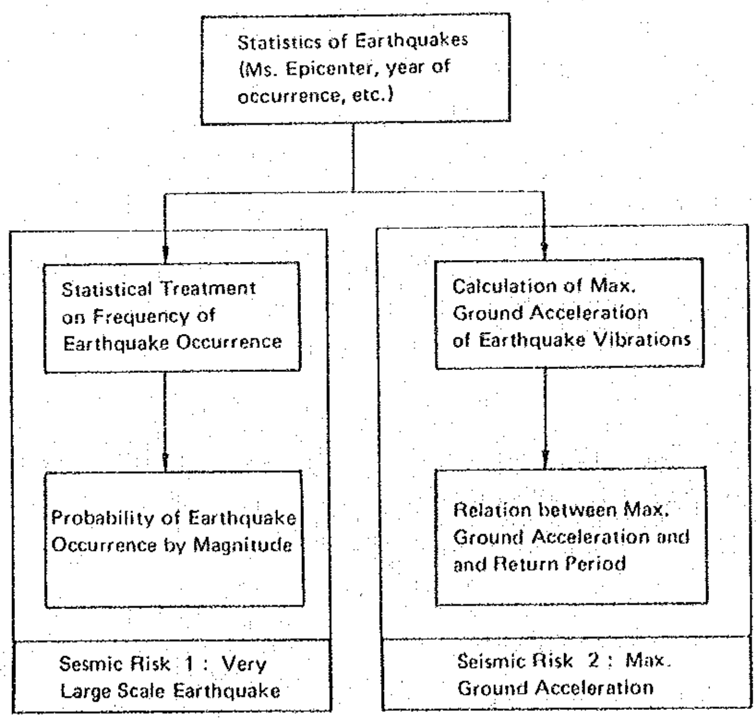


Fig. VIII-3-1 Procedure of Seismic Risk Evaluation

(2) Earthquake Statistics

The occurrence of strong earthquakes which damage structures is very rare in any specific earthquake zone. In estimating seismic risks, the best results are obtained by using earthquake statistics covering a long period.

This seismic risk evaluation uses the earthquake statistics in the study report prepared by Universidad Católica de Chile entitled "Programa de Inversion para el Sistema Portuario Quinto Region: 1986-2000" which is shown in Table VIII-3-1. The statistics include all the earthquakes of not less than 5.5 magnitude which occurred in the earthquake zone of 31°00' - 35°30' south latitude and 70°00' - 72°30' west longitude during 71 years from 1906 to 1977. In addition, five large-scale earthquakes of more than 8.0 magnitude which occurred during 1730 to 1906 are also considered. The earthquakes considered in the statistics are determined so as to include all the earthquakes which cause maximum ground vibrations equivalent to 0.15 g at the ports of Valparaiso and San Antonio.

Although the erthquakes listed in the statistics are not uniform, the set of earthquake data is considered sufficient for our study of seismic risk evaluation.

(3) Seismic Risk of Large-Scale Earthquakes

1) Maximum Ground Acceleration to be Considered

The dynamic responses of structures during earthquakes are greatly different from those assumed in the static analysis by the seismic coefficient method currently used for the design of port structures. This difference is quantitatively expressed by the following equation as presented in Section III.

$$K_E = \frac{1}{3} \times \left(\frac{\alpha}{g} \right)^{1/3}$$

where K_E: Seismic coefficient corresponding to the maximum ground acceleration

α : the maximum ground acceleration (gal) on an SMAC-B2 accelerograph basis

g : gravity acceleration = 980 gal

Table VIII-3-1 Earthquake Statistics

Estadistica Sismica de eventos de magnitud
Ms ≥ 5.5 en el escenario

N°	Year	Month	Day	Epicenter Lat.	Long.	Focal Depth (Km)	Magnitude (Ms)
1	1730	Jul.	8	Stgo. y	Valpso.	-	≥8.0
2	1822	Nov.	19	33.0	72.0	46	≥8.0
3	1847	Mar.	8	La	Ligua	-	≥8.0
4	1973	Jul.	7	La	Ligua	-	8.0
5	1880	Ago.	15	31.5	71.5	-	8.0
6	1906	Ago.	17	33.0	72.0	40	8.4
7	1928	Dic.	1	35.0	72.0	25	8.0
8	1931	Mar.	18	32.5	72.0	Sup.	7.1
9	1943	Abr.	6	30.7	72.0	Nor.	7.9
10	1945	Sep.	13	33.2	70.5	100	7.1
11	1958	Sep.	4	33.8	70.2	10	6.9
12	1965	Mar.	28	32.4	71.2	61	7.4
13	1969	Abr.	26	30.6	71.4	23	6.0
14	1969	Abr.	26	30.6	71.5	Sup.	6.3
15	1969	May.	5	30.8	71.8	38	5.5
16	1969	Dic.	13	32.7	70.0	105	6.1
17	1970	Abr.	9	34.0	70.1	120	5.7
18	1970	Sep.	14	33.9	72.0	Sup.	5.5
19	1970	Sep.	17	31.8	70.0	118	5.8
20	1970	Sep.	18	33.8	72.1	25	5.7
21	1970	Sep.	19	33.5	71.9	21	5.6
22	1970	Oct.	5	34.0	72.2	53	5.5
23	1970	Dic.	8	30.7	71.2	50	6.4
24	1971	Ene.	22	30.6	72.0	66	5.8
25	1971	Jul.	9	32.5	71.6	60	7.5
26	1971	Jul.	9	32.2	71.7	53	5.7
27	1971	Jul.	9	32.4	71.5	47	5.7
28	1971	Jul.	10	32.6	71.5	55	5.5
29	1971	Jul.	11	33.0	71.9	49	5.5
30	1971	Jul.	11	32.1	71.7	45	5.5
31	1971	Jul.	11	32.3	71.8	36	6.3
32	1971	Jul.	25	32.4	71.7	53	5.7
33	1971	jul.	31	32.4	71.5	46	6.2
34	1971	Ago.	2	32.8	72.0	9	5.8
35	1971	Ago.	31	30.8	71.4	43	5.7

continued

N°	Year	Month	Day	Epicenter Lat.	Long.	Focal Depth (Km)	Magnitude (Ms)
36	1971	Sep.	28	32.0	70.0	110	6.3
37	1972	Ene.	13	32.3	70.9	80	6.2
38	1972	Ene.	21	35.0	70.3	11	5.7
39	1972	Feb.	4	32.2	71.9	23	5.8
40	1972	May.	13	32.7	71.8	40	6.0
41	1972	Jun.	8	30.5	71.8	57	6.2
42	1972	Jun.	8	30.5	71.8	399	6.6
43	1972	Oct.	2	33.9	70.8	31	6.2
44	1972	Nov.	27	32.1	72.2	31	5.5
45	1972	Dic.	29	30.6	71.0	60	7.0
46	1973	Abr.	23	34.0	70.6	85	5.7
47	1973	Jul.	24	30.5	71.6	60	6.3
48	1973	Oct.	5	32.5	71.5	Nor.	6.7
49	1973	Oct.	5	33.0	71.9	14	6.5
50	1973	Oct.	5	32.9	71.9	24	6.3
51	1973	Oct.	9	31.6	71.8	39	5.7
52	1973	Oct.	12	33.1	72.1	29	5.5
53	1974	Ene.	7	33.1	71.9	24	5.5
54	1974	Ene.	13	35.5	72.7	Nor.	5.5
55	1974	Feb.	21	35.2	71.0	87	5.5
56	1974	Mar.	24	33.0	70.3	104	5.8
57	1974	Abr.	9	31.5	71.0	84	5.5
58	1974	Jul.	22	35.8	71.5	86	6.0
59	1974	Ago.	15	35.2	71.0	96	6.3
60	1974	Oct.	11	30.9	71.6	65	5.5
61	1974	Nov.	12	33.2	70.6	90	6.2
62	1974	Dic.	29	33.0	70.0	99	6.2
63	1975	Ene.	2	33.1	70.0	108	5.7
64	1975	Jun.	14	32.5	70.7	94	6.5
65	1975	Sep.	14	33.8	70.5	37	5.7
66	1976	Jul.	16	31.5	71.3	60	6.0
67	1976	Nov.	8	30.4	71.3	59	6.0
68	1976	Dic.	29	30.3	71.3	59	5.5
69	1977	Ene.	11	31.7	71.4	35	6.0
70	1977	Jul.	30	30.7	71.4	45	5.5
71	1977	Nov.	7	32.5	71.5	84	5.5

Nota: Sup. indica profundidad menor a 60 Kms.
Nor. indica profundidad restringida á 33 Kms.
Source: CIAPEP report prepared by the Universidad Católica de Chile

It will be evident that the design seismic coefficient is closely related to the design procedures and must be determined in the field of port and harbour engineering through many experiences of earthquakes and damages to port structures. In the Japanese standard method of design, a seismic coeffiecient of 0.25 is approimated as the highest practically adaptable beyond which the stability of such submerged structures as quaywalls can not be maintained. It is therefore understood that the seismic resistance of port structures to be provided for the strongest earthquake vibrations is 0.25.

The maximum ground acceleration corresponding the seismic coefficeint of 0.25 is computed applying the above equation as:

413 gal on an SMAC-B2 accelerograph basis
or 537 gal on an SMA-1 accelerograph basis

2) Reconstruction of the Objective Earthquake Area

It is necessary to review the objective earthquake area within which the study report by Universidad Católica de Chile lists the past earthquakes.

The earthquake intensity at a specific site is dependent upon the magnitude of the earthquake and the distance from the epicenter zone to the site as expressed by the following general equation:

$$\alpha = A \times 10^{BMs} \times (\Delta + \Delta_0)^C$$

where α : index representing intensity of seismic vibration
M_s : magnitude of earthquake
Δ : distance related to the attenuation of seismic vibrations.
A,B,C : constants

The above relation is acknowledged to express the attenuation of the seismic vibrations by distance between the epicenter zone and the specific site. Many empirical formulas are proposed at present, but the locality of the earthquake region is said to be one of the significant factors to evaluate the relation.

Among others, the following formula is proposed by Fresard and Saragoni (1985) [1] and is considered appropriate to be adopted for our study.

$$A_{max} = \frac{1088e^{0.85\ Ms}}{(R + 60)^{1.59}}$$

where A_{max} : maximum surface ground acceleration on the basis of an SMA-1 accelerogram (gal)

Ms : magnitude of earthquake

R : distance between the epicenter zone and the site.

Because the largest earthquake in central Chile was the event in 1906 with a magnitude of Ms = 8.3[2], the maximum distance between the epicenter of the earthquake (Ms = 8.3) and the ports to cause the maximum ground acceleration of 413 gals (SMAC-B2) or 537 gals (SMA-1) is computed to be 72 km based on the above formula. This destance can approximate the earthquake zone within the limited area of 32°00'-34°50' south latitude and of 70°50'-72°50' west longitude. In the limited zone, a set of earthquakes (Ms ≧5.5) to cause the strongest vibrations at both ports can be extracted for our study. The large scale earthquakes which occured outside this zone are recognized to induce earthquake vibrations lower than those corresponding to 0.25 g.

3) Frequency of Earthquake Occurrence

The frequency of earthquake which occurrence in a specific zone is generally given by the experiential formula as follows:

$$\log N = a - bMs \text{ (by Gutenberg-Richter)}$$

Where N: number of earthquakes occurred in a given time span

Ms: magnitude of the earthquakes on the Richter scale

a,b: constants

---

1) Source: R. Saragoni H, P. Gonzalez S,M.Fresard B; Analisis de los Acelerogramas del Terremoto del 3 de Marzo, 1985.

2) Source: A. Eisenberg and others; Sismicidad Historica y el Terremoto del 3 de Marzo, en la Zona Central de Chile.

The constsnts "a" and "b" can be determined using the same procedures of analysis as those adopted in the study by Universided Católica de Chile as follows.

① to extract a set of earthquakes which occurred in the earthquake zone of 32°00'-34°50' south lat. and 70°50'-72°50' west long.

② to compute the frequency of earthquake occurrence at defferent levels of magnitude

③ to determine constsnts "a"and"b" by adopting the least squares

The above analysis results in the following recursion formula.

$$\log N = 5.585 - 0.944\ Ms \quad (Ms \geqq M)$$

It indicates that large-scale earthquakes ($Ms \geqq 8.0$) occur with a frequency of N = 0.0108 per year or once in a 93 year period. According to the research in th field of seismology, it is said that the Pan-Pacific Earthquake Belt Zones are periodically affected by large-scale earthquakes, an example of which for the southern South American continent is shown in Fig. VIII-3-2 and Table III-3-2.

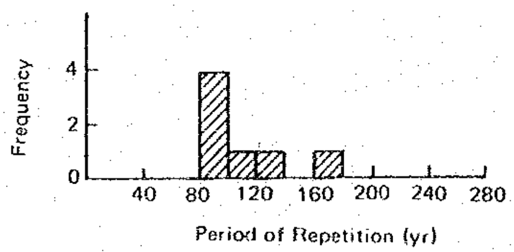


Fig. VIII-3-2 Frequency of Repetition Period of Large-Scale Earthquakes[1] (Southern South America)

Source: T. Rikitake; Tectonophysics (1976)

Table VIII-3-2 Frequency of Repetition Period of Large-Scale[1] Earthquakes

Earthquake Region	Period of Repetition	Standard Deviation
Japan (Tokai-Nankai)	117 Yrs	35.0 Yrs
Japan (Hokkaido)	85.3	24.6
Aleutian-Alaska	27.2	8.9
Central America	34.5	3.6
Northern South America	46.3	30.0
Southern South America	100	22.5
All these regions	88.2	65.4

4) Seismic Hazard by Magnitude of Earthquake

If earthquakes occur periodically and accidentally, their frequency of occurrence approximates a Poisson distribution as follows:

$$P = (NT)^n e^{-NT} / n!$$

where P : probability of a number (n) of earthquake occurrences in a given time span (T)

N : average number of earthquake in a given time span

Since the probability of no earthquake occurrence in the time Span (T) is e^{-NT}, the probability that at least one earthquake occurs in the time spen (T) is

$$P\,[0,\ T] = 1 - e^{-NT}$$

Applying the previous study results on the frequency of earthquake occurrence (N), the seismic hazard by magnitude of earthquake is calculated as shown in table VIII-3-3.

Source: T. Rikitake; Tectonophysics (1976)

Table VIII-3-3 Probability of Earthquake Occurrence by Magnitude

Magnitude Ms ≥	Year of last event	Annual average frequency of occurrence(N)	Probabilitiy of Occurrence P[0, T] (%)						
			1990	1995	2000	2005	2010	2020	2030
6.0	1985	0.8337	98.5	99.98	about 100				
7.0	1985	0.0948	37.7	61.2	75.9	85.0	90.7	96.4	98.6
8.0	1906	0.0108	59.6	61.8	63.8	65.7	67.5	70.8	73.8

$\log N = 5.585 - 0.944\ Ms$

It is generally recognized in the field of seismology that there is a periodicity of earthquake occurrence in the same specific region. This is due to the accumulation of strain energies in the crusts explained by the plate tectonic theory and, therefore, the probability of earthquake occurrence derived as above is recognized as physically significant.

However, the probability only reflects the statistical average status of a set of earthquake events and therefore can never be used to reliably predict the next earthquake. Specific earthquake occurrences must be evaluated based on the understanding of the mechanisms of the crust fracture, the energy release and the sequence of occurrence by location, etc. This is the subject of earthquake prediction theory.

Therefore, it should be construed that the study result provides a preliminary probability of large-scale earthquake occurrence in the future, and is only to be used by the Government of Chile as a reference to help determine the acceptable level of seismic risk.

(4) Maximum Ground Acceleration Expectancy

1) Attenuation of Ground Acceleration

It is essential to obtain the seismic risk on a ground acceleration basis. This is because the majority of port structures are evaluated for seismic resistance in terms of ground acceleration in the design practice of the seismic coefficient method.

Possible ground accelerations of earthquakes at both ports are computed based on the attenuation relationship proposed by Fresard and Saragoni

(1985) for all the earthquakes listed in the study report prepared by Universidad Católica de Chile. Table VIII-3-4 shows the maximum ground acceleorations of earthquakes which are relatively strong at the ports.

Table VIII-3-4 Maximum Ground Acceleration Estimated at Valparaiso and San Antonio

Year of occurrence	Magnitude	Epicenter Lat./Long.	Valparaiso		San Antonio	
			Epicenter distance	Accelera-tion	Epicenter distance	Accelera-tion
1730	M ≥ 8.0	Val. y Santiago	55 km	410 gal	60 km	380 gal
1822	M ≥ 8.0	33S/72W	40	500	74	320
1847	M ≥ 8.0	La Ligua	74	320	140	170
1873	M ≥ 8.0	"	74	320	140	170
1880	8.0	31.5S/71.5W	185	120	240	α<100
1906	8.4	33S/72W	40	700	74	440
1928	8.0	35S/72W	240	α<100	210	100
1931	7.1	32.5S/72W	74	170	37	240
1943	7.9	30.7S/72W	280	α<100	220	α<100
1945	7.1	33.2S/70.5W	110	120	115	α<100
1958	6.9	33.8S/70.2W	170	α<100	145	α<100
1965	7.4	32.4S/71.2W	74	190	124	120
1971	7.5	32.5S/71.6W	65	230		α<100
1972	7.0	30.6S/71W	300	α<100	240	α<100
1973	6.7	32.5S/71.5W	65	130		
1973	6.5	33.0S/71.9W	20	200		
1973	6.3	32.9S/71.9W	31	160		

1)Source: Report prepared by the University of Catoica entitled "Programma de Inversion para el Sistem Portuario Quinto Region: 1986 - 2000"

2) The maximum Ground Acceleration is computed based on the attenuation curve proposed by Fresard and Saragoni (1985)

2) Maximum Ground Acceleration and Corresponding Return Period

Based on the above results, the seismic risk defined as the relationship between the maximum ground acceleration and the corresponding return period is evaluated by adopting linear recursion analysis.

The return period (T_R) of a maximum ground acceleration is computed using the data given the rank (m) from the maximum as follows:

$$T_R = K/m$$

Where T_R : return period

K : time span within which the earthquake data are used

m : ranking of the data from the maximum

The relationship between the maximum ground acceleration (α) and corresponding return period (T_R) expressed as log T_R = A + B log is computed by linear recursion analysis at both ports. The linear recursion formulae obtained for both ports are:

Valparaiso : $\log T_R = -2.217 + 1.605 \log \alpha$

San Antonio : $\log T_R = -2.270 + 1.715 \log \alpha$

The relationship obtained is shown in Fig. VIII-3-3.

3) Probability that Structures will be Affected by Earthquakes

The relationship between the maximum ground acceleration and the return period provides the seismic risk in the future on tha basis of an indefinite time span. As mentioned in section III, the probability of earthquake occurrence within a period (T_D) of an indefinite time span is expressed as follows based on the random access theory.

$$P\ [Y > y,\ T_D] = 1 - \{ 1 - \frac{1}{T_R} \}^{T_D}$$

Therefore, the probability of earthquake occurrence causing a seismic intensity (Y) of not more than y within the same period (T_D) , i.e. the non-exceedant probability, is given by the following equation and is shown in Fig. VIII-3-4.

$$P\ [Y < y,\ T_D] = (1 - \frac{1}{TR})^{TD}$$

This new idea of the non-exceedant probability of earthquake occurrence was recently introduced into the determination of the seismic resistance of structures to be assessed for the seismic risk in the future. In designing port structures, it is rational to determine the seismic resistance considering a reasonable level of seismic risk and the appropriate service life of the structure.

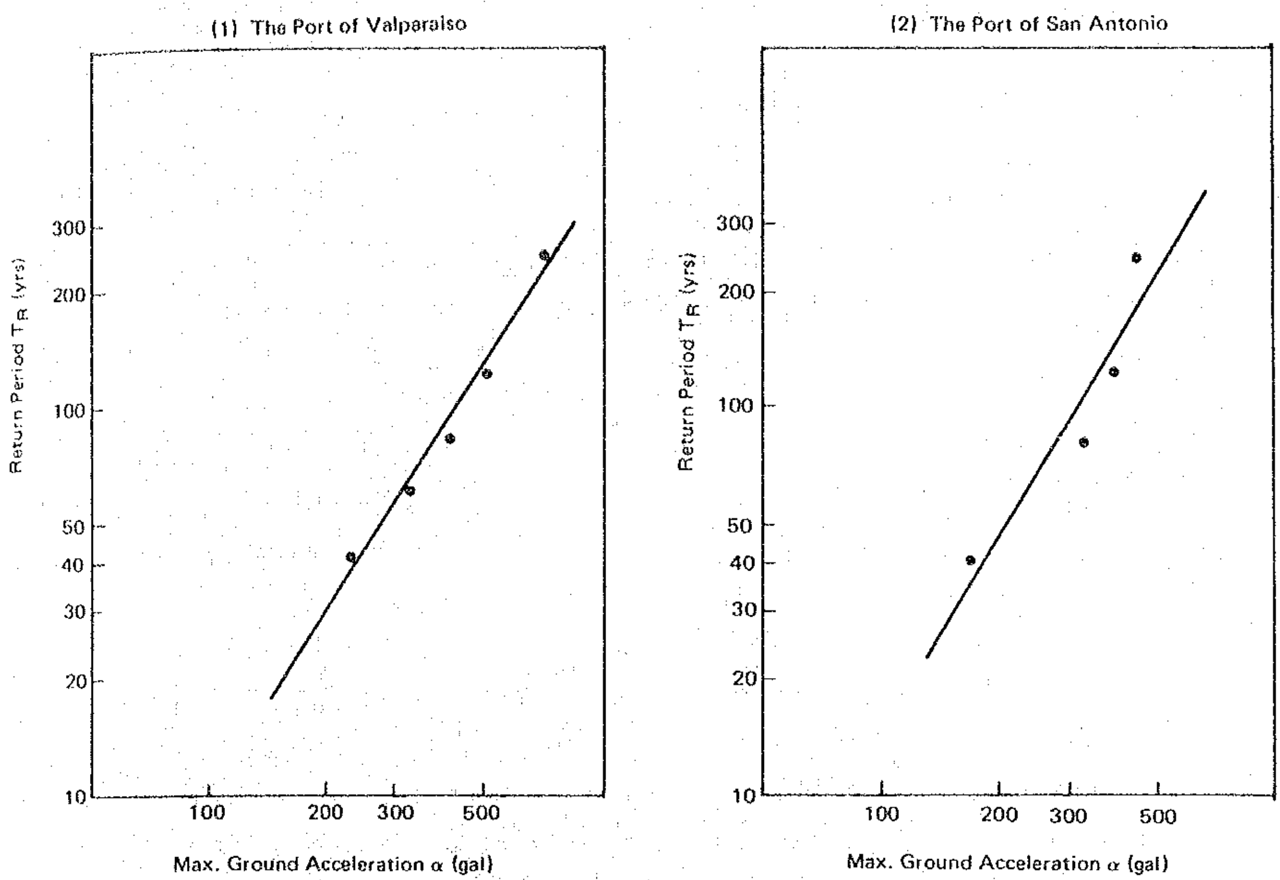


Fig. VIII-3-3 Max. Ground Acceleration vs. Return Period

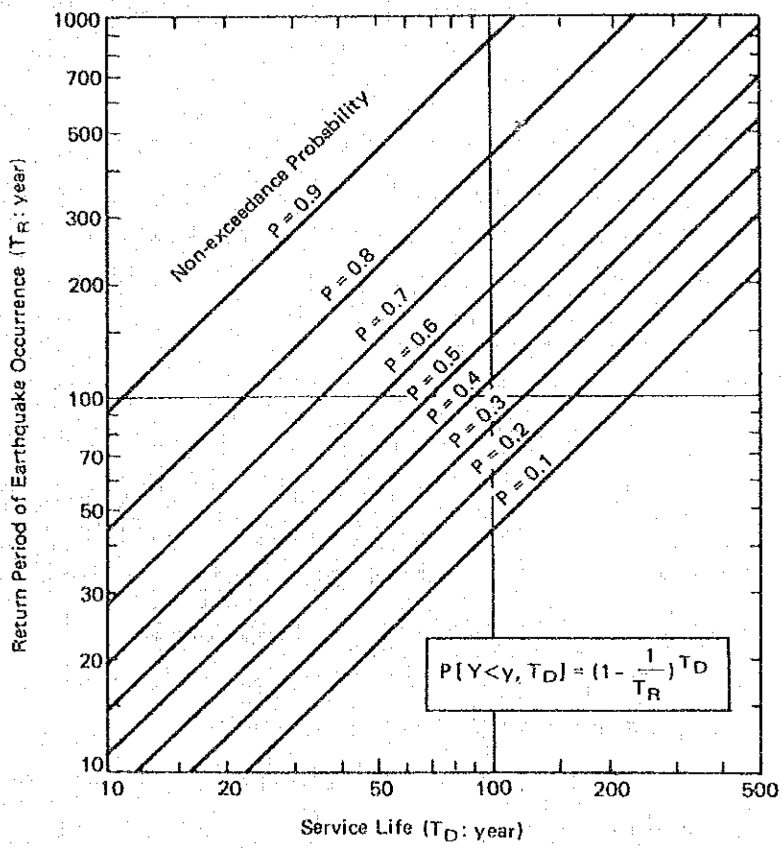


Fig. VIII-3-4 Non-exceedance Probability of Earthquakes

VIII-4 Design Conditions

The port facilities comprise various structures. It is necessary to clearly set forth the design conditions to be used in determining their structural dimensions. The following are the principal design conditions to be used for designing port structures proposed in the master plan.

(1) Berth Dimensions

① Objective Ships

The largest sizes of ships whic are to be accommodated at each berth proposed in the master plan are stated in Section VII and require 11.0 to 13.0 m water depths of berths for safe accommodation.

In the long-term development plan, the largest container ship size is 40,000 DWT. Although the container berth is designed with a -12.0 m water depth in this study, it will be preferable to execute the berth at -13.0 m in the short-term development plan if the construction costs between -12.0 m and 13.0 m berths are not so different.

② Copeline Height

This is one of the factors which determines th serviceability of berths as well as the cost of construction. The guideline in Japan recommends the copeline height to be 1.0 - 2.0 m above the highest high water level for berthing facilities to accommodate larger size ships. The adoption of this guideline results in a moderate copeline height of approx. +4.0 m above the port datum.

This figure is 1.0 m lower than the present elevation. Of course, the final decision must be subject to the future development plan of the port because of the necessity to consider the overall rehabilitation of warehouses, port yards, etc.

③ Apron Width

The current narrow berth aprons and back-of-port yards seem not to meet the modernized standard of port construction. This is also pointed out by the JICA Japan Expert Mission. In order to modernize the por facilities as practically as possible, an apron width of not less than 20 m should be provided for berths to accommodate ocean-going general cargo ships.

(2) Seismic Resistance of Structures

The strandard practice for design of structures in Japan provides the following methods of evaluation for the seismic stability of structures:

① Seismic coefficient to be determined based on the seismic hazard represented by the regional seismic soefficient

② Seismic coefficient to be determined by the dynamic soil response analysis for the specific earthquake of which the probability of occurrence is very high and urgently requires such countermeasures as high aseismatic berth construction.

1) Application of Japanese Standard Method

In Japan, the design seismic coefficient method is adopted designing port facilities. The seismic coefficient stands for the ratio of the earthquake acceleration against the gravity acceration (g) and represents the intensity of earthquake vibrations. The design seismic coefficient (Kh) is determined based on the following formula in consideration of the seismic risk level of the region where the port is located (Ko), the factor for subsoil conditions (Ks) and the importance of the structure (Ki).

$$Kh = Ko \times Ks \times Ki$$

The seismic risk level of the region is represented by the regional seismic coefficient (Ko) which is appropriately determined based on the seismic hazard of the region. Table VIII-4-1 shows the examples on the expectancy of peak acceleration and the regional seismic coefficient adopted for designing port facilities at five defferent ports in Japan.

It will be observed in Table VIII-4-1 that the regional seismic coefficient adopted in Japan is o.15 for ports where the expectancy value of acceleration for return periods of 75 years is 200 - 300 gals on the ground level. The peak ground acceleration expectancy for the 75 year return period at both ports is estimated based on the seismic risk as follows:

Valparaiso : 350 gals for T_R =75 yrs
San Antonio : 260 gals for T_R =75 yrs

Basically, the acceleration of earthquake vibrations on base rock is lower than this value, although it depends upon the subsoil conditions. Based on the above, the seismic scale of acceleration of 0.15 is appropriate for use as the regional seismic coefficient in designing aseismatic structures at Valparaiso and San Antonio.

Considering subsoil condetions at the ports and the importance of port facilities, the design seismic coefficient appropriate to port facilities for Valparaiso and San Antonio will be,

$$Kh = Ko \times Ks \times Ki$$
$$= 0.15 \times 1.0 \times 1.2 \doteqdot 0.20$$

Where Kh: Design Seismic Coefficient
Ko: regional design seismic coefficient
Ks: factor for subsoil conditions
Ki: factor for structural importance

When designing the high seismic resistance berths, the design seismic coefficient of 0.25 can be adopted as the importance factor of 1.5 is recommended.

Table VIII-4-1 Examples of Approximate Expectancy of Acceleration and Regional Seismic Coefficients in Japan

Researcher(s)	Return period (years)	Port				
		Tokyo	Osaka	Akita	Hosojima	Hachinohe
Kawasumi (on ground)	75	300	200	100	50	100
ditto	100	600	300	100 - 150	100	150
Goto and Kameda (on ground)	75	300	250	200	150	150
Hattori (on rock)	100	200	50 - 100	150	100	150
Uwabe and Kitazawa (on rock)	75	250	220	250	200	200
	100	270	250	280	220	220
Regional seismic coefficient (Ko)		0.15	0.15	0.10	0.10	0.10

Source: Report on Damage to Port Facilities in the Port of Valparaiso by the Earthquake on March 3, 1985; Japanese Export Mission, April 2, 1985

2) Determination of Seismic Coefficient

The seismic risk in the future helps to determine the appropriate levels of the seismic resistance of structures. It may be appropriate to consider more than one level of seismic resistance in designing future port structures. Along these lines, the high seismic resistant berth provides a minimum operational capacity against the highest level of earthquake expected while the other structures are designed against smaller earthquakes so as to optimize the economical solution between the capital cost and the operational capacity of the ports.

(i) Ordinary Berths

Recently, the new idea of the non-exceedant probability of earthquakes is proposed for the determination of the earthquake vibration level to be considered in the design of structures, as presented in Fig. VIII-3-4. In general, the service life expectancy (T_D) and the return period of earthquake (TR) to be adopted in design of structures are 50 years and 75 years respectively so that a non-exceedant probability of 0.51 is maintained. The probability of p = o.51 means that the structure will not be affected by the design earthquake vibrations during its service life with a 51% probability.

Moreover, the following relationship between the maximum ground acceleration (α) and the corresponding seismic coefficient (K_E) will be used for evaluation of the appropriate design seismic coefficients.

$$K_E = \frac{1}{3} \times \left(\frac{\alpha}{g}\right)^{1/3} \qquad \alpha \geq 200 \text{ gals}$$

Appling the above to the port of Valparaiso and San Antonio, the following design seismic coefficients are obtained.

	Valparaiso	San Antonio
- Return Period of Earthquake (years)	75	75
- Service Life (years)	50	50
- Maximum Ground Acceleration (gals)	350	260
- Design Seismic Coefficient	0.236	0.214

$$K_E = \frac{1}{3} \times \frac{\alpha}{g}\ 1/3$$

It will be appropriate to adopt the design seismic coefficient of 0.20 for ordinary structures, considering the discussion on the applicaton of the Japanese standard method.

(ii) High Seismic Resistant Berths

A seismic coefficient of 0.25 is considered the highest to be practically applicable to the design of port structures on the basis of standard practice used in Japan. Therefore, the seismic coefficient of 0.25 is reasonable for the design of high seismic resistant berths if the government of Chile considers that the high seismic resistant berths should be provided in order to assure minimum operational capacity in each of the ports for the strongest expected earthquake.

The seismic coefficient of 0.25 corresponds to 9 maximum ground acceleration of 413 gals with a return period of 96 and 165 years for Valparaiso and San Antonio, respectively. When the non-exceedant probability of 0.50 is adopted, the service life expectancy is 66 years for Valparaiso and 114 years for San Antonio.

The highly aseismatic berths should be basically provided against the strongest earthquake that is evaluated as likely to occur. Our study shows that the probability of occurrence of a large scale earthquake ($Ms \geqq 8.0$) is 60% in the year 1990 and about 70% in the years 2010 - 2030. The judgement on whether the high seismic resistant berth is needed is dependent upon the assessment of the value of the probability. In Japan, highly aseismatic berth construction is implemented as one countermeasure against the high possibility of occurrence of the largest scale earthquake which is predicted not only by earthquake statistics, but also by such earthquake precursors as strain accumulation in the crust.

(3) Availability of Construction Materials

Construction materials required for the project were surveyed by conducting interviews at Government offices and laboratory, local contractors and others. The annual average production of cement, stone and steel were confirmed through on-the-spot surveys at factories, quarry sites, stock piles, etc. The information gained is outlined as follows:

① Ready-mixed concrete

At present, there is no manufacturer of ready mixed concrete in the proximity of Valparaiso or San Antonio. Moreover, since the small scale of the projects will not induce local firms to begin production of ready-mixed concrete, the construction will utilize concrete from a temporary concrete plant erected for the development.

② Cement

In chile, the business scale of cement production is not so large. Two-thirds of the total national consumption of 3 million tons is produced by five manufacturers. At present, only two types of portland cement, ordinary cement and high early strength cement, are produced by the local manufacturers. Generally, the locally produced cement is handled as bagged cement in Chile.

③ Aggregates for use in Concrete, Stones and Rocks

Aggregates for use in concrete are abundant in the proximity of the study sites. The quality of the materials is good enough to be used for concrete production. River sands, gravels and crushed stones may be used for the aggregates.

There are several quarry sites in close proximity to Valparaiso. Two of them are Sausalito and Cucharas, run by Valparaiso city, which are located 18 km and 16 km distant from the site, respectively. Rocks produced by the quarry are granite which is sufficiently hard. The quantity available is more than sufficient for the project. At San Antonio, one of the available quarries is located at Panul, about 3 km north of the port of San Antonio. The rocks are granite of good hardness and the quantity is sufficient.

Table VIII-4-2 Sources of Stones and Rocks

Port	Source	Distance(km)	Quality	Unit Cost at the Project Site (peso per cu.m)
Valparaiso	Sausalito	18	Granite	1,800 for 20～100kg
-ditto-	Cucharas	16	-ditto-	2,500 for 100～1000kg
San Antonio	Panul	3	-ditto-	1,400 for 20～100kg 2,000 for 100～1000kg

④ Materials for Reclamation

The future development of the ports requires a large quantity of reclamation materials. The dredging work to obtain reclamation materials for the port of Valparaiso is very much restrained due to the deep water of the port.

The following borrow pits can be expected to be used for the reclamaton work of th port of Valparaiso.

Table VIII-4-3 Borrow Pits for Reclamation at Valparaiso

Borrow Pit	Distance from the Port (km)	Cost at the Port (Peso/cu.m)	Remarks
Laguna Verde	15	800	500 ~ 800 thousand cu.m sea sands available
Curharas	16	1,000	river sands and hill soils, about 1 million cu.m available
Colmo	30	1,200	sands at Aconcagua river, about 800 thousand cu.m available
Playa Punta de Piedra	30 ~ 35	1,200	Fine sands, abundantly available

The reclamation materials from these sources can be brought to the port of Valparaiso principally by land transportation or by sea transportation in the case of playa Punta de Piedra. But, sea transportation by barges may be difficult due to rough sea conditions outside the summer season.

⑤ Prestressed Concrete Products

At present, several prestressed concrete factories are in basiness in the Santiago region. They manufacture such pre-or post-tensioned products as square piles and columns, beams and electric lighting poles, etc.

Maximum length of their products is 18 m due to traffic restriction in Chile. The product cost is roughly estimated at 40,000 - 60,000 pesos per cubic meter, although it depends upon the size and shape of the product.

⑥ Steel Materials

Round as well as deformed bars are produced locally at Concepcion. The scale of this production is 400 thousand tons per year, but is planned to increase up to one million tons per year.

Sizes of locally available steel bars are:

round bars	6 to 26 mm dia.
deformed bars	10 to 36 mm dia.

Steel materials available locally are steel plates, various mateials for use in building works, shaped steels and steel pipes. However, the shaped steels and steel pipes available locally are of smaller sizes produced by welding or pressing, and will require close inspecton. The major steel materials of the project will have to be imported shaped steels, and high-tension steels for use in prestressed concrete members.

VIII-5 Design studies

(1) General

In practice, the structural type of berth structure is largely determined by the prevailing subsoil conditions. In this study, we have investigated the optimum solution by berth among various structural types construction materials.

(2) Options

1) Open Piled Structures

Piles are used to carry working loads down to firm soils when the subsurface soil is weak and the firm soil is found at greater depths. Open piled structures can be designed either as marginal wharfs with an uninterrupted ground surface from the suspended deck to the land behind the quay or as island wharfs or jetties with approach bridges from the shore to save cost.

Open pile structures provide stronger seismic resistance than other types of structures owing to the flexibility and lightness of these structures. But, when the sea bed is extremely deep and the subsurface weak soil is relatively thin, the pile foundation becomes prohibitively expensive and physically unstable particularly curing construction.

Open pile structures are recommended as a satisfactory solution if the site subsoils are not strong. Selection of the type of open pile structure, either marginal wharf or island wharf, is made based on the economic balance between the additional cost of the marginal wharf and the potential savings from operational efficiency.

2) Quaywall Structures

Quaywalls have the advantage of massiveness and thus withstand the berthing impacts of ships more readily than lighter open piled structures. Moreover, quaywalls have an easier and simpler form of construction. However, one of their great disadvantages is the heavy loads they impose on th ground and, therefore, quaywalls require strong ground at or near the foundation level.

If the subsoil just below the required water level is not strong enough to support the walls or if the existing sea bed is too deep, the quaywall foundation must be taken deeper with resulting additional works such as removing the weak subsoil or placing a firm base mound. These works increase costs considerably.

Quaywall structures are only viable where the subsoil conditions are stron enough to carry the loads. When the existing sea bed is considerably deep, it becomes necessary to compare alternative designs in order to estimate the construction cost accurately enough to select the most economical solution.

(3) The Port of Valparaiso

The copeline of the wharfs porposed in the master plan is determined on the assumption that all the structure are to be constructed as marginal wharfs with an uninterrupted surface from the copeline to the land behind the quay. The final judgement will be made based on the view that the additional costs of the marginal wharf construction can be balanced by the potential savings from operational efficiency, including;

- operational access and control
- less distance of cargo movement from the copeline to the storage yard
- less cost for cargo handling equipment
- higher efficiency of labour activities, etc.

In the port of Valpaiso, the subsoil conditions are strong enough to permit extension of the land area, and there is no technical restraint for adoption of marginal wharf construction by reclamation in terms of the localized shear failure as well as the failure of th whole earth mass.

The recommended structural types for the individual berths at Valparaiso are presented below.

1) Berth C-1, C-2

Either gravity quaywalls or open pile structures can be used at these berths because the existing seabed is a moderate depth of -10 m below datum and the subsoil is hard enough to withstand the loads. But, due to the relative hardness of the subsoil, only open-ended steel pile foundations would be viable in the case of open pile construction to minimize the pile tip resistance during driving operations.

Open Structures have an advantage in that the superstructure can be made as light as possible to reduce the effects from earthquake vibratons.

This results in a higher seismic resistance of the structures. On the contrary, the lightness of open pile structures reduces the capacity of these structures to absorb such heavy loads as the berthing impacts of ships and so, in addition to the provision of docking bumpers along the copeline, it is necessary to increase the lateral resistance of the pile foudation.

In this respect, the lateral resistance of the pile foudation is minimal because the relatively shallow rock formation level at the site permits pile embedment into the subsoils of only less than 10 m. Considering the subsoil conditions of the site, open piled construction in combination with a gravity quaywall is recommended as a satisfactory solution to maintain the advantages of both open pile and gravity quaywalls. Among other options of quaywall structures, steel wall cells may be used, providing enough space to permit pile foundations.

2) Berths C-3 and G-1

In designing the new proposed structure along the existing berth 8, one of the decisive economic factors is a possible shift of the berth copeline from the existing alignment as follows:

Case-1 : to construct along the same alignment as before replacing all or part of the existing quaywall
----- will be costly and gives no allowance to widen the berth apron for the time being.

Case-2 : to construct along a line somewhat forward to the harbour side by reinforcing the existing quaywall
----- will be economical but assurance of long-term seismic resistance may be difficult.

Case-3 : to construct a new berth structure in front of the existing quaywall
----- will be costly but will result in an ideal aseismatic berth of the appropriate dimensions.

The most stable structure is obtained in case-1 because of the consolidated base rock foundation. However, the choice involves costly investment for additional removal works of the existing quaywall structure as well as partial demolition of existing warehouses.

The best type for design of a new berth structure should be determined by comparing alternative structural types. We have found that the use of caissons mounted on the artificial base rock is most preferable in terms of aseismicty, durability and adaptability to deep water. Figs. VIII-5-1(2) and (3) show the cross section of the proposed new berths for C-1 and G-1 using precast concrete caissons. In the framework of the proposed master plan, the new general cargo berth G-1 is identified as an high seismic resistant berth to be urgently consturcted to assure the operational capacity of the port of Valparaiso.

3) Berths G-2 to G-5

Berths G-2 to G-5 are to be newly developed at the offshore area along the waterfront east of the existing berth 8. The seabed at the proposed area is 25 to 35 m below datum, the depth of which technically rules out the use of piling methods for open piled structures and sheet piled walls.

Although detailed soil test results at the proposed offshore site are not available, it is certain that the sandy seabed subsoils are strong enough to withstand the loads from the gravity quaywalls of 40 tons per sq. m as investigated by our soil investiagtion at on-land boring no. 4. Th construction costs of the gravity quaywalls would be somewhat higher, but no more than those for open piled structures.

Since the seabed is very deep, the gravity quaywalls must be founded upon a base rock mound. However we have not looked into the question of the serious settlement of the quaywalls except for that instantaneous settlement which occurs during construction in the case of sandy soils. The possible form of quaywall failure would be a massive earth slip on a circular plane with collapse of the entire ground behind the walls and a heave of the ground in front of the wall. With trial slip circles, it is found that the factor of safety for the whole earth mass failure is more than unity and, therefore, there would not be a slip failure. The preceding gravity quay-wall construction of the existing berths 6 to 8 has demonstrated that a vertical faced quaywall structure mounted upon the artificial base rock is a viable solution, although a careful construction procedure might be required.

(4) The Port of San Antonio

As mentioned before, the wharf structures can be designed either as island wharfs or as marginal wharfs. It is fair to say that, considering all the factors related to port operations, marginal wharves for general cargo and container berths are preferable. But, because the marginal wharves involuve extra capital costs, the advantages must be carefully investigated and weighed against the extra costs in each particular case.

Form our design studies, marginal wharf construction is recommended as the optimum solution for the general cargo berths. Chemical and grain berths cannot, in our views, be constructed ad marginal wharves due to the imbalance between the extra cost and the potential savings in opeational efficiency and, therefore, we recommend that they be constructed as island wharves. The island wharves should be connected by approach bridges from the shore so that when the port faces the peak operation demands these berths can be fully utilized for handling cargoes other than chemical products and grain.

Our overall view on the subsoil conditions in the port of San Antonio shows that the subsurface sandy or clayey soils are strong enough to support the gravity walls and the bearing strata for th stractures is found at relatively shallow depths. This would make pile foundation difficult, but not impossible, and th resulting minimal lateral resistance of piles due to insufficient embedment into the subsoils might be a problem.

The individual berths at San Antonio are considered below:

1) Chemical Berth

The subsurface soil just below the required water depth having not less than 40 N-value is strong enough to support a quaywall structure. Generally, quaywall structures are constructed to form continuous walls but, in certain circumstances, the quaywalls are used island wharfs connected to the shore by access bridges. Such quaywall structures have obvious economic advantage.

Among quaywall structures, the use of steel walled cells is best suited to hard subsoil conditions. Since the quaywalls from very high vertical walls, they should be constructed as light as possible in view of seismic resistance, adopting a piled deck structure in combination.

2) Berth G-1

The existing anchored steel sheet pile walls appear to be inadequate in the horizontal seismic resistance of anchoring if the berth is utilized as a berth having an -11.0 m water depth. In addition, the residual strength of the steel sheet piles is uncertain at present and must be subject to the ongoing investigation by the Government of Chile.

The subsurface soil at the site is very hard clay with an N-value around 30. But, as demonstrated in the construction of the existing berth, pile foundation is technically viable but with some difficulties during construction.

Possible structural modifications to modernize the berth are:

Altermative-A : Re-use of the existing sheet pile wall subject to the reinforcement of anchoring

Alternative-B : Provision of a new steel sheet piled structure in front of the existing copeline anchored properly by piled structures

Alternative-C : Alternative-C : Provision of a new structure in front of the existing copeline, reusing the deformed sheet pile wall as much as technically possible.

Alternative "A" is completely subject to the assessment of the residual strength of the existing front walls of the steel sheet piles. Even if positive results are obtained through the investigation, it will be mandatory to reinforce the resistance of or replace the existing anchoring walls. This would be costly.

The newly constructed sheet pile walls as well as the horizontal anchoring in alternative "B" would require a minor change of the copeline alignment of the berth. The adjustment of the deformed copeline alignment would be easy. However, this measure would be somewhat costly and would probably encounter difficulty in pile driving works at the back yard due to the existence of baxkfill rock.

Alternative "C" would be practical because of the re-use of the existing sheet pile walls. The design is aimed at supplementing the inadequate lateral resistance of the existing sheet pile walls by the new structure. About a 10 m shift of the copeline seaward would be required to provide enough space for constructing the new structure. Also, this new structure could be preferably designed in terms of seismic resistance.

Alternative "C" is judged better than the other alternetives due to the ease of construction and the seismic resistance. The possible occurrence of soil liquefaction in backfill soils requires sand compaction works as a countermeasure against strong earthquake vibrations.

Furthermore, if adverse structual problems are observed in the existing sheet pile walls through the investigation, corresponding countermeasures must be taken based on a comprehensive technical assessment of the stability of the quaywall. This may require that a contingency plan be established to modify the engineering design. only the detailed enogineering study to be made after the field investigation can therefore finalize the structural design of the proposed berth G-2.

3) Grain Berth

The subsurface soil upon the bearing strata at approx. 20 m. below datum is clay having a hardness of 15 in N-Value. An island wharf founded on steel piles and connected to the shore by approach bridges appears to be the optimum solution.

Because the site of the berth faces the mouth of the port to the northwest direction, the berth may be subject to waves, especially in the winter season. The open piled structure would decrease the effects of wave action to the structure more readily than a gravity quaywall structure.

However, an open piled structure reduces the capacity of the structure to absorb heavy lateral loadings such as the berthing impacts of ships. It is thus essential to provide docking bumpers in the design to minimize the damages by ship berthing. In practice, steel piled foundations with a combination of vertical and raked piles are used to withstand heavy lateral loads.

4) Berths M-1 and G-2

The existing open piled pier at berth 5 was designed at a seismic coefficient of 0.15. However, no essential damage to the structure was observed during the very strong vibrations of the last earthquake, which demonstrates that open piled structures have higher seismic resistance than other quaywall structures because of their flexibility and lightness.

The existing berth 5 was newly constructed in 1979 and, therefore, the extent of aging or deterioration to the structural materials is minimal. In our view, the existing structure should be used effectively in the framework of the future development plan of the port. However, this view imposes the design of rehabilitation measures to berths M-1 and G-2 proposed in the master plan.

Under this special circumstances, constructon of a new structure with complete removal of the existing backfill materials is indeed the only technically viable alternative. The additional cost of the removal works can be apparently offset by the cost saving for the construction of a new structure in front of existing berth 5.

Either open pile or gravity quaywall construction is technically viable considering the subsoil conditions of the site. However open pile construction is more readily adjustable to the existing open pier structure of berth 5. The construction costs would be somewhat higher than those of quaywalls, but such advantages of the open piled construction as higher seismic resistance and minimum effects from wave action would balance the extra costs.

5) Berth G-3 and G-4

According to the soil investigation additionally carried out by the Government of Chile, a very thin layer of subsurface soil is founded upon the base rock formation arund 16m below the datum at the site for the proposed new berths G-3 and G-4. The subsurface soil of 5 to 8 m thickness is very hard.

In such circumstances, the optimum type of structure is a gravity quaywall with the advantages of massiveness, simpler construction and generally lower construction costs. But, the one great disadvantage is that the heavy weight of the structure can cause a strong earthquake load during the siesmic vibrations resulting in less seismic resistance than open piled structures.

Less seismic resistance is considered the decisive factor to rule out the use of gravity quaywall construction in the case when the structure is identified as a high seismic resistant berth strong enough to assure minmum operational capacity against the maximum expected earthquake. In our view obtained through comparative design studies on different types of structures, open piled construction in combination with sheet pile walls is the satisfactory solution for the berths.

(5) Details of Structures

1) Container Berth

A specilized container terminal requires such port facilities as a wide open storage yard, a container freight station, an administration building, specialized gantry cranes and equipment and various other service utilities. The size of these facilities varies according to the container handling system. Since thses port facilities require a high capital investment, a detailed study on the container operations as well as the possible investment in new equipment by the port users should be considered.

In certain circumstances, it is prudent that the container berth also be designed as a multipurpose berth so that the utilization can change readily and effectively as the port faces the peak demand caused by the seasonal cargo variations or as the cargo mix changes. However, it is clear that a transit shed is not necessary for the container traffic and a shed would rather be considered as an obstruction causing quayside congestion. A wide open deck is required, allocating ample maneuvering space for container operations.

Special gantry craned may be preferable for highly efficient container handling operations. The future possible traffic of container shipments will require two 35 ton capacity cranes per berth. The deck of the wharf must be designed to be strong enough to bear all the deck loads and to transmit the loads to the subsoils through the foundations.

2) General Cargo Berth

A trasit shed is required on the quay side as near to the copeline as possible to reduce cargo handling distance. The minimum width of the front aporn of the berth must be determined in view of necessary cargo handling space.

Provision of rail tracks on the apron impose restraints on maneuvering, occupying about 4 m. It is likely that a mobile crane will occupy the cope side of the track (5 m) with provision of a minumum 6 m wide access way between the rail track and the transit shed. Accordingly, the minimum width of the front apron is approximately 15 m. The minimum turing circle for a 20 ton trailer (gross weight) is about 24 m, but the turning on the front apron is not likely to occur. From pracitical experience, a 20 m wide front apron is the minimum size that can be said to be adequate for modern berths.

3) Grain and Chemical Berths

It is recommended that the grain and chemical berths be used as multipurpose berths so as to supplement the general cago handling capacity during peak demand. A wide open deck without a transit shed is basically required for the specializes cargo traffic. An island berth of a minimum 15 - 20 m width is, in our view, the optimum solution in view of economy in construction and ample maneuvering space for general cargo traffic.

To allow for access from the shoreline, the access bridges should be 7 m wide to maintaning enough space for two-way traffic with some allowance.

4) Quayside Cranes

For the near future, it is agreeable to make full use of existing wharf cranes, for which necessary provision of facilities should be made. Nevertheless, in the long term as part of the modern and improved port being descussed in the framework of the future development, the existing wharf cranes should be retired as they are old and their capacity will no longer be sufficient.

Apart from special gantry cranes for container handlings, positive utilization of ship gear and mobile cranes should be introduced for the future high demand of specialized cargoes in line with the master plan. Most ships have thier own adequate handling gear. However, such smaller ships as those used for coastal trade may have some difficulty in handling cargoes by their own gear and, in this circumstances, it is preferable to have mobile cranes to promote flexible cargo handling operations both on the berth apron and in the strorage yard.

5) Deck Details

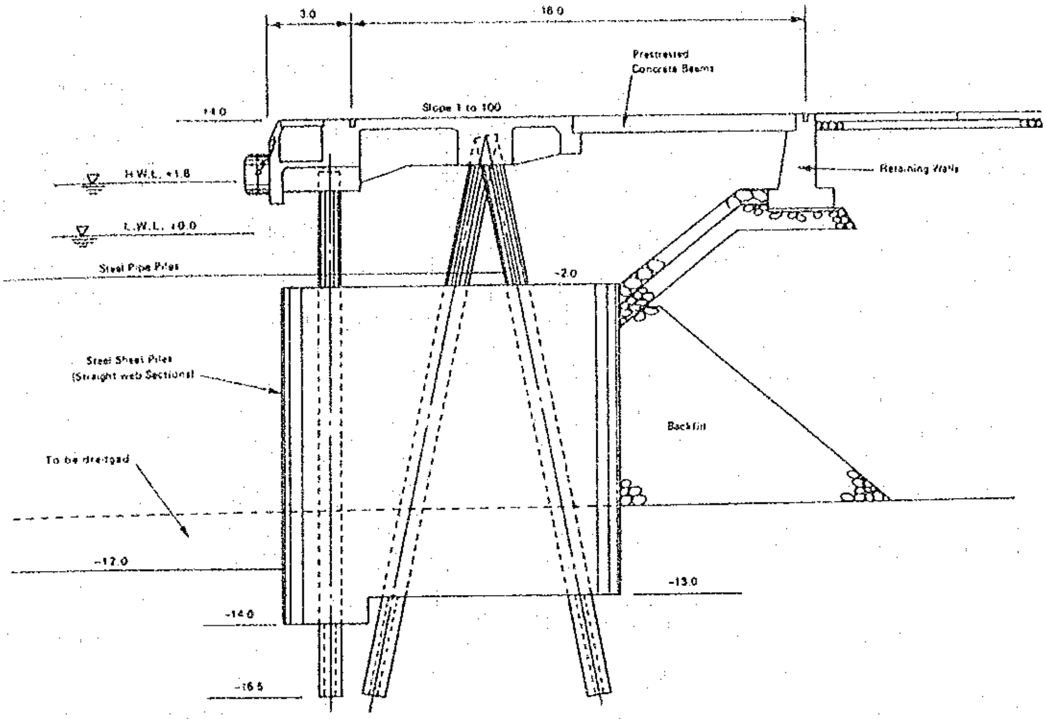
The berth structures must be protected from the berthing impact of ships. Rubber bumpers mounted on the cope face are recommended for all the proposed berths in the master plan. The size and number of the rubber bumpers is to be determined in the detailed design stage, but a large size tyre unit is tentatively proposed in this study because of its low price and local availability in Chile.

The front face of the berth has to provide ample space to recieve the rubber fenders and to cater to the objective size of ships. The top of the copeline should preferably cut away obliquely to minimize damages from the flared bows of larger size ships when ship berthing occasionally occurs at an angle to the copline.

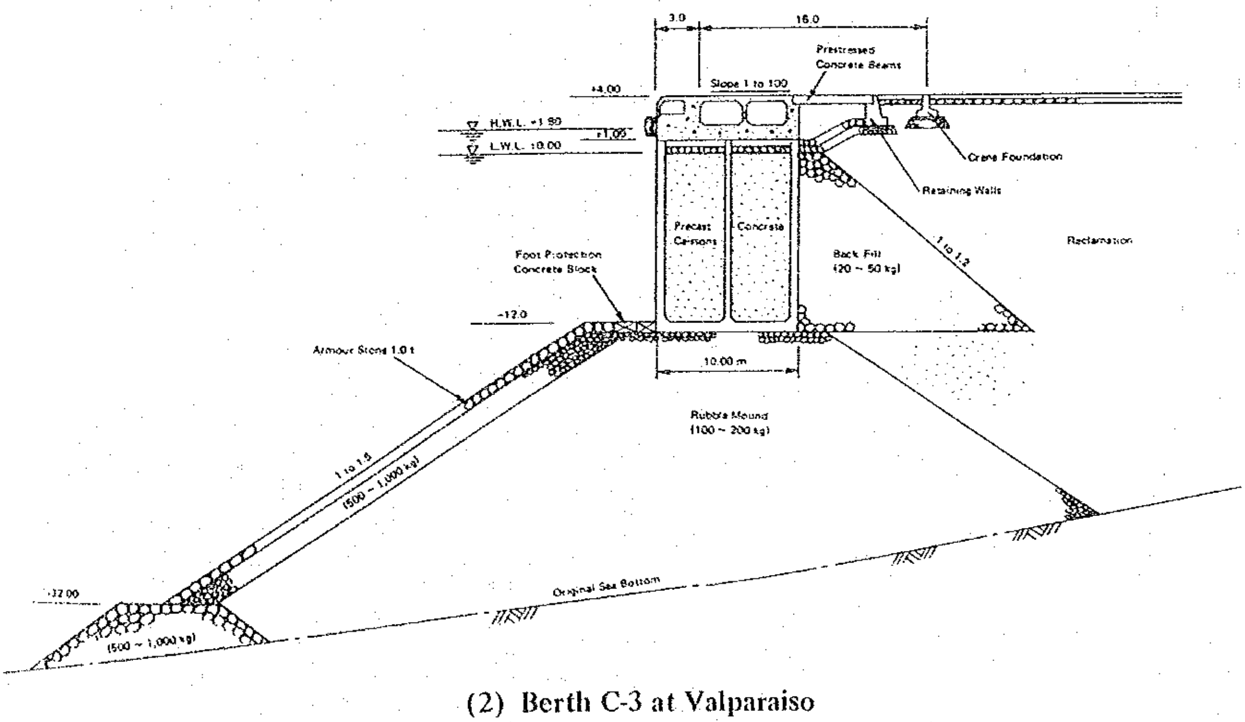
The berth apron surface should be about 1 in 60 to 1 in 100 slope to the front copeline for drainage. It is also recommended to provide corner curbs along the edge line of the berths.

6) Service Utilities

Service utilities ducts for potable water, high pressure fire fighting water and electric supply cable are provided along the front copeline of the berth decks. An allowance in duct sapce should preferably be provided for possible future provision of such other utility lines as bunkering fuel and telephone service to ships.

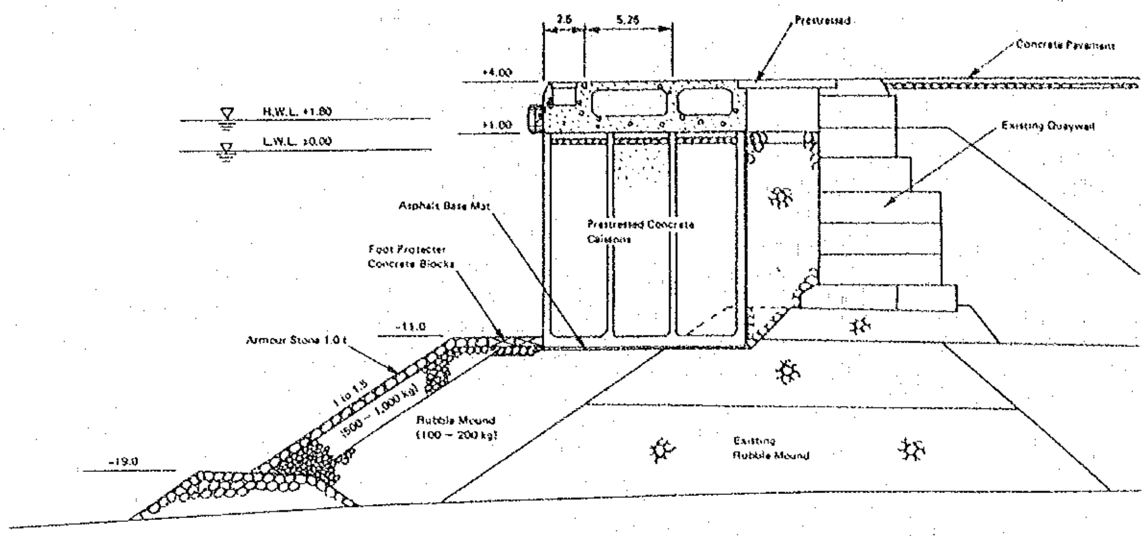


(1) Berths C-1 and C-2 at Valparaiso

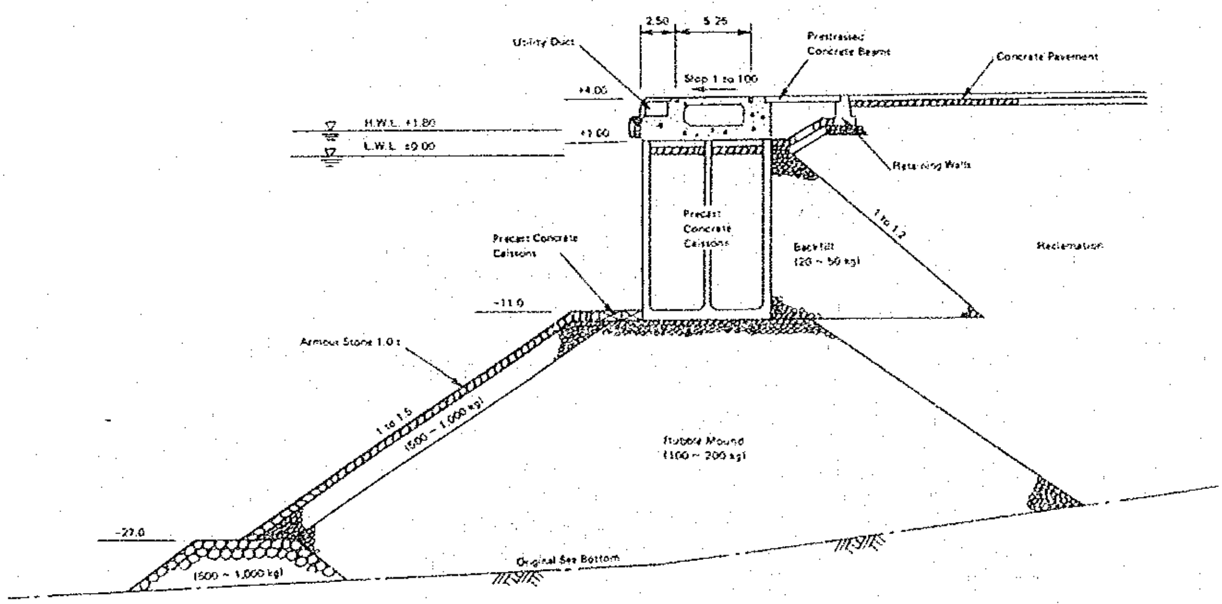


(2) Berth C-3 at Valparaiso

Fig. VIII-5-1 Proposed Designs of Berths at Valparaiso

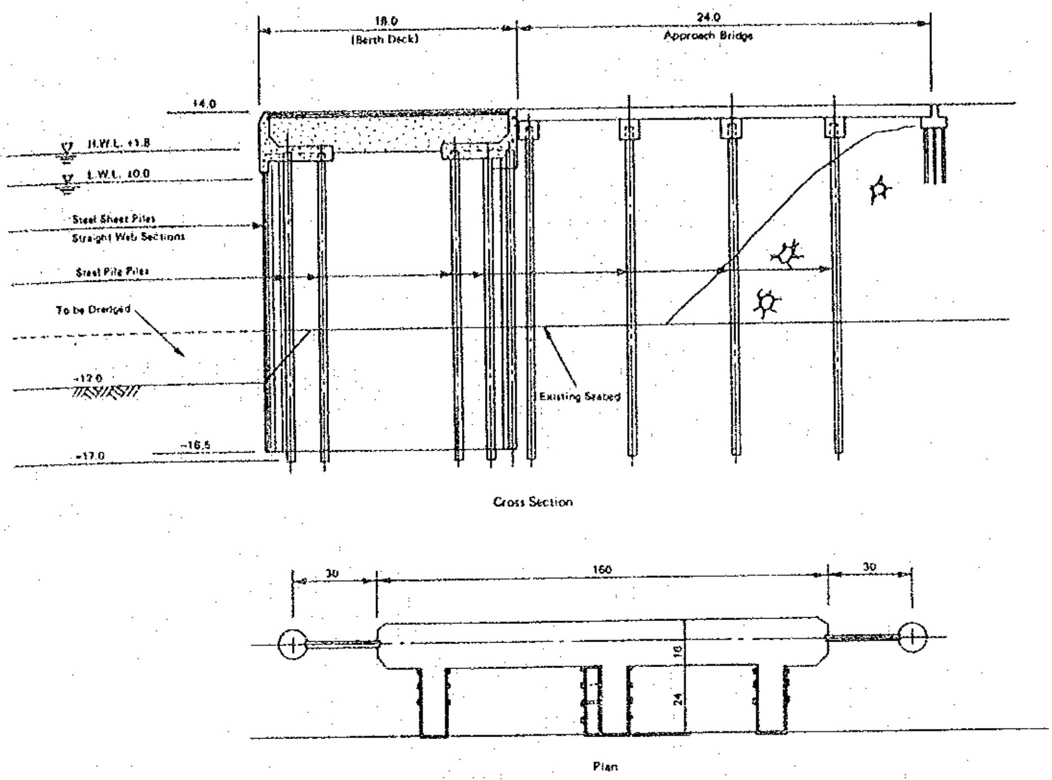


(3) Berth G-1 at Valparaiso

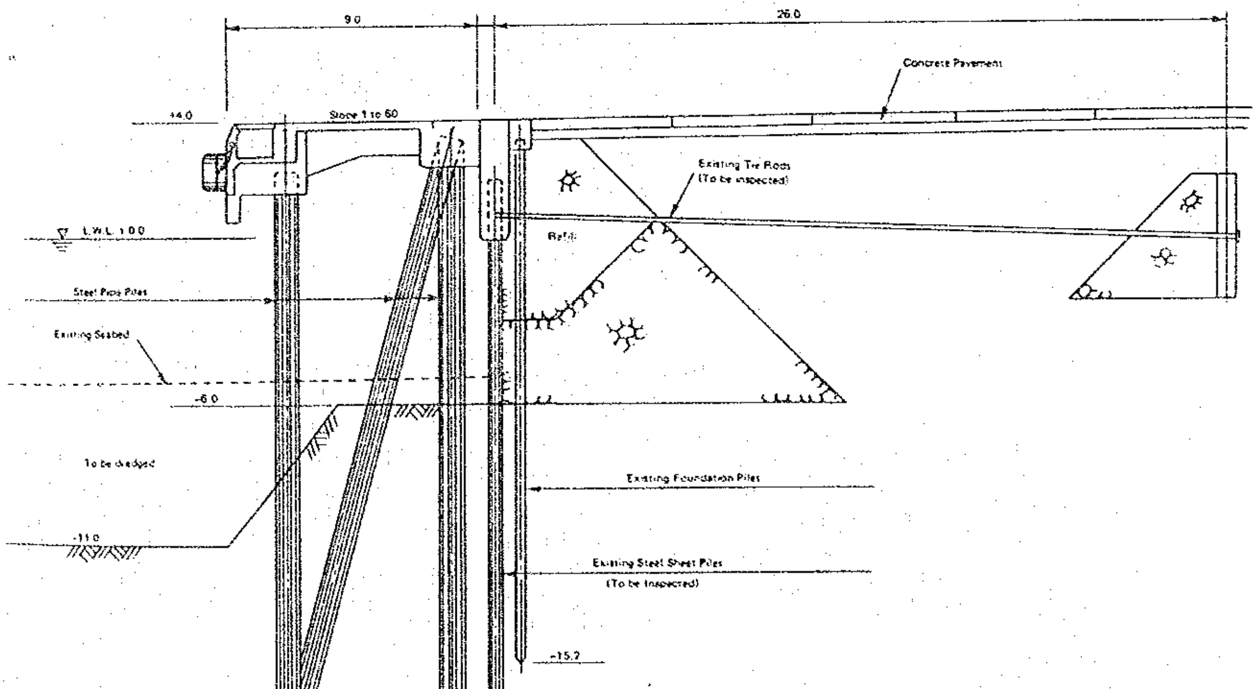


(4) Berths G-2 to G-5 at Valparaiso

Fig. VIII-5-1 Proposed Designs of Berths at Valparaiso

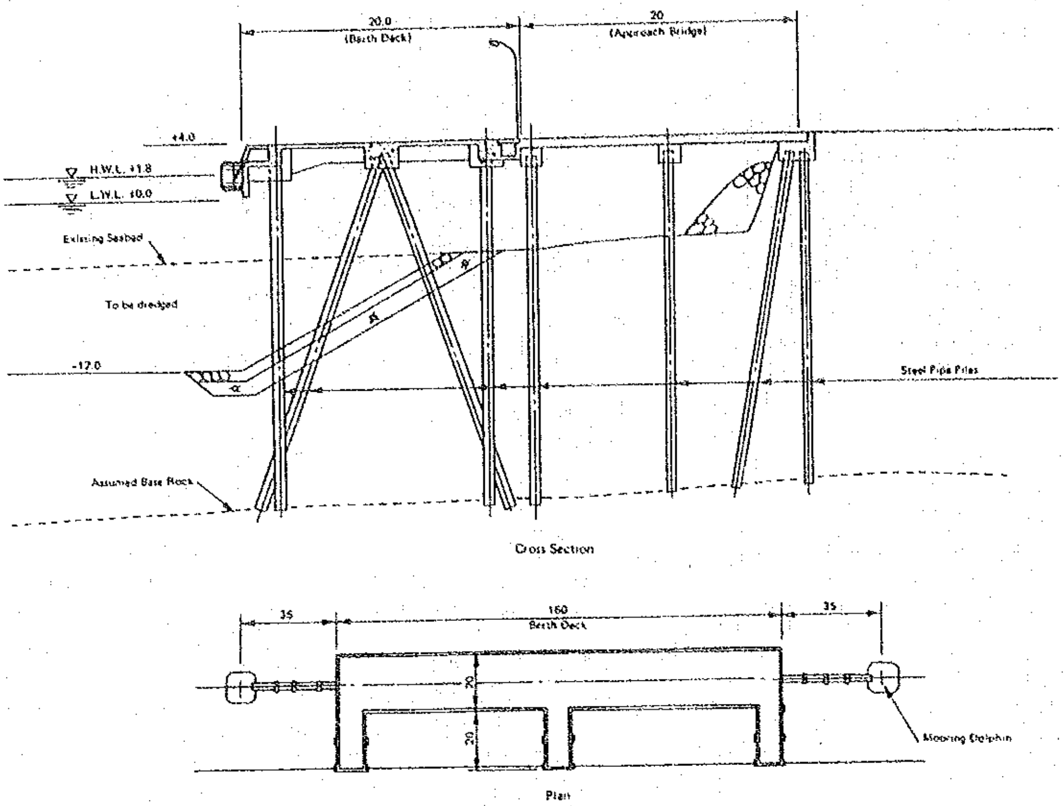


(1) Chemical Berth at San Antonio

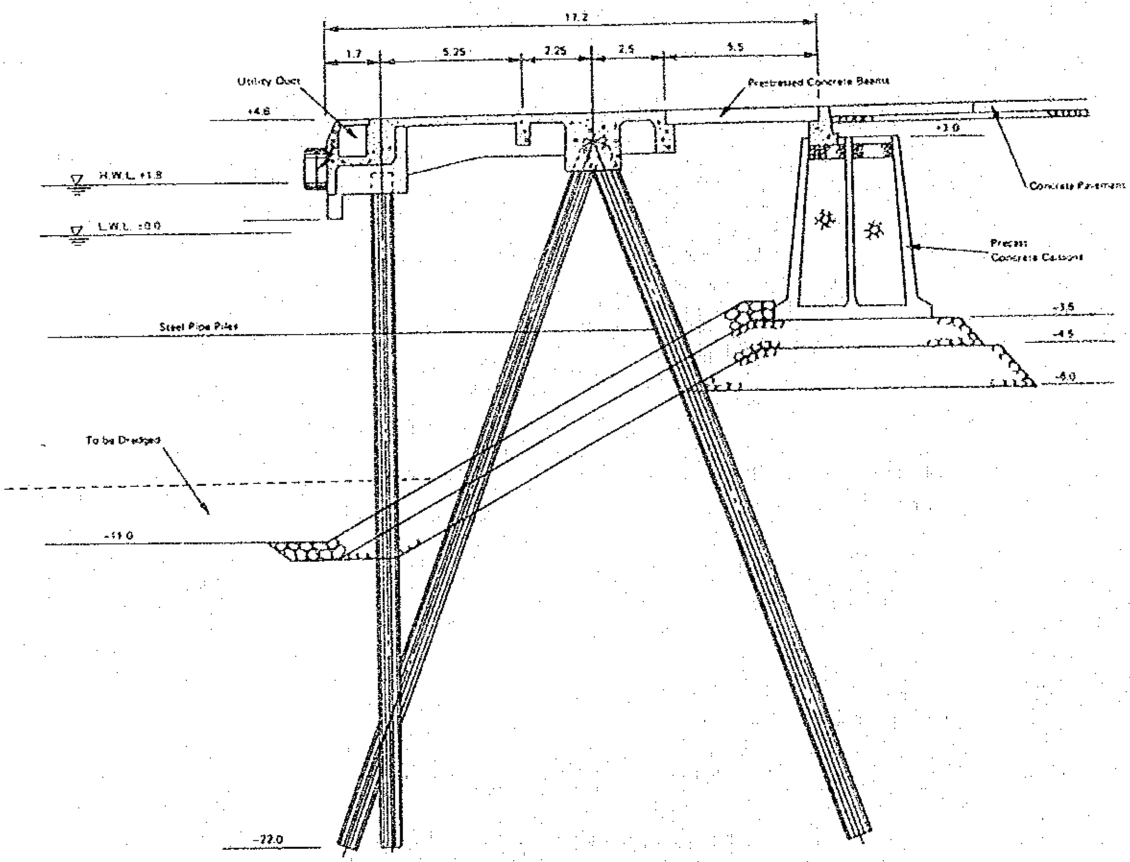


(2) Berth G-1 at San Antonio

Fig. VIII-5-2 Proposed Designs of Berths at San Antonio

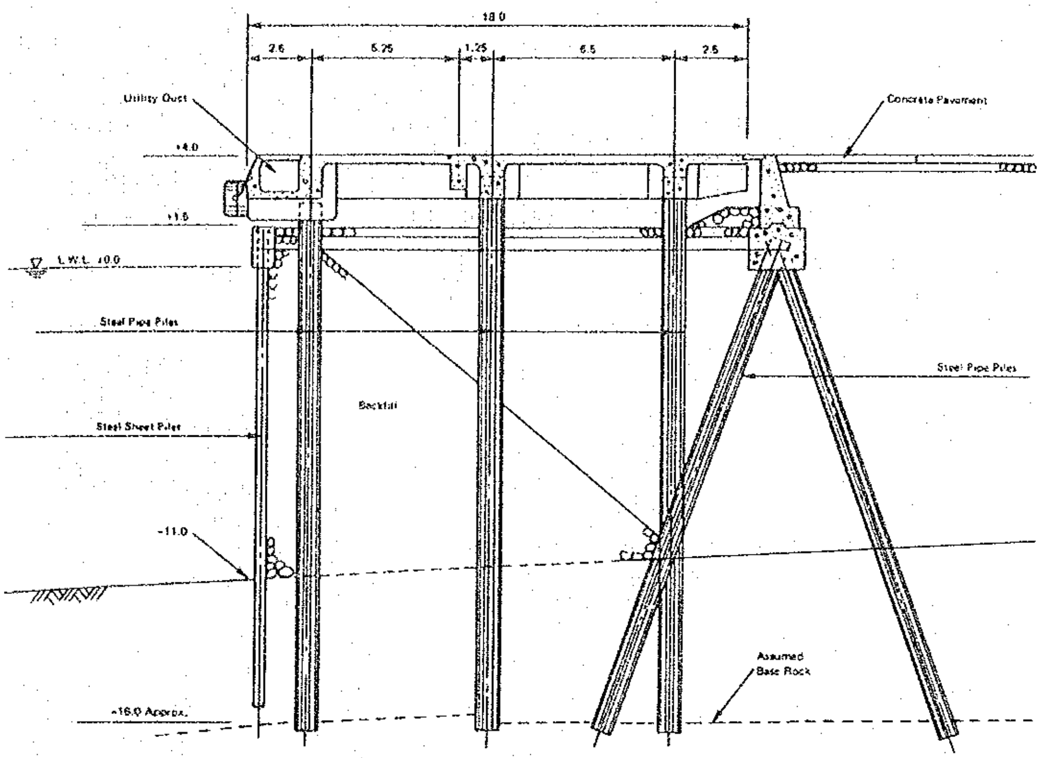


(3) Grain Berth at San Antonio



(4) Berths M-1 and G-2 at San Antonio

Fig. VIII-5-2 Proposed Designs of Berths at San Antonio



(5) Berths G-3 and G-4 at San Antonio

Fig. VIII-5-2 Proposed Designs of Berths at San Antonio

VIII-6 Cost Estimate and Time Schedule

(1) Cost Estimate for the Master Plan

1) Overall Project Cost

The cost estimate is made on the overall project of the master plan of the ports. The project cost include all the port civil works at the planned berths, the related on-land works and procurement of container cranes excluding other cargo handling equipment.

The overall project cost excluding price escalation is summarized in Table VIII-6-1 and VIII-6-2. The breakdowns of the project cost for the master plan into direct cost are shown in Table VIII-6-3 and VIII-6-4. The overall project cost for both Valpariso and San Antonio is estimated at $70.7 billion Chile pesos, as summarized below.

Port	Local Currency	Foreign Currency	Total Cost
Port of Valparaiso	24.1	25.9	50.0
Port of San Autonio	9.3	11.4	20.7
Total	33.4	37.3	70.7

in billion Chile pesos
(= $1,000,000,000)

The main cost items are divided into:

(i) Direct Cost for Construction and Procurement
(ii) Indirect Cost
(iii) Incorporation
(iv) Engineering Study and Construction Supervision
(v) Physical Contingency.

2) Conditions of Cost Estimation

This cost estimate is based on the following assumptions:

① Exchange Rate

- The prevailing rate of 1 US dollar = 180 Chile pesos as of 1985 is applied.
- The prevailing market prices as of 1985 are applied.

② Tax

- Materials and construction plants imported for this project are exempt from import duties and import sales tax.

- The value added portions by the contractor are exempt from duty.
- Incorporation tax of 2.5% of the contract total (=50% of net income assumed to be 5% of the contract total) is applied.

③ Indirect Costs

- Indirect costs of 30% for the construction and 12% for the procurement are assumed to cover all the costs for mobilization, demobilization, temporary works, insurance premiums, stamp duty, overhead, profit and other miscellanews expenses

④ Engineering Study and Construction Supervision

We have allowed a sum of 5% against the construction cost to cover feasibility study (=0.5%), detailed design study including field investigation (=2.o%), tender evaluation and construction supervision (=2.5%).

⑤ Contingency

15% of the construction cost and engineering studies is allocated to cover unknown physical factors. No allowance for price escalation is included.

⑥ Foreign and Local Currency Requirements

The cost of the project is estimated in foreign and local currency portions. The foreign currency component constitutes the cost for all import expenditures and the cost for use of locally available materials and equipment which include foreign currency exchange input for their production. Local currency expenditure includes wages for Chilean workers and all the locally produced materials and fuels, etc. which excludes the portion of the cost spent in foreign currency inputs for their production.

(2) Construction Time Schedule

The construction time schedule for the master plan is shown in Fig. VIII-6-1 in the form of a bar chart. Overall construction works for this development program are divided into 3 phases as shown the chart.

The high seismic resistant berths for general cargo berths G-1 at

Valparaiso and G-3 and G-4 at San Antonio are given first priority. So, they are scheduled to be constructed in the first phase of the construction.

Table VIII-6-1 Construction Cost of Master Plan at Valparaiso

(Unit: 1,000,000,000 pesos)

Description	Construction			Procurement			Total
	Local Currency	Foreign Currency	Sub-Total	Local Currency	Foreign Currency	Sub-Total	
I. Direct Cost	16.9	11.0	27.9	0.2	4.2	4.4	32.3
II. Indirect Cost including Miscellaneous, Expenses, for Site Works, Overhead and Profit. [30% of Construction (I) and 12% of Procurement (I)]	2.5	5.9	8.4	0.1	0.4	0.5	8.9
Sub Total (I + II)	19.4	16.9	36.3	0.3	4.6	4.9	41.2
III. Incorporation Tax. [2.5% of (I + II)]	0.5	0.4	0.9	0.0	0.1	0.1	1.0
Sub Total (I + II + III)	19.9	17.3	37.2	0.3	4.7	5.0	42.2
IV. Engineering Study including site survey, Construction Supervision [5% of Construction (I + II + III)]	0.8	1.1	1.9				1.9
Sub Total (I to IV)	20.7	18.4	39.1	0.3	4.7	5.0	44.1
V. Physical Contingency [15% of Construction (I to IV)]	3.1	2.8	5.9				5.9
Grand Total (I to V)	23.8	21.2	45.0	0.3	4.7	5.0	50.0

Table VIII-6-2 Construction Cost of Master Plan at San Antonio

(Unit: 1,000,000,000 pesos)

Description	Construction			Procurement			Total
	Local Currency	Foreign Currency	Sub-Total	Local Currency	Foreign Currency	Sub-Total	
I. Direct Cost	6.5	5.9	12.4	0.0	0.7	0.7	13.1
II. Indirect Cost including Miscellaneous, Expenses for Site Works, Overhead and Profit. [30% of Construction (I) and 12% of Procurement (I)]	1.1	2.6	3.7	0.0	0.1	0.1	3.8
Sub Total (I + II)	7.6	8.5	16.1	0.0	0.8	0.8	16.9
III. Incorporation Tax. [2.5% of (I + II)]	0.2	0.2	0.4	0.0	0.0	0.0	0.4
Sub Total (I + II + III)	7.8	8.7	16.5	0.0	0.8	0.8	17.3
IV. Engineering Study including site survey, Construction Supervision [5% of Construction (I + II + III)]	0.3	0.5	0.8				0.8
Sub Total (I + IV)	8.1	9.2	17.3	0.0	0.8	0.8	18.1
V. Physical Contingency [5% of Construction (I to IV)]	1.2	1.4	2.6				2.6
Grand Total (I to V)	9.3	10.6	19.9	0.0	0.8	0.8	20.7

Table VIII-6-3 Breakdown of Direct Cost for Master Plan at Valparaiso

(Cost: 1,000,000 pesos)

Description	Unit	Quantity	Unit Price (1,000 pesos)	Local Currency	Foreign Currency	Total Cost
(A) Construction						
(1) Container						
① Container Berth C-1, C-2				1,260	1,624	2,884
- Steel sheet pile cells	ton	3,960	252	(200	798	998)
- Steel pipe pile	piece	360	950	(68	274	342)
- Filling gravel for cells	m³	52,800	2.9	(107	46	153)
- Cover concrete for cells	m³	3,300	30	(69	30	99)
- Coping concrete	m³	9,900	55	(381	164	545)
- Approach deck	m³	2,880	55	(111	47	158)
- Back filling gravels and sands.	sum	1		(135	58	193)
- Concrete retaining wall	m	600	290	(122	52	174)
- Auxiliary facilities, miscellaneous materials	sum	1		(67	155	222)
② Container Berth C-3				1,643	1,203	2,846
- Concrete caisson	m	300	2,971	(446	445	891
- Rubble mound	m3	186,000	7.6	(848	566	1,414)
- Coping concrete	m3	5,880	45	(186	79	265)
- Back filling	m3	36,300	2.9	(73	32	105)
- Concrete retaining wall	m	300	174	(36	16	52)
- Approach deck	m³	840	55	(32	14	46)
- Auxiliary facilities, miscellaneous materials	sum	1		(22	51	73)
③ Yard pavement and utilities services	m²	229,000	13.3	2,132	914	3,046
④ Reclamation C-3	m³	1,020,000	2	1,428	612	2,040
⑤ Others				100	77	177
- Dredging in front of berth	m³	4,000	1	(3	1	4)
- Lighting Tower	piece	11	3,000	(13	20	33)
- Temporary embankment C-2	m	100	1,400	(84	56	140)
Sub total				6,563	4,430	10,993
(2) General Cargo						
① General Cargo Berth G-1 (High Seismic Resistant Berth)				847	686	1,533
- Concrete caisson	m	210	3,546	(373	372	745)
- Rubble mound	m³	40,110	10.5	(252	168	420)
- Coping concrete	m3	4,788	45	(150	65	215)
- Back filling	m3	12,390	2.9	(25	11	36)
- Approach deck	m3	588	55	(22	10	32)
- Auxiliary facilities, miscellaneous materials	sum	1		(25	60	85)
② General Cargo Berth G-2 ~ G-5	m			3,922	2,849	6,771
- Concrete caisson	m3	840	2,487	(1,045	1,044	2,089)
- Rubble mound	m3	430,980	7.5	(1,939	1,293	3,232)
- Coping concrete	m³	16,464	45	(519	222	741)
- Back filling	m	84,840	2.9	(172	74	246)
- Retaining wall	m3	840	169	(99	43	142)
- Approack deck		2,352	55	(90	39	129)
- Auxiliary facilities, miscellaneous materials	sum	1		(58	134	192)
③ Yard pavement and utilities services G-1 ~ G-5	m²	126,000	9.1	803	344	1,147
④ Reclamation	m³	2,200,000	2	3,080	1,320	4,400

(Cost: 1,000,000 pesos)

Description	Unit	Quantity	Unit Price (1,000 pesos)	Local Currency	Foreign Currency	Total Cost
⑤ Others				758	866	1,624
- Sheds (8,000m^2 x 3 sheds)	m^2	24,000	50	(516	684	1,200)
- Lighting Tower	piece	30	2,000	(24	36	60)
- Temporary embankment G-2 ~ G-3	m	260	1,400	(218	146	364)
Sub total				9,410	6,065	15,475
(3) Miscellaneous						
① Roads	m	3,000	200	420	180	600
② Improvement of Baron Pier				282	188	470
- Removal of existing slab.	m^2	6,380	14.3	(55	36	91)
- Improvement of slab and beam	m^2	6,380	59.4	(227	152	379)
③ Demolition works				246	164	410
- existing sheds	m^2	87,300	3.3	(173	115	288)
- existing pavement	m^2	122,000	1.	(73	49	122)
Sub total				948	582	1,480
Total - (A)				16,921	11,027	27,948
(B) Procurement						
(1) Container Crane						
① Container Crane	piece	6	730,000	180	4,200	4,380
Total - (B)				180	4,200	4,380
Grand total [(A) + (B)]				17,101	15,227	32,328

Table VIII-6-4 Breakdown of Direct Cost for Master Plan at San Antonio

(Cost: 1,000,000 pesos)

	Description	Unit	Quantity	Unit Price (1,000 pesos)	Local Currency	Foreign Currency	Total Cost
(A)	Construction						
(1)	Multipurpose Berth				558	642	1,200
	① Multipurpose Berth						
	- Steel pipe piles	piece	200	1,318	(53	211	264)
	- Concrete caisson	m	250	1,094	(137	137	274)
	- Rubble mound	m^3	13,825	10.4	(86	58	144)
	- Coping concrete	m^3	4,400	55	(169	73	242)
	- Back filling	m^3	8,125	2.9	(17	7	24)
	- Concrete retaining wall	m	250	50	(9	4	13)
	- Approach deck	m^3	700	55	(27	12	39)
	- Auxiliary facilities, miscellaneous materials	sum	1		(60	140	200)
	② Yard pavement and utilities services	m^2	62,500	13.3	582	249	831)
	③ Lighting Tower	piece	6	3,000	7	11	18
	Sub total				1,147	902	2,049
(2)	General Cargo Berth, Others						
	① General Cargo Berth G-1				316	464	780
	- Steel pipe pile	piece	196	1,209	(47	190	237)
	- Coping concrete	m^3	3,150	55	(121	52	173)
	- Removal of existing pavement and repair	m^2	8,400	9.8	(49	33	82)
	- Connecting of existing quaywall	sum	1		(22	9	31)
	- Auxiliary facilities, miscellaneous materials	sum	1		(77	180	257)
	② General Cargo Berth G-2				470	538	1,008
	- Steel pipe piles	piece	168	1,318	(44	177	221)
	- Concrete caisson	m	210	1,094	(115	115	230)
	- Rubble mound	m^3	11,610	10.4	(73	48	121)
	- Coping concrete	m^3	3,700	55	(143	61	204)
	- Back filling	m^3	6,825	2.9	(14	6	20)
	- Concret retaining wall	m	210	50	(8	3	11)
	- Approach deck	m^3	588	55	(22	10	32)
	- Auxiliary facilities, miscellaneous materials	sum	1		(51	118	169)
	③ General Cargo Berth G-3 ~ G-4 (High Seismic Resistant Berth)				932	1,145	2,077
	- Steel sheet pile	ton	1,302	211	(55	220	275)
	- Steel pipe pile	piece	798	834	(133	532	665)
	- Backfilling gravels and sands	m	420	604	(178	76	254)
	- Coping concrete	m^3	14,322	53	(531	228	759)
	- Auxiliary facilities, miscellaneous materials	sum	1		(35	89	124)
	④ Chemical Berth				338	651	989
	- Steel sheet pile cells	ton	1,850	265	(98	392	490)
	- Steel pipe pile	piece	220	795	(32	128	160)
	- Filling gravel for cells	m^3	33,242	2.9	(67	29	96)
	- Coping concrete	m^3	2,665	45	(84	36	120)
	- P.C. slab	m^3	470	55	(18	8	26)
	- Concrete pavement for cells	m^3	2,620	9.1	(17	7	24)
	- Auxiliary facilities, miscellaneous materials	sum	1		(22	51	73)

(Cost: 1,000,000 pesos)

Description	Unit	Quantity	Unit Price (1,000 pesos)	Currency	Currency	Total Cost
⑤ Grain Berth				398	615	1,013
- Steel pipe pile	piece	364	1,407	(102	410	512)
- Coping concrete	m^3	5,000	55	(193	82	275)
- P.C. slab, P.C. beam	m^3	590	55	(22	10	32)
- Rubble mound	m^3	7,480	10.2	(46	30	76)
- Auxiliary facilities, miscellaneous materials	sum	1		(35	83	118)
⑥ Yard pavement and utilities services	m^2	125,000	9.1	797	341	1,138
⑦ Dredging and Reclamation				788	337	1,125
- Dredging and Reclamation (G-3 ~ G-4)	m^3	750,000	1	(525	225	750)
- Dredging (Slip)	m^3	750,000	0.5	(263	112	375)
⑧ Others				815	744	1,559
- Sheds (6,500m^2 x 2 sheds)	m^2	13,000	50	(260	390	650)
- Revetment (G-2, G-3, G-4)	m	250	1,372	(206	137	343)
- Lighting Tower	piece	36	2,000	(29	43	72)
- Sand Compaction (G-3, G-4)	m^2	12,600	15	(132	57	189)
- Inspection of sheet piles, tierods and anchorwall (G-1)	sum	1		(35	15	50)
- Removal of existing inner breakwater (G-4)	m	150	1,000	(90	60	150)
- Temporary embankment (G-3)	m	150	700	(63	42	105)
Sub total				4,854	4,835	9,689
(3) Miscellaneous						
① Roads	m	2,750	200	385	165	550
② Demolition works				56	38	94
- existing sheds	m^2	1,280	3.3	(2	2	4)
- existing pavement	m^2	90,000	1	(54	36	90)
Sub total				441	203	644
Total - (A)				6,442	5,940	12,382
(B) Procurement						
(1) Container Crane						
① Container Crane	piece	1	730,000	30	700	730
(2) Navigation						
① Navigation	sum	1		0	11	11
Total - (B)				30	711	741
Grand total [(A) + (B)]				6,472	6,651	13,123

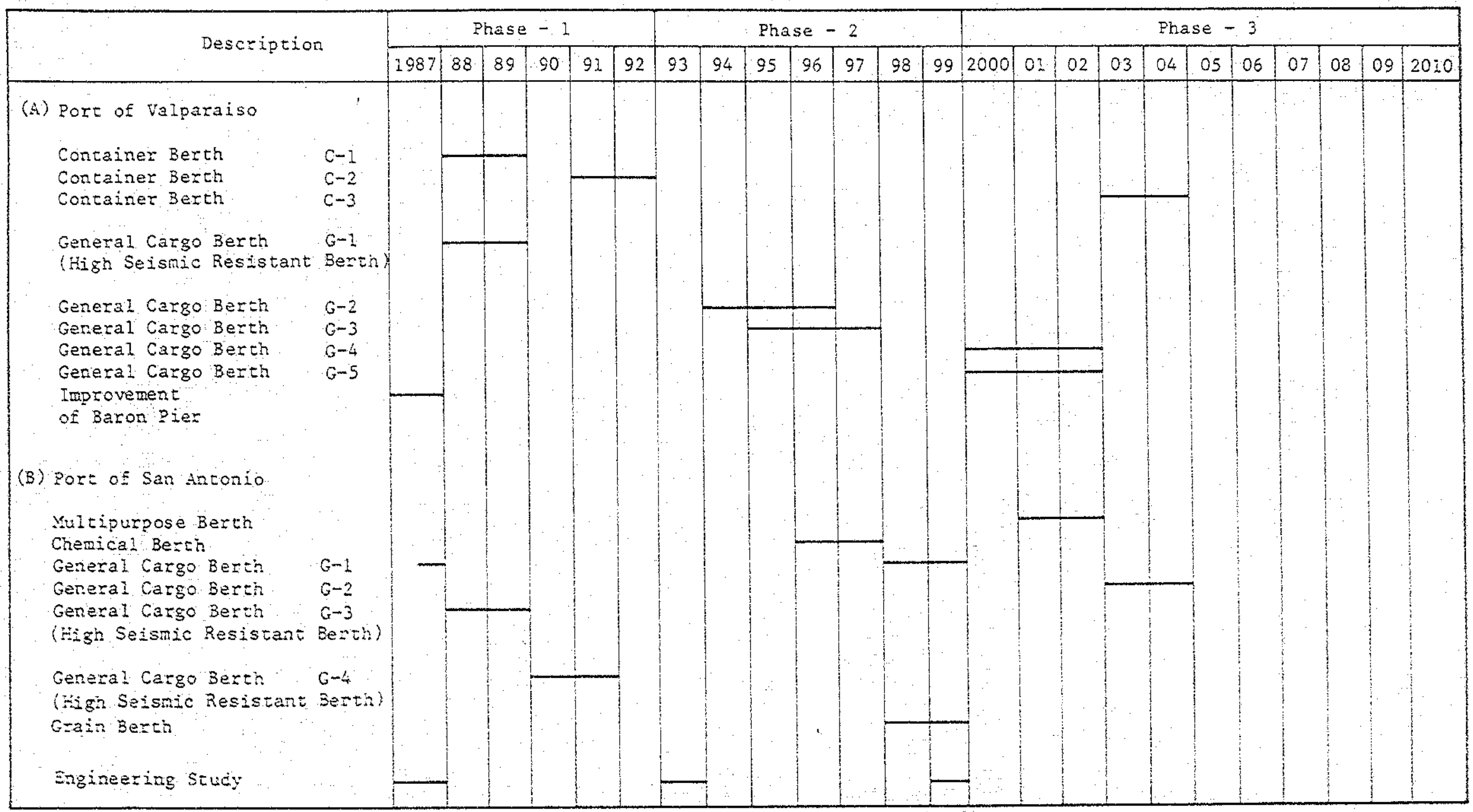


Fig. VIII-6-1 Construction Schedule for the Master Plan

CHAPTER IX IMMEDIATE RESTORATION PLAN

CHAPTER IX IMMEDIATE RESTORATION PLAN

IX-1 Identification of Port Facilities

(1) General

The immediate restoration planning fundamentally depends upon technical considerations based on the results of the survey on the extent of damages and the stability investigation of the existing quaywall structures. The immediate measures for restoration also have to be determined from the economic viewpoint to obtain efficient utilization of the existing facilities at the least cost, taking into account both the needs for immediate restoration and the economic situation of Chile.

Furthermore, the overall future development of the ports will serve as a guideline in determining the immediate measures for restoration. Practical measures for immediate implementation will be taken without spoiling the future possibility of port development. In this connection, some of urgent repairs are already taking place under the direction of the Government of Chile. These ongoing repairs should be reviewed from the viewpoint of the comprehensive future port development.

(2) Review of Immediate Measures by the Government of Chile

The overall program of the immediate measures already contracted and being carried out at present is summarized as follows.

1. Project Financed by the World Bank		
1) The port of Valparaiso (work items are summarized in Table IX-1-1)		$222,900,000
2) The port of San Antonio (work items are summarized in Table IX-1-2)		$261,140,000
3) Dredgers		$145,000,000
4) Procurement of 2-Locomotives		$333,500,000
	Sub total	$962,540,000
2. Project Financed by Emporchi		
1) Procurement of Microcomputers		$1,350,000
2) Recreation Center		$4,610,000
3) Protection for Berth 4 at Valparaiso		$23,090,000
	Sub total	$29,050,000
	Total	$991,590,000
		(Chilean Pesos)

The overall cost of the work is 991,590,000 pesos for both Valparaiso and San Antonio, of which 962,540,000 pesos are financed by loans from the World Bank. The work programme covered by the World Bank loans constitutes 29 work items for the port of Valparaiso and 25 work items for San Antonio excluding dredgers and procurement of locomotives. These work items for the ports of Valparaiso and San Antonio are summarized in Table IX-1-1 and IX-1-2 respectively.

Table IX-1-1 Restoration Works ongoing or planned by the Chilean Government (The Port of Valparaiso)

Berth N°	1	2	3	4	5	6	7	8	9	10	Breakwater
Repair of quaywalls											-
Repair of aprons/yards	o			o	o	o	o	o			-
Repair of wharf cranes		o		o		o	o	o			-
Repair of crane railings and railway tracks				o	o						-
Repair of sheds/ warehouses											-
Repair of Breakwater	-	-	-	-	-	-	-	-	-	-	o
Repair of Utilities	o	o			o	o	o	o			-
Investigation of damages	o			o	o	o	o	o	o	o	o

Key

o : Measures ongoing or planned

- : No facilities

Table IX-1-2 Restoration Works ongoing or planned by the Chilean Government (The Port of San Antonio)

Berth N°	1	2	3	4	5	6	7	Breakwater
Repair of quaywalls								-
Repair of aprons/yards				o	o	o	o	-
Repair of wharf cranes	o	o				o	o	-
Repair of crane railings and railway tracks						o	o	-
Repair of sheds/warehouses	-	o	-	-	-		-	-
Repair of breakwater	-	-	-	-	-	-	-	o
Repair of utilities		o		o	o	o	o	-
Investigation of damages	o	o		o	o	o	o	o

Key

o : Measures ongoing or planned

- : No facility

The work items covered by the program are more or less minor and are basically related to repairing back-of-port facilities in addition to conducting a field investigation of the damages at the port.

It is appropriate that the above measures have already been initiated by the Government of Chile. The work items appear to be minimal but essential to recover the former capacity of the ports as soon as possible. The measures planned by the Government of Chile are practically necessary to respond to the traffic demand at the ports.

However, the implementation of these measures should take place in close cooperation with the framework of the immediate restoration and future development programs proposed in this study.

(3) Immediate Restoration Plan

The overall plan of the immediate measures necessary for restoration is tabulated in Tables IX-1-3 and IX-1-4. The measures for restoration by berth are classified as following:

- Berths subject to the master plan (marked "A").

- Berths to be immediately restored as before for utilization provisionally or on a long-term basis (marked "B").

1) Berth Facilities

The restoration measures for the berths classified as "A", that is berths 1, 2, 8, 9 and 10 at Valparaiso and 1, 2, 3, 6 and 7 at San Antonio should be reviewed as part of future development plans. This is necessary to ensure efficient investment in the future.

The immediate measures for restoration of berths 3 to 7 at Valparaiso and berths 4 and 5 at San Antonio, which are classified as "B", are closely related to the future development.

2) Wharf Cranes and Other Facilities

The existing wharf cranes seem stable and there is a general concept to make full use of the existing equipment as much as possible. Therefore, there is no objection in principle to continuous use of the existing wharf cranes over a short span of time.

The total capacity of the existing wharf cranes is sufficient without the use of ship gear to handle the commodity throughput for several years to come.

However, all the cranes were exposed to extreme stress in their structural elements during the earthquake. Especially, the cranes at berths 6 to 8 at Valparaiso should be inspected throughly before full use, and should be maintained periodically with close observation.

The permissible tolerance for rail deformation is generally 1/300 to 1/500 in inclination both horizontally and vertically. These figures may be reluctantly reduced to 1/200 for practical use for immediate restoration measures. The rails, especially those at berths 6 to 8 at Valparaiso, must be readjusted to the appropriate alignment and level.

Table IX-1-3 Immediate Restoration Plan for The Port of Valparaiso

Berth N°		1	2	3	4	5	6	7	8	9	10
Berth Length (m)		175	175	260	200	165	245	120	240	220	205
Type of Structure		Gravity type (concrete blocks)	Gravity type (concrete blocks)	Gravity type (concrete blocks)	Gravity type Open type Compound type	Gravity type (concrete blocks)	Gravity type (concrete blocks)	Gravity type (caisson)	Gravity type (concrete blocks)	Open type	Open type
Immediate Restoration Measures	Berth classification	A	A	B	B	B	B	B	A	A	A
	Quaywall	Y	Y	××	××	××	××	××	××	Y	Y
	Berth Apron	Y	Y	××	××	××	××	××	××	Y	Y
	Crane Rail and Railway Track	Y	Y	××	××	××	××	××	××	Y	Y
	Back of Port yard and facilities	Y	Y	×	×	×	–	–	–	–	–
	Warehouses	Y	Y	Y	–	–	Y	Y	Y	–	–
	Roads	×	×	×	×	×	×	×	×	–	–

Note 1: For berth classification

A: Subject to Master Plan

B: To be restored as before

Note 2: –: No facilities

Y: No measures needed

××: Measures needed

×: Measures to be implemented by the Government of Chile

Table IX-1-4 Immediate Restoration Plan for The Port of San Antonio

Berth N°		1	2	3	4	5	6	7
Berth Length (m)		452		200	383		200	120
Type of Structure		Gravity (concrete blocks)	Gravity (concrete blocks)	Steel Sheet pile type	Steel Sheet pile type	Open type	Open type	Open type
Immediate Restoration Measures	Berth classification	A	A	A	B	B	A	A
	Quaywall	Y	Y	××	××	××	Y	Y
	Berth Apron	Y	Y	××	××	××	Y	Y
	Crane Rail and Railway track at Berth apron	Y	Y	××	××	××	Y	Y
	Back of Port yard and facilities	Y	Y	×	×	×	×	×
	Warehouses	Y	Y	–	–	–	Y	–
	Roads	–	–	×	×	×	Y	Y

Note (1)

A: subject to Master Plan

B: to be restored as before

Note (2)

×× : measures needed

× : measures to be implemented by the Government of Chile

Y : no measures needed

– : no facilities

IX-2 Immediate Measures

(1) The Port of Valparaiso

The restoration measures largely depend upon the extent of damages due to the earthquake and the structural problems which intensify the damages. These damages and structural problems should be remedied as much as possible for safe berthing and normal cargo handling operation at the berth apron.

Table IX-2-2 is a summary of the present conditions of the berths and the selected measures to restore the damages or repir the structural problems of different sections of the wharves. Table XI-2-3 summarizes the measures to be implemented at each of the berths, as outlined below.

① Copeline Deformation and Displacement of Quaywall Elements

Fundamental restoration to adjust copeline alignment and displacement of quaywalls is costly. Berths 5 and 6 are closely related to the future port development. Berth 5 is not efficiently utilized due to insufficient water depth. These berths should be temporarily restored for short-term use through minor works. No measures are needed to restore berth 4 as the deformation is not critical.

② Gaps between Concrete Blocks

Measures are determined by the extent and nature of the gaps. Table IX-2-1 shows the comparison of measures to be considered to repair the gaps as part of the immediate restoration.

All the measures except for filling by stones (measure D) are to be adopted, depending upon the extent of the openings and the loss of backfill materials. Basically, measure A is adopted for wider gaps at berths 6 and 7 and measures B and C for smaller gaps at berths 3 to 6.

③ Deterioration or Aging of Concrete Materials

The deterioration of concrete blocks used at gravity type quaywall berths (Nos. 1 to 8) is minimal and is not considered absolutely necessary to compensate for the loss of backfill materials. The deterioration of the concrete materials of the superstructure of Baron pier is quite severe, and appropriate measures should be considered as part of the future development planning of the port.

Table IX-2-1 Comparison of Measures to fill in gaps

Measures / Item	A	B	C	D
	Concrete pouring	Bagged concrete fill	Cement paste with clay	Fill by stones
Adaptability	wide gap	10 ∿ 30cm gap	gap less 10cm	gap 10 ∿ 50cm
Efficiency	good	good	not reliable in the long term	not reliable in the long term
Economy	costly	moderate	costly	moderate
Recommendation	wider gaps more than 20cm and the portion subjected to heavy loss of backfill	gap having width of 10 ∿ 20cm	gap having width of less than 10cm	not recommended

④ Pavement of Berth Aprons

In principle, the heavily damaged berth (No. 7) should be repaired using concrete pavement while the less damaged berths (Nos. 3 to 6) should be overlaid with bituminuous materials. It is also recommended that measures at berths Nos. 4 - 6 which are related to the future development plan be executed as economically and practically as possible. Fundamental restoration measures for the concave in the backfill area immediately behind the quaywalls must completely preclude the loss of materials through the quaywalls. Possible measures include the use of sand-proof sheets or the filling of gaps in the quaywalls. Since these fundamental measures are costly, refilling and compaction are adopted to correct the concave in the backfiled areas.

⑤ Repair of Rails

Only the heavily damaged portions of the rails at berths No.4 to 7 will be repaired to normalize operations.

It should be noted that these restoration meaasures are only a temporary treatment to preclude problems for the time being. Furthermore, these measures are subject to various later studies and the detailed design work

Table IX-2-2 Structural Problems and Selection of Measures at Valparaiso

Portion of Berth	Present Conditions	Structural Problems for usage	Selected Measures
Quaywalls	Copeline tilting to seawards	∘ difficulty in safe berthing ∘ reduction of stability	∘ Providing Docking Fenders ∘ Structural modification to adjust copeline alignment
	Horizontal sliding or rotation of quaywall elements	Ditto	∘ Providing Docking Fenders ∘ Re-installation of quaywall element ∘ Breaking buldged portion of concrete
	Gap between quaywall elements	∘ loss of backfilled materials	∘ Packing the gap with new materials ∘ Re-installation of quaywall element ∘ Casting New Concrete in front of berths
	Aging or deterioration of quaywall elements at berths 1 to 8	∘ widening the gap between blocks	∘ Replacing elements ∘ Packing the gaps with new materials
Base Mounds	Scouring the surface	∘ tilting of quaywall ∘ reduction of stability	∘ Reforming the base mound
Apron Pavement	∘ Subsidence and cracks in paving concrete ∘ concave in backfilled areas	∘ difficulty in cargo handling operations ∘ subsidence	∘ Overlaying ∘ Patching up cracks ∘ re-pavement ∘ compaction of backfills
Crane Rails and Railway Tracks	deformation	∘ difficulty in travelling ∘ disconnection between berths	∘ adjustment of rail foundation ∘ re-setting the rails

Table IX-2-3 Restoration Measures for Valparaiso

Damages or Structural Problems	Restoration Measures	Berth 1, 2	3	4	5	6	7	8	9, 10
Copeline Deformation	Providing Docking Fenders	Subject to Master Plan	×	×	○	○	×	Rehabilitation measure	Subject to Master Plan
	Structural Modification				–	–			
Sliding or Rotation of quaywall elements	Providing Docking Fender		○			○			
	Reinstalling of blocks		–	–	×	–	×		
	Breaking bulged portions		○			○			
Gap between quaywall elements	Pouring concrete		–	–	–	○	○		
	Filling with bagged concrete		○	○	○	○	–		
	Filling with cement paste and with clay		○	○	○	○	–		
	Filling with stones		–	–	–	–	–		
Deterioration or Aging of concrete elements	Replacing materials		–	–	–	–	×		
	Packing the gaps								
Base Mound	reforming		×	×	×	×	○		
Settlement of Pavement	Overlaying with Asphalt		○	○	○	○	–		
	Re-paving		–	–	–	–	○		
	Filling and Compacting		–	–	–	–	○		
Railway Track Deformation	Resetting the rails		○	○	○	○	–		
Crane Track Deformation	Resetting the rails		○	○	–	○	○		

× : no problem or minor
– : no measures
○ : measures to be provided

prior to the implementation of the immediate restoration plan. Again, it is important to note that these measures are not designed to restore the port facilities on a permanent basis.

(2) The Port of San Antonio

The damage items and restoration measures at San Antonio are presented in Table IX-2-4. Table IX-2-5 is a summary of the immediate restoration measures by berth. The selection of immediate measures for restoration is carried out considering the following:

① Berths 1 and 2 which were completely destoryed and berths 6 and 7 which suffered fundamental structural damage require costly restoation measures. Restoration of these berths should therefore be reviewed in the framework of the future port development plan.

② The main structural problem at berth 4 is the deterioration and damage to the front walls of the steel sheet piles. This can be corrected by adopting the following measures.

- Openings along vertical joints: underwater welding
- Holes on the surface : underwater welding
- Loss of concrete blocks : Fill using bagged concrete

③ Repair of the pavement at Berth 4 is not absolutely necessary as the settlement is relatively minor. Also, cathodic protection is not included in the plan. For long-term use, the berth should be rehabilitated in the future because of the inadequate seismic resistance of anchoring.

④ Necessary measures at berth 5 are the urgent restoration of the retaining walls and pavement immediately behind the open type structure. Possible measures to repair the retaining walls include:

(a) Re-installation of the existing retaining walls
(b) Replacement with a new approach slab to be founded on a newly constructed base behind the existing walls.

Plan (b) is preferable. The measure should also be expected to minimize the active earth pressure working on the existing walls.

We must emphasize once again that the restoration measures recommended above do not improve the structural resistance of the berths against earthquake vibrations. Particular attention must be paid to the utilization of the berths in the scope of the immediate restoration plan. The general procedure for implementation of the plan requires detailed engineering studies to finalize the design work of the immediate restoration measures.

Table IX-2-4 Structural Problems and Selection of Measures at San Antonio

Portion of Berth	Present Conditions	Structural Problems	Selection of Measures
Quaywalls	Copeline tilting seawards	∘ difficulty in safe berthing ∘ reduction of stability	∘ Provision of Docking Fender ∘ Structural modification to adjust copeline alignment
	Damages to steel sheet Piles	∘ reduction of stability ∘ loss of backfill	∘ Welding of damaged portions
	Steel corrosion	∘ reduction of structural strength	∘ Rehabilitation of overall structure ∘ Provision of corrosion protection
	Deformation of retaining walls	∘ reduction of stability	∘ Replacement of walls ∘ Structural modification
	Settlement of approach to jetty at berth 5	∘ hindering cargo handling operations ∘ collapse of approach slab	Ditto
	Deterioration of concrete	∘ intensification of deterioration ∘ reduction of strength	∘ Overall rehabilitation
Pavement	Settlement and cracks	∘ difficulty in cargo handling	∘ Overlaying ∘ Patching up the cracks ∘ Re-pavement
Crane Rails and Railway Tracks	Deformation	∘ difficulty in travelling ∘ disconnection between berths	∘ Adjustment of rail foundation ∘ Re-set the rails
Others	Liquefaction	∘ intensify damages during earthquake	∘ Soil improvement ∘ Structural reinforcement

Table IX-2-5 Restoration Measures for San Antonio

Damages, Problems	Measures	Berth 1	Berth 2	Berth 3	Berth 4	Berth 5	Berth 6, 7	
Bulging of Copeline	∘ Provide Docking Fenders ∘ Structural Modification	Subject to Master Plan	Subject to Master Plan	Subject to Master Plan	×	×	Subject to Master Plan	Berth 1, 2 are completely collapsed.
Deformation of quaywall elements	∘ Reinstallation of blocks ∘ Provide Docking Fenders ∘ Breaking the bulged portions				—	—		
	∘ Structural Modification				—	○		
Deterioration of Steel Sheet piles and H-piles	∘ Structural Modification				—	×		
	∘ Repair of the deteriorated portions by welding steel				○	×		
	Fill by bagged concrete				○	×		
Corrosion of Steel Materials	∘ Overall Rehabilitation				—	×		
	∘ Corrosion Protection				—	×		
Concrete Aging	∘ Replacing all materials ∘ Replacing deteriorated portions				—	×		
Settlement or Cracks in Pavement	∘ Repavement (Concrete)				—	—		yard only
	∘ Overlay (Asphalt)				○	○		
	∘ Filling and Compaction of paving base				○	○		

× : no problems or minor

— : no measures

○ : measures to be provided

IX-3 Construction Program

(1) Basis for Construction and Cost Estimates

The major conditions for construction and cost estimates are summarized as follows. These conditions are commonly applicable to the immediate restoration plans for both Valparaiso and San Antonio.

① Exchange Rate: 1 US$ dollar = 180 Chile pesos as of 1985

② Prices: based on the prevailing market prices as of 1985

③ Taxation
- Exempt from import duties and import sales Tax
- Tax exempt from sales tax (IVA) for the value added portion by the contractor
- incorporation tax of 2.5% of the contract total (=50% of the net income, assumed 5% of the contract total) is imposed on businesses to involved in the Government projects.

④ Indirect Cost: 30% against the direct cost of construction to cover mobilization, demobilization, temporary works, insurance, stump duty, overhead and profit, etc.

⑤ Engineering Fee: 5% against the contract total for engineering study and construction supervision.

⑥ Contingencies: 15% for unknown physical factors but no allowance for price escalation.

(2) Cost Estimates

The cost estimates are made on the overall project cost for the immediate restoration Plan.

The overall project cost excluding price escalation is summarized in Tables IX-3-1 and IX-3-2. The breakdowns of the project cost into the direct costs for restoration measures by port are shown in Tables IX-3-3 and IX-3-4. It is estimated that the overall project cost for both Valparaiso and San Antonio is $348 Million Chile pesos.

This overall project cost is outlined below:

(Unit: Million Pesos)

	Local Currency	Foreign Currency	Total
The Port of Valparaiso	112	108	220
The Port of San Antonio	76	52	128
Total	188	160	348

(3) Construction Time Schedule

The construction time schedule by berth is shown in Fig. IX-3-1 in the form of a bar chart. By this schedule, the important milestones are:

Completion of restoration measures at Valparaiso
----- 10 months from the notice to proceed

Completion of restoration measures at San Antonio
----- 8 months from the notice to proceed

Also shown in the time schedule is the number of berths available during the construction period.

Table IX-3-1 Construction Cost of Immediate Restoration Plan at Valparaiso

(Unit: Million Pesos)

Description		Local Currency	Foreign Currency	Total Cost
I. Direct cost	See breakdown	77	60	137
II. Indirect Cost including Miscellaneous Expenses at Work Site, Overhead and profit	(I × 30%)	12	29	41
Sub Total (I + II)		89	89	178
III. Incorporation Tax	(I+II x 2.5%)	2	2	4
Sub Total (I+II+III)		91	91	182
IV. Engineering Study (including site survey), construction supervision	(I+II+III) × 5%	6	3	9
Sub Total (I+II+III+IV)		97	94	191
V. Physical Contingency for the works	(I+II+III+IV)× 15%	15	14	29
Grand Total (I to V)		112	108	220

Table IX-3-2 Construction Cost of Immediate Restoration Plan at San Antonio

(Unit: Million Pesos)

Description		Local Currency	Foreign Currency	Total Cost
I. Direct Cost	See breakdown Table IX-3-5	53	26	79
II. Indirect Cost including Miscellaneous Expenses at Work Site, Overhead and profit	(I × 30%)	7	17	24
Sub Total (I+II)		60	43	103
III. Incorporation Tax	(I+II × 2.5%)	2	1	3
Sub Total (I+II+III)		62	44	106
IV. Engineering Study (including site survey), construction Supervision	(I+II+III) × 5%	4	1	5
Sub Total (I+II+III+IV)		66	45	111
V. Physical Contingency for the work	(I+II+III+IV) × 15%	10	7	17
Grand Total (I to V)		76	52	128

Table IX-3-3 Direct Costs for Immediate Restoration Plan at Valparaiso

Item		Berth	Size/Quality	Unit	Quantity	Unit Price (pesos)	Cost Local Currency	Foreign Currency (1,000 pesos)	Total cost
①Quaywall	①Fill gap by bagged concrete	No. 3		m^3	12.5	46,000	259	316	575
		4		m^3	50	46,000	1,035	1,265	2,300
		5		m^3	37.5	46,000	776	949	1,725
		6		m^3	225	46,000	4,658	5,692	10,350
	②Fill gap by cement paste with clay	No. 3		m^3	2.5	100,000	100	150	250
		4		m^3	20	100,000	800	1,200	2,000
		5		m^3	12.5	100,000	500	1,750	1,250
		6		m^3	15	100,000	600	900	1,500
	③Pour concrete into gap	No. 6	under water	m^3	228	33,000	3,010	4,514	7,524
		7	on land	m^3	130	30,000	1,560	2,340	3,900
	Sub total						13,298	18,076	31,374
②Fender	Docking Fender	No. 3	Tire Type	piece	2	80,000	128	32	160
		5	"	piece	6	80,000	384	96	480
		6	"	piece	8	80,000	512	128	640
	Sub total						1,024	256	1,280
③Apron and yard	Overlay Pavement (Asphalt)	No. 3		m^2	1,000	2,400	1,680	720	2,400
		4		m^2	6,000	2,400	10,080	4,320	14,400
		5		m^2	4,950	2,400	8,316	3,564	11,880
		6		m^2	3,750	2,400	6,300	2,700	9,000
	Sub total						26,376	11,304	37,680
④Crane rail	Reset crane rails	No. 3	One side rail only	m	50	20,000	400	600	1,000
		4	One side only	m	200	10,000	800	1,200	2,000
		6	One side rail only	m	250	20,000	2,000	3,000	5,000
		7	One side rail including base	m	110	40,000	1,760	2,640	4,400
	Sub total						4,960	7,440	12,400
⑤Railway	Reset rail of railway	No. 3	include base	m	50	30,000	600	900	1,500
		4	"	m	200	30,000	2,400	3,600	6,000
		5	"	m	165	30,000	1,980	2,970	4,950
		6	"	m	250	30,000	3,000	4,500	7,500
	Sub total						7,980	11,970	19,950
⑥Others	①Perform base mound (include leveling)	No. 7		m^3	5,760	4,000	16,128	6,912	23,040
	②Fill, compact and re-pave with concrete	7		m^2	1,800	6,000	7,560	3,240	10,800
	Sub Total						23,688	10,152	33,840
	Total						77,326	59,198	136,524

Table IX-3-4 Direct Costs for Immediate Restoration Plan at San Antonio

Items		Berth	Size/Quality	Unit	Quantity	Unit Price (Pesos)	Cost Local Currency	Foreign Currency (1,000 pesos)	Total Cost
①Apron and yard	Overlay Pavement (Asphalt)	No. 4	yard only	m^2	10,000	2,400	16,800	7,200	24,000
		5		m^2	4,500	2,400	7,560	3,240	10,800
		6, 7	"	m^2	10,000	2,400	16,800	7,200	24,000
	Sub total						41,160	17,640	58,800
②Others	①Repair deteriorated steel sheet pile by welding	No. 4		L.S.	1		212	496	708
	②Fill by bagged concrete	No. 4		place	1		41	51	92
	③Replacement of connecting board	No. 5		m	118	167,000	11,824	7,882	19,706
	Sub total						12,077	8,429	20,506
	Total						53,237	26,069	79,306

Description year / month	1											
	1	2	3	4	5	6	7	8	9	10	11	12
(A) Port of Valparaiso												
Berth												
Berth 4												
Berth 5												
Berth 6												
Berth 7												
Mobilizatio /Demobilization												
Berths available	4/10	4/10	4/10	4/10	5/10	5/10	5/10	5/10	6/10	7/10	8/10	8/10
(B) Port of San Antonio												
Berth 4												
Berth 5												
Berth 6, 7												
Mobilization/Demobilization												
Berths available	2/7	2/7	2/7	2/7	1/7	2/7	2/7	2/7	2/7	2/7	2/7	2/7
Berths avaialble at both ports	6/16	6/17	6/17	6/17	6/17	7/17	7/17	7/17	8/17	9/17	10/17	10/17

Fig. IX-3-1 Construction Schedule for Immediate Restoration Plan

CHAPTER X RESTORATION AND IMPROVEMENT PLAN FOR VALPARAISO PORT

CHAPTER X RESTORATION AND IMPROVEMENT PLAN FOR VALPARAISO PORT

X-1 Outline of the Restoration and Improvement Plan

(1) General

The Restoration and Improvement Plan for Valparaiso Port is a first phase development plan for the target year 1992. Although the Master Plan determines the port's overall future development course, the aim of the restoration and improvement plan is to concretely propose the restoration and improvement of port facilities which should take place by 1992, as a short-term plan (hereinafter referred to as the "First Phase Plan").

The First Phase Plan is drawn up based on various technical, economic and financial evaluations.

The following items have to be considered in formulating the First Phase Plan.

① The First Phase Plan is a stage plan to realize the Master Plan.

② The proposed first phase port facilities should have enough capacity to handle the forecast cargo volume in the target year 1992.

③ Existing port facilities will be used effectively in consideration of the aseismicity and deterioration of facilities.

④ The investment should be minimized.

(2) Scale of the First Phase Plan

The scale of the First Phase Plan is proposed in Section VII-6, phased plan, as Fig. X-1-1.

The following items have to be examined in formulating the First Phase Plan.

① Continuity to the Master Plan: Can facilities provided under the First Phase Plan be readily shifted for use under the Mastrer Plan?

② Containerization: Is it possible to cope with containerization soon and completely?

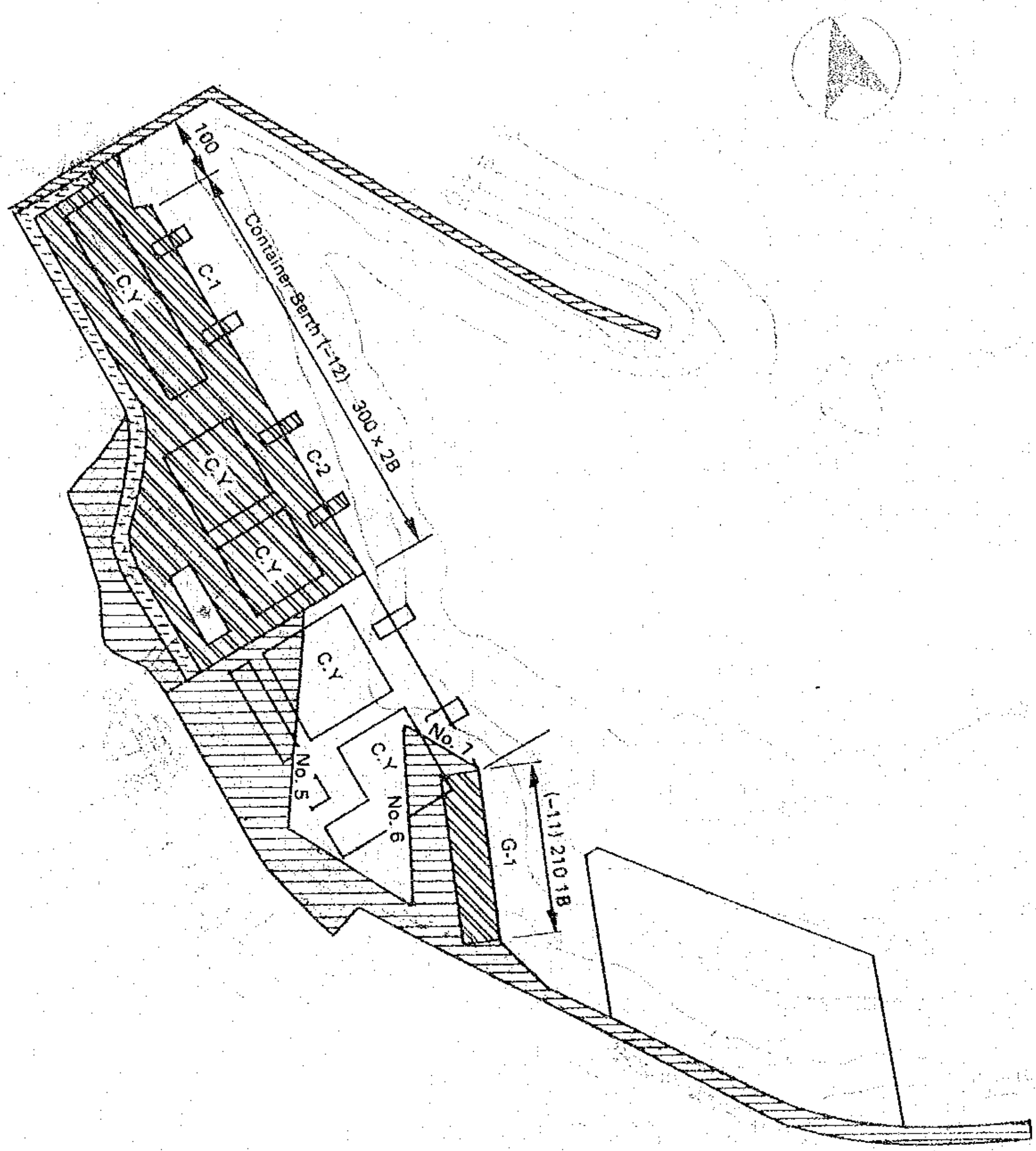


Fig. X-1-1 First Phase Plan

③ Efficient Use and Operation of Existing Facilities: Can the efficient use and operation of existing port facilities be realized by the layout of facilities?

④ Early Utilization of Aseismic Berth: Can the aseismic berth be provided as soon as possible?

⑤ Amount of Investment: What is the amount of investment? Will the money invested and put into the construction prove to have been spent wisely?

Now the proposed First Phase Plan must be examined in accordance with the above items as follows.

First, regarding the container berths, it is desirable that existing berths No.4 and 5 which are currently used as container berths are also used as container berths during the construction of new berths. Therefore, it may be appropriate that the container berths be constructed one by one from C-1. If C-3 were constructed first, it would prematurely halt general cargo operations at existing berths No. 4 -7 and cause the loss of handling capacity for containers during the construction. Moreover, it would increase the initial investment due to the large amount of reclamation necessary. However, the construction of C-1 will not increase the area of the container yards greatly. However, in this case, the area behind existing berths No. 3 - 5 will be available as the container yard.

Next, as for the general cargo berths in Valparaiso Port, it is expected that the berthing capacity is sufficient with the existing number of berths until about year of 2000. Therefore, if we disregard the fact that the existing facilities are not modern, the general cargo berths will be constructed one by one adjusting the construction schedule of new container berths as substitute berths, and it is desirable to minimize the initial investment for the new construction works by using existing berths. However, it is also desirable that the new berths be constructed soon considering modernization and the aseismicity of port facilities because the extent of deterioration is severe and the existing aseismicity is low.

On the other hand, general cargo berths are more advantageous as aseismic berths than container berths from the viewpoint of economy.

Consequently, it is proper from the viewpoint of minimizing the investment and providing efficient use of the facilities that the G-1 berth be constructed early.

X-2 Basic Design Studies

(1) General

It is usually necessary to determine the optimum type of structure through preparing alternative designs. But, in certain cases, the type of structures is largely determined by the subsoil conditions at the sites. In this subsection, we investigate various types of construction and different construction materials to select the most economical and suitable solution for the berth structures proposed in the first phase development plan at the port of Valparaiso.

(2) The Port of Valparaiso

1) Container Berth C-1 and C-2

The prevailing profile of the subsoils at the proposed site are characterized by the shollow base rock formation found 16 to 17 m below datum and the dense subsurface soils having an N-value of 35. Under such subsoil conditions, gravity quaywall construction or gravity quaywall in combination with open piled construction is the only viable solution. Among other types of construction, the following structures are considered as alternative designs which are possible solutions considering the site conditions.

- gravity quaywalls using steel sheet pile walled cells

- gravity quaywalls using precast concrete caissons

- open piled construction in combination with submerged steel sheet pile cells

All the alternative designs would be constructed in front of the existing berths 1 to 3. This is because such types of structures as anchored sheet pile walls require the disturbance of existing backyards which is considered impractical due to the existence of hard backfill rocks.

A comparative study on the proposed alternatives is summarized in Table X-2-1. Alternatives "A" and "B" using gravity quaywalls have the great disadvantage of less seismic resistance, although this type of structure is best suited to the subsoil conditions. It is recommended that the berth construction should be as light as possible so as to minimize the effects of earthquake vibrations. In view of the seismic resistance of the structure, alternative "C" is judged better than the other alternatives.

Table X-2-1 Alternative Designs for Container Berths C-1 and C-2 at Valparaiso

Alternative	A	B	C
	Steel sheet pile walled cells	Precast concrete caissons	Open Pier in combination with steel sheet piled cells
Ease of Construction	easy and simple	easy and simple	somewhat complicated but no problem
Seismic Resistance	better	good	best
Availability of Materials	to be imported	available locally	to be imported
Economy	economical	costly	somewhat costly
Overall Assessment			recommended

Steel materials used for the recommended alternative design must be imported. In this respect, we have also studied the possibility of concrete piles. However, the hardness of the subsoils rules out the use of concrete piles.

3) General Cargo Berth G-1

The new general cargo berth G-1 is proposed at the site where the existing berth 8 is located. The berth is identified as an aseismic berth. We have studied the possibility of an open deck structure founded on piles which is in general better in terms of seismic resistance than other types of structures such as gravity quaywalls or sheet pile walls anchored to the rear walls. However, only gravity type structures can practically be adopted because of the existence of the high mound of base rock along existing berth 8.

As viable alternative designs, the following gravity quaywall structures are selected based on the site conditions.

- precast concrete caissons
- precast concrete cellular blocks
- precast concrete blocks

Table X-2-2 summarizes the comparison of the different gravity type quaywalls proposed as alternative designs.

Table X-2-2 Alternative Designs for General Cargo Berth G-1 at Valparaiso

Item	Type		
	Concrete Caissons	Concrete Cellular Blocks	Concrete Blocks
Aseismicity and Durability	A	B	B
Ease of construction	B	B	A
Economy of construction	B	A	B
Adaptability to unevenness of Base mound	A	B	B
Adaptability to berth having deep water	A	B	C
Overall assessment	A	B	B

A: Excellent

B: Good

C: Not Good

As shown in the table, the use of caissons is the optimum solution in terms of its aseismicity, durability and adaptability to deep water, and emerges cleary as the optimum solution. In order to provide ample seismic resistance, concrete caissons are placed upon asphalt base mats. The measure is aimed at increasing the stability for horizontal sliding from which the gravity quaywall is most likely to suffer damage during strong earthquake vibrations.

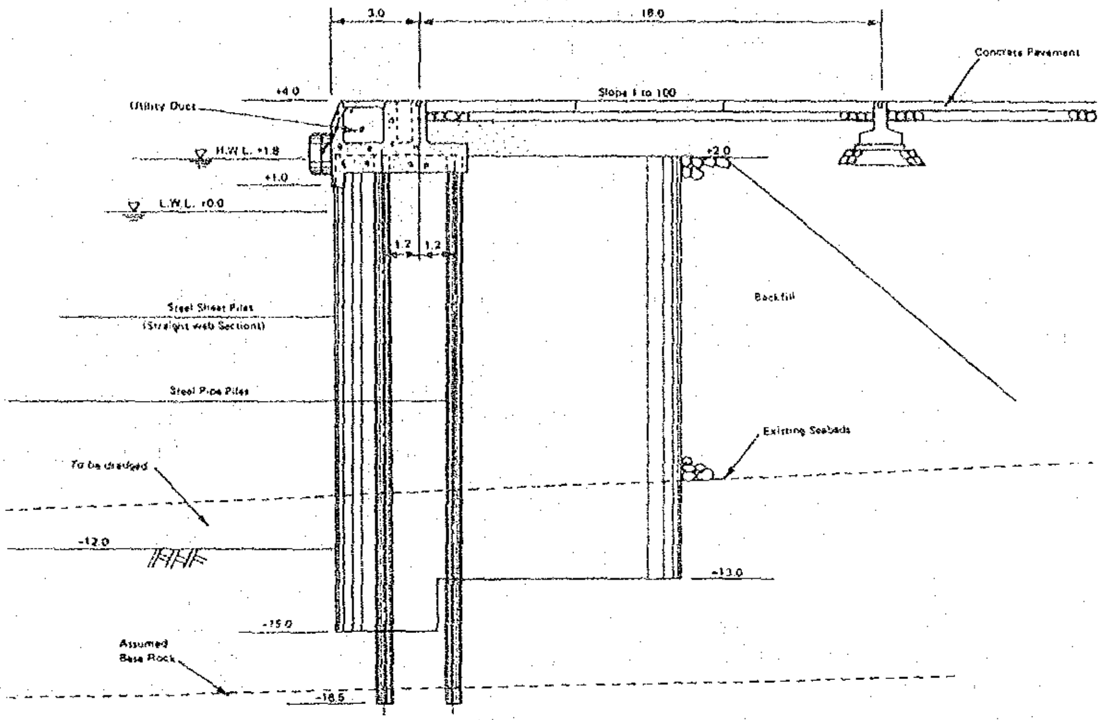


Fig. X-2-1 Alternative Design "A" for Berths C-1 and C-2 at Valparaiso

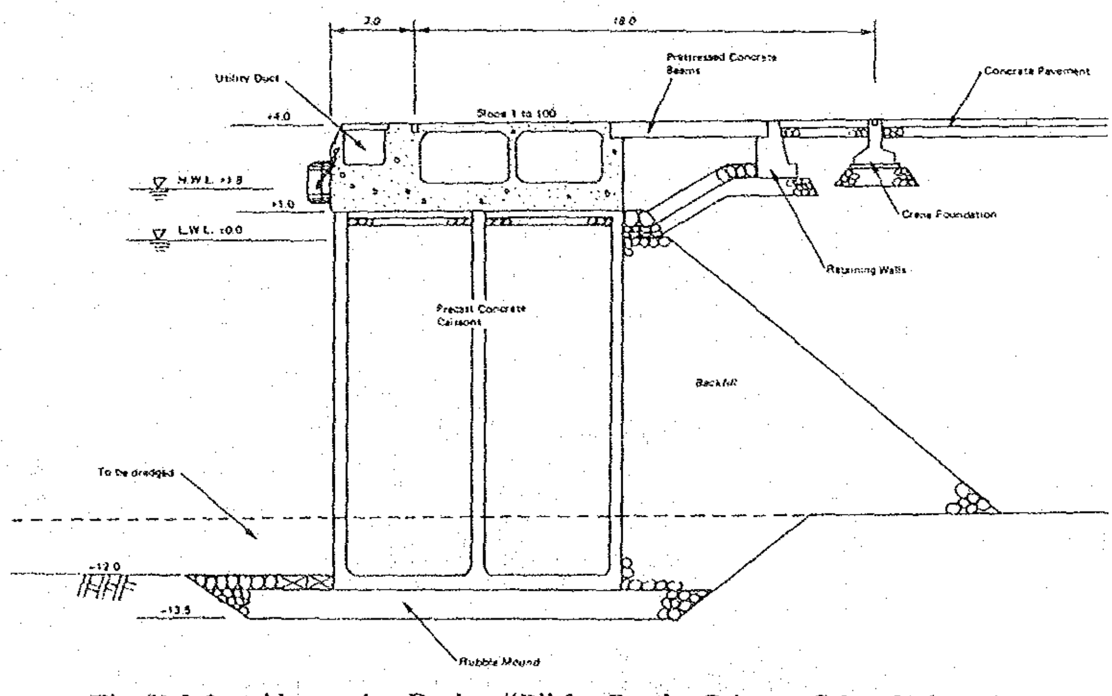


Fig. X-2-2 Alternative Design "B" for Berths C-1 and C-2 at Valparaiso

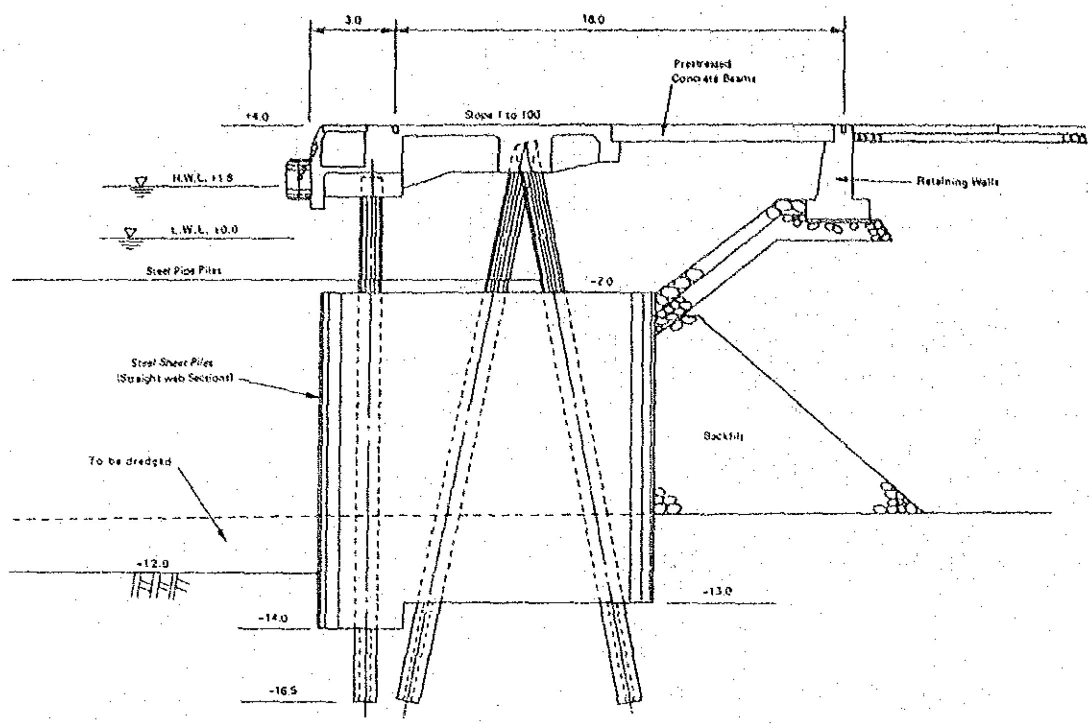


Fig. X-2-3 Alternative Design "C" for Berths C-1 and C-2 at Valparaiso

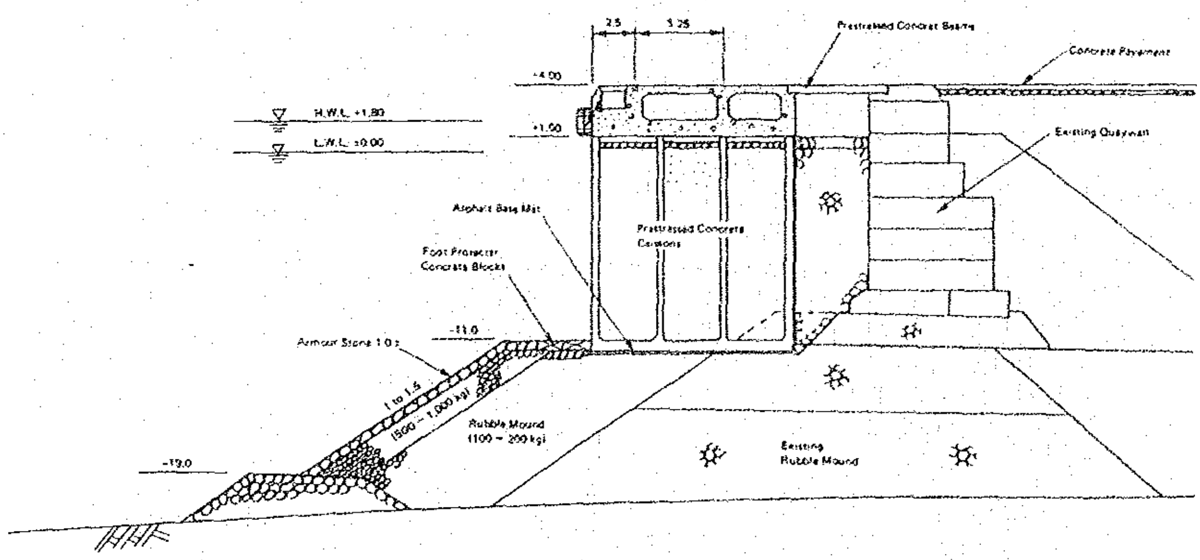


Fig. X-2-4 Alternative Design for Berth G-1 at Valparaiso

X-3 Construction Cost and Implementation Program

(1) Cost Estimate

The required quantities of construction materials are determined based on the comparative designs of the berths. The most economical method of construction is investigated among other practical methods. Based on the unit costs obtained through our studies, the construction cost is estimated for the first phase development program.

Out estimate of the cost of civil engineering works for the first phase development of 600 m of container berths (C-1 and C-2) plus a 210 m general cargo berth (G-1) at Valparaiso is $14,121 million pesos at 1985 prices. Details of the makeup of this amount are given in the following Tables X-3-1 to X-3-3. We have also broken the figures down into the programmed expenditure by quarter for the 6 year implementation program; the details are given in Fig.X-3-1. The direct construction cost by berth is shown in Tables X-3-4 and X-3-10.

The cost estimates include all the port civil works at the programmed berths and the procurement of container cranes, but do not include the dredging works required for the construction of the container berths. We have allotted a sum of 30% for cover the indirect costs of construction, 2.5% for incorporation tax, 15% for physical contingencies and 5% for engineering.

The cost estimate does not include:

① Costs for the Phase I development of 420 m of general cargo berths at San Antonio, which should be estimated by the Government of Chile.

② Costs of mechanical cargo handling equipment except for container cranes.

③ All the costs necessary to provide temporary berths to accommodate cargo demand during the construction works.

(2) Implementation Program

The implementation schedule for the Phase I development program is shown in Fig. X-3-1. The period of this development program is 6 years from January 1987 to December 1992. By January 1993, all of the new port facilities will be operational to cope with the cargo demand. The engineering study will be started in January 1987.

We estimate the time for completion of the recommended works at about 6 years from the instruction to proceed with the design and preparation of tender documents. Our implementation program allows only 3 to 4 months for evaluation of tenders and award of contracts. However, it would be acceptable to select the contractor or consortium leader following the normal tendering procedure, which may require a longer period for tender evaluation and award of contracts.

The question must be asked whether it is desirable to arrange for construction using one or two package contracts in the interest of rapid implementation and lower construction cost. The contracts could be divided into a contract for the container berths and other for the general cargo berth. It must be noted that the two package contract system would only be recommendable if the cost is considered less important than timing.

Table X-3-1 Construction Cost for Container Berth C-1 at Valparaiso

(Unit: 1,000,000 pesos)

Description	Construction			Procurement			Total	Remarks
	Local Currency	Foreign Currency	Sub Total	Local Currency	Foreign Currency	Sub Total		
I. Direct Cost	1,194	1,103	2,297	60	1,400	1,460	3,757	See breakdown for Alternative -C
II. Indirect Cost including Miscellaneous Expenses for Site Works. Overhead and Profit,(30% of Construction (I) and 12% of Procurement (I))	207	482	689	52	123	175	864	
Sub-Total (I + II)	1,401	1,585	2,986	112	1,523	1,635	4,621	
III. Incorporatin Tax,(2.5% of (I + II))	35	40	75	3	38	41	116	
Sub Total (I + II + III)	1,436	1,625	3,061	115	1,561	1,676	4,737	
IV. Engineering Study (including site survey) Construction Supervision, (5% of construction (I + II + III))	61	92	153	0	0	0	153	
Sub Total (I + II + III + IV)	1,497	1,717	3,214	115	1,561	1,676	4,890	
V. Physical Contingency, (15% of Constructin (I to IV))	224	258	482	0	0	0	482	
Grand Total (I to V)	1,721	1,975	3,696	115	1,561	1,676	5,372	

Table X-3-2 Construction Cost for Container Berth C-2 at Valparaiso

(Unit: 1,000,000 pesos)

Description	Construction			Procurement			Total	Remarks
	Local Currency	Foreign Currency	Sub Total	Local Currency	Foreign Currency	Sub Total		
I. Direct Cost	1,489	1,227	2,716	60	1,400	1,460	4,176	See breakdown for Alternative -C.
II. Indirect Cost including Miscellaenous Expenses for Site Works. Overhead and Profit,(30% of Construction (I) and 12% of Procurement. (I))	244	571	815	52	123	175	990	
Sub Total (I + II)	1,733	1,798	3,531	112	1,523	1,635	5,166	
III. Incorporation Tax,(2.5% of (I + II))	43	45	88	3	38	41	129	
Sub Total (I + II + III)	1,776	1,843	3,619	115	1,561	1,676	5,295	
IV. Engineering Study (including Site survey) Construction Supervision, (5% of Construction (I + II + III))	72	109	181	0	0	0	181	
Sub Total (I + II + III + IV)	1,848	1,952	3,800	115	1,561	1,676	5,476	
V. Physical Contingency, (15% of Consturction (I to IV))	277	293	570	0	0	0	570	
Grand Total (I to V)	2,125	2,245	4,370	115	1,561	1,676	6,046	

Table X-3-3 Construction Cost for General Cargo Berth G-1 at Valparaiso

(Unit: 1,000,000 pesos)

Description	Construction			Procurement			Total	Remarks
	Local Currency	Foreign Currency	Sub Total	Local Currency	Foreign Currency	Sub Total		
I. Direct Cost	965	714	1,679	0	0	0	1,679	
II. Indirect Cost including Miscellaneous Expenses for Site Works. Overhead and Profit, [30% of Construction (I) and 12% of Procurement. (I)]	151 151	353 353	504 504	0 0	0 0	0 0	504 504	
Sub Total (I + II)	1,116	1,067	2,183	0	0	0	2,183	
III. Incorporation Tax, [2.5% of (I +II)]	28	27	55	0	0	0	55	
Sub Total (I + II + III)	1,144	1,094	2,238	0	0	0	2,238	
IV. Engineering Study (including site survay) Construction Supervision Construction Supervision, 5% of [5% of construction (I + II + III + IV)]	45 45	67 67	112 112	0 0	0 0	0 0	112 112	
Sub Total	1,189	1,161	2,350	0	0	0	2,350	
V. Physical Contingency [15% of construction (I to IV)]	179	174	353	0	0	0	353	
Grand Total (I to V)	1,368	1,335	2,703	0	0	0	2,703	

Table X-3-4 Direct Cost for Container Berth C-1 at Valparaiso

Item	Unit	Quantity	Unit Price (1,000 pesos)	Cost (Unit: 1,000,000 Pesos) Local Currency	Foreign Currency	Total cost	Remarks
(A) Construction							
① Quaywall	m	300	4,807	620	822	1,442	See breakdown for Alternative -C
② Yard Pavement and Utilities Services	m^2	38,200	13.3	356	152	508	
③ Dmolition works				129	86	215	
- existing sheds	m^2	56,200	3.3	(111	74	185)	
- existing pavement	m^2	30,000	1	(18	12	30)	
④ Others				89	43	132	
- Roads	m	600	200	(84	36	120)	
- Lighting Tower	piece	4	3,000	(5	7	12)	
Sub Total				1,194	1,103	2,297	
(B) Procurement							
① Contrainer Cranes	piece	2	730,000	60	1,400	1,460	
Sub Total				60	1,400	1,460	
Total				1,254	2,503	3,757	

Table X-3-5 Direct Cost for Container Berth C-2 at Valparaiso

Item	Unit	Quantity	Unit Price (1,000 Pesos)	Cost (Unit: 1,000,000 Pesos) Local Currency	Foreign Currency	Total cost	Remarks
(A) Construction							
① Quaywall	m	300	4,807	620	822	1,442	
② Yard Pavement and Utilities Services	m^2	67,500	13.3	629	269	898	
③ Demolition works				31	21	52	
- existing sheds	m^2	6,800	3.3	(13	9	22)	
- existing pavement	m^2	30,000	1	(18	12	30)	
④ Others				209	115	324	
- Roads	m	300	200	(42	18	60)	
- Lighting Tower	piece	4	3,000	(5	7	12)	
- Temporary embankment	m	100	1,400	(84	56	140)	
- Reclamation	m^3	56,000	2	(78	34	112)	
Sub Total				1,489	1,227	2,716	
(B) Procurement							
① Container Cranes	piece	2	730,000	60	1,400	1,460	
Sub Total				60	1,400	1,460	
Total				1,549	2,627	4,176	

Table X-3-6 Direct Cost for General Cargo Berth G-1 at Valparaiso (High Aseismic Berth)

Item	Unit	Quantity	Unit Price (1,000 pesos)	Cost (Unit: 1,000,000 Pesos) Local Currency	Foreign Currency	Total cost	Remarks
(A) Construction							
① Quaywall	m	210	7,300	874	659	1,533	
② Connection to existing quaywall	m	46	2,000	55	37	92	
③ Yard Pavement and Utilities Services	m^2	4,200	9.1	27	11	38	
④ Demolition works for existing pavement	m^2	4,200	1	2	2	4	
⑤ Lighting Tower	piece	6	2,000	7	5	12	
Sub Total				965	714	1,679	
Total				965	714	1,679	

Table X-3-7 Direct Cost of Alternative - A for Berths C-1 and C-2 at Valparaiso

(Cost per meter of berth)

Description	Unit	Quantity	Unit Price (peso)	Cost (1,000 Pesos) Local Currency	Foreign Currency	Total Cost
(1) Cells				567	1,650	2,217
- Steel sheet pile	ton	8.9	122,000	(0	1,086	1,086)
- Steel sheet pile driving	m	34	22,000	(299	449	748)
- Filling gravel for cells	m^3	132	2,900	(268	115	383)
(2) Steel pipe pile				54	285	339
- Steel pipe pile	piece	0.5	407,000	(0	204	204)
- Steel pipe pile driving	piece	0.5	270,000	(54	81	135)
(3) Coping concrete	m^3	8.3	45,000	262	112	374
(4) Others				437	389	826
- Back filling gravels	m^3	95	2,900	(193	83	276)
- Back filling sand	m^3	93	1,900	(124	53	177)
- Dredging in front of berth	m^3	20	1,000	(14	6	20)
- Crain rails	Sum	1		(31	72	103)
- Cathodic protection	Sum	1		(36	84	120)
- Auxiliary facilities miscellaneous materials	Sum	1		(39	91	130)
Total				1,320	2,436	3,756

Table X-3-8 Direct Cost of Alternative - B for Berths C-1 and C-2 at Valparaiso

(Cost per meter of berth)

Description	Unit	Quantity	Unit Price (peso)	Cost (1,000 Pesos) Local Currency	Foreign Currency	Total Cost
(1) Caisson				1,539	1,432	2,971
- Concrete caisson	m^3	135	20,000	(1,350	1,350	2,700)
- Filling sand for caisson	m^3	110	1,900	(146	63	209)
- Cover concrete of caisson	m^3	2.2	28,000	(43	19	62)
(2) Mound				207	106	313
- Rubble base mound for caisson	m^3	18	6,700	(73	48	121)
- Levelling base mound	m^2	24	8,000	(134	58	192)
(3) Coping concrete	m^3	19.6	45,000	617	265	882
(4) Others				697	442	1,139
- Toe protection blocks	m^3	1	40,000	(28	12	40)
- Back filling gravels	m^3	86.6	2,900	(176	75	251)
- Back filling sands	m^3	105.8	1,900	(141	60	201)
- Concrete retaining wall	m^3	3.5	40,000	(98	42	140)
- Base gravels for retainning wall	m^3	7	4,800	(24	10	34)
- Crane rail	Sum	1		(31	72	103)
- Approach deck	m^3	2.8	55,000	(108	46	154)
- Dredging for quaywall	m^3	85.5	1,000	(52	34	86)
- Auxiliary facilities miscellaneous material	Sum	1		(39	91	130)
Total				3,060	2,245	5,305

Table X-3-9 Direct Cost of Alternative-C for Berths C-1 and C-2 at Valparaiso

(Cost per meter of berth)

Description	Unit	Quantity	Unit Price (peso)	Cost (1,000 pesos) Local Currency	Foreign currency	Total Cost
(1) Celles				638	1,445	2,083
- Steel sheet pile	ton	66	122,000	(0	805	805)
- Steel sheet pile driving	m	30	28,600	(343	515	858)
- Filling gravel for celles	m3	88	2,900	(179	76	255)
- Cover concrete for celles	m3	5.5	30,000	(116	49	165)
(2) Steel pipe pile				60	510	570
- Steel pipe pile	piece	0.2	653,600	(0	131	131)
- Steel pipe pile (Raking pile)	piece	0.4	722,400	(0	289	289)
- Steel pipe pile driving	piece	0.6	250,000	(60	90	150)
(3) Coping concrete	m3	16.5	55,000	636	272	908
(4) Others				733	513	1,246
- Backfilling gravels	m3	40.3	2,900	(82	35	117)
- Backfilling sands	m3	108	1,900	(144	61	205)
- Approach deck	m3	4.8	55,000	(185	79	264)
- Concrete retaining wall	m3	4.9	45,000	(155	66	221)
- Base gravels for retaining wall	m3	9.9	7,000	(48	21	69)
- Dredging in front of berth	m3	20	1,000	(14	6	20)
- Crane rail	Sum	1		(12	28	40)
- Cathodic protection	Sum	1		(54	126	180)
- Auxiliary facilities miscellaneous material	Sum	1		(39	91	130)
Total				2,067	2,740	4,807)

Table X-3-10 Direct Cost of General Cargo Berth G-1 at Valpariso

(Cost per meter of berth)

Description	Unit	Quantity	Unit Price (peso)	Cost (1,000 pesos) Local Currency	Foreign Currency	Total Cost
(1) Caisson				1,835	1,711	3,546
- Concrete Caisson	m3	162	20,000	(1,620	1,620	3,240)
- Fillsand for caisson	m3	120	1,900	(160	68	228)
- Cover concrete of caisson	m3	2.8	28,000	(55	23	78)
(2) Mound				1,198	800	1,998
- Rubble mound	m3	117	6,700	(470	314	784)
- Armour stones	m3	74	9,600	(426	284	710)
- Levelling stones	m3	63	8,000	(302	202	504)
(3) Coping concrete	m3	22.8	45,000	718	308	1,026
(4) Others				409	321	730
- Toe Protection blocks	m3	1	40,000	(28	12	40)
- Backfilling gravels	m3	59	2,900	(120	51	171)
- Approach deck	m3	2.8	55,000	(108	46	154)
- Crane rail	Sum	1		(12	28	40)
- Demolition work of existing guaywall	Sum	1		(87	58	145)
- Auxiliary facilities, miscellaneous materials	Sum	1		(54	126	180)
Total				4,160	3,140	7,300

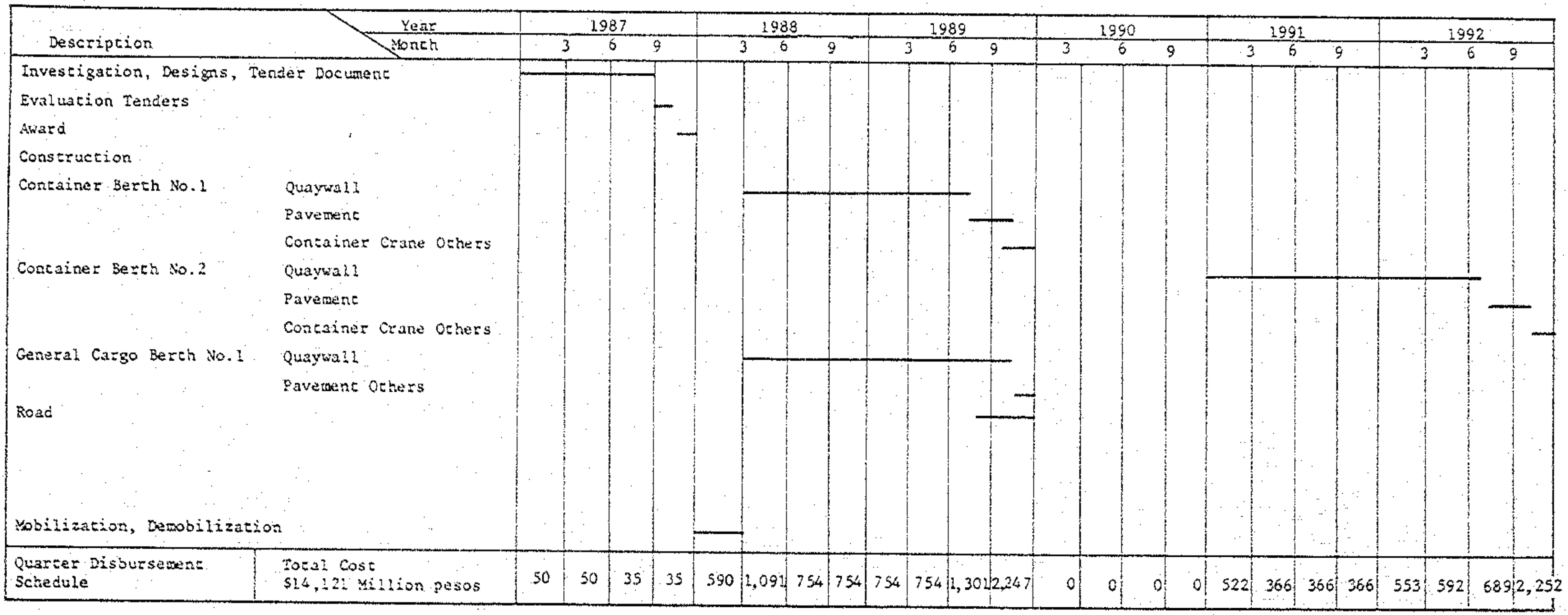


Fig. X-3-1 Implementation Schedule for Restoration and Improvement Plan of Valparaiso