Japan International Cooperation Agency (JICA)
Ghana Ports and Harbours Authority

NO.

FINAL REPORT

VOL. 4 SHORT-TERM DEVELOPMENT PLAN FOR TEMA PORT

THE DEVELOPMENT STUDY OF GHANA SEA PORTS IN THE REPUBLIC OF GHANA

February 2002

The Overseas Coastal Area Development Institute of Japan (OCDI)
NIPPON KOEI CO.,LTD.

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List of Abbreviations

AEC	Assumed Environmental Criteria
ASEAN	Association of Southeast Asian Nations
B/L	Bill of Lading
BOD	Biochemical Oxygen Demand
BOR	Berth Occupancy Ratio
BOT	Built-Operate-Transfer
BRV	Bulk Road Vehicles
BU	Bulk Carrier
C.D	Chart Datum
CEPS	the Customs Exercise and Preventive Service
CFS	Container Freight Station
CIF	Cost, Insurance and Freight
CM	Container/Multipurpose Carrier
CO	Container Cellular Vessel
COD	Chemical Oxygen Demand
CRMS	Computerized Risk Management System
CT	Container Terminal
CY	Container Yard
DO	Dissolved Oxygen
DO	Delivery Order
DR	Dock Receipt
DWT	Dead Weight Tonnage
EDI	Electric Data Interchange
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPZ	Export Processing Zone
FEU	Forty-foot Equivalent Unit
FOB	Free On Board
GAFCO	Ghana Agro-Food Company
GBC	Ghana Bauxite Company
GC	General Cargo Carrier
GDP	Gross Domestic Product
GEPC	Ghana Export Promotion Council
GFZB	Ghana Free Zones Board
GHATIG	Ghana Trade and Investment Gateway Project
GPHA	Ghana Ports and Harbours Authority
GRC	Ghana Railway Corporation
GT(GRT)	Gross Tonnage
H1/3	Significant Wave Height
HWL	High Water Level
IALA	International Association of Lighthouse Authority
IAPH	International Association of Ports and Harbors
JICA	Japan International Cooperation Agency

KIA	Kotoka International Airport
KN	Kilo Newton (=0.102 tf)
L0	Wave Length
LOA	Length Overall
LWL	Low Water Level
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MOF	Ministry of Finance
MOFA	Ministry of Food and Agriculture
MOL	Mitsui O.S.K Line
MORT	Ministry of Road and Transport
MPa	Mega Pascal (=N/mm2)
MR	Mate's Receipt
NCA	National Communication's Authority
NCP	New Container Platform (at Takoradi Port)
NEAP	National Environmental Action Plan
OCDI	Overseas Coastal Area Development Institute of Japan
OECD	Organization for Economic Co-operation and Development
OECF	The Overseas Economic Cooperation Fund
PIANC	International Navigation Association
RO	Ro-Ro Vessel
Ro/Ro	Roll on / Roll off
RTG	Rubber Tyre mounted Gantry crane (= Transfer crane)
S.F.	Safety Factor
SAPS	Special Assistance for Project Sustainability
SO	Shipping Order
SS	Suspended Solids
T1/3	Significant Wave Period
TDC	Tema Development Cooperation
TEU	Twenty-foot Equivalent Unit
TFCC	Tema Food Complex
TG	Tugboat
TK	Tanker
TMA	Tema Municipal Assembly
TOR	Tema Oil Refinery
UNCTAD	United Nations Conference on Trade and Development
VALCO	Volta Aluminium Company Limited
VLTC	Volta Lake Transport Company
VRA	Volta River Authority
WAG	West Africa Gas
WTO	World Trade Organization

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PART V SHORT-TERM DEVELOPMENT PLAN FOR TEMA PORT

Chapter 24 Short-term Development Plan for Tema Port

24.1 Planning Requirement for Short-term Development Plan

24.1.1 Strategy for Development

As explained in Chapter 14.1, Tema Port has advantages for future development and the port must make the most of its advantages to play its expected role. However, we must not forget that the port is competing with other ports in acquiring container and transit cargoes. This means that investment and construction of facilities should be implemented timely.

The strategy of the short-term development plan is to limit investment to high priority projects and making the most of existing facilities.

24.1.2 Future Cargo Demand

Future cargo demand was forecasted and the results are summarized in Table 24.1.1 and Table 24.1.2. Main cargoes in which volumes will increase are clinker, bauxite and container cargo.

Table 24.1.1 Future Cargo Demand Forecast at Tema Port

(tons)

IMPORT	1991	2000	2010
Dry Bulk	1,061,685	1,652,557	2,157,747
Alumina	365,906	301,775	384,950
Clinker	470,277	972,772	1,262,240
Liquid Bulk	1,106,336	1,853,315	3,439,000
Crude Oil	165,112	1,000,000	2,575,747
Petrol Products	168,901	850,000	858,500
Bagged Cargo	301,253	537,553	597,518
General Cargo	201,898	235,135	701,388
Containerized Cargo	397,663	833,529	1,875,000
Total	**3,068,835**	**5,112,088**	**8,770,653**
Export	**1991**	**2000**	**2010**
Liquid Bulk	198,070	246,584	401,659
Bagged Cargo	84,092	104,370	26,891
General Cargo	192,109	156,230	106,734
Containerized Cargo	103,904	382,371	820,835
Total	**578,175**	**889,555**	**1,356,118**
Grand Total	**3,647,010**	**6,001,643**	**10,126,771**

Table 24.1.2 Future Container Cargo Demand Forecast at Tema Port

	1991	2000	2010
Import	35,071	81,861	202,447
Export	35,852	79,782	213,282
Transit		2,648	10,835
Transshipment		1,858	58,749
Total	70,923	166,149	485,313

24.2 Facility Requirement for Short-term Development Plan

24.2.1 Berthing Facilities

(1) Cargo Handling Productivity

As explained in chapter 14.3 and the development strategy mention above, new container berths have a higher priority among projects in the master plan. Therefore, the cargo handling productivity at 2010 for cargoes handled at multipurpose berths is set at the same level of that of the year 2000.

Table 24.2.1 Gross Cargo Handling Productivity at Tema Port in 2000 and 2010

Type	Commodity	Unit	Productivity 2000	Productivity 2010	Remark
IMPORT					
DB	Alumina	t/hour/vessel	211	210	Unlader
DB	Clinker/Gypsum	t/hour/vessel	299	350	Belt conveyor
DB	Wheat	t/hour/vessel	70	150	Ship gear, grab
LB	Petro products	t/hour/vessel	385	600	Pipeline
BC	Rice, Fertilizer	t/hour/vessel	50	75	Ship gear
GC	Cars, Steel product	t/hour/vessel	70	70	Ship gear
GC	Gen. Valco	t/hour/vessel	125	125	Ship gear
CO	Container	box/hour/vessel	16	24	Container crane
EXPORT					
LB	Petro products	t/hour/vessel	385	385	Pipeline
BC	Cocoa beans	t/hour/vessel	30	75	Ship gear
GC	Aluminum	t/hour/vessel	85	85	Ship gear
GC	Cocoa products	t/hour/vessel	30	50	Ship gear
GC	S/Timber, Wood product	t/hour/vessel	30	75	Ship gear
CO	Container	box/hour/vessel	16	24	Container crane

Note: Productivity 2000 is calculated from data of Jan. to Nov. in 2000

(2) Vessel Size at Target Year

Based on the analysis explained in Chapter 14.2.1, vessel sizes in the year 2010 are set as described in Table 14.2.2.

Table 24.2.2 Vessel Size at the Target Year 2010 at Tema Port

Vessel Type	2000		2010 (Standard Size)		
	Max.DWT	$DWT_{1/4}$	DWT	Length	Draft
	(tons)	(tons)	(tons)	(m)	(m)
Bulk carrier	51,694	47,263	30,000	185	11.0
Cellular container	31,975	20,245	35,000	260	12.0
RO-RO	39,900	28,175	28,000	210	11.0

Note: $DWT_{1/4}$ means DWT of one fourths largest vessel

(3) Number of Berths Required

Number of berths by berth type required for the short-term development plan to meet future cargo demand is determined by the method explained in Chapter 14.2.1 and is checked by a computer simulation for vessel berthing. The result of required berth number by berth type is shown in Table 24.2.3.

A multipurpose berth with a depth of 12m will be constructed by improving existing Berth No.5, No. 6 and a part of Berth No.4. However, reclamation works for cargo handling area behind the berth will be done in the next stage to reduce the project cost. Even assuming that the present cargo handling productivity mentioned in Table 17.2.1 would remain unchanged, the new multipurpose berth and other conventional berths have the capacity to handle conventional cargoes in 2010 except mineral bulk cargoes and petroleum products.

Table 24.2.3 Scale of Berths for Short-term Development Plan of Tema Port

Berth	Commodity	Number	Depth	Length
Container Berth	Container	2	13.0m	300m

Besides new container berths, new oil berth with the depth of 11.5m (redevelopment of existing oil berth) and new Valco berth with the depth 11.5m and the length of 240m were also examined. These projects included dredging works and berth construction works and the estimated cost was US$ 13,375 thousands. However, a financial analysis revealed that these projects were not feasible. Therefore, these projects were deleted from the project list of the short-term development plan.

24.2.2 Water Facilities

(1) Entrance Channel

As explained in the master plan, width of the new entrance channel is set at 160m and depth is 15m.

(2) Turning Basin

Turning basins are to be located in front of new container berths and have a diameter of two times the overall length of design vessel.

24.2.3 Breakwater

New breakwaters with the length of 1,350m and 200m will be constructed to protect the new container berths to satisfy the criteria that the non-excess probability under 0.5m in wave height be at least 95% in the case of container berths. The result of the non-excess probability under 0.5m in wave height in front of the new container berths is 98 %.

24.2.4 Storage Area

(1) Container Yards and CFS

Two container berths with sufficient container yards will be constructed. These container berths are the first dedicated container berth at the port. Details of the new container terminal are explained in chapter 24.5.

(2) Shed

As explained in the master plan, new sheds are not planned in the short-term development plan

24.2.5 Road

(1) New Access Road for Container

The traffic volume generated by port activities is estimated by applying the following equation.

$$V = \upsilon / 24 \times \sigma / \delta / \varepsilon$$

Where,

υ	1,477	Number of trucks at peak day
σ	4.0	Variation ratio per hour
δ	0.5	Cargo related vehicle ratio
ε	0.5	Ratio of vehicle with load
V	985	Number of vehicles at peak hour

According to the estimated traffic volume, 4 lanes are required.

(2) Main Harbour Road

The traffic volume generated by port activities is estimated by applying the following equation.

$$V = \upsilon / 24 \times \sigma / \delta / \varepsilon$$

Where,

υ	712	Number of trucks at peak day
σ	4.0	Variation ratio per hour
δ	0.7	Cargo related vehicle ratio
ε	0.5	Ratio of vehicle with load
V	339	Number of vehicles at peak hour

The estimated traffic volume requires 2-lane road.

(3) Parking Space

A new parking area for trucks for transit cargo is proposed. The necessary area for parking space is estimated by applying the following equation. The new parking area is proposed to construct near gate 3.

$$A = (V / T \times \lambda \times \delta / \mu) \times U$$

Where、

V	:	237,432	Annual throughput of transit cargo (tons)
T	:	363	Annual working days
λ	:	2	Peaking factor to the daily average
δ	:	1	Average dwelling time (days)
μ	:	15	Unit load per truck (tons/truck)
U	:	140	Unit parking area per truck (sq.m)
A	:	12,210	Parking space (sq. m)

24.3 Port Facility Layout Plan for Short-term Development Plan

Based on the analysis described above, port facility layout plan is formulated. Fig. 24.3.1 and 24.3.2 show the proposed layout. Table 24.3.1 shows the list of main facilities of the short-term development plan.

Table 24.3.1 List of Main Facilities for Short-term Development Plan of Tema Port

Facility	No.	Dimension / Capacity
Container Berths Navigational aids	2 1	Length 300m, depth 13m 2 Light beacons, 2 Buoys
Tugboat	1	2,500Hp
New entrance channel	1	One way, width 160m, depth 15m
New turning basin	1	Radius 290m, depth 14m
Container yard	1	25ha
New breakwater	1	1,350m, 200m
Revetment	1	630m
Access road development	1	1 set
Inner harbour road	1	1 set
Parking space	1	12,200m^2
Container crane	4	45 tons
Transfer crane	12	40 tons, 1 over 4
Tractor head	16	For container cargo

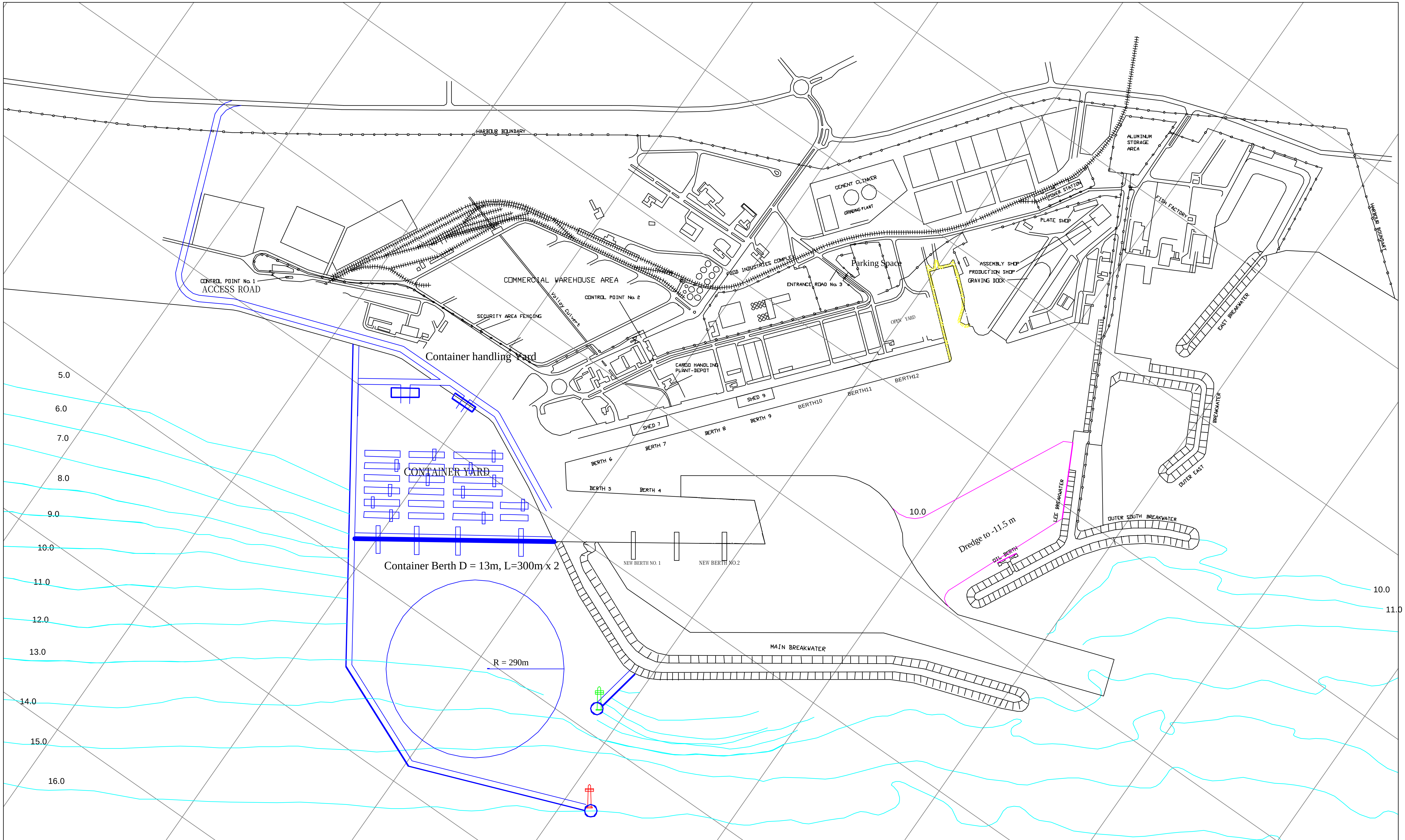


Fig. 24.3.1 SHORT-TERM DEVELOPMENT PLAN of Tema Port

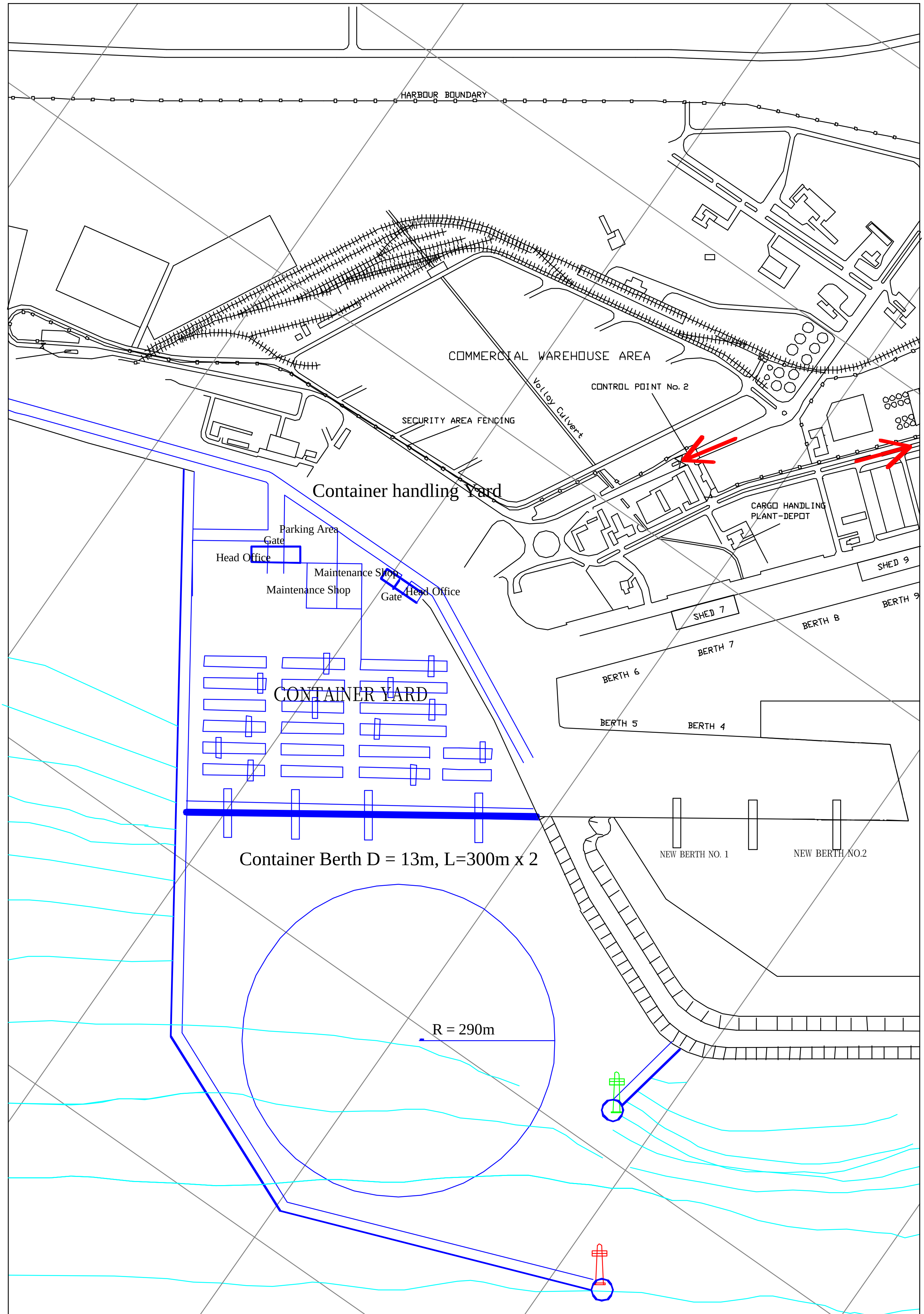


Fig. 24.3.2 SHORT-TERM DEVELOPMENT PLAN of Tema Port (Main Facilities)

24.4 Other Facilities

24.4.1 Navigational Aids

It is proposed that buoys be installed as shown Fig. 24.3.1 so as to allow vessels to enter and departure from the port even at nighttime. The list of navigational aids is shown in Table 24.4.1.

Table 24.4.1 Proposed Navigational Aids at Tema Port

No	Position	Kind	Color	Light	Top-mark
1	West end of new main B.W.	Lateral Mark Light Beacon	Red	Flashing	Single red cylinder
2	East end of new lee B.W.	Lateral Mark Light Beacon	Green	Flashing	Single green cylinder
3	Entrance of new channel	Light Bouy	White	Flashing	-
4	Entrance of new channel	Light Bouy	White	Flashing	-

24.4.2 Tugboats

The maximum thrust is required when moving a mother vessel athwart direction, and an empirical formula on the thrust based on vessels' deadweight and external force (mainly by wind force) is shown in Fig. 16.4.1.

According to Fig. 16.4.1, assisting a 50,000 DWT mother vessel against a wind of 10 m/s (probability of exceeding 10 m/s at Tema is less than 1%) requires a total of 3,600 hp (2 tugs 1,800 hp each). There are four tugboats at Tema Port with respective hp's of 2,203, 2,466, 2,500 and 2,500.

Although the estimated number of vessels which call at Tema Port in 2010 is at the same level of the present because of the increase of cargo volume handled per vessel, new container berths with a entrance channel will be constructed at the short-term development plan. This means that sometimes two teams of tugboats will have to be engaged in the operation at the same time and four tugboats at maximum will be engaged in the operation. A new tugboat with 2,500 Hp will be purchased for reserve.

24.5 Proposal for Efficient Port Operation

24.5.1 Container Cargo

(1) Container Handling at New Container Terminal

Table 24.5.1 Estimated Storage Area for Container Cargo

Port of Tema		2000	2010	unit
Volume of Container Cargo		166,149	485,313	TEU
Volume of Container Cargo		128,798	376,212	Box
Productivity		16	24	box/hour/vessel
Working day		365	365	day
Cargo throughput in a day		455	1,330	TEU/day
Average Dwelling Time(Target)		12	6	day
Peak Ratio		1.3	1.3	
		2000	2010	
Required Capacity Volume		7,098	10,374	TEU
for Container storage				
Required Area	2 tiers	88,725	129,675	m2
for Container Storage	3 tiers	59,150	86,450	m2
	4 tiers	**44,363**	**64,838**	**m2**

Size of 20ft Container	
Length(l)	6.058 m
Widgh(w)	2.438 m
Height(h)	2.438 m
Bottom Area(=l x w)	15 m2
Area for 1slot	
(+ 50cm space on each side)	
lengh + 50cm x 2(ls)	7.058 m
widgh + 50cm x 2(ws)	3.438 m
Bottom Area(=ls x ws)	25 m2

・The construction of new container terminal at the western side of Tema port is proposed in the short-term plan (depth -13m x 300m x 2berths). The transfer crane method is suitable for terminals because it can take the most effective storage capacity in the same area.

・Fifty-five percent of container cargo will be handled at the new container terminal, and the rest (45%) will be handled at the existent berths of Quay1 and Quay2.

Table 24.5.2 Estimated Storage Area for Container Cargo at New Container Terminals

		0%	55%	
Port of Tema (New Cont.T)		2000	2010	unit
Volume of Container Cargo		0	266,922	TEU
Volume of Container Cargo		0	210,175	Box
Productivity		16	24	box/hour/vessel
Working day		365	365	day
Cargo throughput in a day		0	731	TEU/day
Average Dwelling Time(Target)		12	6	day
Peak Ratio		1.3	1.3	
		2000	2010	
Required Capacity Volume		0	5,702	TEU
for Container storage				
Required Area	2 tiers	0	71,273	m2
for Container Storage	3 tiers	0	47,515	m2
	4 tiers	**0**	**35,637**	**m2**

Size of 20ft Container	
Length(l)	6.058 m
Widgh(w)	2.438 m
Height(h)	2.438 m
Bottom Area(=l x w)	15 m2
Area for 1slot	
(+ 50cm space on each side)	
lengh + 50cm x 2(ls)	7.058 m
widgh + 50cm x 2(ws)	3.438 m
Bottom Area(=ls x ws)	25 m2

・At Tema port, the forecasted volume of container cargo in 2010 is 485,313 TEUs(refer to Table 24.5.1). Assuming that 55% of the forecasted volume of container cargo will be handled at the 4 new berths, and the rest will be handled at the container berths of Quay2 and Quay1 berths, container handling volume at the new container berths is estimated as below:

Daily container handling volume at new container berths
＝ 485,313 x 55% / 365 = 731 TEUs/day
Average dwelling day = 6 days (as Target value in 2010)
Container storage capacity at new container terminals = 731 x 6 x 1.3 = 5,702 TEUs
Minimum area for container storage = (5,702 / 4) x 25m^2 = 35,638 m^2
(4 tiers high, 1TEU=25m^2)

The layout of the new container berth is shown in Figure 24.5.3. The storage area under these layouts is 7,480 TEUs and is sufficient for the estimated container throughput.

・Four gantry cranes should be installed in the new container berths (2 gantry cranes in 1 berth x 2 berths).
・The required number of transfer crane (RTG) for gantry cranes (Ntc) is estimated as below.

Ntc = Nqsc x 2 + A/(T x Ptc x E) +Ntc-backup
= 8 + 1.19 + 2 = 11.19 → 12 units

Nqsc = Number of Quay Side Gantry Cranes	4 units
A = Annual Throughput in TEUs	266,922 TEUs
T = Annual Maximum available working hours	8,760 hours/year
Ptc = Net Productivity of Transfer Cranes	20 boxes/hour/Tcrane
E = Conversion rate (TEU/box)	1.28 TEUs/Box
Ntc-backup = Number of Transfer Crane for backup	2 units

・Between quay side and marshaling yard, container cargo should be carried by yard tractor-trailers. The required number of yard tractor-trailers for each gantry crane Nytt is estimated as below.

Nytt = （Ttr＋Lytt /（Vytt/60））/ Tqsc＋Nbackup
= 2.33 + 1 = 3.33 → 4 units

Ttr = Handling time under transfer crane	3 minutes/cycle
Lytt = Average travelling length of yard tractors（1km）	1 km/cycle
Vytt = Average travel speed of yard tractor-trailers	15 km/h
Tqsc = Handling time under quay-side crane	3 minutes/cycle
Nbackup = Number of Yard tractor-trailer for backup	1 unit

Therefore, the required number of yard tractor-trailers is estimated as 16 units for 4 gantry cranes.

In total for new container terminals:	Quay side gantry crane:	4 units
	Transfer crane:	12 units
	Yard tractor trailer:	16 units
	Storage capacity:	7,480 TEUs
	（layouts	Figure 24.5.3）

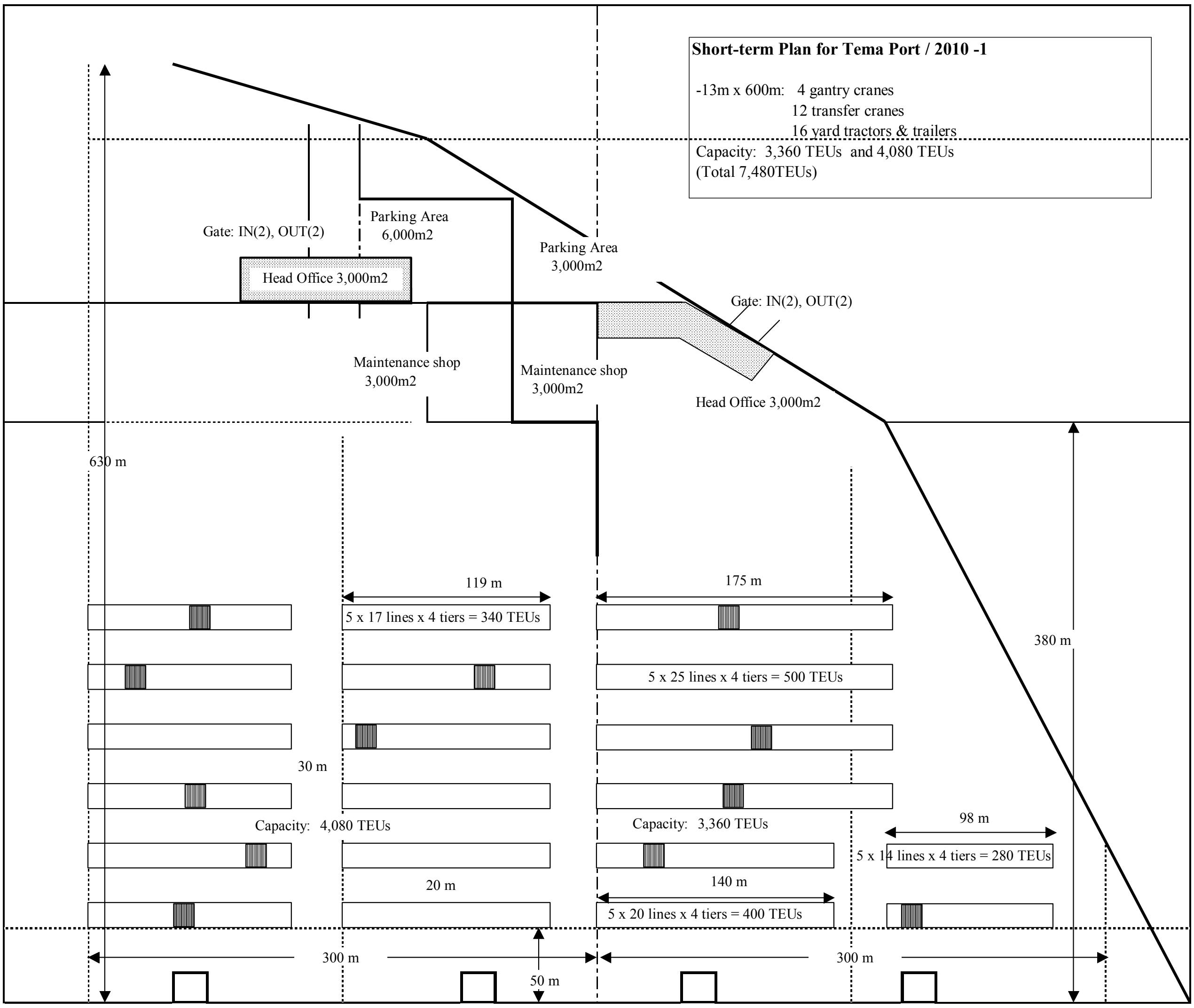


Figure 24.5.3 Layout of New Container Berths（Depth -13m, 300m x 2 berths）

(c) The Container Yard at the existing port area (Quay1 and Quay2)

Container handling volume inside the existing port (Quay1 and Quay2) is calculated in Table 24.5.4.

Table 24.5.4 Estimated Storage Area for Container Cargo at Quay1 and Quay2

		100%	45%	
Port of Tema (Quay1 &2)		2000	2010	unit
Volume of Container Cargo		166,149	218,391	TEU
Volume of Container Cargo		130,826	171,961	Box
Productivity		16	24	box/hour/vessel
Working day		365	365	day
Cargo throughput in a day		455	598	TEU/day
Average Dwelling Time(Target)		12	6	day
Peak Ratio		1.3	1.3	
		2000	2010	
Required Capacity Volume for Container storage		7,098	4,664	TEU
Required Area for Container Storage	2 tiers	88,725	58,305	m2
	3 tiers	59,150	38,870	m2
	4 tiers	44,363	29,153	m2

Size of 20ft Container	
Length(l)	6.058 m
Widgh(w)	2.438 m
Height(h)	2.438 m
Bottom Area(=l x w)	15 m2
Area for 1slot	
(+ 50cm space on each side)	
lengh + 50cm x 2(ls)	7.058 m
widgh + 50cm x 2(ws)	3.438 m
Bottom Area(=ls x ws)	25 m2

・Forty-five percent of container cargo (218,391 TEUs) will be handled at the Quay1 berths and at the container terminal on Quay2 that will be re-constructed. Container handling volume at the Quay1 and Quay2 is estimated as below.

Daily container handling volume at Quay1and Quay2
= 485,313 x 45% / 365 = 598 TEUs/day
Average dwelling day = 6 days (as Target value in 2010)
Container Storage capacity at Quay1 and Quay2 = 598 x 6 x 1.3 = 4,664 TEUs
Minimum area for container storage = (4,664 / 3) x 25m^2 = 38,870 m^2
(3 tiers high, 1TEU=25m^2)

The required minimum area for container storage at the existing port area is calculated as about 39,000m^2. At present, there are some container yards behind berths 10-11 (about 37,000m^2). In addition, GPHA plans to establish a new container yard at the Quay2 (945 slots, 23,625 m^2) and in the area where at the Cocoa shed is currently located (about 52,000m^2). These container yards behind berth 10-11 and new container yard are sufficient for future container storage (3-tier stacking) at the existing port area. However, computer management for container storage will be required with the new container terminals.

(d) Additional Measures to Increase the Efficiency of Port Operation

Additional measures such as the introduction of a computer system and new customs inspection for container handling are required at Tema. These systems are described below:

(i) Introduction of Computer Systems

New computer system for container operation will be installed in the new container terminal and new multipurpose berth. For efficient operation with gantry cranes and transfer cranes, rapid control of their operation is required and this work is difficult to do without computers. Operation control system by computers will be also connected to port EDI system or some system of shipping companies for rapid information exchange for operation control. Yard planning system will be also introduced for efficient control of container inventory and container delivery/receiving. The optimum location plan of containers in the container yard should be decided in consideration of the vessels' calling schedules and the shippers' delivery/receiving schedules.

Following operation works will be done by computer system;

- Vessel Operation（Loading/Discharging Operation Control）
- Gantry Crane Allocation
- Transfer Crane Allocation
- Yard Planning
- Container Inventory Control
- Container Delivery/Receiving Control（Gate Operation）

(ii) Customs Inspection for Container Cargo

Present Customs Inspection is based on the "Destination Inspection Scheme" and all of import containers are opened for inspection. For efficient container handling without long retention in container yards, it is proposed that number of containers subject to mandatory inspection is desirable to be at least less than 10% of all import containers.

24.5.2 Bulk cargo (Clinker)

Volume of clinker being handled at Tema port is increasing. However, bulk vessels for clinker cannot be accommodated at berth 12 with their full draft because of insufficient depth. The deepening of berth 12 will eliminate the need for these vessels to shift berths and also increase handling productivity. For highly bulk cargo handling efficiency, these bulk cargo such as clinker, gypsum are supposed to be handled mainly at the berths 10-12.

From the forecasted volume of bulk cargo in 2010, the required bulk cargo storage area at berth 12 is estimated as shown in Table 24.5.5.

Table 24.5.5 Estimated Storage Area for Bulk Cargoes

Bulk cargo volume		2000	2010	unit
Alumina		301,755	384,950	ton
Clinker, Gypsum		1,113,669	1,402,016	ton
Productivity	Alumina	210	210	ton/hour/vessel
	Clinker	299	350	ton/hour/vessel
Working Day		365	365	day
Cargo throughput in a day	Alumina	827	1,055	ton/day
	Clinker	3,051	3,841	ton/day
Average Dwell Time	Alumina	14	14	day
	Clinker	14	14	day
Estimated Minimum Capacity for Storage	Alumina	11,574	14,765	ton
	Clinker	42,716	53,776	ton
Required Storage Capacity for Storage	Alumina	12,000	15,000	ton
	Clinker	43,000	55,000	ton

24.5.3 Bagged Cargo

Wheat and rice are imported as bagged cargo in Tema port. These cargoes are handled by sling nets or pallets by ship gears. In the case of unloading, palletized cargoes are lifted to the apron by ship gears and then onto the trucks by forklift. But these cargoes are de-palletized by hand on the trucks, which greatly reduces efficiency. These cargoes should be carried with pallet or net and be de-palletized at a shed or another appropriate place. And the same number of extra sling nets or pallets should be prepared for the next loading/unloading at vessels. This system will make the performance of bagged cargo handling better.

At present, bagged cargo is handled at most of berths of Tema port. To increase handling efficiency, bagged cargo handling should be concentrated at berths 6-9. (container cargo handling will be concentrated at berths 1-4 and new container terminals, and bulk cargo handling will be concentrated at berths 10-12.)

To further improve efficiency, the introduction of a three-shift (24 hours) working system is desirable. (At present, handling is only conducted from 7:30 to 18:00.)

From the forecasted volume of bagged cargo in 2010, the required bagged cargo storage area at Tema is estimated as shown in Table 24.5.6.

Table 24.5.6 Estimated Storage Area for Bagged Cargo

Bagged cargo volume	2000	2010	unit
Import	537,752	597,518	ton
Export	104,370	26,891	ton
Total	642,122	624,409	ton
Productivity	60	100	ton/hour/vessel
Working Day	365	365	day
Cargo throughput in a day	1,473	1,637	ton/day
Average Dwell Time	7	7	day
Estimated Minimum Capacity for Storage	10,313	11,459	ton
Estimated Minimum Area for Storage(Shed)	4,125	4,584	m2

24.5.4 Ro/Ro Cargo, General Cargo

Ro/Ro cargo and general cargo are handled at berths 1-11. Berths 1-11 will be more available because the handling efficiency of the other cargo such as container or bulk will be better. The congestion will be expected to decrease and Ro/Ro and general cargo can be handled more efficiently. Ro/Ro vessels usually carry a lot of container cargoes. Container with Ro/Ro should be handled in berths 1-4 in Quay2 with other containers in the same place.

Wheat is also imported as a grain bulk cargo, and is discharged using ship gear, grab bucket and hopper to trucks. These grain bulk wheat is desired to handle at mainly berths 6-9.

24.5.5 Introduction of a Three-Shift Working System and Training System.

Two-shift working schedule for dock workers is now adapted, that is from 7:30 to 19:30 for the 1st shift and from 19:30 to 7:30 for the 2nd shift (with overtime period 17:00 to 19:30 for 1st shift, 3:30 to 7:30 for 2nd shift). It is difficult to realize continuous works under this system. The introduction of a third-shift (for 8 hours) is required to achieve more effective cargo handling by workers. Continuous 24 hours cargo handling needs to be maintained.

To effectively utilize new equipment such as cargo handling machines (gantry crane, transfer crane, etc.) and the computer system for container handling, periodic training for workers is desirable. This will help to prevent accidents as well as enhance the skill level of workers.

24.5.6 Introduction of Port EDI System

Refer to Chapter 15.1.4.

Chapter 25 Structural Design of Main Port Facilities

25.1 Design Requirements and Conditions

25.1.1 Required Facilities of Short Term Development Plan

The following facilities are proposed in the Short Term Development Plan of Tema Port:

Table 25.1.1 Facilities Required in Short Term Development Plan

Facilities	Requirement
1. Breakwater	- Construction of New breakwaters for New Container Terminal · Type I (water depth: -7.0 ~ -15.5m): L = 1,350m (Total) Type IA (water depth: -10.0 ~ -15.5m) Type IB (water depth: -7.0 ~ -10.0m) · Type II (water depth: -5.0 ~ -12.0m): L = 200m
2. Container Berths and Container Yard	- Construction of New container berths: · -14.0m x 300m x 2 berths: Total 600m - Reclamation: Approxi. 28 ha - Revetment: L = 650m
3. Basin and Navigation	- Dredge to -13.0m for New container berths and channel - Navigation Aids: Two (2) lighted buoy, Two (2) light beacons
4. Building & Utilities	- Admin. Office & Gate, Maintenance shop for New Container Terminal, Lighting, etc.
5. Others	- New Port Access Road, Drainage, Yard Paving, Removal of a part of exist. breakwater parapet/wave walls to fit the new container terminal area

25.1.2 Basic Design Conditions

(1) Design Vessels

Table 25.1.2 Design Vessels Specification

Vessel Type	Max .DWT (GT)	Length Overall (m)	Breadth (m)	Max. Draft (m)	Remarks
Container ship	35, 000	260	32.0	12.0	Container wharf
Bulk carrier	30, 000	185	27.5	11.0	Valco berth
General cargo ship	30, 000	185	27.5	11.0	Valco Berth
Oil Tanker	30, 000	180	29.2	10.9	Oil Berth

(2) Marine Conditions

- Tidal Conditions :Design High Water Level (H.W.L);CD + 1.60
  :Design Low Water Level (L.W.L); CD ± 0.00
- Design Waves (50 years return period waves)

Table 25.1.3 Design Waves

Wave Characteristics	Deep Water Wave Direction				
	SW	S	SE	E	All direction
Deep Water Wave Ho (m) To (sec)	5.10 9~11	5.40 9~11	4.80 9~11	4.40 5~9	5.00 9~11
Lo (m)	126.4 - 188.8			39.0 – 126.4	126.4 – 188.8
Design Waves At-15.0 m water depth $H^1/_3$(m)	3.70	4.40	4.40	3.80	4.00
$T\ ^1/_3$ (sec)	9~11			5~9	9~11

- Design Max. Current Velocity : 1.0 m/sec

(3) Subsoil Conditions

Table 25.1.4 Subsoil Conditions

Location	Micaseous Quarts or Design Parameters of Subsoil
New Container Terminal Area	Granitic Gneiss Unit Weight : 25.0 KN/m^3 Compressive Strength : 10 to 50 MPa
Exist. Port Area	Granitic Gneiss Unit Weight : 26.0 KN/m^3 Compressive Strength : Over 200 MPa

(4) Seismic Force Coefficient : 0.15

(5) External Forces

- Tractive forces of ships Container Ship (35,000 DWT) ; 2,000 KN
  Bulk carrier/General
  Cargo Ships/Oil Tanker (30,000 DWT); 1,500 KN

- Crane Load and Surcharge

Load	Normal Condition	Seismic Condition
Crane Load	400 KN/Wheel	400 KN/Wheel
Surcharge	20 KN/m^2	10 KN/m^2

25.2 Breakwater

In other to obtain the required calmness level for the planned new container berth, a total 1,550m long breakwater is to be provided. A preliminary design has been carried out under the design conditions specified in 25.2.1, and the required rock sizes of seaward side armor layers have been determined.

The typical cross section of the breakwater is indicated in Figure25.2.1.

25.2.1. Design Conditions

		Type I (IA)	Type IB/II
(1) Design Wave	:	$H^1/_3$ = 4.4m (50 years return period)	$H^1/_3$ = 3.8m
	:	$T^1/_3$ = 9~11 sec.	$T^1/_3$ = 5~9 sec.
	:	Lo = 1.56 T^2 = 126.4~188.8 m	Lo = 39.0 ~ 126.4m
(2) Structural Type	:	Rubble Mound Type	Rubble Mound Type

(3) Dimensions of Breakwater

- Crest Height : CD. + 5.0 m
- Crest Width : 10.0 m
- Slope

	Above CD - 6.0^m (-5.0m)	Below CD - 6.0^m (-5.0m)
Seaward Side	1 : 2	1 : 1.5
Lee Side	1 : 1.5	1 : 1.5

25.2.2 Armor Rock Sizes

The desirable size of seaward armor is determined using the following Hudson Formula;

$$W = \frac{WrH^3}{K_D\,(Sr - 1)^3 \cot\alpha}$$

Where;

W : Minimum weight of rock (tons)
Wr : Unit weight of rock in air (t/m3).
Sr : Relative mass density of rock (relative to seawater)
α : Angle of the slope to horizontal plane
H : Significant wave height H1/3 at the water depth where the structure is constructed (m)
K_D : Stability coefficient

When, Wr = 2.60 tf/ m^3, cot α = 2,
K_D = 2.4~4.0 (Under damage rate 0-5%) are used;

The desirable minimum rock weight is as follows;

Type IA: 8.0~13.0 tf/pcs ($H^1/_3$ = 4.4m)
Type IB/II: 5.0~10.0 tf/pcs ($H^1/_3$ = 3.8m)

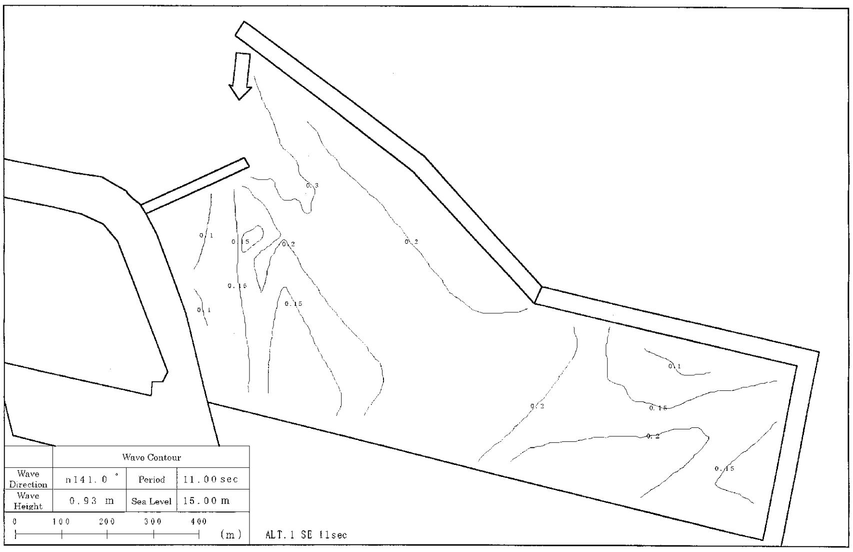
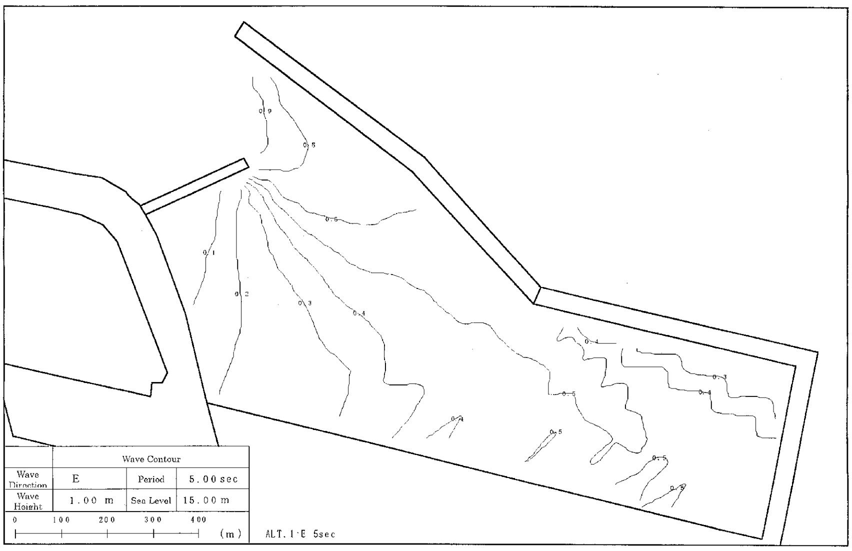
It is therefore recommended to use 10.0~15.0 tf/pcs size rock for the primary armor of Type IA Breakwater and 5.0~10.0 tf/pcs for Type IB and Type II.

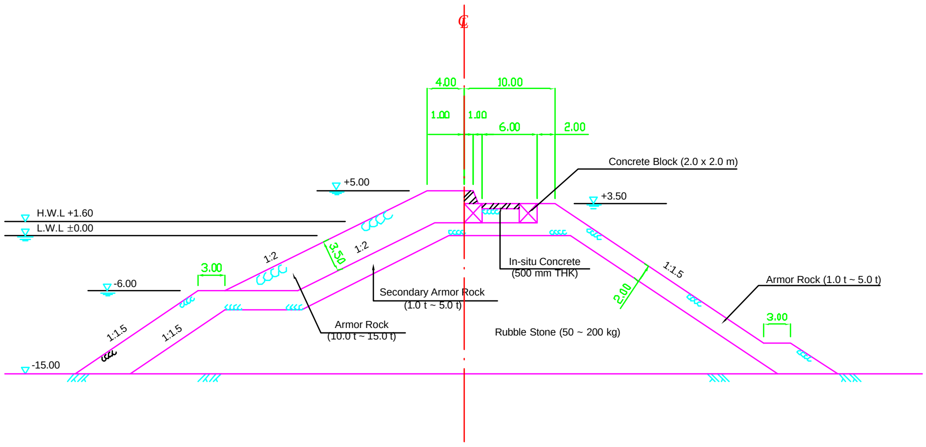
25.2.3 Calmness Ratio Analysis

A calmness ratio analysis has been carried out to examine the workability of the New Container berth under the planned port layout. The calmness ratio estimated at New Container Berth with the provision of 1,550m breakwater is at least 98% under operative wave height limit at 0.5m, which is acceptable for container cargo handling.

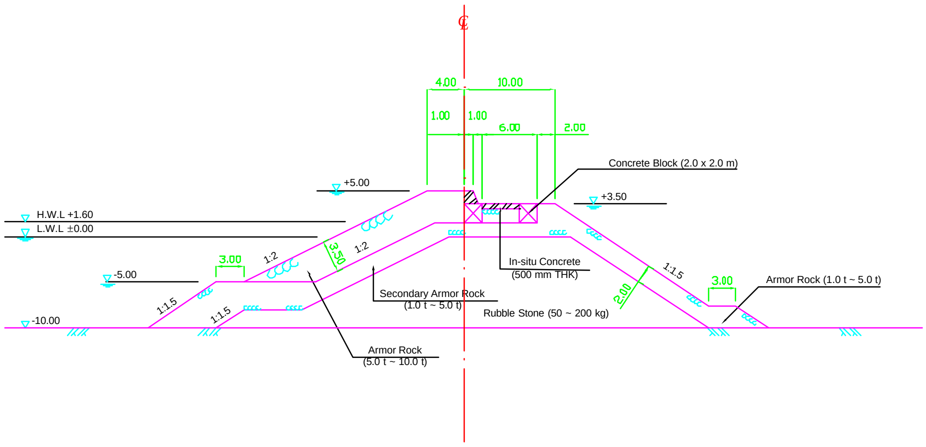
The wave height ratio obtained from the analysis is indicated in Table 25.2.1.

Table 25.2.1 Wave Height Ratio at New Container Berth

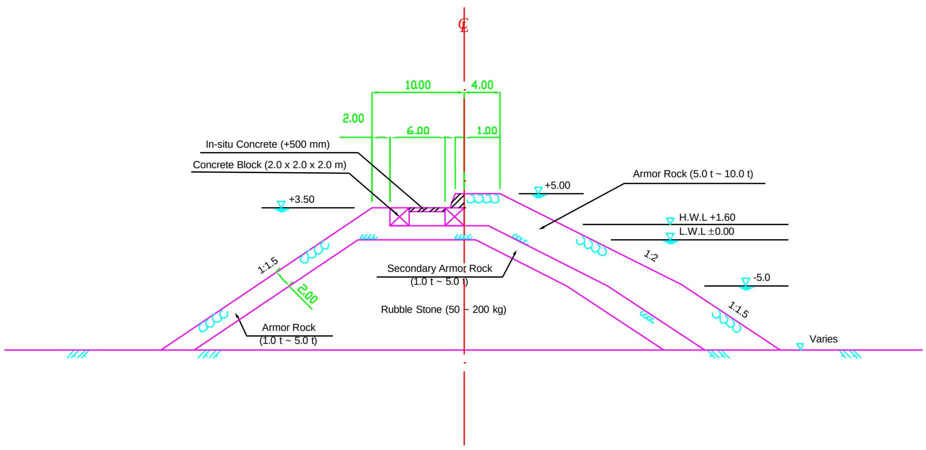
<table>
<tr><th>Design Wave</th><th>Wave Height Rate</th></tr>
<tr><td>Wave Height : 4.40 m
Direction : SE
Period : 9 ~ 11sec
Height Ratio : 0.126 ~ 0.132</td><td>
</td></tr>
<tr><td>Wave Height : 3.80 m
Direction : E
Period : 5 ~ 9sec
Height Ratio : 0.532 ~ 0.461</td><td>
</td></tr>
</table>



Type I-A (-10.0 m and Over)



Type I-B (Less -10.0 m)



Type II (-5.0 ~ -12.0 m)

Fig. 25.2.1 Typical Section of Breakwater

25.3 New Container Berth

In the Short-Term Development Plan, the required water depth is -13.0m (objective vessel: 35,000 DWT). It is however considered in the design of the berth to accommodate future vessel size of 50,000 DWT container ship (required water depth -14.0m).

25.3.1 Design Conditions

(1) Structural Type : R.C. Caisson

(2) Design Vessels and Sectional Dimensions

Table 25.3.1 Design Vessels and Sectional Dimensions

Design Vessel	Container Ship 50,000 DWT
Water Depth	- 14.0 m
Deck Elevation	C.D. + 3.30
Apron Width	50 m
Exist. Seabed Level	C.D. -5.0~-7.5 m

(3) Subsoil Conditions

Seabed : Rock (Compression Strength Less than 50 MPa),
Back-fill : Quarry-run (Unit weight 19.6 KN/m^3)

(4) External Forces

The following external forces are considered in the design;

Table 25.3.2 Loading Conditions of External Forces

	Dead Load	Crane Load	Surcharge	Tractive force	Earth pressure	Seismic force
Normal Condition	O	O	O	O	O	N.A
Seismic Condition	O O	O X	O (1/2) X	N.A N.A	O O	O O

Note; O: to be considered, X: not considered, N.A: not applicable

25.3.2 Structural Design of New Wharf / Berth

Using the above design conditions, a preliminary design has been carried out and the following basic dimensions of the R.C. caisson unit for New Container Berth are recommended.

Location	Length(m)	Width (m)	Height (m)	Weight per Unit (tf)
Container Berth (-14.0 ^{m})	20.0	11.0 (13.0)	15.0	1,800

Note; Figures in parenthesis indicate bottom widths.

The examination results on the stability are as shown in Table 25.3.3.

Table 25.3.3 Stability Examination Results

Item	Normal	Seismic
Sliding	S.F=1.99	S.F=1.11
Over-turning	S.F=1.62	S.F=1.30
Bottom bearing Pressure	420 KN/m^2	690 KN/m^2

The examination conditions used in the design are as follows;

(1) Stability of Structure ;

(a) Safety factor for sliding, which expressed by the following equation is not less than 1.2 and 1.0 under normal condition and seismic case respectively.

$$S.F. = \frac{\mu (W-U)}{P}$$

(b) Safety factor for overturning is not less than 1.2 and 1.0 under normal condition and seismic condition respectively.

$$S.F. = \frac{W t - Mu}{Mp}$$

Where,
- P : Total Horizontal Force
- W : Total vertical load of structure
- U : Total up-lift force
- μ : Coefficient of friction
- t : Arm length of gravity center from the heel of the caisson.
- Mu : Moment of up-lift pressure
- Mp : Total moment of horizontal force

(2) Bearing Capacity of Foundation

Allowable bearing capacity of foundation used in the design is as follows:
- Normal condition : Not more than 500 KN / m^2
- Seismic condition : Not more than 700 KN / m^2

Based on the results of the preliminary design, the recommended structural section is shown in Figure 25.3.1.

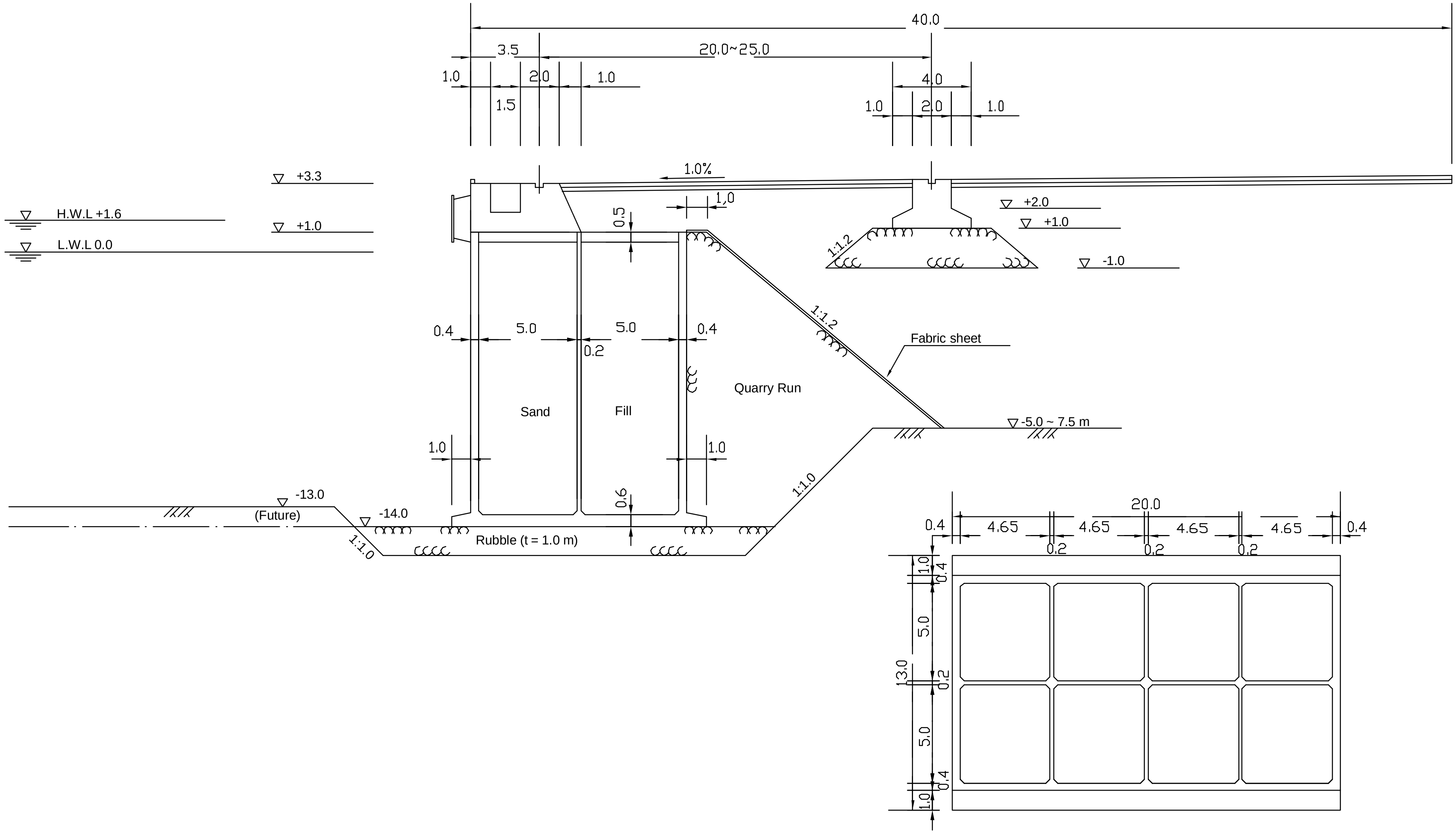


Figure 25.3.1 Typical Section of New Container Berth (-14.0m)

25. 4 Revetment

A 650m long revetment is to be provided to form the reclaimed land area for the new container terminal. The water depth along the planned reclamation line ranges from ±0.0 to -7.5m below C.D.

The planned location of the revetment is exposed to a severe wave conditions, it is therefore necessary to be designed to function as a sort of breakwater especially at the places where its water depth exceeds C.D -5.0m.

The proposed design section of the revetment (less than C.D. -5.0m) is shown in Figure 25.5.1. The revetment located at water depth deeper than -5.0m should be constructed with the similar design used for Breakwater Type II.

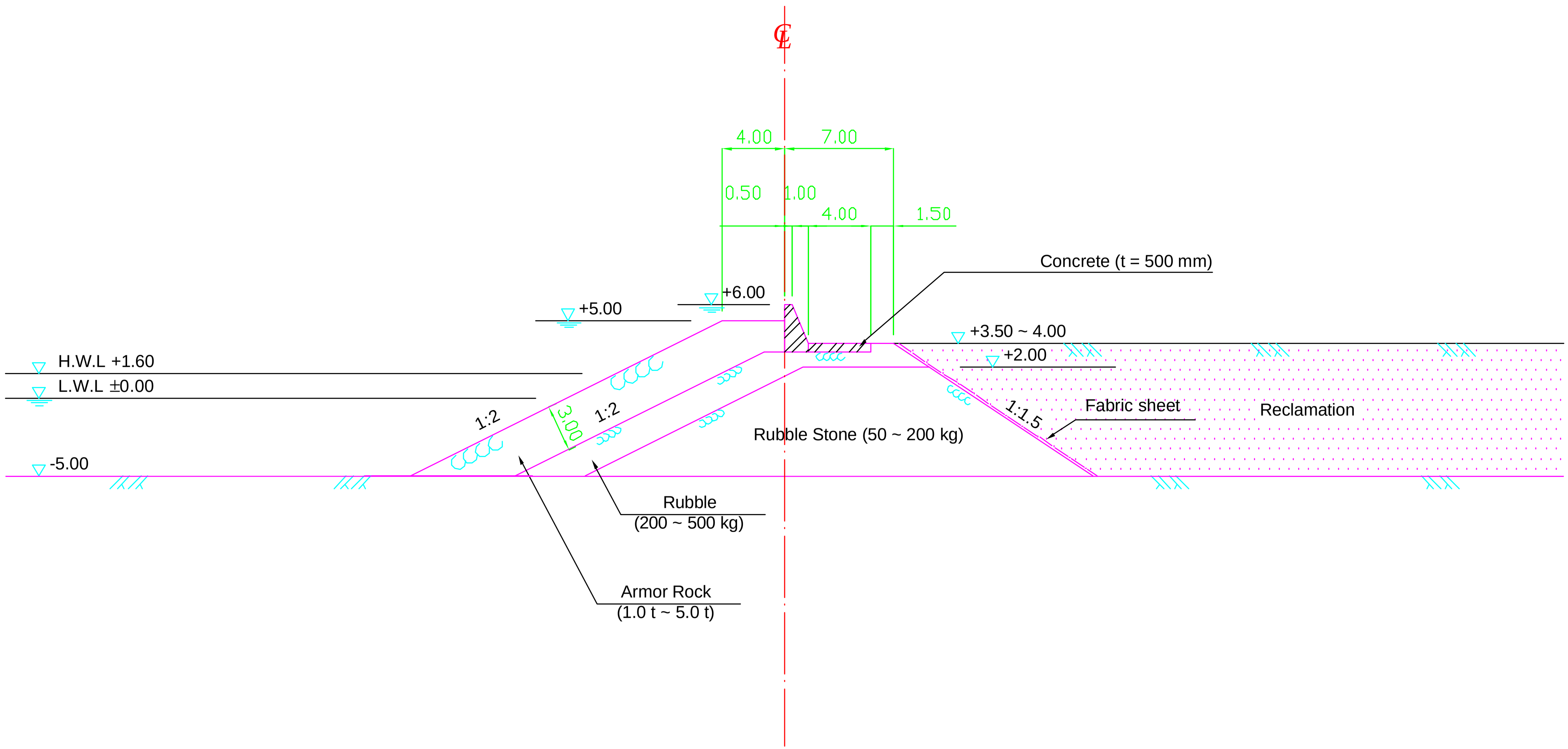


Fig. 25.4.1 Typical Section of Revetment