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An Introduction to The Terminal Layouts & Design Procedure of Liquid Bulk Terminal

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Chen

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ABSTRACT: <p>In recent years, the government encourages the private sectors to make their investment in construction of the port facilities, and many petrochemical competitors are dedicated to the construction of the liquid bulk terminal. Liquid bulk includes not only the petrochemical raw material but also the chemical products with low danger, such as grease of the livestock and harmless raw material of food. Each kind of liquid bulk has different demand on the terminal facilities and standard of safety. The main purpose of this study is to develop a standard procedure for the layout and structure design of the liquid bulk terminal.</p> <p>The liquid bulk terminal could be divided into Apron and the tank farm. The main facilities in the Apron include wharf structure, loading/unloading facilities and fire fighting facilities, etc., and the relative facilities in the tank farm include storage tank, impounding dike, roads, filling plant, management center, fire fighting facilities, parking lots and detention pond of sewage water, etc. Base area, berthing ship, operating style, the varieties and capacity of the liquid bulk, regulations of fire fighting and environmental factors are the key factors for the layout of the liquid bulk terminal. This study focuses on the analysis of the factors mentioned above, and analyzes the annual capacity and the demand of land area for the general liquid bulk terminal. The dimensions of the general liquid bulk terminal are also proposed for the references of the planner.</p> <p>In the design of the liquid bulk terminal structures, structural safety should be the first priority and some special considerations which are the space preservation for pipeline, the loading on the wharf structure, installation of the loading/unloading arm, large variation on the berthing vessels, fire fighting and illumination requirement, prevention of environmental pollution and prevention of settlement in the storage tank zone, etc. should also be taken. After evaluation, gravity type, sheet pile, trestle type, dolphin, and mooring buoy are regarded as suitable structure types for liquid bulk terminal. The flowcharts and checklists for the design work of these five structure types of berths are given in the report as references for the design and review work.</p>			
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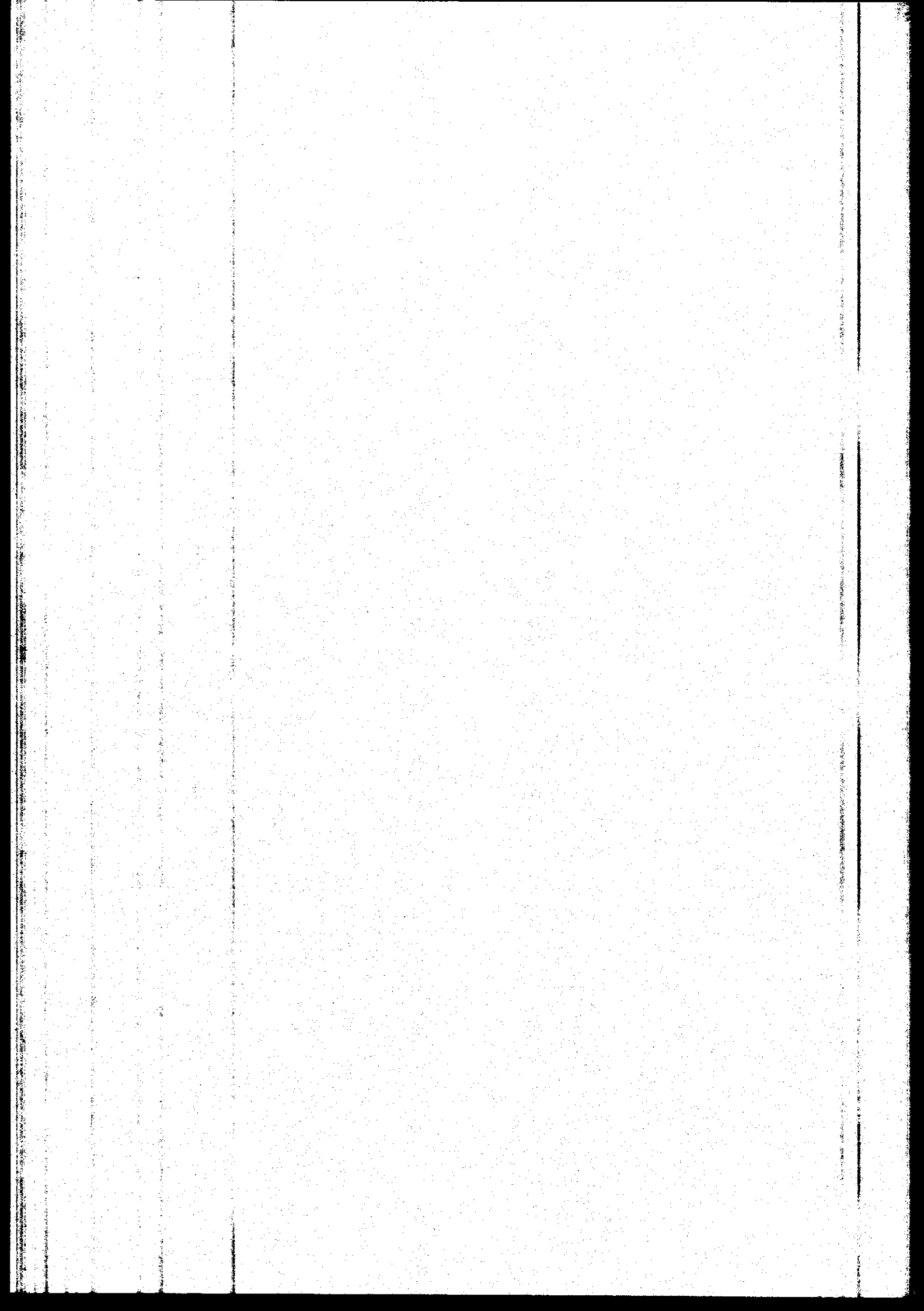
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1. Preface

1.1 Preface

Petrochemical industry is a technology and capital-intensive industry. In the past, most of the naphtha refineries were built near the sources of crude oil. But more and more new refineries are established near the consumer-concentrated area in consideration of the reduction in the material handling cost. Therefore, the naphtha refinery may set up the distribution or transportation center in the appropriate port in order to transfer the petrochemical raw material and products conveniently at a lower transportation cost. In the future, it is expected that demand of liquid bulk terminal will increase substantially.

In recent years, the government encourages the private sectors to make their investment in construction of the port facilities, so petrochemical refinery owners make investment in the construction of the port facilities in order to catch up the trend of market development. Because of the dangerous characteristics of the petrochemical raw material and products, special considerations should be given in the design of the terminal and storage facilities.

Liquid bulk includes not only the petrochemical raw material but also the chemical products with low danger, such as grease of the livestock and harmless raw material of food. Every kind of liquid bulk has different demand on the terminal facilities and standard of safety.

This study focuses on the planning of the related facilities in liquid bulk terminal and establishes a universal standard procedure for terminal design and planning to reduce the problems occurred during the loading and unloading operation of the terminal. The purposes of this study are aimed to increase the working efficiency of the

terminal and strengthen the safety of terminal.

The objectives of the study are as follows:

Terminal layout:

- ◆ Analysis on the characteristics of the liquid bulk carrier
- ◆ Analysis on the loading and unloading characteristics of the liquid bulk terminal
- ◆ Analysis on the layout of tank farm of liquid bulk terminal
- ◆ Evaluation on the capacity of the liquid bulk terminal and the demand of land area

Design of terminal structure:

- ◆ Establishing the standard design procedure of the liquid bulk terminal facilities
- ◆ Analyzing the force and loading on the liquid bulk terminal facilities
- ◆ Advising the details of the facilities layout for liquid bulk terminal.
- ◆ Establishing the checking lists for design of the liquid bulk terminal

1.2 Flowchart of the study

The flowchart of this study is shown as Fig 1-1.

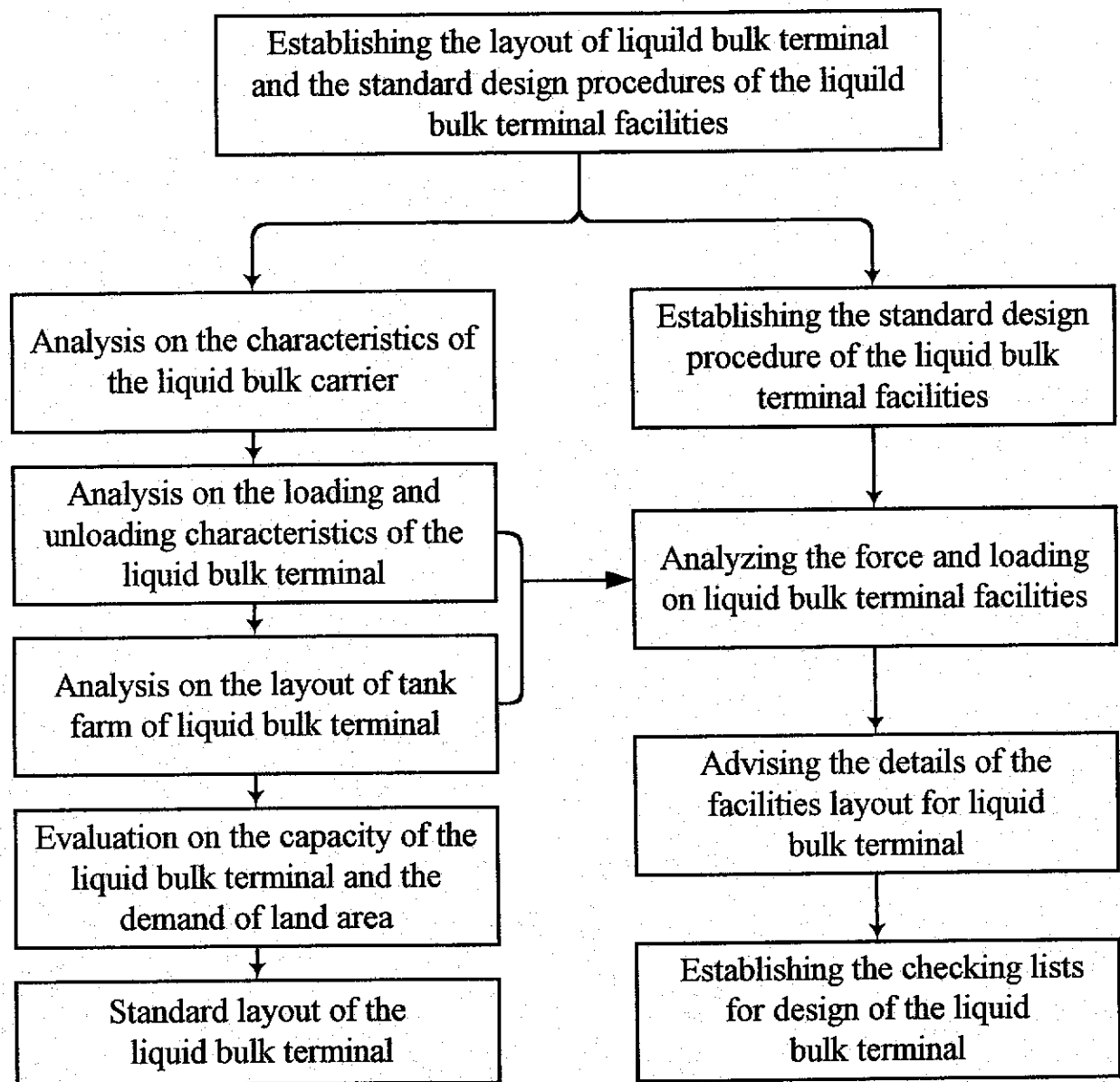


Fig 1-1 Flowchart of the study

2. Analysis on the characteristic of the liquid bulk carrier

2.1 Classification of the liquid bulk

2.1.1 Classified by the carrier

There are many kinds of the liquid bulk and they could be classified by their carriers as follows:

- ◆ Liquefied natural gas (LNG)
- ◆ Liquefied petroleum gas (LPG)
- ◆ Crude oil
- ◆ Oil products
- ◆ General liquid bulk

The characteristics of each type of liquid bulk are described as follows:

(1) Liquefied Natural Gas (LNG)

LNG is natural gas that has been purified and liquefied by extremely low temperature -160°C . The volume of liquefied natural gas could be reduced to 1/625 of its gas form so it could be transported and stored in liquid form. The liquefied natural gas consists of methane, ethylene, propane and a few of butane, hydrogen. Only water vapor, carbon dioxide and non-harmful gas are generated after the burning of natural gas so it is considered as the cleanest commercial fuel in the world.

The characteristics of the liquefied natural gas are shown as follows:

- Liquefied natural gas is lighter than water, its specific gravity is 0.47 (water is 1).
- Natural gas is lighter than air, its specific gravity is 0.68 (air is 1).
- LNG diffuses pretty fast once leakage is detected, so it is safer relatively.
- Natural gas burning density (the mixture percentage to air)

is 4.5% ~ 15%, so natural gas burns completely.

Liquefied natural gas is transported by special carries that could be classified by the shape of the tank into two categories, one is Moss-Rosenberg spherical tank (see Fig 2-1) and the other is Gax-Transport Membrane tank (see Fig 2-2). Spherical tank is subject to higher wind force than Membrane tank with the same loading capacity due to larger area against the wind.

Due to its shallow draught and higher freeboard, LNG carrier have more restrictions during the berthing and loading / unloading operation.

(2) Liquefied Petroleum Gas (LPG)

Liquefied petroleum gas was refined from the crude oil, and around 71% of the local consumption of LPG is for family use in the form of high pressure steel bottle.

LPG and LNG are different in manufacturing procedure, main chemical components, temperature, density and stability. LPG consists of propane butane and it is transparent and tasteless. If LPG leaks away, it may cause serious damage, so stinker is added into LPG to remind people of such case.

The pictures of LPG carrier are shown on Fig 2-3.

(3) Crude oil

Crude oil is the basic raw material of all petrochemical products. Base on the considerations of economic of transportation, most crude oil is carried by very large vessel. The picture of crude oil carrier is shown on Fig 2-4.

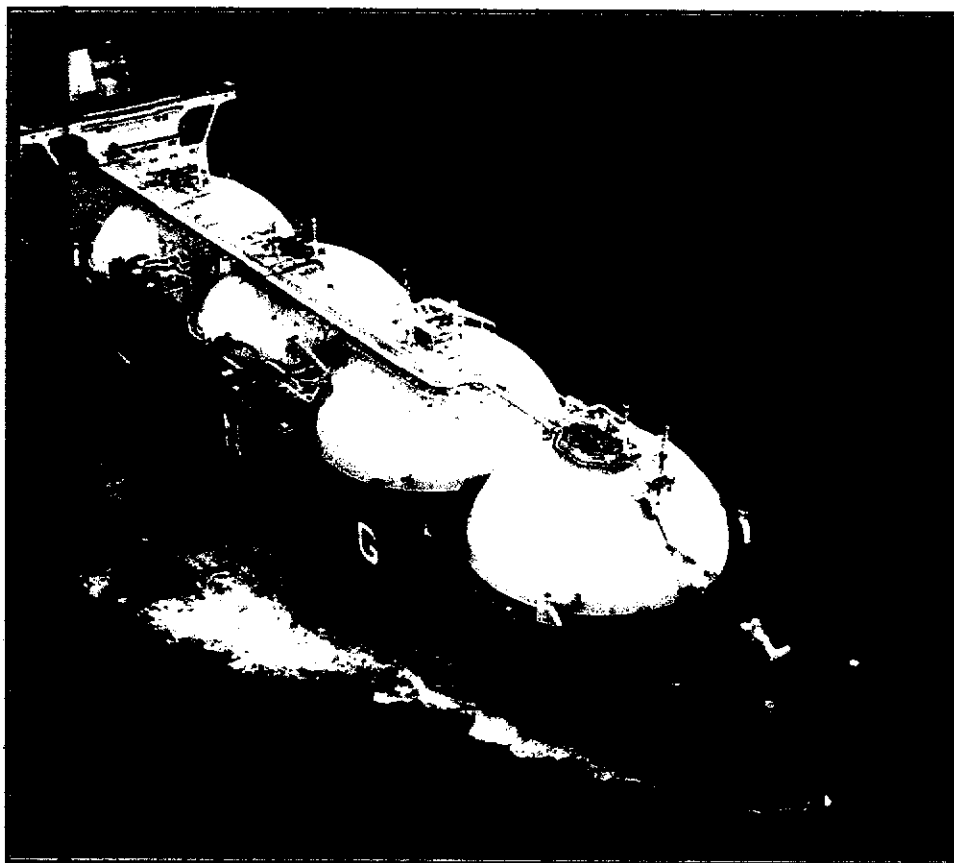


Fig 2-1 Liquid natural gas carrier with spherical tank



Fig 2-2 Liquid natural gas carrier with Membrane tank

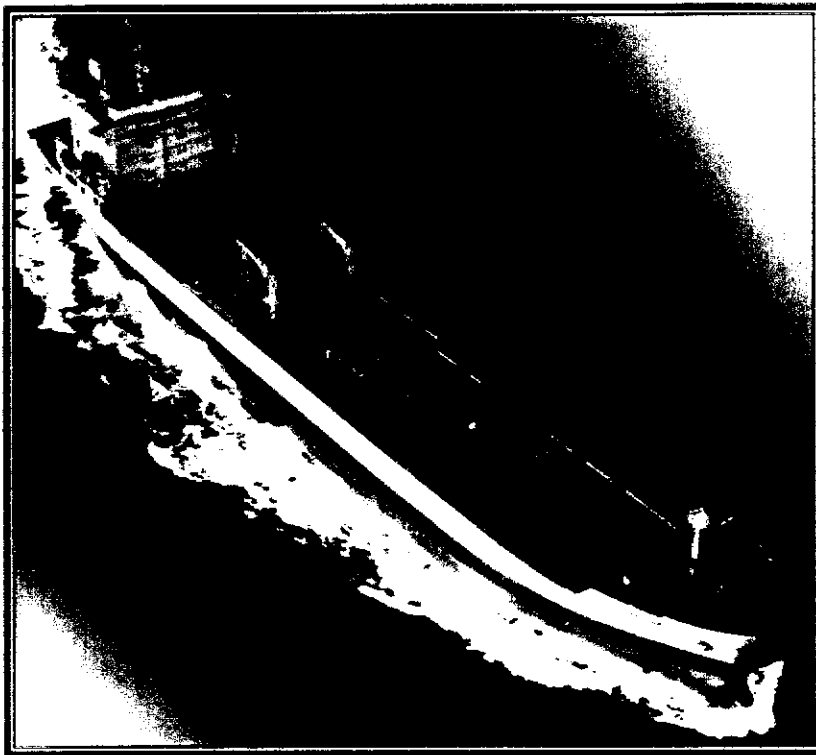


Fig 2-3 LPG carrier



Fig 2-4 Crude oil carrier

(4) Oil products

Oil products are part of petrochemical products, including gasoline, diesel and fuel oil. In consideration of higher consumption rate, transportation cost and capacity of the storage tank, larger carrier than the average liquid bulk carrier ships the oil products. The major type of the oil product carrier is handymax carrier (shown on Fig.2-5).

(5) General liquid bulk

General liquid bulk includes chemical products, raw material of food, organic chemical products, inorganic chemical products, and grease, etc. Organic chemical products are the major types of oil products and the raw material of food includes cooking oil and molasses, etc. Ordinary liquid bulk carriers are shown on Fig 2-6 and Fig 2-7.

2.1.2 Classified by the danger of liquid bulk

Liquid bulk can be classified as danger cargo and non-danger cargo. Danger cargo is classified into 9 classes according to CNS 6864 25071. Most of liquid bulk is classified as danger cargo except raw material of food and grease, etc.

2.2 Analysis on liquid bulk carrier

2.2.1 Analysis on size of carrier

According to IAPH classification, the standard sizes of crude oil carrier, oil product carrier and bulk carrier are shown on table 2.1. In most case, crude oil is loaded / unloaded by the offshore facilities. In order to have an economic transportation cost, crude oil is transported by the carrier with larger tonnage.

LPG berth usually separates for other berth, but sometime it is

adjunctive to the chemical product berth. Sizes of LPG carriers are shown on Table 2.2.

Most LNG carriers use the dedicated berth for loading / unloading of LNG. Sizes of LNG carriers are shown on Table 2.3. The draughts of the LNG carriers are shallower than the bulk carriers with the same loading capacity, due to the reason that the specific gravity of LNG is only 0.45. The possible sizes of the LNG carriers in the future are shown on Table 2.4. According to the table, with the increase of the loading capacity, the draught and width of the carrier don't have an obviously change except the Kvaerner Masa-Yards.

2.2.2 The transportation development of the chemical product carriers

(1) Sea-borne volume of global chemical product and total tonnage of ship

Chemical products include organic chemical products, inorganic chemical products, grease, etc. And organic chemical products are the major part of the chemical products.

The total volume of the global chemical products transportation is 90.4 millions ton in 1990 which is about 5.1% of the sea-borne petroleum transportation 1788.8 million tons.

During 1985~1995, the weight of the chemical transportation increased more than 50%. However the total tonnage of the global chemical products carriers didn't increase with the transportation volume. During 1985~1995, the tonnage of the chemical products carriers increased about 43%.

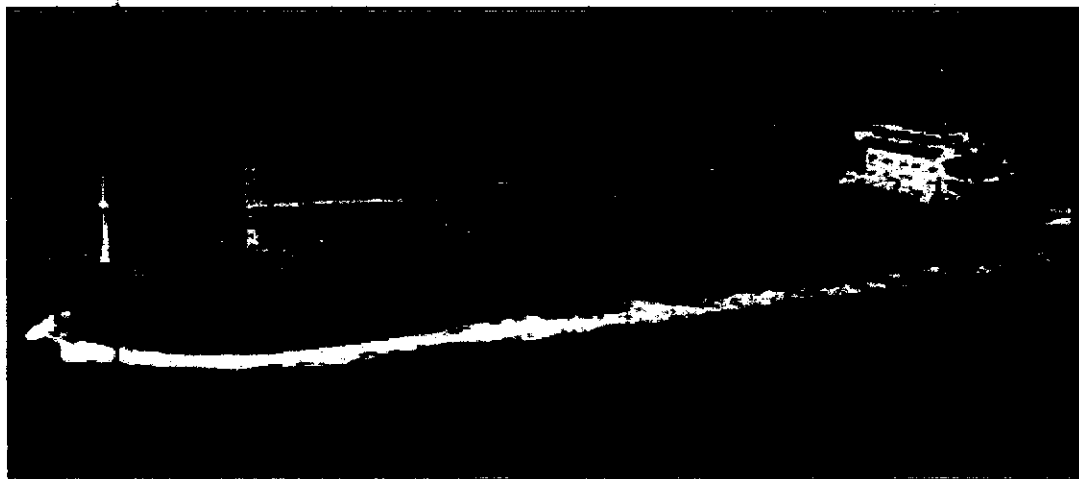


Fig 2-5 Handymax liquid bulk carrier



Fig 2-6 General liquid bulk carrier (I)

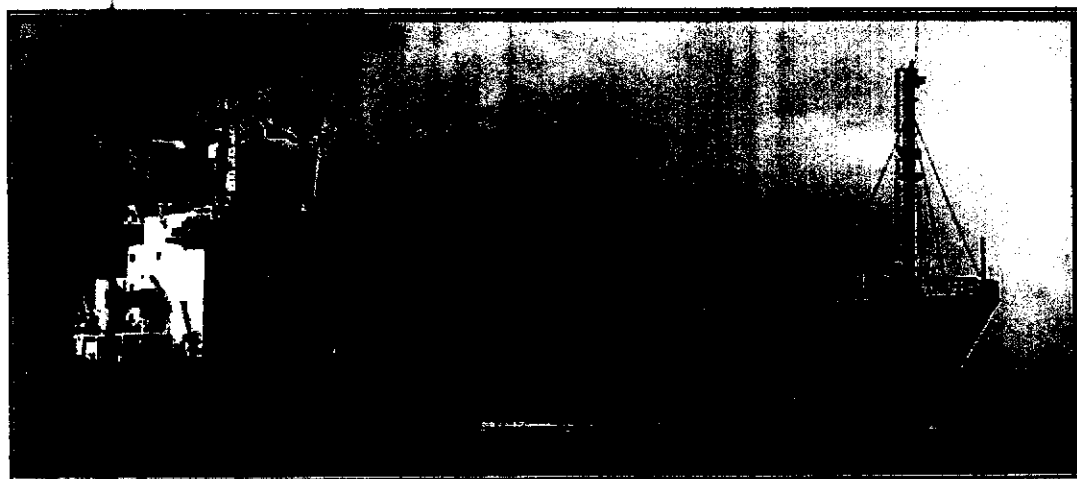


Fig 2-7 General liquid bulk carrier (II)

Table 2.1 The standard sizes of all types of carriers

Types	DWT	Displacement(ton)	Length (M)	Width (M)	Draught (M)
Oil carrier	310,000	-	332.9	58.0	-
	250,000	-	338.0	51.8	20.6
	175,000	217,000	300.0	52.5	17.7
	150,000	186,000	285.0	49.5	16.9
	125,000	156,000	270.0	46.5	16.0
	100,000	125,000	250.0	43.0	15.1
	80,000	102,000	235.0	40.0	14.0
	70,000	90,000	225.0	38.0	13.0
Oil Products Carrier	60,000	78,000	217.0	36.0	13.0
	50,000	66,000	210.0	32.2	12.6
	40,000	54,000	200.0	30.0	11.8
	30,000	42,000	188.0	28.0	10.8
	20,000	29,000	174.0	24.5	9.8
	10,000	15,000	145.0	19.0	7.8
	5,000	8,000	110.0	15.0	7.0
Bulk carrier	3,000	4,900	90.0	13.0	6.0
	60,000	74,000	220.0	33.5	12.8
	40,000	50,000	195.0	29.0	11.5
	20,000	26,000	160.0	23.5	9.3
	10,000	13,000	130.0	18.0	7.5

Data source : Approach Channels A Guide for Design, IAPH (1997)

Table 2.2 The sizes of LPG carriers

Capacity(M ³)	DWT	Length		Width (M)	Draught (M)
		LOA(M)	LBP(M)		
100,000	-	-	234	39.9	12.7
81,000	-	-	216	35.5	13.7
-	50,743	230	219	36.6	10.6
-	50,000	-	214	36.0	11.5
-	49,999	-	209	36.0	11.6
-	47,000	224	-	34.0	12.0
-	30,900	-	174.2	30.0	11.5

Table 2.3 The sizes of LNG carriers

Capacity (M ³)	Length (M)	Width (M)	Draught (M)
137,000	276.0	46.0	10.8
137,000	290.0	46.0	10.8
136,400	290.0	46.0	10.8
135,000	290.0	48.1	11.3
130,000	280.1	41.6	11.0
130,000	268.0	43.0	11.0
125,800	287.5	43.3	11.0
125,000	272.0	47.0	11.4
125,000	285.0	44.0	11.5
125,000	293.0	41.6	11.5
125,000	270.4	42.7	11.0
125,000	270.0	44.8	11.5
125,000	275.0	42.6	12.9
125,000	266.0	41.6	11.0
125,000*	284.1	42.7	11.0
125,000*	275.0	42.6	12.9
125,000*	266.0	41.6	11.0

Table 2.4 The sizes of the future LNG carriers

Capacity (M ³)	Length (M)	Width (M)	Draught (M)	Remark(data source)
168,000	330	48.1	11.2	Kvaerner Masa-Yards(Finland)
163,700*	292	45.2	11.6	Gaztransport & Technigaz
160,000	312	45.5	12.5	Feasibility Report, Port Facilities at Ras Laffan, Qatar
160,000	283	42.2	11.9	Gaztransport & Technigaz

The change of the market demand causes this situation. Taking organic chemical products, the major part of the chemical products, as the example, after the world economy revives from first and second oil crisis, the demand of the petrochemical products gets higher and higher and the demand of the carrier also gets stronger around the world. During 1980~1986, the total tonnage of the new-built ship is 7.10 million tons that is equal to 46% of the total tonnage of chemical products carrier in 1980. After the peak development of the world economy, the demand of the chemical product carrier shrank with the world economic. The prosperity cycle of the market is the major reason affecting the transportation of the liquid bulk.

(2) Distribution of the tonnage of the chemical products carrier

According to statistic from ISL Germany, the total number of the chemical products carrier is 1317 in the world and the total tonnage of the chemical products carrier is 8.38 million ton, the distribution of the range of the tonnage are shown on Table 2.5. The tonnage of most carriers is below 80,000 tons and the average tonnage of the carrier is 6,363 tons.

Table 2.5 The dead weight tonnage of chemical product carriers

DWT	Number	Total DWT
- 4,999	915	1,583,000
5,000 - 9,999	187	1,368,000
10,000 - 39,999	205	4,976,000
40,000 - 79,999	10	453,000
Sum	1,317	8,380,000

2.2.3 Typical carriers of each chemical product

The sizes of the liquid bulk carriers range from VLCC to 2000 ton, the typical sizes of specific product carriers are shown on Table 2.6.

Table 2.6 The typical sizes of liquid bulk carriers

Liquid bulk	DWT range	Typical DWT	Size (L x B x Draft)	Remark
Crude oil	100,000~250,000	250,000	338x51.8x20.6	Suezmax
LNG	60,000~168,000M ³	135,000 M ³	290x48.1x11.3	
LPG	4,000~125,000 M ³	87,000 M ³	235x36.6x10.6	
Oil products	3,000~60,000	40,000	210x32.2x12.6	Handymax
Chemical products	3,000~60,000	5,000	110x15.0x7.0	
General liquid bulk	3,000~60,000	5,000	145x19.0x7.8	

2.2.4 Demand of the berth length and water depth

In order to satisfy the berthing demand of the design ship, the berth should be designed in consideration of the types, tonnage, draught of the vessel, some allowance should be provided to absorb the silt of the berth.

The water depth should deeper than 1.1 times the maximum draught plus the possible allowance for silt.

2.3 Transportation of liquid bulk in Taiwan

2.3.1 The liquid bulk berth in Taiwan

As mentioned above, crude oil is unloaded by the offshore mooring buoy. Chinese Petroleum Company (CPC) has such facilities in Kaohsiung and Taoyuan. And CPC also owns LPG terminal and LNG receiving terminal in Sen-au and Yung-an. The liquid bulk terminals within the international ports in Taiwan are shown on

Table 2.7.

2.3.2 Annual loading and unloading capacity of the liquid bulk terminal

CPC imports the liquid bulk in dedicated terminals, other companies unload the liquid bulk in the international ports in Taiwan. Mi-Liau industrial port of Formosa Plastics Group had started business operation; the main loading and unloading cargo is petrochemical raw material and products. Kuan-Tan industrial port of Duntex Group has passed the Environmental Impact Access (EIA) and start to design, the loading and unloading cargo will include LNG, LPG, oil products, etc..

CPC imported 23.9 million barrels crude oil and 3.98 million tons LNG in 1998. The annual loading and unloading capacity of liquid bulk in other ports in Taiwan are shown on Table 2.8.

Table 2.7 The liquid bulk facilities of the international ports in Taiwan

Port	Terminal code	Length (M)	Depth (M)	Remark
Keelung	West 33	210	-11.5	Oil products terminal
	West 33B	95.8	-6.5	Oil products terminal
Taichung	#2	250	-13	
	#3	250	-13	42 storage tanks
	#4	200	-11	54 storage tanks
	West 1	250	-13	40 storage tanks
	West 2	250	-14	71 storage tanks
	West 3	250	-14	8 storage tanks
	West 4			
	West 5	250	-14	
Kaohsiung	#27	222.3	-9.8~-11.3	Area 6,357.69M ²
	#28	235.97	-10.8~-11.9	Area 2,116.89M ²
	#29	149.91	-10.5~-11.7	Area 6,611M ²
	#56	200	-10.5	
	#57	183.6	-10.5	
	#59	164	-2.0~-10.5	
	#60	150.75	-5.6~-7.0	Area 127,490M ²
	#61	230	-10.6~-11.5	Area 127,490M ²
	#62	230	-10.2~-11.5	Area 127,490M ²
	#103	270	-9.1~-11.6	
	#104	251.67	-14.1~-16.5	
	#105	300.17	-13.5~-15.9	
Hualien	#4	160	-8.5	
	#19	310	-14	

Table 2.8 Annual throughout of liquid bulk of the international ports in Taiwan

Year	Keelung	Taichung	Kaohsiung	Hualien
1990	3,422,569	5,588,210	26,163,923	443,076
1991	4,070,368	8,191,678	24,056,568	329,014
1992	3,674,434	8,358,367	26,391,874	358,157
1993	4,849,885	8,765,307	24,739,279	296,400
1994	5,036,786	10,188,388	25,326,098	401,860
1995	4,662,078	12,166,526	25,325,600	399,400
1996	3,987,817	12,935,491	31,881,241	357,353
1997	3,979,022	11,756,850	36,658,749	431,901
1998	4,365,749	11,992,067	39,534,513	460,920

Remark : unit : ton

2.3.3 Analysis on loading and unloading capacity of liquid bulk in single voyage

Crude oil carrier, LNG carrier and LPG carrier carries only one single type of cargo in each shipment, so transportation capacity in each voyage is close to the maximum transportation capacity of each carrier. The transportation capacity of other liquid bulk carriers is more much complicate than the dedicated carriers.

According to the statistic of port of Taichung, the single shipping volume of most chemical carriers are less than 5,000 ton. The volume of each shipment is strongly affected by the market demand and capacity of the tank farm.

2.3.4 Evaluating the future transportation capacity of liquid bulk in Taiwan

A large portion of the import / export liquid bulk except petrochemical products, grease of the livings and raw material of food in Taiwan are transported by CPC. The market of petroleum products will be liberalized by the government, CPC will be privatized in the near future. The No. 6 naphtha cracking plant of

Formosa Plastics Group (FPG) will become competitor of CPC in the future.

The No. 6 naphtha cracking plant of FPG has an industrial port itself. The cost of transportation and storage will be the lowest in Taiwan petrochemical product market. It will be a threat to the market now controlled by CPC.

After the liberalization the petrochemical products market, CPC, FPG and import traders will compete severely in the local market and it will have great influence in the demand of liquid bulk terminal.

After the No. 6 naphtha cracking plant of FPG starts operation, the capacity of oil refineries in Taiwan will be more than 40 million tons per year. This manufacturing capacity is far more than the demand in Taiwan. Although oil products of FPG can export to foreign market directly from Mi-Liau industrial port, but distribution of oil products in Taiwan also rely on sea-borne transportation around the island. Evaluation of the transportation capacity of oil products in the future in Taiwan is as follows:

- ◆ The oil refine capacity in Taiwan are over 40 million tons per year, and more than 10 million tons petrochemical products have to be exported to foreign market.
- ◆ After the government allows the import of oil products, the local oil refineries could not force every sale spot to sell their products only. So the gas station owners may invest the liquid bulk terminal to import the oil products from foreign market since the international oil price is lower than the domestic price. It will affect the existing market shared by COC and FPG.

3. Analysis on the loading and unloading characteristics of liquid bulk terminal

Liquid bulk is loaded or unloaded by conduits, so liquid bulk carrier is not necessary to come alongside the berth. Even carrier comes alongside the berth; it doesn't have to use the crane or straddle carrier to load / unload the liquid bulk. The terminal labors only connect the conduits between the carrier and the terminal by soft pipe (See Fig 3-1) or "loading arm" (See Fig 3-2) and connect the power system on both side. Therefore the carrier has high efficiency of handling operation and low time spending.

The loading and unloading characteristics of liquid bulk are as follows:

- ◆ Using the conduits to load / unload the liquid bulk.
Although loading / unloading of liquid bulk is operated by the conduits, but different type of liquid bulk has each handling ways.
- ◆ High efficiency of loading and unloading operation
- ◆ Loading / unloading time of high efficiency liquid bulk carrier is usually under 24 hours. Due to the power system from the carrier or the terminal, loading / unloading operation would not stop because of labor working time off.
- ◆ High danger of loading / unloading operation
- ◆ More restriction for the carriers with the dangerous liquid bulk
- ◆ Lower loading weight during handling operation in terminal
- ◆ Using the rigging hook in stead of bollard



Fig 3-1 Loading and unloading with soft pipe

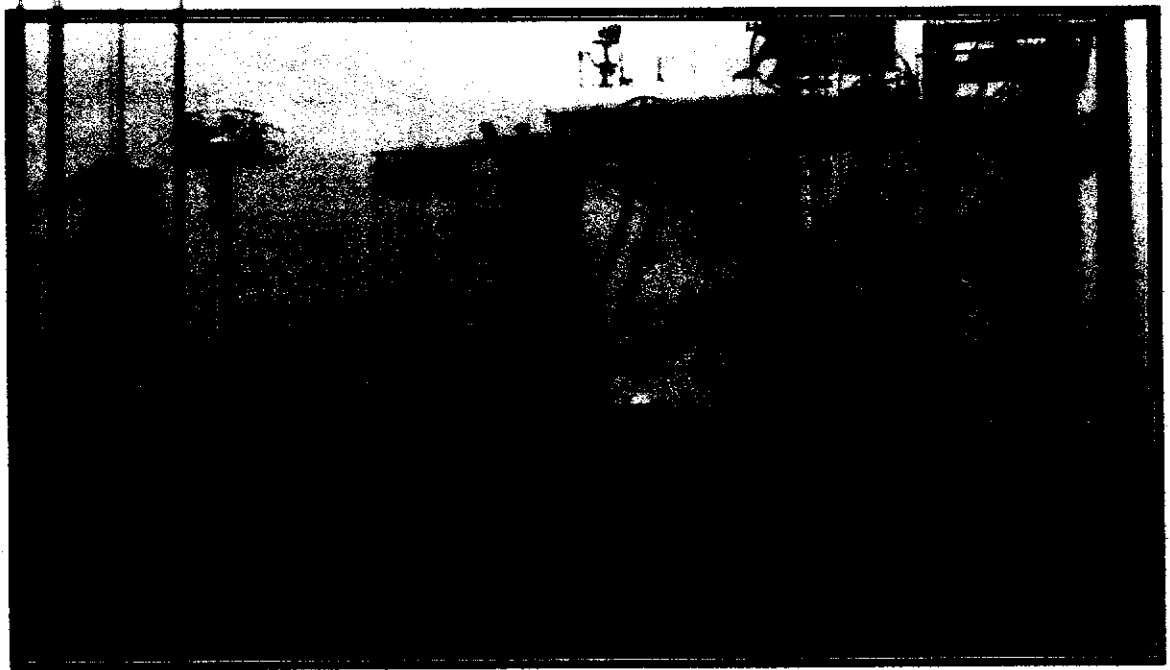


Fig 3-2 Loading and unloading with "loading arm"

4. Analysis on the layout of tank farm of liquid bulk terminal

4.1 Key elements in the layout of tank farm

Key elements in the layout of tank farm are as below:

(1) Base area

The planning of the layout of tank farm of terminal is restricted on land area. Land area of storage tank farm has a close relationship with capacity of carrier, because the capacity of storage tank must be bigger than total volume of every signal carrier.

(2) Classification of storage tank

◆ The storage tanks for the refineries

The storage tank in tank farm of the terminal which is close to the refineries, only store the raw material or products for the refineries itself, and don't engage the business to other manufacturers for storage. The terminal with the offshore mooring buoy to unload the liquid bulk, the industrial port or the terminal with the large tank farm could be built the manufacturing factories with this kind of storage tank.

The return of investment in this kind of storage tank is the reduction of the raw material and products transportation and curtailment of expenditure in storage facilities.

◆ The public storage tank

The storage tanks, which in the dangerous material terminal of Taichung port are the typifications, in the terminal back yard, are not only belonged to one company. Besides

loading and unloading the liquid bulk for the client, the storage company also offers the storage for the liquid bulk. The return of investment is the reduction in loading and unloading cost and rent payment of the storage tank.

◆ The storage tank for products distribution

The functions of this type of storage tank are not only for liquid bulk storage but also for transferring center of the product distribution, for example the storage tank of FPG in Taipei harbor is the transferring center of products distribution in North Taiwan.

(3) The varieties and capacity of the liquid bulk

Base on fire prevention and economy consideration, different types of storage tanks have different distance interval, diameter and storage capacity. Even the same storage tank in the same base area stores different liquid bulk, the capacity of each storage tank is different. The storage time of liquid bulk has close relationship with the cycle time and annual capacity of the storage tank.

(4) Regulations of fire fighting and safety

The different kinds of liquid bulk have different regulation of fire fighting and safety. The regulations have influence on the diameter, capacity and distance interval of the storage tank. It also has influence on the layout of storage tank farm and total capacity of the storage tank.

(5) Terminal length and water depth

General speaking, the width of the storage tank farm in the back yard of the terminal is the same as the length of the terminal, and

the capacity of the storage tank is matched in the capacity of carriers. And the water depth also related to the draught of carrier.

(6) Environmental factors

- ◆ Terrain
- ◆ Wind direction
- ◆ Earthquake
- ◆ Loading capacity of the fundament
- ◆ Conduits system of the storage tank
- ◆ Impounding dike

4.2 Classification of storage tank

Four types of storage tank, which are classified by the operation pressure, are as below:

(1) Atmospheric tank

The operation pressure of atmospheric tank is about atmosphere. The roof of the storage tank can bear over 0.5 psig pressure.

(2) Low pressure tank

This type of storage tank usually is erect cylinder storage tank. According to API standard, the range of operation pressure of this type tank is higher than atmosphere to 5 psig.

(3) High pressure tank

The operation pressure of high pressure tank is over 15 psig. High pressure tank includes spherical storage tank, spheroid storage tank, cylinder storage tank, etc.

(4) Refrigerated container

Refrigerated container usually is insulated by the special material

or concrete and store the liquefied bulk at temperature about 0°C ~ -196°C.

4.3 Relative facilities in the tank farm

The tank farm of the terminal has different facilities depended on purpose of the terminal and loading / unloading operation. Although the relative facilities in every terminal are different but they are quite similar in some ways.

The relative facilities in the tank farm are shown as below:

- ◆ tank farm
- ◆ Impounding dike
- ◆ Roads in tank farm
- ◆ Filling plant
- ◆ Management center
- ◆ Fire-fighting facilities
- ◆ Parking lots
- ◆ Detention pond of sewage water
- ◆ Special facilities

4.4 Referenced publications and regulations for storage tank

Handling operation:

- ◆ IMDG CODE
- ◆ IBC CODE
- ◆ IGC CODE
- ◆ NFPA

Layout of storage tank:

- ◆ NFPA
- ◆ ASME

- ◆ API
- ◆ CNS

4.5 Safe distance interval of tank farm

(1) Safe distance interval of storage tank

The longer the distance interval of storage tanks, or storage tank to the refinery is, the safer the storage tank and all facilities are. In case the storage tank has a fire, the tanks in neighborhood even don't catch fire either but may be damaged by the heat radiation however. Both of Industrial Risk Insurers (IRI) and National Fire Protection Association (NFPA) have suggestions in distance interval of storage tanks.

But the distance interval of IRI is evaluated by some real accident, not proceeded in scientific calculation. General speaking, the separation distance of IRI is conservative.

Taiwan government also made regulations that reference in publications of IRI, NFPA and etc., for distance interval of storage tank. And Port of Taichung Authority also has its own regulations of distance interval of the storage tanks that are shown on Table 4.1.

Table 4.1 Regulations of distance interval of the storage tanks

Facilities name		Regulations of government	Regulations of IRI and NFPA	Regulations of Taichung harbor
Normal pressure storage tank	Floating top	>1000KL	1/3D IRI: 1/2D NFPA: 1/3D(D<45) 、 1/2D(D>45)	1/3D
		1000~25000KL	1/3~1/2D IRI: D NFPA: 1/3D(D<45) 、 1/2D(D>45)	1/3D
		25000~50000KL	1/2~2/3D IRI: D NFPA: 1/3D(D<45) 、 1/2D(D>45)	1/3D
		>50000KL	1/2~3/4D IRI: D NFPA: 1/3D(D<45) 、 1/2D(D>45)	1/3D
	Steady top	<1000KL	1/3D IRI: 1/2D NFPA: 2/3D(D<45) 、 1/2D(D>45)	1/3D
		Class I 1000~25000KL	1/2~2/3D IRI: D NFPA: 1/3D(D<45) 、 2/3D(D>45)	1/3D
		Class II & III 25000~25000KL	1/3~1/2D IRI: 1/2D NFPA: 1/3D(D<45) 、 2/3D(D>45)	1/3D
		Class II & III >25000KL	1/2~2/3D IRI: 1/2D(V=1590~47700KL) NFPA: 1/3D(D<45) 、 2/3D(D>45)	1/3D
	Pressure tank		D>30 IRI: 2/3D>30	2/3D>30
Refrigerated container		D>30	IRI: 2D>60	D>30

Remark : D is the bigger diameter of the storage tank

(2) Distance from the boundary to tank farm

The study suggests the regulations of NFPA30 for minimum separation distance from boundary to tank farm. The details are shown on Table 4.2 and Table 4.3.

Table 4.2 Unstable liquids

Type of tank	Protection	Minimum distance in feet from property line that is or can be built upon, including the opposite side of a public way	Minimum distance in feet from nearest side of any public way or from nearest important building on the same property
Horizontal and Vertical Tanks with Emergency Relief venting to Permit Pressure Not in Excess of 2.5 psig (gauge pressure of 17.2kPa)	Tank protected with any one of the following: approved water spray, approved inerting, approved insulation and refrigeration, approved barricade	Table 4.3 but not less than 25ft	Not less than 25ft
	Protection for exposures ²	½ times Table 4.3 but not less than 50ft	Not less than 50ft
	None	times Table 4.3 but not less than 100ft	Not less than 100ft
Horizontal and Vertical Tanks with emergency Relief Venting to Permit Pressure over 2.5 psig (gauge pressure of 17.2 kPa)	Tank protected with any one of the following: approved water spray, approved inerting, approved insulation and refrigeration, approved barricade	2 times table 4.3 but not less than 50ft	Not less than 50ft
	Protection for Exposures ²	4 times Table 4.3 but not less than 100ft	Not less than 100ft
	None	8 times Table 4.3 but not less than 150ft	Not less than 150ft

Remark: SI units: 1ft = 0.3m

¹See NFPA69, Standard on Explosion Prevention systems.

²See definition of "Protection for Exposures."

Table 4.3 Reference table for use in Table 4.2

Capacity Tank(gal)	Minimum distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property
275 or less	5	5
276 to 750	10	5
751 to 12,000	15	5
12,001 to 30,000	20	5
30,001 to 50,000	30	10
50,001 to 100,000	50	15
100,001 to 500,000	80	25
500,001 to 1,000,000	100	35
1,000,001 to 2,000,000	135	45
2,000,001 to 3,000,000	165	55
3,000,001 or more	175	60

Remark: SI units: 1ft=0.3m, 1gal=3.81...

(3) Distance from the developing area to storage tank

The distance from the developing area to storage tank is shown on Table 4.4.

Table 4.4 The distance from the developing area to storage tank

Material	Maximum tank size (t)	Distance (m)
LPG, pressure >1.4bar	25~40	300
	41~80	400
	81~120	500
	121~300	600
	>300	1,000
	≥25	100
LPG, pressure ≤1.4bar	≥50	1,000
Phosgene	≥2	1,000
Chlorine	10~100	1,000
	>100	1,500
Hydrogen fluoride	≥10	1,000
Sulfur trioxide	≥15	1000
Acrylonitrile	≥20	250
Hydrogen cyanide	≥20	1,000
Carbon disulphide	≥20	250
Ammonium nitrate	≥500	-
Sulphru dioxide	≥20	1,000
Bromine	≥40	600
Ammonium	≥100	1,000
Hydrogen	≥2	500
Ethylene oxide	5~25	500
Propylene oxide	-	-
Atmospheric tank	≥5	250
Pressure tank	5~25	500
MIC(Methy isocyanate)	1	1,000

(4) Other regulations of spacing distance

The minimum distance from the storage tank to house, public place, public roads, etc. is shown on Table 4.5.

Table 4.5 The distance from the house, public space to storage tank

Facilities name	Distance (M)	
house	15	
Public space (school, hospital, theater, library and etc.)	30	
Ancient building	50	
Highway, roads	Heavy oil	23
	Light oil	30
Impounding dike	Diameter<15M	1/3H
	Diameter≥15M	1/2H
Electric cable	7,000volt< voltage <35,000volt	3
	Voltage >35,000volt	5

The minimum distance for storage tank to compressor, flare, vessel, etc. is shown on Table 4.6.

Table 4.6 The distance from storage tank to specific facilities

Facilities name	Regulation of IRI	China petroleum company	Regulation of Taichung harbor
Compressor	250	126	155
flare	300	158	179
Vessel	250	100	150
Fired equipment	300	108	131
Control room	50	78	70

4.6 Layout of the roads in tank farm

The design guideline of the road inside the tank farm is avoiding the dead-end road, moveable facilities can pass through and emergency car could drive through easily.

The regulations of road width inside the petrochemical zone in Japan are shown on Table 4.7.

Table 4.7 Regulations of road width inside the petrochemical zone

Zone area , m ²	Storage area , m ²	Road width
<20,000	<10,000	>6m
>20,000~40,000	10,000~20,000	>8m
>40,000~60,000	20,000~40,000	>10m
>60,000	>40,000	>12m

The major consideration of road width outside the tank farm is emergency situation. Road must be wide enough to let emergency car pass through and more than 10-meter width at least.

4.7 Earth covered tank (ECT)

Flammable liquid at atmosphere and liquid gas is usually stored in spherical tank. In recent years, there are more and more earth covered tanks for storing the explosive and dangerous liquid in Europe. Germany started to store LPG and PROPANE in earth covered tank since 1971 (see Fig 4-1).

FPG also apply the earth covered tank in No. 6 naphtha cracking plant in Taiwan.

This section focuses on the merits of ECT, application restriction and regulations of ECT.

Merits of ECT:

- ◆ Earth covered thickness is about 0.6 ~ 1.0 meter, and covered dirt could avoid boiling-liquid-expanding-vapor-explosion (BLEVE).
- ◆ The minimum distance of two ECT is 1 meter; it's more efficiency than traditional storage tank in land resource.
- ◆ ECT could be constructed in soft fundament, so it has lower

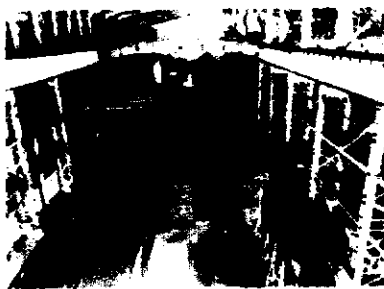
demand to geographical structure.

- ◆ ECT could be useful against the typhoon, earthquake and human destroy.
- ◆ ECT is more efficiently in water of fire fighting.
- ◆ ECT could correspond the environmental requirement.
- ◆ It's easier to maintenance because of Bitumen Coating of ECT.
- ◆ ECT can be manufactured in the factories then transported to site.

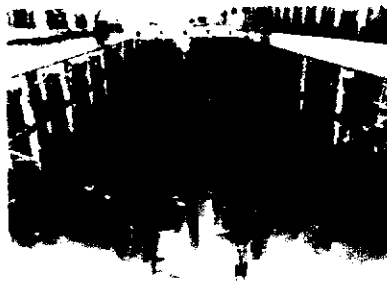


Formosa Plastics Group No.6 Naphtha Cracking Complex

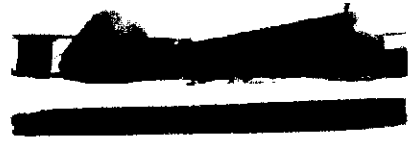
Fimisa Geavt Ubdystrues Ciro.



Sgitbkast → Cut → Form → Single shell



Multi → Accessories → ECT complete



Hyd. Test



Butyneb Ciatubg



Transportation+Erection

ECT 96 SETS (ASME U2)	
1) 3000 ³	4.0m DI X 25.5m L, 1 ST
2) 5000 ³	4.0m DI X 45.5m L, 3 ST
3) 1,000 ³	6.5m DI X 32.5m L, 10 ST
4) 2,000 ³	6.5m DI X 62.7m L, 5 ST
5) 3,000 ³	7.3m DI X 74.3m L, 55 ST
6) 4,000 ³	8.0m DI X 82.3m L, 22 ST



ECT on Sandbed & Civerubg



ECT+Sandbed+Covering are Completed

Fig 4-1 Earth covered tank

Application of ECT:

ECT can apply for storing the liquefied petroleum gas in atmospheric or liquefied ammonium in high pressure.

The regulations for ECT:

- ◆ Order on pressure vessels
- ◆ Gas pressure vessels and filling plants
- ◆ Germany AD-Merblatt
- ◆ Germany TRB 801.Nr.55
- ◆ British code 5500
- ◆ ASME Section VIII Div.2

4.8 The demand of land area of liquid bulk terminal

The demand of land area of liquid bulk terminal is based on length of terminal, and the length of terminal is about maximum length of the ship plus two times width of the ship. The length of terminal is usually the width of the tank farm of terminal. Therefore the relative facilities layout of storage tank in liquid bulk terminal depend on the length of terminal. The area of tank farm depends on total sum of each facilities minimum working area, roads, parking lots, etc.

5. Evaluation on the annual capacity of the liquid bulk terminal

The annual capacity of the liquid bulk terminal could be evaluated in three aspects:

- ◆ Annual capacity of the shipping for the terminal
- ◆ Annual loading and unloading capacity of the ships for the terminal
- ◆ Annual turnover capacity

5.1 Annual capacity of the shipping for the terminal

$$AC_s = C_s \times N_s$$

AC_s : annual capacity of the shipping

C_s : average loading and unloading capacity per ship

N_s : average number of ship berthing in the terminal

5.2 Annual loading and unloading capacity of the ships for the terminal

$$AC_l = E_t \times P \times R_t \times T \times 24$$

AC_l : annual loading and unloading capacity of the ships

E_t : net efficiency of loading and unloading capacity for the ship

P = actual operation time/berthing time in the terminal

R_t = annual actual berthing time /annual total berthing time which can be provided in the terminal

T = allowable working day per year

5.3 Annual turnover capacity

$$AC_t = \frac{C_t \times 365}{\bar{D}}$$

AC_t : annual turnover capacity of the terminal

C_t : total storage capacity of the tank

\bar{D} : average dwelling time of the liquid bulk

6. The standard layout of liquid bulk terminal

The layout of liquid bulk terminal depends on cargo, carrier, land area, terminal location, storage tank and distance of each facilities. The most important factor could affect the terminal layout is cargo.

The special cargo, like LNG or LPG that is stored in low temperature and transported by conduits system, has different demand in terminal facilities and terminal storage tank farm from other liquid bulk terminal. This section focuses on general liquid bulk terminal.

6.1 The typical size of liquid bulk terminal

This study suggests the typical size of liquid bulk terminal be shown on follows:

Table 6.1 The typical size of liquid bulk terminal

Cargo	Length	Width of apron	Water depth	D.W.T of ship	Remark
1. general	200	25	-9	3,000-6,000D.W.T.	
2. oil products	250	30	-14	30,000-60,000D.W.T.	Handymax or Panamax
3. LPG	300	30	-12.5	87,000m ³	
4. LNG	390	30	-12.5	135,000m ³	

6.2 The typical size of terminal storage tank farm

Table 6.2 The typical size of terminal storage tank farm

Cargo	Length	Width	Storage capacity	Remark
1. general	200	375	150,000m ³	
2. oil products	250	370	185,000m ³	

6.3 The standard layout of general liquid bulk terminal

The dead weight tons of general chemical carrier usually are under 40,000 tons, there fore applying the capacity of Handymax ship for design ship capacity in economical consideration is feasible. If Annual terminal working capacity is 1.8 million tons and the turnover rate of storage tank is ten times, then the demand capacity of storage tank are 180,000 tons per year.

There could be 20,000 tons storage capacity per ha, so the demand of land area is over 9 ha in tank farm of liquid bulk terminal. The standard layout of general liquid bulk terminal is shown on Fig 6-1.

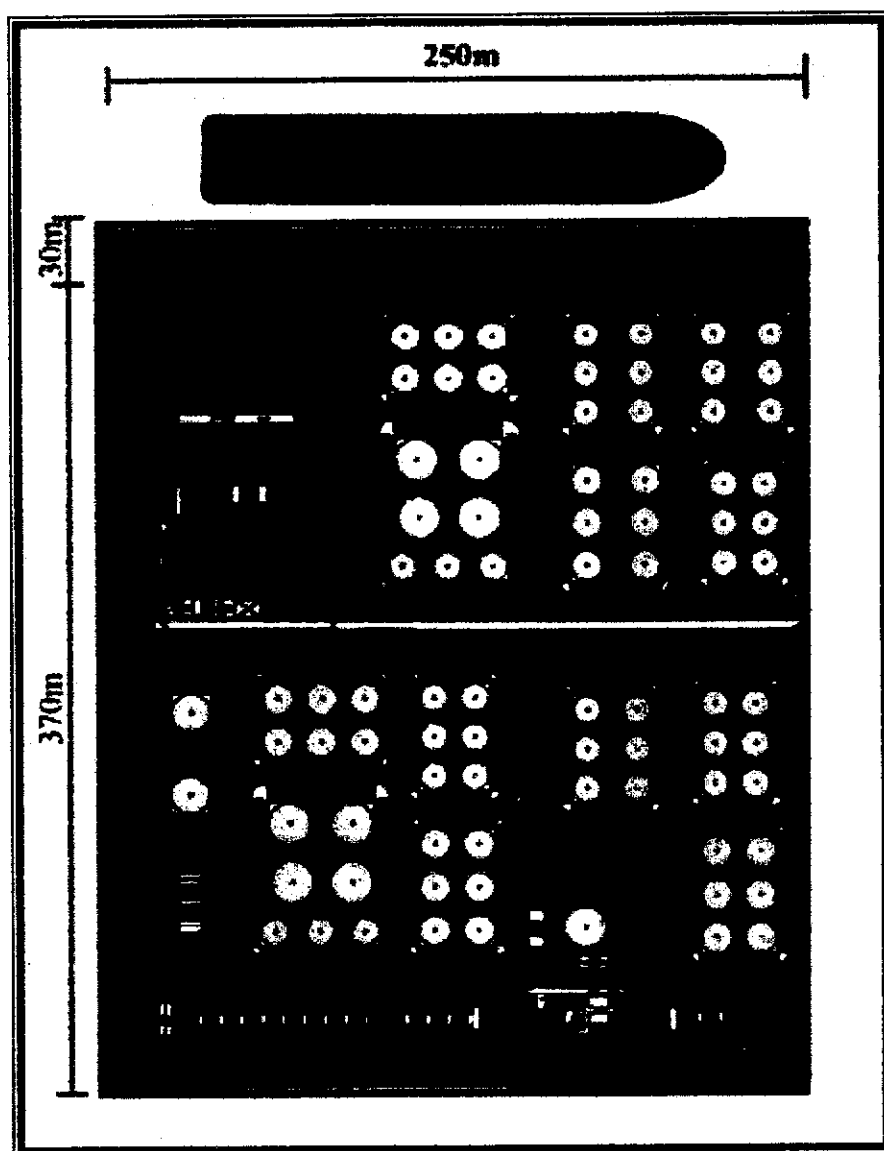


Fig 6-1 The standard layout of liquid bulk terminal

7. Design elements of the liquid bulk berth

7.1 Types of berth structure

There are many types of berth structures; they could be categorized into the following groups:

- ◆ Gravity Type (Fig 7-1)
- ◆ Trestle (Fig 7-2)
- ◆ Sheet Pile (Fig 7-3)
- ◆ Sheet Pile Wall with Relieving Platform (Fig 7-4)
- ◆ Other Types (Fig 7-5 、 Fig 7-6)

7.2 Special consideration on the operation of liquid bulk berth

The special consideration on the operation of a liquid bulk berth is as follows:

- ◆ Space preservation for pipeline installation
- ◆ The loading on the wharf structure is lighter than the ordinary general cargo berth
- ◆ Installation of the loading / unloading arm on the dock of the wharf structure
- ◆ Large variation on the berthing vessels
- ◆ Fire-fighting and illumination requirement
- ◆ Prevention and cure of environmental pollution
- ◆ Prevention of settlement in the tank area

7.3 Factors considered in the selection of berth structure

The factors considered in the selection of the type of berth structure are:

- a. Types of the liquid bulk
- b. Engineering characteristics of the site
- c. Draft of the design ship

- d. Distribution of the tonnage of the calling vessels
- e. Bearing capacity and geological distribution of the soil
- f. Earthquake resistance capability
- g. Loading and Unloading types
- h. Tranquility of the harbor basin
- i. Difficulty of the construction work
- j. Construction cost
- k. Construction period
- l. Quality control of the construction work
- m. Maintenance cost in the future

The factors could be divided into two groups, group I includes factors a~h which could be called as structural factors, group II includes factor i~m which could be called as management and construction factors. The selection of the type of the berth structure is divided into two stages. The selected berth structures should be structurally sound under the local natural conditions and berth requirements in the first stage evaluation. The second stage evaluation will be concentrated on the cost, construction and maintenance issues of the selected berth structures. The flow diagram of the evaluation process is shown on Fig 7-7.

7.4 Recommended structure types for liquid bulk terminal

Because large variation on the liquid bulk ships, so the draft of ships is the main consideration in the selection of berth structures. For example, gravity type and sheet pile type is usually suitable for shallow water structure and trestle will be suitable for deep berth and mooring buoy is often adopted for the oil tankers which need deep draft and dolphin is usually adopted off shore on the site with shallow water depth near the bank. There is no universal specification for the liquid bulk terminal. The details of the terminal vary with the demand

and functional design of the terminal. According to a preliminary study, the types of the berth structures, which could be possibly adopted as the berth structure for liquid bulk berth, are:

- ◆ Gravity type
- ◆ Sheet pile type
- ◆ Trestle type
- ◆ Dolphin
- ◆ Mooring buoy

The suitable site conditions for the above types of berth structure are listed on Table 7.1

Table 7.1 List of suitable site conditions for each type of berth structure

Type of Berth Structure	Suitable Site Conditions	Remark
Gravity Type	<ol style="list-style-type: none"> 1. Rock stratum, difficult for pile driving work 2. Hard stratum, unequal settlement of the foundation will not happen 3. Relatively shallow berth (The distance from the sea bottom to deck < 15meter) 4. Budget is limited 5. Heavy construction equipment are not available on site 	
Sheet Pile Type	<ol style="list-style-type: none"> 1. Sandy soil 2. Relatively shallow berth (The distance from the sea bottom to deck < 15meter) 3. Shorter construction period is required 4. Good tranquility of the harbor basin 5. Budget is limited 6. Heavy construction equipment are not available on site 	
Trestle Type	<ol style="list-style-type: none"> 1. Deep berth 2. Tranquility of the basin is not good 3. Seismic area 4. Area with high soil liquefaction potential 5. Abundant in heavy construction equipment and skillful workers 	
Dolphin	<ol style="list-style-type: none"> 1 Shallow water depth near the bank and difficult for dredging 2.The site that has good tranquility of the harbor basin and hard stratum which is difficult for pile driving work could adopt gravity type dolphin, otherwise could adopt trestle type dolphin 3.Abundant in heavy construction equipment and skillful workers 4.Using water for separation of the berth structure and tank area for fire-fighting needs 	
Mooring buoy	<ol style="list-style-type: none"> 1. For the oil tankers which need deep draft 2. Budget is limited 	

7.5 Main elements of the liquid bulk berth

The main elements on a liquid bulk terminal can be categorized into the following six groups:

- ◆ Superstructure
- ◆ Substructure
- ◆ Retaining structure
- ◆ Auxiliary facilities
- ◆ Dredging
- ◆ Tank area

A description of these 6 elements in each of the possible types of berth structures is listed on Table 7.2.

7.6 External forces to be considered in the berth design

The external forces acting on the liquid bulk berth will be slightly different types of berth structures, but they could be categorized into the following groups.

- a. Vessel Impact Force
- b. Tractive Force Acting on Mooring Post
- c. Force Acting on the Floating Body
- d. Earth Pressure
- e. Water Pressure
- f. Earthquake Forces
- g. Weight of the Structure Itself
- h. Surcharge
- i. Loading from the Stevedoring Equipment
- j. Wind Load
- k. Wave Force
- l. Current Force

Table 7.2 Main elements of the liquid bulk berth

Structure Type	Superstructure	Substructure	Retaining Structure
Gravity Type	<ul style="list-style-type: none"> - Concrete pavement or AC pavement - Solid structure, capable of resisting the ship impact force 	<ul style="list-style-type: none"> - Rubble mound foundation - Caisson or block structure - Not suitable for soil of low bearing capacity - Higher reflected wave height 	<ul style="list-style-type: none"> - The main structure is the retaining structure - The leakage of the backfill material should be carefully observed
Sheet Pile Type	<ul style="list-style-type: none"> - Concrete pavement or AC pavement - Solid structure, capable of resisting the ship impact force 	<ul style="list-style-type: none"> - Sheet pile with anchor system - Not good for deep water berth - Higher reflected wave height - Cathodic protection is required 	<ul style="list-style-type: none"> - The main structure is the retaining structure - Low probability of leakage of the backfilled material
Trestle Type	<ul style="list-style-type: none"> - Beam and girder structure - The accuracy of construction work is required - Subject to wave uplift force - The hollow area and slope below the deck is good to absorb the wave energy 	<ul style="list-style-type: none"> - Upright piles or upright piles with battered piles - Underwater slope protection with rocks - Cathodic protection is required - Good for deep water berth - Good for area with low bearing capacity 	<ul style="list-style-type: none"> - L-block, cantilever beam are used as the retaining structure, the leaking of the backfill soil should be observed
Gravity-Type Dolphin	<ul style="list-style-type: none"> - Concrete pavement or AC pavement - Solid structure, capable of resisting the ship impact force 	<ul style="list-style-type: none"> - Rubble mound foundation - Caisson or block structure - Not suitable for soil of low bearing capacity - Higher reflected wave height 	<ul style="list-style-type: none"> - Connecting bridge is used for the connection of the terminal and the tank area - The type of retaining structure is selected by the engineering characteristics of the tank area

Table 7.2 Main elements of the liquid bulk berth (continued)

Structure Type	Superstructure	Substructure	Retaining Structure
Pile-Type Dolphin	<ul style="list-style-type: none"> - Beam and girder structure - The accuracy of construction work is required - Subject to wave uplift force - The hollow area and slope below the deck is good to absorb the wave energy 	<ul style="list-style-type: none"> - Upright piles or upright piles with battered piles - Underwater slope protection with rocks - Cathodic protection is required - Good for deep water berth - Good for area with low bearing capacity 	<ul style="list-style-type: none"> - Connecting bridge is used for the connection of the terminal and the tank area - The type of retaining structure is selected by the engineering characteristics of the tank area
Mooring Buoy	<ul style="list-style-type: none"> - Buoy - Main chain - Sinker chain - Ground chain 	<ul style="list-style-type: none"> - Anchor - Sinker 	<ul style="list-style-type: none"> - None
Gravity Type	<ul style="list-style-type: none"> - Fender, bollard, car stopper, loading/unloading arm foundation, fire-fighting equipment, removal of static electricity, communication, water supply, etc., 	<ul style="list-style-type: none"> - The dredging amount is greater than other types of structure 	<ul style="list-style-type: none"> - The settlement near the deck area is not easy to control
Sheet Pile Type	<ul style="list-style-type: none"> - Fender, bollard, car stopper, loading/unloading arm foundation, fire-fighting equipment, removal of static electricity, communication, water supply, etc., 	<ul style="list-style-type: none"> - Amount of dredging work is smaller 	<ul style="list-style-type: none"> - Unequal settlement will not be the problem
Trestle Type	<ul style="list-style-type: none"> - Fender, bollard, car stopper, loading/unloading arm foundation, fire-fighting equipment, removal of static electricity, communication, water supply, etc., 	<ul style="list-style-type: none"> - The area below the deck should be dredged 	<ul style="list-style-type: none"> - Unequal settlement near the deck area should be observed

Table 7.2 Main elements of the liquid bulk berth (continued)

Structure Type	Superstructure	Substructure	Retaining Structure
Gravity-type Dolphin	- Fender, bollard, car stopper, loading/unloading arm foundation, fire-fighting equipment, removal of static electricity, communication, water supply, etc.,	- The dredging amount is smaller	- Settlement is usually easy to control
Pile-Type Dolphin	- Fender, bollard, car stopper, loading/unloading arm foundation, fire-fighting equipment, removal of static electricity, communication, water supply, etc.,	- The dredging amount is smaller	- Settlement is usually easy to control
Mooring Buoy	- Mooring ring or quick release hook - Fender	- Dredging is usually unnecessary	- Tank area is far from the mooring buoy, so the erection of the tank area should be done independently

7.7 Related design codes

◆ Design codes

The design codes adopted in the berth design are shown on Table 7.3

Table 7.3 Related design codes and references

Subject	Design Codes of References
R.C. Structure	ACI, Local National Standards Local Codes on Port Structure Local Building Codes Local Codes on Bridge Design Japanese Design Codes on Port Structure (English version) Port Engineering (by Per Brunn)
Steel Structure	AISC, AWS, BS, DIN, JIS, Local National Standards Local Codes on Port Structure Local Building Codes Local Codes on Bridge Design Japanese Design Codes on Port Structure (English version)
Pavement	AASHTO Local Design Codes on Road Structure
Drainage and Retaining Structure	Local Codes

◆ Material specifications

The material specification adopted in the design procedure are as followings:

- ACI
- ASTM
- BS
- CNS
- AASHTO
- JIS
- Local National Specification

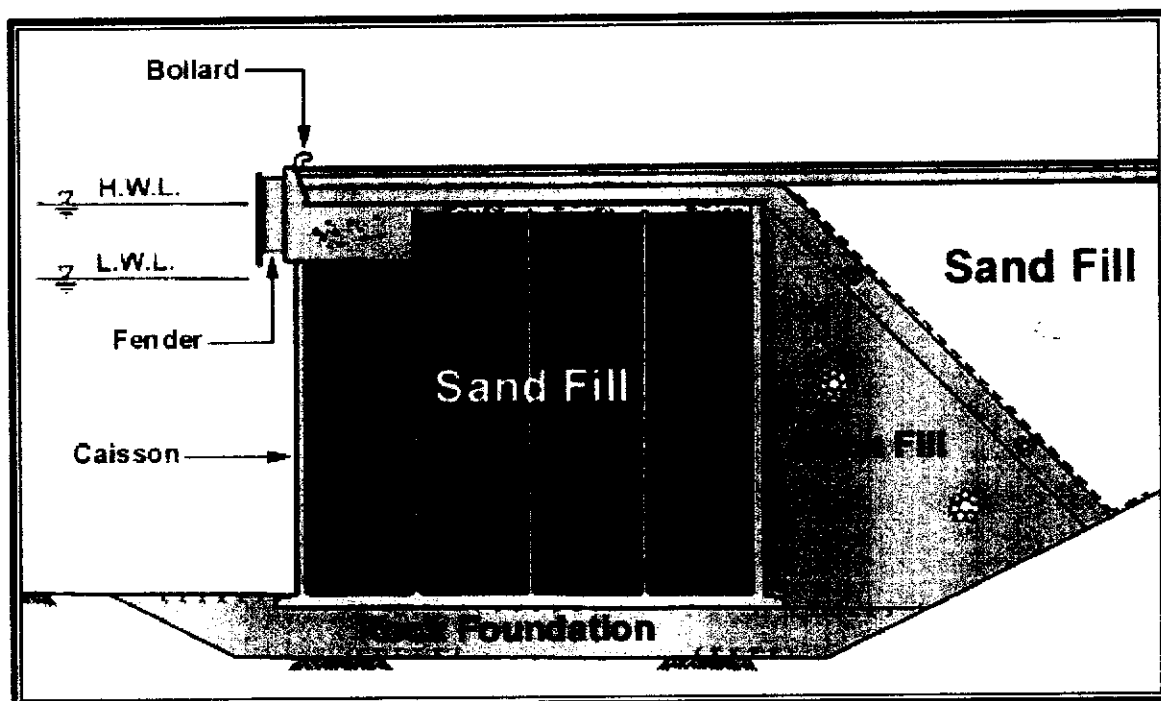


Fig 7-1 Caisson gravity type

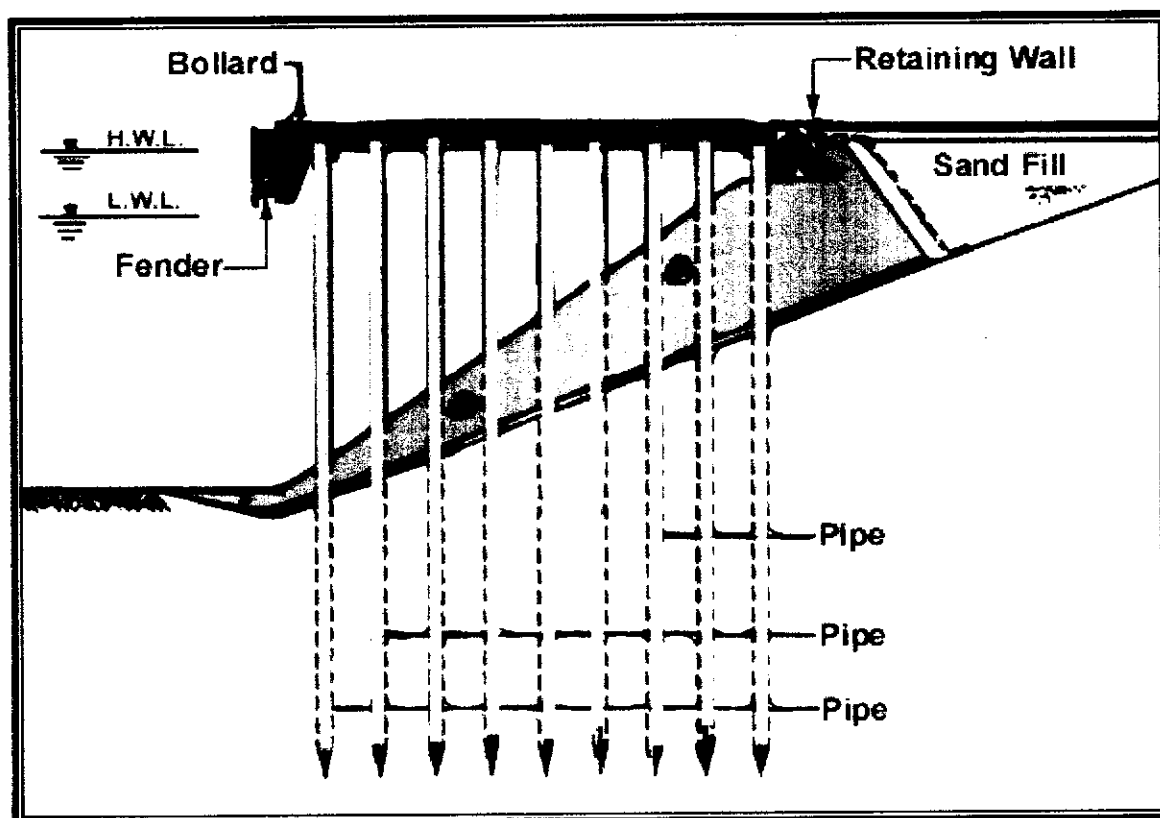


Fig 7-2 Sheet pile type

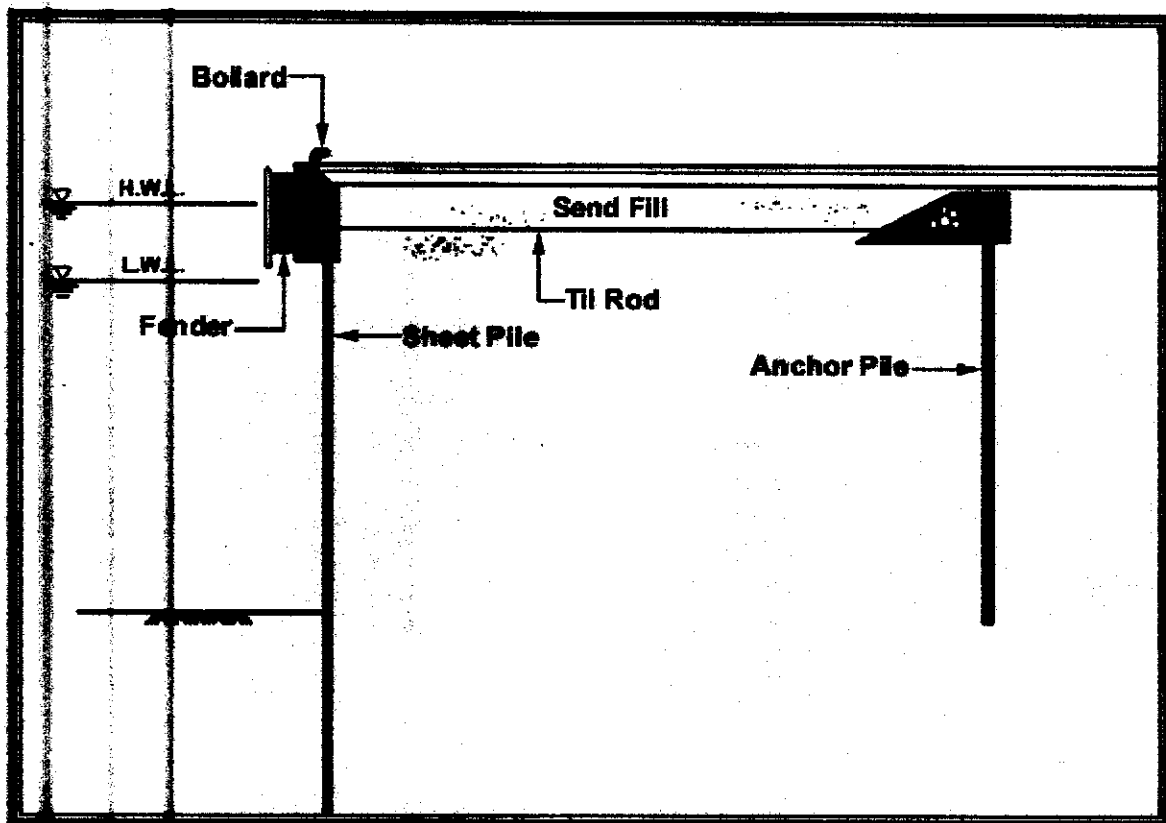


Fig 7-3 Sheet pile with relieving platform

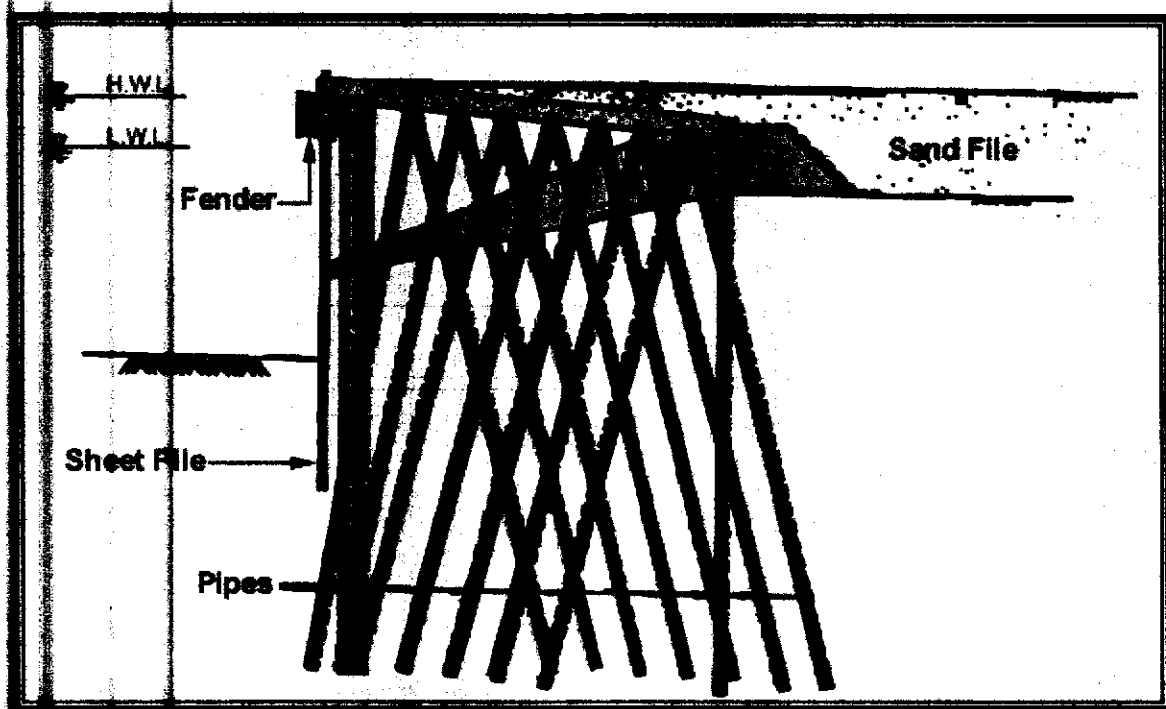


Fig 7-4 Trestle type

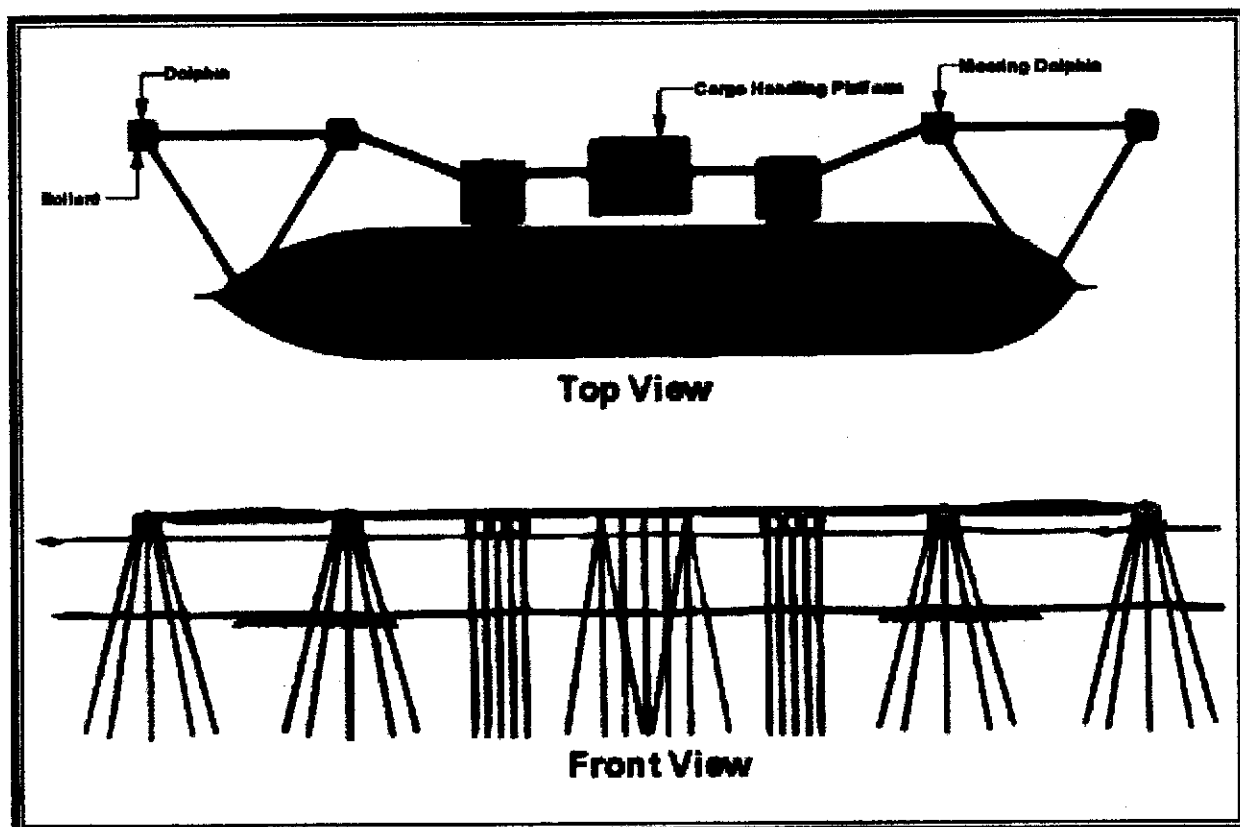


Fig 7-5 Dolphin

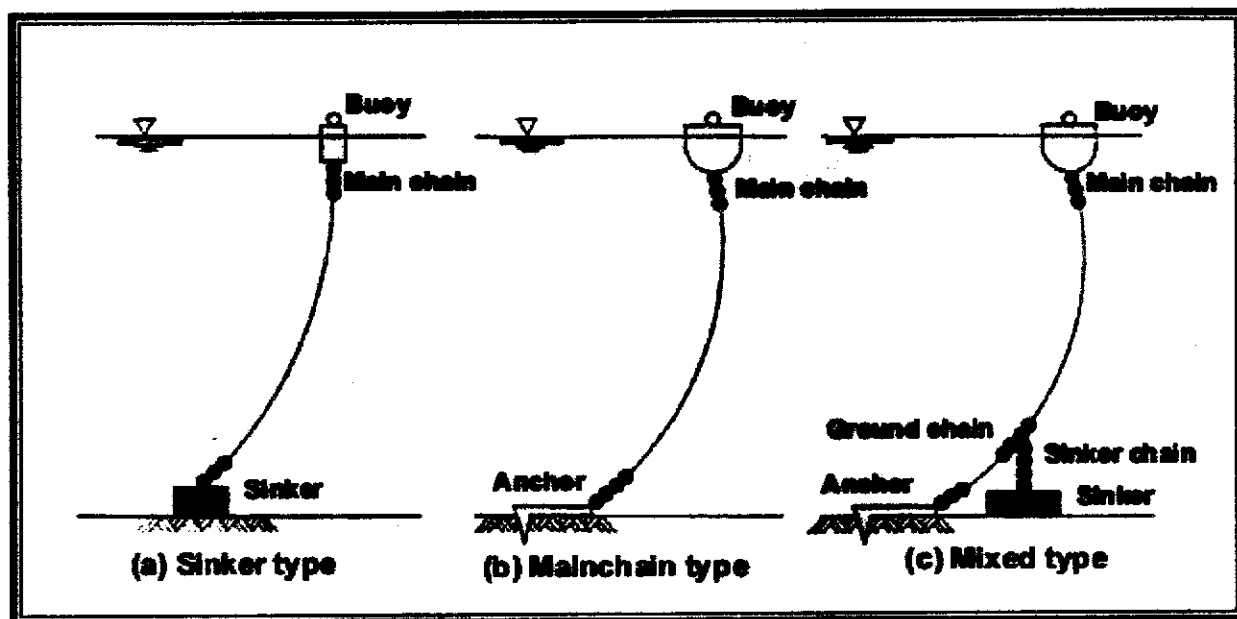


Fig 7-6 Mooring buoy

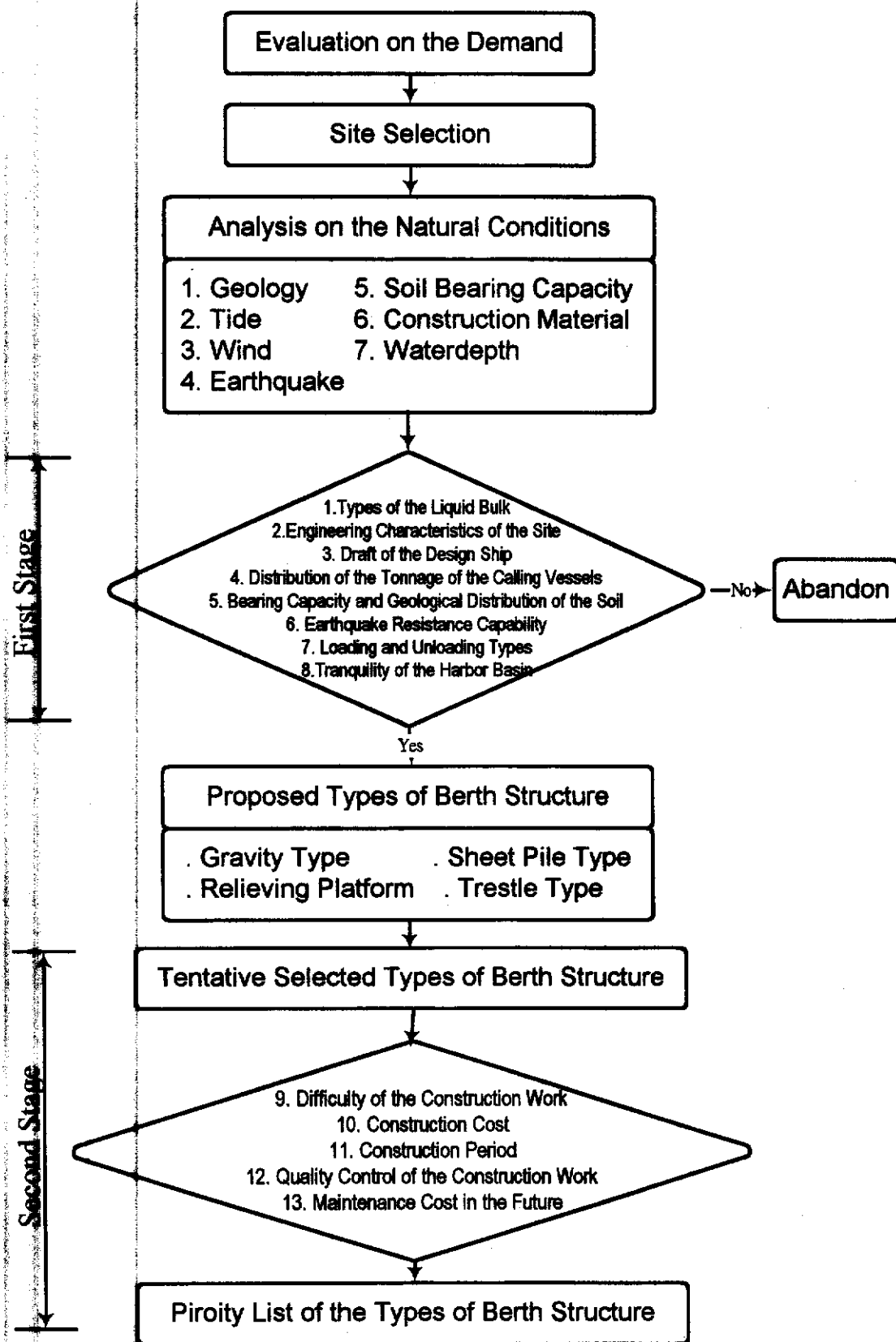


Fig 7-7 The flow chart of the selection of berth structure

8. Flow chart of the liquid bulk berth design

The design flow chart of the 5 selected liquid bulk berth structures are shown on Fig 8-1~8-5.

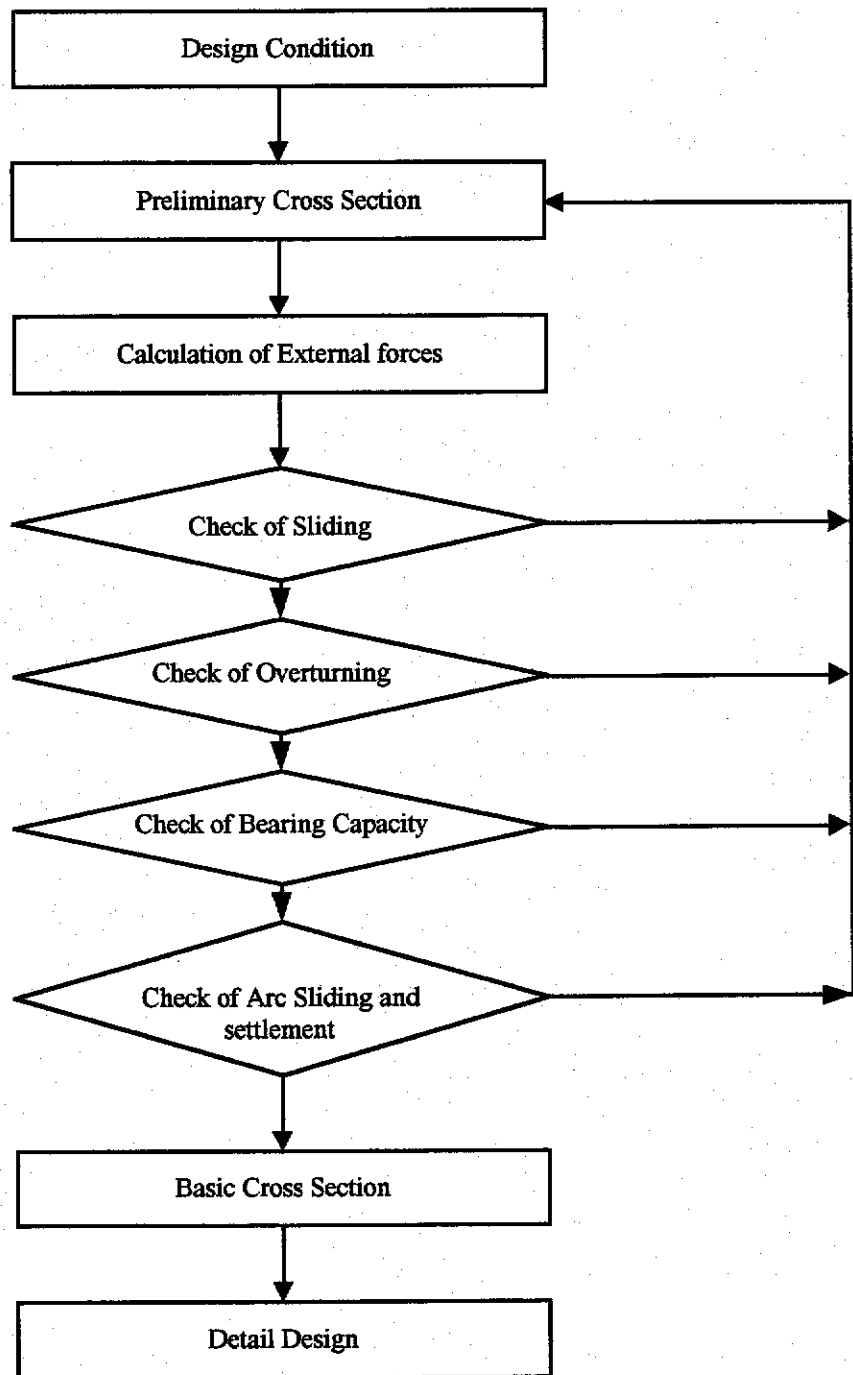


Fig 8-1 Design flow chart of caisson gravity type berth

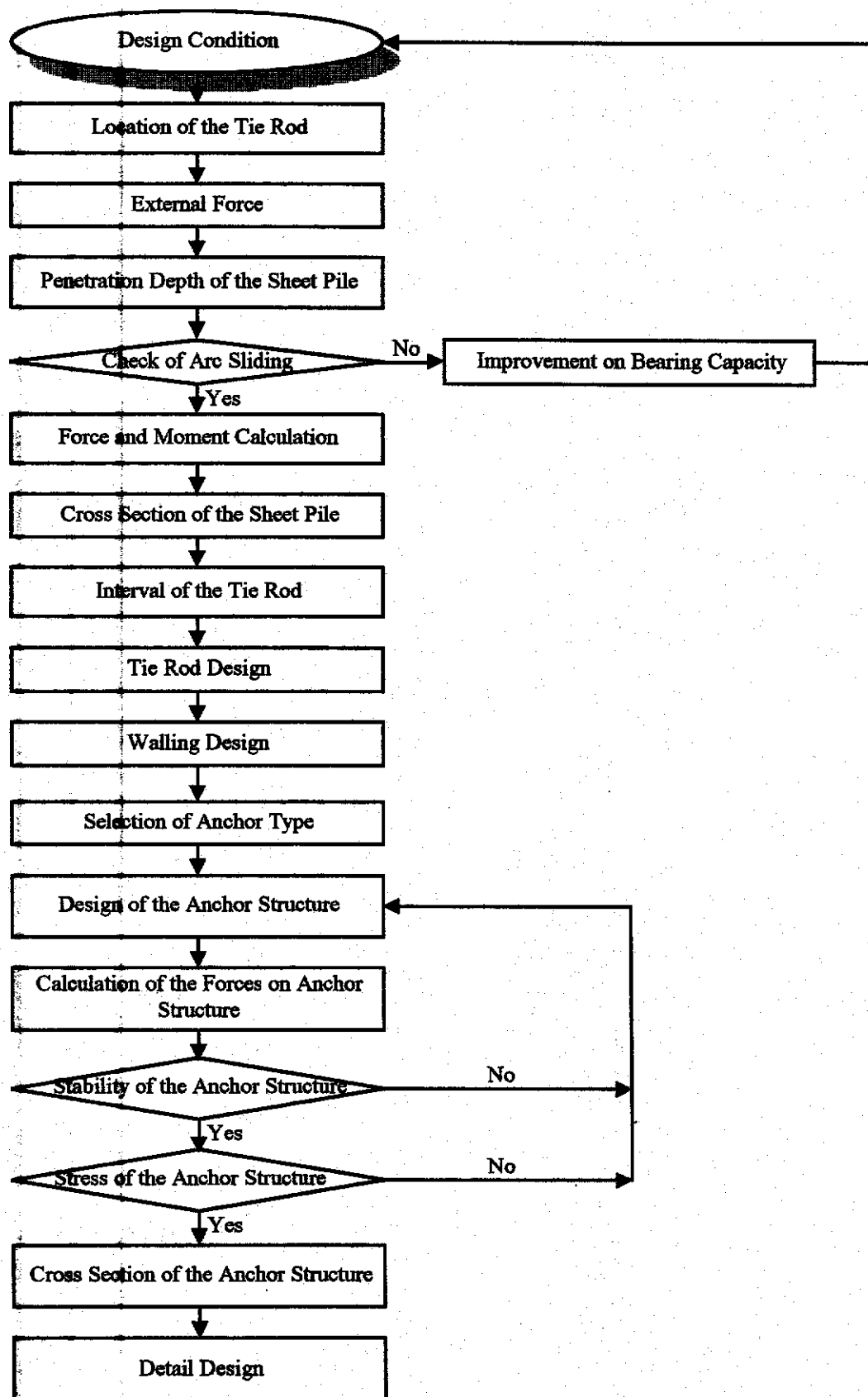


Fig 8-2 Design flow chart of sheet pile berth

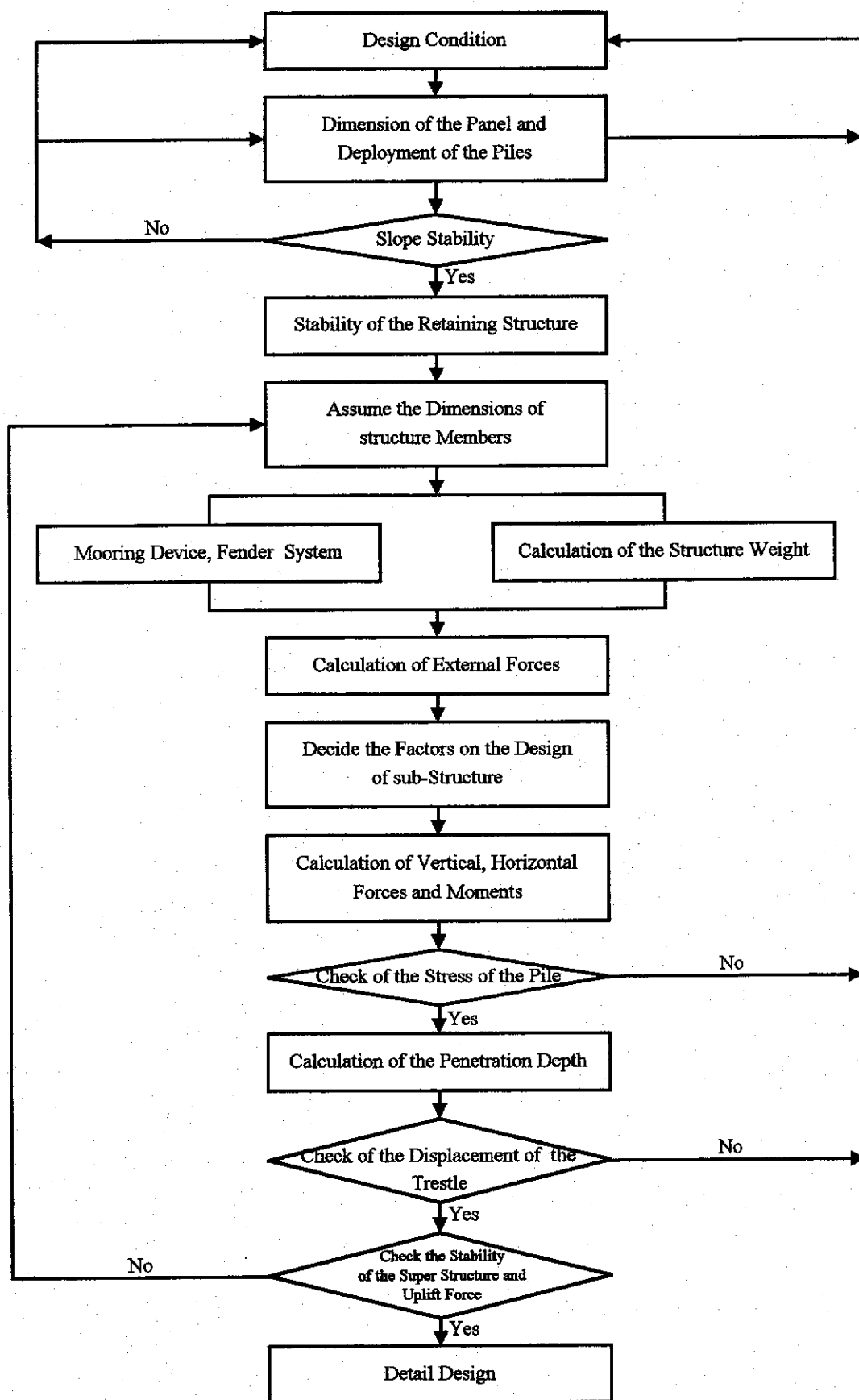


Fig 8-3 Design flow chart of the trestle berth

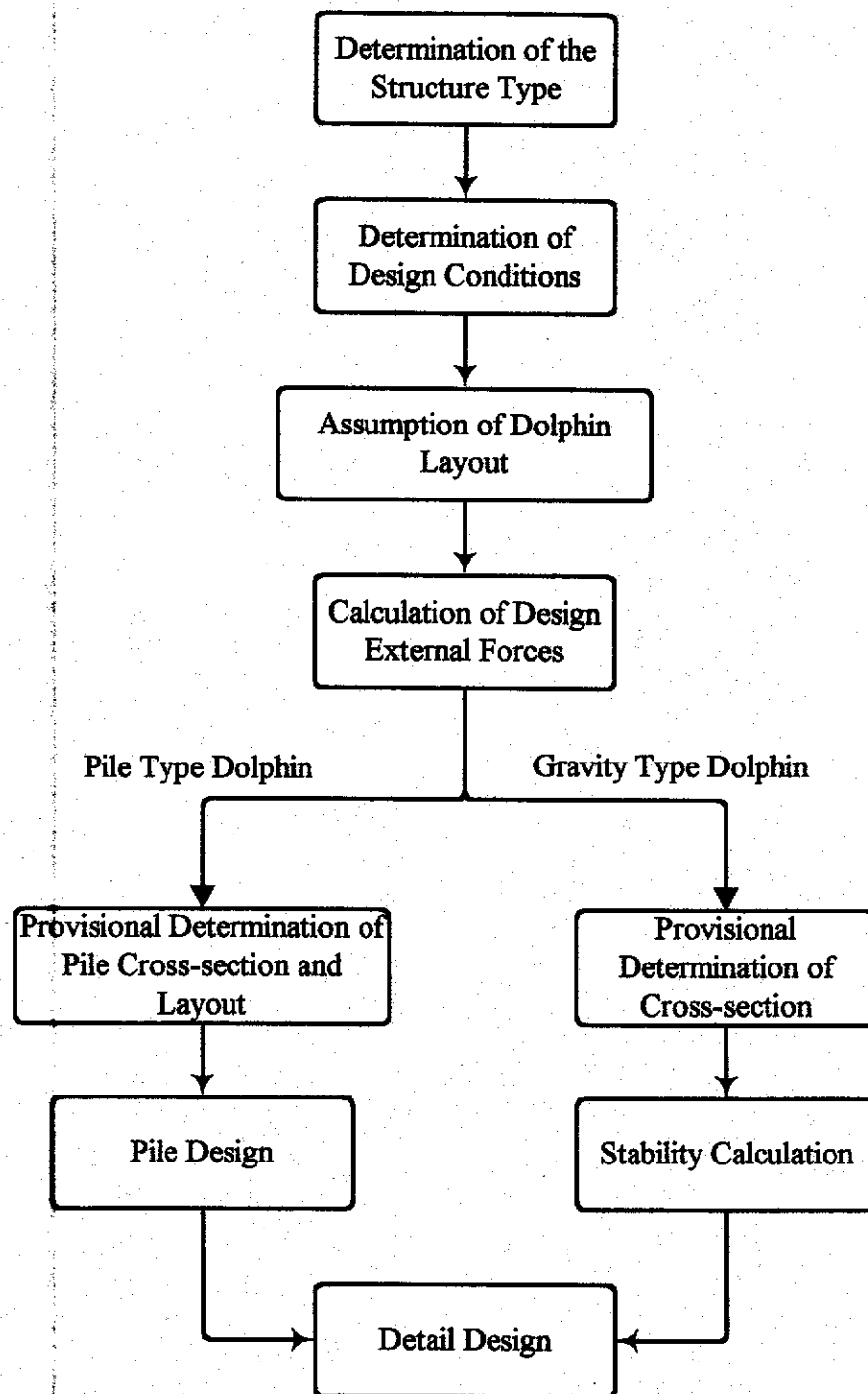


Fig 8-4 Design flow chart of dolphin

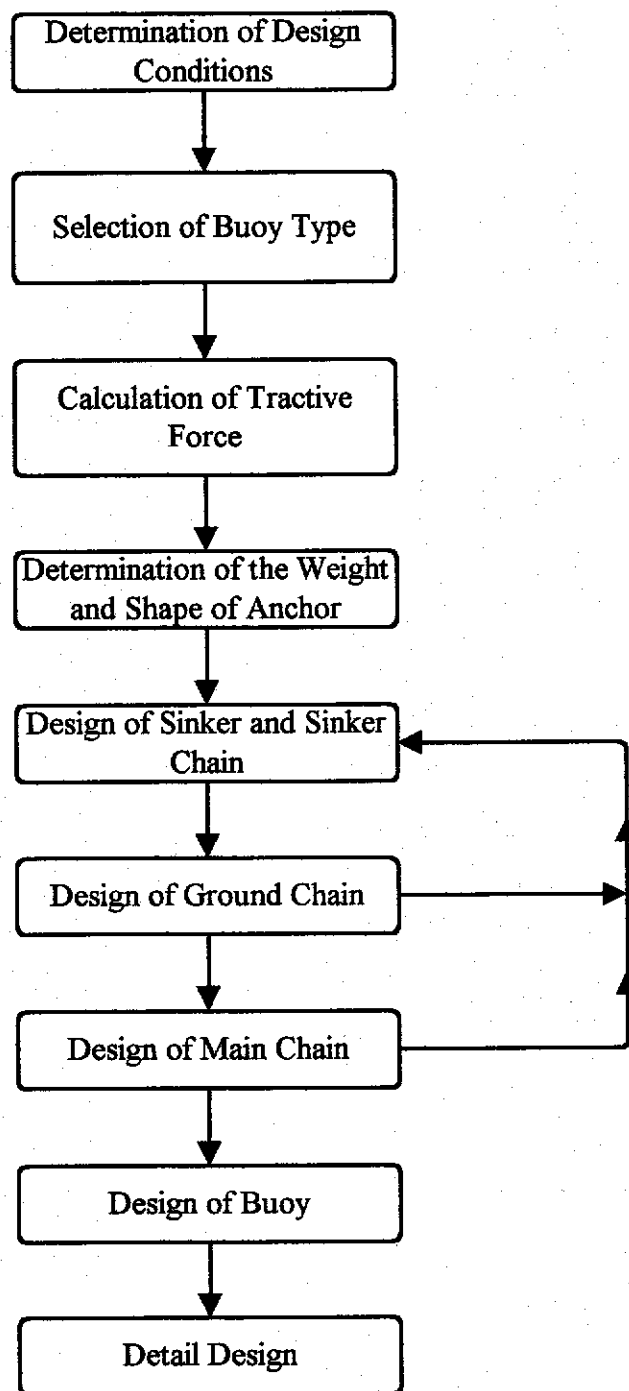


Fig 8-5 Design flow chart of mooring buoy

9. Check list of the liquid bulk terminal

9.1 checking list of the berth design

The checking list for the design of liquid bulk berth could be divided into three categories,

- ◆ Layout (Table 9.1)
- ◆ Design general terms (Table 9.2)
- ◆ Design detail terms (Table 9.3~9.8)

Table 9.1 Checking list of the layout of tank area in liquid bulk terminal

Items	Description	Remark
Environmental Factor	1.Elevation	
	2.Wind direction	
	3.Structure design should meet the regulations of the seismic design code	
Storage area	1.Width of road in emergency	
	2.Installation of exit gate in emergency	
Storage tank	1.The minimum horizontal distance requirement between tanks	
	2.The minimum horizontal distance requirement between tank field and boundaries	
	3.Other distance requirement according to the national codes	
	4.Design of the top of the storage tank to resist design pressure	
	5.Pressure-relieving devices	
	6.The holdup of the diked area shall be at least 110 percent of the volume of the largest tank within the diked area	
	7.The height of the dike should be more than 0.5 meter	
	8.The number of the storage tank should not be more than 10 in each diked area	
	9.The minimum horizontal distance requirement between tank and road	
	10. The minimum horizontal distance requirement between tank and dike	
	11.The area within the dike should be less than 80,000m ²	

**Table 9.1 Checking list of the layout of tank area in liquid bulk terminal
(continued)**

Items	Description	Remark
	12. Pipelines irrelevant with the tank within the diked area should be avoided	
	13. The necessary measures to do with the pipelines which go through dike wall	
	14. Drainage outlet in the diked area	
	15. Automatic sensor to detect the leakage of the tank	
	16. Stairways and walkways should be provided every 30 meter for the dike whose height is more than 1 meter	
	17. A minimum clearance of 3 meter should be provided between pumps and other equipment	
	18. The minimum horizontal distance requirement between pump and tank	
	19. Pumping house should be made of incombustible material	
	20. The window of the pumping house should be fire-preventing	
	21. Proper slope of the ground and installation of the collecting well in the pumping house	
	22. The installation of ventilated equipment in the pumping house	
	23. Carbon disulfide tank should be erected in R.C. structural pond	
	24. If pump is installed outdoors, the ground should not be designed to be seeped through or the area 3 meter nearby should be enclosed with at least 0.5 meter high of wall	

**Table 9.1 Checking list of the layout of tank area in liquid bulk terminal
(continued)**

Items	Description	Remark
	25.If the stocks of the tank can not mix with water, the surrounding area should be enclosed with water-proof equipment	
	26.Installation of hydrants above 5 meter outside the diked area	
Filling Plant	1.Be built in a safety space, and have no irrelevant building	
	2.The installation of emergency shut-off valve should be 5 meter away from the tank	
	3.Installation of shower and eye-washing facilities for emergency use	
	4.Warning equipment for emergency use	
	5.Installation of pipeline for disposal and release of hazardous gases	
	6.The building with pumps and compressors should be made of incombustible material	
	7.The pumps and compressors installed outdoors should be enclosed with railings	
	8.Removal facilities of static electricity of the pipelines	
	9.If the diameter of the pipeline is more than 50mm, welding should be adopted for the connection of pipeline and tank	
	10.The connecting method between pipes or pipe and valve should adopt welding method	
	11.Electric and illumination equipment should be installed according to the national regulations	

**Table 9.1 Checking list of the layout of tank area in liquid bulk terminal
(continued)**

Items	Description	Remark
	12. Installation of high voltage electric equipment in the hazardous location should be avoided	
	13. The buried depth of the pipeline should not be less than 60cm	
	14. The cross area of the wire used for the removal of static electricity should not be less than 55mm ²	
	15. Buildings should be designed according to the national building code, and the lightning rod should be installed according to the national regulations	
	16. If the area of the filling house is more than 600m ² , the fixed spray fire-fighting system should be used, and the flow rate of the spray system should be more than 7l/min per square meter of area	
	17. For hydrant installed outdoors, the jet pressure should not be less than 3.5kg/cm ² , and the flow rate should not be less than 350l/min	
	18. For the filling plant with the spray fire-fighting system, the volume of the fire water should be enough for more than 20 min	
	19. Two hydrants should be installed at least for the area 15~40 meters around the high voltage equipment	
Container Store Room	1. The container store room should be made of incombustible material	
	2. Measures to prevent stay of flammable gases	

Table 9.1 Checking list of the layout of tank area in liquid bulk terminal
(continued)

Items	Description	Remark
	3.The container store room should be a bungalow building	
	4. Automatic detecting device to detect the leakage of gases should be installed in the container store room, while the container stocks is combustible or poisonous	
	5. 20 percent space of the container store room should be kept as the passage	
Foundation of Operating Facilities and Steel Structure	1. The buildings should be erected according to the national building code	
	2. The loading used in structural design should be considered in detail	
	3. The arm-rest should be covered in the ladder design	
	4. The electric equipment installed in the hazardous zone should be explosion-proof	
	5. Removal of static electricity for the electric equipment	
	6. Lightning protection equipment should be installed for the important electric equipment	
	7. Pipelines, fittings and valves should be designed according to the related codes	
	8. The layout of the pipeline should be considered as straight as possible	
	9. Welding should be adopted for the connection of pipelines used in the transfer of stocks with explosibility	

**Table 9.1 Checking list of the layout of tank area in liquid bulk terminal
(continued)**

Items	Description	Remark
	10.The foundation bolts should be installed properly	
Management Center	1.The location should be safely installed and be next to the road outside the plant	
	2.The horizontal distance should be kept 30 meter away from the process unit or equipment with flammable liquids or gases	
	3.The building should be made of incombustible material	
	4.Instrument room should be separated with the office, living room and resting room	
	5.The electric facilities of the instrument room should be separated	
	6.The instrument room should have more than one door for the access	
	7.Fire-fighting equipment should be installed according to the national code	
	8.The installation of control system, warning and broadcast system and remote control system etc	

Table 9.2 Checking list for the general terms of berth design

Subject	Items	Result	Remark
General condition	Ship tonnage		
	Water depth of the berth		
	El of the berth		
Natural condition	Tide		
	Geological condition		
	Wind direction & speed		
	Water depth and sea bottom slope		
	Wave		
Basic data for the calculation of external forces	Unit weight of material		
	Coefficients of earthquake force		
	Coefficients of wind force		
	Approaching speed of the ship		
	Approaching angle of the ship		
Strength of the material and allowable stress	Concrete		
	Steel		
	Tendon for prestress		
	Steel pile		
	Steel sheet pile		
	Tie rod		
	Wale		
	Anchor		
	Ground chain		
	Anchor chain		
	Sinker chain		
	Others		

Table 9.3 Checking list for the design of caisson gravity berth

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Surcharge				
	Dead weight				
	Live load				
	Earth pressure				
	Residual water pressure				
	Buoyancy				
	Earthquake force				
	Pulling force of the vessel				
	Impact force of the vessel				
Check of the stability	Sliding				
	Overturning				
	Bearing capacity				
	Circular sliding				
	Settlement				
Check of the caisson design	Check of the towing safety				
	Design of the outer wall				
	Design of the partition wall				
	Design of the bottom slab				
Check of the other items	Bumper				
	Mooring facility				
	Loading/unloading				
	Arm foundations				
	Traffic flow				
	Fire-fighting system				
	Drainage				
	Water supply				
	Illumination				
	Communication				
	Power supply				

Table 9.4 Checking list for the design of sheet pile berth

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Surcharge				
	Earth pressure				
	Residual water pressure				
	Pulling force of the vessel				
	Impact force of the vessel				
Check of the stability	Penetration depth of sheet pile				
	Section of sheet pile				
	Design of tie rod				
	Design of wale				
	Design of anchor facility				
Check of the other items	Bumper				
	Mooring facility				
	Loading/unloading arm foundations				
	Traffic flow				
	Fire-fighting system				
	Drainage				
	Water supply				
	Illumination				
	Communication				
	Power supply				

Table 9.5 Checking list for the design of trestle berth

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Surcharge				
	Dead weight				
	Live load				
	Lifting force				
	Wind force				
	Earthquake force				
	Horizontal force exerted by the retaining structure				
	Pulling force of the vessel				
	Impact force of the vessel				
Check of the structural analysis	Check of the structural analysis				
Check of the structural members	Design of pile				
	Design of beam				
	Design of slab				
Check of the other items	Bumper				
	Mooring facility				
	Loading/unloading				
	Arm foundations				
	Traffic flow				
	Fire-fighting system				
	Drainage				
	Water supply				
	Illumination				
	Communication				
	Power supply				

Table 9.6 Checking list for the design of pile type dolphin

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Surcharge				
	Dead weight				
	Live load				
	Tractive force				
	Lifting force				
	Wind force				
	Earthquake force				
	Vessel impact force				
	Wave force				
Check of the structural analysis	Check of the structural analysis				
Check of the structural members	Pile stress				
	Pile bearing capacity				
	Deflection				
	Design of beam				
	Design of slab				
Check of the other items	Bumper				
	Mooring facility				
	Loading/unloading Arm foundations				
	Traffic flow				
	Fire-fighting system				
	Drainage				
	Water supply				
	Illumination				
	Communication				
	Power supply				

Table 9.7 Checking list for the design of gravity type dolphin

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Surcharge				
	Dead weight				
	Live load				
	Earth pressure				
	Wave force				
	Buoyancy				
	Earthquake force				
	Impact force of the vessel				
	Pulling force of the vessel				
Check stability analysis of	Sliding				
	Overturning				
	Bearing capacity				
	Rotation of the whole structure				
	Circular sliding				
	Settlement				
Check of connecting bridge design	Foundation design				
	Design of beam				
	Design of slab				
Check of the other items	Bumper				
	Mooring facility				
	Loading/unloading Arm foundations				
	Traffic flow				
	Fire-fighting system				
	Drainage				
	Water supply				
	Illumination				
	Communication				
	Power supply				

Table 9.8 Checking list for the design of mooring buoy

Subject	Items	Allowable Value	Design Value	Result	Remark
Check of the external force	Tractive force of buoy				
	Tractive force of main chain				
	Tractive force of ground chain				
	Tractive force of sinker chain				
Check of anchor design	Horizontal resistant				
	Vertical resistant				
Check of design of sinker and sinker chain	Weight of sinker				
	Diameter of sinker chain				
	Length of sinker chain				
Check of anchor chain design	Diameter of anchor chain				
	Length of anchor chain				
Check of buoy design	Stability design				
	Structural design				
Check of the other items	Bumper				
	Mooring facility				
	Pipeline				

10. Conclusions

- ◆ Key elements in the layout of storage tank farm are shown as below:
 - Base area
 - Classification of storage tank
 - The varieties and capacity of the liquid bulk
 - Regulations of fire fighting and safety
 - Terminal length and water depth
 - Environmental factors
- ◆ The relative facilities taken into consideration in planning in the storage tank farm are shown as follows:
 - Storage tank farm
 - Impounding dike
 - Roads in tank farm
 - Filling plant
 - Management center
 - Fire-fighting facilities
 - Parking lots
 - Detention pond of sewage water
 - Special facilities
- ◆ The annual capacity of the liquid bulk terminal could be evaluated in three aspects:
 - Annual capacity of the shipping for the terminal
 - Annual loading and unloading capacity of the ships for the terminal
 - Annual turnover capacity.
- ◆ The recommended land requirement for the standard liquid bulk terminal is as follows :
 - 250 meter of terminal length
 - 30 meter of terminal width

- 100,000 square meter of land requirement in back yard
- ◆ The main consideration on the operation of a liquid bulk berth is as follows:
 - Space preservation for pipeline installation
 - The loading on the wharf structure is lighter than the ordinary general cargo berth
 - Installation of the loading/unloading arm on the dock of the wharf structure
 - Large variation on the berthing vessels
 - Fire-fighting and illumination requirement
 - Prevention and cure of environmental pollution
 - Prevention of settlement in the tank area
- ◆ The factors considered in the selection of the type of berth structure are:
 - Types of the liquid bulk
 - Engineering characteristics of the site
 - Draft of the design ship
 - Distribution of the tonnage of the calling vessels
 - Bearing capacity and geological distribution of the soil
 - Earthquake resistance capability
 - Loading and Unloading types
 - Tranquility of the harbor basin
 - Difficulty of the construction work
 - Construction cost
 - Construction period
 - Quality control of the construction work
 - Maintenance cost in the future
- ◆ The operation mode and area of the back yard are the key factors to the capacity of the liquid bulk terminal. The selection of the operation mode and decision of the yard area should be carried out through a comprehensive study taking account of engineering, financial and

economic factors.

- ◆ There is no universal specification for the liquid bulk terminal. The details of the terminal vary with the demand and functional design of the terminal. According to a preliminary study, the types of the berth structures, which could be possibly adopted as the berth structure for liquid bulk berth, are:
 - Gravity type
 - Sheet pile type
 - Trestle type
 - Dolphin
 - Mooring buoy
- ◆ The external forces acting on the liquid bulk berth will be slightly different types of berth structures, but they could be categorized into the following groups.
 - Vessel Impact Force
 - Tractive Force Acting on Mooring Post
 - Force Acting on the Floating Body
 - Earth Pressure
 - Water Pressure
 - Earthquake Forces
 - Weight of the Structure Itself
 - Surcharge
 - Loading from the Stevedoring Equipment
 - Wind Load
 - Wave Force
 - Current Force
- ◆ This introduction will be served as a basic guide for those who are interested in the liquid bulk terminal operation. The content is for a typical liquid bulk terminal; the readers should incorporate the local codes, regulation, economic situation, and other related factors in their planning work of a liquid bulk terminal.