# DRY DOCKS: OVERVIEW OF DESIGN AND CONSTRUCTION

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## ABSTRACT

*Drydocks are exposed to special conditions such as thee xtreme degree of humidity, marine conditions, special loading phases, and other conditions related to themarine environment. In this paper,a general guidance and overview for the design and construction of the docksare presented. Docks subdivide into two types, wet docks, and dry docks, for wet docks, these structures are built for human services, like trading, ship anchoring, military services, and other services, while dry docks are designed and constructed for vessels services. Drydocks have two main types, the graving drydocks which have their own considerations and conditions while the other type is the floating drydocks, each one will be discussed and illustrated with all terms and requirements with adescription of first appearance and early days concepts.*

**Keywords:** Docks,Drydocks, Vessel, Graving, Floating, Planning, Design, Construction

## INTRODUCTION

Water occupies about 70% of our planet and separates old world (Europe, Asia, Africa) from the new one, humans needed to get throw the sea in order to communicate and make trades, so ships or sea vessels were invented, these ships got throw high seas and oceans, carrying merchandise and men from all around the globe, then we need to ask this question "how did they build these vessels in the first place?", well we can see that in early times vessels were somehow small and the could be built onshore then moved to the sea, at those days the maintenance concept was pretty much simple, whenever repairs are needed vessel can be moved to the shore, but by time passing, vessels became bigger, more merchandise needed to be carried, distances became longer and longer, that's why a new era of building and maintenance concept saw the light, because vessels can no longer be held away to the shore for repairing procedure, this era was of what was called "drydocks".

### Historical View

Throughout history and since the concept of drydocks where invented, techniques differed from one way to another, one of the first pioneers in this field were the Chinese in about 1088 A.C. In 965 A.C., a couple of dragon type vessels with length of 63 m each, where presented to the emperor to show loyalty, after lot of cruises bodies decayed and needed repairs, but repairs where impossible offshore due to their sizes, so in the period of king "Hsi-Ning", the official of the palace made a suggestion, a dock was dug in a lake that was capable to contain this type of vessels. Construction procedure was with the use of huge crossed beams located on a piled raft foundation. After that a hole was dug to make water flow into the dock, so the ships can move in the basin, after the ship settles in the basin the hole closed and the water was pumped away using wheel pumps, so the ship could rest in the air, after repairs finished, basin was filled again so the ship can sail again, finally the basin was roofed so the ships can be protected during repairs (Levathes, 1994).



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Europeans, however, also made drydocks in a quite similar way, in England the first and oldest surviving drydock (since 1495), was established at “HMNB Portsmouth” in the era of “Henry VII” of the “Tudor” dynasty, This basin nowadays keeps the oldest battleship, which is “HMS Victory” (Noel, 1988).

Meanwhile, it is possible that the earliest floating drydock was established in Vince in 1590, an anonymous inventor asked for a method of rescuing damaged vessels, and then proceeded and described his approach, the method was flanking the shop by a couple of natant platforms, creating a ceiling above the ship. The ship is located in a proper position by using bonds, fixed to the structure (Sarton, 1946).

**Modernistic View**

Drydocks showed, are modernly became inefficient, and that inefficiency caused by vessels themselves, because modern vessels became bigger, longer, heavier, and more complicated than the old wooden one, that’s why even drydocks were about to develop to stay along with the evolution of vessels, however, construction methods, materials, and design of drydocks changed, but the main concept of drydocks stayed still, for some example we have from Portugal. The “Alfredo da Silva” drydock, which meant to be the biggest drydock until the end of the previous millennium, that’s when it was shut down after transiting to the city of Setúbal, which were before located in “Linsave dockyards” in “Almada”.

Statistics nowadays, say something else, they say that biggest and more complicated drydocks were established worldwide, and here are some of them:

i. In Northern Ireland, located a huge dock with dimensions of 556mx93m, in this dock two huge cranes standstill, the first is Goliath with a height of 96m, and the other is Samson with a height of 106m.

ii. In France, however, located one of the biggest docks worldwide, it has dimensions of 1200mx60m.

iii. The biggest excavated dock in the Mediterranean Sea in 2009 was at the Hellenic Shipyards in Greece.

iv. The biggest ceiled drydocks located in Germany, specifically in “Papenburg”, this in a shipyard called “Meyer Werft”, this drydock is 504 by 125 meters, with a total height of 75 meters.

v. The USA, however, has its participation in this field, in “Newport News Shipbuilding”, there is a Dock called “Dock 12”, it has a length of 662 meters, and a width of 76 meters, and it’s the largest drydock in Northern America.

**Drydocks Principles**

Before running into determining, reviewing, and illustrating each type of drydocks, there are two main questions, the first one represents the concept of drydocks.

Drydock is a type of onshore structures, which is used for a specific purpose, main purposes of using this kind of structures are repairing decayed or damaged vessels, or even building new ones.

The second question represents fields of use in addition to vessels’ servicing.

In fact, drydocks actually participate in many fields in the construction industry; many drydocks participate in megastructures constructing operations, such as dams, bridges, immerged tube tunnels, and even oil offshore platforms.

## TYPES OF DRYDOCKS

After reviewing the history, present, definition, and uses of drydocks, a general view of drydock types can be taken into consideration.

There are two main types of drydocking methods, each type is used according to the vessel's and operator's requirements, and these are: a) Graving drydocks, b) Floating drydocks.

### General Planning Factors

All types of drydocks share the same target which is getting the vessel out of the water so they can be repaired properly, but they differ by the method of accomplishing this target.

While most of them depend on pulling the vessel higher than water-level, one of them which is the graving drydocks don't, in this method the vessel actually stays lower than water-level, in a dried basin, this primary different makes a straight comparison between graving drydock and other systems difficult, on the other hand, graving drydocks are mainly built for serving huge vessels, that's why comparison is rarely important (Salzer, 1986).

The most significant factors to be considered while choosing drydocking system are:

i. The essential purpose of the drydock: is this drydock is meant to be used only for repairing and maintenance operations, or it will be used in building operations.
ii. Dimensions, weight, and full characteristics of a full range of vessels meant to be served.
iii. Siting influences.
**iv.** Future's expansion possibilities.

### Influences by Vessel's Size

As drydocks are meant to serve vessels (repair, build, etc.), sizes of these vessels directly influence type and size of chosen drydocking method, in graving drydocks, however, it has been found that the size is generally unlimited, and actually some graving drydocks have been built with a capacity of 100,000 DWT tankers in many places worldwide, on the other hand, floating drydocks and Ship lifts became larger throw years, and the present sizes are not the largest considered  feasible, Marine Railways are selected depending on the cost of their civil works, but they are usually limited to the size of 8000 tons, although the 12000 tons sizes have been considered, while mobile marine lifts are limited to vessels up to 250 tons only.

Maybe the most essential factor is not meant to be the total weight nor the size of the vessel, but rather the weight distribution of the vessel which will be served, the weight per unit length of each vessel rarely been constant, so the highest possible loading among keel in some specific parts must be taken into consideration.

Figure 1 illustrates the influence of vessels' sizes of selecting drydocking method (Salzer, 1986).


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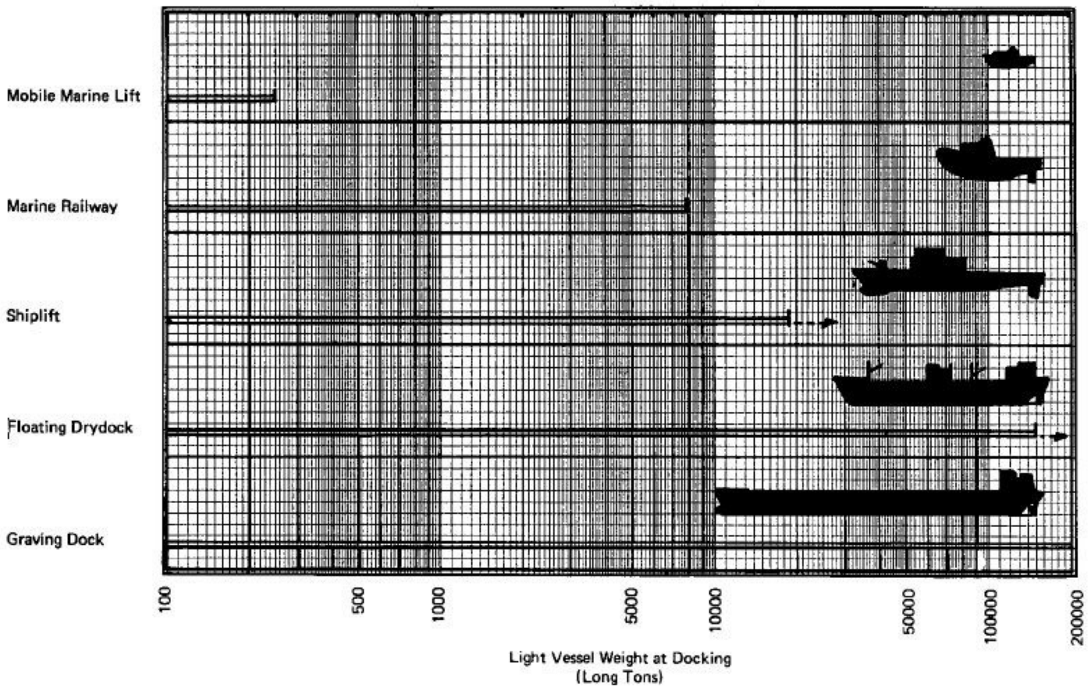



Fig. 1.Size influence (Salzer, 1986)

## GRAVING DRYDOCKS

Graving drydocks, considered as the main types of drydocks, are named so, because of their main structural nature, which is constructed lower than ground level, where operations take place, this type of drydocking methods consist of a fixed basin built into the ground at water's edge, this basin has its gate at the waterside's end, which will be closed after the targeted vessel been navigated into the basin, and as mentioned before after the gate is closed the water in the basin is pumped away so the vessel can settle down on the block, and its lower body will be prepared for dry works.

To build the basin, many techniques are used, these techniques have their own requirements each, so to use the proper and feasible decision of the technique to be used, there are some factor to be taken in consideration, like initial cost, life expectancy, designer's or owner's will, local conditions, site conditions, labor's level of experience, and available construction materials, and intended function of the dock,  In the designing process some site conditions must be taken into consideration, some of them will effect on sidewalls of the basin, while others effect on the ground (Salzer, 1986).

Soil, however, has its major effects, on both sidewalls and ground, on sidewalls applied the weight of soil in addition to the weight of water (moisture), while on the ground it will be the water uplift pressure.

Loading factors that are considered in designing approach are separated into three categories: "Dead loads, live loads, and hydrostatic pressure".

### Designing Factors

#### *Dead load*

The weight of concrete structure: This includes the weight of the structural elements involved, and generally taken as 2403 kg/m$^3$ (UFC, 2012).

The soil pressure: This includes the pressure due to weight of the soil surrounding and generally taken as 961 kg/m$^3$ for submerged soils and 1602 kg/m3 for non-merged soils, calculations will be:

$$Ps = \frac{1}{3}\,\gamma s \times hs \times Ko \qquad (1)$$

Where:

$$Ko = \frac{(1-\sin\emptyset)}{(1+\sin\emptyset)} \qquad (2)$$

***Hydrostatic Pressure***

They are caused by moisturized soil, generally taken as 1025 kg/m3 for seawater, and 1002 kg/m3 for fresh water, computations will be as follows (UFC, 2012):

$$P_w = \frac{1}{3}\,\gamma_w \times h_w \quad \text{(Sidewalls)} \qquad (3)$$

$$P_w = \gamma_w \times h_w \quad \text{(Uplift)} \qquad (4)$$

Buoyancy computations are calculated in three phases:

i. Extreme high water.
ii. Mean high water.
iii. Extreme low water.

***Live load***

The concept of live loads is that they are the non-permanent loads, for designing purposes live loads are (UFC, 2012):

i. Ship loads
ii. Crane wheel loads
iii. Local static and moving loads
iv. Railroad track loadings
v. An impact allowance
vi. Earthquake resistance

Main designing differences were about preventing the structure from floating, at early days designers thought that the solution will be designing a structure with a huge mass of concrete and stones so the weight of the structure will overtake the floating problem, this concept was called "gravity drydock" (see Fig. 2).

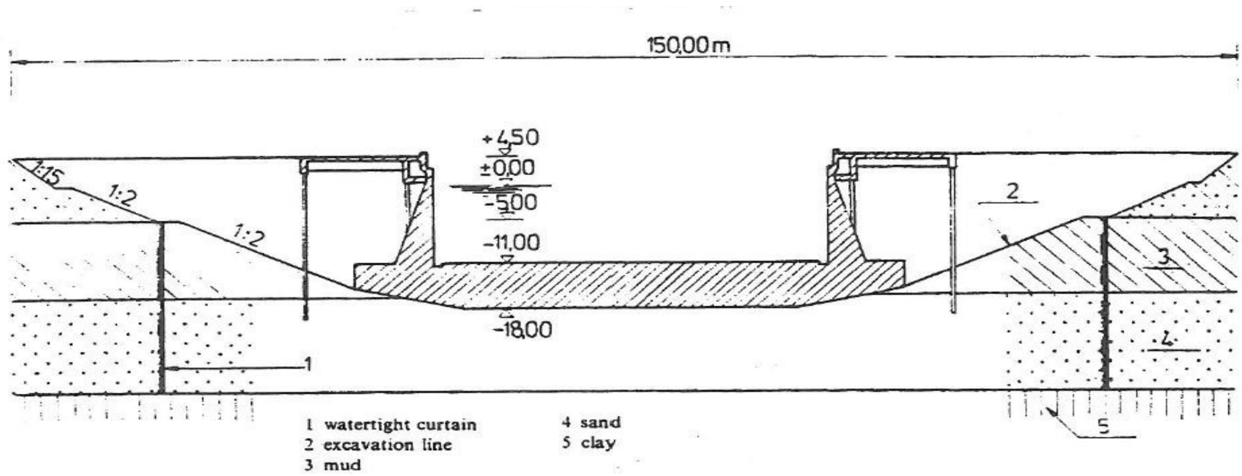



Fig. 2. Gravity graving drydock (Sadeghi, 2001 and Oza, 2016)

While time goes by, designers found that gravity drydocks are quite expensive, so intended to create a new concept that will be cheaper, and at the same time overtake floating problem, so they thought about getting rid of the water affecting the structure, so chose to make a drainage system that will get the unwanted water far from the structure so it will have influence on it will be limited, but the system was costly, so they came with an idea to use piles beneath the dock's floor so the pumps nor big huge mass are no longer needed, these piles will work backwards so the will hold down the structure by taking advantage of friction with soil so the structure will be holding the ground instead of just lying on it (see Fig. 3) (Oza, 2016).

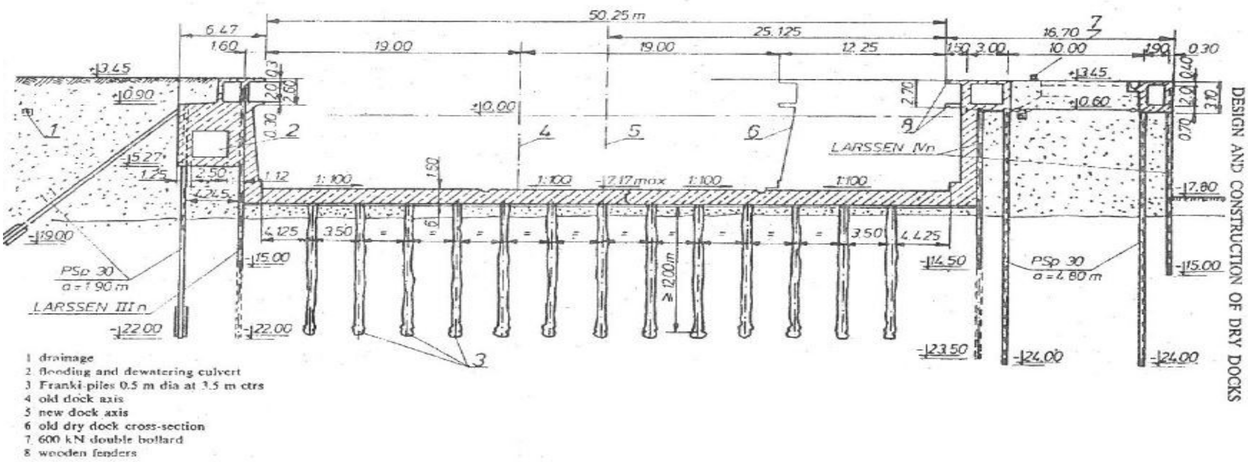



Fig. 3. Piled graving drydock (Sadeghi, 2001 and Oza, 2016)

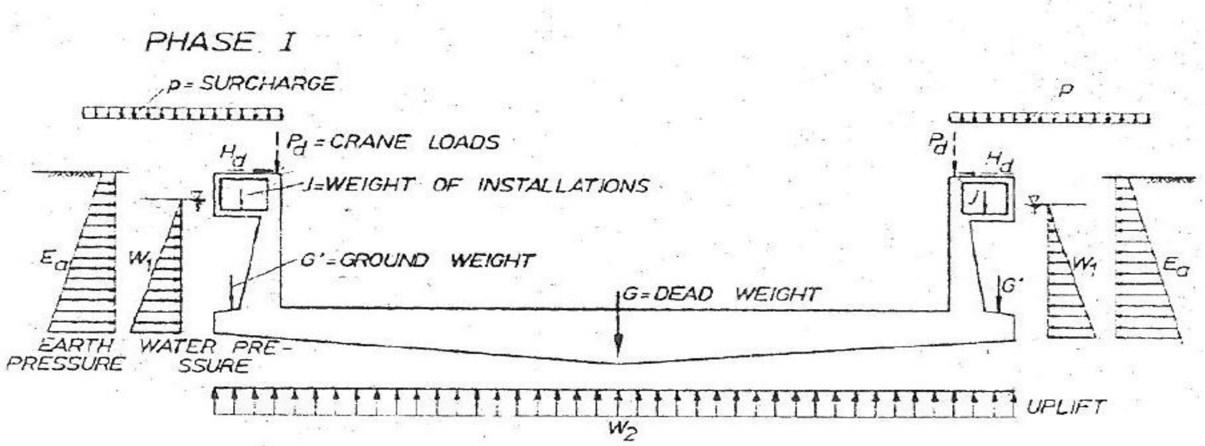
***Loading Combinations***

There are three main phases of loading combinations as shown in Fig. 4 (Oza, 2016):

i. Phase I: illustrates the dry condition of the dock, and shows uplift pressure on the ground in combination with soil and water pressures subjected on side walls.

ii. Phase II: illustrates the dry but functional condition of the dock, and shows uplift pressure and vessel's weight applied on the ground, with soil and water pressure subjected on sidewalls.

iii. Phase III: illustrates the wet condition of the dock, and shows uplift pressure with the weight of the water contained in the dock on the ground, with soil and water pressure on sidewalls.



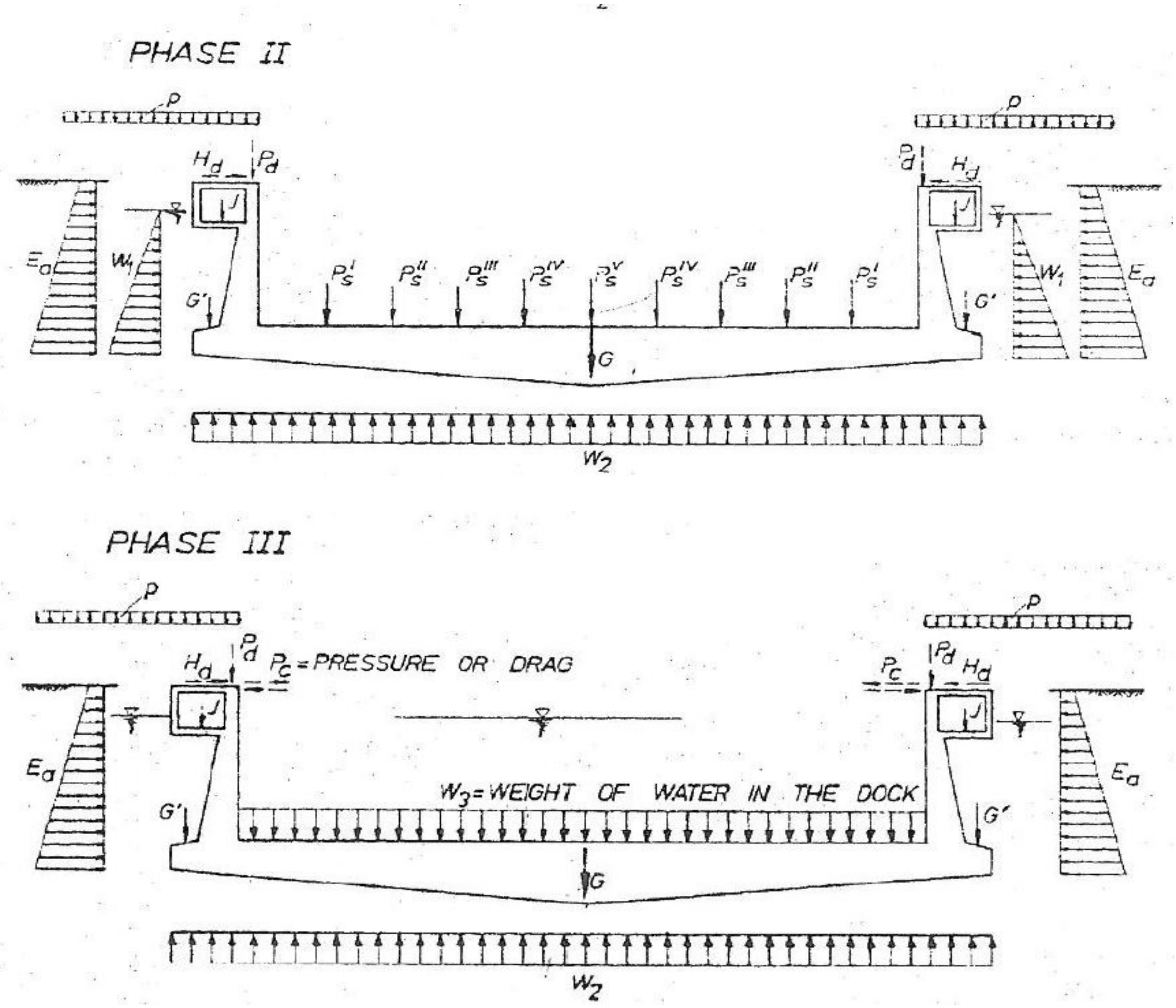



Figure 4. Loading combination phases (Sadeghi, 2001 and Oza, 2016)

**Disadvantages**

Every method has its disadvantages, and for this type, they are: (Salzer, 1986; Sadeghi, 2001 and Oza, 2016)

i. Non-movability.
ii. Foundational problems appearance.
iii. Maintenance cost when docks grow old.
iv. Docking/undocking are quite slow.

**Dock Gating**

Due to the functional nature of the graving drydock, which is drying the basin after the vessel set in position, so the vessel can be settled properly, then the basin should be sealed, to keep dock dry, so gates are needed to do this function.

Gating, however, has many methods developed over time, these methods differ due to many circumstances like size, cost, site conditions, etc.

The main types of the gate are (Hassani, 1987):

i. Caisson Gates ii. Cantilever Flap Gate, iii. Cantilever Flap Gate

### *Caisson Gates*

*Floating Caissons*

Floating caisson the mechanism is quite simple, this type has many chambers in it, they are filled with air, when the basin needs to be sealed, the caisson is navigated in position, and then the chambers are filled with water so it can settle properly and seal the gate (Veron-Harcourt, 1911).

*Sliding Caissons*

The other type is the sliding caisson, the main composition is quite the same, but the difference is in the method of closing and opening, with the floating one needs to be navigated, this one has somehow a railway and can move on it, this type requires a chamber for it where it can settle is the opening status (Veron-Harcourt, 1911).

### *Cantilever Flap Gate*

This type of gates is more efficient, easier to apply, with less initial and maintenance cost than caissons, the bottom hinged type will be discussed, this type consist of the gate hinged in the bottom edge, and these gates come in three types (Hassani, 1987):

i. Caisson type hinged gate.
ii. Single stiffened skinned with supporting floating tanks.
iii. Double-skinned cantilevered from the bottom, with an air compressing supporting floating tanks.

### *Separating –intermediate- Gate*

Separating gates are used generally in case of two or more operations are concurrent, these gates allow dividing huge drydock into smaller separated units, in order to accomplish more than one operation in synchronized time, this type could be mechanized (using a crane or sliding caissons) or not depending on the circumstances (Hassani, 1987).

## FLOATING DRYDOCKS

There is another main type of the drydocks, as every construction which is a combination of steel, concrete and timber. Construction of this type has its terms and conditions, practically. The first use was in world war II because of the ability of moving, while in that time the need of mobile serving unit was getting larger due to war circumstances, this wasn't the first appearance of this type of drydocking, because (as shown before) it was known just in the 16$^{th}$ century, so it already has been used before, but in tight range.

Floating drydock can manage itself, its movement is available in all directions because it is a motorized unit, so it can be moved to any place needed and it looks like a non-completed rectangular tube. It is made by many parts, to perform its U shape, these parts are connected to make the whole floating drydock (Volney, 1957).

### Detailed View

As a detailed view of the structure, it consists of a number of hatches in the pontoon and sponsons. These components have an operating nature that when a vessel needs to be served, these hatches are filled with water to allow the dock to lower in order to let the ship come onboard, and after vessel is located at a proper position, hatches are emptied using pumps, so the dock rises again with the vessel on, so the vessel's lower body will be exposed. Timbers and wooden planks (or any available materials) can be used to support the vessel to settle properly on the dock. When the repairing works are finished the hatches are opened once again so the water will come in, and that will make the dock partially sink in the water, and the vessel can be navigated out (see Fig. 5) (Inch-Pound, 2009).

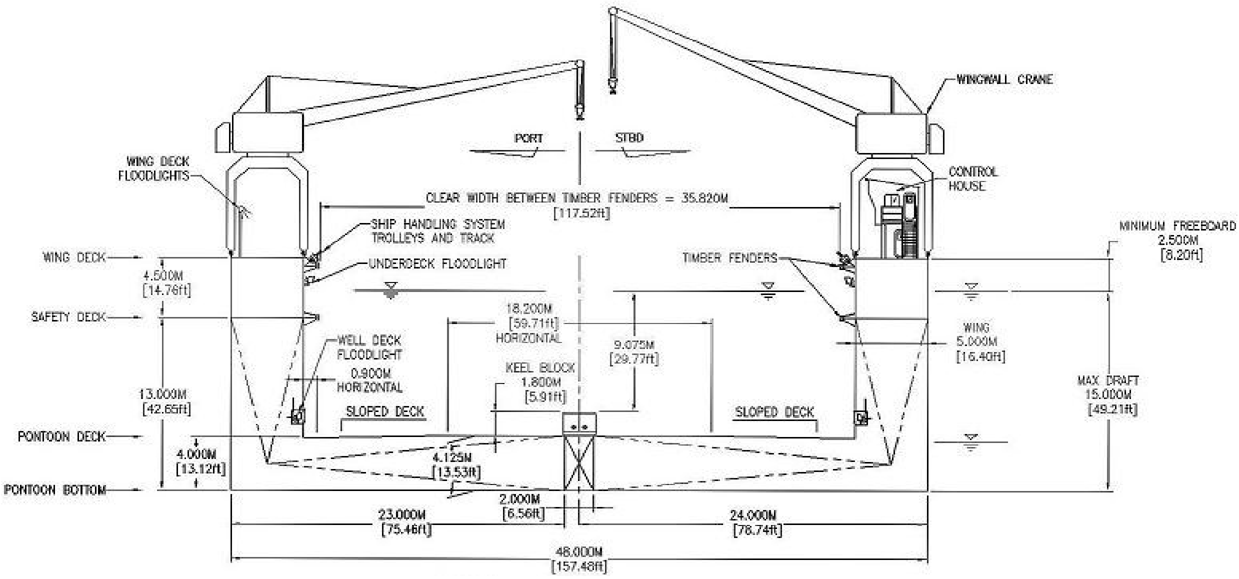



Fig. 5. Floating drydock (Inch-Pound, 2009)

## Design Factors

Generally the main designing factors are the same with the graving, but in floating drydocks there are some differences such as neglecting soil influences, and focusing on stability of the structure while sailing and serving the vessels, as it floats on the surface of water so it'll tip under the effect of waves so The are limitations of slope which are generally $19^o$ (in the direction of the length) and $27^o$ (in the direction of the width), In addition of the design of individual chambers, and connections, are performed in addition to the dynamic load caused by moving cranes (Inch-Pound. 2009).

## Advantages & Disadvantages

Cost of the maintenance and repairing is cheaper comparing with the others drydocks especially graving drydocks, easy mobility make it able to sail and this is the main advantage of this type drydocking method, contrary to the other drydocking methods which are fixed and are unable to provide services offshore (Vernon-Harcourt, 1911; Volney, 1957 and Inch-Pound, 2009).

The disadvantages can be described as follows:

i. Short maintenance periods.
ii. Operations require well knowledge and ware.
iii. Need of a special trained crew to sail

For additional information on the environmental data together with necessary formulas and the data needed for design and analysis of such structures, the instructions, data and recommendations given by (API, 2010), (Sadeghi, 1989, 2001, 2004, 2007a, 2007b and 2008), (US Army Coastal Engineering Research Center, 1980), (US Army Corps of Engineers, 2002), (Nouban and Sadeghi, 2013 and 2014), (US Army Corps of Engineers, 2011), (Nouban, 2016) can be used.

## CONCLUSION

This paper presents an overview of the main type of marine structural systems, illustrated that structural systems differ according to many conditions and functions, this paper presents also the types of marine structures, with their history and evolution, shows as well the operation fields, main requirements, boundaries, building materials used in the construction process, depended criteria, designing influential factors, advantages, and disadvantages of each individual type, in addition to structural, functional and operational differences between each type.

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