NAVAL ARCHITECTURAL CONSIDERATIONS IN THE DESIGN OF FLOATING DOCK

(DOI No: 10.3940/rina.ijme.2017.a2.415)

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SUMMARY

A brief introduction about floating docks, its advantages and types have been described. The naval architectural considerations which play a significant role in the design of floating dock have been explained. Typical ratios of L/B and L/D as a function of Dock's lifting capacity have been presented. Empirical formulation for the same have also been indicated wherever applicable. Intact stability and its criterion as applicable for a floating dock have been described. Critical positions during evolution of docking operation and important considerations while performing stability calculations have been highlighted. Attention has also been drawn to the damage stability of floating dock. Aspects of longitudinal and transverse bending moment, which are the governing aspects in the scantling calculations have been described. Also typical methods for securing and mooring of floating dock, without compromising on flexibility for docking operations have been described. Methodology and consideration which has to be kept in mind while using design software (such as NAPA) have been indicated. Simple size optimization techniques which result in steel / ballast volume reduction have also been explained.

1. INTRODUCTION

Floating docks are structures with sufficient dimensions, strength, displacement and stability to lift a vessel from the water. Floating docks range in lift capacities from a few hundred tonnes to over 100,000 tonnes. Unlike conventional dry dock it does not use valuable waterfront real estate. It can be built at the yard and towed to the site; this keeps construction costs low by increasing competition. It can be sold on the world market and keeps resale values high. Dock can be operated with a list or trim to facilitate docking vessels which have list or trim (damaged vessels). This can reduce block loading and reduce or eliminate vessel stability problems during keel touch down (bracing position). Vessels which are even longer than the dry dock can be docked by overhanging the bow and/or stern. The dock can be easily relocated during dredging. Few disadvantages of floating dock is that their operation requires special knowledge and care. Difficulties may arise because of high maintenance requirement on steel structure. Also when the dock is placed offshore, routing of men and material becomes restricted. Large tidal variations can complicate gangways, mooring etc.

The floating dock is operated by opening the flood valves and flooding the internal ballast tanks by gravity to submerge the dock. As the dock is going down, varying the rate of flooding of individual ballast tanks can control list, trim, deflection and bending moment of the dock. For de-ballasting pumps are used.

Pontoons are the main supporting body that must displace the weight of the vessel and dry dock in order to lift the vessel using buoyancy. The pontoon must distribute the concentrated load of the ship along the dock's centerline to the uniform buoyant support of the water pressure. The wing walls provide stability when the pontoon is submerged and also contribute for the longitudinal strength. The components of floating dock are shown in Figure.1. It is important to note that stability can be critical in floating docks with small wing walls or having walls that do not extend to the length of the dock.

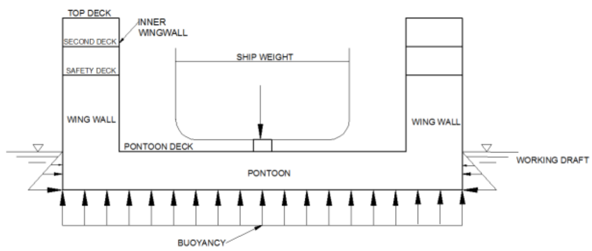

Figure.1 Floating dock Components

Floating docks can be broadly classified into three main types:

(a) Rennie type floating dock

The pontoon or "Rennie" type docks have continuous steel wings spanning a series of detachable pontoons as shown in Figure.2. The pontoon sections usually can be self-docked by detaching them from the wings, turning them 90 degrees and docking them on the remaining sections. This type dock is generally weaker in the longitudinal direction than the one-piece dock since only the wingwalls are effective for longitudinal strength. Ocean tow is usually not possible (unless the dock is cut into shorter sections) due to the lower longitudinal strength. The structure of a "Rennie" type dock is generally heavier than the one-piece dock since double transverse bulkheads are needed at the gaps (end bulkheads for each pontoon section), and the wingwalls must be heavier to get the required longitudinal strength.

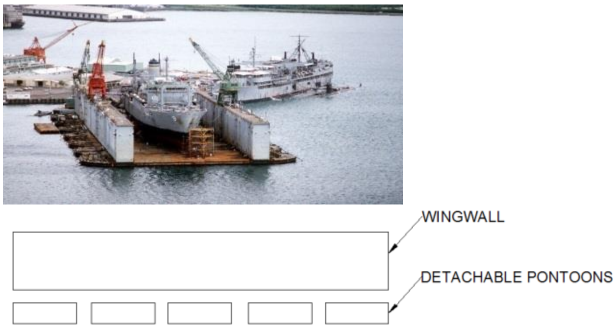

Figure.2 Rennie Type Floating dock

(b) Caisson type floating dock

The caisson, box or one-piece type dock is built in one piece, with continuous wing walls and pontoon as shown in Figure.3. This type dock can be lighter and stronger than the other types since its full depth is effective in longitudinal bending. The capability to ocean tow a one-piece dock is easier to achieve, although not all one-piece docks can be ocean towed. A one-piece dock cannot be self-docked. It's also harder to build it in sections and join afloat.

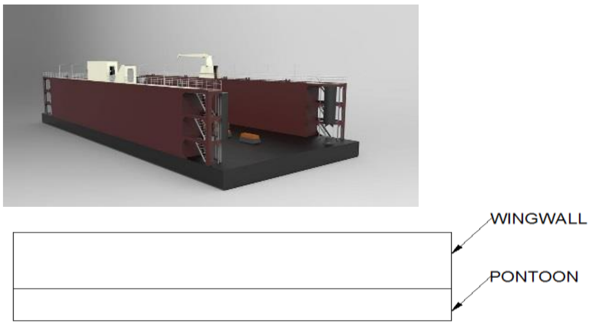

Figure.3 Caisson Type Floating dock

(c) Section dock type floating dock

A floating dock, which has no structural continuity over its length, is a sectional dock (both pontoon and wing walls are not continuous as shown in Figure.4). Sectional docks are joined with movement connections (pins or plates at the top and bottom of the wings) and act like a "Rennie" type dock. Additionally, ballasting and de-ballasting operations can be very critical on these types of docks due to bending and deflection. Sectional docks are usually self-docking.

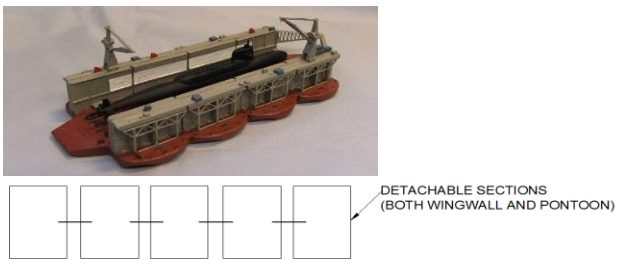

Figure.4 Section Type Floating dock

2. SIZING OF FLOATING DOCK

The principal particulars of the floating dock, as shown in Figure.5, are primarily governed by the type of ships that are intended for docking (i.e. size of ships, its displacement, draft etc.). The optimal size of the dock is generally arrived through an iterative process. The driving factors which govern the principal parameters of the floating dock are elaborated below:

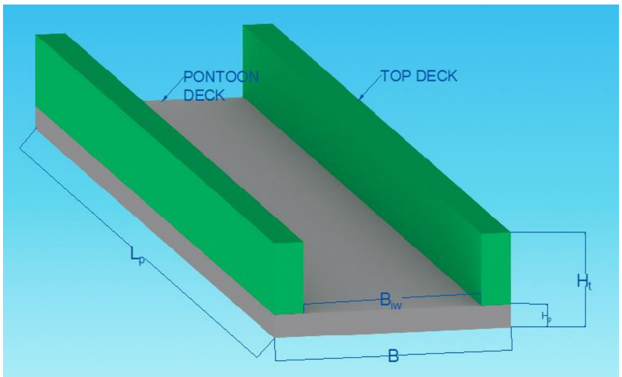

Figure.5 Caisson type floating dock

2.1 LENGTH OF PONTOON (L_P)

The length of the pontoon is measured between the aft bulkhead of the pontoon and the fore bulkhead of the pontoon, disregarding the extension of the platforms. Typically, the length of the pontoon would depend on the maximum length of the ship that is envisaged to be docked. Owners generally specify the types of ships which are envisaged to be docked along with their principal parameters, docking drafts, load distribution etc. For the purpose of getting the first estimate of length of pontoon, the following empirical relation as given in LR rules, can be used

Generally, $L_s = 0.8 * L_P$

Where, L_P is the length of the pontoon,

L_s is the shortest ship with displacement equal to maximum lifting capacity

2.2 BREADTH BETWEEN INNER WINGWALLS (B_{IW})

The breadth between the inner wingwalls is decided based upon the maximum breadth of ship to be docked inside the floating dock. In case of multiple docking enough space must be provided for the clearance between the ships and on each side of the docked ship a certain space must be left free for staging, as well as for working devices for mechanized cleaning and painting of the ship's side and to give sufficient air, light; and access to ship's bottom. The walkways at the inner wing walls as well as the hauling system should be appreciated, which limit the maximum breadth of the vessel to be docked.

$$B_{iw}\ (Breadth\ between\ inner\ walls) \\ = Maximum\ possible\ breadth\ of\ the\ docked\ ship \\ + Clearances\ for\ staging \\ + Clearance\ for\ maintenance + Walkways \\ + Transverse\ clearance\ between\ ships$$

Note: Transverse clearance is valid only in case of multiple docking.

2.3 BREADTH OVERALL (B)

Breadth overall is decided by two major parameters, breadth of inner wingwalls and the breadth of top deck. The breadth of the top deck depends upon the deck machineries.

Deck machineries include the following:

- Cranes
- Winches
- Hauling system, etc.

It needs to be noted that sufficient spacing between the deck machineries is to be provided for personnel movement/statutory requirements (escape route etc.). In special cases, there may be a requirement for special deck equipment like movable cover etc. Breadth of dock has a direct impact on the stability of the dock. Since the floating docks have inherently higher beam, intact stability requirement gets easily complied at the working draft. However, for other phases of docking as explained in *Sec 4*, wingwall width would play a significant role for achieving the required stability.

Varying breadth of wingwall along the height of dock: Generally the floating docks are U shaped. However, by providing a cut section as shown in Figure.6, we can reduce the buoyancy thereby reducing the requirement of ballast water. Lower safety deck height can be achieved with this lowered ballast water requirement. All in all, this accounts to reduction in steel weight by lowering the safety and top decks and providing the cut section in addition to lesser pumping requirements

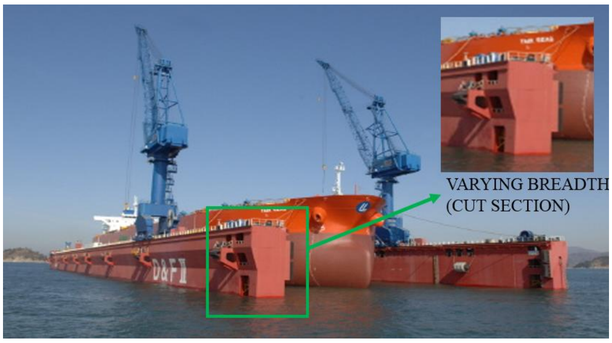

Figure.6 Varying breadth of wingwall along the height of the dock

2.4 LIGHTWEIGHT OF THE DOCK (LWT)

Preliminary lightweight estimation is done by estimating all the structural weights, hull outfit, electrical, machinery and dock equipment weights. Unlike ships where the effort is generally to reduce the light weight as much as possible, in the case of floating dock, the weight should neither be too high nor too low. If the weight becomes more, the free board requirement would get impacted and if the weight becomes less the submergence draft can't be achieved.

Normally, weight margins in the range of 3 to 5% of total estimated weight are considered depending on the stage and in-depth development of a design.

2. 5 DEADWEIGHT OF THE DOCK (DWT)

All other weights which are not an integral part of the lightweight and more likely act as a support item to the dock are considered as deadweight items as listed below:

- Fuel oil
- Fresh water
- Ballast water other than rest water and compensating ballast (explained in subsequent paragraphs)
- Constant weights such as
  - Dock spare parts not belonging to the lightweight
  - Persons onboard, workers.
  - Provisions and store items.
  - Documentations, handbooks, manuals, loose tools and gears.
  - Incidental items in docks stores.
  - Cables for welding, hoses for gas cutting, gas bottles for flame cutting.
  - Scaffoldings for docked ship.
  - Cherry picker, forklift truck.
  - Garbage container, steel scrap container, paint buckets and miscellaneous etc.

2. 6 REST WATER (RW)

The ballast water remaining in the tanks which the pumps cannot discharge is defined as rest water (un-pumpable water). The quantity of rest water plays a significant role in the dock design (sizing of the dock), since this weight of water would get added to the displacement of the dock. Rest water would be part of the lightweight of the dock. The typical height of rest water ranges from 0.5 to 0.65m. For a typical 10000 tonnes dock, the quantity of rest water would be of the order of 3000 tonnes to 4000 tonnes. The aim of the designer should be to keep this weight as low as possible so as to arrive at an optimal size.

2. 7 COMPENSATING BALLAST (CW)

The compensating ballast is typically catered for correction of bending moment, deflection, heel and trim at the working draft. It would be part of Lightweight of the dock. The suggested methodology is to be adopted, for arriving at an optimal value of compensating ballast water, (when a ship of weight W which is equal to the lifting capacity is docked, the loadcase is assumed to be the worst case possible which is generally defined by owner). A typical illustration is indicated in Figure.7 and Figure.8.

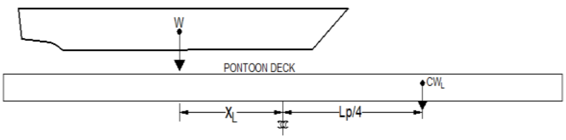

Figure.7 Longitudinal section of floating dock with docked ship

Moment balance with respect to the centerline in the longitudinal direction (to balance trim):

$$CW_L * \frac{L_p}{4} = W * x_L$$

This compensating ballast is filled in the volume available for ballasting, in this case, ahead of midship to bring the dock to level trim.

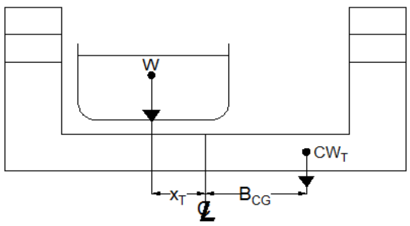

Figure.8 Transverse section of floating dock with docked ship

Moment balance with respect to the centerline in the transverse direction (to balance heel):

$$CW_T * B_{CG} = W * x_T$$

The final compensating ballast water is the maximum of these two values obtained, CW_L and CW_T.

2.8 LIFTING CAPACITY (LC)

The lifting capacity is the displacement of the heaviest ship which is intended to dock in normal service. Lifting capacity is an important parameter which in turn drives the main particulars of the dock

Table 1 below gives details of typical Floating docks with Lifting capacities ranging from 8000T to 12000T dock.

Table 1 List of floating docks (Source: Internet)

Floating dock/Shipyard	L_p (m)	B(m)	H_t (m)	LC (t)
Dubai Drydocks;	205.5	43	13.1	15000
Bai Yun Shan Shanghai;	190	26.9	13	11500
Hai Hua;	192	40.5	14.4	12000
Vuyk,Rotterdam;	100.8	28.52	11.7	3500
IPP engg,TLG Services, Hamburg;	164	33.4	15.62 5	6000
Floating Dock, Port Blair, India;	188.7	40	15.5	11500
SINE 212CD dock;	190	42	13	10000
Gorodets Shipyard (Russia);	158	36.85	13.35	8000
Metalsjips & docks;	162	30.8	24.8	8000
Shipyard Yantar JSC;	150	29	17.7	12000
Barelang Satu,P.T. ASL Shipyard Indonesia;	123.44	39.62	10.97	5000
Rodson universal PTE.LTD;	155	32.4	12.8	8500
P.T. ASL Shipyard Indonesia;	123.44	39.62	10.97	5000
MAN Gutehoffnungshütte AG;	190	40	14.5	15000

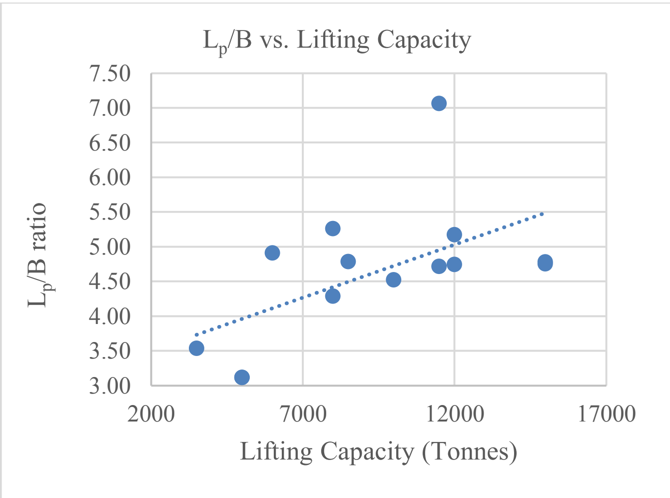

Figure. 9 L_p/B versus Lifting Capacity

Based on the data collected from various docks, the typical sizing parameters namely L_p/H_t, L_p/B have been plotted against Lifting capacity (LC). It can be noticed that there is scatter of few points in Figure 9 and 10. These outliers essentially indicate owner specific requirement for a given beam or dock height vis-a-vis displacement depending of type of ship to be docked.

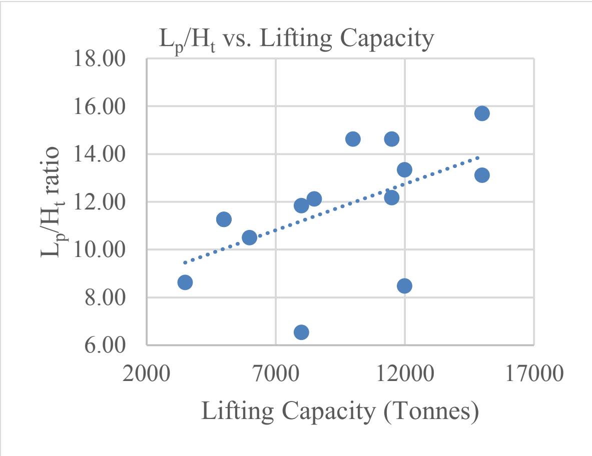

Figure. 10 L_p/H_t versus. Lifting Capacity

2.9 WORKING DRAFT (T_W)

The working draft is the distance measured vertically on the midship transverse section, from the molded base line to the draft at which the dock is operated. The working draft depends upon the following parameters like length of the pontoon, the breadth of the pontoon, the lightweight, the deadweight, the rest water, the compensating ballast and lifting capacity.

$$T_w = \frac{LWT + DWT + RW + CW + LC}{L_p * B * 1.025}$$

The floating dock is then designed for this maximum lifting capacity with which the volume of ballast required would have to be calculated.

2.10 PONTOON DECK HEIGHT (H_P)

The pontoon is the structure which supports the dock blocks for docking of the ships. Typically this deck extends between the inner wing walls and an "in line stringer" at the wing walls as shown in Figure.11. The pontoon deck height is decided based on the working draught plus the statutory free board requirement (as indicated in Section 4.3).

In order to enable smooth draining of water on the pontoon deck, camber is typically provided. Generally the height of camber provided is about 0.5% of Breadth between wingwalls (B_{iw}) with its highest point at centerline and gradually tapers towards the wingwalls as shown in the picture. The introduction of camber on the pontoon deck would result in some air entrapment just below the pontoon tank top thus creating an air cushion. This volume of air cushion would need to be accounted for the following

a) Reduction in the ballast volume. The actual volume of ballast water that can be taken inside a tank is the reduced by the volume of air cushion.

b) Free surface correction during stability calculations.

$$Pontoon\ Deck\ height\ (H_p\ at\ centre) = Working\ Draft\ (T_w) + Freeboard\ requirement$$

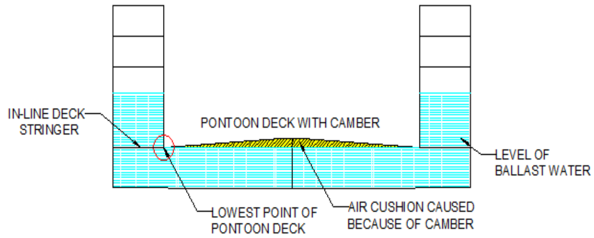

Figure. 11 Pontoon Deck

2.11 SUBMERGENCE DRAFT (T_S)

The submergence draft is the maximum permissible draft to which the floating dock can get immersed at level trim. This submergence draft is an another important parameter which governs the size of the dock which in turn is guided by the following - pontoon deck height, height of the keel blocks, the clearance between keel blocks and the docked ship, maximum draft of the docked ship (stipulated by owner).

$$Submergence\ draft(T_s) = Pontoon\ deck\ height(H_p) + keel\ block\ height + clearance\ between\ keel\ blocks\ and\ ship + Maximum\ possible\ draft\ of\ the\ docked\ ship$$

2.12 SAFETY DECK HEIGHT (H_S)

As the name indicates, the safety deck is the deck extending over the length of the wing walls located below the top deck and above the ballast tank, which is watertight. The height of Safety deck depends upon the maximum submergence draft. The volume of ballast water required to achieve the maximum submergence draft decides the safety deck height.

$$Ballast\ requirement\ for\ acheiving\ submergence\ draft\ (T_s) = Disp\ at\ T_s - LWT - DWT$$

$$Ballast\ to\ be\ provided\ by\ wing\ wall = Ballast\ requirement\ for\ acheiving\ T_s - Ballast\ that\ can\ be\ provided\ upto\ H_p$$

$$Minimum\ height\ of\ water\ required\ in\ wing\ tanks\ to\ achieve\ submergence\ draft = \frac{(Disp\ at\ T_s - LWT - DWT) - (L_p * B * H_p * 1.025)}{2 * Length\ of\ wingwalls * Breadth\ of\ wingwalls * 1.025}$$

$$Safety\ Deck\ Height\ (H_s) = Pontoon\ Deck\ Height (H_p) + Minimum\ height\ of\ water\ required\ in\ wing\ tanks\ to\ achieve\ submergence\ draft + margin$$

Note: While calculating the ballast requirement, we need to eliminate the volume that cannot be ballasted (e.g., Pump room etc.)

Generally a designer margin in terms of volume is given to the volume of ballast water to decide the height of safety deck. The typical value is of the order of 3-4 % of total ballast volume.

2.13 TOP DECK HEIGHT (H_T)

The top deck means the uppermost continuous deck extending over the length of the wing walls. The top deck must be atleast 1m above the maximum submergence draft as specified by class rules (as shown in Section 4.3). The top deck height is normally governed by the safety deck height and the accommodation deck(s) height. Generally a top deck camber of 50mm is provided to allow drainage of water with the highest point at inner wing wall and gradually tapers towards the outer wing wall as shown in Figure.12.

$$Top\ Deck\ Height\ (H_t) = Safety\ Deck\ Height\ (H_s) + Accommodation_1\ Height + Accommodation_2\ Height$$

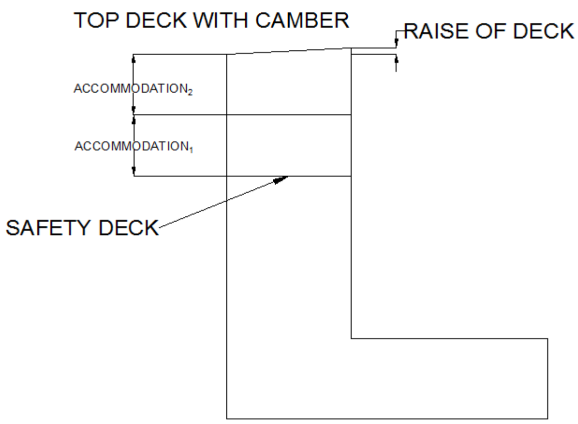

Figure. 12 Top Deck

3. USE OF EXCEL SPREAD SHEET & NAVAL ARCHITECTURAL SOFTWARE FOR SIZING

As described in the previous paragraphs, a mathematical model is developed with simple spread sheets to iteratively arrive at the optimal size of the floating dock. Also, with the availability of basic design software like NAPA, Maxsurf®, Autoship® etc., it would be possible to accurately determine hydrostatics / stability / loading cases for a given size of the dock at an early stage.

Use of Excel Spread Sheet: Spread sheets are used to obtain optimal principal parameters – Length of pontoon (L_p), Breadth overall (B), Breadth between inner wingwalls (B_{iw}), Lifting capacity (LC), Deadweight (DWT), Rest Water (RW), Lightweight (LWT), Compensating Ballast (CW), Pontoon Deck Height (H_p), freeboard requirement, keel block height, keel block clearance, draft of docked ship etc. under various combinations of input conditions (i.e. Owner's requirements and limitations based on the type of ships that are to be docked). Using such kind of excel spreadsheets, we can arrive at the principal parameters of the dock, for each and every combination. The designer can choose the optimal size, keeping in mind the constraints imposed by the owner, imposed by the location, class / statutory requirements etc.

Use of Naval Architectural Software: It is recommended to arrive at a preliminary size using the excel macro described above and thereafter carry out the modeling using any of the basic design software such as NAPA Maxsurf®, Autoship® etc. For example, sample modelling in NAPA is shown in Figure.13:

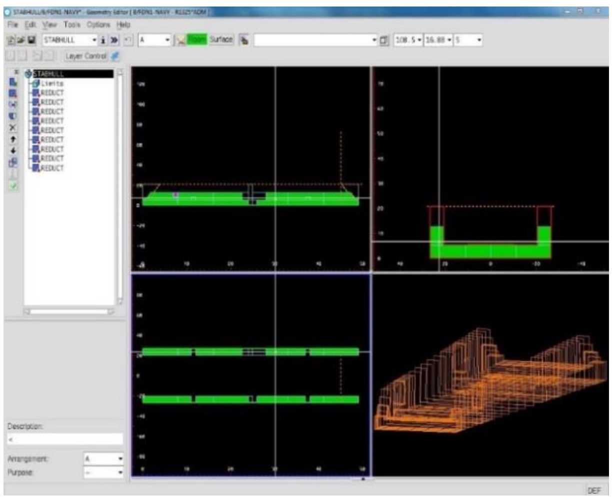

Figure. 13 Sample Floating Dock model in NAPA software

a) Preliminary hydrostatics

The hydrostatic output for a typical floating dock is shown in Figure. 14. This would clearly bring out the ballast, buoyancy, weight which in turn would confirm the lifting capacity of the floating dock. Also it should be noted that there will be significant reduction in MCT and TPC values of the dock soon after the submergence of pontoon deck because of significant reduction in waterplane area.

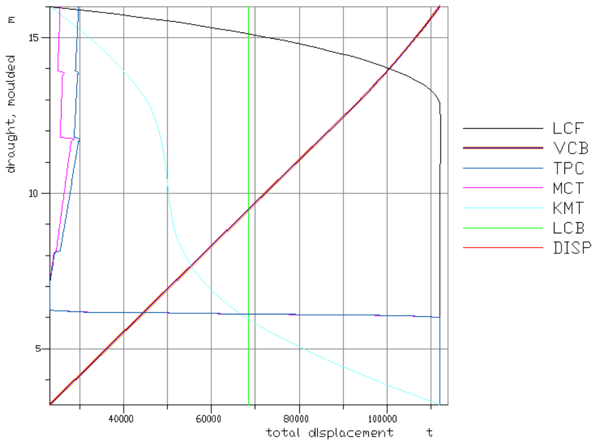

Figure. 14 Hydrostatic Curves from NAPA Software

b) Preliminary Load cases

The floatation, trim and stability can be checked for a number of load cases. This would give a clear estimate of the following parameter for various possible load cases – dock's draft, trim, heel, bending moment, shear force, individual tank volumes, differential head, metacentric height, freeboard requirements, margin, and optimal tank filling sequence. A snapshot from NAPA software is shown in Figure.15.

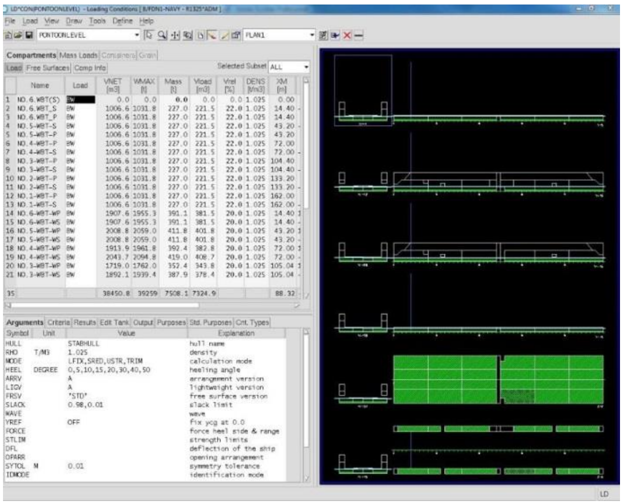

Figure.15 Loading Conditions in NAPA Software

c) Preliminary estimate of damage

We can have a preliminary assessment of the damage conditions as elaborated separately at section 4.4.

Unlike ships, there are some unique features for the floating docks, which need to be incorporated in the software model for floating docks so as to arrive at correct results. Some of these features are given below:

- Care is to be taken that a minimum amount equal to rest water is present in all ballast tanks for all loading conditions expect lightship condition.
- Since the pontoon deck invariably has camber, there would be some air which would get entrapped. The volume of air trapped is to be calculated and subtracted from respective tank volumes.
- Free surface correction due to entrapped air has to be considered.
- The constant weight (mentioned in Section 2.5) will be different in different phases of docking. For example: constant weight will be higher in working condition (Phase 5 of Section 4.1(a)) as all the cherry picker, forklift etc. will be present on pontoon deck for refit of the vessel whereas in other phases the same will not be present.
- Accurate modeling as far as possible is required since any change in weight/volume will lead to reduction of design margins.

4. STABILITY OF DOCK

4.1 INTACT STABILITY

Unlike a typical ship, the stability parameters, particularly the waterplane area of the floating dock drastically changes during different phases of the docking operation. This change in water plane area has an effect on the GM. It must be ensured that the floating dock be stable throughout the entire docking or undocking process.

4.1(a) Phases of Docking

Stability of the dock/ship system is usually investigated for five separate phases of docking or undocking process. These phases are:

- Floating Dock at full submergence – No ship (Phase 1) as shown in Figure.16
- Partial Lift of ship – ship has been lifted approximately half its docking draft (Phase 2) as shown in Figure.17
- External waterline at top of the keel blocks (Phase 3) as shown in Figure.18
- External waterline just over pontoon deck (Phase 4) as shown in Figure.19
- Dock at normal operating draft (Phase 5) as shown in Figure.20
- Floating Dock at full submergence – No ship (Phase 1)

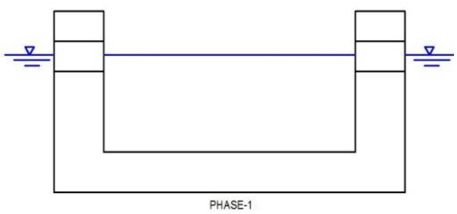

Figure.16 Phase 1 – Dock at full submergence

- Partial Lift of ship – ship has been lifted approximately ½ its docking draft (Phase 2)

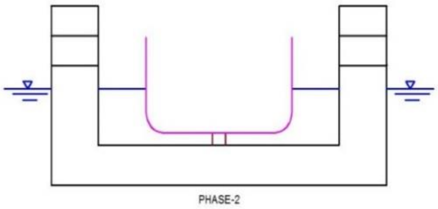

Figure.17 Phase 2 – Partial lift of ship

- External waterline at top of the keel blocks (Phase 3)

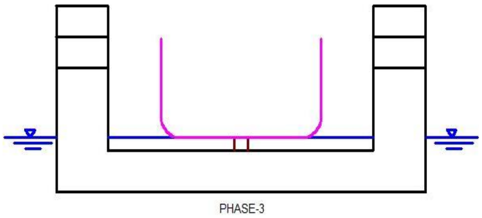

Figure.18 Phase 3 – External waterline at top of keel blocks

- External waterline just over pontoon deck (Phase 4)

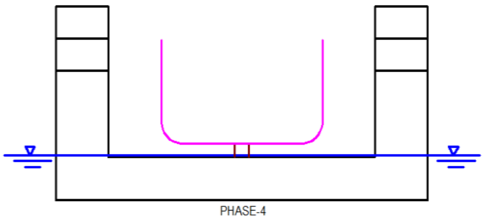

Figure.19 Phase 4 – External waterline just over pontoon deck

- Dock at normal operating draft (Phase 5)

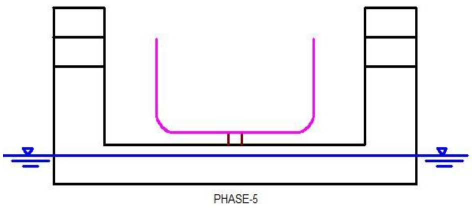

Figure.20 Phase 5 – Dock at normal operating draft

4.2 STABILITY CRITERIA BY VARIOUS CLASSIFICATION SOCIETIES

Different classification societies stipulate the minimum GM which should be attained in all of the five phases described above as indicated in Table.2.

Table.2 Stability Criteria as given by different classification societies

Classification society	Stability Criteria in any of the 5 phases
LR	GM ≥ 1 m
GL	GM ≥ 1 m
DNV	GM ≥ 1 m
RINA	GM ≥ 1.5 m

The typical GM values for different phases of stability are shown in Figure 21. It has to be noted that Phase 3 and Phase 4 has the least stability due to sudden loss of water plane area thereby causing loss of GM.

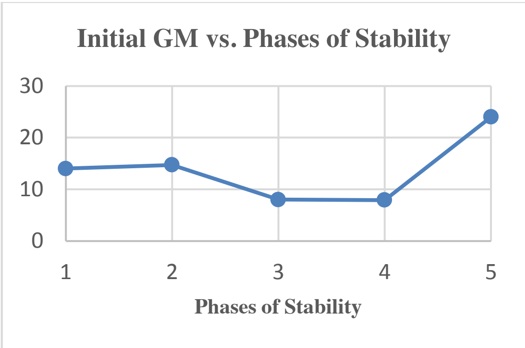

Figure.21 Initial GM variation for a typical dock of Lifting capacity 10000 tonnes

The typical stability curves (GZ curves) for a floating dock of lifting capacity 10000 tonnes, during each phase are presented for information (in Figure.22) although the class rules do not state any criterion regarding GZ curves.

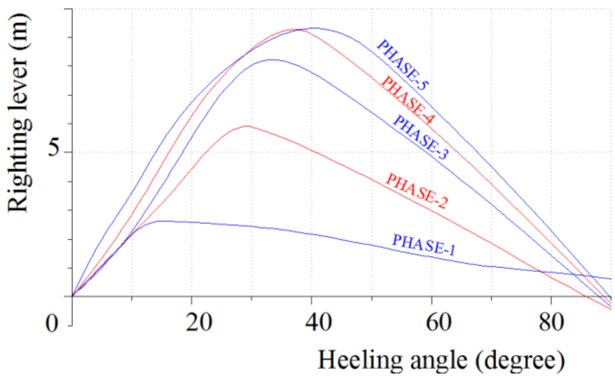

Figure.22 GZ curves for different phases for a typical dock of Lifting capacity 10000 tonnes

The U.S. Navy's MIL-STD-1625D describes GM as a function of the dock's lifting capacity as indicated in Figure.23.

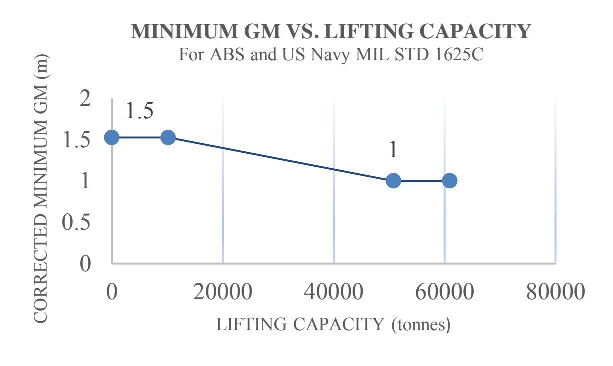

Figure.23 Min. GM versus. Lifting Capacity

4.3 FREEBOARD REQUIREMENT

Different Classification societies stipulate the free board requirement for both the pontoon deck and the top deck as indicated in Table.3.

Table.3 Free board Criteria as given by different classification societies

Classification society	Freeboard criteria for Pontoon Deck at centerline	Freeboard criteria for Pontoon Deck at inner wingwalls	Freeboard criteria for Top Deck
LR	f ≥ 300 mm	f ≥ 75 mm	-
GL	f ≥ 300 mm	No pontoon deck submersion at any loading condition.	f ≥ 1000 mm
DNV	f ≥ 300 mm	f ≥ 75 mm	f ≥ 1000 mm
ABS	f ≥ 300 mm	f ≥ 75 mm	f ≥ 1000 mm
RINA	f ≥ 300 mm	f ≥ 75 mm	f ≥ 1000 mm

The above limits however, assume the travelling crane(s) are positioned so as to give no trim; the freeboard at level trim is to be such that when crane(s) are moved to the forward end or to the aft end of the dock, the pontoon deck is not submerged.

4.4 DAMAGE STABILITY

Though damage stability requirement for floating dock has not been explicitly stated by the classification societies, the military standards (MIL-STD-1625D (SH) - Section. 5.1.3.3.1.c) has stipulated certain basic norms which are to be met for the floating docks.

Extent of Damage: The MIL standard specifies the minimum damage stability requirements under two conditions i.e. one in working condition (Phase 5 of Section 4.1(a)) and the other under fully submerged condition (Phase 1 of Section 4.1(a)).

Fully submerged condition (Phase 1): In the fully ballasted condition (Phase 1) the following two types of damaged scenarios and resultant flooding shall be assumed:

- Side shell damage: Damage shall be assumed to occur between main transverse bulkheads with penetration upto but not through the inner wing wall as shown in Figure.24. The safety deck shall be assumed to be ruptured.

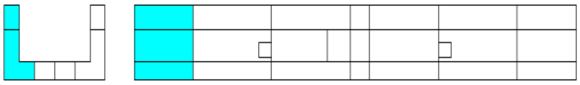

Figure.24 Extent of flooding in side shell damage in fully ballasted condition (section and profile view shown)

- Bottom shell damage: Damage shall be assumed to occur between main and transverse bulkheads such that the complete space between main transverse bulkheads floods as shown in Figure.25. The safety deck may be assumed to remain watertight.

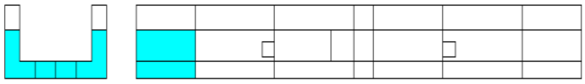

Figure.25 Extent of flooding in bottom shell damage in fully ballasted condition (section and profile view shown)

Working condition (Phase 5): In the working condition, with docked ship on the keel blocks (phase 5), the following two types of damaged scenarios and resultant flooding shall be assumed:

- Side shell damage: Damage shall be assumed to occur on the side shell at a main transverse bulkhead such that the two adjacent tanks or spaces are flooded. Damage shall be assumed to penetrate upto but not through the inner wing wall. The safety deck shall be assumed to be ruptured as shown in Figure. 26. For closed-ended docks, the basin shall be assumed flooded.

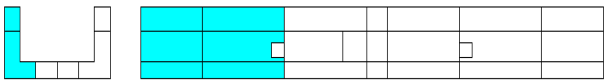

Figure.26 Extent of flooding in side shell damage in de-ballasted condition (section and profile view shown)

- Bottom shell damage: Damage shall be assumed to occur on the dock bottom at the intersection of a main transverse watertight bulkhead and a main longitudinal watertight bulkhead such that all tanks or spaces adjacent to the intersection are flooded as shown in Figure.27. The safety deck shall be assumed to be undamaged. For closed-ended docks, the basin shall be assumed flooded.

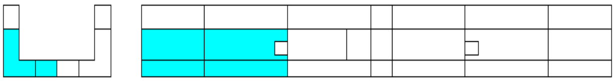

Figure.27 Extent of flooding in bottom shell damage in working condition (section and profile view shown)

4.4 (a) Criteria for damage stability

The damage criteria governing both the working condition as well as the submerged condition as per the MIL standards are as follows: - the conditions with which the vessel will be stable even under damaged condition. But for floating docks, no damage criteria have been defined by classification society except for MIL-STD. According to MIL-STD-1625D (SH), the Damage stability criteria are as follows:

- Margin line Criterion: The margin line of 3 inches (76 mm) below the top wingwall deck or the lowest non-watertight wingwall penetration of a floating dock, as shown in Figure.28 should not get immersed under any damaged condition

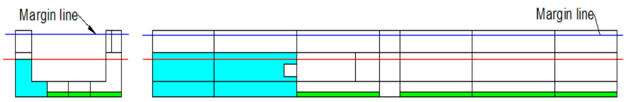

Figure.28 Margin Line criterion (at 76 mm from the top deck) (section and profile view shown)

- Heel and trim Criterion: In the worst combination of damage, Heel to be less than 15^0 and trim to be lesser of 3^0 or 20 feet. An example case of dock being subjected to heel and trim is illustrated in Figure.29

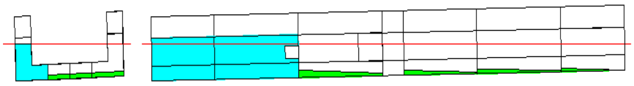

Figure.29 Dock subjected to heel and trim because of damage to side shell (section and profile view shown)

Also it is must be ensured that maximum allowable differential head not to be exceeded under any of the damage condition as stated above.

5. STRENGTH CALCULATIONS

5.1 LONGITUDINAL STRENGTH

The longitudinal strength is to be calculated for the condition, the ship of length L_s is supported on the keel blocks, the center of the ship's length being over the mid-length of the dock. The typical loading, shear force and bending moment curves for a floating dock are shown in Figure.30 and Figure.31.

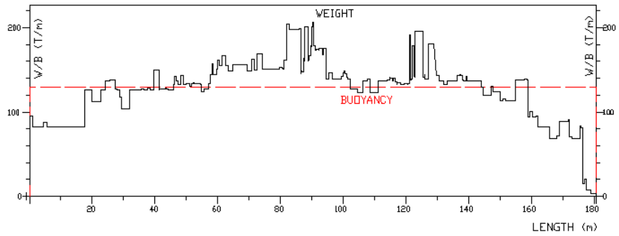

Figure.30 Typical Weight and Buoyancy Distributions acting upon the dock

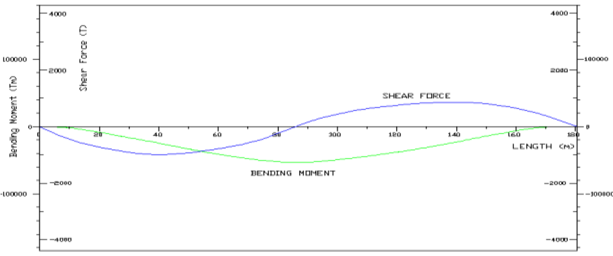

Figure.31 Resultant Bending Moment and Shear Force Distributions

Different classification societies give different methodologies for estimating the longitudinal bending moment. Lloyd's Register (LR) gives a very simple empirical formula for finding bending moment – one for uniform ballasting and other for non-uniform ballasting.

Uniform ballasting: Ballast operation is done in an equal manner, ensuring the internal ballast is maintained at equal level throughout the dock. In this method of filling, there would be no control of list, trim, bending moment and deflection using ballast water.

- Minimum section modulus (cm^3)
  $Z_{min} = 8.93 * LC * (L_p - 0.917 * L_s)$
- Permissible still water bending moment (kNm)
  $M_s = 137.34 * Z_{min} * 10^{-3}$

Non-Uniform ballasting: In this case, the ballasting/deballasting is undertaken in a controlled manner through a ballast control system, i.e. differential emptying of ballast tanks is feasible through ballast control system, so as to ensure the peak values of bending moment/shear force are much lower compared to uniform ballasting.

- Minimum section modulus (cm^3)
  $Z_{min} = 5.682 * LC * (L_p - 0.917 * L_s)$
- Permissible still water bending moment (kNm)
  $M_s = 137.34 * Z_{min} * 10^{-3}$

In addition to the above two conditions, for all cases which involve ocean towage of floating dock to the operation site, it must also be ensured that the maximum bending moment experienced during the voyage (still water bending moment + wave bending moment) is also within the permissible limits. The typical values recommended by Lloyd's register are as follows:

- Permissible bending moment during ocean towage (kNm)

$$M_w = 170 * Z_r * 10^{-3}$$

(Where Z_r is the actual section modulus at bottom or deck whichever is lesser)

Loadcases: Once the permissible values of bending moment/shear force are estimated (based on the class rules as indicated above), the actual value of bending moment experienced by the dock under various load cases for different condition of loading, ballasting etc. are checked. Few typical load cases are indicated in Figure 32, Figure 33 and Figure 34:

(a) Heaviest possible ship in the middle of dock.

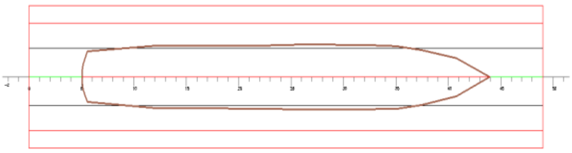

Figure.32 Loadcase showing the heaviest ship placed at the middle of the dock

(b) Two ships docked side by side transversely (total load not exceeding the lifting capacity).

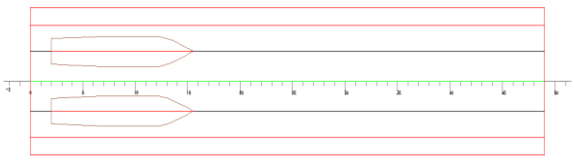

Figure.33 Loadcase showing two ships placed side by side in the transverse direction

(c) Multiple docking of ships at various locations along the length of the dock (total load not exceeding the lifting capacity).

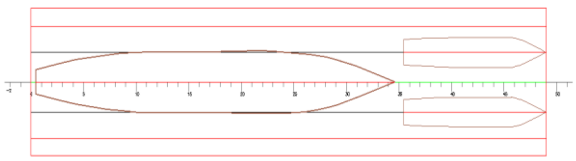

Figure.34 Loadcase showing two ships placed side by side in the transverse direction and one more ship placed with its centerline in-line with dock's centerline

In all the above load cases, it must be ensured that the algorithm of ballast control system is capable of handling any of the above combination so as to ensure that the limiting value of bending moment/shear force is not exceeded as shown in Figure.35. Ballast control system is an intricate system which is used for controlled ballasting and deballasting of the dock. The main function of the ballast control system is to control amount of submersion and limit the dock's list, trim and deflections within permissible limits.

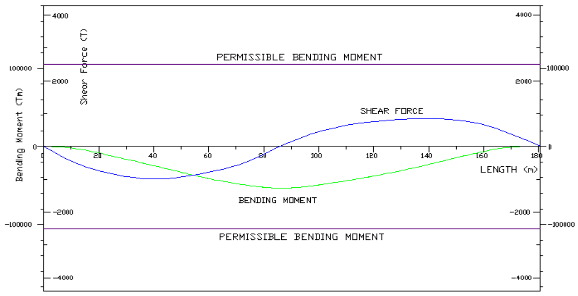

Figure.35 Limiting values of Bending Moment

5.2 TRANSVERSE STRENGTH

In case of floating docks, the transverse bending moment also assumes significance, given the type of loading on the dock in combination with the ballasting. The transverse strength calculations are done to obtain the maximum transverse bending moment acting upon the dock. The scantling of the dock is to be checked for both transverse and longitudinal bending moments. In typical docks, the scantling of pontoon deck and bottom plate is normally driven by transverse buckling criterion. For a typical section of the dock, the transverse loading (neglecting the effect of side loading) is shown in Figure.36.

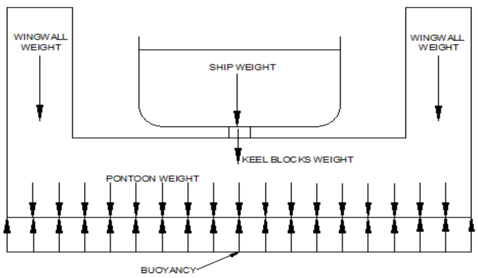

Figure.36 Forces acting on the dock in the transverse view

The force exerted by each item (such as docked ship, wingwalls, pontoon, water (buoyancy)) can be defined in terms of Load/unit length, the value of which is derived from the following expressions:

$$Ship\ Load/Unit\ length = \frac{1.167 * LC}{Ls}$$

$$Keel\ Blocks\ Load/Unit\ length = \frac{1}{Lp}\left(\frac{LC}{600} + 43\right)$$

The weights of the pontoon and wingwalls can be estimated by linearly interpolating the Lightweight with respect to volume. The same is shown below:

$$Wingwall\ weight = \frac{Wingwall\ Volume * LWT}{Total\ Volume}$$
$$Pontoon\ weight = \frac{Pontoon\ Volume * LWT}{Total\ Volume}$$

After attaining the loads at wingwalls and at the centerline, the net load will be taken and integrated along the width of the vessel. This integrated value will be the shear force distribution along the width. Further integrating shear force distribution along the width will give us the Bending Moment distribution. An excel macro can be developed for estimating the transverse bending moment.

6. SCANTLING CALCULATIONS

The various classification rules provide empirical formulae for estimation of scantling for various regions of the floating dock viz-a-viz ballast tanks, watertight bulkhead, decks, longitudinal bulkheads, floors etc. The inputs required for undertaking the scantling estimation are as follows:

- Principal particulars of the dock
- Height of safety deck, top deck
- Material factor (k)
- Differential head
- Longitudinal / transverse frame spacing
- Longitudinal bending moment
- Transverse bending moment
- Limiting wave bending moment (for ocean towage)
- Lifting capacity
- Maximum submergence draft

The scantling estimation for the plate would typically involve the estimation of "minimum thickness" based on the tank pressure (i.e., head) and check for buckling (both longitudinal and transverse buckling). Unlike normal ships, the transverse bending is more predominant in deciding the plate scantling / size of stiffeners (as described at Section 5.2). An excel macro can be prepared for optimization of these scantling.

Floating docks do not have much opportunity for regular underwater maintenance both external and internal. As the design life of floating dock is generally about 40 years, necessary protection against corrosion is required. Typical means for protection against corrosion are

- High performance paint with ~15 years lifetime
- Sacrificial anodes
- ICCP.

Also, corrosion allowance is necessary for scantling calculation according to classification society rules. For example LR considers corrosion allowance of 2.5 mm for ballast tanks, which is part of their empirical formulation.

7. MOORING / SECURING SYSTEMS

Floating docks are generally operated in sheltered waters. However wave drift forces and the current tend to take the floating body away from the initial position. The purpose of mooring is to restrict these motions of the body on the horizontal plane – the surge and sway motions. The movements in the horizontal plane need to be controlled for providing a safe working condition. Also mooring arrangement should have enough flexibility to allow vertical movement of the dock during docking operation and yet should have enough line tension to keep the dock in place without being drifted.

The general means adopted for mooring of floating docks are through mooring with anchor chain arrangement or through guide pin mechanism.

Mooring with anchor chain arrangement: The mooring arrangement consists of the following elements as shown in Figure.37.

- Mooring lines which connect the platform to the sea bed
- Anchors on the sea bed
- Fairleads and lugs/fixing brackets for guiding the mooring lines.

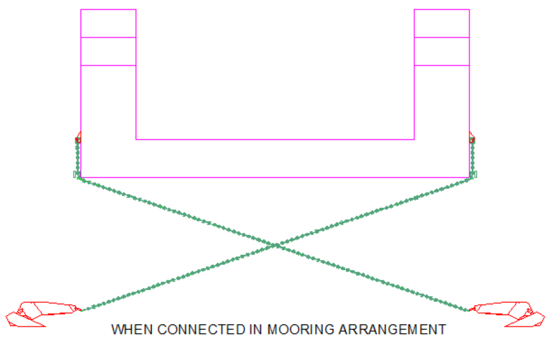

Figure.37 Securing dock with mooring lines

7.1 GUIDE PIN MECHANISM

The system consists of two pipe guides and two gripper arms. The grippers engage the pipe guides and allow the dock to move up and down with the tide or during the submergence operation. To move the dock away from the pier, a quick disconnect mechanism, will ensure that the gripper arms rotate open when the dock is pulled away. The arms automatically close when the dock is pushed back into the moorings. There are two variants of the system.

In variant 1, the mooring grippers are mounted on the floating dock. The vertical pipe is driven into the ground at the mud line and tied back to the pier or dolphin. This concept is shown in Figure.38.

In variant 2, the mooring grippers are mounted on the pier or mooring dolphins and the pipe guides are mounted on the side of the dry dock. This concept is shown Figure.39.

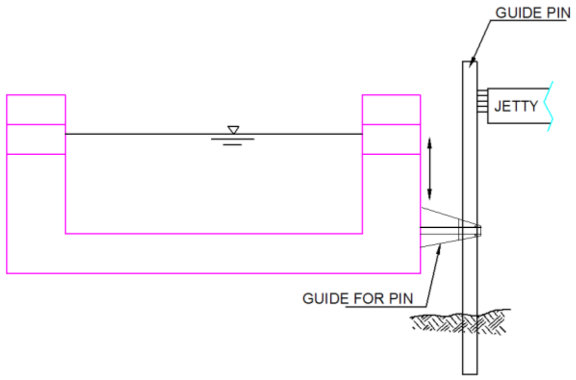

Figure.38 Variant 1: Guide pin welded to the jetty

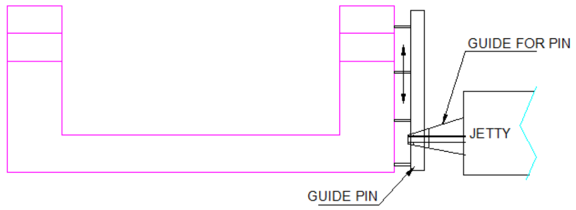

Figure.39 Variant 2: Guide pin welded to the floating dock

8. CONCLUSION

In this paper, we have made a conscious effort to consolidate and present all relevant Naval architectural aspects from various sources such as class regulations, published literatures etc. suitably combined with our own in-house design work

An overview of all naval architectural aspects involved in designing of floating dock which includes sizing of dock, intact stability, damage stability, longitudinal / transverse strength and scantling has been presented. We have also described the optimization process using simple excel spread sheets combined with use of naval architectural software like NAPA.

It is feasible to develop an optimal design for a new floating dock through successive iterations using excel macros. By a simple technique of varying the wing wall width as described in Section 2.3 it is possible to achieve considerable reduction in ballast volume and steel weight without any compromise on the performance.

Normally there is no class requirement for undertaking damage stability assessment for floating docks. In this paper, we have highlighted the methodology for undertaking damage stability calculations for a floating dock, using the limiting values which are stipulated in the MIL standard. This in turn can be suitably fed to any software like NAPA to undertake damaged stability assessment.

Also we have touched upon the methods of mooring and securing of the dock as wave drift forces and current tend to take the floating body away from the initial position. The purpose of mooring is to restrict these motions of the body on the horizontal plane and providing enough flexibility to allow vertical movement of the dock during docking operation.

9. ACKNOWLEDGEMENTS

The use of NAPA 2015 software is gratefully acknowledged. A lot of iterations were possible due to diverse feature of the software.

10. REFERENCES

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