# FIRST JACK-UP RIG LOAD-OUT IN VIET NAM

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## Summary

***This paper presents the design concept and operation results of load-out for the jack-up rig LTI model 116E built on two skid beams (without dry dock facilities). It was the first attempt to build a jack-up rig, almost completely, on two skid beams on the ground and load-out it using the submersible barge "Giant 2". The major characteristics of load-out structures, which depend on a jack-up rig configuration composed of general jack-up rig type hull and other structures, were its heavy weight of approximately 9,000 metric tons and long length of 74.09m compared to breadth and depth, i.e. x 62.79 x 7.95m. So, special consideration was required for safe load-out operation compared to previous load-out of other offshore structures (jackets, topsides) where the weight was less than 4,000 - 5,500 metric tons. The strength and longitudinal deflection of the jack-up rig were carefully analysed with appropriate weight distribution. All facilities for load-out including ground foundation, strain jack system and pulling system were designed based on the results of this analysis and the friction force between the skid way and hull supports (skid shoe). The ballasting operation for the barge was controlled by the control system (PLC) in the control room. Relative deflection in way of jack-up rig was monitored during the load-out operation. The motion of the jack-up rig during the load-out process, towing to float-off site and float-off phase were analysed and compared to model test results.***

***The load-out concept and methodologies described here are verified through the successful load-out operation of the first jack-up rig project in Viet Nam. The concept and experience gained can be adopted for the load-out design of extra-heavy structures where the weight is more than 15,000 metric tons. Guidelines for the development of an efficient construction method for offshore and ship type structures are also suggested for future application of this concept.***

## 1. Introduction

Mobile & Floating types of offshore structures have shown a rapid overall increase in market share during the last several years in the offshore construction field. Generally, the fabrication and assembly of floating offshore structures, like Mobile Offshore Drilling Unit - Jack-up Rig (MODU), Tender Assist Drilling Barge (TAD), Floating Storage and Offloading system (FSO), Floating Production Storage and Offloading system (FPSO), Floating Production Unit (FPU), semi-submersible and ships, have been carried out in the dry dock of a shipyard by stacking unit blocks sequentially from lower to upper levels.

In case of ship type of offshore structures, the lower hull or whole main hull fabrication and assembly are carried out in a dry dock as the conventional ship construction method and the topside/above main hull modules and legs sections are installed by a heavy lifting crane near the quay side. This method has great dependency on the dock schedule and tight fabrication process of the yard. So, it is very important to match the fabrication schedule between the remaining structural parts to meet the total project schedule. In such cases, it is difficult to incorporate any design change or modification required by the clients. On the other hand, if shipyard does not have a dry dock, they cannot do anything else.

The On-Ground Build Method applied to the 90m water depth Jack-up Rig Project is a new construction concept in Viet Nam for the above offshore structures in order to reduce the total construction schedule and have flexibility in the fabrication phase. The main hull and other structural parts are assembled on ground at the same time. The completed structure will be loaded-out and floated-off using submersible barges. This construction method requires the yard's experience including engineering capability of load-out and float-off operations to launch the completed structure.

This paper describes the design concept of the load out system and the operation results verified through successful operation.

## 2. Overview of load-out plan

### *2.1. Characteristic of jack-up rig 116E*

The jack-up rig, the target structure of load-out, is composed of the main hull with the accommodation, cantilever with derrick above and three 74m long legs, weighing of about 9,020 metric tons lightweight. The rig's hull configuration is typically triangular shaped, with flat sides with two main longitudinal bulkheads at 7.9m centreline offset. The principal dimension of jack-up is summarised as follows:

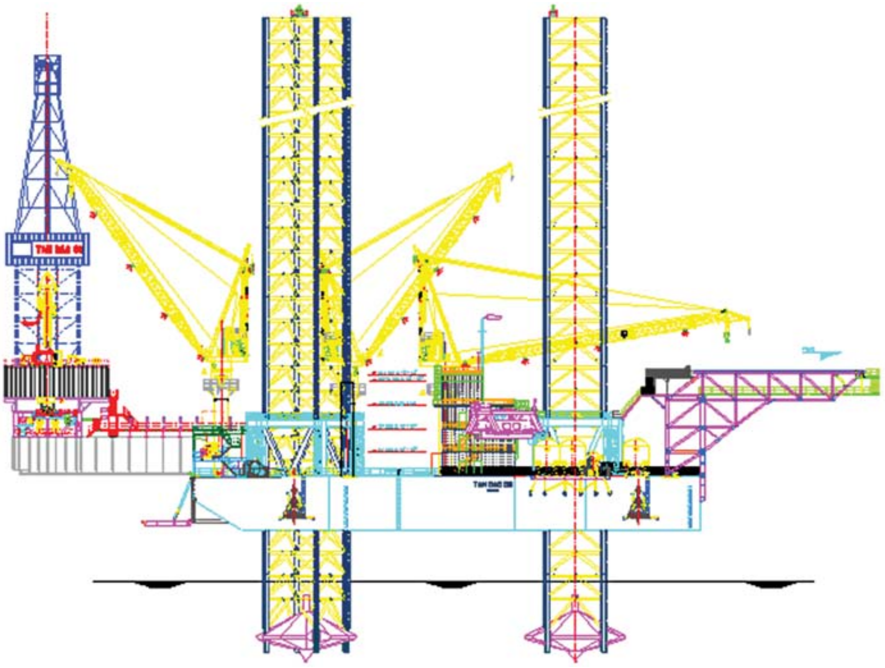

***Fig.1.*** *Jack-up Outboard Profile*

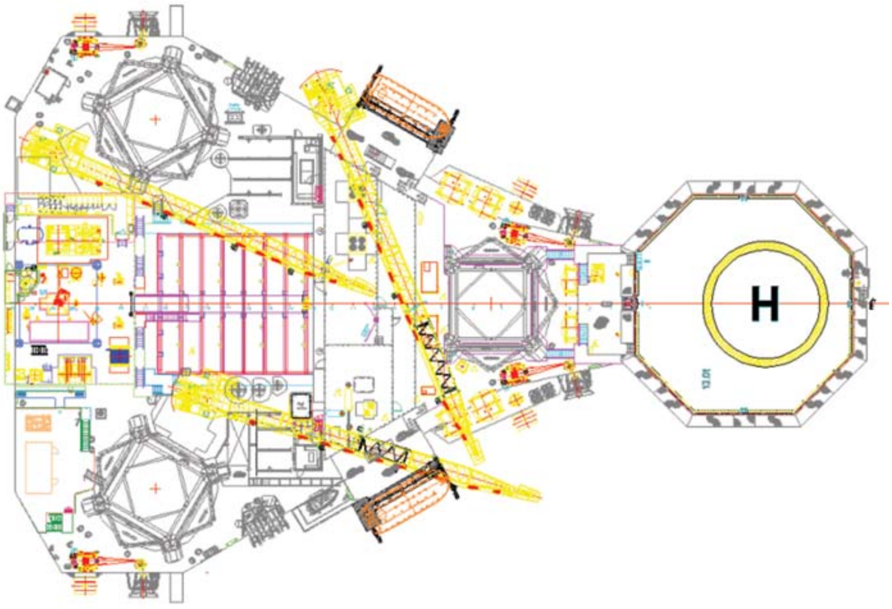

***Fig.2.*** *Jack- up Overall Plan*

- Length (overall): 74.09m;
- Breadth (molded): 62.79m;
- Depth (molded): 7.95m;
- Design Draft (molded): 5.0m;
- Light weight: 9,020 metric tons.

### *2.2. Yard layout and load-out plan*

Generally, the assembly location of the load-out structure is decided by considering the weight of the structure (line load) and the water depth adjacent to quay side for mooring of the load-out submersible barge. Fig.3 shows the general arrangement of the load-out system, such as the skid way, strain jack & pulling system, the load-out submersible barge and the jetty.

## 3. Load-out system design basis

Various static, dynamic loads and other limitations that were considered during the design of the load-out system are detailed below.

### *3.1. Static loads*

Light weight including 10% margin and friction force is considered as the static load for design of the load-out system.

More than 1/3$^{rd}$ of jack-up total length (74.09m) is supported by two skid beams arranged on two (2) skid ways in way of the jack-up area.

The friction force between the skid way and the skid shoe can be calculated by multiplying the weight and friction coefficient. The contact materials between the skid shoe and skid beam are fluoroslip skid way plate (FL 415 PTFE) and 20% static (breakout) friction coefficient was applied for the contact material. This leads to conservative design of load-out systems. A 12% dynamics (sliding) friction coefficient was observed at break out condition during the actual operation [9, 11].

### *3.2 Dynamic loads*

Environmental forces, such as wind, wave and current, influence the motion of the load-out semisubmersible barges and, consequently, the dynamic load to load-out system. Estimation of the barge motion and wave bending moment is very important to the design of the load-out system. Table 1 shows the environmental conditions for load-out operation of the jack-up rig 116E [3].

Table 2 is the summary of motion analysis result (using MOSES software). This result was verified through model tests in a towing tank.

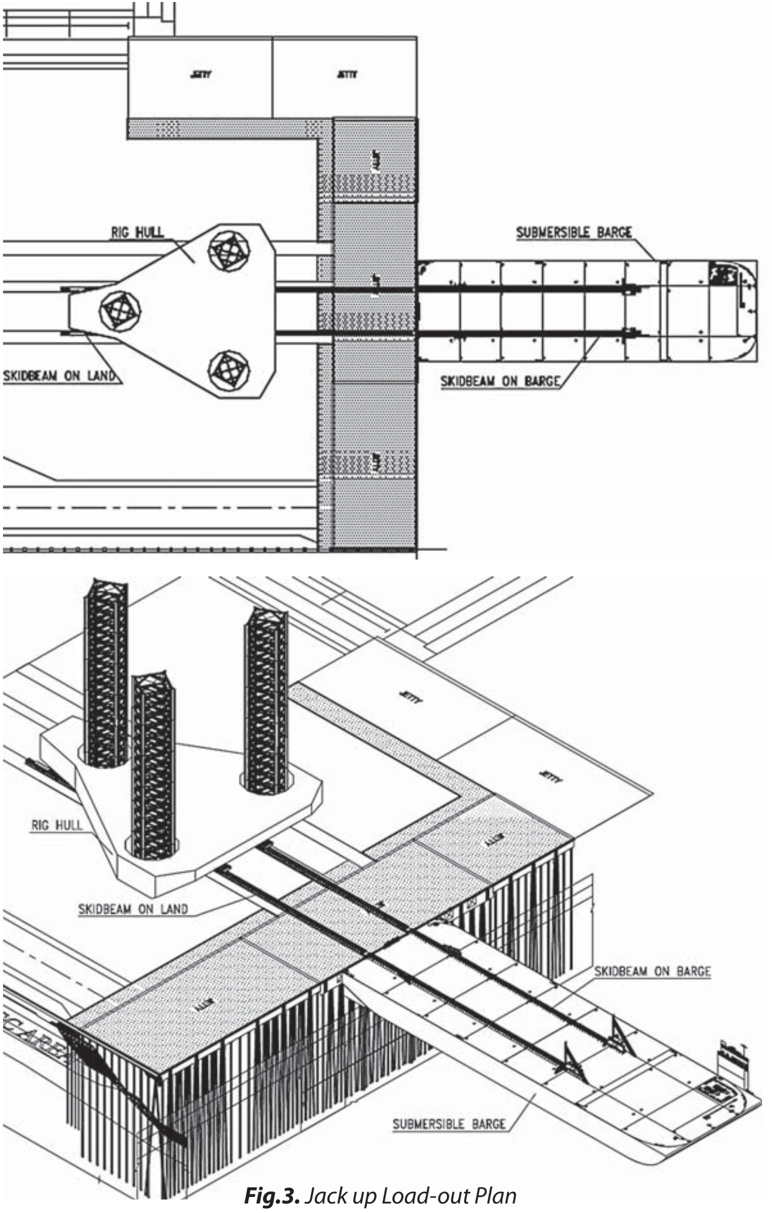

**Fig.3.** *Jack up Load-out Plan*

### *3.3. Other limitations*

There are various limitations to be considered during load-out design depending on the load-out facilities, characteristics of the load-out structure and the yard ground conditions. The following limitations were considered in jack-up rig load-out design.

- Hydraulic jack capacity and maximum stroke;
- Pulling jack capacity and speed;
- Strength and deflection of jack-up structure;
- Ballasting capacity and speed of load-out barges;
- Strength of load-out barges including fender;
- Capacity of ground and jetty;
- Other load-out facilities of the yard.

## 4. Load-out system design

This section presents design viewpoints of the load-out system, the required analysis items and results considering given design conditions described in the previous section. The jack-up rig structure was assembled as supported by temporary supports during the fabrication phase.

### *4.1. Skid way on ground and barge*

The skidding method, which is the general method for load-out of offshore structures, was applied for jack-up rig load-out. Two skid beams on the ground and on the barges were designed to support the skid shoes and jack-up rig, i.e side shell, transverse bulkheads and longitudinal bulkheads. The surface of the skid beam was made of special material to reduce friction force (fluoroslip skid way plate - FL 415 PTFE).

Each skid beam on the ground skid way was supported by rigid foundation consisting of concrete mat and pile foundation for the ground skid way, and grillage beam foundation for the barge skid way. These foundations should be designed not to settle down beyond the jack stroke limitation.

### *4.2. Jetty stability analysis*

Jetty stability should be verified in an early stage of load-out design by checking various failure modes considering the expected load conditions. The jetty is analysed for the following loads:

- Line load due to weight distribution;

- Pulling force caused to pressure load in front of the quay.

- Barge berthing/mooring load.

The safety of the jetty is mainly related to the line load applied during the load-out process. So, the load-out system should be designed to minimise the line load as much as possible and the calculated safety margin of the jetty should be sufficient considering uncertainty.

### 4.3. Load-out barge and ballasting plan

The following factors are to be considered while selecting the load-out barge:

- Dead weight considering berthing draft;

- Deck area to accommodate required active shoe length;

- Ballasting speed considering pulling speed;

- Longitudinal strength and deck local strength;

- Float-off stability.

The semi-submersible barge "Giant 2" of Smit Division was selected considering the above requirements. A 14-step ballasting plan was prepared for the load-out process. The ballasting status and relative deflection were monitored during the load-out operation [4].

#### 4.3.1. Principal Dimensions of "Giant 2"

The principal dimensions of the load-out barge (Giant 2) are summarised as follows:

- Length (overall): 140m;

- Breadth (molded): 36m;

- Depth (molded): 8.5m;

- Submerged draft: 6.68m;

- Dead weight: 24,000 metric tons;

- Classification LR, 100A1 semi-submersible ocean going transportation barges, 1966.

***Table 1.*** *Environmental condition for load-out*

| Environmental condition | Wind (knots) | Wave Hs (m) | Wave Tz (sec) | Current (Knots) | Tide (m) |
|---|---|---|---|---|---|
| | 20 | 0.6 | 3 | 1 | |

***Table 2.*** *Maximum motion & Acceleration*

| Hs = 0.6m | Surge | Sway | Heave | Roll | Pitch | Yaw |
|---|---|---|---|---|---|---|
| Tz = 3s | [m], [m/s$^2$] | | | [deg], [deg/s$^2$] | | |
| Displacement | | | | | | |
| Accelerations | 0.09 | 0.39 | 0.40 | 0.24 | 0.24 | 0.12 |

#### 4.3.2. Ballasting control

The ballasting control should be performed to keep the barge draft, trim and heel within operational limits, which are ±0.25 degree for trim and ±0.2 degree for heel. The ballasting was divided to fourteen steps for approximately 6m moving distance. Also the ballasting plan includes estimated ballasting time due to moving speed in relation to the pulling jack speed & tide table. The actual ballasting status during load-out was monitored by measuring the draft from draft gauge and by theodolite.

In order to control the "Giant 2" barge draft, trim and heel condition during the load transfer and also to compensate ballasting due to tide variation, external pumps independent of the main ballasting system were installed and operated to the barge internal pumping system. The capacity of external pumps and selection of tank were decided considering the tide variation rate and the variation rate of barge displacement. Twenty-four Nos. 10 PS submersible pumps were provided, with each pump capable of 800m$^3$/hr [2].

### 4.4. Analysis of jack-up rig strength and deformation

The safety of load-out structure should be verified by 3-D FEM analysis (using ANSYS and SACS software). The stress ratio, plate buckling capacity, and deformation should be checked against actual line load related to hydraulic jack load.

The analysis results showed that the jack-up structure had sufficient safety during the load-out operation. In addition, stress ratio and deformation values were less than those of the in-place condition. The maximum von-mises stress was found as 180N/mm$^2$ in way of side shell plate near the mid ship bottom area and maximum Z-deflection was 120mm in way of the supporting region of the hydraulic jacks. This natural deformation should be maintained by jack stroke during the load-out operation

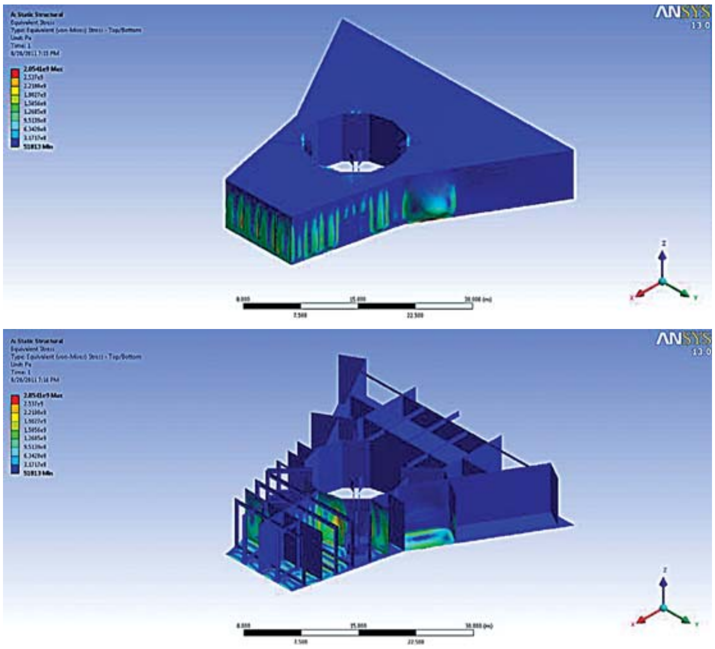

**Fig.4.** *Stresses at BHD and Yoke from the portside*

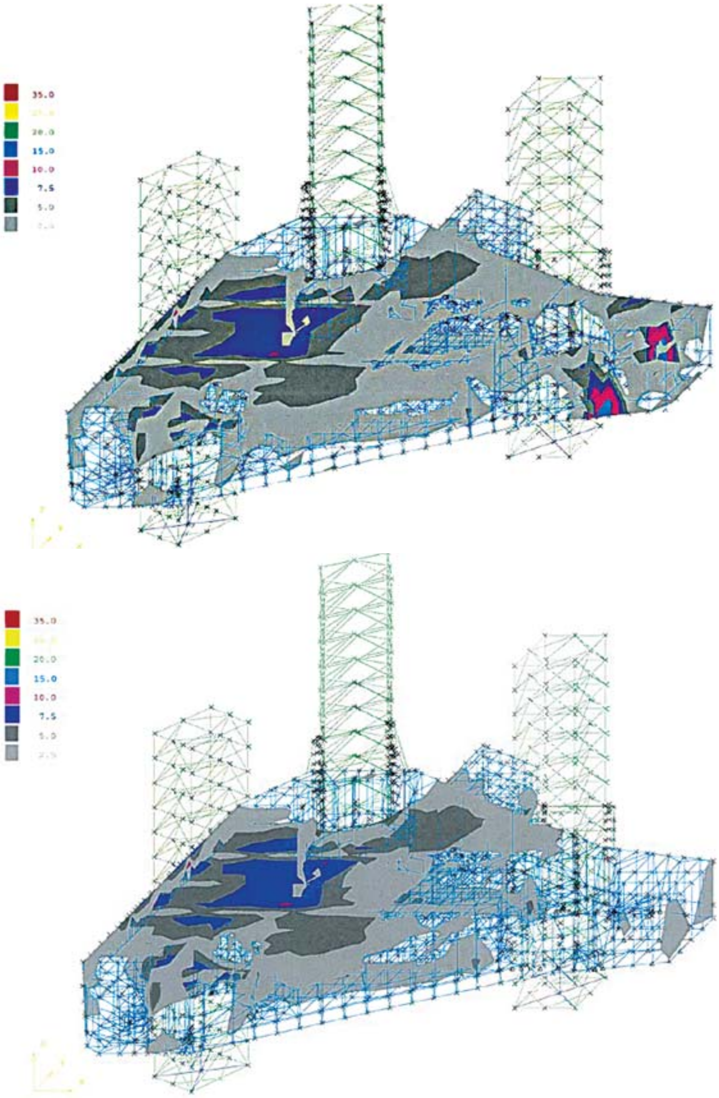

**Fig.5.** *Plate Stresses for loadcase 1 and loadcase 2*

so as not to cause local concentration of loads. A shimming plate should be designed that can keep the deformation of jack-up within limits in case of active jack failure. The deformation of the load-out barge due to still water and wave bending moment should be considered in the total deformation, which is covered by the jack stroke. Fig.2 shows the combined stress plot and Fig.4 shows the deformation during load-out condition [16, 17].

### *4.5. Pulling jack system*

The required pulling force for the load-out structure increases linearly with the increase of friction force. For the jack-up rig load-out, the required pulling force was about 1,808.4 tons considering a 20% static friction coefficient. The pulling system should be designed to be able to control the load-out direction. Typical pulling system using strand jacks was adopted on the basis of experience of previous load-out projects.

The pulling jack system had six (06) Nos. G-SJ27 strand jacks, with nominal pulling capacity of 441.5 tons each, installed at the end of the hydraulic jack support, a fixed anchor welded to load-out barge deck, and strand wire connecting the strand jack and fixed anchor. Skidding of the load-out structure was done by operation of strand jacks.

A strand jack, which has 441.5 tons pulling capacity (max PPU pressure 350 bar), 500mm stroke and 12m/hour pulling speed, was used for jack-up rig load-out [1, 4]. The jack capacity was designed to exceed 115% of the estimated friction force in order to cover any unexpected increase in friction. The components in the load-out system design such as link beam, steel fender and skid way, which are subject to pulling force, should be designed considering the total pulling capacity.

### *4.6. Fender*

Steel fenders were used for linking each ground skid way to the barge. These two linking facilities supported line load and total pulling force, respectively. Fig.2 - 3 shows the arrangement of the linking systems.

Steel fenders installed between the front wall of the quay and the transom of the barges took compression force due to the pulling operation. The required berthing area per fender was about 1.5m by 4.5m as derived from the quay stability analysis result. The barge transom structure was checked to determine whether it had sufficient strength against pulling compression. The fender itself was designed to resist pulling compression and 20% of lateral force considering the barge movement.

### *4.7. Mooring system*

"Giant 2" was moored at the quayside throughout the load-out operation. The mooring lines were designed to keep the barge position based on technical guidance (against a 10-year return environmental condition) as shown on Table 1. The maximum mooring force was approximately 29.49 tons due to a wide wind area that had never been experienced. The most critical condition in mooring design was the condition after load-out. In this case, the total force had to be resisted by the mooring lines only. Emergency mooring activities were prepared considering a sudden occurrence of a typhoon based on 100-year storm condition [8]. In this case, the link beams were fastened to take the role of a mooring line and also additional mooring lines were required.

### *4.8. Monitoring system*

Points of concern which might disturb operation were listed and monitored continuously during load-out. These data were compared with estimated values and verified to keep within the limit. The main items to be monitored are listed bellows.

- Hull deflection level;
- Ground settlement;
- Load-out moving direction;
- Hydraulic jack pressure & stroke;
- Pulling jack load;
- Barge draft level & positioning;
- Relative deflection of barge connection frame.

### 5. Points of concern for operation

All expected risky items raised in the design phase through HAZOP should be carefully monitored and controlled during actual operation. Because of the characteristics of the load-out structure in case of the jack-up rig, there many points to be considered as follows:

- Controlling the skidding direction due to the huge length of the load-out structure;
- Even distribution of excessive pulling force to quay wall;
- Strength verification in way of barge connectors from measured data.

Excessive pulling force, barge connection, and control of "Giant 2" are highlights of jack-up rig load-out operation.

### 6. Conclusion

The design methodology described in this paper contributed to the successful load-out operation of Vietnam's first on-ground build jack-up rig. The paper suggests a new construction methodology in Viet Nam that is different from the conventional dry dock construction of floating offshore structures, such as jack-up rig, TAD barge, FPU, FPSO, semi-submersible, and drilling ship, applicable in the near future.

***Table 3.*** *Mooring Line Tension checking results*

| **Environment direction** | **Maximum line tension (tons)** | | | | | |
|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | S1 | S2 | S3 |
| From Stern | 18.18 | 27.39 | 27.65 | 16.20 | 21.57 | 25.00 |
| From Stbd Quarter Stern | 9.07 | 11.12 | 9.85 | 5.76 | 6.40 | 13.86 |
| From Stbd | 6.83 | 9.94 | 27.31 | 7.72 | 11.60 | 29.49 |
| From Stbd Quarter Bow | 6.97 | 7.77 | 14.10 | 9.50 | 9.71 | 9.99 |
| From Bow | 5.52 | 5.89 | 6.61 | 5.21 | 5.36 | 5.81 |
| From Port Quarter Bow | 9.98 | 11.48 | 12.39 | 6.68 | 6.37 | 13.15 |
| From Port | 8.06 | 11.47 | 31.77 | 6.79 | 9.85 | 27.49 |
| From Port Quarter Stern | 6.45 | 7.95 | 14.99 | 8.36 | 9.10 | 8.05 |
| Maximum | **18.18** | **27.39** | **31.77** | **16.20** | **21.57** | **29.49** |
| Line Tension Criteria<br>< 32.2 tons (for P1, P2, S1, S2)<br>< 37.4 tons (for P3 & S3) | OK | OK | OK | OK | OK | OK |

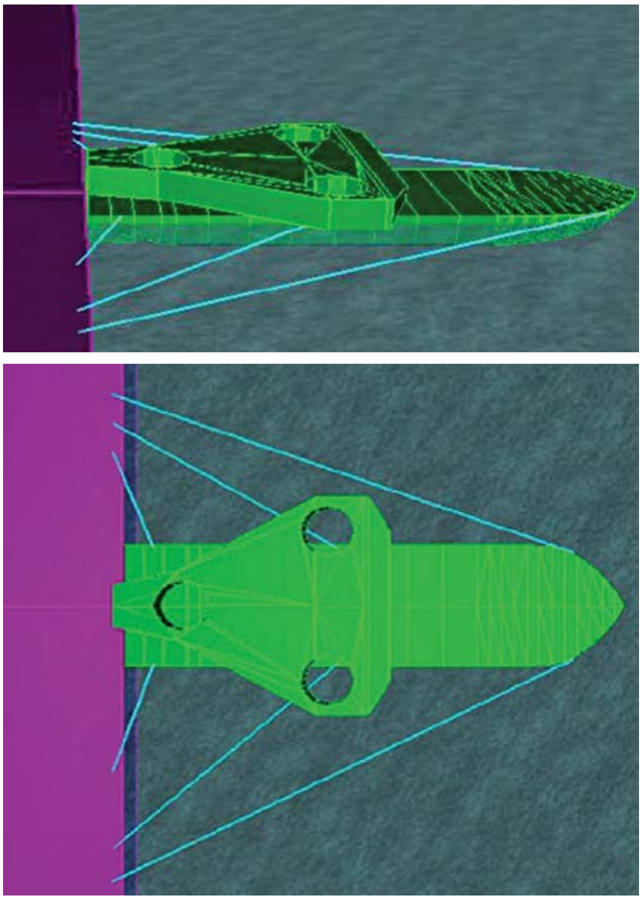

***Fig.6.*** *Semi-submersible Barge Mooring Arrangement*

This construction method can allow major work for commissioning to be completed on the ground. It will provide a more convenient working environment than conventional construction methods in view of the service of good facilities such as cranes, accessibility and multiple-working.

This construction method can also be applied to conventional ship construction to reduce the assembly schedule and increase efficiency even without a dry dock since this method indicates the possibility of load-out and float-off of large floating offshore structures and ship blocks to be finally mated in the sea.

Above all, this paper will provide the design basis and experience gained to develop load-out methodology of huge size structures such as Mega Float and Barge Mounted Plant (BMP), which cannot be accommodated in the present dry dock facility of a shipyard.

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