

# Optimization Study of Eight-Legged Fixed Offshore Jacket Platform



V. Suryaprakash and N. Sunil Kumar

**Abstract** Fixed offshore platform plays a major role in oil exploration and production and basically, a huge steel-framed structure used for different purposes such as drilling, processing and living. The quantity of steel required to meet the extreme environment of the ocean will be comparatively high and by using modern techniques and developments, researchers and consultants are trying to adopt the innovative methods to optimize the weight of the jackets. In this paper, a typical eight-legged jacket platform is taken for study and optimization is carried out by concentrating in various aspects such as leg batter, rechecking the member size requirements, bracing arrangement, utilization of FRP mud mats, rechecking the load calculations and contingency factors. The modelling, analysis and design are done using SACS, a 3D finite element software exclusively for offshore structures. Generally, during the tender stage of the projects, and due to the time constraint, many possible checks shall not be done especially for optimization. Being a contractor's consultant, it is the consultant's responsibility to provide economical design. This study will provide the fair idea about the possible routes for the optimization. This paper concludes with the final optimum weight of the jacket platform and highlighting the spaces where the weight of the jacket structure can be reduced. The percentage of reduction is summarized in the conclusion for the comparison purpose.

**Keywords** Fixed offshore platforms · Jackets · Optimization · FRP mud mats SACS

## 1 Introduction

Fixed offshore platforms are the widely used structures in the oil and gas industry, and it shall be used for the various purposes such as drilling, processing and living, especially for the shallow water depths, fixed offshore platform is considered as the

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suitable one. Basically, the fixed offshore platform consists of the deck supported by means of the jacket. The dimensions of the structure will vary with respect to the purpose of the platform. The jackets are acted as the template for driving the piles. The platform type may be either skirt pile jacket or main pile jacket but the economic and technical influences involved in the decision-making of the structural system of the jacket.

This paper mainly concentrates on the processing platform which typically consists of the eight-legged or six-legged platform. Hence, the weight of the typical eight jacket platform shall be from 5000–9000 tonnes (substructure alone). Depending upon the design consultants and the other functional requirements, the weight of the jacket platform will vary. In the present situation, especially after the supply of the crude oil increased rapidly the requirement of fixed offshore platform became fade. Hence, getting new projects in the field of the fixed offshore platform became more challenging and it paves the way for the optimization and innovative ideas to design the project cost-effective.

## **2 Need for Optimization**

The current scenario in the oil and gas filed, especially for the fixed offshore platform, the project available is quite low when compared to the earlier decades, however, the design consultants are subjected to work on the innovative solutions and better trial-and-error methods to provide the economical design. Hence, winning the project in the tender stage is quite difficult in this competitive field.

This paper concentrates on the major weight reduction routes for the jacket platform during the tender stages, and especially concentrates on the modification of the structural system and configuration. For a few decades, the researches and consultants are trying different innovative ideas to reduce the cost of fabrication and installation of the platform and at the same time, the safety of the platform also be ensured. Hence, those innovative ideas are recommended and that helps the consultants to face the challenging ocean environment. The studies based on both the analytical and the experimental shall be done and verified, so that the risk factors and the chances of the failures shall be minimized.

## **3 Structural Configuration of Jacket**

### ***3.1 General***

The typical eight-legged jacket is selected for the optimization study and the jacket is assumed as the launch type skirt pile jacket. SACS a three dimensional finite element software used for the design and analysis. The basic details assumed for the jacket platform are shown in Table 1.

**Table 1** Structural configuration

S. no	Description	Remarks
1	Design life	25 years
2	Water depth	57.9 m for storm
		57.1 m for operating
3	Marine growth	10 cm from +6 to -30 m
		5 cm from -30 m to mud line
4	Wave height	<i>Operating</i>
		Wave height—11.5 m
		Wave period—11.0 s
		Current velocity—1.4 m/s at surface
		<i>Storm</i>
		Wave height—17.7 m
		Wave period—14.5 s
		Current velocity—1.7 m/s
4	Jacket type	Skirt pile jacket
5	Number of piles	16 no's
6	Diameter of piles	84 inch
7	No. of risers and J tube	Present—1 no's
		Future—10 no's
		J Tube—1 no's
8	Caisson	1 sump caisson
		1 firewater caisson
9	Gross and net pile capacity	60.5MN and 54.9MN
10	Pile penetration	110 m below sea bed
11	Number of boat landing and riser guard	1 no. of boat landing
		1 no. of riser guard

For the above-mentioned data, the current jacket weight is 6100MT and the optimization study is done from the above benchmark. Typical dimensions of the jacket at the sea deck level and mud mat level are shown in Fig. 1 (Fig. 2).

The initial dimensions and all other parameters of the jacket are kept as the benchmark and the optimization process is started from this stage.

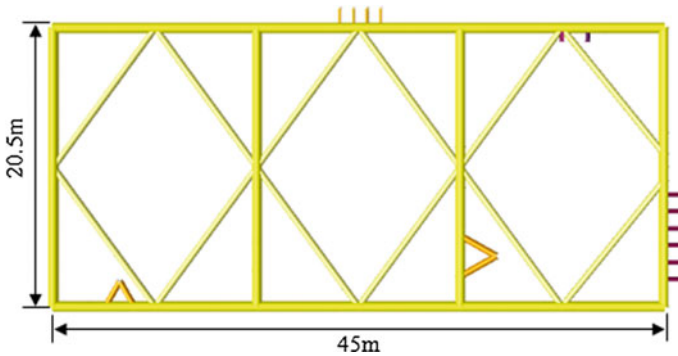


Fig. 1 Sea deck framing dimension—(+) 7.60 m

## 4 Optimization Methods

The optimization is done by changing the structural arrangement, material properties and the other considerations in loads and contingencies.

### 4.1 Leg Batter Arrangement

The suitable leg batter of the jacket shall be found out by comparing the jacket weight [1], pile axial load and the leg batter. Figure 3 shows the comparison between the axial load, self-weight and the leg batter.

When the leg batter of the jacket is increased from 7.5 to 9, the optimum design of the jacket is found to be 8.5. Since from 7.5 to 8.5, the self-weight reduction of the jacket is around 1.31% but the pile loads shall be maintained at 28.5MN. The pile load 28.5MN shall be helpful in achieving the factor of safety for the pile in both operating and storm conditions. It has been clearly observed that by increasing the structural batter base, area of the jacket increased which leads to the increase in the pile axial load.

### 4.2 Utilization of FRP Mud Mats

The need and utilization of FRM mud mats are becoming vast recently. Many vendors are supplying readymade FRP mud mats with many advantages such as

- High flexural strength and stiffness
- Steel weight reduction
- Reduction in anodes due to mud mat plate area reduction

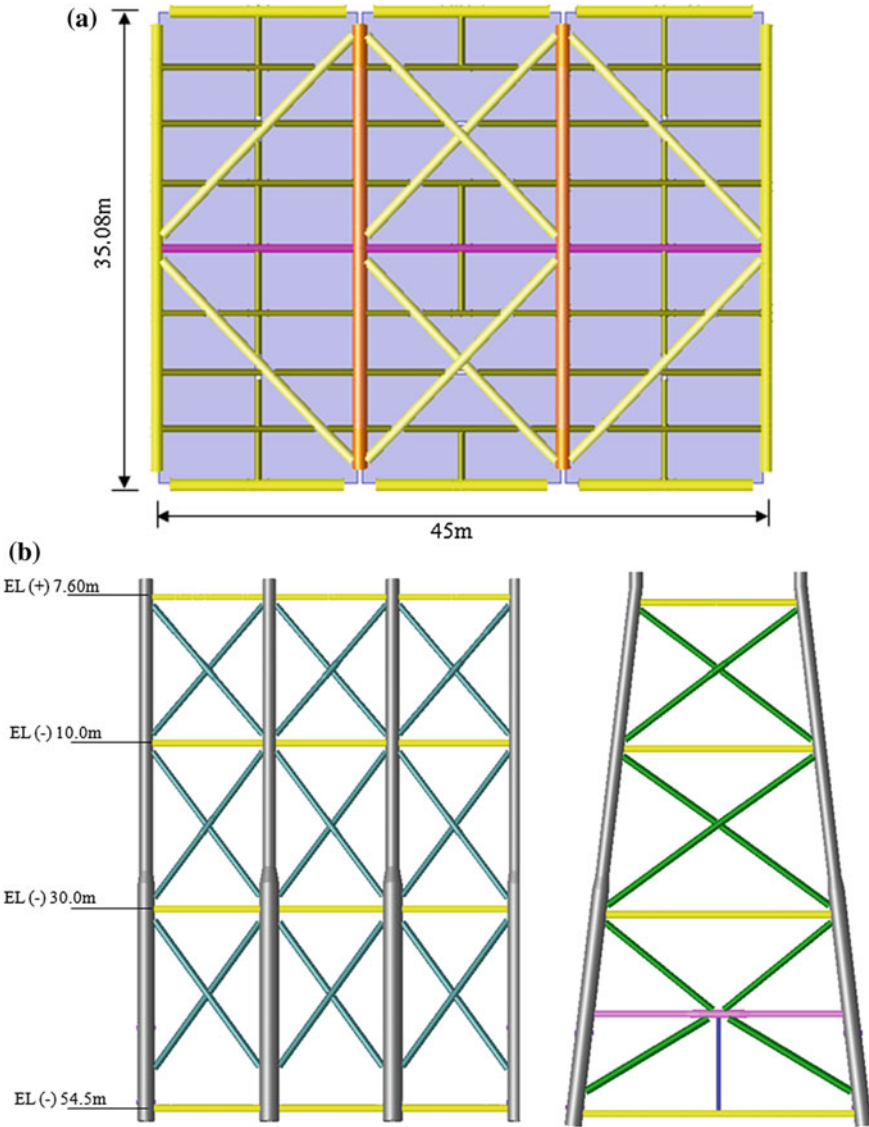


Fig. 2 Mud mat framing dimension—(–) 54.50 m

- Easy to handle.

For the analytical purpose, the physical properties [2] of the mud mats are considered in the analysis. The range of those physical properties value shown in Table 2 are collected from various research articles.

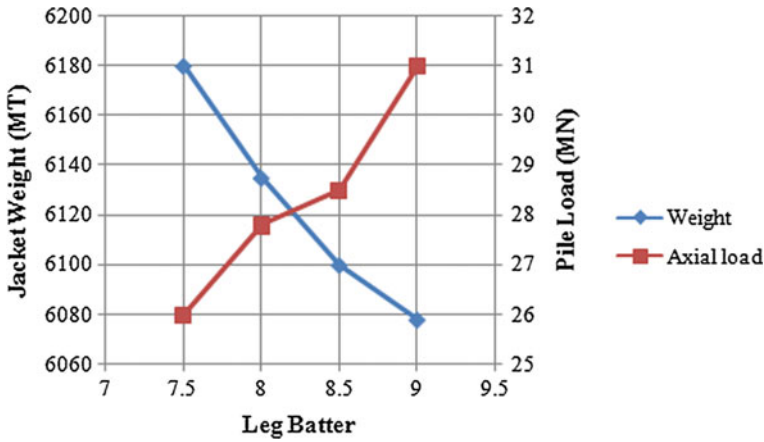


Fig. 3 Lag batter comparison

Table 2 Physical properties of FRP MUDMATS

S. no	Description	Remarks
1	Modulus of elasticity	23,000–24,000 N/mm <sup>2</sup>
2	Moment of inertia (major axis)	$1.1 \times 10^6$ – $1.2 \times 10^6$ mm <sup>4</sup>
3	Density	1750–1950 kg/m <sup>3</sup>
4	Cross-sectional area	4000–4400 mm <sup>2</sup>
5	Weight of mud mat per area	0.28–0.32 kN/m <sup>2</sup>

Thus, the properties of the FRP will change with respect to the vendor specification and hence, the generalized values between those specified ranges are selected for the analysis.

On-bottom stability analysis having the greater impact among all the pre-service analysis and the it helps both directly and indirect way such as,

- Direct weight reduction of steel plate that helps in reduction of steel tonnage
- Indirectly, the reduction of surface area calculation helps in reduced number of anodes in the mud mat zone
- Reduction of number of joints for fabrication of the arrangement plan of mud mat framing has been changed.

The structural behaviour does not change due to the change in the mud mat properties in the 3D model, however that helps in the greater reduction of the mud line elevation weight and tends to the reduction in the member stresses at the Mudline framing.

It has been found that the weight of the mud mat has been reduced to 36% from 759MT to 480MT. Due to this reduction, the mud mat framing member sizes shall

be rearranged and the reduction shall be done and the net reduction weight is around 98MT. The intermediate additional framing members shall be removed.

### ***4.3 Other Routes of Optimization***

The other options of optimization includes in the following aspects, but it will vary with respect to the projects and the clients [3].

#### **4.3.1 Load Assumptions**

The load and load factors/contingencies assumptions shall vary with respect to the client and the location of the project. For instance, at the tender stage, the weight contingency shall be kept around 1.20, and this may affect in buoyancy in the floatation analysis. If the design consultant and client had a mutual agreement, it shall be reduced up to 1.15–1.175, and on the other hand if it is not accepted, this option shall be ruled out.

#### **4.3.2 Member Sizes Rechecking**

The member sizes are fixed based upon all in service and pre-service analysis, but it is not the point that all the members are stressed completely in all analysis. There may be the members which are governing only in some analysis other than that the utilization ratio shall be kept at 0.8, and the member size shall be reduced accordingly. Many trial-and-error methods are available in the form of algorithm [4] to find the optimized member size determination. These techniques shall be helpful during the tender stages to find out the optimum member sizes.

Another important point to remember is to maintain the symmetric between the jacket while changing the member sizes, so that the cog shift will not be maximum. Another factor influencing the resize is the ‘readily available materials’, and many projects will face this issue like design has to be done only with available member size and thickness in such cases, the optimization shall be done only with the limited member dimensions.

#### **4.3.3 Internal Ring Stiffeners**

One of the major advantage in the skirt pile jacket is the joints shall be stiffened by using the internal ring stiffeners. The major fatigue governing joints shall be checked against the tubular joint design to find out punching shear and in such cases, it is not mandatory to change diameter and thickness of the braces, utilization of the internal ring stiffeners which will help both load and strength utilization ratio of the joints.

The internal ring stiffener number shall be increased until it affects the fabrication scenario, for the further failure in the joints, profile grinding, i.e. smoothening the surface of weld around the joints shall be performed.

#### 4.3.4 Platform Orientation

In many cases, the platform orientation shall not be modelled according to the true north, and this may attract the heavy wave loads and that will result in the higher member size and thickness. Hence, it is necessary to find out the true north of the platform and by orienting the structure accordingly may help in the reduction of the pile load. In some cases due to the change in the orientation of the platform may result in the increase in the pile load also, hence, this factor also depends upon the project location and ocean environment.

## 5 Conclusion

From the study, it has been clearly observed that the innovation in the optimization is directly proportional to the technical advancements. By utilizing the FRP mud mats in this typical study, it is observed that around 98MT shall be saved. Other than this, the construction handling of FRP mud mats are easy when compared to the steel mud mat, and gives higher flexural capacity than the steel mud mat. Leg batter of 1 in 8.5 is suitable for this jacket when compared to other. Other possible routes of the optimization are generalized and this may vary with respect to the project, due to the variance in the location, client and contractor. Hence, from the design consultant's point, recent advancements and innovative ideas will help this optimizing area.

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