Calculation and analysis of sea-fastening support and welding strength of topside module

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Abstract: Marine structures are usually built on land as a whole modular, using barges to transport to the designated area for installation. This paper presents the sea-fastening design methodology and results of the topside module which is to be transported by self-propelled barge. The combination of its self-weight, wind load and barge acceleration in waves will act on the topside module and barge in the process of marine transportation, this paper mainly analyzes and calculates the temporary support frame and the grillage members of the topside module by SACS software. Then the top plates and the base plates transmit the member end forces of sea-fastening grillage members taken from SACS output, in order to ensure the strength, the bracket plates are welded to the grillage columns, braces and the bottom of temporary support frame. The strength of all fillet welds shall be checked.

1. Introduction

Marine structures are usually built on land as a whole modular, using barges to transport to the designated area for installation, loading on board can use sliding, rolling on and lifting, offshore installation can use floating and lifting. When sailing on the sea, the barge loaded with topside module will be affected by the dead weight, wind load and the transportation acceleration of the barge such as rolling, pitching, and heaving. Therefore, sea-fastening design should be undertaken for the transportation of the topside module on barge to ensure that the module and ship is safe in the transportation[1].

This paper mainly analyzes and calculates the support and welding strength of topside module in the process of marine transportation. The strength of support members and welding not only is important for the safety of the structure, but also provides reference for the design of other similar projects.

2. General

When topside module is transported using barge on the sea, it needs to bear the combined load of the structural self-weight, wind load and six degrees of freedom transportation acceleration such as rolling, pitching and heaving caused by waves[2]. The module is supported by temporary support frames and bottom of the module legs are clipped by brackets welded on both the columns and the temporary girders., and all the loads in the transportation process are transferred to the barge through the support and brackets. Therefore, the strength of the sea-fastening support and welding directly affects the safety of the module transportation in barge.

The temporary support frames is checked according to API RP 2A WSD and AISC-ASD 9th, and

the brackets welding is checked according to AWS D1.1/D1.1M_2015, all the marine operations should comply with the specification DNV GL-ST-N001_2016 as the design basis.

In this paper, the size and weight of the topside module are calculated as follows:

Table 1 The Size and Weight of The Module

Module Description	QTY	Dimensions (m)			Total Gross Weight (MT)
		Length	Width	Height	
Topside Module	1	24.6	25.4	14.8	958.69

NOTE: The weight above including the temporary balance beam weight.

3 Design Philosophy

This paper presents the sea-fastening design methodology and results of the topside module which is to be transported by self-propelled barge, and then the module will be installed by floating crane at designated location[3]. The sea-fastening analyses are three-dimensional frame analyses that performed via the SACS, developed and marketed by Bentley Engineering.

The loads applied for the analyses consist of the structural self-weight and dry weights of other disciplines - such as Piping, E & I and Mechanical - under the action of wind and transport motion load cases.

The module is supported in barge by temporary support frames. Sea-fastening grillages are settled between the strong points of both the temporary support frames and barge frames. The sea-fastening grillage consists columns and braces that to be welded on base plates and then base plates welded onto barge deck where is strongly supported by barge girder or bulkhead. Cap beams spanning on barge girders are also planned to spread the loads to barge safely.

The barge transverse frames are typically 2100 mm/2800 mm spaced from AP. The longitudinal girders and bulkheads are 3500 mm/7700 mm/9800 mm/14000 mm started from ship center line. The typical barge frames consist of different size girders made of fabricated T-shape girders.

The member end forces of sea-fastening grillage members taken from SACS output are considered as contributed forces applied onto barge hull deck. The forces on top of the grillage columns are carried by fillet weld around top plates to bottom of temporary support girders. If any gap between the top plate and the temporary support are larger than 6mm, where direct welding cannot be applied efficiently, additional brackets are to be double-fillet welded between the temporary support and top plate equivalently.

The forces at bottom of the grillage columns and braces are carried by welding between base plates or cap beams and the barge deck. Sets of stiffener plates are to be double-fillet welded on cap beams and on hull deck above barge girders or bulkhead to spread the load to barge frame evenly.

4. Design Condition

4.1 Computer Model & Boundary Condition

The computer models for sea-fastening analysis are modeled based on the detailed design model for the module. Effective part of the barge is modeled for barge strength check. Figure 1 shows the entire analysis models with boundary conditions at the barge member ends. In general, ends of the barge pillars and bulkheads are fixed (111111), and ends at girder centers are pined (111000).
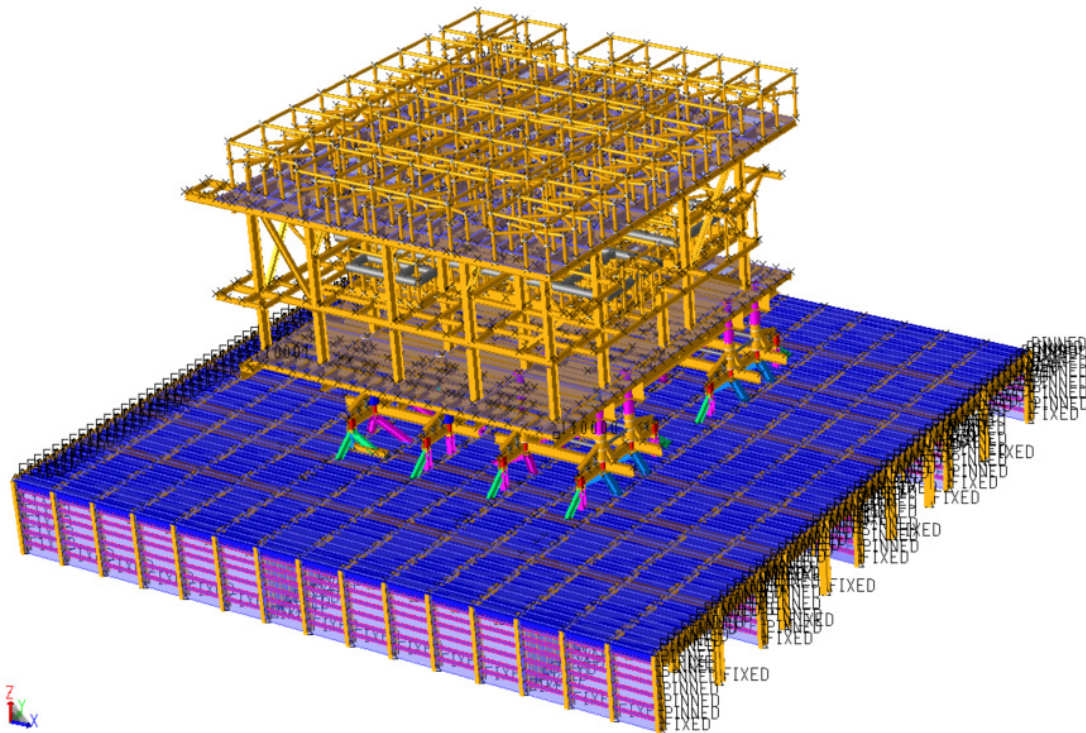
Figure 1 Topside Model and Boundary Condition

4.2 Design Loads

4.2.1 Gravity Loads

The module weight and COG adopted in the analyses were taken from the latest WCR. Temporary support is also added into the overall weight for sea-fastening analyses. The weight and COG summarized in Table 2 are used in motion acceleration calculation.

The COG in the table below is relative to the barge, X is the direction from stern to bow, based on after perpendicular(AP). Y is the direction from starboard to port, based on the center line of barge, and Z is the direction from baseline to deck of barge, based on the baseline.

Table 2 Module Transportation Weight

Module	Gross Weight(MT)	COG w.r.t.AP (m)		
		X	Y	Z
Topside Module	958.69	71.24	0.8	20.178

4.2.2 Wind Load

Wind load calculation is according to API RP 2A WSD 22nd.Wind load values in in-place conditions and FPSO transit shall follow the requirements to the "Site Conditions and Available Utilities" in which wind speed at 10 meters above mean sea level(MSL) and 10 minute duration. For topside structural design, 10-year wind load shall be applied for transportation conditions[4].

So 27.42m/s is used. Wind on all the exposed frontal areas has been considered with a shape coefficient of 1.0 and in accordance with API's wind speed variation with height above MSL. The barge design draft is 6.2m, for conservative, half of DEPTH MOULDED (10.9m) i.e 5.45m draft is considered for the module transportation, then the MSL(z) for wind load is 14.728m at module COG.

Eight direction wind load is considered for the module. Wind loads in 0°/90°/180°/270° are

considered in Head Seas and Beam Seas conditions while only wind loads in 45°/135°/225°/315° are considered in Quartering Seas, as showed in figure 2.
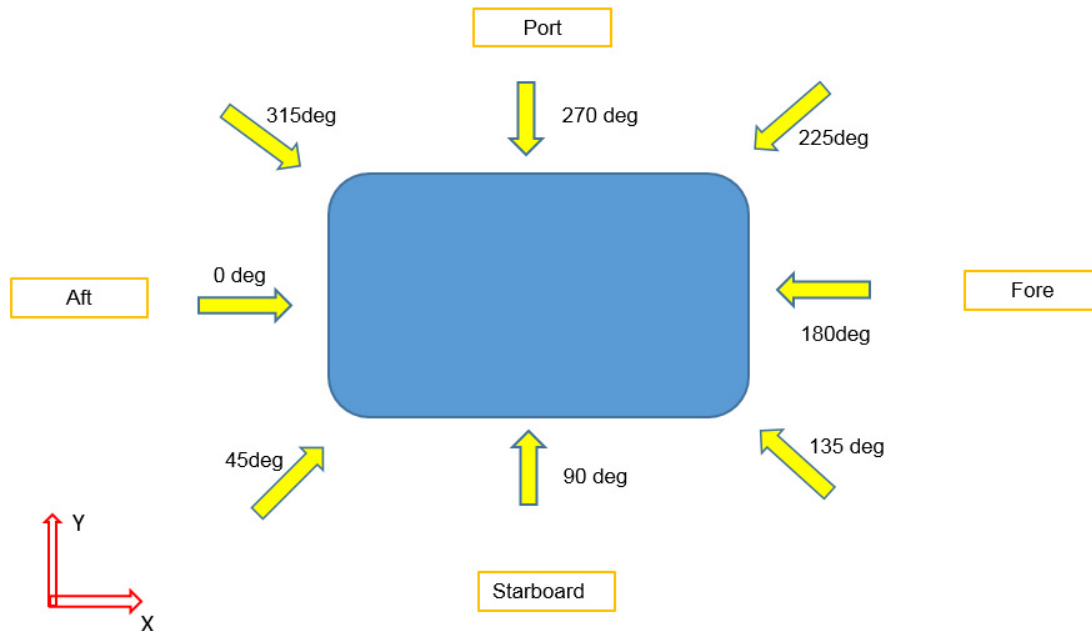

Figure 2 Eight Direction Wind Load

4.2.3 Transportation Accelerations

The ship motion data is used for barge transportation analysis in following table 3:

Table 3 Module Transportation Accelerations

Full Cycle Period	Roll	Pitch	Heave
Topside module	10°	5°	±0.1g

The roll and pitch center is located at the barge center at waterline and is used in inertia loads calculation. Distance from barge center to the center of module gravity (COG) is shown in Table 4 and Stowage Plan with COG location shown in Figure 3.
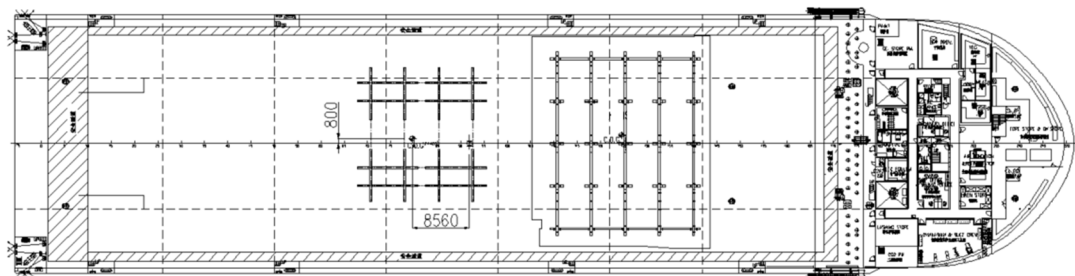

Figure 3 Stowage Plan for Topside Module

Table 4 Distance from Barge Center to COG of Module (Unit: m)

Module Description	Longitudinal XG	Lateral YG	Vertical ZG
Topside Module	8.560	0.800	14.728

The acceleration used for the module transportation is calculated below and summarized in following table 5.

Table 5 Summary of Acceleration Load

Module Description	Summary of Acceleration Load			
	Load Case	AX(g)	AY(g)	AZ(g)
Topside Module	AXB	0.148		
	AYB		0.294	
	AZB			0.126
	AXBQ	0.104		
	AYBQ		0.208	

Note: AXBQ, AYBQ means acceleration load in Quartering Seas. AXBQ = 0.707 AXB ; AYBQ = 0.707 AYB[5].

4.2.4 Load Combination

The load combination for module transportation is list in the below table.

Table 6 Sea-Transportation Load Combination

Lcomb	Limit State	Dead Load	27.42m/s Wind Load								Roll 10°,Pitch 5° Period 10s, Heave 0.1g				
		DEAD	0 deg	90 deg	180 deg	270 deg	45 deg	135 deg	225 deg	315 deg	AXB	AYB	AZB	AXBQ	AYBQ
5001	Head Sea	1.0	1.0								1.0	1.0			
5002		1.0		1.0							1.0	1.0			
5003		1.0	1.0								1.0	-1.0			
5004		1.0				1.0					1.0	-1.0			
5005		1.0			1.0						-1.0	1.0			
5006		1.0				1.0					-1.0	1.0			
5007		1.0			1.0						-1.0	-1.0			
5008		1.0		1.0							-1.0	-1.0			
5009	Beam Sea	1.0	1.0									1.0	1.0		
5010		1.0		1.0								1.0	1.0		
5011		1.0			1.0							1.0	-1.0		
5012		1.0		1.0								1.0	-1.0		
5013		1.0			1.0							-1.0	1.0		
5014		1.0				1.0						-1.0	1.0		
5015		1.0	1.0									-1.0	-1.0		
5016		1.0				1.0						-1.0	-1.0		
5017	Quartering Sea	1.0					1.0						1.0	1.0	1.0
5018		1.0					1.0						-1.0	1.0	1.0
5019		1.0							1.0				1.0	1.0	-1.0
5020		1.0							1.0				-1.0	1.0	-1.0
5021		1.0						1.0					1.0	-1.0	1.0
5022		1.0						1.0					-1.0	-1.0	1.0
5023		1.0								1.0			1.0	-1.0	-1.0
5024		1.0								1.0			-1.0	-1.0	-1.0

5. Barge Frame and Sea-fastening Member Check Results

5.1 Check Result for Half Grillage Loaded During Loadout

As half of the grillages need to be settled after SPMT removed, the worst case during loadout is

checked in this section considering only part of the grillages taking module load on barge, the grillage that settled later is released and shown in the following figure. No ship motion acceleration considered in the check as the barge is moored to quay side stably during loadout.
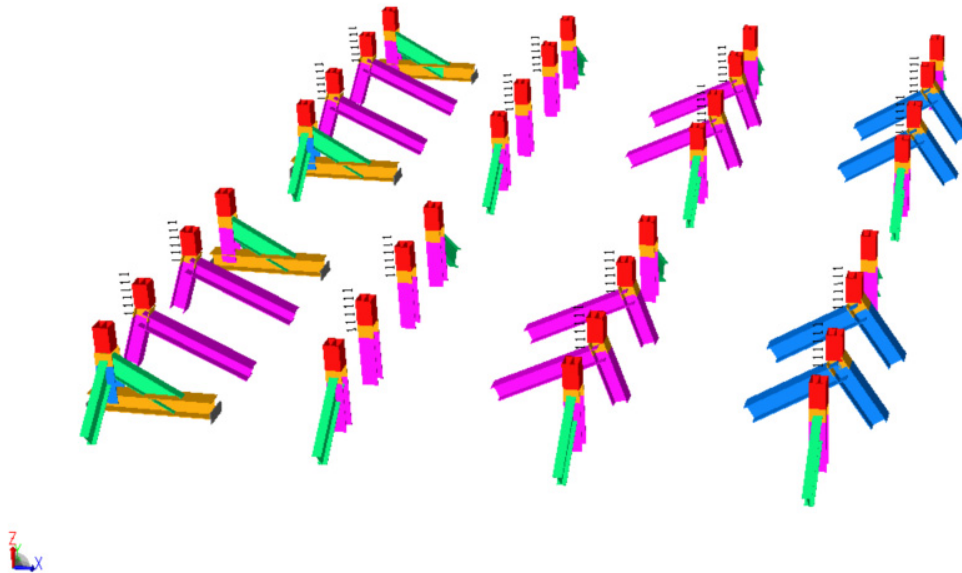

Figure 4 Grillage Member Released During Loadout

Grillage, balance beam and barge frame member group summary for topside module with half grillages loaded is taken from SACS output results. And the results show that all members meet the strength requirements of the code.

5.2 Check Result for Sea-Fastening During Voyage
The barge frame and sea-fastening member group summary is taken from SACS output results. The results show that all members meet the strength requirements of the code in combined UC plots.

6. Plates and Welding Check
The member end forces of sea-fastening grillage members taken from SACS output are considered as contributed forces applied for plate and welding check.

Grillage members shall be set between temporary support frame of module and barge deck to check welding strength. The top plates are welded around to the bottom of temporary support frame, and the base plates are welded around to the barge deck, and the columns and braces are set between the top plate and the base plate. In order to ensure the strength, the bracket plates are welded to the grillage columns, braces and the bottom of temporary support frame. Fillet weld is used for all welds and 100% MPI is required.

7. Conclusion
This paper mainly carries on the sea-fastening design of the topside module in the process of marine transportation by SACS software. Design from the following two aspects:

1) The topside module is connected with the barge by temporary support frames and the grillage members as the sea-fastening design. When bearing the combined load of dead weight, wind load and rolling, pitching and heaving of the barge, different working conditions shall be calculated by SACS software. The analysis result indicates the sea-fastening members for topside module and the barge structure can withstand the tow loads specified by Noble Denton General Guidelines for Marine Transportations.

2) Temporary support frames, grillage members, the topside module and the barge are connected by welding, and stiffeners are added while appropriate. Therefore, welding strength also has a crucial impact on the safety of the structure. In this paper, the member end forces of sea-fastening grillage members taken from SACS output are added to the structure by hand calculation to check the welding strength. The results show that 100% MPI of fillet welding can meet the strength requirements.

The calculation of temporary support frames and welding strength is important for the safety of the topside module during marine transportation, and also provides reference for the design of other similar projects. Due to the limited space, only the design load is described in detail, and the calculation results are analyzed simply. In the future, the strength of different support forms can be analyzed, and the effectiveness of various support forms.

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