

Loading of Offshore Structure on Barge Using SPMT

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ABSTRACT

Load-out is one of critical part during construction of an offshore structure and one of the load-out methodology is load-out by using SPMT (Self Propelled Modular Transporter). SPMT can transport to the uneven ground condition by using hydraulic system. Three point suspension set-up and four point suspension set-up are two common levelling hydraulic system on SPMT. There is a significance difference during preparation of SPMT on each levelling system in term of time and cost. This study aims to analyse the structural integrity of offshore structure including barge response during load-out transportation. This study compares load-out transportation arrangement between each levelling system during cross over to the barge by using simulation. Transportation analysis to check offshore structural integrity during cross over to the barge is done by Staad Pro and PIAS software. Three point suspension set-up is more safely used for super heavy weight structure and four point suspension set-up is better for normal and intermediate heavy weight structure with considering cost, time and productivity to setting the suspension set-up and transportation arrangement.

KEY WORDS: *Load-out, Self Propeller Modular Transporter, Offshore Structure.*

NOMENCLATURE

SPMT Self-Propeller Modular Transporter

PIAS Program Integral Approach Ship

WCF Weight Contingency Factor

1.0 INTRODUCTION

Offshore structure such as topside and substructure is fabricated at yard and need to be transported and installed to their site operation. Load-out is the transfer of a major assembly onto a barge by horizontal movement or by lifting [1, 2]. load-out process is more complex than simply sliding it off the quay onto the barge since most structures in the offshore industry are of a large scale and heavy weight, the weight of the structure to be transported will affect the stability, draft and the structure of the barge [3]. On the heavy-lift of offshore structure, SPMT (self-propelled modular transporter) are capable of carrying heavy load, SPMT is a flat platform transporter with high capacity can accommodate 30 tons of load each 4 or 6 axles lines [4]

Transferring offshore structure from quay to the barge can inflict several problems since the state of the stress in the offshore structure happen during transportation therefore SPMT can ensure the balance loads and stability on uneven road surfaces using hydraulic leveling system. Each wheel of SPMTs is individually controlled by several computer controls and cylinder attached to each wheels can be adjustable in ride height. This allows the moving step an offshore structure between during load-out between quayside to the barge is positioned to remain flat evenly weight distribution. Hydraulic leveling system of SPMT are provided to ensure the stability of structure when SPMT running on uneven road. Three or four point supporting technique for leveling achieved from SPMT suspension cylinder. It point leveling apply for different working condition and normally three point or four suspension set-up will be used and all load of each suspension point will be distributed equally to the axles in group division plan [5].

Even though each leveling system can ensure the stability of offshore structure when transporting to the uneven road, but there is a significance difference during preparation SPMT on each leveling system in term of time and cost. From the previous study there is limited researcher study about load-out methodology by

using SPMT Therefore, this study will analyze the barge response and effect to the barge structure also integrity of offshore structure during load-out with comparison of different leveling system.

2.0 RESEARCH METHODOLOGY

To conduct the research objectives shall be follow research methodology as a direction to achieve the result and Figure 1 shown the flow chart of framework research methodology of this study

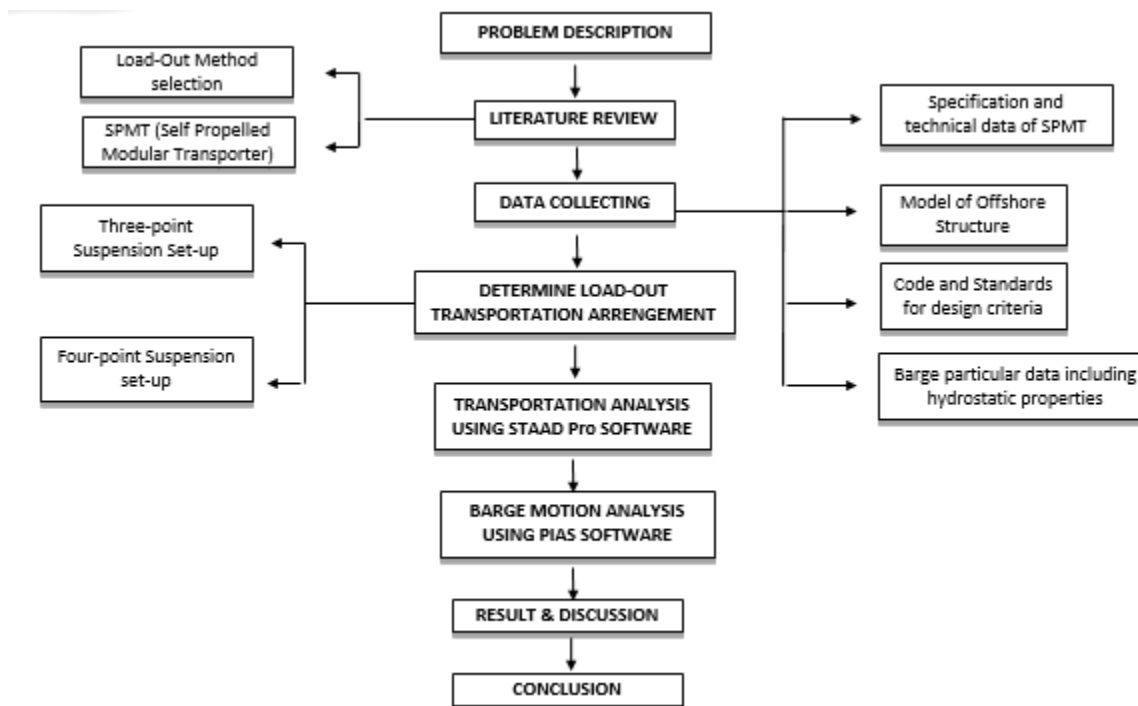


Figure 1: Flow chart of research activity

2.1 Design Consideration

For this study to achieve the objectives using simulation analysis shall be follow design consideration and this study using STAAD PRO software for the modelling and provide the structural analysis and for barge motion during load-out transportation using Program for the Integral Approach of Ship design (PIAS) software. Design consideration to modelling in software on this methodology is based on literature study on Load out and Self-propelled modular transporter [6, 7, 8 & 9]. The part of design consideration on modelling is weight, structure modelling, boundary condition, environmental load and dynamic force.

2.2 Performing analysis on STAAD Pro

The analysis of effect the offshore structure on SPMT with different levelling system will be performed in STAAD Pro Software. STAAD Pro is structural analysis software which can solve structural static problem with API standard such as stress, deflection, strain of the structure. For the analysis will be done in two stages using the same model. Stage 1 is where the support reactions at the three point suspension set-up centers/ four point suspension set-up centers are derived. Stage 2 is the structural analysis and integrity check of the structure and the SPMT beams.

2.3 Performing analysis on PIAS

The analysis of effect the barge response including barge stability during load-out the offshore structure by using SPMT will be performed in Program for the Integral Approach of Ship design (PIAS) software. PIAS is the naval architecture software which can solve stability calculation, hydrodynamics, and longitudinal strength.

3.0 SELF PROPELLER MODULAR TRANSPORTER

There are two common hydraulic system stability areas on SPMT three point suspensions sets up and four point suspensions set-up.

3.1. Leveling system stability area

SPMT consists of two main parts, power pack unit to producing power to driven force and platform body bearing the cargo load. The common standards unit of SPMT is 4 and 6 axes unit [5]. Configuration transportation arrangement depends on dimension, weight and also the transportation route including slope condition [10]. The most important choice is to make the group of cylinder arrangement carrying the offshore structure as stable as possible. Each component has a hydraulic system and the system consist valves, piping lines and cylinders. The hydraulic system allows the hydraulic connection of several SPMT in terms of width,

options, and length to disconnect and connect the cylinders. Figure 2 shows one configuration of hydraulic three point and four suspension setup. Three points suspension setup give triangular stability area shown on the red color in the figure. Four point suspension setup give rectangular stability area which is four-point setup statically determined or usually called hyper static.

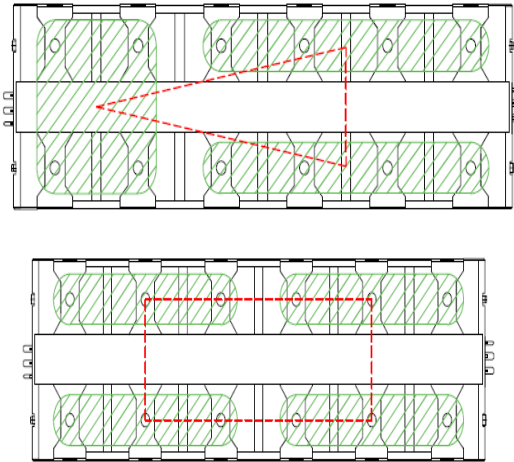


Figure 2: Top view of SPMT three-point Suspension setup (Left) and four point suspension setup (Right) [5].

The hydraulic suspension setup configuration of the SPMT considered be stable and it is necessary accurate calculation to determine the forces acting on the transportation model and the following forces equation is taken into consideration:
Dead weight

$$M = g \cdot (mload + \sum_{i=1}^n Mi) \quad (1)$$

Where M is the sum of the SPMT weight, auxiliary component, and Structure load this model considered forces applied in center of gravity and the vector force equation is determined by vector and point.

$$(Fx + xCoG) \cdot X + (Fy + YCoG) \cdot y + (Fz + ZCoG) \cdot Z = 0 \quad (2)$$

Where, the vector is the force combination and the point is the center of gravity reaction of the suspension group the three suspension system is statically determined or usually called isostatic the reactions is performed following assumption below there are no moment in the Z and there is the force in X and Y plane, the ground consideration as a rigid plane, the load (W) and the reaction forces (F1, F2, and F3) are perpendicular to the stability plane and the system is subject to quasi static loading or mass are assumed to be irrelevant. Figure 3 shown reaction forces in three point suspension set-up in stability plan triangular area.

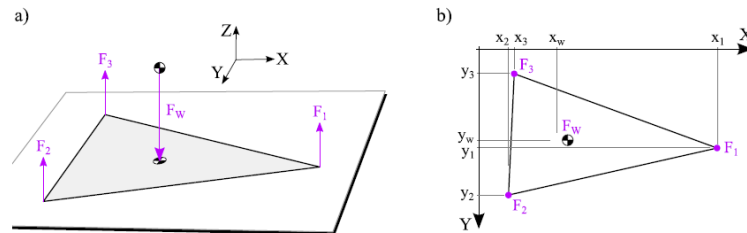


Figure 3: forces on three point suspension set-up (a. xyz stability plan) (b. stability plan) [10].

4.0 DATA AND SIMULATION

4.1 SPMT Technical Data

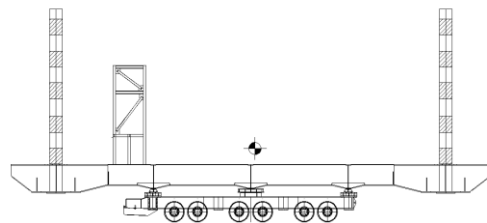
Technical Data for the SPMT based on Belleli manual book [9]. For the SPMT, the following technical data shall be considered on this analysis based on Belleli User Manual model Self propeller trailer STD 600 JD 12WD with 6 axles and capacity 600 ton

4.2 Offshore Structure Data

Based on data from PT Saipem Karimun Yard KAOMBO module process deck will be used as a model for offshore structure and to be implemented on design of transportation arrangement, three-point or four-point hydraulic circuit arrangement. Module process deck which has total weight assumed 285 MT, Yield strength of steel 420 MPa and it will be used for transportation modelling load out by SPMT

4.3 Transportation Arrangement

The position of the plan view three-point suspension set-up on SPMT with Process Deck Module is shown. Side view transportation arrangement and the transport analysis is performed considering a three point suspension set-up or isostatic system with the hydraulic circuits of the three groups as shown in Figure 4. The data of distribution load on three point suspension set-up and four point suspension set-up shown on Table 1 and Table 2. Hyper static system or four point suspension set-up with the hydraulic circuits of the groups is shown in Figure 5.



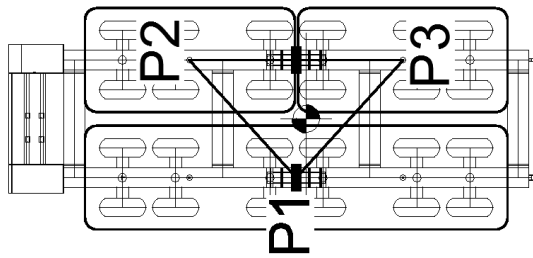


Figure 4: Side view the transportation arrangement and Hydraulic zone of SPMT three point suspension set-up

Table 1: Load distribution on three point suspension set-up transportation arrangement circuit.

Circuit	Number of wheels	Load on circuit (Ton)	Load each wheels (Ton)
P-1	12	184.72	15.39
P-2	6	85.27	14.21
P-3	6	99.46	16.58
Total		369.45	

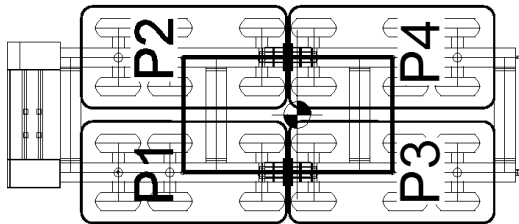


Figure 5: Hydraulic zone of SPMT four point suspension set-up

Table 2: Load distribution on four point suspension set-up transportation arrangement circuit.

Circuit	Number of wheels	Load on circuit (Ton)	Load each wheels (Ton)
P-1	6	85.285	14.214
P-2	6	85.285	14.214
P-3	6	99.435	16.57
P-4	6	99.435	16.57
Total		369.45	

According to Belleli SPMT 600 T manual book, preparation time of setting hydraulic set up for four point suspension set-up on SPMT Belleli is taken at least 2 hours which is depending on transportation arrangement and how many SPMT will used for the transportation to arrange the hose connection, transportation beam and arrange the structure on the SPMT as per design arrangement [9]. Four point suspensions set-up arrangement is easier to setup than three point suspension set-up. The comparison each point suspension set-up in term of time for setting the leveling system is 4 hours for three point suspension set-up and 2 hours for four suspension set-up.

4.4 Simulation Using STAAD Pro

The load out transportation analysis will use the self weight of the structure computed by the Staad Pro software. Additional loading

are computed and included in the command line of the software as joint or member loads. The weight of the assembly from the Staad software is 369.45 MT.

A Weight Contingency Factor (WCF) equal to 1.08 is used to account for weight items that may be added to the assembly prior to transportation. Dynamic forces during the initial movement (tractive effort) of SPMT is computed by multiplying gross weight by the corresponding Dynamic Amplification Factor (DAF) equal to 1.05 for structures with a weight greater than 100 MT. Figure 4.3 shown model of offshore structure transportation arrangement each levelling system by using STAAD pro.

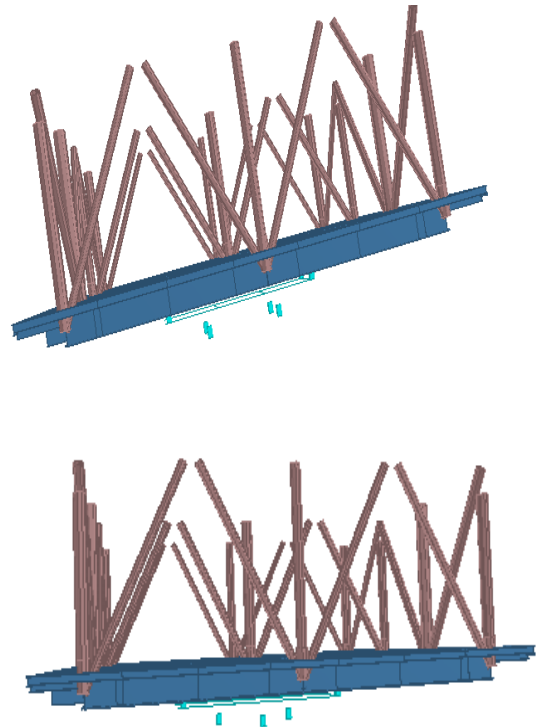


Figure 6: 3D model four point suspension set-up (left) and three point suspension set-up (right)

5.0 RESULT AND ANALYSIS

Offshore structural integrity is the ability of offshore structure to retain its shape, strength, and function with acceptable limits without failure. Offshore structural integrity during transportation will be analyzed each steps during cross over to the barge. There are 3 steps until the offshore structure reach the final position and each step will be analyze by using STAAD pro simulation with sketch of each step by using Autocad. Table 3 Show the Description of each step during cross over to the barge.

Table 3: Description of each step during cross over to the barge

No	Step Number	Description
1	Step 0	Before offshore structure cross over to the

		barge
2	Step 1	During cross over to the barge and the offshore structure travelling 4.5 m from quay wall (step 0)
3	Step 2	During cross over to the barge and the offshore structure travel 3.75 m from step 1
4	Step 3	During cross over to the barge and the offshore structure travel 4.05 m from step 2

Based on result and analysis shown above the comparison between three point suspension set-up and four point suspension set-up levelling system in term of offshore structural integrity on deflection of offshore structure during step 0 until step 3 are shown in Figure 7.

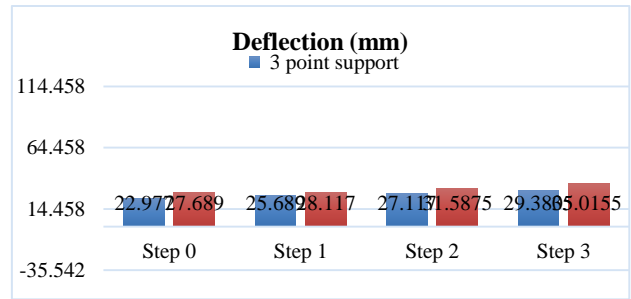


Figure 7: Comparison each levelling system on structural joint deflection (Step 0-Step 3)

From the graph show that four point suspension set-up deflection is more higher than three point suspension set-up which is the deflection of four point suspension set-up is 35.0155 mm on Step 3 occur on longest span of the offshore structure and three point suspension set-up is 29.3805 on step 3 mm also occur on longest span of the offshore structure. Each levelling system below the maximum is allowable deflection at longest span. The comparison each levelling system in term of bending moment and shear factor occur on offshore structure Step 0 until step 3 during cross over to the barge. For the shear force comparison is shown in Figure 8 and Bending Moment shown in Figure 9.

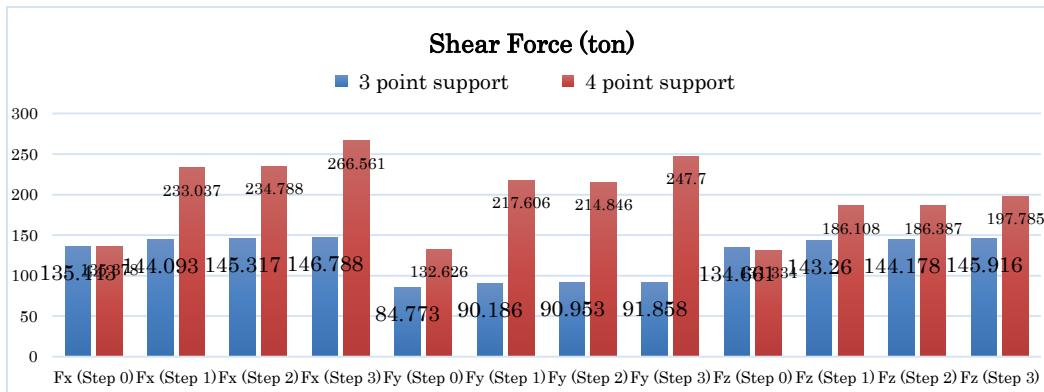


Figure 8: Comparison each levelling system on shear force (Step 0-Step 3)

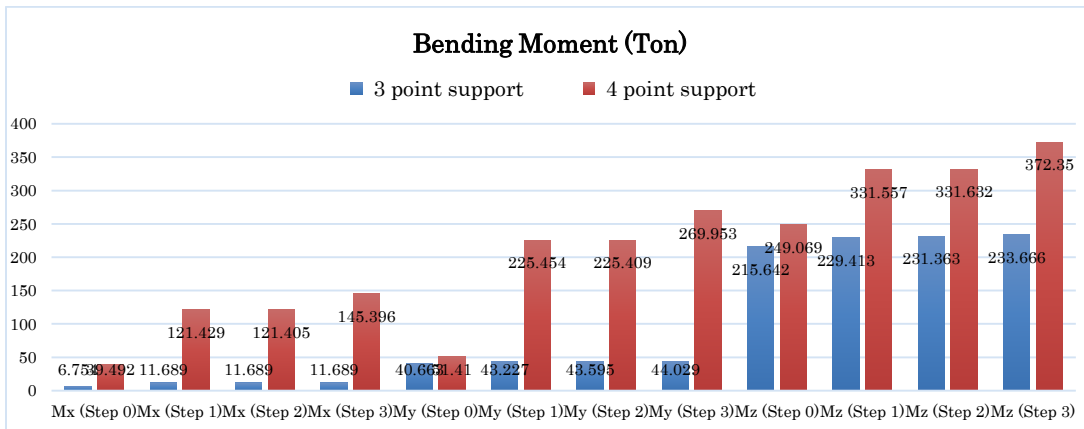


Figure 9: Comparison each levelling system on bending moment (Step 0-Step 3).

From the graph on Figure 8 show that four point suspension set-up Shear force is higher than three point suspension set-up which is the shear force of four point suspension set-up is 266.561 ton on Step 3 occur on Fx and three point suspension set-up is 146.788 ton on Step 3. From the graph on Figure 9 show that four point suspension set-up Bending Moment is higher than three point suspension set-up which is the higher bending moment of four point suspension set-up is 372.35 Tonm on Mz and three point suspension set-up is 233.666 Tonm occur on Step 3. Mx and My four point suspension set-up is the higher than three point suspension set-up. The comparison each levelling system in term of beam stress occur on offshore structure Step 0 until Step 3 during cross over to the barge shown in Figure 10.

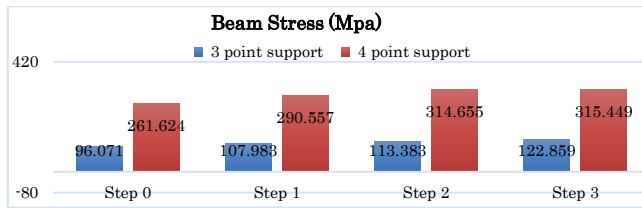


Figure 10: Comparison each levelling system on beam stress (Step 0-Step 3)

From the graph on Figure 10 show that four point suspension set-up Beam Stress is higher than three point suspension set-up which is the Beam Stress of four point suspension set-up is 315.449 MPa and three point suspension set-up is 122.859 Mpa occur on Step 3. The maximum beam stress of offshore structure steel is 420 MPa which mean each levelling system still below the allowable steel stress.

Each levelling system still below the maximum allowable standard for deflection and beam stress which is the factor of safety for maximum deflection occur on the offshore structure is 3.27 for four point suspension set-up and 3.89 for three point suspension set-up for maximum beam stress on four point suspension set-up is 1.32 and on three point suspension set-up is 3.42. Three point suspension set-up levelling system is better than four point suspension set-up during load-out in term of offshore structural integrity which consist deflection, shear force, bending moment, and beam stress of the offshore structure. Distribution force of the offshore structure spread out evenly on the three point suspension set-up proved from result of the maximum bending moment and shear force as shown on Figure 11.

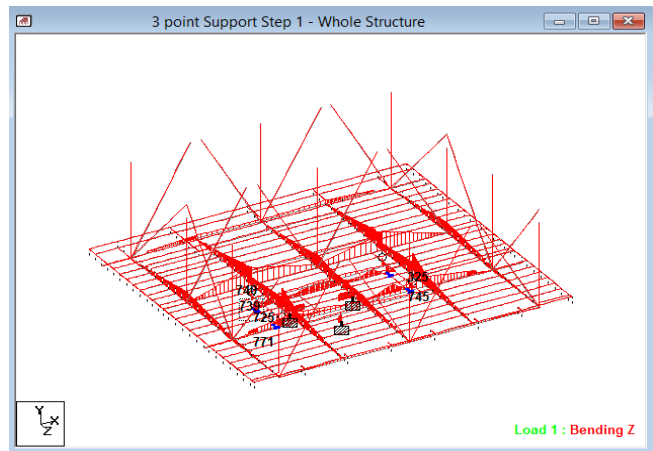
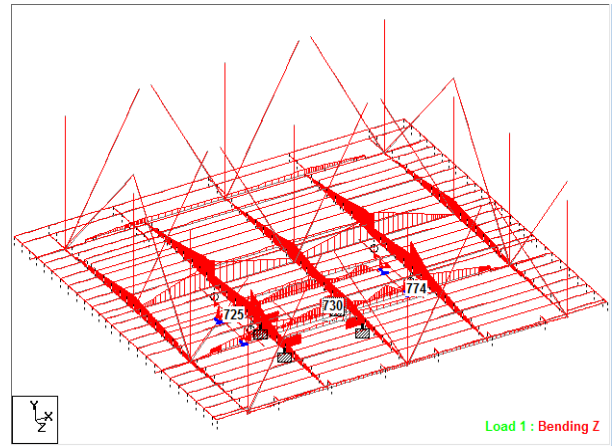


Figure 11: Location maximum beam stress and shear force occur four point suspension set-up (left) and three point suspension set-up (right)

The result show that maximum shear force and bending moment on three point suspension set-up spread out to the different beam on the offshore structure meanwhile maximum shear force and bending moment on four point suspension set-up only occur on certain beam.

Effect of barge strength and motion during load out transportation will be analyzed each steps during offshore structure cross over into the barge. The result of barge strength is calculated using PIAS software. There is no significance difference between each levelling system on bending moment and shear force of the barge during cross over. The result of barge motion during cross over shown on table 4

Table 4: Barge Motion and Stability Step 0-Step 3

Name	trim (degree)	heel (degree)	GM (m)
3 point suspension set-up (Step 0)	0.05f	0.01p	22.065
4 point suspension set-up (Step 0)	0.05f	0.01p	22.065
3 point suspension set-up (Step 1)	0.02a	0.01p	21.93

4 point suspension set-up (Step 1)	0.02a	0.01p	21.935
3 point suspension set-up (Step 2)	0.08a	0.01p	21.781
4 point suspension set-up (Step 2)	0.08a	0.01p	21.787
3 point suspension set-up (Step 3)	0.14a	0.01p	21.617
4 point suspension set-up (Step 3)	0.15a	0.01p	21.617

6.0 CONCLUSION AND RECOMMENDATION

For intermediate heavy weight structure four point suspension set-up is better than three point suspension set-up during load out to the barge in term of cost, time and productivity to setting the levelling system and transportation arrangement. Three point suspension set-up is more safely used for super heavy weight structure than four point suspension set-up during load out to the barge to avoid overload on each circuit of levelling system if system failure happen.

Based on the current research, some recommendations for future research are as Combination of SPMT on each levelling system such as using more than 1 SPMT to carrying the heavy load structure need to be considered to check the structural integrity also the stability of the structure. Optimization method of load-out by using SPMT to consider load-out plan for transportation arrangement and choosing levelling system need to analyze.

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REFERENCE

1. GL Noble Denton Technical Standards Committee. (2015). 013/ND-Guidelines for Load-Out. Hamburg: Germany.
2. J. Koto, Moh Hafidz. E, Amirrudin. Y, *Construction of Ships and Offshore Structures*, Ocean & Aerospace Research Institute (OcARI), Indonesia, Second Edition.
3. Verhoef, N.L.M. (2017). *Optimization of the skidded load-out process*, M Sc Thesis, Delft University of Technology.
4. Mohanasundaram, P. (2009). *Structural analysis of a heavy-lift vessel*, M Sc Thesis, University of Stuttgart.
5. Maoyao, Z., & Juan, W. (2016). Load-out design of jacket with SPMT, *Proceedings of the international conference on civil, transportation and environment*, Guangzhou, China, Offshore oil engineering corporation Ltd, China, pp.224-228.
6. Yang, Y.T., Cho, H.G., Yoon, K.Y., Ha, S.S. & Kang, H.S. (2003). Development of load-out methodology for on-ground –build FSO, *Proceedings of the 2003 offshore technology conference*, Houston, Texas, USA, Hyundai Heavy Industries Co.,Ltd, pp.1-5.

7. Dung, N.T. (2013). *First Jack-up rig load out in Vietnam*, Petrovietnam Journal, Vol 6, pp.48-54.
8. Saipem Indonesia Karimun Yard. (2014). Design Criteria for Land Transportation by Self-Propelled Trailer. Karimun: Indonesia.
9. Belleli. 2008, User instructions manual SPT STD 600JD 12 WD. Mantua: Italy.
10. Garcia, R.E., Platten, A., & Cope, N. (2016). *Stability model for abnormal load transport, proceeding of international sustainable ecological engineering design for society*, Leeds sustainability institute, pp.485-496.
11. ESTA (Europäische Schwertransport Automobilkran). (2016). Best practice guide for Self-Propelled Modular Transporter. Munich: Germany.
12. Samson, N., Ogonnaya, E., & Kuvie, E. (2013). *Stability analysis for the design of 5000-tonnes offshore work barge*, International journal of Engineering and Technology, Vol 3 no 9, pp. 849-857.
13. Yang, Y.T., Kang, H.S. & Park, B.N. (2003). Structural evaluation of FSO ground build load out, *Proceedings of the thirteenth international offshore and polar engineering conference* Honolulu, Hawaii, USA, International Society of Offshore and Polar Engineers, pp.227-234.