Comparative Analysis of Modular SPMT Load Out Methods

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Abstract. This research takes a module structure platform project in Bohai as an example, and arranges two different SPMT loading plans for the completed module structure on land, namely the north-south support beam SPMT loading plan and the north-south support column SPMT loading plan. A relevant load out model was established using SACS software, and the two load out schemes were calculated and analyzed. The results were compared, providing a reference for similar modular platform projects in the future to use SPMT loading.

Keywords: module structure · SPMT · load out · offshore engineering

1 Introduction

For the transportation of module structures from land to barges, three main methods are currently used: lifting loading, sliding loading, and SPMT loading. With the gradual enlargement of the size and weight of offshore engineering structures, SPMT transportation is widely used in the field of offshore oil engineering due to its advantages such as flexibility, convenient loading and unloading, and large load capacity.

The Chinese name of the SPMT (Self Propelled Modular Transporter) transport vehicle is a free structure transport vehicle, also known as a free hydraulic flat car. This type of transport vehicle, as a special type of vehicle, can be assembled or self assembled from multiple bodies based on the form, size, and weight characteristics of offshore engineering structures to meet the transportation goals. It can transport structures weighing over 50000 tons [1].

This study is based on a module platform project in Bohai, and provides a detailed introduction to two SPMT loading schemes for the module structure. SACS software was used to model these two loading schemes, and relevant structural calculations and verification checks were conducted. The advantages and disadvantages of the two methods were compared and analyzed, providing reference for future SPMT loading of similar module structures.

2 Overview of a Certain Module Project

A modular platform in Bohai is located in the central and southern region of the Bohai region, with a water depth range of 26 to 33 m. The platform is a 4-legged structure, mainly composed of the following three decks. The generated SACS 3D model is shown in Fig. 1.

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Upper deck: EL (+) 23500 mm.
Middle deck: EL (+) 18500 mm.
Lower deck: EL (+) 12500 mm.

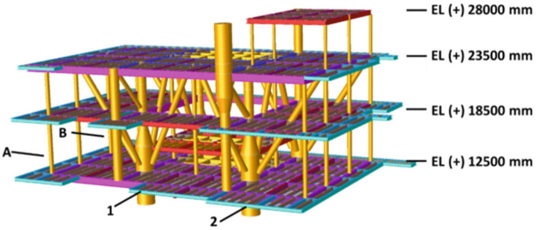

Fig. 1. SACS 3D Model of a certain module structure

The self weight of this module platform is approximately 750 tons, and the specific weight control data is shown in Table 1.

Table 1. Weight control of a modular platform

NO	ITEM	FACTORED WEIGHT (MT)	C.O.G. LOCATION (M)		
		DRY	X	Y	Z
1.00	STRUCTURE	744.94	0.68	−1.95	17.73
2.00	MACHINERY	137.50	−3.82	−5.48	22.38
3.00	PIPING	117.30	−8.00	−2.65	16.89
4.00	SAFETY	16.12	−8.16	4.57	17.57
5.00	ELECTRICAL	151.90	7.36	−0.86	17.18
6.00	COMMUNICATION	3.50	−3.50	0.00	19.50
7.00	OUTFITTING	65.78	9.19	−1.32	17.42
8.00	INSTRUMENT	85.58	3.51	0.00	17.75
9.00	HVAC	21.23	−12.69	−2.75	19.51
SUMMARY		1343.85	0.42	−2.01	17.93

The structure was analyzed as a three-dimensional model. SPMT (Self Modular Trailer) is used to load the platform onto a barge, taking into account the acceleration generated by trailer motion and the reaction forces generated by trailer configuration.

3 Introduction to Module Structure SPMT Loading Plan

The module structure SPMT loading plan needs to meet the needs of transporting the module structure to the dock barge after the completion of site construction. Therefore, the SPMT loading design is a highly comprehensive and complex task, which needs to consider comprehensive factors such as wind speed, deviation of module structure center of gravity, trolley load adjustment, and construction site. Generally speaking, before carrying out the SPMT trolley loading design, the dimensions and weights of the module structure, barge data, and docking dock data have been determined. Based on these data, the tidal conditions during loading should be verified first, and the restricted height of the tide should be identified. At the same time, the distance between the barge bottom and the seabed should be greater than 1 m.

The basic size diagram of SPMT is shown in Fig. 2. The maximum total weight of a vehicle axis is 40 tons per line, including SPMT self weight and power pack weight [2].

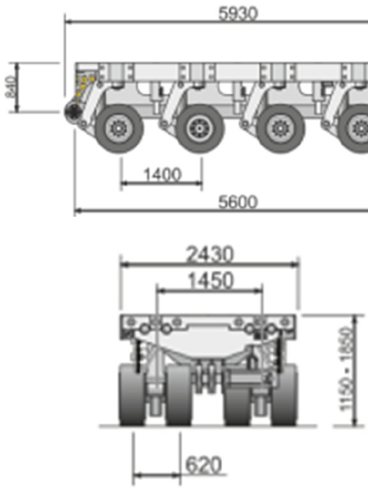

Fig. 2. Schematic diagram of basic dimensions of SPMT

In order to save computational space and ensure the effectiveness of the mechanical analysis of the SPMT loading plan, the SACS loading model used in this study is roughly the same as the in place analysis model, and some details have been modified as follows:

(1) The module structure model retains structures such as decks, beams, and columns above 9 m above the deck level. Below the deck level of 9 m, all structures such as jackets, piles, ship platforms, and caissons have been removed.
(2) Remove all future loads, offshore installation loads, content loads, crane operation loads, general loads (backup), and live loads.
(3) The SPMT spine longitudinal beam will be modeled using virtual components with zero material density. Its purpose is to provide a method of applying axial loads to the model, which can accurately distribute transverse loads, longitudinal loads, and bending moments into the module structure, as shown in the Fig. 3.

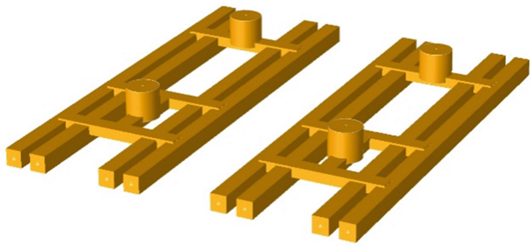

Fig. 3. Schematic diagram of SPMT modeling

(4) In order to ensure the stability of the module structure during the analysis process, four virtual brackets were introduced into the SACS model. The reaction force generated on these virtual supports is zero. Add horizontal and vertical springs at the bottom of the bracket to provide horizontal constraints and avoid rigid body motion, with spring stiffness set to 20 KN/m.

This study calculates and analyzes the following two module structure SPMT loading plans, namely the north-south support beam SPMT loading plan and the north-south support column SPMT loading plan. The idea for calculating and analyzing the SPMT loading process is as follows:

(1) As mentioned earlier, based on the establishment of the SPMT model, design a reasonable SPMT layout plan and create necessary "virtual" forces to simulate the deviation of the center of gravity.
(2) In the SACS model, for groups A, B, and C, the nominal unit load (9.81 KN) of each axis is sequentially applied to the underside of the SPMT spine beam.
(3) Generate horizontal frictional loads on the SPMT spine beam to balance all applied horizontal loads. Combine these friction conditions with all applied forces to obtain the load combination.
(4) Read the bending moment situation in the SACA model and balance the generated bending moment by applying reaction force.
(5) Generate load factors to be applied to each of the three sets of single loads. Re introduce these load factors into the SACS input file to obtain the load case series. Simultaneously create the final load combination to run the analysis.

3.1 Calculation of SPMT Loading Plan for Module Structure North-South Support Beam

The module structure supports the SPMT loading plan of the crossbeam in a north-south direction, as shown in Fig. 4a. The X-axis points forward to the north of the platform, the Y-axis points forward to the east of the platform, and the Z-axis points forward above the platform. This layout plan selects four groups of small cars to transport the module structure, with a north-south direction. Above the SPMT, a lifting beam is arranged to support the module structure crossbeam.

For the loading plan of the module structure supporting the beam SPMT in the north-south direction, the SPMT is divided into three independent hydraulic separation

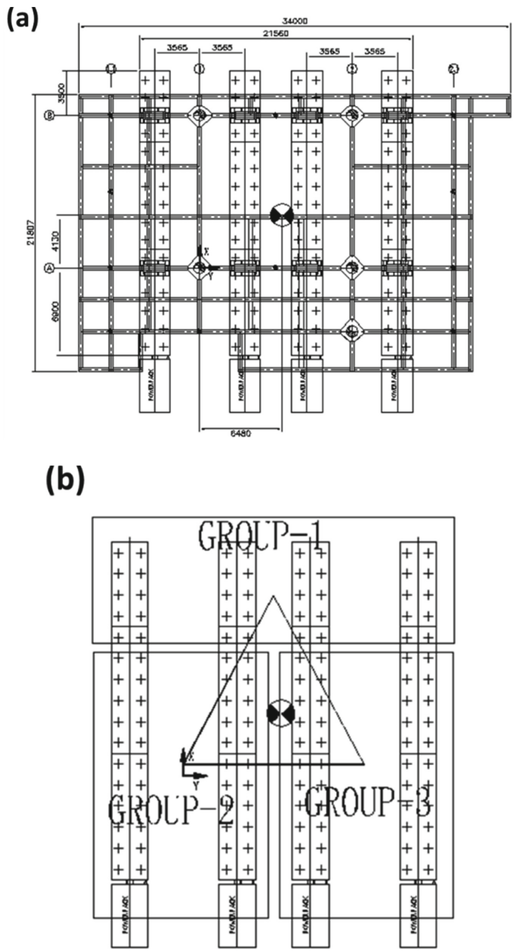

Fig. 4. Layout and grouping diagram of SPMT loading plan: (a) Layout diagram of SPMT loading plan for north-south supporting crossbeam; (b) SPMT group diagram

groups. Group A consists of 32 axes, while Group B and Group C each consist of 48 axes. The variation of COG is defined as being located within a rectangle centered around the theoretical COG position, with edges equal to 10% of the total module width and length, but not greater than 2 m in a horizontal plan view. This COG offset is modeled by applying global bending moments in the My and Mx directions, as shown in Fig. 4b.

According to the above SPMT layout plan, the longitudinal beam of the SPMT spine will be modeled using virtual components with zero material density, and a lifting beam will be established to support the structural beam of the module. The final SACS three-dimensional model is shown in Fig. 5.

Among them, the wind load acting on the module deck was calculated by the SACS program. In this study, the analysis used a one minute average velocity with a value of

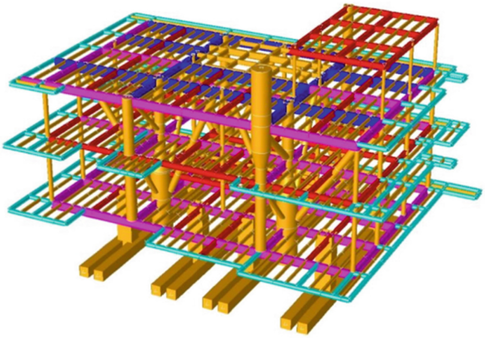

Fig. 5. Module structure north-south support beam SPMT loading model

20.3 m/s, taking into account four directions of wind action, namely 0°, 90°, 180°, and 270°. Table 2 shows the load name and wind direction.

Table 2. Wind Load Conditions

Load case	Type	Direction
LC52	Wind Load	90°
LC53 = −LC52	Wind Load	270°
LC54 = −LC55	Wind Load	180°
LC55	Wind Load	0°

This calculation and analysis will consider the longitudinal and transverse forces of 0.08G and 0.04G, respectively, where the power comes from the tilting, acceleration, and braking at the top of the module structure. In SACS software, load L502 represents the forward direction of SPMT, and the direction of L501 is perpendicular to the forward direction.

At the same time, during the SPMT transportation module structure process, it is not only subjected to the power provided by the tilting, acceleration, and braking at the top of the module structure mentioned above, but also subjected to wind loads. Therefore, the horizontal component of weight generates a set of horizontal reaction forces on the lower side of the structure, as shown in Fig. 6. These reactions are generated by SPMT friction, and this set of forces will be applied as loads L240 and L241, evenly distributed along the entire length of SPMT [3].

During the motion process, the horizontal loads generated by wind, acceleration, and braking force generate a global torque Mz. Due to the different positions of the load centroid, the magnitude of this torque is different from the torque generated by the frictional load on the trailer. The imbalance in torque Mz is corrected by applying a balancing moment to generate balance. In SACS calculations, these loads will be defined as L242 and L243, as shown in Fig. 7.

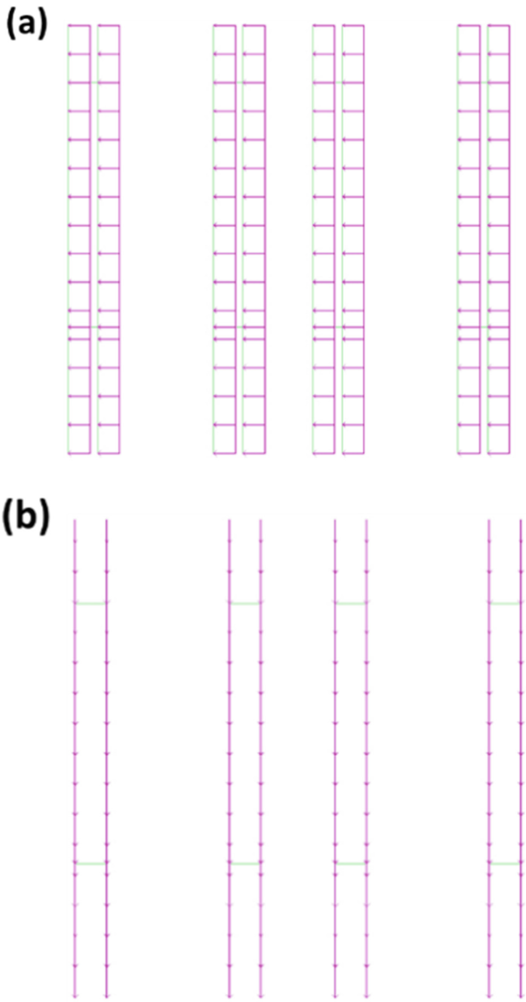

Fig. 6. Reaction force: (a) Horizontal reaction force L240; (b) Vertical reaction L241

Apply a nominally uniformly distributed upward load to the SPMT spine, which is equal to 9.81 KN. The loads L231, L232, and L233 correspond to groups A, B, and C of SPMT, as shown in Fig. 8.

Based on the weight control data, the gravity loads of various specialties under the action of gravity are first merged as a preliminary load combination. Then, all the applied forces (self weight, gear movement, wind, acceleration, etc.) and reaction forces (only frictional loads) are combined as load case1. Finally, three sets of uniformly distributed upward loads (L231, L232, and L233) are substituted into the SACS software for calculation, and the calculation list of the SPMT loading plan for the north-south support crossbeam of the module structure can be obtained, as shown in Fig. 9.

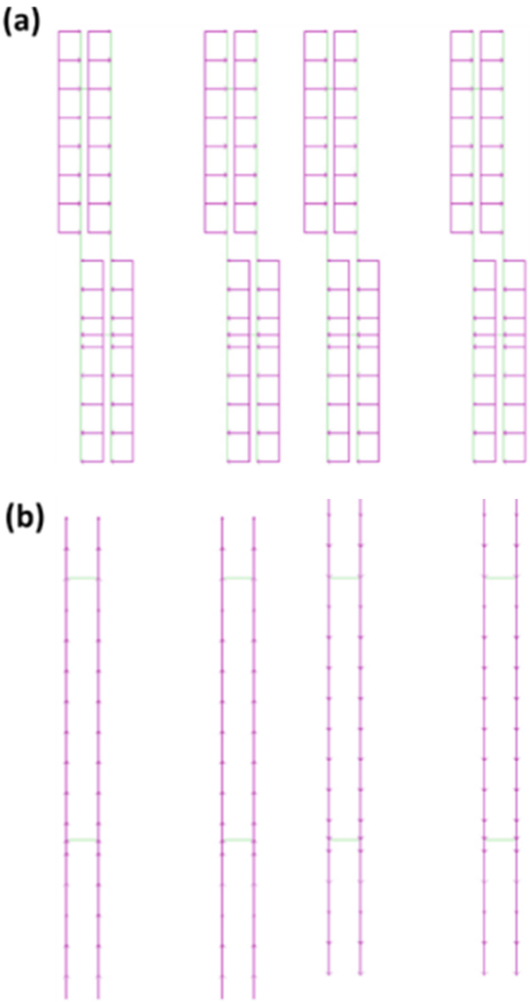

Fig. 7. Balance moment reaction force: (a) Horizontal reaction force L242; (b) Vertical reaction L243

3.2 Calculation of SPMT Loading Plan for Modular Structure North-South Support Columns

Compared with the previous scheme, the difference between the module structure with north-south support columns and the SPMT loading scheme is only that the lifting beam is arranged between the two sets of SPMTs, and then the module structure columns are supported, while the rest are basically consistent with the former.

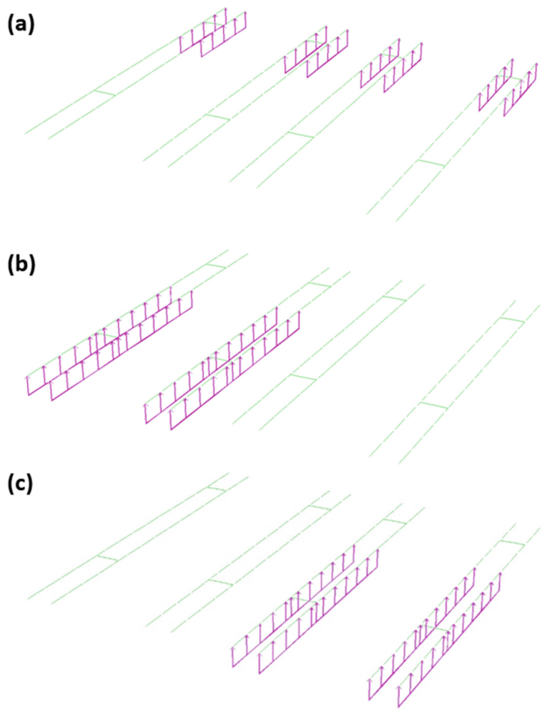

Fig. 8. Three sets of vertical loads for SPMT: (a) L231; (b) L232; (c) L233

8000	0.00	0.00	-0.06	-0.6	-0.6	0.0
8001	-0.80	0.00	0.09	-0.6	-0.8	0.1
8002	-0.57	-0.01	-0.01	0.6	3.4	0.0
8003	0.00	-0.01	0.57	-0.5	0.2	0.0
8004	0.57	-0.01	0.14	0.3	0.7	-0.1
8005	0.80	0.00	0.11	1.9	-0.5	-0.1
8006	0.57	0.01	0.07	1.5	1.9	0.0
8007	0.00	0.01	0.10	-0.5	1.4	0.0
8008	-0.57	0.01	0.05	1.0	-2.0	0.1
8100	0.00	0.00	0.04	1.7	2.4	0.0
8101	-0.80	0.00	-0.13	-0.8	2.2	0.1
8102	-0.57	-0.01	-0.09	-0.4	-0.2	0.0
8103	0.00	-0.01	-0.12	1.6	0.3	0.0
8104	0.57	-0.01	-0.55	2.5	0.9	-0.1
8105	0.80	0.00	-0.11	1.7	2.5	-0.1
8106	0.57	0.01	-0.02	0.5	-1.6	0.0
8107	0.00	0.01	0.02	-1.5	-2.2	0.0
8108	-0.57	0.01	-0.17	0.8	1.0	0.1
8200	0.00	0.00	-0.61	1.8	0.9	0.0
8201	-0.80	0.00	-0.46	1.8	0.7	0.1
8202	-0.57	-0.01	0.06	-0.2	1.2	0.0
8203	0.00	-0.01	0.02	1.8	1.7	0.0
8204	0.57	-0.01	0.21	-0.5	-1.5	-0.1
8205	0.80	0.00	0.65	-1.3	0.2	-0.1
8206	0.57	0.01	0.13	0.7	-0.3	0.0
8207	0.00	0.01	0.17	-1.3	-0.8	0.0
8208	-0.57	0.01	-0.02	1.0	2.4	0.1
8300	0.00	0.00	0.02	0.4	2.9	0.0
8301	-0.80	0.00	0.17	0.4	2.8	0.1
8302	-0.57	-0.01	0.21	0.8	0.4	0.0
8303	0.00	-0.01	-0.14	0.4	0.9	0.0
8304	0.57	-0.01	-0.25	3.7	1.4	-0.1
8305	0.80	0.00	-0.13	0.4	3.1	-0.1
8306	0.57	0.01	-0.03	-0.8	-1.1	0.0
8307	0.00	0.01	0.32	-0.3	-1.6	0.0
8308	-0.57	0.01	-0.18	-0.4	1.5	0.1
8400	0.00	0.00	-0.13	0.3	1.5	0.0
8401	-0.80	0.00	0.03	0.3	1.4	0.1

Fig. 9. Calculation List Results of SPMT Loadout Scheme for North-South Support Cross Beam of Modular Structure

The loading plan for the module structure with north-south support column SPMT is shown in Fig. 10a, where the X-axis points forward to the north of the platform, the Y-axis points forward to the east of the platform, and the Z-axis points forward to the upper part of the platform. This layout plan also selects four sets of small cars to transport the module structure in a north-south direction, but lifting beams are arranged between the two sets of SPMT, and then the module structure columns are supported.

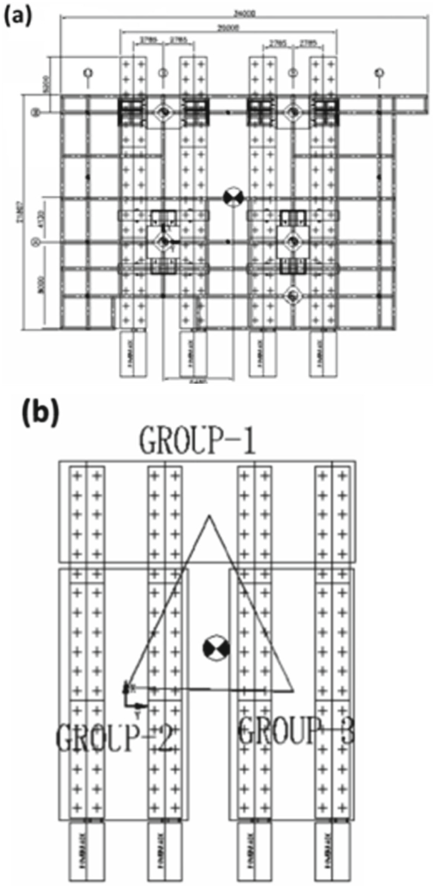

Fig. 10. Layout and grouping diagram of SPMT loading plan: (a) Layout diagram of SPMT loading plan for north-south support columns; (b) SPMT group diagram

According to the loading plan for the SPMT supporting column mentioned above, the longitudinal beam of the SPMT spine is modeled, and a lifting beam is established to support the structural column of the module. The final SACS three-dimensional model is shown in Fig. 11.

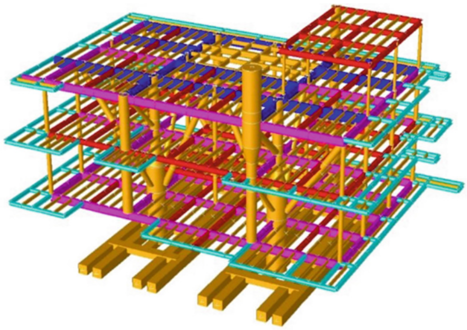

Fig. 11. Module structure north-south support column SPMT loading model

4 Comparative Analysis of Two Modular Structures SPMT Loading Results

This article compares the calculation results of the north-south support beam SPMT loading scheme and the north-south support column SPMT loading scheme. It can be seen that the north-south support beam SPMT loading scheme results in many main beam frame UC values being too large on the lower deck, posing a safety risk. This may be due to insufficient strength of the lower deck beam structure, which is insufficient to support the entire module structure platform, as shown in Fig. 12a–b. For the north-south support column SPMT loading plan, it can be seen that the entire module structure does not exhibit excessive UC values, as shown in Fig. 13. The SPMT loading layout plan plays a decisive role in the success of the entire module structure platform loading, therefore, in the design phase, a reasonable layout plan must be proposed based on the needs and starting points of the engineering site.

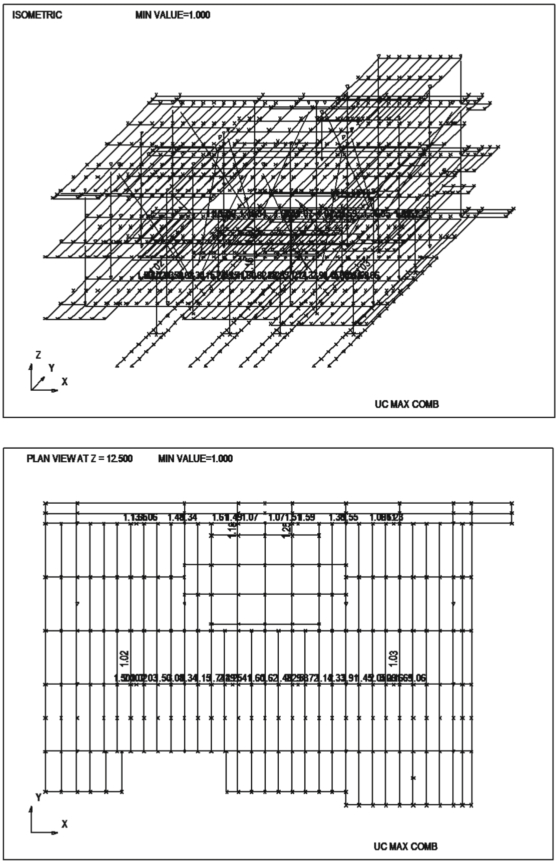

Fig. 12. UC value results of SPMT loading plan for north-south support crossbeam

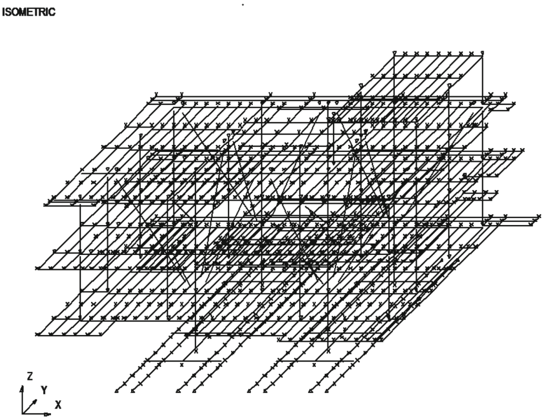

Fig. 13. UC value results of SPMT loading plan for north-south support columns

5 Conclusion

This article takes a module structure platform project in Bohai Sea as an example, and arranges two different SPMT loading plans for transporting this module structure platform to a barge. Then, SACS software is used to establish the north-south support beam SPMT loading models and the support column SPMT loading models. The two loading plans are calculated and analyzed, and the results are compared. It can be seen that the north-south support column SPMT loading plan is more safe, There was no significant increase in UC values for all structures.

It is worth noting that the choice of support method depends on the needs and starting point of the engineering site. For the SPMT loading plan for supporting the bottom deck crossbeam, it is more conducive to the layout of on-site small vehicles, which can better distribute the load of the small vehicles, and has lower requirements for the capacity of the small vehicles; The SPMT loading plan for supporting columns is more conducive to structural strength analysis due to the fact that the support position is basically the same as the platform's in position working condition. However, the position of the support point is limited and the reaction force is large, which requires higher axle load capacity of the trolley.

Therefore, based on the above research, this article suggests planning the layout plan of the small car early in the design stage, comprehensively considering the site bearing capacity, on-site transportation, and loading plan. If using beam support is more advantageous for the project, it can be appropriately strengthened in the design to avoid modifications in later construction, in order to achieve a balance between design and construction needs.

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