

USING THE F.E.M. METHOD IN STATICAL ANALYSIS FOR A ROMANIAN JACK-UP STRUCTURE IN THE BLACK SEA

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ABSTRACT

The static analyses of a Romanian jack-up structure was determined by the authors with COSMOS programme, based on F.E.M. method, with designer hypothesis considering and extreme conditions in the Black Sea.

The structural model of a Romanian jack-up structure was loaded with hydrodynamic loads and wind loads obtained in paper „The loadings which acts on a Romanian jack-up structure in the Black Sea” (by the same authors, TMT 2007) in this way: the main vertical pipes (chords) were loaded with 100% hydrodynamic forces from diagram; the secondary pipes (horizontal and diagonal) were loaded with percentage of hydrodynamic forces from diagram, depending on diameter of chord and diameter of secondary pipes ratio, for each level.

The results of the analyses were: the values and the diagram of von Mises stresses, on levels and beam types and the displacement of structures.

Keywords: Romanian jack-up, F.E.M. method, von Mises stresses

1. INTRODUCTION

The tension and deformation state from the structure components was determined by the authors through static calculation, based on the finite element method (F.E.M.), using the COSMOS program, taking into consideration the hypothesis (data bases) of the designer [1], as follows:

- the construction structure is that of the jack-up already in exploitation;
- length of the legs is 121,619 m;
- body mass at location 6640 t;
- longitudinal distance between legs 38,43 m;
- transversal distance between legs 33,26 m;
- water depth, $h = 90$ m;
- air space (the distance between the water surface and the bottom of the platform) = 11,2 m;
- maximum wave height, $H_{\max} = 12$ m;
- wave period, $T = 10$ s;
- maximum wind speed, $v_{\max} = 44,72$ m/s;
- the less favorable loading situation is when both wind and wave act simultaneously from N.

2. STRUCTURE LOADS PRODUCED BY WINDS AND WAVES

The loading of the spatial model of the Romanian jack-up was made according to the following principles.

I. The force of the wind, F_v , calculated in [2], was applied in the gravity center of the sail area of the jack-up model [3].

II. The loading of the structure with the loads generated by the waves was calculated as follows:

- legs 3 and 4 (fig. 1) were loaded – considering the legs are hit by the crest of the wave – accordingly to the loads given by the diagram in figure 4, thesis [2];
- legs 1 and 2 were loaded in conformance with:
 - loads given by the diagram in figure 4, thesis [2];
 - wave length, $\lambda = gT^2 / (2\pi) = 156,131$ m;
 - wave period $T = 10$ s;
 - longitudinal distance between legs = 38,43 m.

The vertical tubes were loaded with hydrodynamic loads in conformance with the diagram in figure 4, thesis [2] and the above considerations, and the diagonal and horizontal pipes with loads proportional to their exterior diameters. The energetic loss of the wave due to the hitting of legs 3 and 4 was not taken into consideration.

3. THE DETERMINATION OF THE TENSION AND DEFORMATION STATE

The determination of the tension and deformation state was done through static calculus, using the COSMOS program. It presents the following possibilities:

- it has at it's base the generalized Hooke law and the equation of continuity;
- it permits the control of structure deformations both in displacements and in tensions;
- the Lagrange interpolation functions transmit the tensions through the whole mass of the material;
- the procedure for solving the structural equilibrium is based on the gradient method;
- the static or dynamic analysis is done in linear or non-linear domain (material, shape or stress non-linearity);
- the numeric integration method used is the modified Newton-Raphson method.

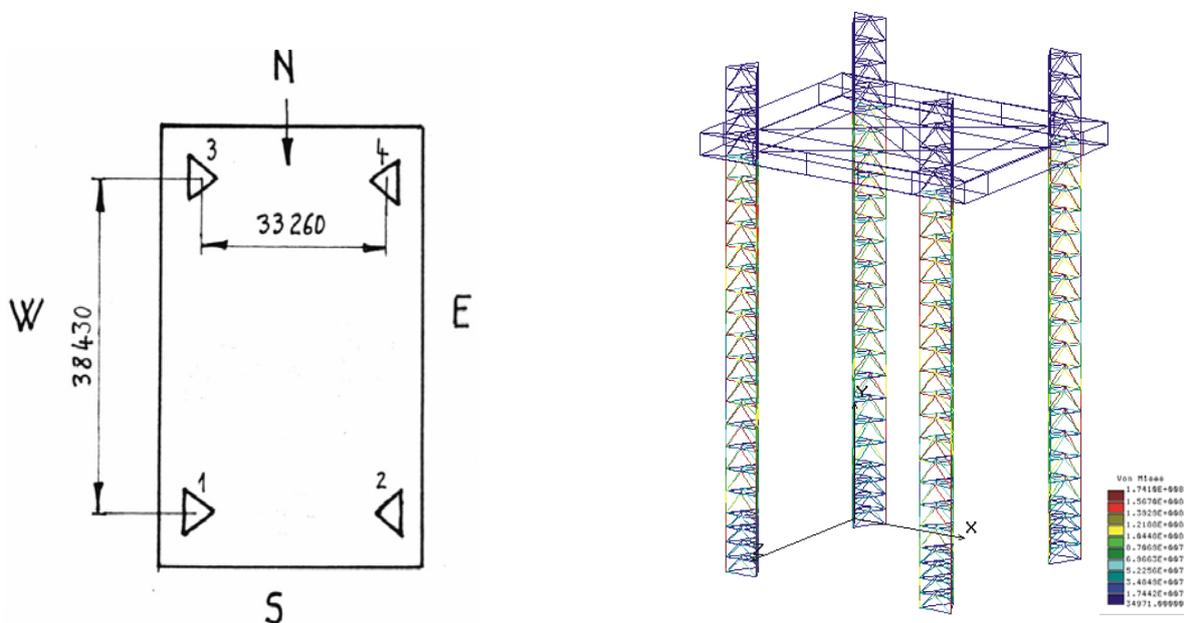


Figure 1. The scheme of the placement of the jack-up Figure 2. The tension state in the jack-up's legs related to the wind and wave direction

The rolling results are presented in figures 2...4 and table 1, as follows:

- figure 2 presents the tension state in the jack-up's legs;
- figure 3 presents the tension state in the bars of leg 4, between levels 25 and 26;

- figure 4 presents the deformed structure of the jack-up, using an amplification coefficient of 100;
 - in table 1 are given the values of the equivalent tensions, calculated with the 5th theory (the theory for the deformation potential energy for modifying shape – von Mises) from Material Resistance, on levels and types of bars, corresponding to the most solicited zones of leg 4.
- Both in figures 2 and 3 as well as in table 1 are given the average values of the equivalent tensions in Pa. The values of the displacements in figure 4 are given in meters.

Table 1. Equivalent tensions (von Mises) in the bars of the leg 4 of the platform

Level	σ_{ech} , MPa		
	Vertical tubes	Horizontal pipes	Diagonal pipes
1	III – 200,3	c – 83,4	c III – 125,1
2	III – 190,5	c – 77,9	c III – 119,4
3	III – 181,7	c – 73,6	c III – 114,7
4	III – 173,2	a – 70,7	a III – 110,5
5	III – 165,9	a – 67,2	a III – 106,3
6	III – 158,1	a – 64,3	a III – 102,2
7	III – 151,4	c – 62,1	c III – 99,1
8	III – 145,3	c – 60,7	c III – 96,5
9	III – 139,6	a – 58,2	a III – 93,6
10	III – 134,1	a – 56,5	a III – 90,7
11	III – 129,7	a – 55,4	a III – 88,4
12	III – 125,3	a – 54,2	a III – 87,2
13	I – 127,1	a – 52,9	a I – 86,1
14	I – 131,6	a – 53,8	a I – 86,9
15	I – 136,5	c – 54,8	c I – 88,2
16	I – 142,3	c – 56,0	c I – 89,6
17	I – 146,7	c – 57,4	c I – 91,1
18	I – 150,2	c – 58,9	c I – 92,8
19	II – 154,4	c – 60,6	c II – 94,3
20	II – 158,7	a – 62,4	a II – 97,1
21	II – 163,2	a – 64,3	a II – 100,4
22	II – 167,9	a – 66,3	a II – 103,6
23	II – 172,5	a – 68,5	a II – 106,5
24	II – 177,4	a – 70,7	a II – 109,4
25	II – 181,3	a – 73,0	a II – 112,0
26	II – 186,2	a – 75,5	a II – 116,2
27	II – 192,4	a – 79,1	a II – 121,7

4. CONCLUSIONS

Taking into consideration the present results, the following conclusion can be formulated regarding the tension state:

- I. The bars in which tensions of maximum values appear are those from the vertical tubes, as follows:
- the bars from the constraining zone oriented towards the Ox axis (S direction) of the legs 4 and 3, respectively 1 and 2 (see fig.2 and table 1) for which $\sigma_{ech} = 185...200$ MPa; the greater values are recorded in the case of legs 4 and 3 which bear stronger constraints, being hit by the waves;
 - the bars from the binding area between the legs and the body, oriented in reversed direction of the Ox axis (N direction) of the legs 3 and 4, respectively 1 and 2 (see fig.2 and table 1) for which $\sigma_{ech} = 185...192$ MPa and in this case the greater values are recorded also in legs 4 and 3.

It shows that the tensions in the binding area between the legs and the body are very close as value to the constrain area, due to the model chosen which is a tension concentrator. The real plausible values

can be considered those from the area right next to the binding area between the legs and the body, namely $\sigma_{ech} = 170...180$ MPa.

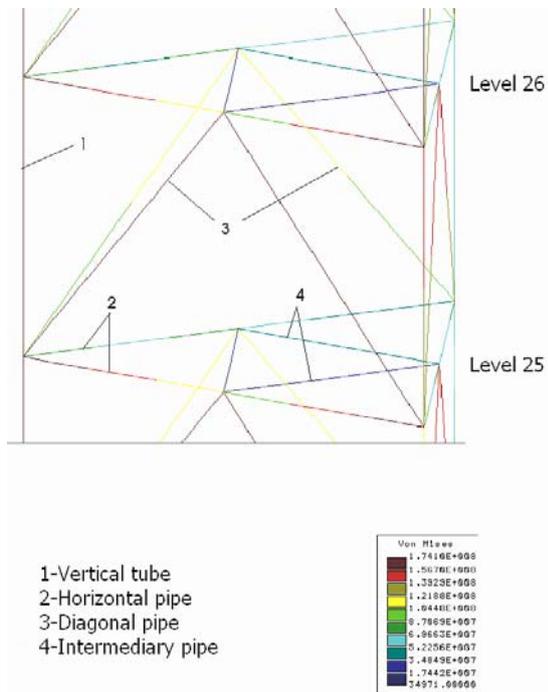


Figure 3. The tension state in the bars of leg 4, between levels 25 and 26

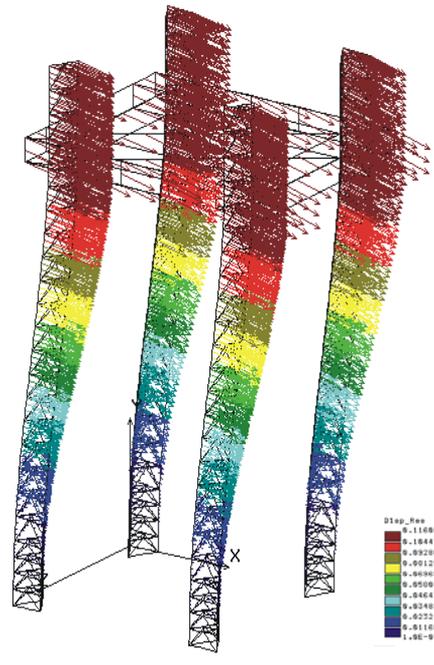


Figure 4. The deformed structure of the jack-up

II. In the horizontal pipes the maximum values of the equivalent tensions are about 40% of the determined maximum values from the vertical tubes. These are recorded in:

- the bars corresponding to the level 1 pipes, at legs 4 and 3, respectively 1 and 2, in the end and middle areas;
- the bars that make up the pipes from level 27, at legs 4 and 3, respectively 1 and 2, in the end areas (oriented in the direction of wind and waves) and in the middle areas of the pipes.

III. The maximum equivalent tensions in the diagonal pipes are about 65% of the maximum determined values for the vertical tubes. These are recorded in the same areas as in the vertical tubes.

IV. Vertically, in the most solicited bars of each type of tubular element, the equivalent tensions increase from the central area of the leg throughout the extremities.

V. The analysis of the tension state within levels 25 and 26 (fig.3) shows maximum tensions in the end areas of the diagonal and horizontal pipes, respectively in the vertical tubes extremities towards the body of the platform.

VI. The deformation state analysis (fig. 4) leads to the conclusion that the maximum recorded displacements – which coincides with the one of the jack-up's body, respectively the leg elements in the leg-body binding area – is 0,116 m. This value is framed within the maximum admissible technological limit for maximum displacement of the body which is 0,3 m.

5. REFERENCES

- [1] xxx Project no. 823 for constructing Romanian jack-up. ICEPRONAV, Galati, Romania, 1988.
- [2] SLĂMNOIU, G , BUNEA, M, ALEXE, N, VLADU, G . The loading which acts on a Romanian jack-up structure in the Black Sea. 11th International Research/Expert Conference „Trends in the Development of Machinery and Associated Technology” TMT 2007, Hammamet, Tunisia, 5-9 September, 2007.
- [3] SLĂMNOIU, G. Contributions to Behaviour in Exploitation, Improving of the Construction and Increasing Performance of the Romanian Marine Drilling Rigs. Doctorate Thesis, “Petrol-Gaze” University, Ploiesti, Romania, 2001.