DROPPED OBJECT ANALYSIS METHODS IN OFFSHORE STRUCTURE USING NON-LINEAR DYNAMIC FE ANALYSIS

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Abstract: *Dropped objects are not critical to the overall integrity of the offshore structure, causing, for the most part, local damage to the structure. A major threat to global integrity is probably puncturing of buoyancy tanks, which could impair the hydrostatic stability of floating installations. The dynamic non-linear finite element analysis, or combined methods by simple energy considerations of elastic-plastic analysis can determine the effect from dropped objects on the structure.*

Keywords: *finite element, offshore, dropped object*

1. Introduction

Offshore structures and other ships require periodic lifting-work for their maintenance and sometimes it leads to drop of an object onto lay-down or traversing areas resulting in the collapse of the impacted structures. The structures exposed to accidental drop events must be evaluated against dimensioning accidental loads because the risk of dropped object is considered as one of the major risk categories in the offshore structures. To protect an equipment from the accidental dropped object, a protective rack structure has been considered. Based on the structural response such as the stress, strain and displacement, the results of analysis methods are compared and their validity is investigated. The dropped object is one of the accidental loads situations that can occur on a vessel. The dropped object load is characterized by a kinetic energy, governed by the mass of the object, including any hydrodynamic added mass, and the velocity of the object at the instant of impact.

In most cases the major part of the kinetic energy has to be dissipated as strain energy in the impacted component and, possibly, in the dropped object. Generally, this involves large plastic strains and significant structural damage to the impacted component. The strain energy dissipation is estimated from force-deformation relationships for the component and the object, where the deformations in the component shall comply with ductility and stability requirements.

The structural response of the dropped object and the impacted component can formally be represented as load-deformation relationships as illustrated below. The part of the impact energy dissipated as strain energy equals the total area under the load-deformation curves.

$$E_s = E_{s,0} + E_{s,i} = \int_0^{w_{0,max}} R_0 dw_0 + \int_0^{w_{i,max}} R_i dw_i \qquad (1)$$

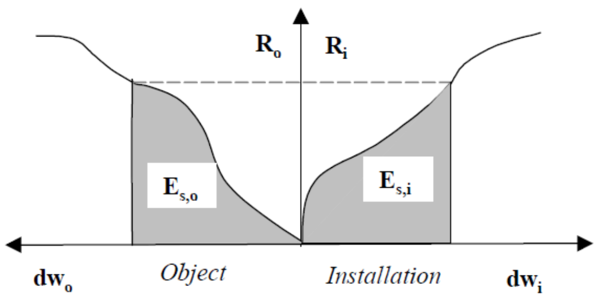

Figure 1: *Dissipation of strain energy in dropped object and installation Ref.[1]*

Calculation of energy dissipation in deformable dropped objects shall be based upon recognized methods for plastic analysis. It shall be documented that the collapse mechanisms assumed yield a realistic representation of the true deformation field.

2. Model description

To protect an equipment from the accidental fall of an object, the protective rack structure has been considered (see Fig. 2).

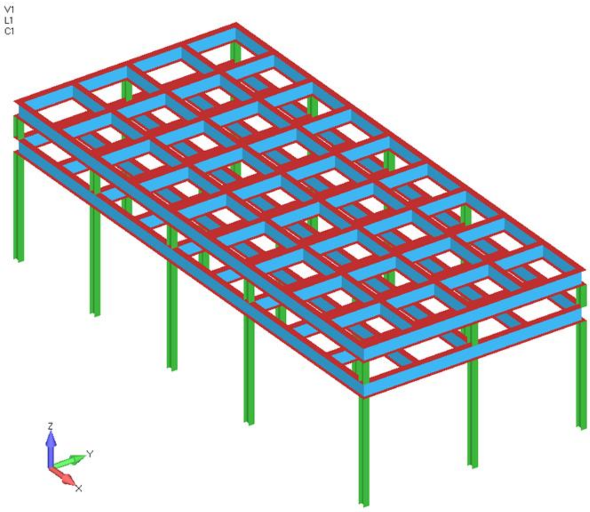

Figure 2: *Protective rack structure*

The structure consists of:

- two horizontal layers of beams: INP200;
- vertical pillars: H100x11.3/90x11.3.

The distance between the two layers is 300 mm. The distance between the horizontal beams is 800 mm.

The material used for all the structural elements is steel of type S355. The mechanical properties used to model the material are as follows:

- Young's modulus E = 210000 MPa;
- Poisson's ratio ν = 0.3;
- Density ρ = 7.81 t/m^3;
- Yield stress σ_y = 355 MPa;
- Ultimate tensile stress σ_u = 470 MPa.

The stress-strain curve describing the material is traced using the values presented in Table 2.

Table 2: *Proposed non-linear properties for S355 steel*

Proposed non-linear properties for S355 steels			
	S355		
Thickness [mm]	t≤16	16 < t ≤ 40	40 < t ≤ 63
E [MPa]	210000		
$\sigma_{prop}/\sigma_{yield}$	0.9		
E_{p1}/E	0.001		
σ_{prop} [Mpa]	319.5	310.5	301.5
σ_{yield} [Mpa]	355	345	335
σ_{yield2} [Mpa]	358.4	348.4	338.4
σ_{ult} [Mpa]	470	470	450
ε_{p_y1}	0.004		
ε_{p_y2}	0.02		
ε_{p_ult}	0.15		
E_{p2}/E	0.0041	0.0045	0.0041

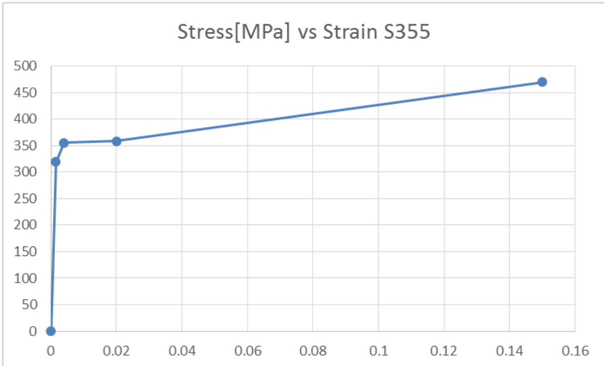

Figure 3: *Stress vs Strain curve for S355 steels*

The strength assessment of the protective rack against dropped objects is based on an object with a mass of 3.5 t. The dropping height is assumed to be h = 3 m.

The corresponding energy of the dropped object is E = 103 kJ.

In the full dynamic analysis, the object is given an initial velocity of 7.2 m/s simulating a drop from 3 m. The maximum deformations are to be read immediately after the object velocity is equal to 0. In order to evaluate the permanent deformations, it is recommended that the analysis time extends sufficient for the velocity of the structure to get to 0 m/s.

For this analysis the rigid element was extended on multiple nodes in for convergence reasons.

The mass of the object is not to be attached directly to the rigid element. This will lead to forced vibration. A gap element should be created between the master node and the concentrated mass.

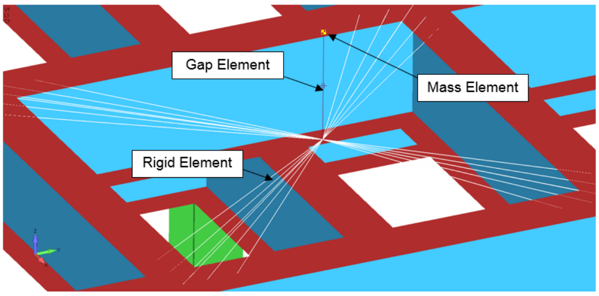

Figure 4: *Rigid, mass and gap element representation*

For this analysis two load sets have been created:

- the impact velocity applied nodal to the mass element (7.2m/s);
- the gravitational acceleration applied as a body load (9.81m/s^2).

The analysis was set as “24. Advanced Nonlinear Explicit” type.

3. Results

The following data needs to be checked for getting relevant results:

- The velocity chart of the concentrated mass
- The translation chart for the zone with the largest displacements
- The Non-Linear Von-Misses Stress plot
- The Non-Linear plastic strain plot
- The Total Translation plot

The velocities charts are useful for observing the time step on which the structure stops form being solicited by the dropped object and when the structure consumes the rest of energy through vibration.

For the same reason the translation chart is needed in order to observe the maximum deformation of the structure and also the permanent plastic deformation.

It can be seen that around the time step 0.05 s the object starts to bounce back, gaining speed until time step 0.06 s then starting to fall again, but at a way more lower speed.

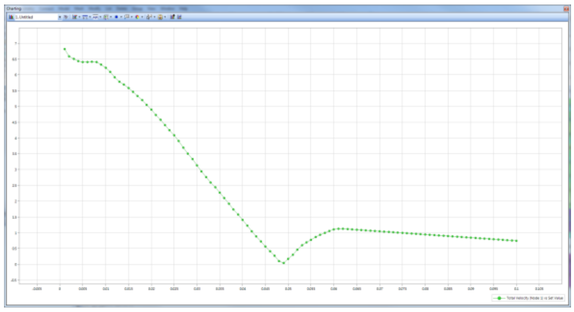

Figure 5: *Dropped object velocity*

In the picture below it can be seen that the maximum deformation of 0.235 m corresponds to the time step at which the object came to the speed of 0 m/s after which it can be seen that the permanent deformation revolves around 0.22 m and this value is less than 0.3 m that is the allowable distance between protective rack and the equipment.

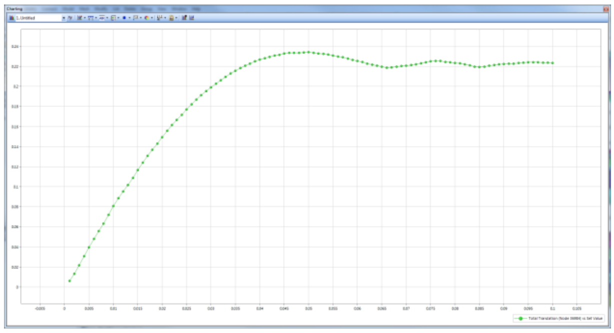

Figure 6: *Structure displacement*

From the stress values it can be observed that the structure suffered plastic deformations which can be seen from the non-linear plastic strain plot.

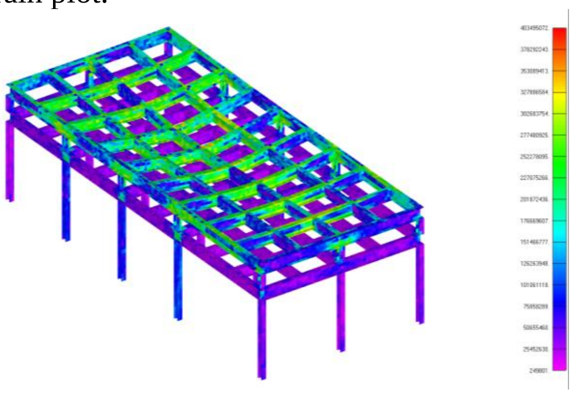

Figure 7: *Non-linear Von Misses stress plot*

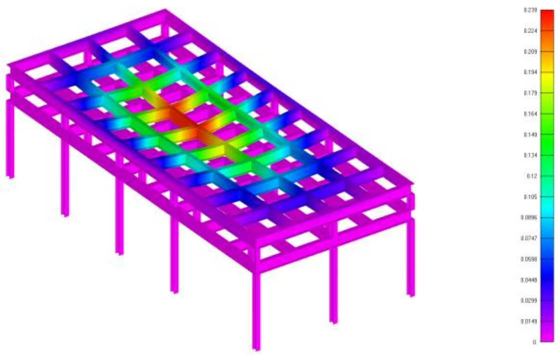

Figure 8: *Maximum Translations plot*

From the plastic strain plot it can be observed the zones in which plastic deformation occurred.

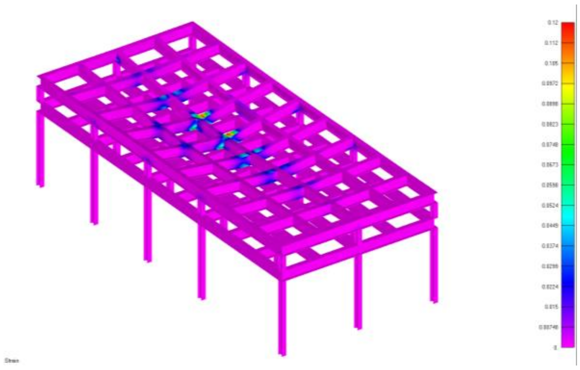

Figure 9: *Non-linear Plastic Strain plot*

4. Conclusions

If the dynamic method is used, the following should be considered:

-"Allow element rupture" may be checked for the analysis in which the structural integrity is verified;

-"Allow element rupture" may not be checked for the analysis in which the maximum vertical displacement is to be verified.

The dynamic method is harder to set up, but is the one who can offer the best results.

For the study to be conservative the dropped object should have only the vertical translation allowed.

For the dynamic analysis to work and to offer relevant results, the measuring units must be according to the International System. (Meters, kilograms, seconds, etc.)

For the dynamic analysis, the concentrated mass is not to be attached directly to the rigid element. This will lead to forced vibration. A gap element should be used.

The main problem with the nonlinear analysis is the non-convergence. This can occur because of a series of factors like:

- Maximum number of iterations is reached;
- The time step may be too large (the use of a small time step is best in order to assure the reliability of the solution);
- The number of iterations is too small (a greater number of iterations is best to be used in order to assure convergence, although this can affect the solution time);
- The convergence tolerances are too small (if in order, the tolerances of the convergence may be changed but this can affect the overall results and prevent convergence in future time steps, thus not solving the problem but making it worst).

5. References

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