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Dynamic analyses of crane subjected to the wind, moving load and earthquake

Solazzi Luigi

Department of Mechanical and Industrial Engineering
University of Brescia (Italy) via Branze 38 _ 25123 Brescia
email : luigi.solazzi@unibs.it

Abstract

The present research concerns the evaluation of the dynamic effect on particular structures, which are the lattice boom cranes. The dynamic actions involved in this research are: wind, moving load and earthquake assumed as actions variable in time. The research starts with the design of a big crane adopting the classical standards for these structures (UNI EN 13001 series). The elaborations were performed through analytical methods followed by the realization of the solid model and finite element analyses (SolidWorks® and Ansys ® software). The subsequent phase was about the definition of the aforementioned loads that act on these structures.

The wind action was evaluated by Van der Hoven and Kaimal models compared with the static approach described in the standards. The payload moving induces very high-intensity actions on the crane's structure; in order to better understand these effects, many different load curves were simulated. The last action considered is the earthquake phenomenon, which is not usually adopted to design this structure type.

Crane design

The crane design is a classical lattice boom crane. The main parameters are: boom length =70m; minimum and maximum angle with respect to the horizontal plane is 21° and 78° respectively; payload 55 t; the height of support structure 16m.

For crane design, EN 13001 standards were assumed. The main boundaries are the magnitude of the stress which is correlated to the safety factors for static and fatigue actions, the displacement and so the stiffness of the crane and the buckling phenomena (local and global).

Figure 1 shows the crane displacement from finite element analyses induces by the working load or payload.

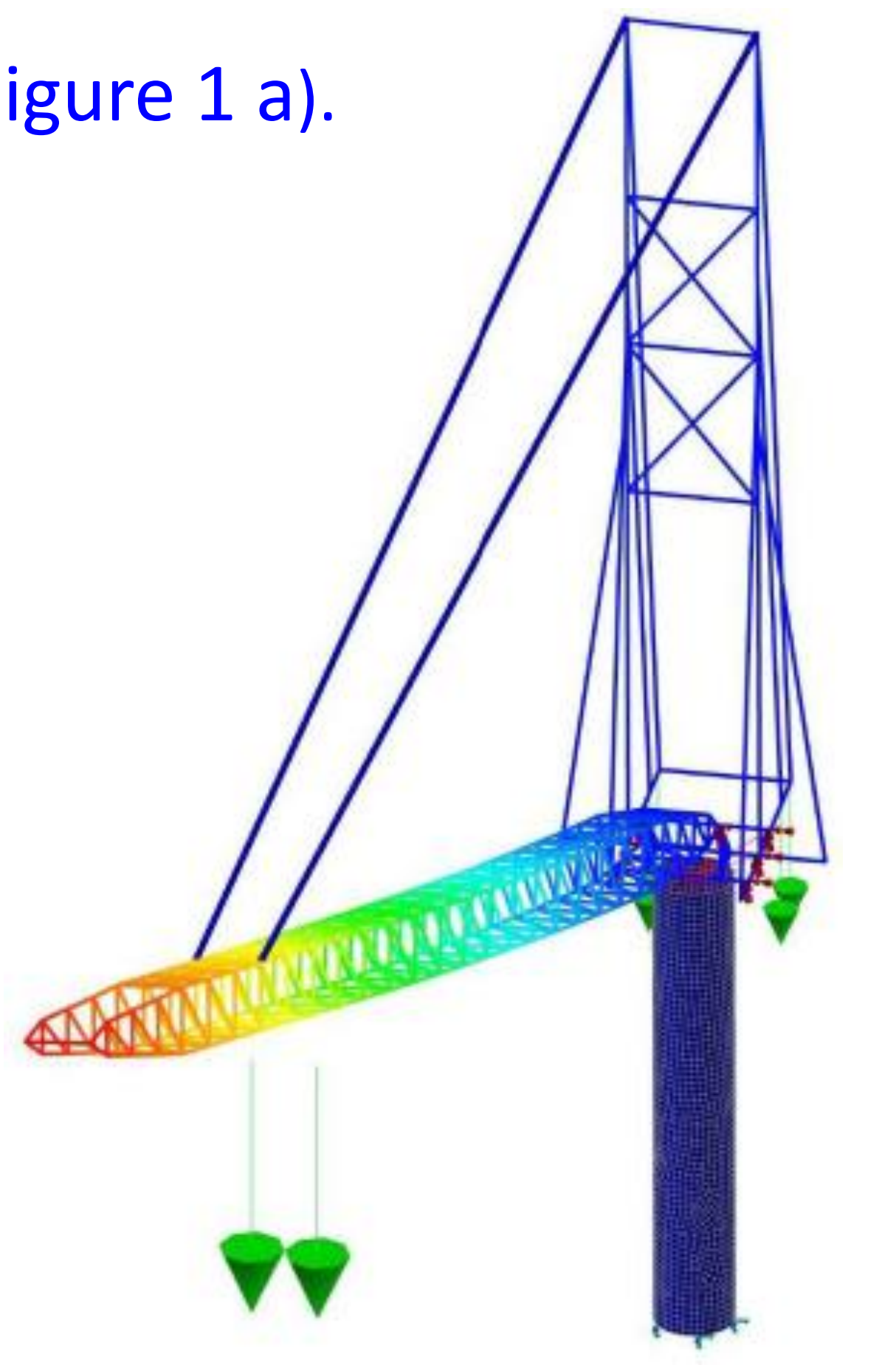


Figure 1 a).

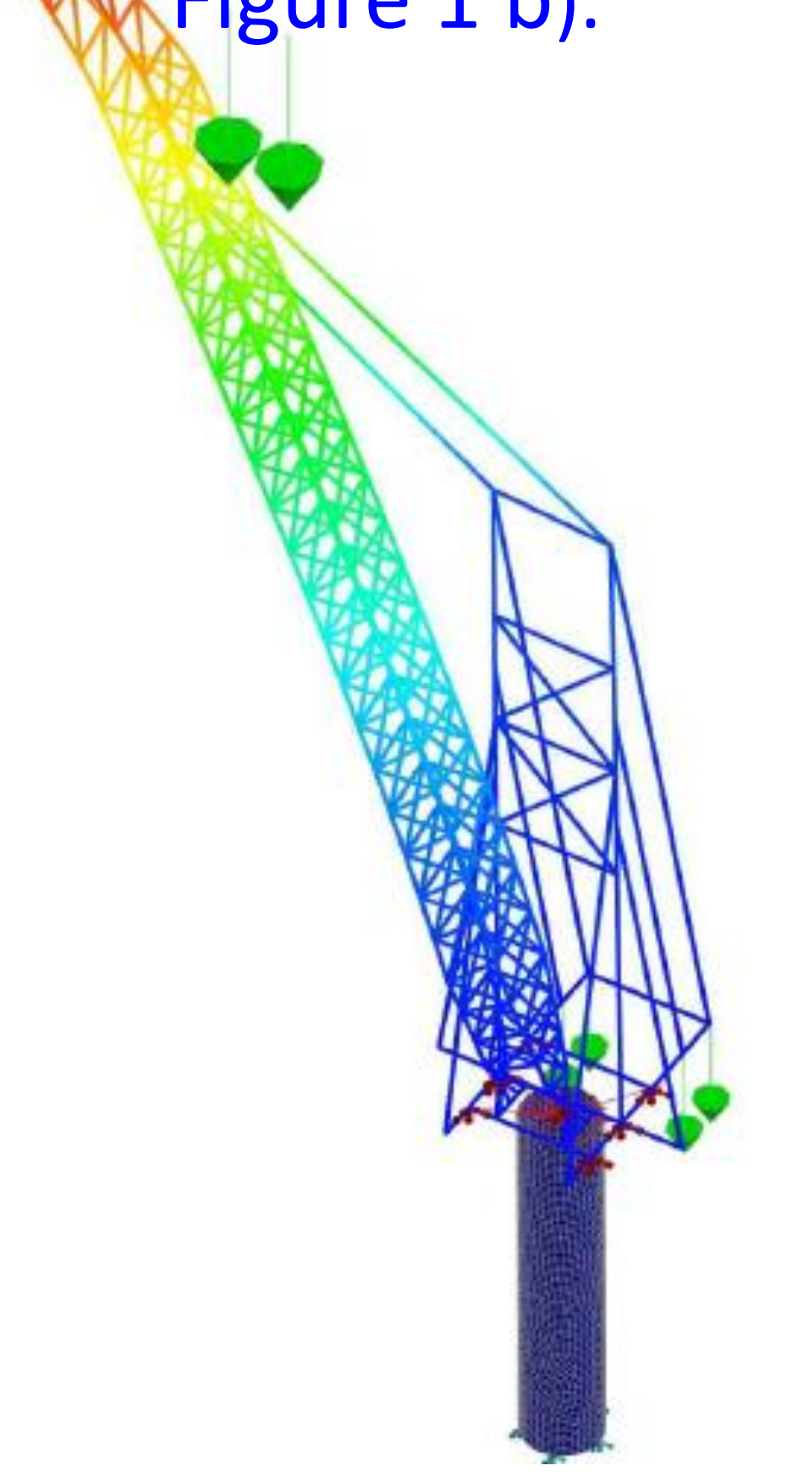


Figure 1 b).

The maximum displacement in the lower configuration (fig. 1a) is about 320 mm while in raised configuration (fig. 1b) is about 280 mm. Table 1 reports the first values of the meaningful natural frequencies.

Table 1.

Configuration	Mode n°	Freq. without load [Hz]	Freq. with load [Hz]
Lowered boom	1	0,395	0,118
	2	0,658	0,289
	3	0,802	0,795
Raised boom	1	0,495	0,150
	2	0,624	0,280
	3	0,887	0,814

Wind, moving load law and seismic effects

The wind actions (variable in time) were evaluated as dynamic action through the power spectrum from the two different models (eq. 1 is the PSD of the Kaimal model). The forces applied to the specific crane points were evaluated multiply the wind velocity (fig.2) by the aerodynamic coefficients (drag and lift) and the specific area involved. Fig. 3 shows the results for the crane in the lowered configuration for different boom points; while table 2 shows the maximum displacement.

$$S_{vv}(\omega, z) = \frac{1}{2}\frac{1}{2\pi}200[u_e(z)]^2\frac{z}{V_0(z)}\frac{1}{\left[1+50(\omega z/2\pi V_0(z))\right]^{5/3}}$$

Equation 1.

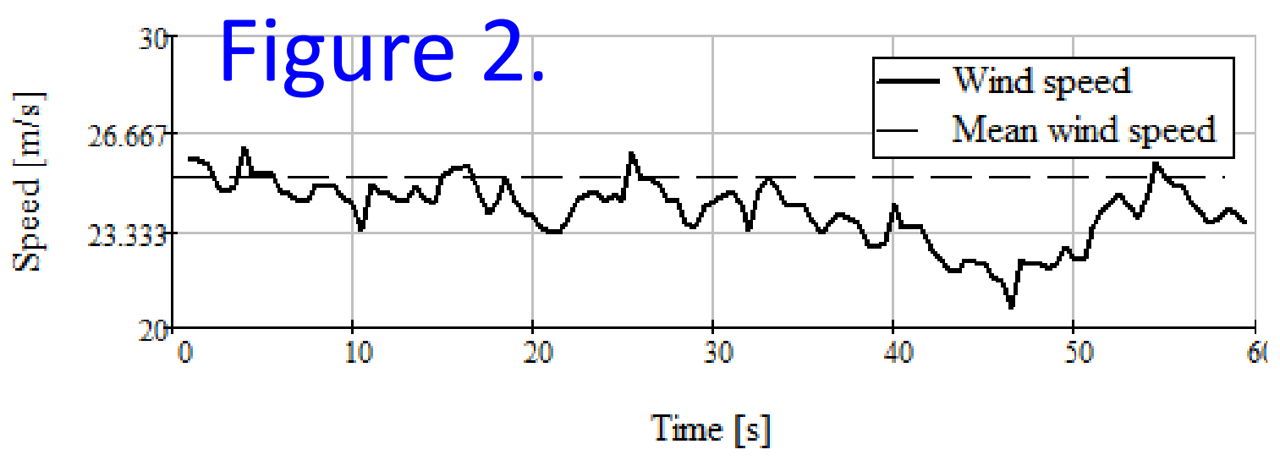


Figure 2.

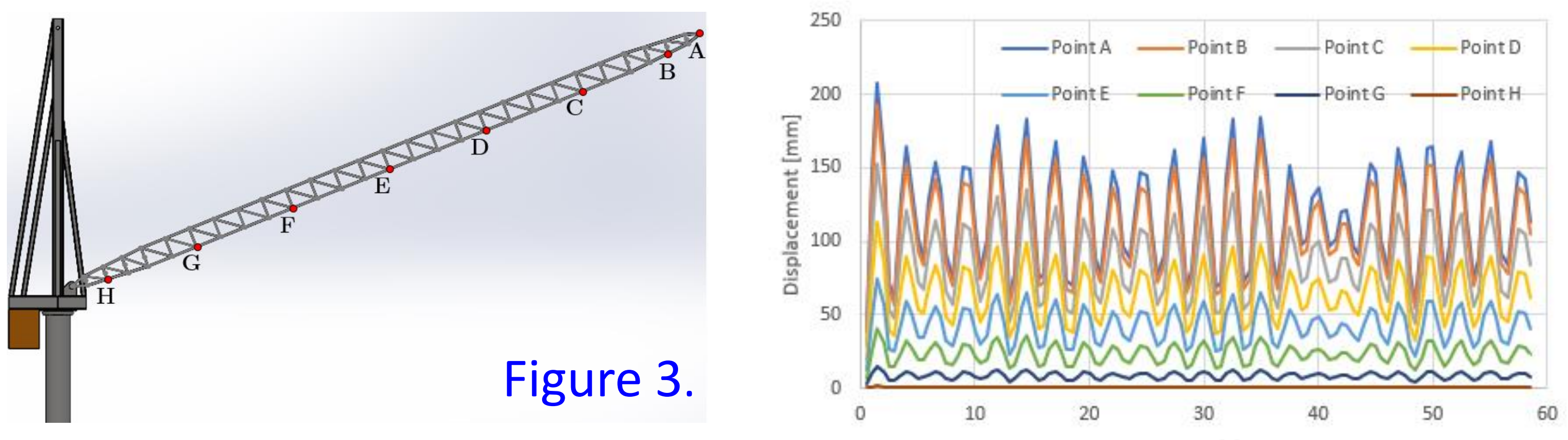


Figure 3.

Table 2.

Displ. [mm]	VdH model	Kaimal model	Const. Velocity
Low. Boom	200,6	207,8	77,9
Raised Boom	240,9	250,0	78,8

The law imposed to move the payload (and crane elements) has a high effect on the effective action applied to the crane. For example, fig. 4 shows a classical trapezoidal law and the displacement on three different boom points A, E and H (fig. 3) in the lowered configuration.

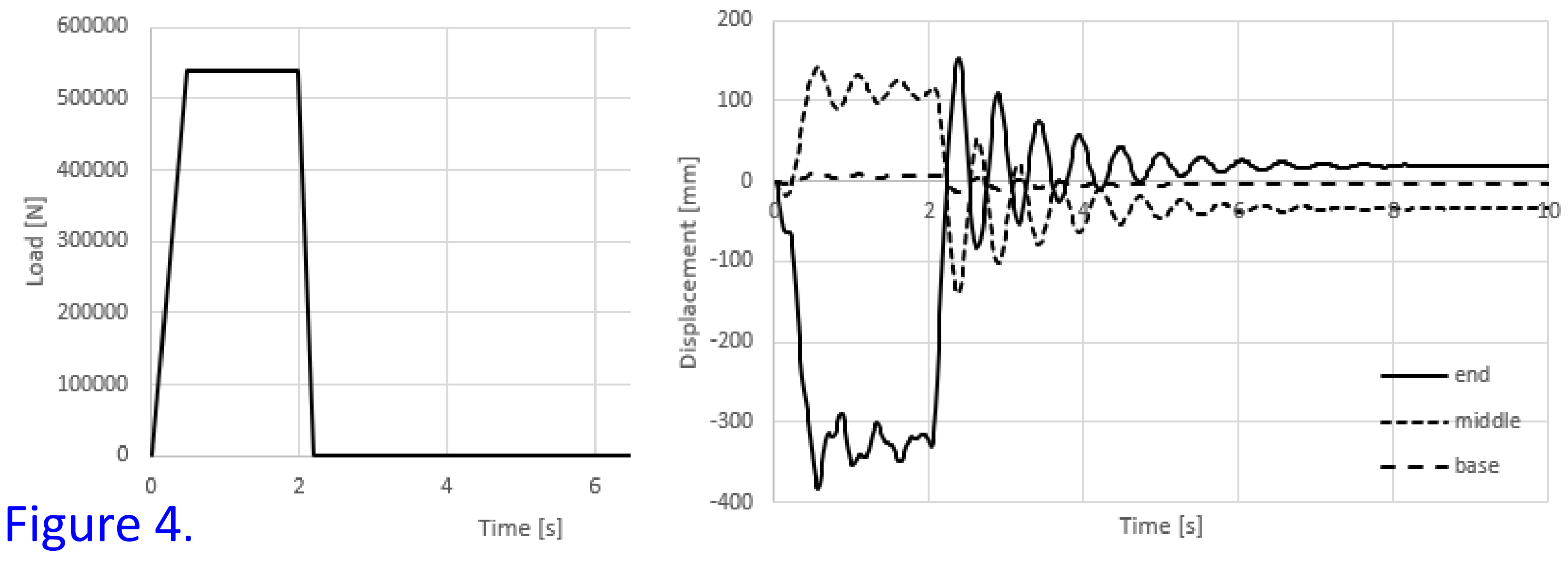
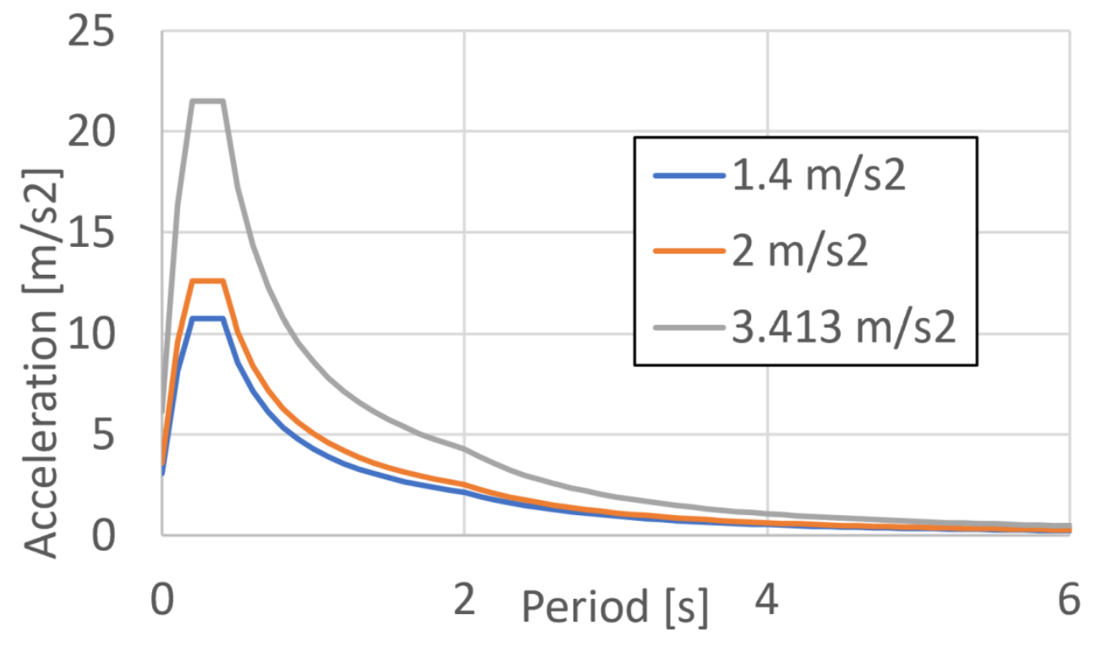


Figure 4.

The earthquake actions are strictly correlated to the site where the crane will be positioned. Three different load spectra (from the standards) were implemented in the fem model. Fig. 5 shows these spectra and table 3 shows the max. displacement (low. config.).



Spectre	Without Payload	With Payload
1,4 m/s^2	475,8	393,4
2,0 m/s^2	559,9	463,1
3,4 m/s^2	955,2	789,9

Conclusions

The synthesis of the results is reported. The wind variable action in time induces high differences in the crane displacements with respect to the one estimated considering constant velocity. The payload and boom movements induce very high actions on the crane with respect to the static actions. Even if the first natural frequency values are very low, the earthquake actions are hazardous for the crane parts (local and global buckling and plastic hinge). The main conclusion is that in order for safety crane design, all the dynamic actions must be involved in the whole design process.