DISPLACEMENTS OF CHIMNEY IN THE LIGHT OF COMPUTER CALCULATIONS AND SURVEYING

Arkadiusz Lew - Kiedrowski, Zygmunt Kurałowicz

Gdańsk University of Technology, Faculty of Civil and Environmental Engineering

1. INTRODUCTION

Knowing the movements of chimneys (classified as the slender structure) has a very important role in the process of their construction and operation. Problem affects both the shaft and foundation of the chimney [1, 2]. Exceeding the maximum displacement of these buildings could in turn lead to the failure or construction catastrophe. This article aims focus on issue on the value of reinforced concrete chimney displacement measured geodesic projection method (without the knowledge of wind loads and nature of displacement during the measurement) and the theoretical displacements obtained for the adopted models in the computer calculation, ie static model and a dynamic model. The article presents the numerical analysis of reinforced concrete chimney displacements, ie shaft and foundation in terms of its displacement caused by standard wind load q in acceptable terms of the foundation and on the hypothetical loads (real) wind, which was carried out geodetic measurements. For analysis used Autodesk Robot Structural Analysis [3] and MSC Marc [4] for accepted model of shaft and substrate flexibility / stiffness Kz. The results obtained modeling the chimney (the analysis of static and dynamic - having a very important role in modern design of slender structures) carried out in two programs, and obtained during the surveying are presented in graphical form table.

2. DESCRIPTION OF THE ANALYZED CHIMNEY

Analyzed a monolithic chimney with a height H = 130.00 m, was build method of sliding with the concrete class B30 by PN3264: 2002 and steel RB500W class. Chimney shaft of reinforced concrete has a variable diameter, ie on the ordinate ± 0.00 to 35.00 Dz equal to 7.80 m decreases to 5.00 m, from ordinate 35.00 to 70.00 equal to 5, 00 m decreases to 3.60 m, from ordinate 70.00 to 130.00 equal to 3.60 m. At the base of the shaft wall thickness is 0.30 m, however at the vertex of chimney 0.25 m. The chimney built on the circular foundation of reinforced concrete with a diameter D = 23.00 m.

3.MODELING AND COMPUTER CALCULATIONS OF CHIMNEY DISPLAMENTS

3.1. STATIC ANALYSIS IN AUTODESK ROBOT STRUCTURAL

ANALYSIS [1]

In the calculation of reinforced concrete chimney displacements described in paragraph. 2, loaded wind (Fig. 1a), in Autodesk Robot Structural Analysis have been used a model of coating structures (Fig. 1b). Model was define by reinforcement and the thickness of the shaft in accordance with the design of the existing chimney. The foundation of the chimney was designed on the substrate susceptible - spring support of coefficient substrate susceptibility K_z = 100000 kPa (Fig. 1 c, d). In analysis, has been taken standard wind load q = 0.836 kN/m^2 (simplified - evenly distributed) in the direction of the x-axis and included gravity load in the direction of the axis OZ. In Fig. 2 shows theoretical displacements of foundation and shaft chimney caused by the static load.

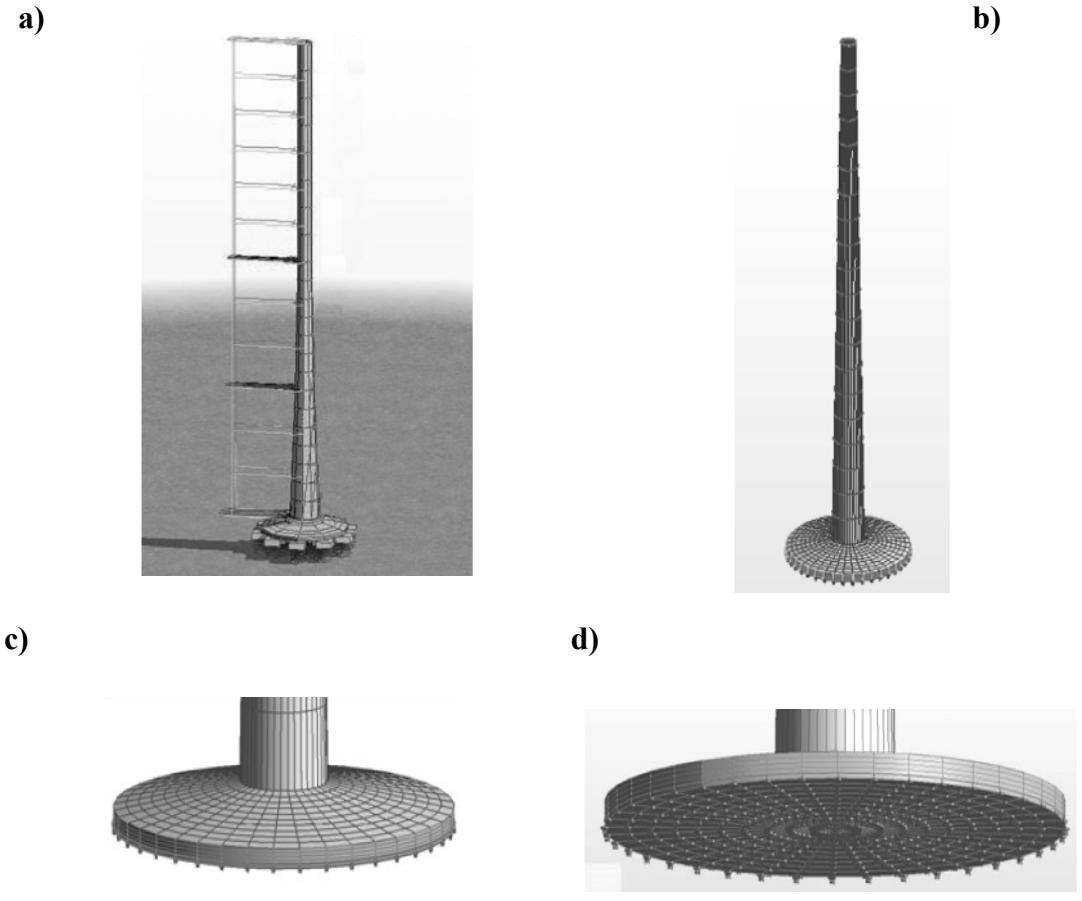

Fig. 1. Model of chimney shaft and circular foundation on elastic foundations: Wind load (a) mesh division of Coons (b, c), elastic supports (d).

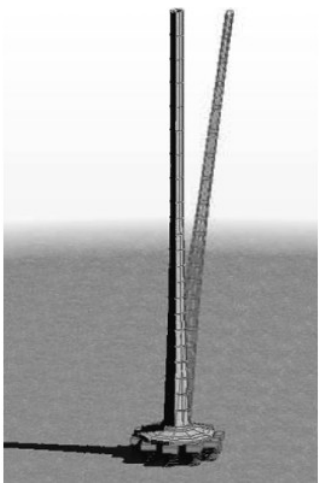

Fig. 2. Displacement shaft and foundation.

3.2. DYNAMIC ANALYSIS IN AUTODESK ROBOT STRUCTURAL ANALYSIS [1]

In the dynamic analysis of chimney displacements in Autodesk Robot Structural Analysis was adopted basic parameters such as: damping (0), tolerance (0,0001), number of iterations (40), the number of mode shapes (10). Selected forms of own vibrations (1, 3, 6, 10) considered chimney is presented in Figure 3.

a) b) c) d)

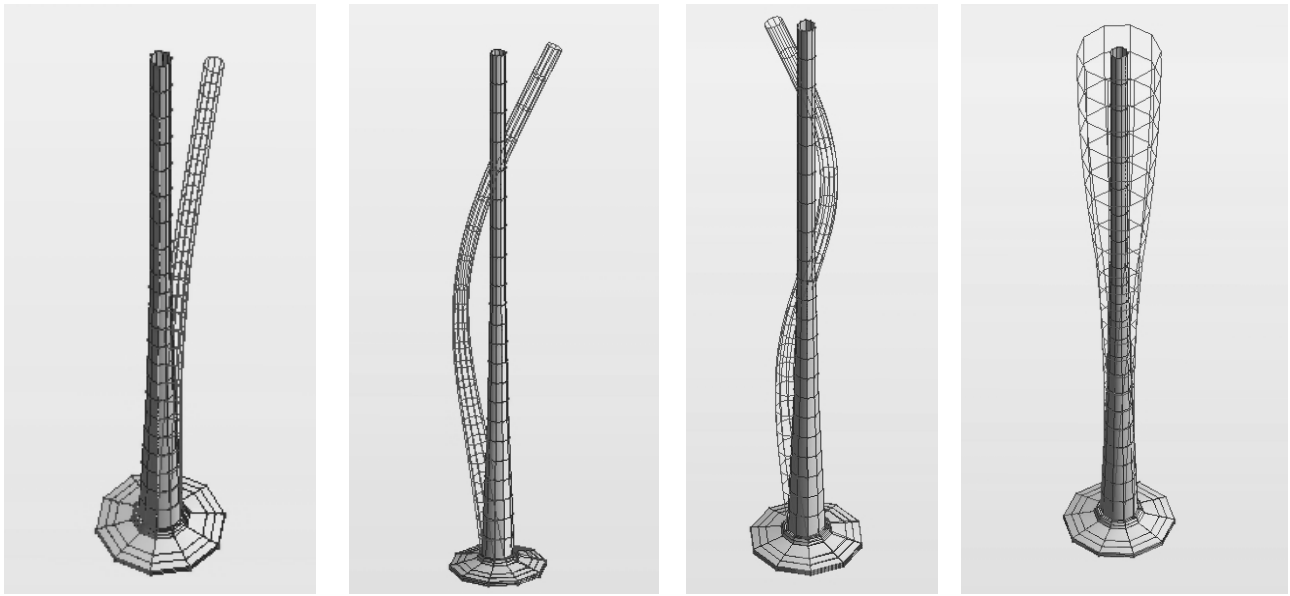

Fig. 3. Subsequent characters form of vibrations (displacements of chimney) as a function of frequency of vibration: form of vibration 1 (a), form of vibration 3 (b), form of vibration 6 (c), form of vibration 10 (d)

3.3. STATIC ANALYSIS IN MSC MARC 2008 R1 [2]

In the static analysis of chimney displacement was used MSC Marc, which was adopted a reinforced concrete chimney as a model of coating structures a wall thickness of 0.5 m. Young's modulus 32 • 10^6 kPa, Poisson's ratio ν = 0.3. Standard wind load q = 0.836 kN/m^2 in the direction of the x-axis (simplified - evenly distributed), and gravity loads in the direction of the axis OZ (Fig. 4a, b). Designed chimney foundation on the susceptible substrate - spring support of coefficient substrate susceptibility Kz = 100000 kPa (Fig. 4c). In fig. 4d shows theoretical displacements of foundation and shaft chimney caused by the static load.

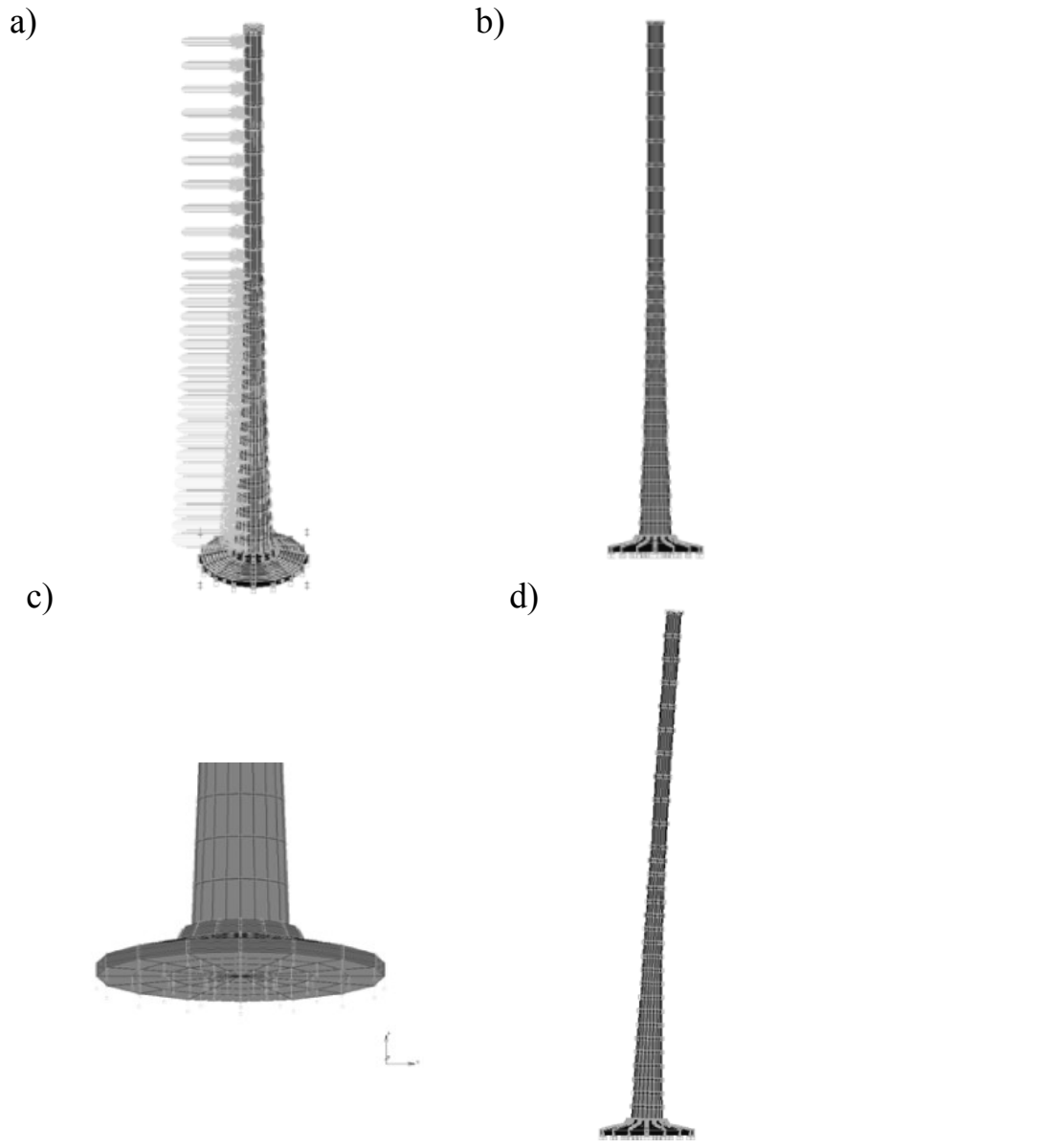

Fig. 4. Calculation model of chimney on elastic substrate: wind load (a), chimney model (b), the elastic support (c), displacement (d).

3.4. DYNAMIC ANALYSIS OF DISPLACEMENTS

IN MSC MARC 2008 R1

In the dynamic analysis of chimney displacements in MSC Marc 2008r1 used a model of coating structure and took into account dynamic properties chimney defined by the natural frequency, damping and shape. Chimney shaft deformation is presented below for some form of vibrations (Fig. 5).

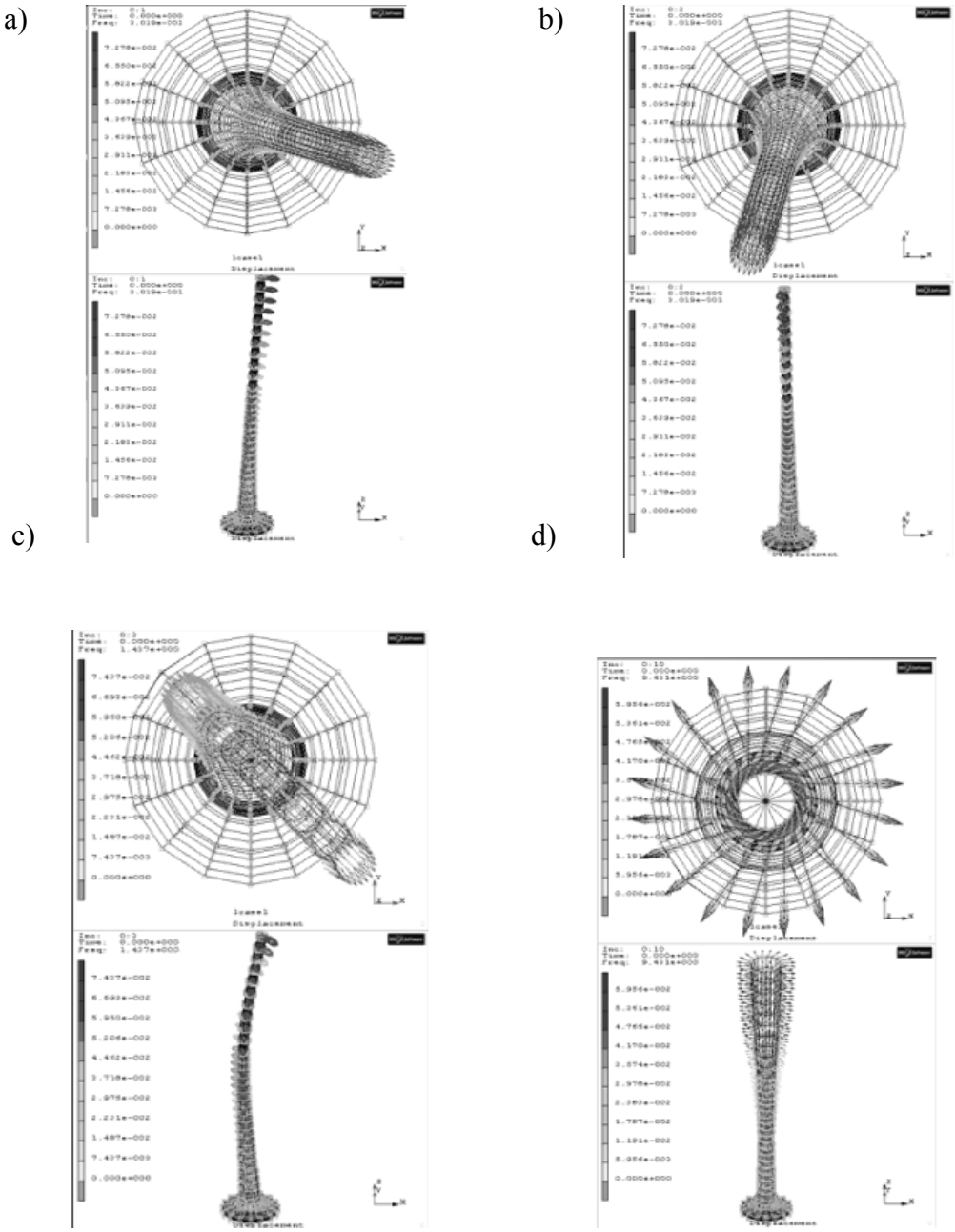

Fig. 5. Subsequent characters vibrations (displacements of chimney) as a function of frequency of vibration: form of vibration 1 (a), form of vibration 2 (b), form of vibration 3 (c), form of vibration 10 (d)

4. RESULTS OF COMPUTER CALCULATIONS

On the basis of the theoretical numerical analysis of displacements for existing chimney using two computer programs and two load models were received results of displacements for 618 points on chimney shaft and foundation in program Robot and for 1176 points on chimney shaft and foundation in Marc. The results of calculations for the characteristic points is given in Table 1. While comparing the displacement of vetrex and foundation of the chimney both analysis, caused by wind loads: standard and the actual with displacements defined geodesic [1] in Table 2 and 3.

Table 1. Results of computer calculation of chimney displacements [mm] caused by standard loads q = 0,836 kN/m^2

Characteristic point	Static/dynamic analysis in Robot	Static/dynamic analysis in Marc
	horizontal displacements of chimney shaft	
vertex (130,00 m)	163,51/210,01 mm	188,92/69,72 mm
intermediate point (79,00 m)	59,41/86,22 mm	79,30/27,41mm
collar (0,00 m)	0,69/1,03 mm	0,13/0,65 mm
	vertical displacements of chimney foundation	
fuller from the wind pressure	8,69/10,17 mm	2,11/0,00 mm
fuller from the suction side wind	9,84/0,28 mm	2,29/0,00 mm

Table 2. Comparison results of chimney displacements [mm] for standard loads q

The point of measurement / calculation	The calculation of q = 0.836 kN/m^2 software "Marc" analysis of static / dynamic	The calculation of q = 0.836 kN/m^2 software "Robot" analysis of static / dynamic	Surveying
Vertex	188,92/69,73	163,51/210,01	30,00
Foundation	2,29/0,00	9,84/10,17	0,90

Table 3. Comparison results of chimney displacements [mm] for actual loads q

The point of measurement / calculation	The calculation of q = 0.13 kN/m^2 software "Marc" analysis of static / dynamic	The calculation of q = 0.13 kN/m^2 software "Robot" analysis of static / dynamic	Surveying
Vertex	29,37/69,73	25,42/37,68	30,00
Foundation	0,26/0,00	9,35/9,43	0,90

5. SUMMARY AND CONCLUSIONS

Nowadays there are many construction software, which in design civil engineers are using, including increasingly popular becoming programs such as Autodesk Robot Structural Analysis and MSC Marc. These programs allow you to accurately analyze such displacements of slender structures induced by different factors of a static and dynamic character. Used programs characterized by slightly different calculation precision, graphical interface and ease of modeling the structure. In the case of static analysis of the chimney is important to correct load the construction. However, in the dynamic analysis (modal) of chimney should be paid special attention to the natural frequency of the structure and its behavior.

On the basis of computational analysis in those programs and comparison the results presented in the article, you can draw the following detail conclusions:

- surveying movements reinforced concrete chimney was carried out during real conditions during the "good weather", but which do not relate to the well-known wind loads acting on the shaft of the chimney,

- the results of geodetic displacement measurements of chimney were information about temporary or permanent relocation of the chimney (with foundation)

- deflection of the stack was less than the maximum displacement, to which the chimney was designed (including standard wind loads),

- the results show that the wind load had little effect on vertical displacement of the foundation,

and general:

- In order to fully assess the displacement or deflection of high chimney to make multiple measurements (several series) such as the vertex and the foundations from several positions simultaneously during the observations carried out during the same weather conditions,

- it was appropriate to not only makes geodetic measurments but also measure wind speed at selected heights of chimney shaft.

- a very slender chimneys should be monitored continuously so that at the appropriate time determine the zone of the maximum displacements close to the permissible

- displacement caused by dynamic wind load requires a detailed numerical analysis and a continuous survey,

- measurement of the chimney foundation displacements can be determined by traditional methods such as leveling and do not necessarily combine with geometric method of measuring shaft in various weather conditions.

REFERENCES

Kurałowicz Z., Chmielecki M., Rudziński K.: „Badanie osiadań i odchylenia od pionu komina żelbetowego H=130 m w zakładach papierniczych Mondi Packaging Paper Świecie S.A. Pol. Gd., Gdańsk 2009 r.

Lew - Kiedrowski A. P., Kurałowicz Z.: „Przemieszczenia budowli smukłych wyznaczane metodą modelowania numerycznego z uwzględnieniem zmiany sztywności podłoża". Archiwum Geomatyki, Praca zbiorowa nt. Monitoring i inżynieryjne pomiary geodezyjne. Gdańsk 2010.

User guide Autodesk Robot Structural Analysis 2009.

User guide MSC Marc 2008r1