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DYNAMIC RESPONSE OF THE INDUSTRY MASONRY CHIMNEY TO SEISMIC LOAD

ODPOWIEDŹ DYNAMICZNA XIX-WIECZNEGO KOMINA PRZEMYSŁOWEGO NA ODDZIAŁYWANIE SEJSMICZNE

A b s t r a c t

The aim of this paper was to investigate the dynamic responses of the industrial masonry chimney under seismic activity. In this study peak ground accelerations equal 0.4 g were assumed for the shock. In the paper there are the results from numerical simulation. The analyses were prepared for two material models: with elastic and inelastic behavior. In both cases the homogenization model of masonry material was used. The study was prepared in ABAQUS software (Simulia, 2013).

Keywords: chimneys, industrial masonry chimneys, earthquake, seismic behavior

S t r e s z c z e n i e

Artykuł poświęcony jest analizie odpowiedzi dynamicznej komina przemysłowego o konstrukcji murowej obciążonego odziaływaniem sejsmicznym (trzęsieniem ziemi). W pracy zaprezentowano wyniki uzyskane drogą numeryczną. Analizę przeprowadzono w pakiecie ABAQUS (Simulia, 2013). Dla potrzeb analizy zostały wykonane dwie symulacje numeryczne: liniowo sprężysta oraz analiza uwzgledniająca uplastycznienie elementów murowych. W obydwu przypadkach wykorzystano model homogeniczny dla konstrukcji murowych. W analizie wykorzystano akcelerogramy osiągające maksymalne wartości 0,4 g.

Słowa kluczowe: kominy, kominy przemysłowe, elementy murowe, trzęsienie ziemi

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1. Introduction

The presented paper focuses on the numerical research of the seismic behavior of the masonry industrial chimney from Poland [1]. Such example of construction sprung up rapidly throughout many parts of world especially of Europe for the period of the industrial revolution. It must be noticed that a lot of existing industrial chimneys are constructed of unreinforced masonry. Such type of structures is found to be vulnerable to damage during strong seismic events [5].

The most important key feature in properly understood response of masonry industrial chimneys under different type of loads is that they have not enough tensile strength to perform suitably due to unreinforced masonry that was used in the their construction. Actually this situation is very dangerous while strong seismic ground motion [5].

The main purpose of the work is comparison between the results for two numerical analyses: the first results are for completely elastic material model the second ones are for inelastic behavior.

2. Basic geometry, material data and numerical model of the chimney

The dimensions of the chimney [1] in meters and a longitudinal section are given in Fig. 1b. The total height of the object is 75.00 m. In Fig. 1c there is numerical model with selected points to calculations. Also it must be pointed that in Fig. 1a the photography of the chimney is presented, which is taken from [1] paper.

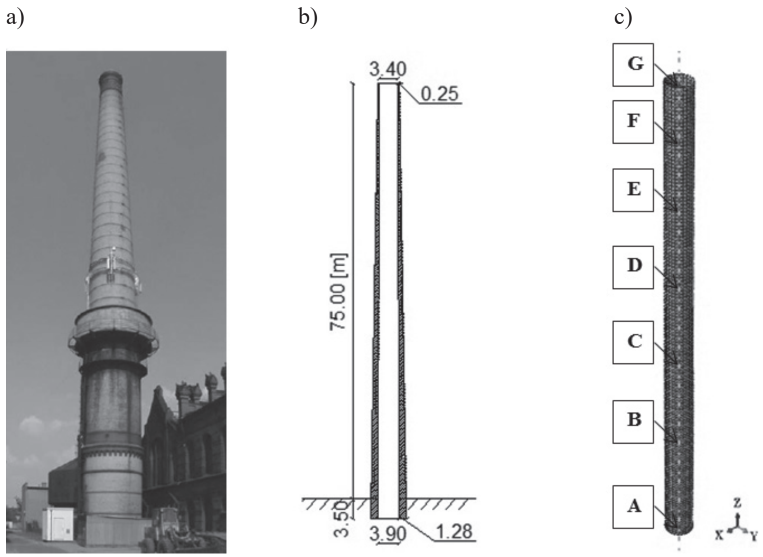

Fig. 1. Industrial chimney: a) condition before renovation [1], b) longitudinal section, c) FE model

For the study a 3D model with shell elements (S8R) has been developed to represent the seismic behavior of the chimney. The total number of nodes in the model is 39,574 and the total number of elements is 12,465. The model was created with the ABAQUS package (Simulia, 2013). The dynamic response of the masonry chimney was estimated for two types of material model: elastic and inelastic. For the inelastic case it was assumed the material model with yield stress. However for both scenarios the homogenization theory for masonry structures was used [3, 4].

Material data used for the calculation for masonry structures [2]: 1) elastic modulus E = 2.1 GPa; 2) Poisson coefficient γ = 0.25; 3) density: ρ = 1800 kg/m^3; 4) uniaxial yield stress in compression σ_{c0} = 1.4 MPa; 5) uniaxial yield stress in tension: σ_{t0} = 0.4 MPa.

3. Data of the seismic shock

The chimney analyzed in this study was subjected to actual earthquake ground motion records registered in Nocera Umbria (central Italy). The selected seismic activity event was of the September 26th, 1997 Umbria-Marche earthquake (ITACA 2015). The signals were applied as kinematic excitations of the structure. The magnitude of the shock was 6.1. In numerical simulation the phase of the ground motion of shock approximately lasted 8 s. Time histories of accelerations of the shock in three directions are presented in Fig. 3. The peaks ground accelerations (PGA) of the shock are: a_x = 4.15 m/s^2, a_y = 4.93 m/s^2, a_z = 3.98 m/s^2.

a) b) c)

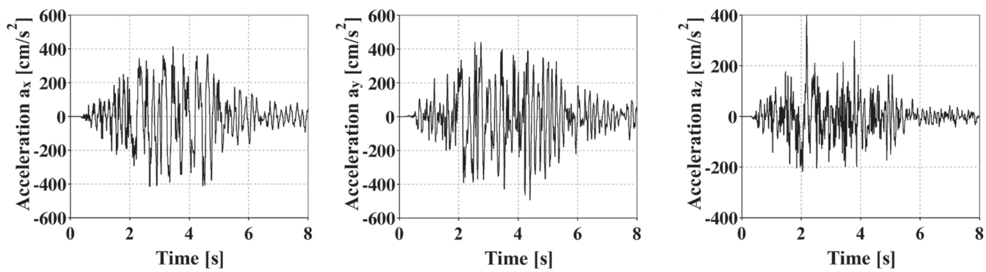

Fig. 2. Time histories of the shock accelerations: a) *x* direction: b) *y* direction; c) vertical (*z*) direction

4. Dynamic response of the chimney to seismic load

Two analyses were prepared in the presented work: the first for completely elastic material model and the second one for inelastic material. In Fig. 4 there is a comparison of results from this analyses. The comparison was prepared for two points from construction: point A and point G (Fig. 1c). The dynamic response of the industrial masonry chimney was estimated using full time history analysis. It was prepared with the Hilber-Hughes-Taylor time integration algorithm provided in the ABAQUS package for a direct step-by-step solution [6]. The step varied from 10^{-5} to 10^{-2} s, according to convergence requirements. For the analysis the Rayleigh model of mass and stiffness proportional damping was applied. The damping coefficients $\alpha = 1.13$ and $\beta = 0.00046$ (where α referring to mass proportional damping and β to stiffness proportional damping) were determined for damping ratios of 5.0%.

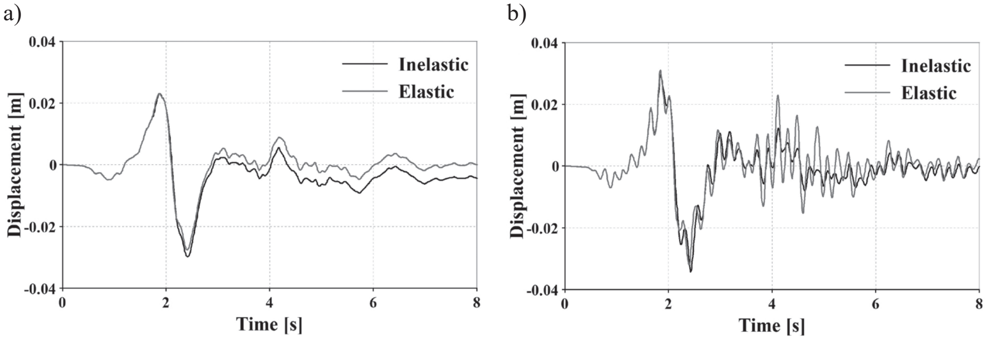

Fig. 3. Comparison of the vertical displacement for selected points: a) point A, b) point G

Taking into account the results from Fig. 4 (distribution of equivalent plastic strain) it can be noticed that this type of chimney is susceptible for fracture in upper parts, especially during strong ground motions. It must be pointed that plasticization of the upper parts of the chimney is a very dangerous phenomenon.

As it could be observed in Fig. 4 there are also the lower parts of the construction that are predisposed to destruction during the earthquake.

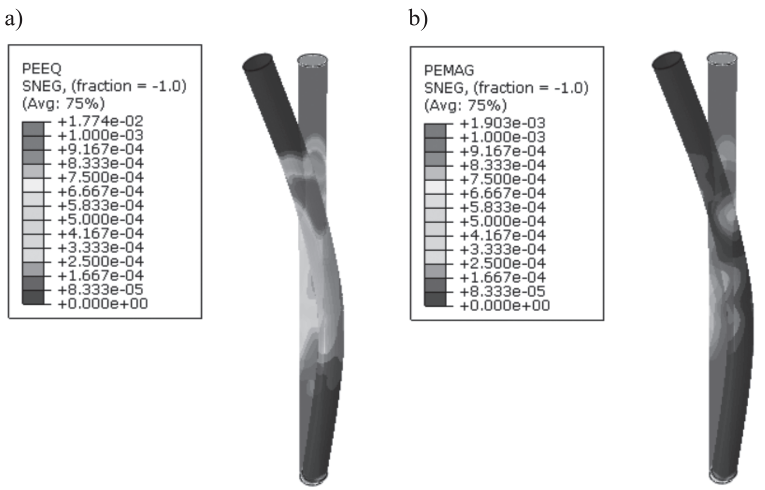

Fig. 4. The results: a) equivalent plastic strain (PEEQ), b) plastic strain magnitude (PEMAG)

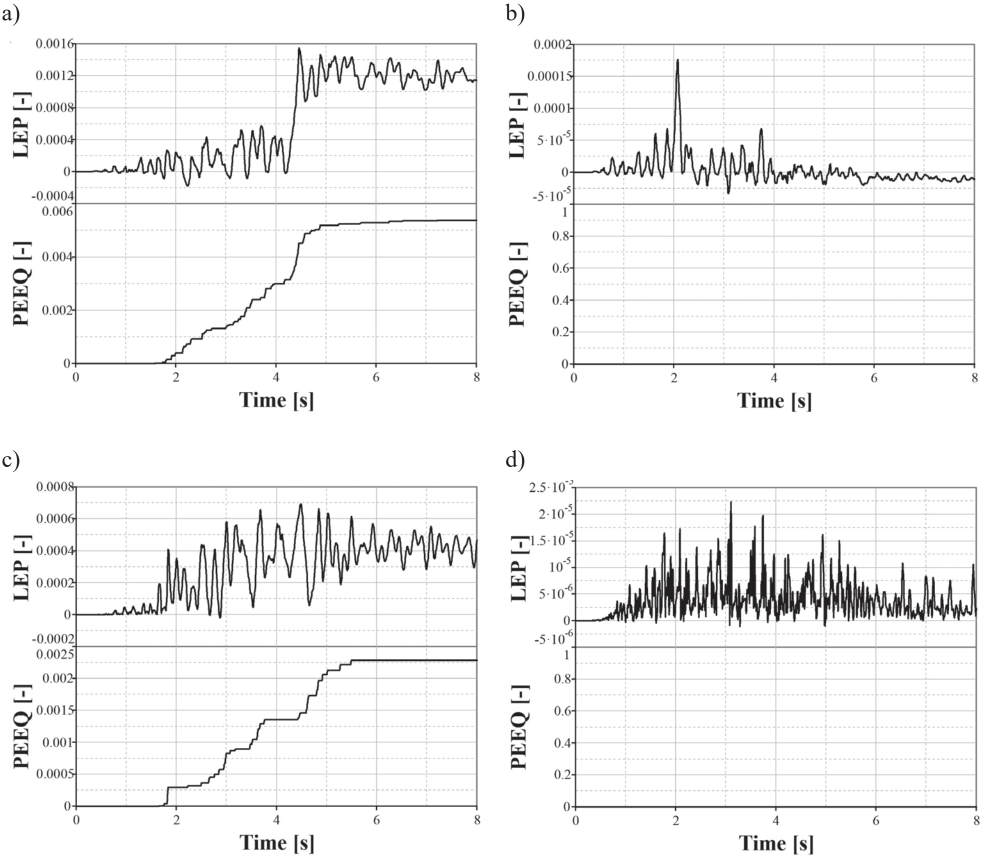

Fig. 5. Time history of plastic (LEP, PEEQ) measures at points: a) A, b) B, c) E, d) G

5. Conclusions

The following conclusions can be formulated on the basis of the results taken from the dynamic analyses of the masonry chimney subjected to strong seismic event:

1. The results obtained from numerical simulations (especially with inelastic material behavior, see Fig. 4) have shown that the crack pattern under strong ground motion can be predicted. What is more, taking into account the results it is possible to create the reinforcement for existing objects.
2. Differences in displacement values for the elastic an inelastic material model are connected with dissipation of energy during shock (Fig. 3). The part of energy taken from seismic activity is distributed on plastic strains during the analysis. For elastic material model it is impossible to calculate the influence of this phenomenon.

References

[1] Błaszczyński T., *Modernizacja XIX-w. komina przemysłowego*, Przegląd Budowlany, 11/2012, 43–46.

[2] Cińcio A., Mrożek M., Mrożek D., *Numeryczna symulacja działania wstrząsu sejsmicznego na budynek murowy z zastosowaniem plastyczno-degradacyjnego modelu materiału*, Modelowanie inżynierskie, 35–42.

[3] Lotfi H.R., Shing P.B., *An appraisal of smeared crack models for masonry shear wall analysis*, Comput. Struct, 41 (3), 1991, 413–425.

[4] Ma G., Hao H., Lu Y., *Homogenization of masonry using numerical simulations*, J. Eng. Mech. 127 (5), 421–431.

[5] Pallarésa F.J., Agüerob A., Martína M., *Seismic behaviour of industrial masonry chimneys*, International Journal of Solids and Structures, Vol. 43, Issues 7–8, 2006, 2076–2090.

[6] Simulia ABAQUS Users' Manual v. 6.13. Dassault Systemes Simulia Corp., Providence, RI, 2013.