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THREE DIMENSIONAL TIME HISTORY ANALYSIS OF MASONRY CHIMNEYS CONSIDERING THE SOIL-STRUCTURE INTERACTION

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Abstract

Chimneys are tall structures with a very high length compared with the body cross section dimensions. In Egypt, masonry chimneys are spread widely along with the masonry brick plants. In this paper, a three dimensional model will be constructed for the chimney considering the soil-structure interaction. The material of the chimney's body is made of masonry bricks as most of the chimneys in Egypt. The foundation of the chimney is RC raft footing. More than one type of soil will be considered in this study. Mohr-Coulomb model will be used to describe the behavior of the soil. Kobe, Northridge and Chi-Chi earthquakes records will be used as the bed rock excitation. The study is concerned with the horizontal and vertical displacements of the chimneys considering the different excitations and the soil types.

Keywords: Masonry chimneys, Finite element method, Time history analysis

1. Introduction

Tall cantilever chimneys have an important real life applications especially in industrial structures. In Egypt, Masonry chimneys spread along the river Nile sides in Egypt as a part of the mud-brick plants near the agricultural lands which are considered the main resource of the raw materials for this industry. The height of these chimneys range between 20 and 100 meters. The seismic behavior of such structures is very important because of the vulnerability nature of the masonry bricks as a construction material and the high ratio between the chimney height and the in plane dimensions.

In this paper the soil-structure interaction is taken in consideration. The soil–structure interaction affected the seismic behavior of the structures by [1], [2], [3]:

- Increasing the natural period and damping of the system.
- Increasing the lateral displacements of the structure.
- Changing in base shear depending on the frequency content of the input motion and the dynamic characteristics of the soil and the structure.

So, it is very important to consider the soil-structure interaction for such structures to have more accurate lateral displacements and drift values.

2. Model Description

Two patterns of chimneys are considered in this paper. 30 and 60 meters height are considered for the first and the second pattern respectively. A 3D model was developed for each pattern with the geometric details shown in Fig. 1 [4], [5]. The 3D model with the mesh configuration is displayed in Fig. 2. Kobe, Northridge and Chi-Chi earthquake records are used as the bedrock excitations. The acceleration and the displacement time histories are shown in Fig. 3, Fig. 4 and Fig. 5 with scaled records to have a PGA of 0.20. The data of the earthquakes used as the bedrock excitations are shown in table 1. Also, the mechanical properties of the soil types considered in this study are shown in table 2.Mohr-Coulomb model was used to describe the soil behavior. The reinforced concrete material used in this study was assumed to have a modulus of elasticity E of 20.0 GPa, density of 2500 Kg/m**3** and Poisson's ratio (ν) =0.25[2], [3]. The unit weight of the masonry has been assumed equal to 1600 Kg/m^3 with Young's modulus of 1200 MPa and Poisson's ratio (ν) =0.30[6], [7].ADINA (2012) (Automatic Dynamic

Incremental Nonlinear analysis) Version 8.9.0 was used for analysis process. This software covers large amounts of material models and element groups.

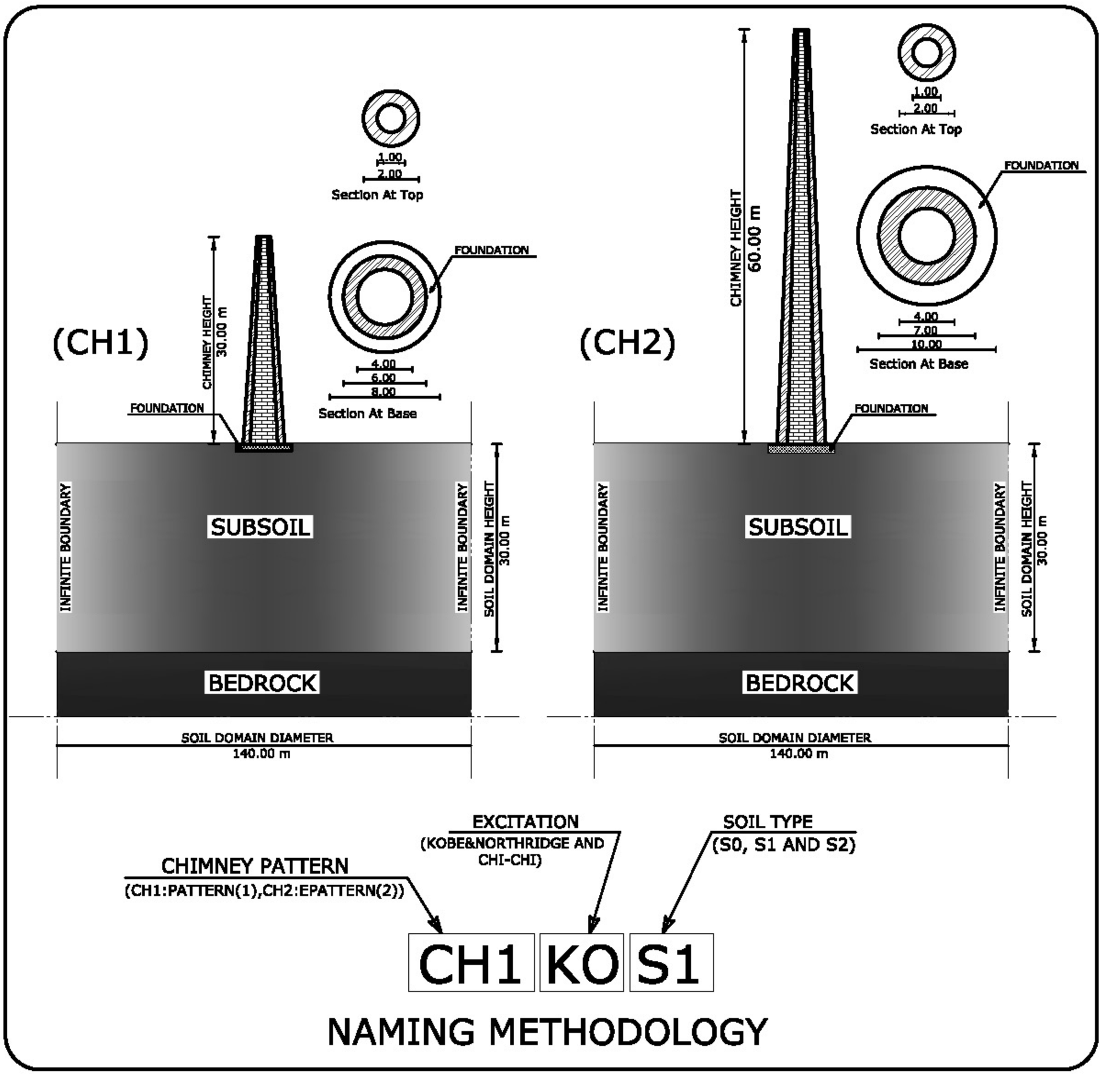

Fig. 1 – Geometry and dimensions of the chimneys and the naming methodology

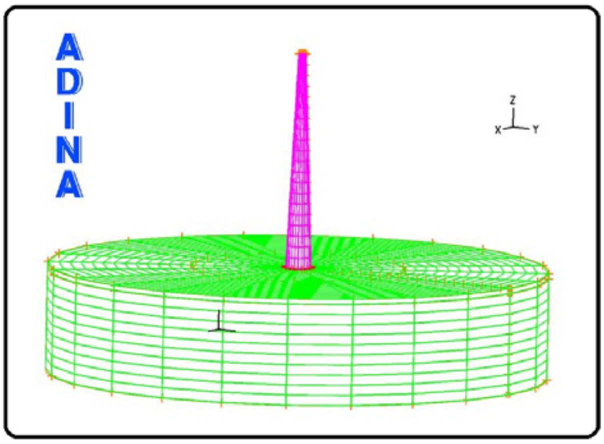

Fig. 2 – 3D model with the mesh configuration

Table 1 – Data of the earthquakes used

Earthquake	Date	Magnitude	PGA
Kobe	January 1995	6.9	0.821 g
Chi-Chi	September 1999	7.6	0.183 g
Northridge	January 1994	6.7	0.217 g

Kobe Earthquake, also may be called as the Great Hanshin earthquake, was an earthquake in Japan. The earthquake occurred on January 17, 1995. It was measured 6.9 on the Richter scale. The epicenter of the earthquake was at 34.59°N 135.07°E in the southern part of Hyōgo Prefecture, Japan. The focal depth was 17.0 km and the distance to fault rupture was 0.6 km. About 6500 people died, 40000 people were badly injured and the worth of damage was about US$ 200 billion.

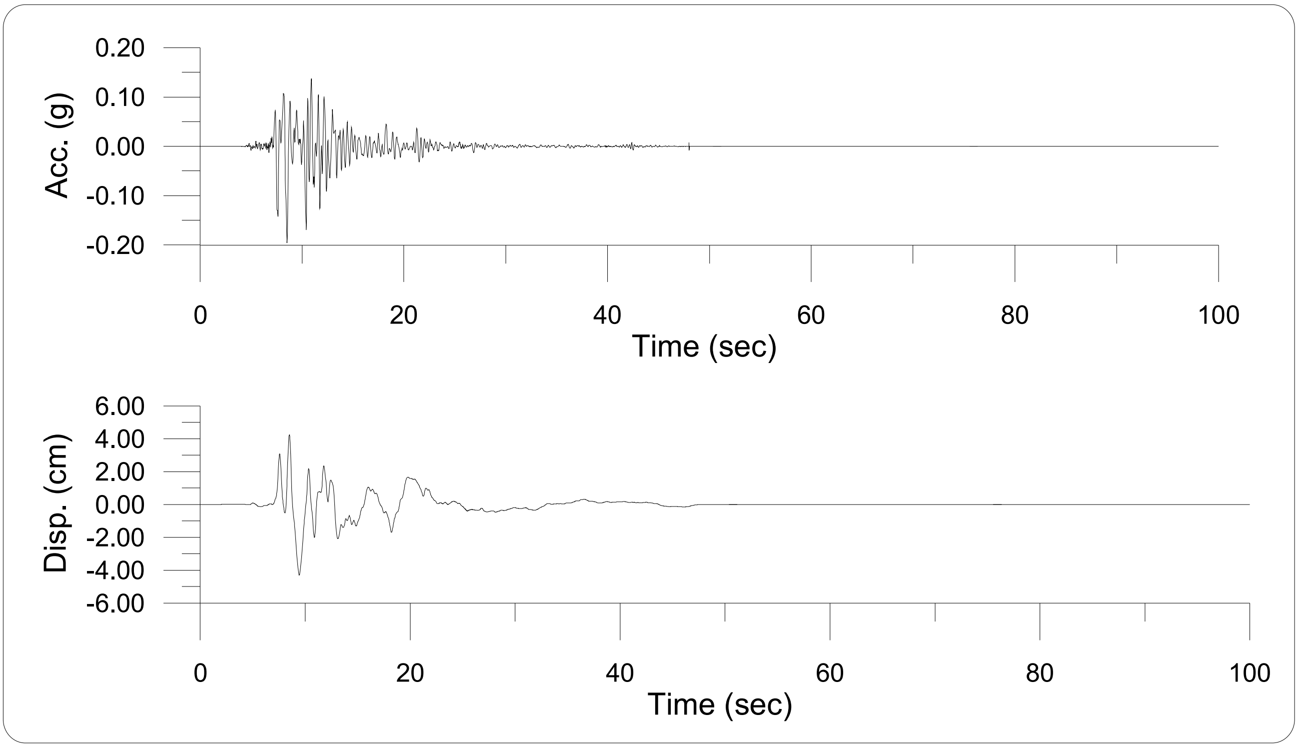

Fig. 3 – Acceleration and displacement time histories for Kobe Earthquake

Northridge Earthquake was an earthquake near Los Angeles, California, US. The earthquake occurred on January 17, 1994. It was measured 6.7 on the Richter scale. The epicentre of the earthquake was at 34.213°N 118.537°W. The focal depth was 18.3 km and the distance to fault rupture was 26.8 km. About 57 people died, 8700 people were badly injured and the worth of damage was about US$ 40 billion.

Chi-Chi Earthquake, also may be called as the 921 earthquake, was an earthquake in Taiwan. The earthquake occurred on September 21, 1999. It was measured 7.3 on the Richter scale. The epicentre of the earthquake was at 23.87°N 120.75°E in Chichi Township of Nantou County, about 12.5 km west of the Sun Moon Lake. The focal depth was 7.0 km. About 2500 people died, 11500 people were badly injured, 44500 houses were completely collapsed, 41500 houses were badly damaged and the worth of damage was about US$ 9.2 billion.

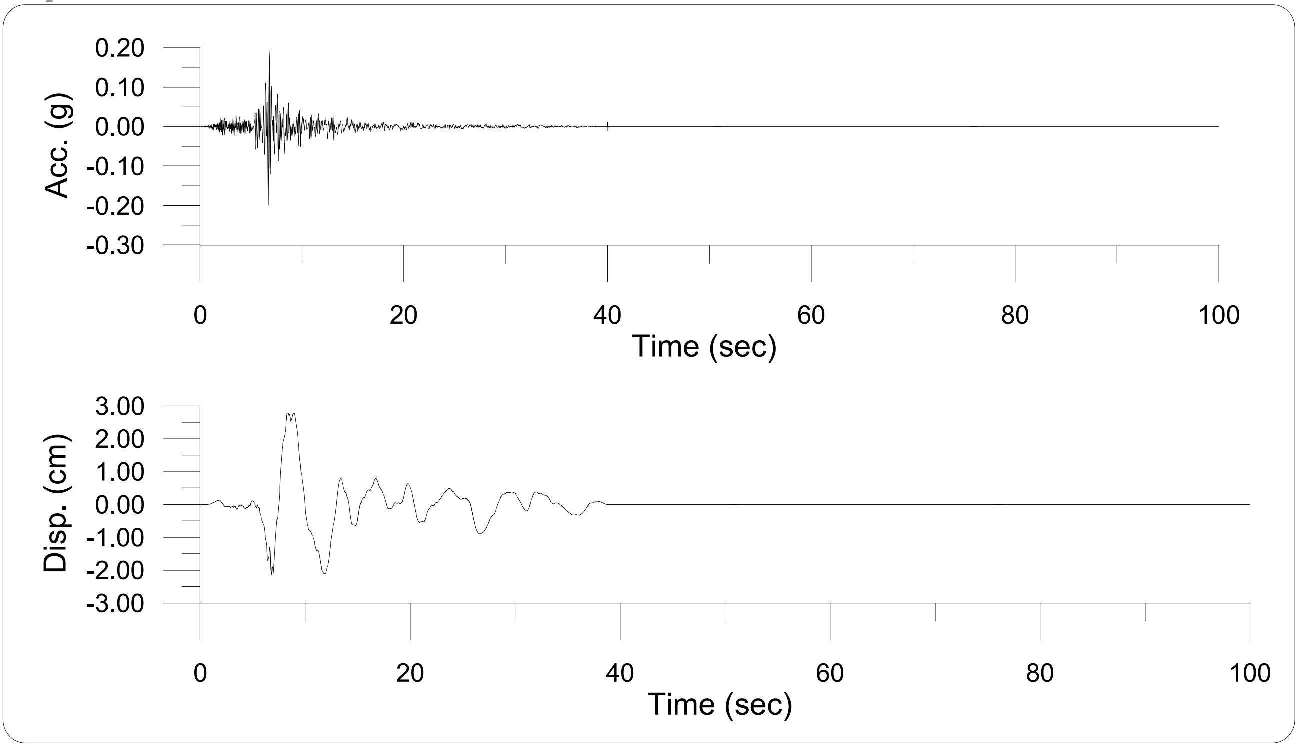

Fig. 4 – Acceleration and displacement time histories for Northridge Earthquake

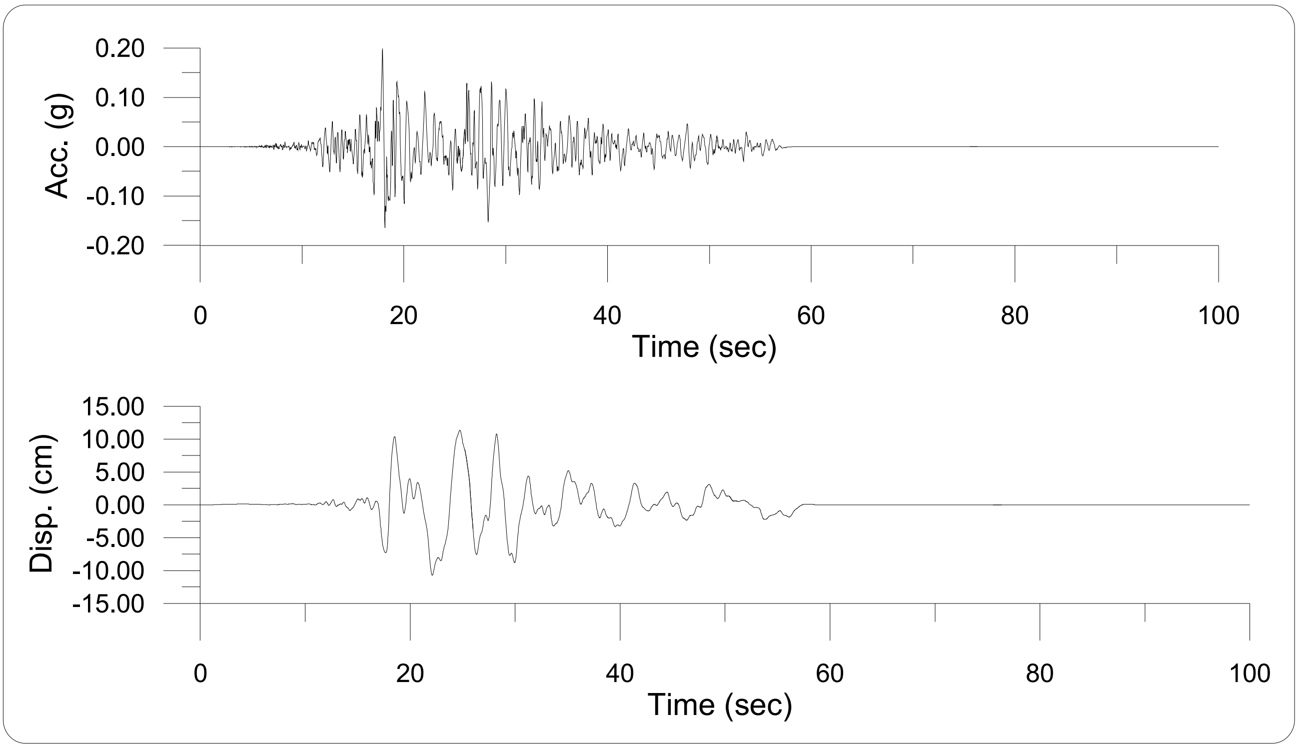

Fig. 5 – Acceleration and displacement time histories for Chi-Chi Earthquake

Table 2 – Mechanical properties of the soil types considered [8]

Soil type	Description	Density (kg/m^3)	Cohesion (KPa)	Compressive modulus (MPa)	Angle of internal friction (ϕ)	Angle of dilation(ψ)	Poisson ratio(ν)
S0	**Rock (Fixed base)**						
S1	Stiff clay	1800	150	20	1	0.00001	0.4
S2	Dense sand	1800	1	80	36	6	0.3

3. Analysis of the Results

The drift and the vertical displacement time histories for CH1KOS0, CH1KOS1 and CH1KOS2 are displayed in Fig 6. The max drift for CH1KOS0 is 1.00 cm at time 18.25 sec, 24.42 cm at time 9.20 sec for CH1KOS1and 8.92 cm at time 9.40 for CH1KOS2. Fig. 7 illustrates the drift and the vertical displacement time histories for CH1NOS0, CH1NOS1 and CH1NOS2. The max drift for CH1NOS0 is 1.21 cm at time 6.88 sec, 24.17 cm at time 23.32 sec for CH1NOS1 and 8.92 cm at time 29.20 for CH1NOS2. Fig. 8 shows the drift and the vertical displacement time histories for CH1CHS0, CH1CHS1 and CH1CHS2. The max drift for CH1CHS0 is 0.88 cm at time 23.36 sec, 1.92 cm at time 7.72 sec for CH1CHS1 and 3.32 cm at time 7.88 for CH1CHS2. These results are shown in table 3.

For this pattern, the effect of the excitation and the type of soil on the seismic behavior of the structure is very significant and clarified.

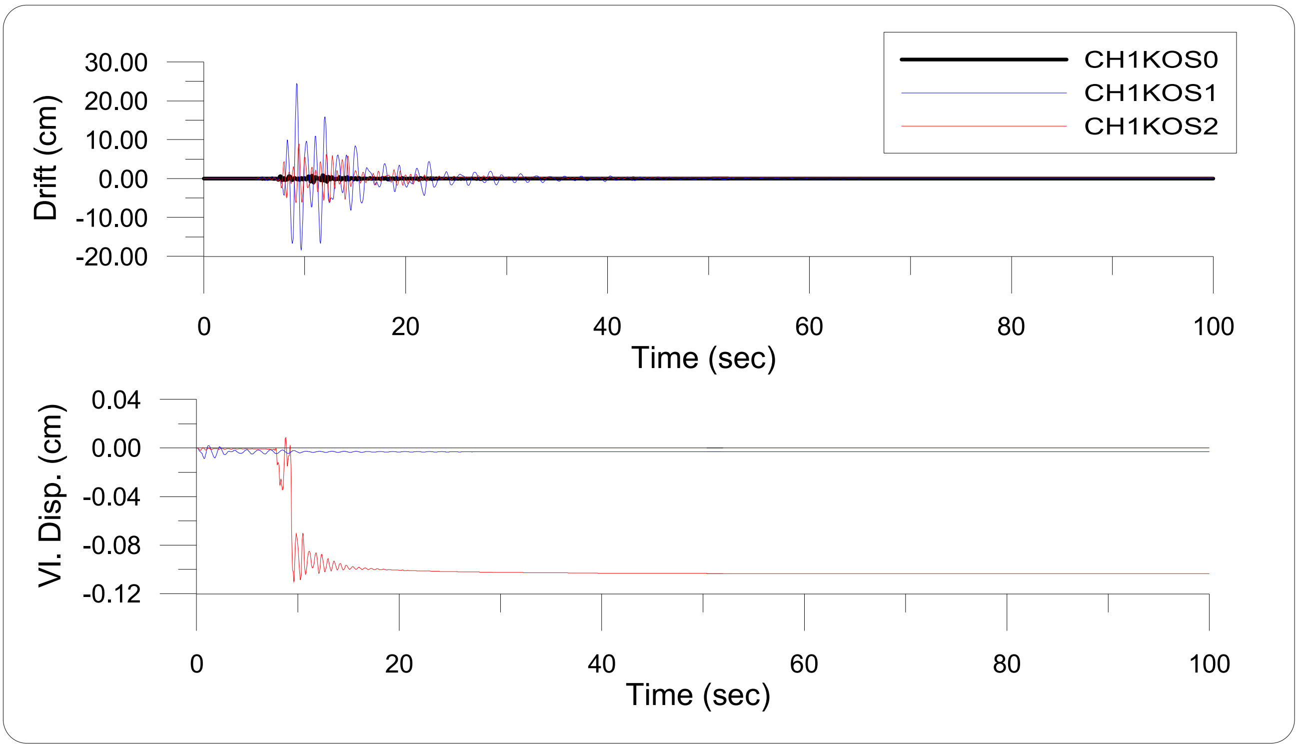

Fig. 6 – Drift and vertical displacement time histories for CH1KOS0, CH1KOS1 and CH1KOS2

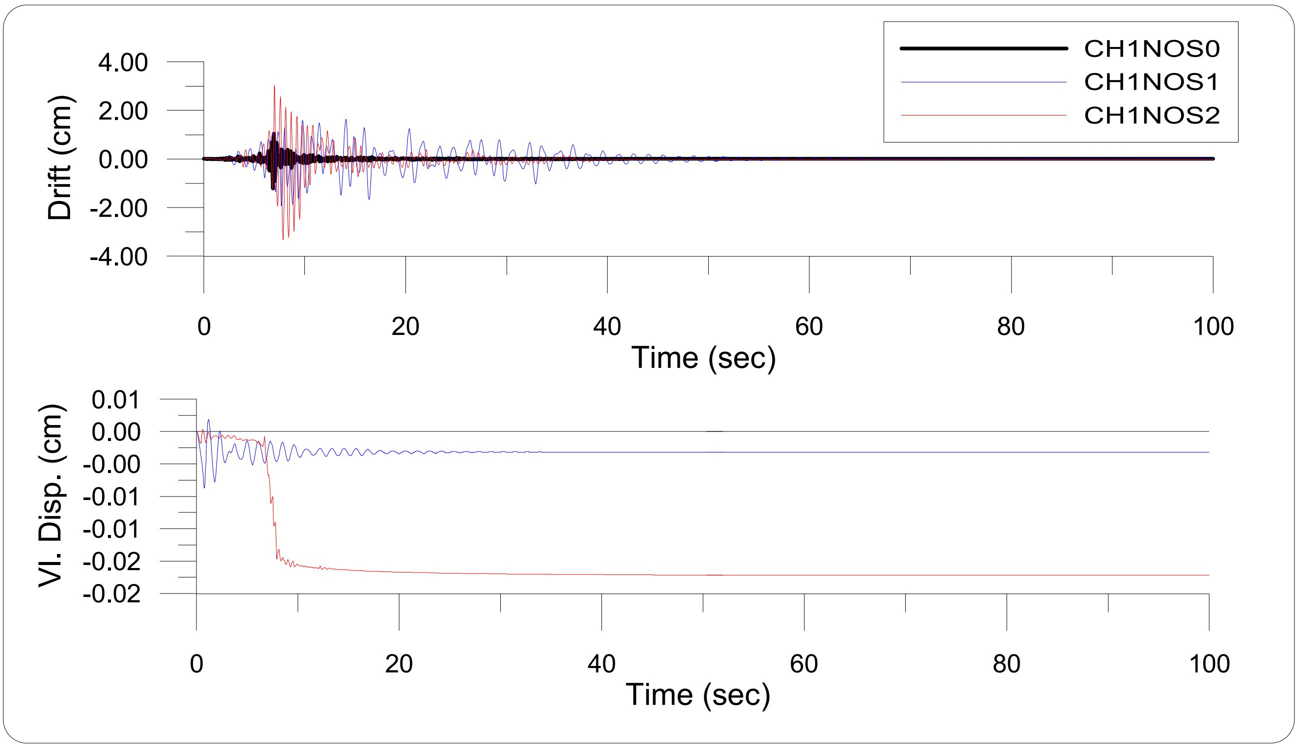

Fig. 7 – Drift and vertical displacement time histories for CH1NOS0, CH1NOS1 and CH1NOS2

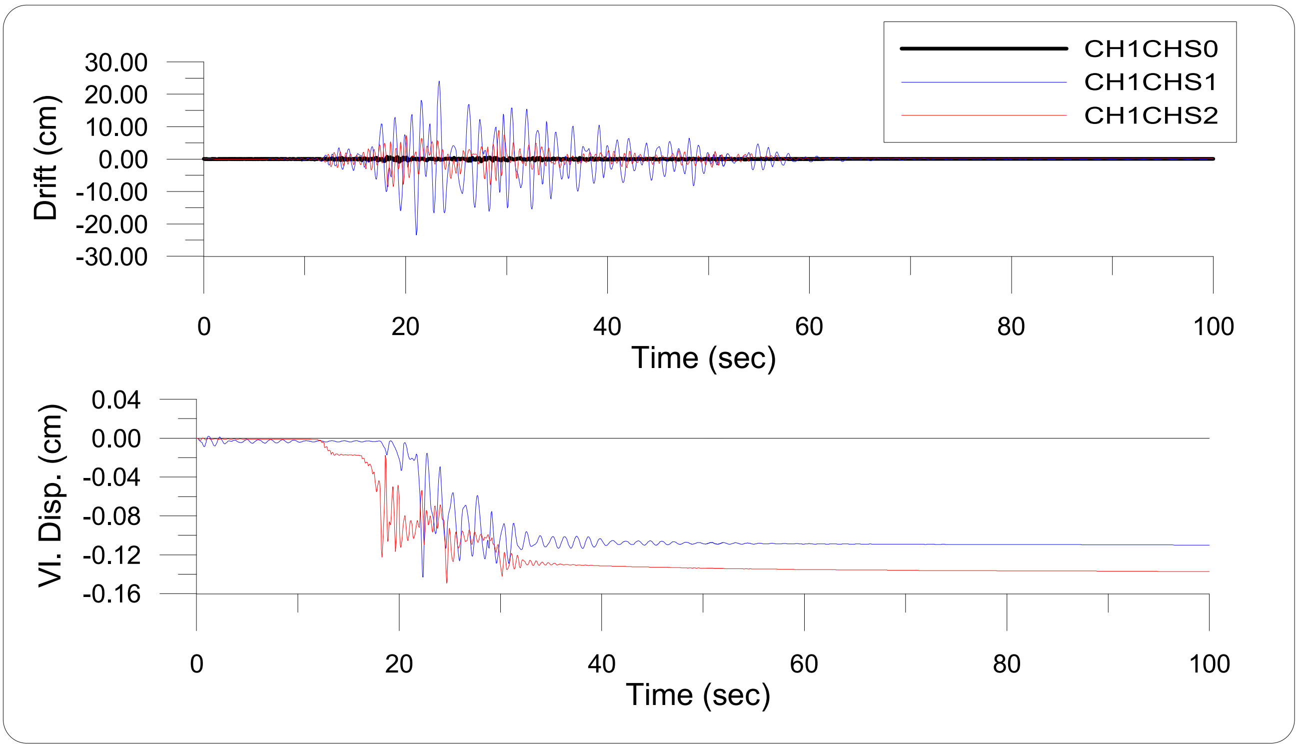

Fig. 8 – Drift and vertical displacement time histories for CH1CHS0, CH1CHS1 and CH1CHS2

Table 3 – Max. drift values for pattern (CH1)

Model ID	Max. Drift (cm)	Time (sec)
CH1KOS0	1.00	18.25
CH1KOS1	24.42	9.20
CH1KOS2	8.92	9.40
CH1NOS0	1.21	6.88
CH1NOS1	24.17	23.32
CH1NOS2	8.92	29.20
CH1CHS0	0.88	23.36
CH1CHS1	1.92	7.72
CH1CHS2	3.32	7.88

The drift and the vertical displacement time histories for CH2KOS0, CH2KOS1 and CH2KOS2 are displayed in Fig 9. The max drift for CH2KOS0 is 16.89 cm at time 9.08 sec, 27.80 cm at time 12.04 sec for CH2KOS1 and 15.97 cm at time 9.00 for CH2KOS2. Fig. 10 illustrates the drift and the vertical displacement time histories for CH2NOS0, CH2NOS1 and CH2NOS2. The max drift for CH2NOS0 is 2.43 cm at time 7.24 sec, 67.33 cm at time 20.28 sec for CH2NOS1 and 20.25 cm at time 20.80 for CH2NOS2. Fig. 11 shows the drift and the vertical displacement time histories for CH2CHS0, CH2CHS1 and CH2CHS2. The max drift for CH2CHS0 is 19.81 cm at time 22.24 sec, 5.55 cm at time 9.48 sec for CH2CHS1 and 3.01 cm at time 7.12 for CH2CHS2. These results are shown in table 4.

For this pattern, the effect of the excitation and the type of soil on the seismic behavior of the structure is very significant and clarified as well the Pattern (CH1).

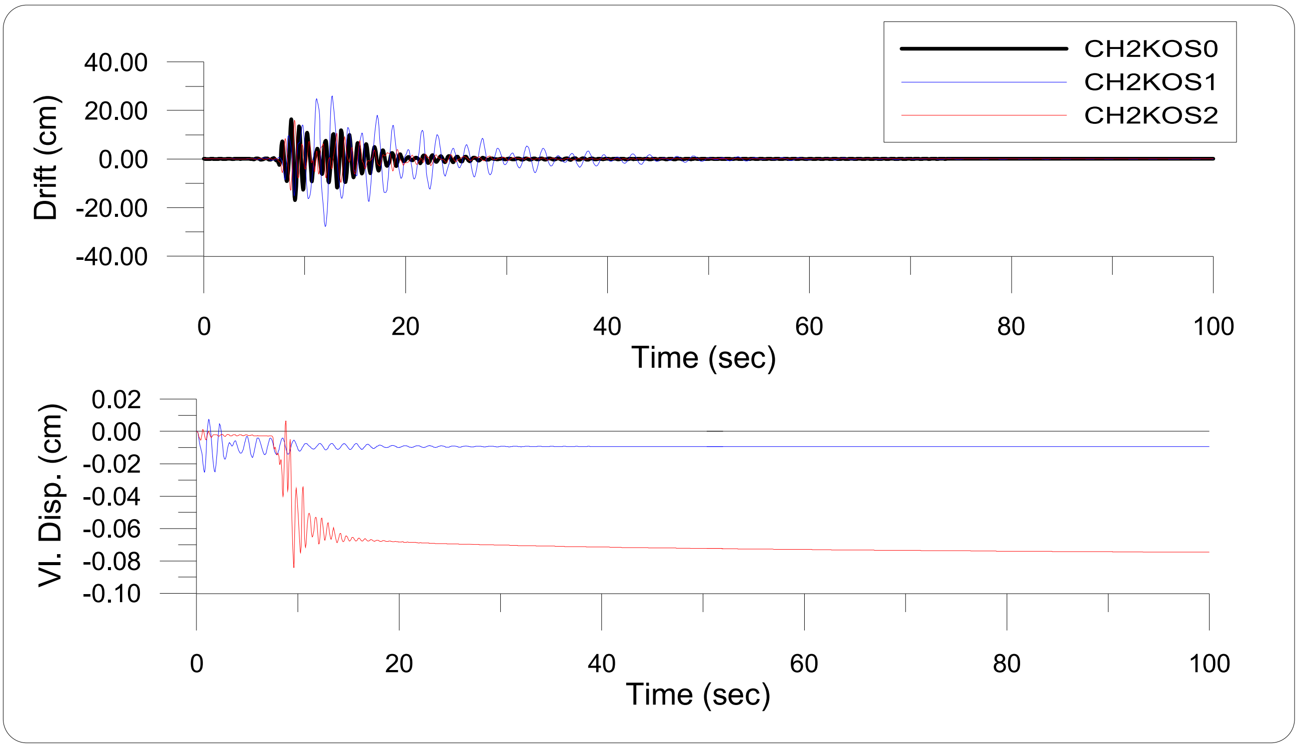

Fig. 9 – Drift and vertical displacement time histories for CH2KOS0, CH2KOS1 and CH2KOS2

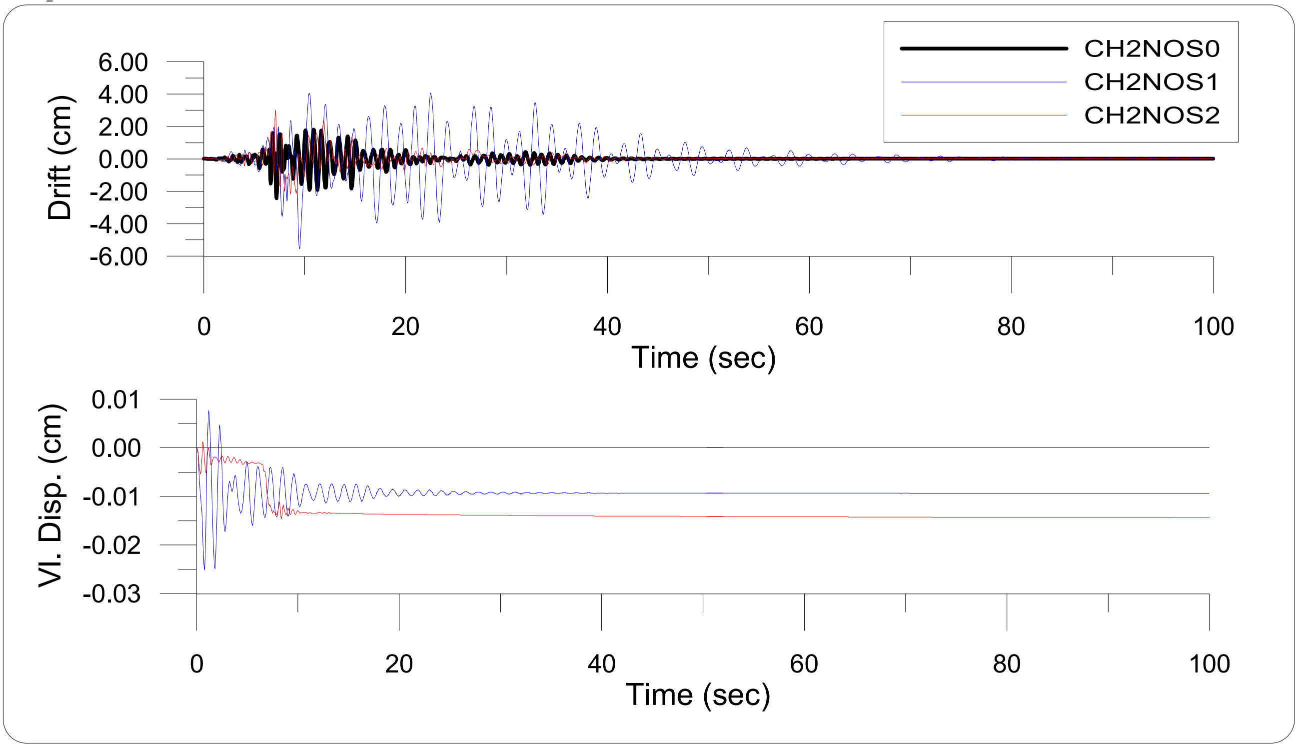

Fig. 10 – Drift and vertical displacement time histories for CH2NOS0, CH2NOS1 and CH2NOS2

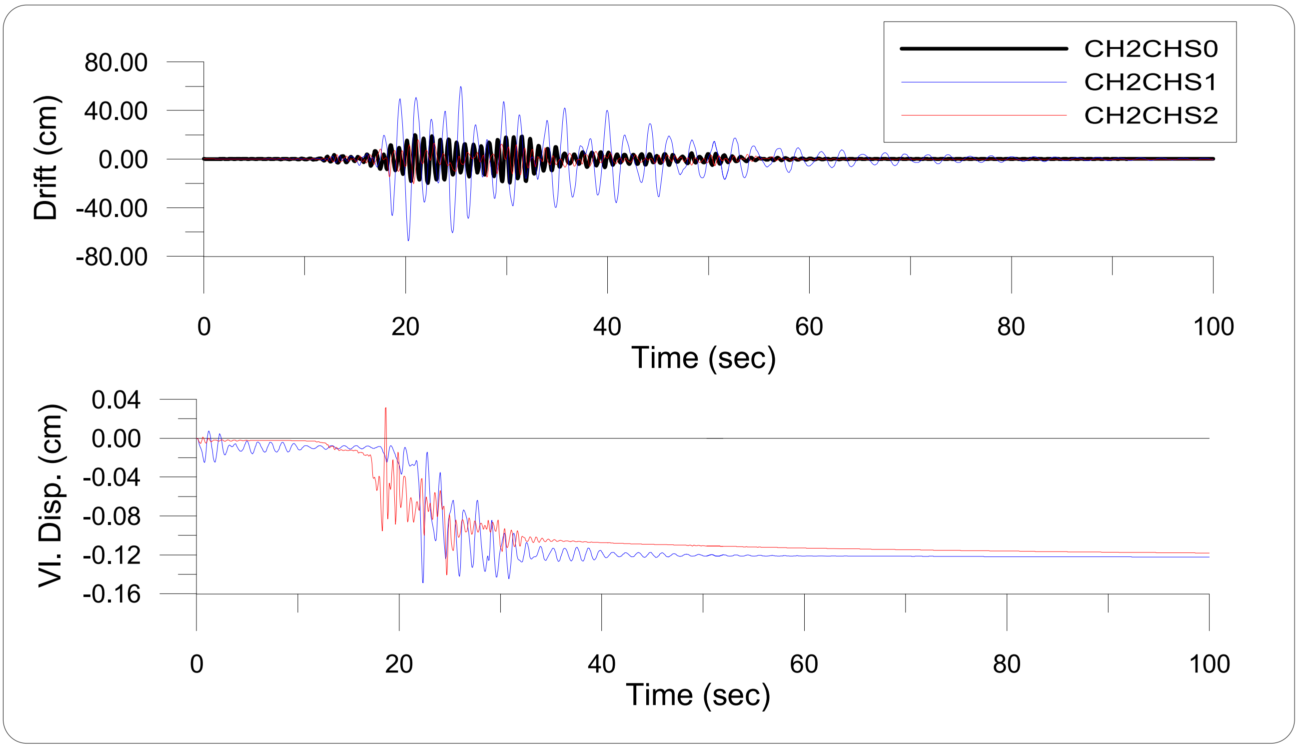

Fig. 11 – Drift and vertical displacement time histories for CH2CHS0, CH2CHS1 and CH2CHS2

Table 4 – Max. drift values for pattern (CH2)

Model ID	Max. Drift (cm)	Time (sec)
CH2KOS0	16.89	9.08
CH2KOS1	27.80	12.04
CH2KOS2	15.97	9.00
CH2NOS0	2.43	7.24
CH2NOS1	67.33	20.28
CH2NOS2	20.25	20.80
CH2CHS0	19.81	22.24
CH2CHS1	5.55	9.48
CH2CHS2	3.01	7.12

4. Conclusion

Numerical analysis of masonry chimneys with soil structure interaction consideration are developed. The analysis of the results leads to some important conclusions. A summary of the most general conclusions of this study are as follows:

- The drift and vertical displacement are independent results (vertical displacement has been measured under the vertical symmetric axis of the chimney model). Maximum drift is not always associated with maximum vertical displacement in the same model.
- Because of the random nature of the seismic action, the seismic behavior of the chimneys differed widely considering excitations with the same PGA.
- Considering the soil-structure interaction in the analysis strongly affects the seismic behavior of the masonry chimneys especially in short models (CH1).

5. References

[1] Livaoglu R, Dogangun A (2007): Effect of Foundation Embedment on Seismic Behavior of Elevated Water Tanks Considering Fluid-Structure-Soil Interaction. *Journal of Soil Dynamics and Earthquake Engineering*, 27, PP. 855-863.

[2] El Khawaga AM, El Nimr AE, Gabr AM (2015): Seismic Assessment of Elevated Water Tanks. *IZIIS-50 Conference*, Northern Europe, Paper No. 153.

[3] El Khawaga AM, Gabr AM (2015): Building Irregularity Effect on the Seismic Response of high Rise Buildings. *IZIIS-50 Conference*, Northern Europe, Paper No. 259.

[4] ADINA (2012): *Automatic Dynamic Incremental Nonlinear Analysis*. ADINA R&D, Inc. USA.

[5] ANSYS (2012): Swanson analysis system Inc. Houston. Pennsylvania. USA.

[6] Ceroni F, Sica S, Pecce M, Garofano A (2012): Effect of Soil-Structure Interaction on the Dynamic Behavior of Masonry and RC buildings. *15th World Conference of Earthquake Engineering*, Lisbon, Portugal

[7] Kazaz I, Akansel V, Gulkan P, Kazaz E (2012): Seismic Behavior of a Four-legged masonry minaret. *15th World Conference of Earthquake Engineering*, Lisbon, Portugal.

[8] Bowles JE (1977): *Foundation Analysis and Design*. McGrawWiley, 2nd edition.

[9] Sobaih ME (2016). Personal communication.