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INFLUENCE OF STIFFNESS ON THE TORSIONAL RESPONSE OF ONE STORY STRUCTURE

BY

MIHAELA MOVILĂ[*]

"Gheorghe Asachi" Technical University of Iaşi
Faculty of Civil Engineering and Building Services

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Abstract. The design provisions establish compliance guidelines, computational methods and detailed rules in order to achieve a corresponding safety degree in accordance with the seismic hazard associated to the building site.

The seismic codes include design rules for considering the effects of torsional behavior occurring in asymmetric structures where the ratio of their translational and torsional periods (uncoupled) approaches to unity.

Multi-storey models were used to study, in a realistic way, the asymmetric structures response. However due to their complexity this models are used to study a few cases of actual structures. For this reason, single storey model remains adequate to obtain general information on the torsional behavior of asymmetric structures.

The model used in this case study is a one storey model. The analysis is performed in elastic domain using the time-history method. In this paper the gravitational loads and elements stiffness, the influence of asymmetric distribution on the dynamic amplification factor, the deformation and torsional responses are studied.

Key words: elements stiffness; eccentricity; torsional response; FEM.

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[*]Corresponding author: *e-mail*: mihaelamovila@yahoo.com

1. Introduction

For a proper behavior to the seismic action, besides the strength and stiffness to lateral loads, a structure must have a high strength and stiffness to torsion. In early researches the effects of the coupled torsion were studied on simple models such as single storey models. These types of models were considered suitable to solve the influence of structural parameters and also to apply them on multi-storey structures. In the last years, multi-storey models were used to realistic study the response of asymmetric structures. Nevertheless, due to their complexity, these types of models were used to study only a few real structures. Therefore, single storey models are more appealing to researches because they are suitable to obtain general information about the torsion behavior of asymmetrical structures (Paulay, 2001).

The structural analysis based on mechanic and dynamic theories aims to determine the behavior and the failure mechanism of elements or of the entire structure (Dusicka, 2000). The main analytical method is the finite element method (FEM). The advantages of this method are:

a) the easiness of modeling and solving various problems from different domains (static analysis, dynamic analysis, non linear analyses and so on);

b) the possibility to model a complex load system (concentrated loads, uniformly distributed loads, time variable loads, pressures, accelerations, initial displacements);

c) the possibility of defining homogeneous, isotropic or anisotropic materials.

2. Case Study

The model used in this case study is a single storey structure. The aim of this analysis is the mass influence and the eccentricity evaluation on the torsional response of the structure.

By changing the mass position and columns rigidity an eccentricity was aimed to obtain. The model used in this study is presented in Fig. 1.

The program used for the structural analysis is ETABS.

The plan dimensions of the structures are 2.40 × 2.40 m and 2 m height. The columns used are made of UNP profiles, the girders are equal double angles 100 × 100 × 10 mm.

For the same structural model there are considered 4 situations (model A, B,C, D) The weight is changed in 6 positions for the four models (A, B, C, D) as it is presented in Fig. 2.

The A model (Fig. 3) has the following characteristics:

a) the columns dimensions are 60 × 60 × 6 mm;

b) in terms of rigidity the model is symmetric.

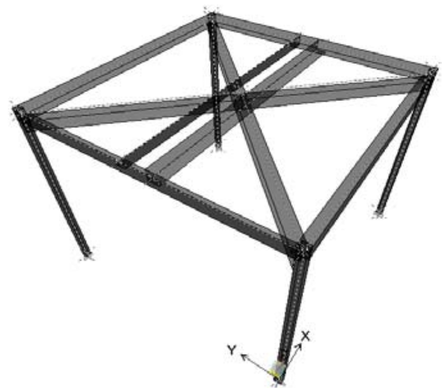


Fig. 1 – The structural model.

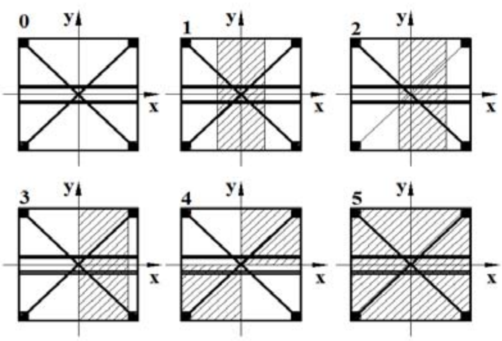


Fig. 2 – Variation of weight position.

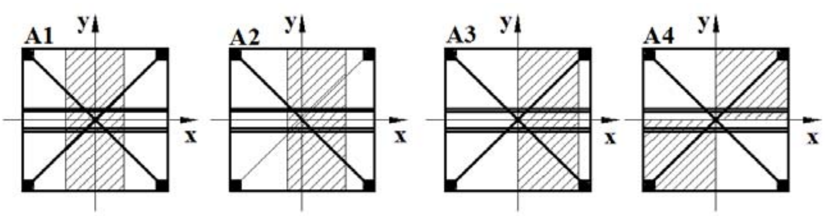


Fig. 3 – A model and weight distribution.

The B model (Fig. 4) has the following characteristics:

a) the dimensions of 3 columns are 60 × 60 × 6 mm and the fourth one dimensions are 60 × 30 × 4 mm;

b) in terms of the rigidity the model is asymmetric, but in terms of the mass it is symmetric.

The C model (Fig. 4) has the following characteristics:

a) C1 model has 2 columns with 60 × 60 × 6 mm dimensions and 2 with 60 × 30 × 4 mm (the model is symmetric, CM – center of mass coincide with CS – center of stiffness);

b) from the geometric point of view C3 model is identical with C1 model, but CM does not coincide with CS.

The D model (Fig. 4) has the following characteristics:

a) the model has 2 columns with 60 × 60 × 6 mm dimensions and 2 with 60 × 30 × 4 mm, but CM does not coincide with CS.

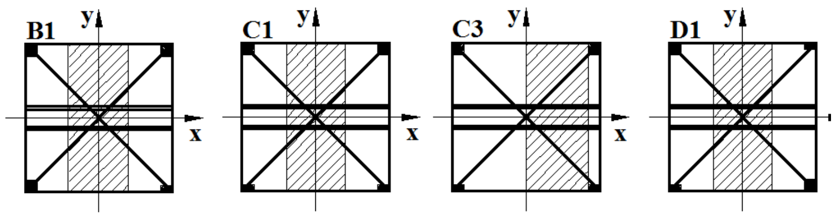


Fig. 4 - B1, C1, C3 and D1 models with the mass distribution

To obtain the linear seismic response of the models a time history analysis is used. The Vrancea earthquake acceleration is used to simulate the dynamic action at the ground motion on *x* and *y* direction. The seismic input was normalized for 0.2 g effective peak ground acceleration (for Iaşi) and divided in 2008 steps taking into account the self weight of the model as load. The used viscous damping factor is equal to 0.05%.

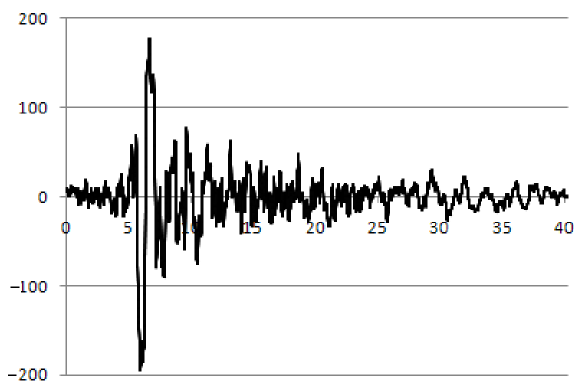


Fig. 5 – Vrancea's seismic input 1977 N–S.

2.1. Static Analysis

The periods of vibration values are presented in Table 1.

Table 1
The periods of vibration values

Model	Time-history analysis		
	T_x, [s]	T_y, [s]	T_θ, [s]
A1	0.3405	0.3405	0.2001
A2	0.3440	0.3405	0.1965
A3	0.3405	0.3543	0.1985
A4	0.3404	0.3405	0.2213
B1	0.3998	0.3675	0.2180
C1	0.5214	0.3968	0.2364
C3	0.5331	0.4043	0.2342
D1	0.4617	0.3966	0.2492

Translation and torsion periods on x and y direction is presented in Fig. 6.

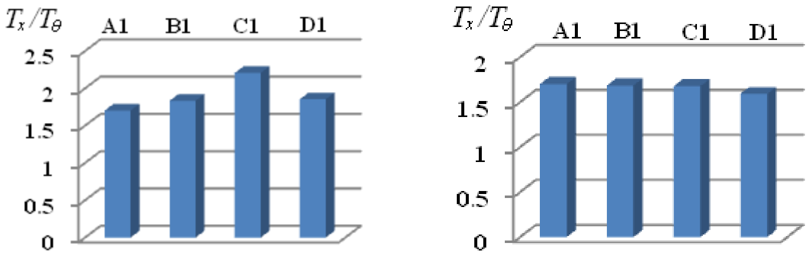


Fig. 6 – Translation and torsion periods ration on x and y direction.

Table 2 presents the eccentricity values.

Table 2
Eccentricity Values

Model	Eccentricity	
	e_x, [cm]	e_y, [cm]
A1	–0.032	0
A2	24.899	25
A3	49.824	50
A4	0.032	0
B1	34.903	–18.709
C1	–0.028	–41.241
C3	49.886	–41.242
D1	–0.037	0.036

The structure's response (acceleration spectrum) was compared with design spectrum from P100-1/2006 norm (Fig. 7).

Although the 1977 earthquake had a severe effect on the structure, in Fig. 7 can be seen that the P100-1/2006 design spectrum is covering in the seismic design and conception of the structures. For the fundamental period of vibration, the maximum amplification factor is obtained.

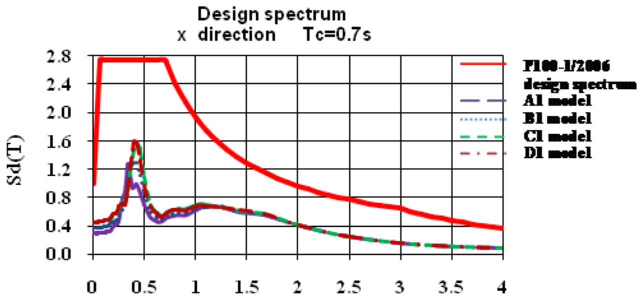


Fig. 7 – Comparison between the obtained spectrum and P100-1/2006 design spectrum.

Deformation values (*x* and *y* direction displacement, rotation) are presented in Fig. 8.

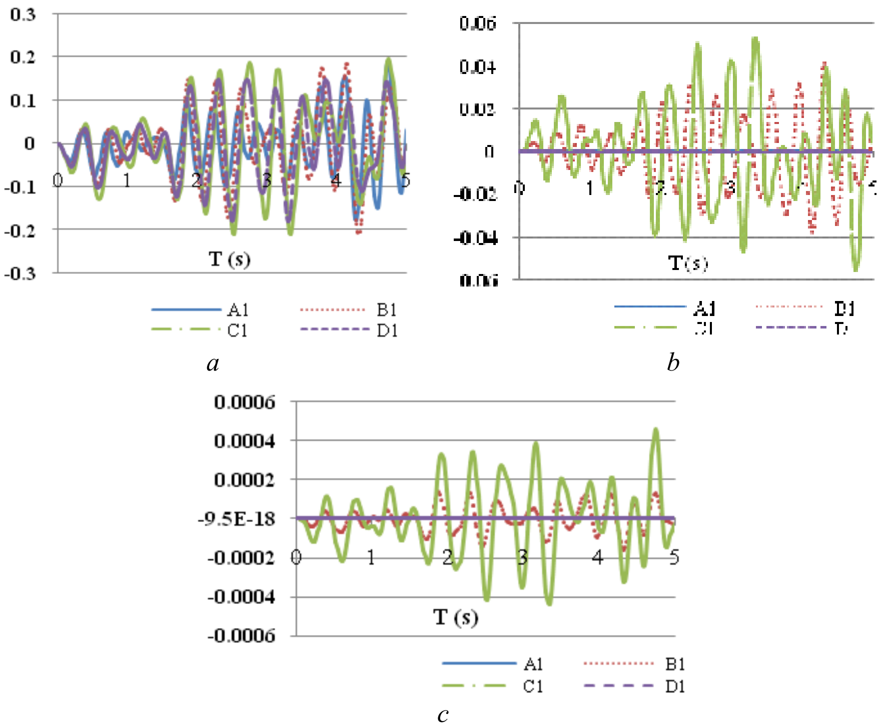


Fig. 8 – Deformation values: *a* – *x* direction displacements; *b* – *y* direction displacements; *c* – CM spin (rotation).

Extreme node displacement values are presented in Tables 3 and 4.

Table 3
Displacement Values on x Direction

Node	A1	A2	A3	A4	B1	C1	C3	D1
A	0.8458	0.7734	0.7085	0.8455	1.1285	1.9977	1.4984	1.985
CM	0.8391	0.8761	0.9688	0.8383	1.3346	2.0037	2.1146	1.9904
B	0.8455	0.9549	1.0872	0.8452	1.5675	2.0266	2.4135	1.9844

Table 4
Displacement Values on y Direction

Node	A1	A2	A3	A4	B1	C1	C3	D1
A	0.845	0.8465	0.8449	0.8451	1.2343	1.8008	1.7542	1.3682
CM	0.8379	0.8394	0.8379	0.8379	1.1116	1.4462	1.4256	1.3661
B	0.845	0.8466	0.8451	0.8451	1.0108	1.1177	1.1139	1.3686

The graphical representation of displacements on x and y direction is shown in figure 9.

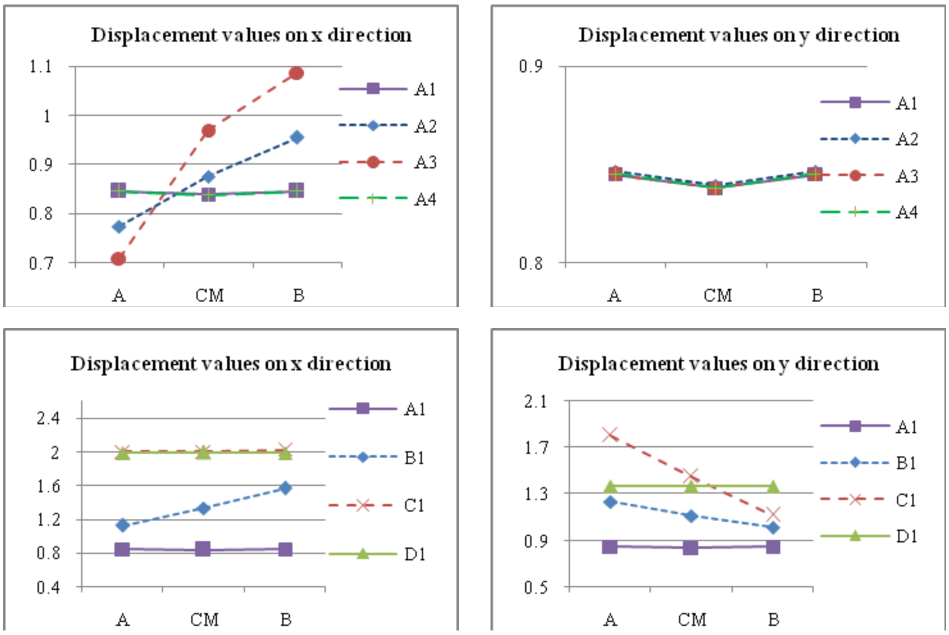
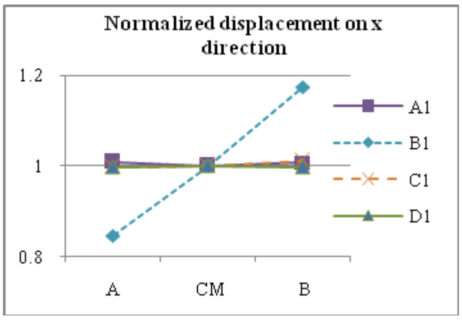


Fig. 9 – Displacement on x and y direction.

Although on the x direction the values of displacements are higher the appearance of torsions is smaller than on the y direction which has smaller displacements and certainly higher torsion effects.

From the seismic response point of view the most disadvantageous situation is case B, because an eccentricity occurs due to the stiffness change of a column which leads to an asymmetry form the stiffness and masses point of view.

In order to evaluate the presence of the torsion the values of displacements of the two extreme points of the model from the mass center are normalized. Fig. 10 presents the torsion response on the *x* and *y* direction.



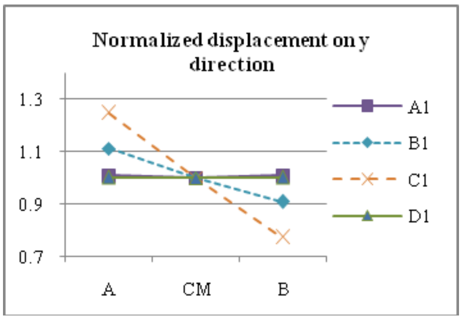


Fig. 10 – Torsional response on *x* and *y* direction.

4. Conclusions

The single storey model was considered to be suitable for clearing the structural parameters influence upon the torsion response of the structures. It can be noticed that the change of the elements stiffness presents a great influence upon the structural response through higher displacements and higher torsion effects.

Based on the dynamic time history analysis it was possible to observe how the change of element stiffness influences the appearance of eccentricity leading to higher displacements and therefore a highlighted torsion effect. By analysing the dynamic amplification factor and comparing it to the Romanian seismic design standard it was noticed that the design spectrum provided by the seismic code is sufficient also for seismic actions like the 1997's Vrancea earthquake.

REFERENCES

Dusicka P., *Numerical and Experimental Investigation of Seismic Torsional Response of Single Storey Ductile Structures*. Ph. D. Diss., The Univ. of British Columbia, 2000.

Paulay T., *Some Design Principles Relevant to Torsional Phenomena in Ductile Buildings*. J. of Earthquake Engng., **5**, *3*, 273-308 (2001).

* * * Design program ETABS.

* * * *Cod de proiectare seismic*. Partea I: *Prevederi de proiectare pentru clădiri*. P–100–1/2006.

INFLUENŢA RIGIDITĂŢII ASUPRA RĂSPUNSULUI LA TORSIUNE A STRUCTURILOR CU UN SINGUR NIVEL

(Rezumat)

Codurile de proiectare stabilesc principii de conformare, metode de calcul şi reguli constructive pentru realizarea unor construcţii sigure în raport cu hazardul seismic asociat amplasamentului.

Codurile de proiectare a clădirilor la acţiunea seismică includ reglementări de proiectare pentru luarea în considerare a efectelor torsiunii apărute în comportarea structurilor asimetrice, în cazul în care raportul dintre perioadele proprii de translaţie ţi torsiune (necuplate) se apropie de unitate.

Modelele cu mai multe niveluri au fost folosite pentru a studia, într-un mod cât mai realist, răspunsul structurilor asimetrice. Cu toate acestea, datorită complexităţii lor, astfel de modele sunt aplicabile pentru studiul câtorva cazuri de structuri reale. Din acest motiv, modelele cu un singur nivel atrag atenţia multor cercetători, deoarece ele rămân adecvate pentru a obţine informaţii generale cu privire la comportarea la torsiune a clădirilor asimetrice.

Modelul folosit în acest studiu de caz este o structură cu un singur nivel. Analiza este realizată în domeniul elastic şi este de tip „time-history" pentru a se obţine răspunsul seismic liniar în timp al modelelor. Este studiată influenţa distribuţiei asimetrice a forţelor gravitaţionale şi a rigidităţii elementelor asupra factorului de amplificare dinamică, deformaţiilor şi răspunsului la torsiune.