All Sciences Proceedings
http://as-proceeding.com/

2nd International Conference on Contemporary Academic Research

November 4-5, 2023 : Konya, Turkey

ICCAR
https://as-proceeding.com/index.php/iccar

Estimation of torsional effects of buildings using modal pushover analysis

Mahmoud Benkhelil [*], Mohamed Badaoui [2]

[1] *Laboratory Built in Environnement, Faculty of Civil Engineering USTHB, Algiers, Algeria*
[2] *Laboratory of Development in Mechanics and Materials LDMM, University of Djelfa, Algeria*

[*]*(benkhelilm7@gmail.com)*

Abstract – The nonlinear static procedures (NSPs) have recently received increasing attention. Those have demonstrated its good accuracy in estimating the seismic response of regular buildings. This assumption can sometimes be insufficient for asymmetrical-plan buildings and high-rise buildings. A simplified method which takes into account higher modes other than the fundamental mode is the modal pushover analysis method (MPA). It has proven effective inelastic responses analysis of regular buildings. It's extended to the analysis of asymmetrical-plan buildings where the phenomenon of torsion is present and which presents one of the most complicated problems in the calculation of structures. In this work, the MPA method is applied to two cases of symmetrical-plan and asymmetrical-plan structures in order to estimate the effect of torsion. The obtained results showed that the torsion effect in the asymmetrical-plan building is significant.

Keywords: MPA; Regular Building; Asymmetric-Plan Building; Inelastic Responses, Torsion.

I. Introduction

In recent years there has been progress in simplified methods for seismic analysis based on nonlinear static analysis (NSPs). Non-linear static analysis (NSA) by progressive pushing is based on the hypothesis that the response is fundamentally controlled by a single vibration mode and that the shape of this mode remains constant throughout the duration of the seismic excitation. This assumption can sometimes be insufficient, particularly after plasticization of the structure. To overcome this limitation, several authors have proposed adaptive load distributions which attempt to follow the redistribution of inertia forces linked to the effects of variation of dynamic characteristics during the inelastic response ([1]-[3]).

Another simplified method which takes into account higher modes other than the fundamental mode is the modal pushover analysis method (MPA). This method, initially developed by Chopra and Goel [1], based on structural dynamics theory retains the conceptual simplicity and computational attractiveness of current procedures with invariant force distribution, but provides superior accuracy in seismic demand on buildings. This method has been extended by Chopra and Goel [4] to the analysis of asymmetric-plan buildings where the phenomenon of torsion is present and which presents one of the most complicated problems in the calculation of structures [5].

The objective of this work essentially aims to put into practice the procedure of modal pushover analysis and to apply it's on symmetric and asymmetrical -plan building for study the effect of torsion on their inelastic responses.

II. Methods and Ground Motion

A. *Static non-linear method*

The static non-linear method it is based on the combination of two curves (Fig.1), one curve of capacity and the other of response spectrum. The capacity curve (base shear and the roof displacement at the top of the structure) can be obtained by the application of a loading gradually increasing incrementally until the rupture or a target displacement, this curve will be transformed into acceleration displacement response spectrum (ADRS) format. The same for the response spectrum which must be transformed into ADRS format, Finally superposition of the two curves brings out a target displacement represented by target displacement and the corresponding shear force at the base.

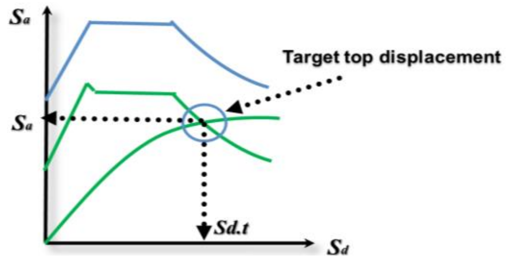


Fig.1 Target displacement on NSA method

B. Modal pushover analysis

This is another method that relies on modal analysis called modal pushover analysis (MPA) (Fig. 2). It has the advantage of taking into account the effect of higher modes, which are not considered in the previous method. The latter only considers the first mode. Additionally, the MPA has a theoretical basis. After having determined the vibration modes, the distributions of the loads applied for the progressive thrust change with the pace of the modes, so we have a number of modes, after that,a target displacement for each mode and subsequently the total target displacement will be calculated by quadratic combination.

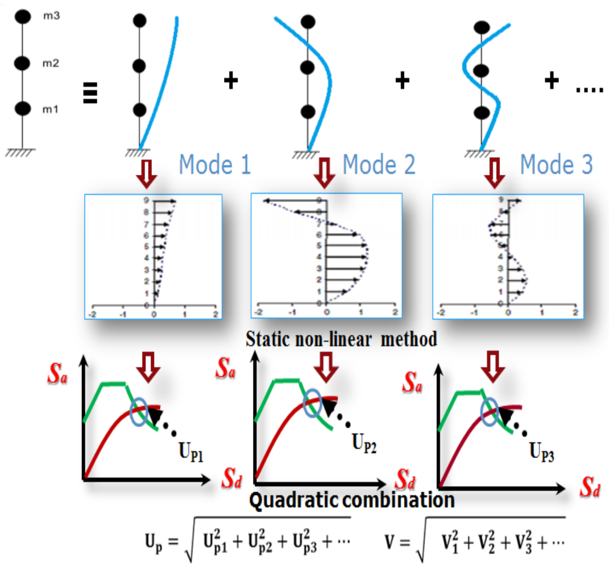


Fig. 2 Modal pushover analysis procedure

C. Ground motion

The ground motion taken in this study is represented by a response spectrum defined in UBC97 standard [6] shown in Fig.4, with damping ratio is 0.05 and seismic coefficients Ca and Cv is 0.4.

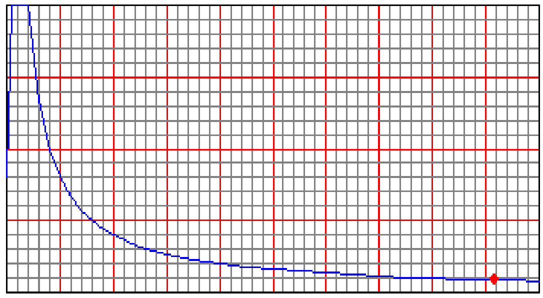


Fig.4 UBC97 standard response spectrum

III. APPLICATION ON BUILDING CASES

In this study, two cases of buildings was selected, the first is a symmetrical building (Fig.5), and the other building is asymmetrical-plan (Fig.6). The seismic action is represented by the response spectrum of UBC97 standard. Two reinforced concrete buildings for residential use located in an area of high seismicity with the characteristics presented in Tables 1 et 2, the length of each span is 4m in both directions, the compressive strength at 28-day is 25 MPa.

Table. 1 Beams and columns of the studied buildings

Building	Story	Columns (cm)	Beams (cm)
4-story	1-2	40x40	
	3-4	35x35	
6-story	1-2	45x45	35x35
	3-4	40x40	
	5-6	35x35	

Table. 2 Gravity loads of the studied buildings

	Roof /Floor	Dead load (kN/m)	Live load (kN/m)
Both buildings	Roof	6.75	1
	Floor	4.2	1.5

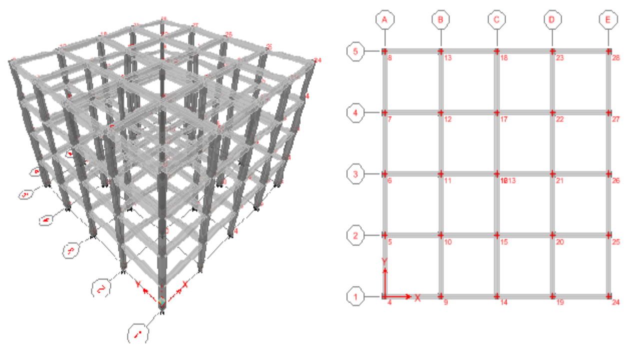


Fig.5 A 4-story symmetrical building (3D view /plan view).

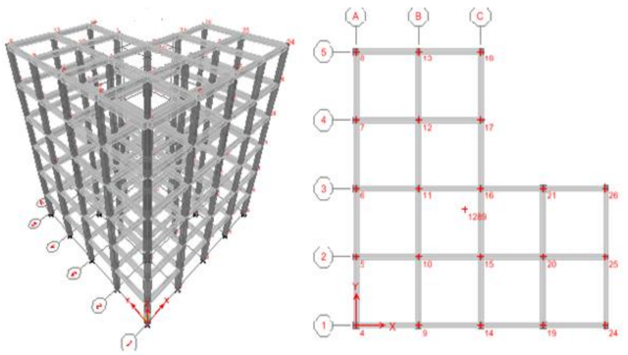


Fig. 6 A 6-story asymmetrical-plan building (3D view /plan view).

IV. Results and Discussion

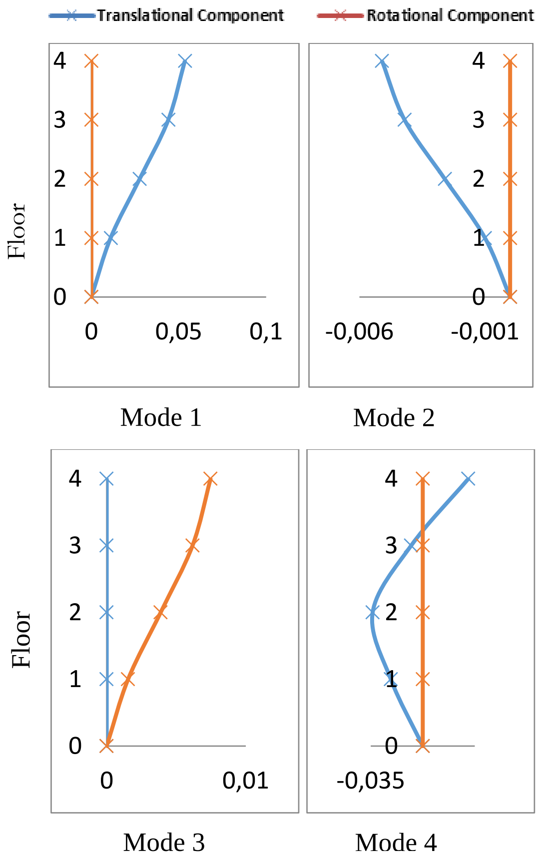
The modal pushover analysis (MPA) was used. The results obtained are presented in terms of vibration modes, and a target displacement in the y direction due to the seismic action applied in the y direction without and with torsion effect.

IV.1. A 4-story symmetrical-plan building

This is the first application in our study; the results obtained can be summarized as follows:

A. *Modes of vibration*

The first six vibration modes are shown in Fig. 7. It is clear that the first, second, fourth and fifth modes exhibit translational modes. The third and sixth modes present pure torsion modes. This can be justified due to the symmetry of the structure.



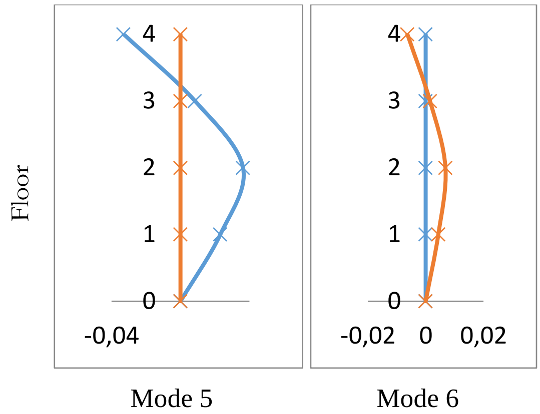


Fig. 7 Vibration modes of a 4-story symmetrical-plan building

B. *Target displacements*

The SRSS combination of target displacements of the corresponding modes and base shear in the modal pushover analysis (MPA) without and with torsion taken into account is calculated. The following table summarizes the results obtained:

Table 3. Target displacement and the corresponding base shear by MPA

	Target displacement (cm)	Base shear (kN)
MPA with torsion effect	3.27	1667.06
MPA without torsion effect	3.27	1667.06

According to Table 3, the target displacement found by the MPA analysis remained constant in the two cases considered without and with torsion taken into account, which is justified because of the symmetry of the building.

IV.2. A 6-story asymmetrical-plan building

This is the second application example of our study. The results obtained will be presented according to the same scheme as the first application.

A. *Modes of vibration*

In this example, the first six vibration modes have been taken in this application (Fig.9). From the Fig. 9, the second and the fifth modes are translation modes and the effect of the torsion is negligible. For the rest of the modes, the effect of torsion is present and which is coupled with translation. This is due to the asymmetry in plan of the building.

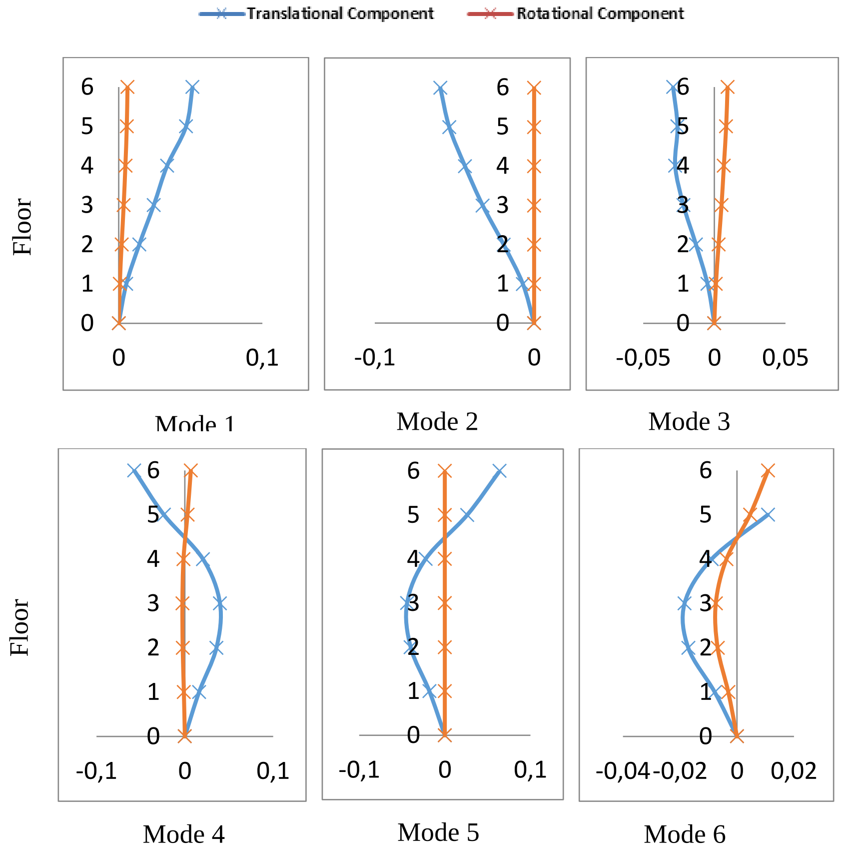


Fig.9. Vibration modes of a 6-story asymmetrical-plan building

B. *Target displacements*

The SRSS combination of target displacements of the corresponding modes and base shear in the modal pushover analysis (MPA) without and with torsion taken into account is calculated. The following table summarizes the results obtained:

Table 4. Target displacement and the corresponding base shear by MPA

	Target displacement (cm)	Base shear (kN)
MPA without torsion	7.47	2938.51
MPA with torsion	16.6	3461.55

Analysis of the results in Table 4 shows the existence of a difference between the target displacement and base shear values obtained by the MPA with and without taking into account the torsion effect. This shift is mainly due to the rotational components around the oz axis appearing in the torsion modes.

V. CONCLUSION

This investigation essentially aims to put into practice a procedure for evaluating the performance of buildings taking into account high modes including the torsion component. This procedure is the modal pushover analysis. The method was presented. Two applications were carried out on two symmetrical and asymmetrical-plan buildings. The results obtained in terms of six modes of vibration and target displacements have shown that the effect of torsion in symmetrical building is negligible but in the asymmetrical-plan buildings is significant. This has led to the conclusion the methods that are based on calculation using only the first mode cannot be used in the calculation of asymmetrical-plan buildings.

REFERENCES

[1] Chopra A, Goel R (2002) A modal pushover analysis procedure for estimating seismic demands for buildings. Earthq Eng Struct Dyn 31:561–582.

[2] Fajfar P, Marusic D, Perus I (2005) Torsional effects in the pushover-based seismic analysis of buildings. J Earthq Eng 9:831–854.

[3] Poursha M, Samarin ET (2015) The modified and extended upper-bound (UB) pushover method for the multi-mode pushover analysis of asymmetric-plan tall buildings. Soil Dyn Earthq Eng 71:114–127

[4] Chopra A, Goel R (2004) A modal pushover analysis procedure to estimate seismic demands for unsym-

metrical-plan buildings. Earthq Eng Struct Dyn 33:903–927.

[5] H. Miloud, Modélisation par macroéléments du comportement non-linéaire des ouvrages à voiles porteurs en béton armé sous action sismique, Thèse de Doctorat en Mécanique et Ingénieries, U.Bordeaux1, Soutenue le 15/04/2010.

[6] Earthquake Regulations, Uniform Building Code 97.

[7] A. Plumier, dans : Conception parasismique dans le contexte de l'Eurocode 8, édition de l'université de Liège, (2011).

[8] M. Anechitei, The torsional eccentricity of the structures in miscellaneous design codes, Technical University "Gheorghe Asachi".

[9] C. ben Azouz, Evaluation des performances sismiques des ossatures en béton arme par la méthode PBSD. Mémoire de Magister en Génie civil, ENSTP, soutenue le 23 /05/ 2009.

[10] A. Y. Rahmani, Nouredine Bourahla, Rita Bento and Mohamed Badaoui (2017) An improved upper-bound pushover procedure for seismic assessment of high-rise moment resisting steel frames. Bull Earthquake Eng, DOI 10.1007/s10518-017-0204-9.

[11] Computers and Structures, Inc: structural and earthquake engineering software v.14.2.2, Berkeley, California,USA.