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The Effects of Place and Kind of Bracing on Steel Structures

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Abstract: Because of architectural condition and structure application, sometimes mass source and stiffness source are not coincidence and the structure is irregular. The structure is also might be asymmetric as an asymmetric bracing in plan which leads to unbalance distribution of stiffness or because of unbalance distribution of the mass. Both condition lead to eccentricity and torsion in the structure. The deficiency of ordinary code to evaluate the performance of steel structures against earthquake has been caused designing based on performance level or capacity spectrum be used. By using the mentioned methods it is possible to design a structure that its behavior against different earthquakes be predictive. In this article 5-story buildings with different percentage of asymmetric which is because of stiffness changes and kind of bracing (x and chevron bracing) have been designed. The static and dynamic nonlinear analysis under three acceleration recording has been done. Finally performance level of the structure has been evaluated.

Key words: Seismic analysis · Brace · Steel structures · Irregular building · Stiffness source

INTRODUCTION

Studying behaviour of structures which were designed according to the common building codes against earthquake loads showed that they have good operation in respect of safety purposes and physical health [1]. But, it lacks the necessary mechanisms for controlling the construction on different operational level. In new codes, designing is done with operation that is respected of structural and non structural ingredients [2, 3] for instance in the instruction of seismic improvement of existing buildings, functional purpose include: collapse prevention, life safety, immediate occupancy after earthquake. In this code operational levels determined for each of structural and nonstructural parts, that acceptable and logical compositions of these two operation levels constitute operational levels of whole building. The operational purpose of buildings can be selected with consideration of operation level of building and level of earthquake risk as one of the operational purpose. This depends on an importance of the building and the owner request. In this paper, the operation of five storey steel buildings with asymmetric resistant element and kind of bracing has been presented. The structures analyzed using nonlinear static and dynamic methods.

Types of Studied Models: In this research the behavior of five storey steel structures with 3.2m height with 4 and 3 bays in length and width direction with span of 5 m have been studied. The structure assumed in a high seismic zone on a soil of type II. Residential usage were assumed for the buildings and the symmetrically and asymmetrically behavior of them have been investigated. Asymmetric is performed by relocation of braces positions in X directions. Structures are named A,B,C,D to distinguish the results. Type A structures are represented symmetric models and structures B,C & D are represents the structures with an eccentricity of 12.5%, 25%, 37.5% respectively in X direction. Distinction of models in kind of bracing are investigated with prefixed C1(case1) and C2(case2), in it C1 is x-bracing and C2 is chevron bracing. These mentioned structures designed in accordance with Iranian code of practice for buildings [4, 5]. Model A is shown in Figure 1 as a typical. After primary designing of models and obtaining the structural profiles, three-dimensionally nonlinear static and dynamic analysis of structures have been conducted using Etabs2000 edition of 9.14 and Sap2000 edition of 11.4 soft wares.

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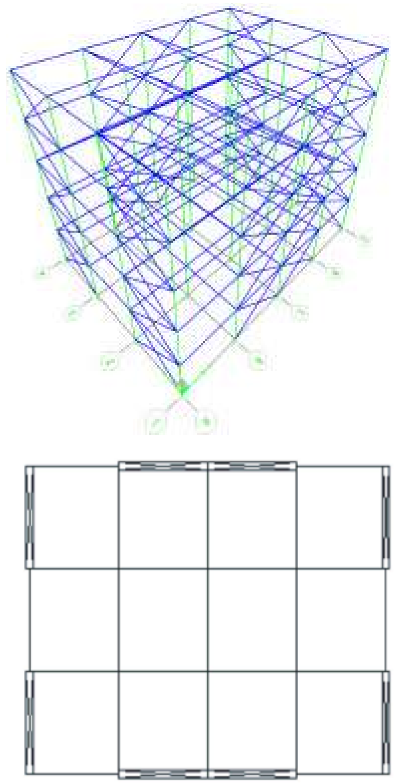
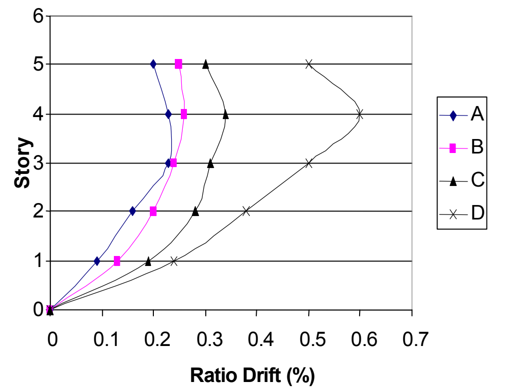


Fig. 1: Plan and 3-dimensional figure of model A

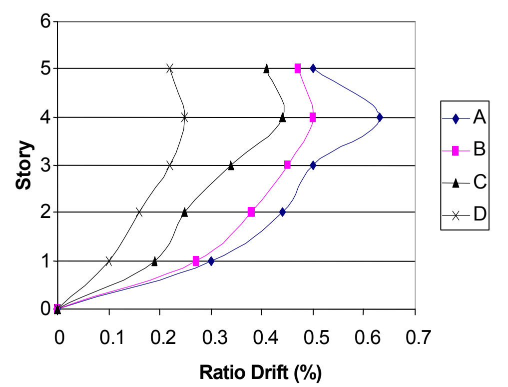
Characteristics of Studied Models: Models are designed in form of simple braced frames. The dead loads of 600 and 500 kg /m^2 were assumed for all floors and roof respectively and the live load of floors and roof were selected equal to 200 and 150 kg/m^2. According to Iranian code, behavior of factor of 6, were assumed for simple building frame system with concentric bracing in both X and Y directions. According to the code the effect of accidental torsion for structures with less than 18 m height can be ignored. In asymmetric models for designing against lateral force in addition to incoming force of each side, 30% of earthquake force from the other side has been considered at the same time. In model designing because of lateral displacement less than 0.02/R, the effect of P-Δ has been ignored according to the Iranian code. The connection between the columns and base assumed as a fixed support. The IPB profile sections are assumed for all columns. All beams assumed to be made from IPE standard sections and finally double channel sections are used for all braces. Studying the behavior of structures with different locations of braces in X direction has been considered and the results of analysis in soft and hard edges of structure in Y direction are used to investigate the structure behaviors. Soft and hard edges of structure are called to the terminal frames of structure which is closer to mass centre and rigidity centre of structure respectively. Mass centre of all floors are assumed in a same location and it is supposed to be in the centre of structure. Shear force on each storey is calculated according to the code and it is represented in Table 1 for both directions.

Table. 1: Shear force of story

Story	1	2	3	4	5
Fx (ton)	8.77	17.42	26.2	35	39.79
Fy (ton)	8.77	17.42	26.2	35	39.79



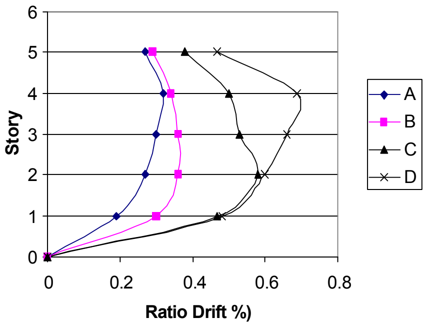
a) Ratio drifts of soft edge (%)



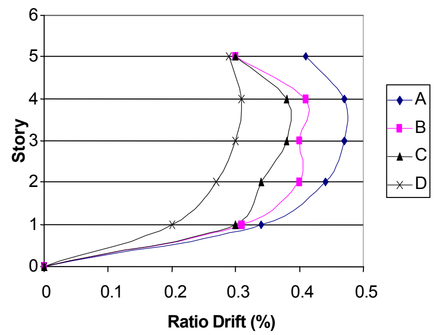
b) Ratio drift of hard edge (%)

Fig. 2: Ratio drifts of soft and hard edges of C1 under

Nonlinear Static Analysis: Operation point of structure is placed at crossing point of capacity curve of structure and necessity curve of it. And the nonlinear static analysis is used to find it. After calculating the displacement of operation point at the roof of the structure, the displacements of the same point, but at the other floor have been calculated. This work performs for different structures and Figure 2,3 is represented ratio drift on soft and hard edges of each floor. As it is shown, the displacement and drift ratio have an increasing rate at the

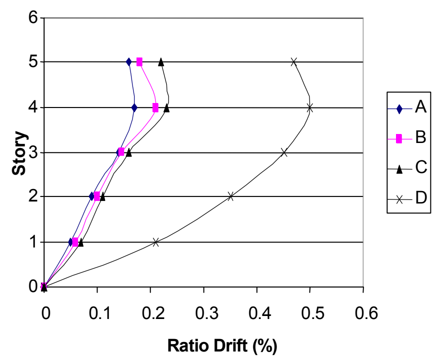


a) Ratio drifts of soft edge (%)

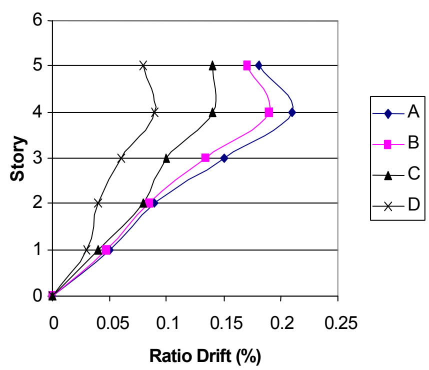


b) Ratio drift of hard edge (%)

Fig. 3: Ratio drifts of soft and hard edges of C2 under nonlinear static analysis

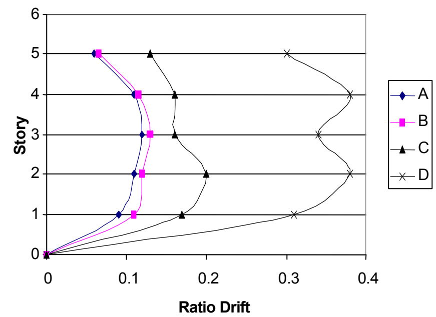


a) Ratio drift of soft edge (%)

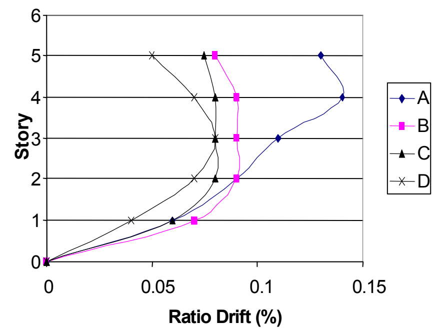


b) Ratio drift of hard edge (%)

Fig. 4: Ratio drift of soft and hard edges C1 under Elcentro earthquake

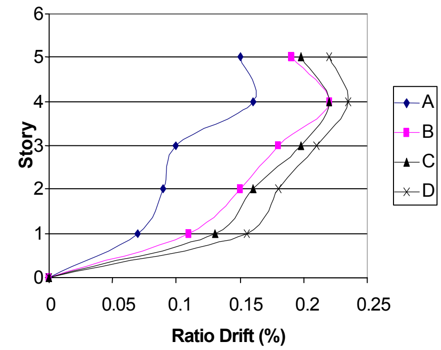


a) Ratio drift of soft edge (%)

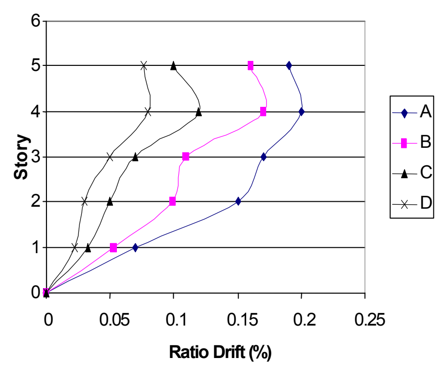


b) Ratio drift of hard edge (%)

Fig. 5: Ratio drift of soft and hard edges C2 under Elcentro earthquake

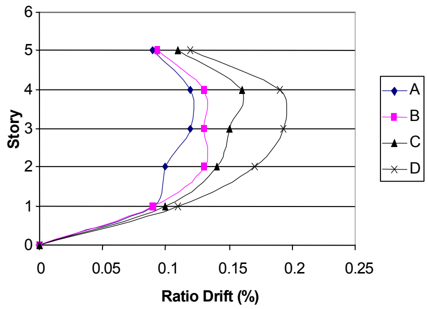


a) Ratio drift of soft edge (%)

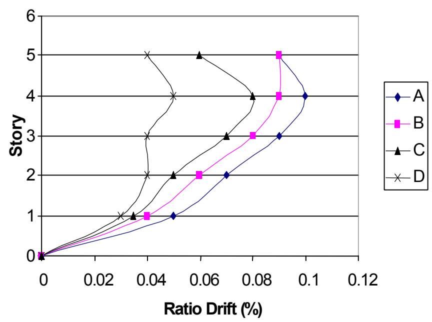


b) Ratio drift of hard edge (%)

Fig. 6: Ratio drift of soft and hard edges C1 under Sylmar earthquake

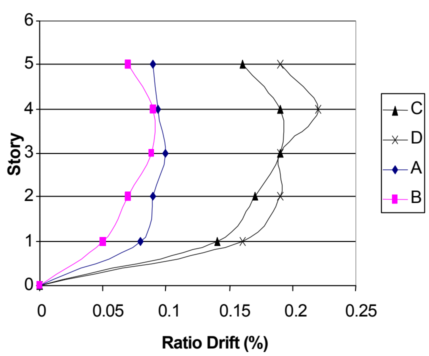


a) Ratio drift of soft edge (%)

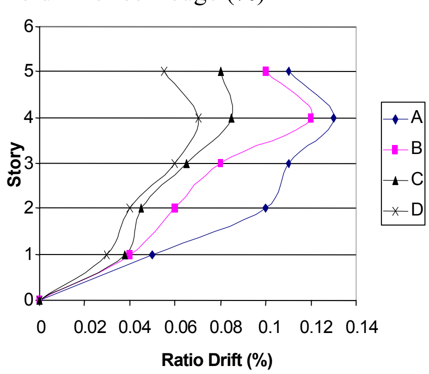


b) Ratio drift of hard edge (%)

Fig. 7: Ratio drift of soft and hard edges C2 under Sylmar earthquake

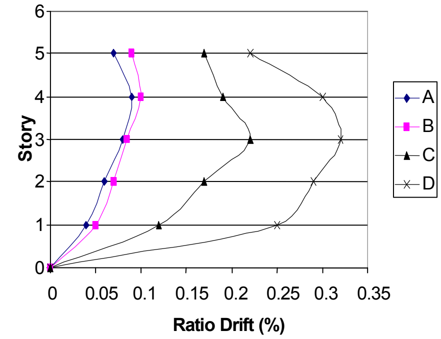


a) Ratio drift of soft edge (%)

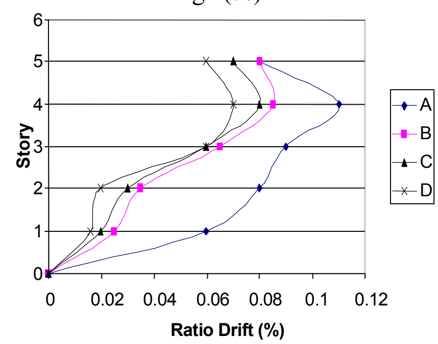


b) Ratio drift of hard edge (%)

Fig. 8: Ratio drift of soft and hard edges C1 under Tabas earthquake



a) Ratio drift of soft edge (%)



b) Ratio drift of hard edge (%)

Fig. 9: Ratio drift of soft and hard edges C2 under Tabas earthquake

soft edge of the structure with increasing of eccentricity and have a decreasing rate hard edge of structure. This indicates torsion effects on structure by reducing the operation level of the structures.

Nonlinear Dynamic Analysis: For performing the nonlinear dynamic analysis on models of structures three types of acceleration, Tabas, Sylmar and Elcentro are selected. These earthquakes are combination of acceleration of some parts of Iran and other parts of the world that is prone to have more earthquakes. According to code they measured to maximum acceleration of 0.852g. After computing the maximum displacement against these three acceleration that is done for structure, displacement of other floors is computed at that time and ratio drift of floors will obtain and obtained outcomes for various structures are represented in Figures 4 to 9.

For controlling the operation point of structure the criterion of ratio drift of floors is applied. In consideration of guidelines of seismic improvement of existing structures for braced frames, we must contemplate the criterion of floor's ratio drift that presented in both constant and transient types [3]. In this table it is considered that the transient ratio drift for operation level of immediate occupancy (IO) is 0.5%, for life safety

Table 2: Maximum ratio drift of each structure

Structure	Maximum ratio drift (%)	Control	Operation
C1A	0.23	0.23<0.5	IO
C2A	0.32	0.32 <0.5	IO
C1B	0.26	0.26<0.5	IO
C2B	0.36	0.36<0.5	IO
C1C	0.34	0.34<0.5	IO
C2C	0.58	0.5<0.58<1.5	LS
C1D	0.61	0.5<0.61<1.5	LS
C2D	0.69	0.5<0.69<1.5	LS

operation level the transient ratio drift is 1.5% and the constant ratio drift is 0.5% and finally for collapse prevention operation level transient ratio drift is 2% and constant ratio drift is 2% too. For control the operation point of structures maximum ratio drift of floors of each structure must be used, that is presented in Table 2.

CONCLUSION

The philosophy of performing nonlinear dynamic analysis on asymmetric structures, is control the answers of static nonlinear analysis with dynamic non linear answers. With comparison of ratio drift results we can conclude that by increasing the eccentricity results became closer to each other. Symmetric and asymmetric structures that are designed for a level of risk according to general codes, don’t have an identical operation level. In consideration of Iranian code, the purpose of designing the residential structures with importance coefficient of 1 for earthquakes with risk level of 1 is life safety. Designing of these structures symmetrically and with eccentricity of 12.5%, 25% (A, B, C models) have identical operation level. These types' structures have immediate occupancy operation against earthquakes with level of risk of 1. With increasing the eccentricity, operation level decreases and changing kind of bracing, C1 into C2, ratio drift increased and operation level decreases. As respects that in all of these structures the mass centre was constant, so if the mass centre be changed, these structures may not fulfill the codes necessities and therefore the structure considered weak. With considering the height of building (16 m) by increase of eccentricity the results of nonlinear static analysis is closed to nonlinear dynamic analysis results. In the other word despite the asymmetric structures static nonlinear analysis can be used.

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