The new method for control and reduction Of torsion with base isolation

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Abstract:

To study the effect of torsion in seismic behavior of base isolated structures ,a symmetric four story concrete structure was chosen as the reference model. Then models with eccentricity of 5%,10%,15% and 20% of the dimension of the structure ,are considered. In nonlinear time history analysis, seven records on soil type C according to IBC2003 code normalize to peak ground acceleration equal to 0.4g are used. The isolations are made of rubber and they have modeled with bilinear behavior, in three types. The purpose of this paper is; studying of maximum isolation deformation among the other bases isolations, calculating the range of bases isolation eccentricity to super structure dimensions and decreasing the effect of torsion in base isolated structure, with stiffening the flexible edge.

Keywords: torsion, base isolation, nonlinear behavior

1. Introduction:

Using seismic isolation and energy absorption systems are two applicable methods to reduce the effects of earthquakes on structures. Changing the structural properties of a building, such as period and damping, these systems can optimize the structure operation, basically. The features of a base isolation system include; 1) horizontal flexibility to increase structural period and decrease earthquake effects (except in sandy soils), 2) energy absorption (damping) in structure to decrease the displacements, 3) efficient primary rigidity in small displacements to encounter environmental loads in service condition. Increase in horizontal flexibility of a structure results in decreasing the internal generated forces in the structure. Displacement decreasing in a base isolation system with a high damping, usually results in shear force decreasing. High damping systems are recommended to secure structural system, while low damping systems are applied to secure secondary systems and sensitive equipments in structures [1] .However, an introductory illustration will show the basic simplicity of the concept and the benefits to the structural engineer and owner of the building . Imagine a conventional steel frame building with beams and columns .At the foundation level ,the columns are connected to the foundation .Now imagine that a high-technology elements, called a base isolator is placed between the bottom of the column attached to the top and the foundation. Now imagine that an earthquake occurs and causes the base isolator and the building to deform .Because of the relatively flexible design of the base isolator , it will experience a large lateral deformation over its high (e.g.,10 to 20 in) [2].

2. Research steps:

2.1. Modeling

The recommended model is a 4-story concrete structure, which has a uniform plan dimensions and the same story high the dimensions are 20*10 (m2). In the X direction four frames with 5 meters width and in the Y direction three frames with 5 meters width and 3 meters height are considerd. The structure has modeled in 2 modes, fixed support and base isolation. The structural system is a bending frame in two directions and has three degrees of freedom which two degrees are translational and one degree is rotational. The structure is studied for five cases:

1. Superstructure with eccentricity (mass center and rigidity center are superposed).
2. Superstructure with 5% mass center eccentricity.
3. Superstructure with 10% mass center eccentricity.
4. Superstructure with 15% mass center eccentricity.
5. Superstructure with 20% mass center eccentricity.

The building is symmetric in respect to stiffness and mass center has a shift relative to rigidity center to cause the eccentricity which applied to the structure. In this modeling, IBC 2003 [3] is used for lateral loading, and according to the code, the structure is located in a high seismicity area on soil type3, and Iran's 519 code is used for gravity loading. SAP2000 was used to analyse, and ACI-305-02 code was used to design.

2.2. Mass Eccentric Models

In this study the structure has eccentricity in X direction and there is no eccentricity in Y direction. Considering a determined percentage of mass in all 4 determined nodes, which are located in 4 west sides of the plan, as shown in figure 1, the 5%, 10%, 15% and 20% mass eccentricity was applied to the structure.

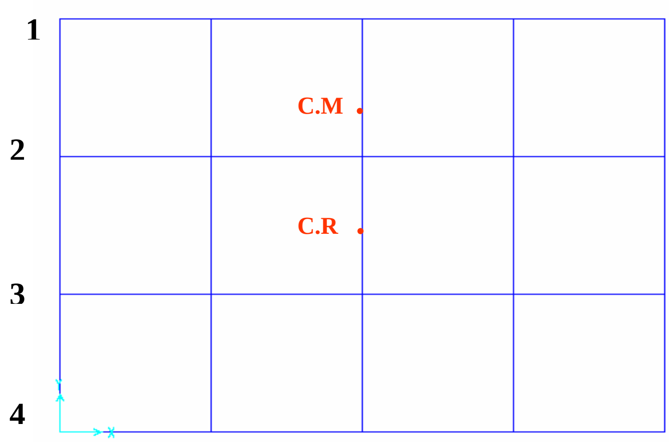


Figure1 Location of mass in determined nodes.

2.3. The modeling method of a base isolation structure

In order to design the base isolation IBC 2003 was used which referred to ASCE7. At first, considering the columns dead load, base isolation are designed, and as shown in figure 2 there are three types.

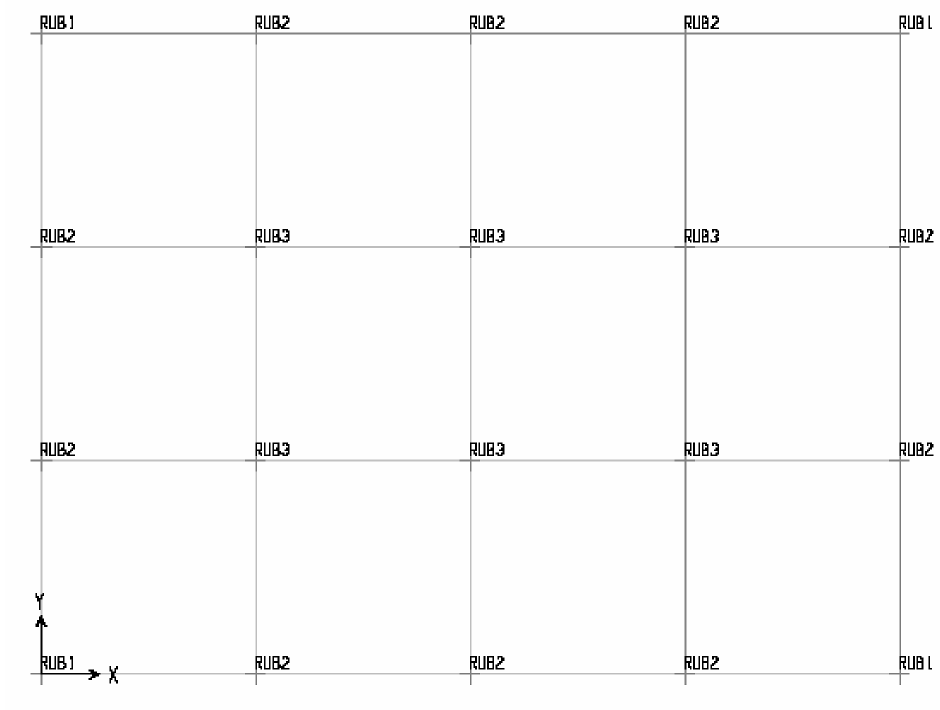


Figure 2 The types of base isolations.

The base isolations are elastometric, and their properties are shown in table 1.

Table 1 Base isolations properties.

Type Isolation	G (MPa)	Damping(%)	γ(%)
Rub1	0.40	4	150
Rub2	0.60	7	150
Rub3	0.80	10	150

In this study period T is 2<T<3, and base isolation system is bilinear with 10% of total structure mass yield force ($V_y/W=0.1$) and the, and post yielding rigidity is 10% of elastic rigidity($K_2/K_1=0.10$). The bilinear base isolation diagram is shown is figure 3.

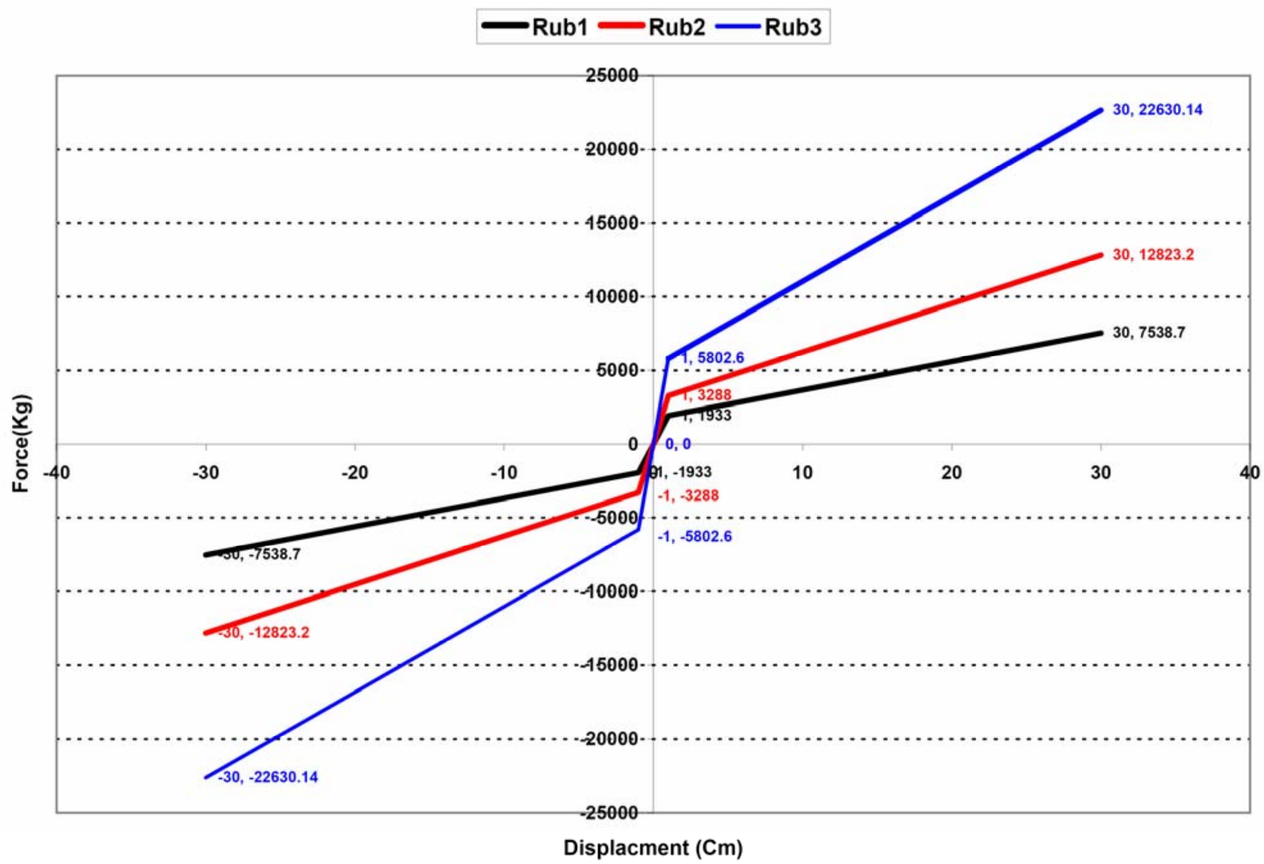


Figure 3 bilinear base isolation design.

2.4. Choosing Earthquake Ground Motion Records

To conduct nonlinear time history analysis, 7 ground motion records are used. The magnitude of these earthquakes are, $6.4 \le M_w \le 7.0$, and all of them are on soil type C in IBC2003 code. These 7 earthquakes are; 1.BIGBEAR 2. ELCENTRO 3. LONG BEACH 4. NORTHRIDGE 5. LOMA PRIETA 6. SAN FERNANDO 7. CAPE MENDOCINO.

Then all records are scaled to peak ground acceleration, equal 0.4g IBC2003 code spectra.

2.5. Nonlinear time history analyses in a fixed supported structure

The aim of these analyses is to study the plastic joints formation, and joints rotation values in beams and columns (structure damaging), stories relative deformation, flexible edge and stiff edge in the structure, comparing the joints rotations in beams and columns, stories relative deformation and stories rotation in each 5 eccentricities modes.

2.6. Nonlinear time history analyses in a base isolation structure

When the superstructure is designed again and isolations are chosen, the structure with 5%, 10%, 15%, and 20% eccentricities are analysed. Of course the base isolation structure period, compare with the fixed supported structure, is increased (See Table2).
According to seismograph respond spectra, this period is increasing, has made the base isolation structure, encounters with the acceleration less than the fixed support structure, and that is one of the reasons to use a base isolation system.

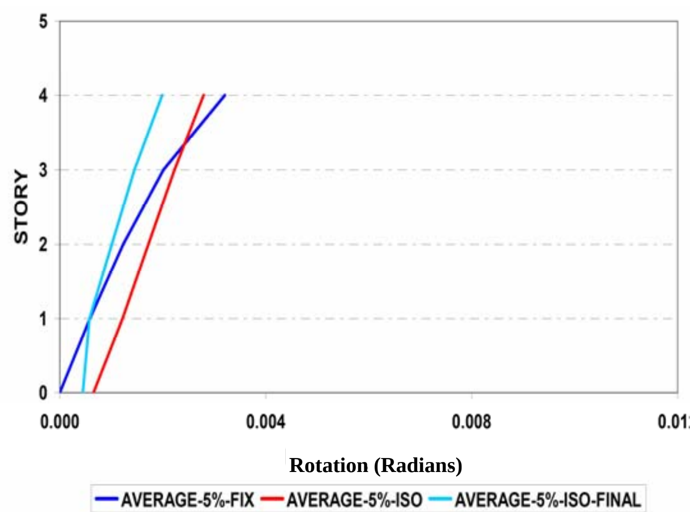
Table 2 The first and the second mode period in Fixed support structure and base solation structure

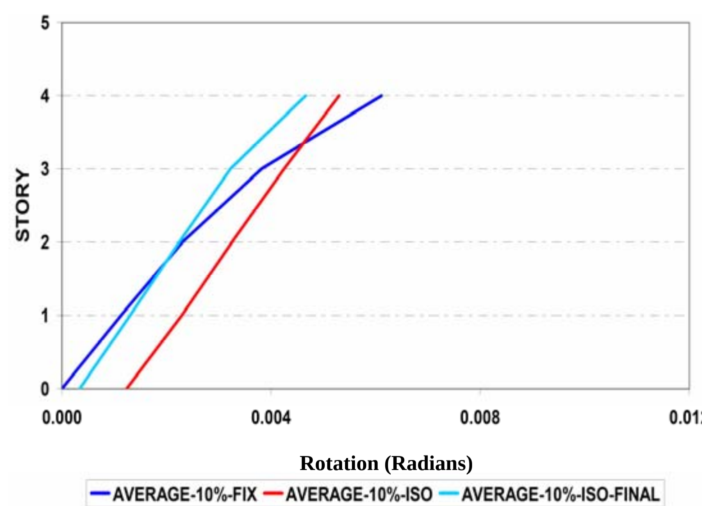
Mass eccentricity	First mode period in fixed support structure (Sec)	Second mode period in fixed support structure (Sec)	First mode period in base isolation structure (Sec)	Second mode period in base isolation structure (Sec)
0%	0.783	0.754	2.062	2.038
5%	0.784	0.754	2.086	2.038
10%	0.796	0.754	2.133	2.038
15%	0.813	0.754	2.197	2.038
20%	0.833	0.754	2.280	2.038

Now according to nonlinear time history analyses in base isolation structure, plastic joints rotation, stories relative deformation and stories rotation values are studies. As it is expected, plastic joints formation or structural damaging is resulted decreasing the relative deformation in base isolation structure comparing with fixed support structure.

2.7. Comparison of nonlinear time history analysis in base isolation structure and fixed support structure

A method for decreasing the effect of torsion in base isolation with 5%, 10%, 15%, and 20% eccentricity, is superposing the superstructure mass center with the rigidity center of the isolation system. In the base isolation structure, the isolations are arranged in three types symmetric. The base isolation rigidity center is located 7.5 meters far from coordination origin, and applying 5%, 10%, 15%, and 20% eccentricity of mass center in superstructure the distances will be 8.25 meters, 9.00 meters, 9.75 meters, and 10.50 meters, far from diaphragm geometric center. Now in order to superpose the base isolation rigidity center with mass center, the rigidity center location has to change. A method is increasing the stiffness of flexible edge, so rigidity center comes toward the superstructure mass center. To increase the rigidity of the flexible edge one approach is to change the dimensions and properties of the base isolation. It is worthwhile to say that, increasing the dimensions and properties the base isolation are limited reinforcing up to an unacceptable value is not possible. So using isolation with a lead core is recommended. For 5% and 10% eccentricities, increasing the dimensions and changing the properties, base isolation makes rigidity center to move and superpose with superstructure mass center, but for 15% and 20% eccentricities it is necessary to use a base isolation with a lead core. When applying the new base isolation and bringing the base isolation rigidity center toward superstructure mass center, nonlinear time history analysis for the 7 earthquakes with 5%, 10%, 15%, and 20% eccentricity was done, stories rotation average was derived and are shown in figure 4, the results have compared with last base isolation structure and fixed support structure. What is observed, is decreasing of stories torsion specially in base isolation structures with 5% and 10% mass eccentricity which is much more than base isolation structures with 15% and 20% mass center eccentricity, hence it is better to limit eccentricity to 10% [4]. Also what is valuable here is decrease in torsion decreasing in bottom of the base isolation structure in all eccentricities.





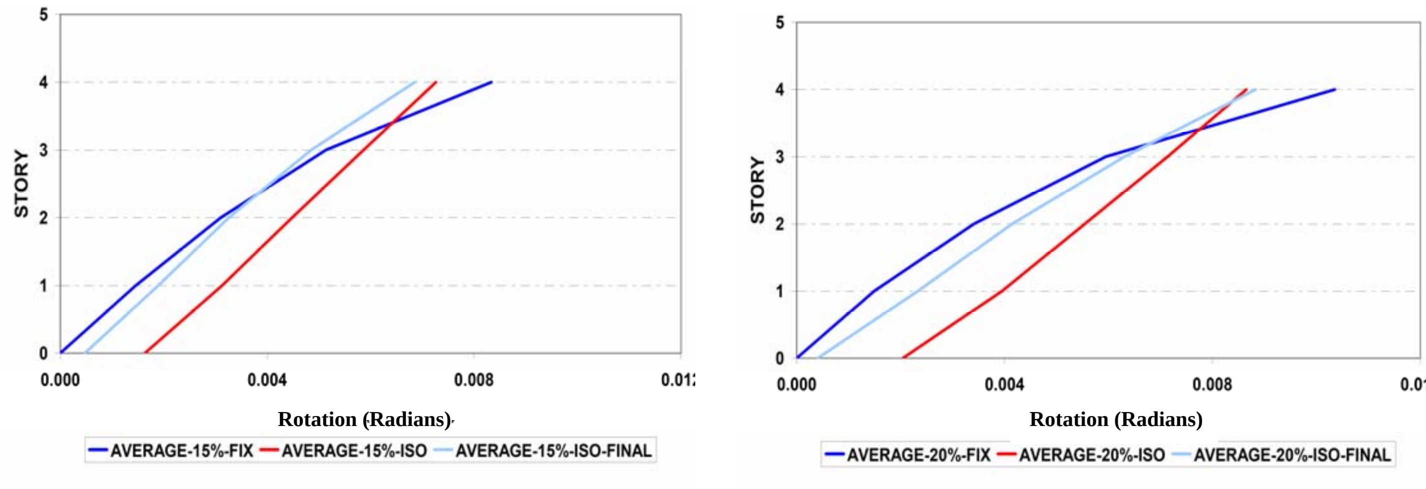
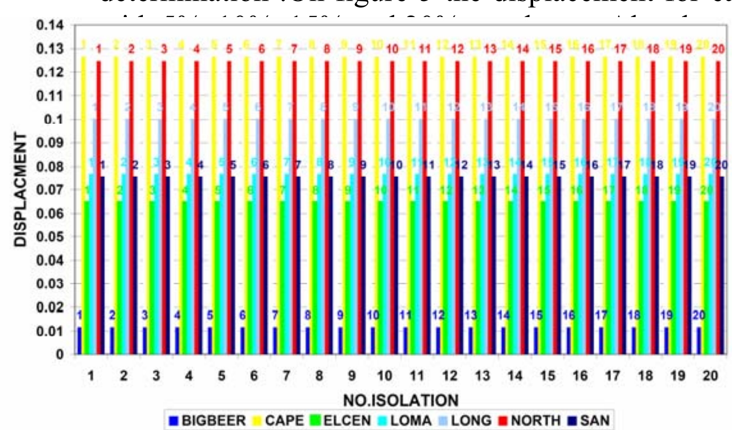
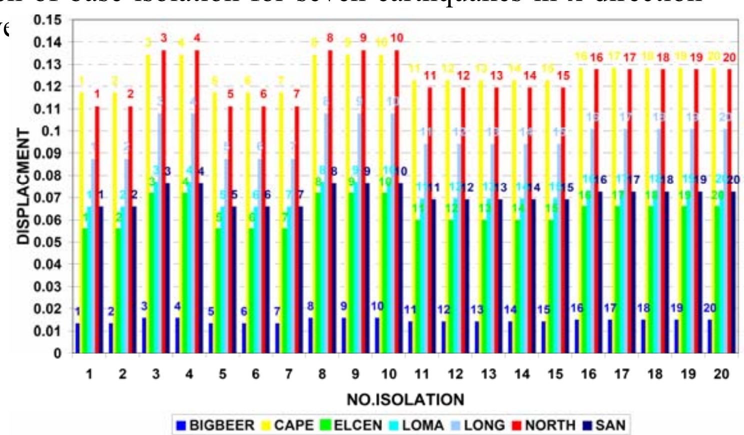


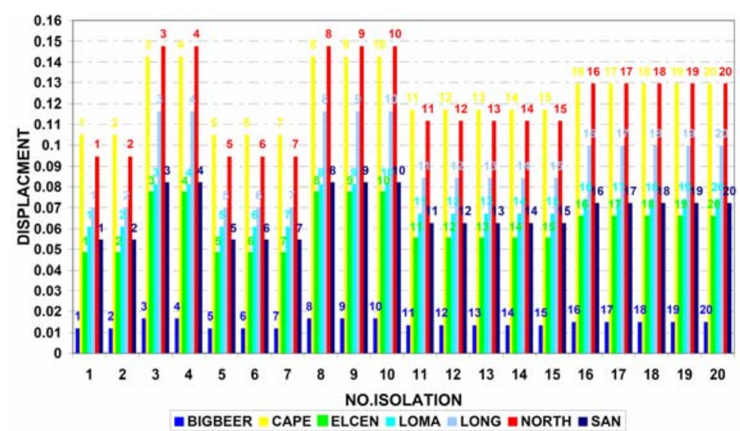
Figure 4 Rotation comparing in fixed support structure with base isolation structure
And base isolation with reinforced flexible edge.

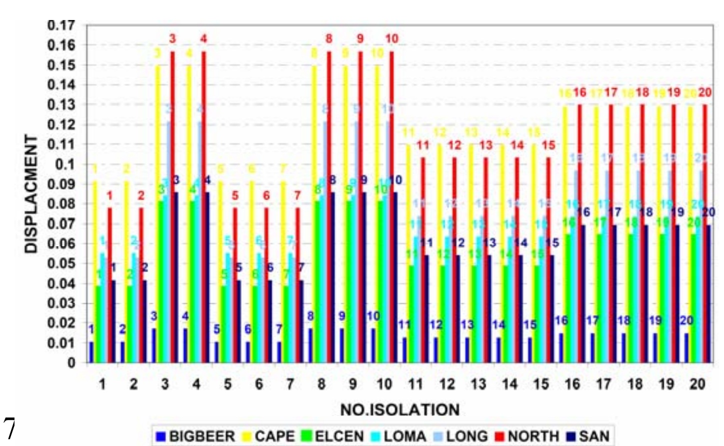
2.8. Peak isolation displacement in base isolation structure

After nonlinear time history analysis for 7 chosen earthquakes with 5%, 10%, 15% and twenty percent, eccentricities and base isolations classification it is the turn of base isolation peak displacement determination .On figure 5 the displacement for each of base isolation for seven earthquakes in x direction









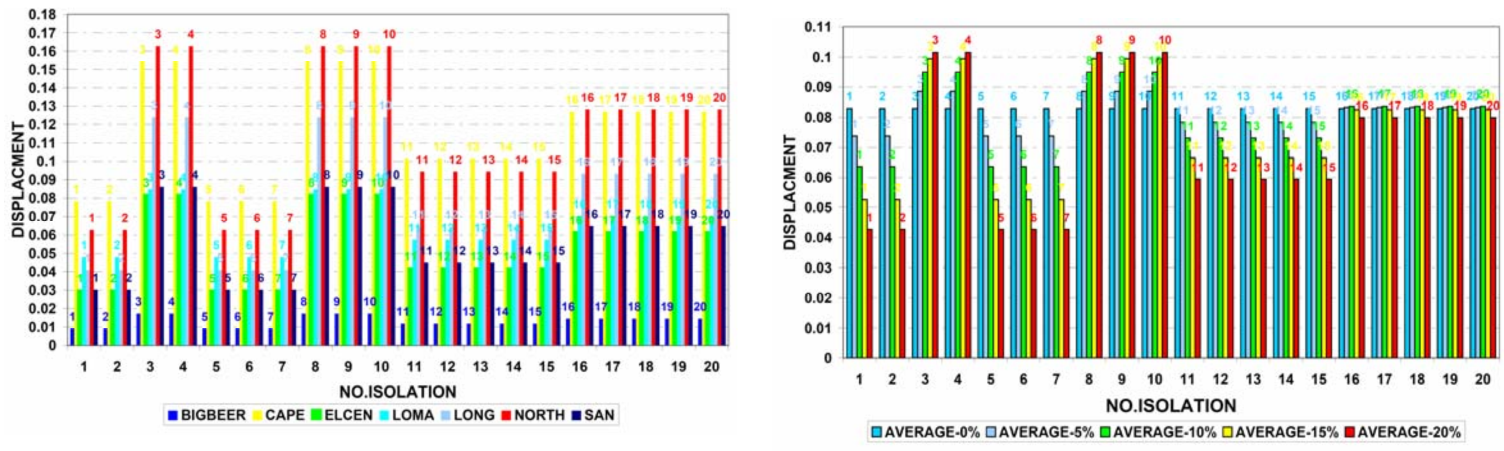


Figure 5 Base Isolation Peak Displacements In X Direction

According to figure 5, increasing eccentricity displacements values increase in flexible edge and decrease in stiff edge.

3. Conclusion

Using nonlinear time history analyses, beams and columns damages in fixed support structures and base isolation structures are compared. Plastic joints formation in base isolation structure beams and columns was low and an important result in base isolation structure is that beams unified damaging in the stories and not to damage (Not to form plastic joints) in bottom of columns comparing with fixed support structures which resulted to structure stability increasing, servicing after earthquake and not to damage to unstructural components. One of the other results in comparing of these two kinds of structure is the procedure of primary base isolation structure isolators are absolutely symmetric and are designed in three types and after non-linear time history analysis flexible edge and stiff edge are determined on the structure. According to base isolation rigidity centre with superstructure mass centre superposing, stories torsion value will decrease so it is needed to increase rigidity on flexible edge and decrease rigidity on stiff edge. But here according to base isolation damaging based on dead load, it is impossible to decrease stiff edge rigidity and the only way is to increase the flexible edge rigidity to move the rigidity centre.
Now in order to increase the isolation rigidity one has to increase the isolator dimensions or increase the physical properties such as shear modulus (G).
Here G is changed from $0.4<G<0.8$ to $0.4<G<1.6$ which means use of rubber isolations with higher damping. This method in 5% and 10% eccentricities is very useful and provides necessary rigidity in flexible edge and make isolation rigidity centre to move toward superstructure mass centre and make stories low rotation in base isolation structure comparing fixed support structure but in 15% and 20% eccentricities in order to move the isolation rigidity centre toward superstructure mass centre, as higher rigidity is needed for flexible edge, so just dimensions and G increasing are not sufficient and because of sections which get huge in these cases the better method is changing the isolation material.

Accordingly, two suggestion can be made 1) using LRB isolations (a rubber and steel plates composites) and 2) using LCRB isolation (isolation with lead core) [5].

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