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Base Isolation in Retrofitting an Existing Office Building in Pingliang City, China

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***Abstract*:** *A 4 story masonry-rehabilitated office building is advanced in base isolation in Pingliang City, to ascertain the structural response. The El Centro, Cholame – Shandon and the Delta Artif. are the ground motions used for the non-linear time history analysis. The SAP2000 software is employed in running the analysis and the lead rubber bearings, LRB 400 and LRB 500 are selected for the base isolation layer. The results obtained from the isolation analysis show significant reductions in the structural responses, effectiveness of usage of base isolation technology for the structural model and applicability for use in related structural types.*

Keywords: Base isolation*, SAP2000, masonry-rehabilitated structure, LRB, ground motions*

1. Introduction

Base isolation is a technique used in attenuating seismic ground motion effects, which has come as a new paradigm, for ensuring that a structure stays safe and does not collapse, especially in the event of an earthquake. The main aim for the use of the seismic base isolators is to decouple the structure from the earthquake action. It could also be from any other mode of vibration that needs to be isolated from other contents of a structure, such as in the case of a factory. The base isolation inculcates a low lateral stiffness within the foundation and the superstructure. It lengthens the fundamental period of the structure and reduces the structural response to earthquake action. Many methods of base isolation have been propounded, such as with the use of elastomeric isolators, friction sliding isolators, viscous dampers and the tuned mass or liquid dampers [1]. This paper concentrates on the effect of lead rubber isolators (LRB) on the inter-story displacements, inter-story drift angles, seismic load forces, shears, torsions, torsional angles, and moments for a masonry – rehabilitated reinforced concrete office building in Pingliang City of China. In other works, the acceleration, velocity and displacements were assessed on the use of the base isolators [2]. Comparison is made, mainly among the ground motions to verify the trend of the structural responses.

2. Structural Model

2.1. Retrofitting the structure

The 4 story existing structural model before rehabilitation was a masonry structure and with the update in the seismic code [3] of practice for China, the structure was found unfit in ultimate bearing capacity and seismic demands, that is to make mention of the seismic precautionary intensity of the situated region, as such the entire structure was advanced in rehabilitation (figure 3), strengthening the wall sections and introducing ring beams and construction columns to tie and hold the surrounding and linking structural members efficiently [3-5]. The floor plans for the model are given in figures 1 and 2. The story heights for the 1st, 2nd, 3rd, and 4th floors are 4.3m, 3.5m, 3.2m and 3.5m, respectively. The structure has dimensions of 43.2mX17.4X14.5m.

http://dx.doi.org/10.17758/UR.U0316345

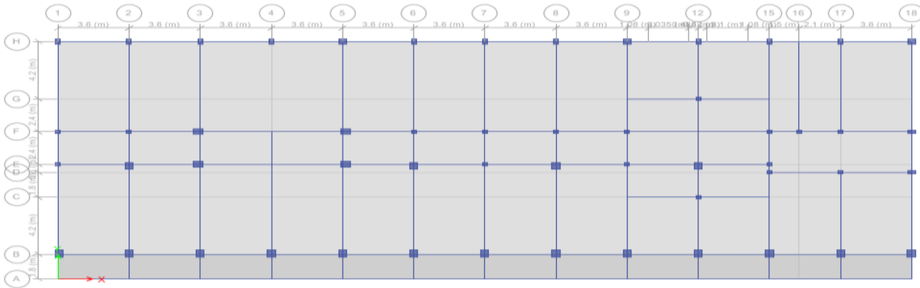


Fig. 1: 2nd Floor arrangement plans.

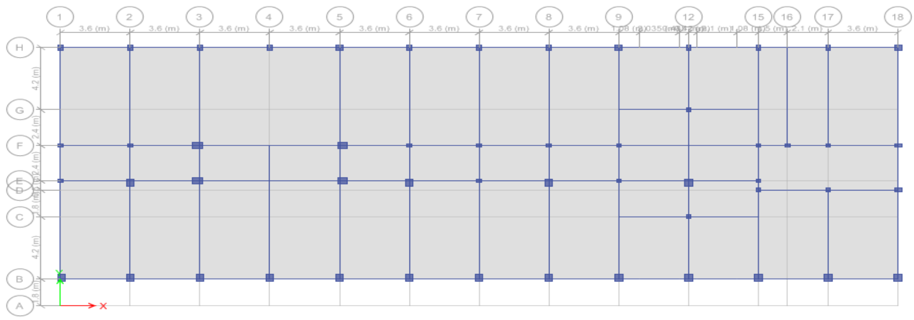
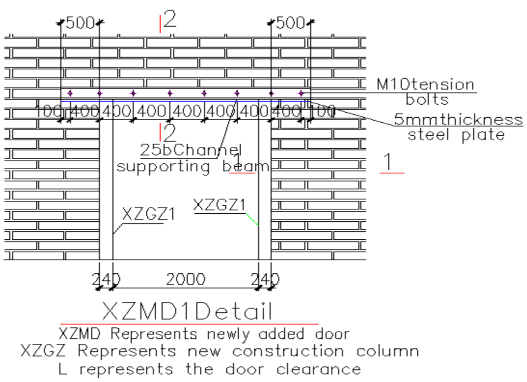
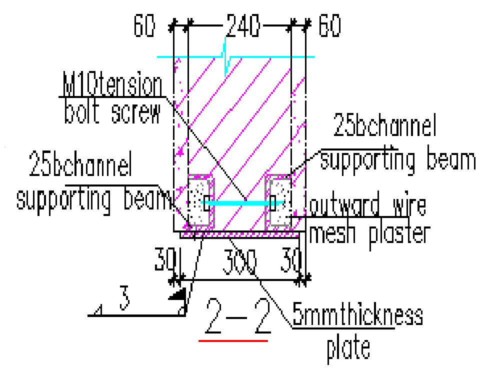


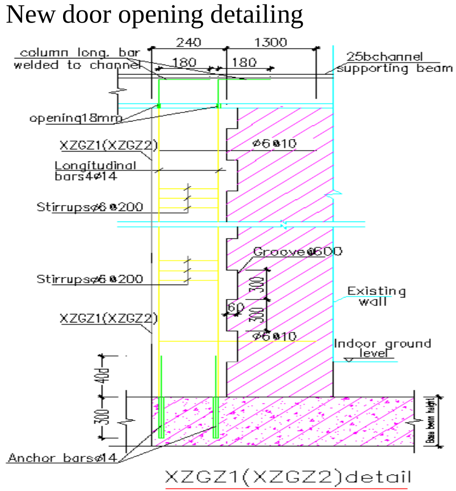
Fig. 2: 3rd to 4th Floor arrangement plans.



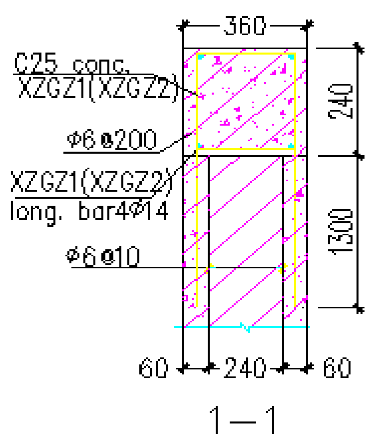
a) New door opening detailing



b) Section 2-2, new beam detailing



c) New column detailing



d) Section 1-1, new column detailing

Fig. 3: Some rehabilitation drawings.

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One of the typical rehabilitation floor plans is shown for the 3rd floor, as illustrated in figure 4. The structure is modelled in the SAP2000 analysis software. 3 ground motions are used, namely, El Centro, Cholame-Shandon and Delta Artif. (artificial ground motion); considering the x and y directions for each, and they are seen to conform to the selection criteria in the code [3].

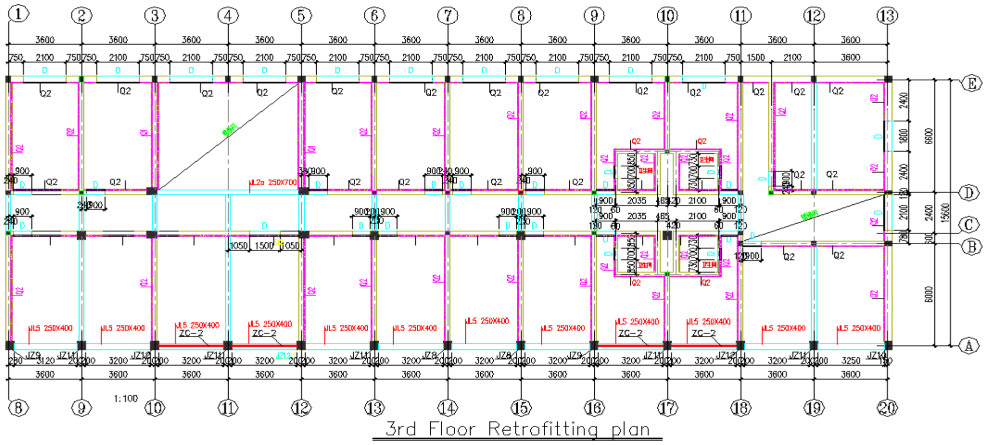


Fig. 4: Typical rehabilitation 3rd floor plan

2.2. Isolating the structure

The base isolators incorporated into the structure are the LRB 400 and the LRB 500 [6]. The figure 5a shows the cross section of an LRB [7] and figure 5b shows a period shift as one of the effects of using the LRB [8]. The fundamental period for the non-isolated structure is 0.492s and that of the isolated for the model is 1.992s. According to the equation of motion:

$$m\ddot{u}+c\dot{u}+ku=-m\ddot{u}_g(t) \tag{1}$$

the force that an isolation device transmits, can be given as

$$f_T = f_S + f_D = ku + c\dot{u} \tag{2}$$

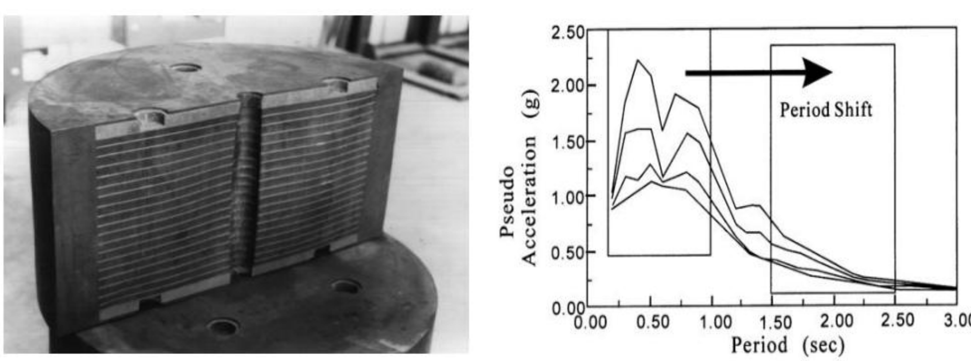
and the transmission force as Liu et al [9] state it :

$$TR = \frac{f_{T\max}}{P_0} = \sqrt{\frac{1+[2\zeta(w/w_n)]^2}{[1-(w/w_n)^2]^2+[2\zeta(w/w_n)]^2}} \tag{3}$$

when the rate of frequency

$$\frac{\omega}{\omega_n} > \sqrt{2} \tag{4}$$

the transmissibility (TR) is seen to be less than 1, and this is good for our isolation model



a) Section of a lead rubber isolator (LRB) [7] b) : Period shift in base isolation [8]

Fig. 5 Lead rubber isolator (LRB)

3. Isolation Results

3.1. Inter-Story Displacements and Drift Angles

The inter-story displacements are shown in the table 1 and the results are observed to conform to an acceptable trend within the floors. The inter-story drift angles, in table 2, show that the code's [3,4] specification of 1/100 has not been exceeded. This is a measure of ensuring that our model has not entered into the plasto-elastic phase, which when entered, is undesirable for our building.

TABLE I: The Inter-story displacements

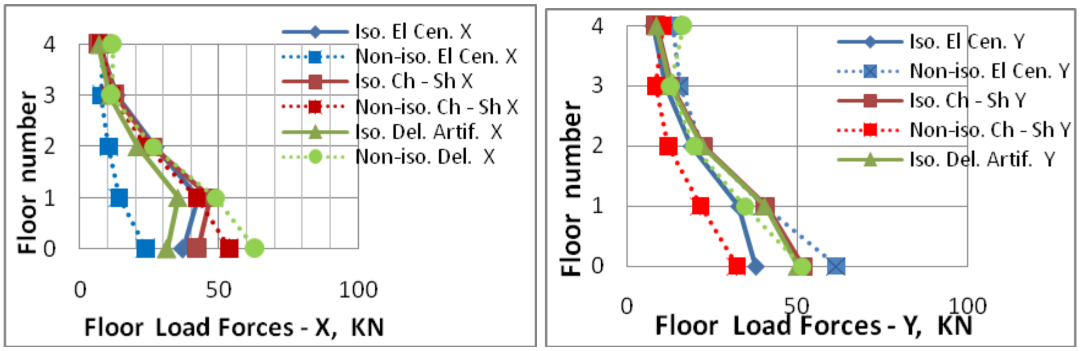
Parameter	Wave type	Direction	Isolated Structure			
			4th floor	3rd floor	2nd floor	1st floor
Inter-story Displacements (mm)	El Centro	X	1.16	1.96	3.69	11.21
		Y	1.38	2.41	5.18	13.98
	Cholame - Shandon	X	1.22	2.06	3.96	11.65
		Y	2.28	4.01	8.61	23.15
	Delta Artif	X	1.01	1.71	3.26	10.71
		Y	1.99	3.46	7.40	19.76

TABLE II: The Inter-story drift angles

Parameter	Wave type	Direction	Isolated Structure				
			4th floor	3rd floor	2nd floor	1st floor	Code specification
Inter-story Drift angles	El Centro	X	1/3016	1/1634	1/950	1/383	1/100
		Y	1/2530	1/1325	1/676	1/308	
	Cholame - Shandon	X	1/2866	1/1551	1/883	1/369	
		Y	1/1533	1/799	1/407	1/186	
	Delta Artif	X	1/3463	1/1877	1/1073	1/401	
		Y	1/1761	1/924	1/473	1/218	

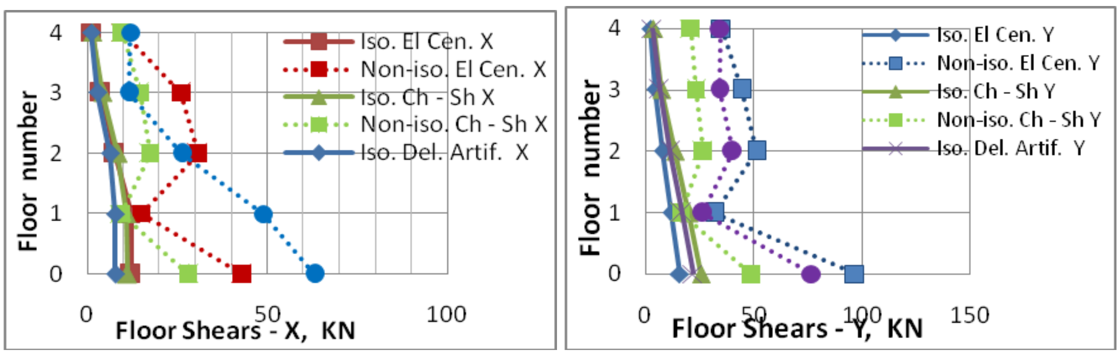
3.2. Other Structural Responses

The structural responses to the floor load forces, after isolation, in figure 6, are seen to have reduced for most of the ground motions. The isolated is displayed in solid lines and the non-isolated, in dashed lines. The floor shearing forces, in figure 7, reduced after base isolation was carried out and a more uniform trend is observed in the inter-story shears as opposed to that of the non-isolated building's. The masonry walls which are load bearing in this model are discontinuous, especially in parts of the 1st floor due to the functional usage of the building, as such the stiffness and mass centres are not coincidental. This effect is observed in the non-isolated building's floor torsions, in figure 8b, as there is a sharp decline in the floor torsions at the 1st floor (wall discontinuities), whereas the isolated has a rather streamlined effect as a result of the isolation. The figure 8a shows the same trend for both isolated and non-isolated conditions but in comparison, the former has larger values. The torsional angles reduced considerably in the x-direction of the isolated building in figure 9a and increased in y-direction, in figure 9b, due to a reduced number of lateral restraining structural members in the y-direction. The floor moments, in figure 10 followed a similar correlation to the floor torsions, but in the case of the isolated, the trend of moments within the floors is more streamlined as compared to the spatial distribution in the non-isolated.



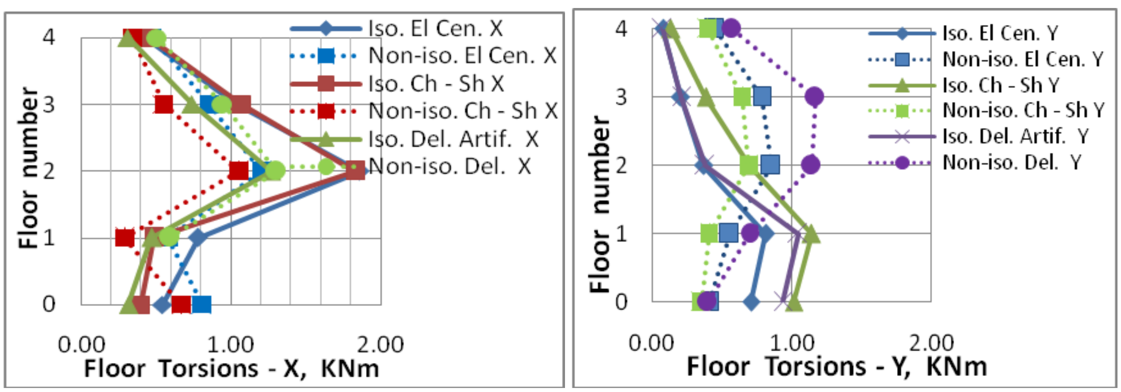
a) X - direction b) : Y - direction

Fig. 6: Floor load forces



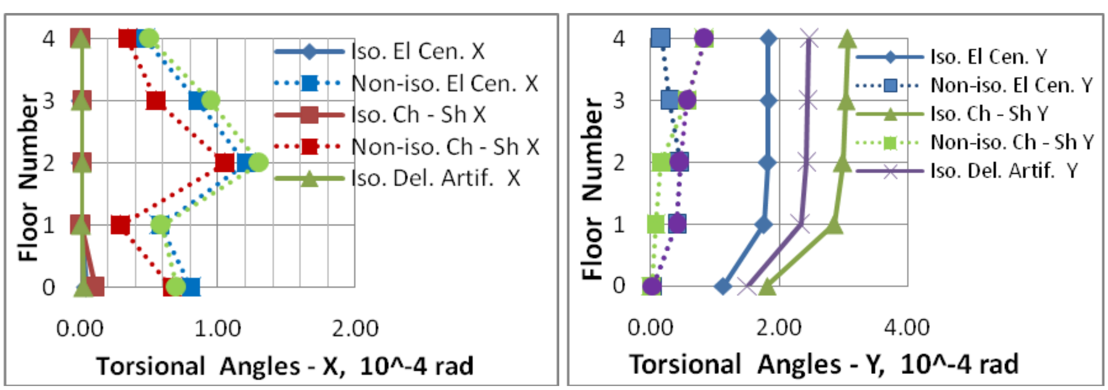
a) X - direction b) : Y - direction

Fig. 7: Floor shears



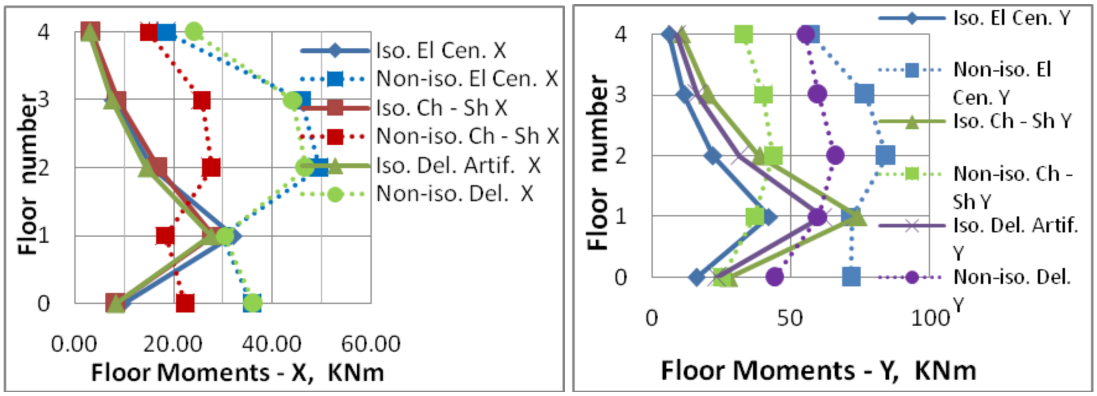
a) X - direction b) : Y - direction

Fig. 8: Floor torsions



a) X - direction b) : Y - direction

Fig. 9: Floor torsional angles



a) X - direction b) : Y - direction

Fig. 10: Floor moments

4. Conclusion

The base isolation carried out on the existing masonry-rehabilitated office building is seen to yield satisfactory results. The technology can be utilized for other structural types that might have similar characteristic features.

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