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A Comparative Study of Base Isolation and Interlayer Isolation Applied to a Twin Tower Shear-Wall Structure with Enlarged Basement While Considering Various Tower Heights

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Abstract: - Nowadays, engineers tend to apply seismic isolation technology into certain buildings to control the structural story drift, in order to protect the precision instrument inside or to maintain the integrity of the buildings during rare earthquakes. The application of seismic isolation technology in a Twin tower shear-wall structure with enlarged basement(2TSSLB) located above ground level has been studied by many researchers, but there is still relatively little research on which seismic isolation scheme is better for 2TSSLB when it has different tower heights, this forms a research gap. The main purpose of this article is to compare the story drift of this 2TSSLB using base isolation and interlayer isolation schemes under three various heights of towers. There are nine models in this study, which represent 14-story, 11-story and 8-story non-isolated structures, base isolated structures and interlayer isolated structures. In this study, ETABS was used for modelling, and those models were analyzed by the combination of response spectrum method and time history analysis method. Finally, on the premise of meeting the standard requirements, the story drifts of each model obtained under αmax (maximum horizontal seismic influence coefficient) =0.45 was compared. It is found that the story drift of these 2TSSLB with various heights has decreased significantly after using the isolation technology. Furthermore, the story drift of 2TSSLB using the interlayer isolation scheme with the isolation layer set on the top of the enlarged basement located above the ground level is lower than that of 2TSSLB using the base isolation scheme. The average story drift of the interlayer isolated structure is 18.5% lower than that of base isolated structure when this 2TSSLB consists of 14-story towers, this number becomes 30.7% when this 2TSSLB contains 11-story towers, and it increases to 31.9% when this 2TSSLB has 8-story towers. This implies that for the 2TSSLB structure, the structure adopting the interlayer isolation scheme has more safety redundancy than the structure adopting the base isolation scheme even if the tower heights changes.

Keywords: Seismic isolation, base isolation, interlayer isolation, story drift, safety redundancy.

I. INTRODUCTION

The earthquake poses a great threat to the safety of human life and property. It may lead to structure collapse, landslides, debris flow, ground cracking, pipeline damage and other events. In case of collapse of structures, serious personal injury or death may be caused. There were many studies of reducing the seismic responses of structures under earthquakes.[1-19] The design concept of traditional structure is to use its own stiffness to resist the seismic force, so as to ensure the safety of the structure during earthquakes. However, when the earthquake intensity exceeds the local basic fortification intensity, the traditional structure may not adapt to the new situation, and the buildings may be damaged or even collapse. In addition, in order to protect the sophisticated instruments inside certain buildings, some buildings have more strict control over their story drift under earthquakes. At this time, isolation technology with better seismic effects can be introduced. The principle of seismic isolation technology is to add an isolation layer in the middle or bottom of the structure, and then increase the structural period to reduce the seismic force exerted on the structure [20].

Many articles have studied the application of seismic isolation technology in buildings, especially in special complex structures. Nishimura et al.[21]designed and studied a structural system composed of three base isolated towers. Li et al. [22] studied the influence of different tower numbers and layout of multi-tower structure with an enlarged basement(the podium building) located above the ground level, including the twin-tower structure with an enlarged basement. Furthermore, Cao et al.[23] studied the seismic reduction effects of a twin-tower shear wall structure with an enlarged basement (2TSSLB) located above the ground level using different isolation schemes, and concluded that the seismic reduction effect of setting the isolation layer on the top of the enlarged basement(the podium building) located above the ground level is better than that of the base isolation scheme. However, for this kind of 2TSSLB, there are few studies on the influence of different tower heights on the selection of isolation

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schemes. The main objective of this paper is to compare the base isolation scheme and the interlayer isolation scheme of the 2TSSLB with different tower heights, so as to determine which isolation technology is more beneficial to the seismic resistance of this kind of structure.

The paper first gives an overview of the 9 models used, including their size, height, seismic precautionary intensity of the area and so on. Then the methodology used in this article are described, including the standards, the software, the results selection of time history analysis and response spectrum method, the concrete information, etc. After that, the story drift of these models under the maximum horizontal seismic influence coefficient(αmax) equals to 0.45 are analyzed. Finally, the article draws a conclusion based on the analysis results.

II. Overviews

The structure consists of two towers (tower A on the left and tower B on the right) and an "enlarged basement"(the podium building) located above ground level. Each floor is 3m in height and each tower is 30.5m in length and 9.2m in width (the narrowest part of the main structure). The enlarged basement spans a length of 93m and width of 26.1m. There are a total of 9 such 2TSSLB models (with different heights) in this study: M1-14 [24], M1-11, M1-8, M2-14 [24], M2-11, M2-8, M3-14 [23], M3-11 and M3-8. "M1", "M2" and "M3" shows different design scheme of this 2TSSLB respectively: "M1" refers to a non-isolated scheme, "M2" refers to a base isolated scheme, and "M3" refers to an interlayer isolated scheme. The total floor numbers of the corresponding model are also marked after "M1", "M2" and "M3". For example, M2-14 indicates that the 2TSSLB is the case that the main structure of model M2 has 14 floors (excluding the isolation layer and the protruding small house at the top). Their three-dimensional graphs are shown in Figure 1.

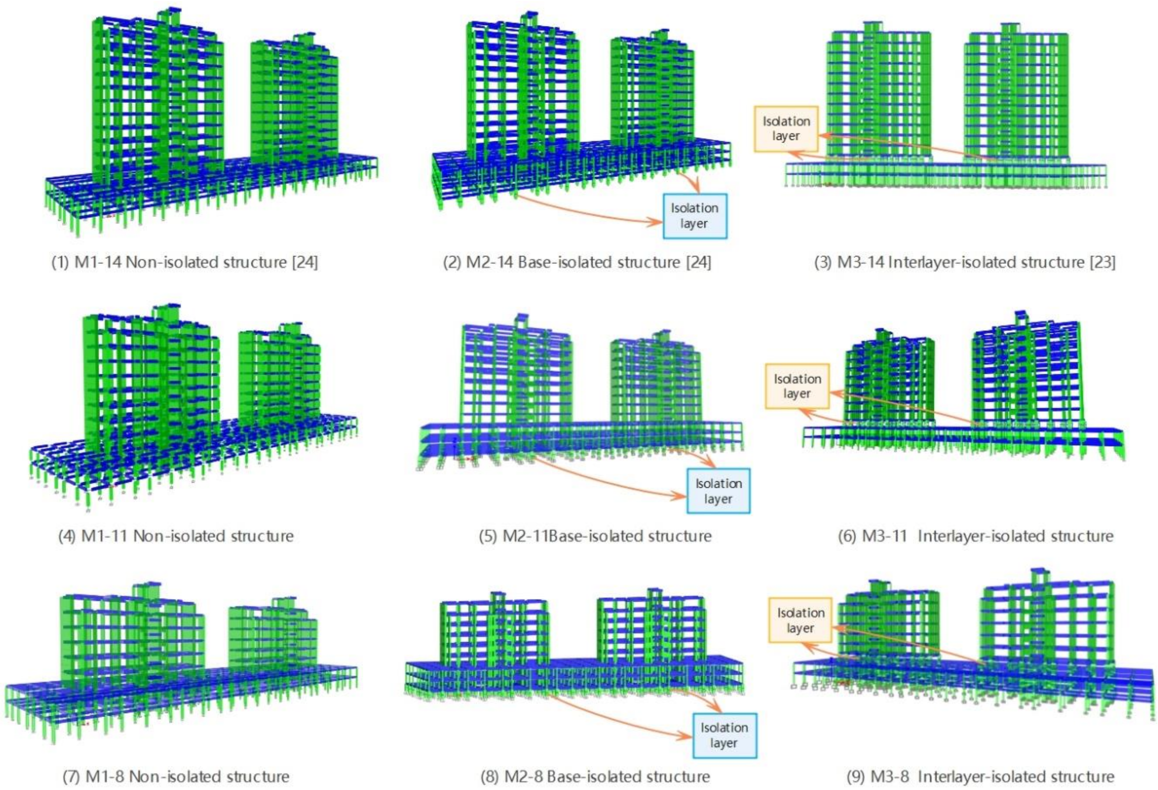

Fig.1 Three dimensional graphs of the model

The precautionary fortification intensity of the areas where these models are located is 8 degrees. The design of non-isolated structures adopts the maximum horizontal seismic influence coefficient αmax=0.16, based on [25], and the design of isolated structures adopts αmax=0.45 [26]. The story drift results of all models will be compared under earthquakes at basic fortification intensity of this area, that means αmax=0.45, obtained from [25]. In addition, the area where they are located is classified as Design Seismic Category I, and the site is recognized as Class II site, according to [25]. All the structures belong to Category C buildings, based on [27].

The structure implements two seismic isolation schemes, the base isolation employed in "M2" and the interlayer isolation employed in "M3". The isolation layer layouts of both base isolated structure(M2) and interlayer isolated structure(M3) remain consistent as the tower heights change, as shown in Figure 2[24] and Figure 3[23]. Moreover, the detailed information of isolation bearings is shown in Table 1[28].

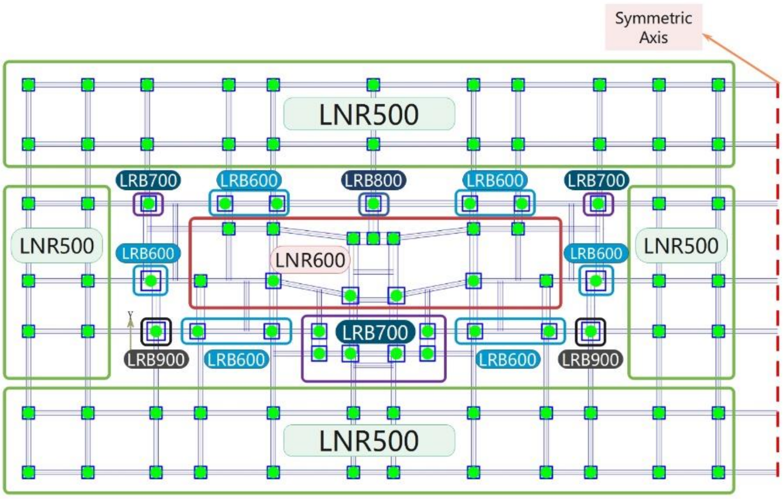

Fig.2 The layout of isolation layer of base isolated structure, adapted from [24]

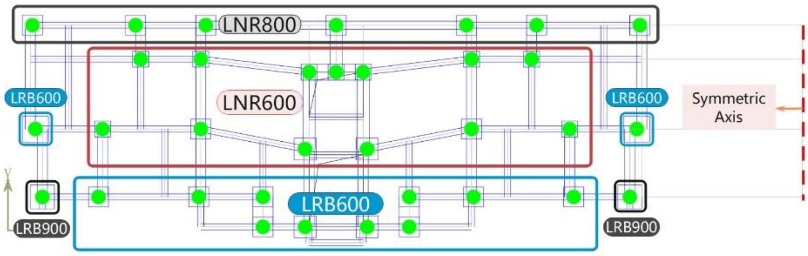

Fig.3 The layout of isolation layer of interlayer isolated structure, adapted from [23]

Table 1：The Details of Isolation Bearings [28]

Types With diameter in mm. and (heights)	Directions	Linear Properties			Non-Linear Properties			GAP Effective stiffness in kN/mm
		Effective stiffness for compression (kN/mm)	Effective stiffness for Tension in kN/mm	Effective stiffness at 100% deformation (kN/mm)	Stiffness in kN/mm	Yield Strength in kN	Post Yield Stiffness Ratio	
LNR500 (140mm)	U1 U2 U3	1600	160	0.81 0.81				1440
LNR600 (165mm)	U1	1900	190					1710
	U2			0.98				
	U3			0.98				
LRB600 (165mm)	U1	2200	220					1980
	U2			1.58	13.11	63	0.077	
	U3			1.58	13.11	63	0.077	
LRB700 (195mm)	U1	2600	260					2340
	U2			1.87	15.19	90	0.077	
	U3			1.87	15.19	90	0.077	
LRB800 (225mm)	U1	2900	290					2610
	U2			2.05	17.35	106	0.077	
	U3			2.05	17.35	106	0.077	
LRB900 (250mm)	U1	3500	350					3150
	U2			2.37	19.67	141	0.077	
	U3			2.37	19.67	141	0.077	

III. METHODS

The model design in this study is based on Code for Seismic design of Buildings [25] and Standard for seismic isolation design of building [26]. As Figure 4 shows, the model is built by ETABS and analyzed under the consistent maximum horizontal seismic influence coefficient $\alpha max=0.45$. Two analysis methods are used in this research, they are response spectrum method and time history analysis. In the time-history analysis method, seven seismic waves, including five artificial waves and two natural waves, are selected according to [26]. The results of time history analysis under these 7 seismic waves are averaged as the result of time history analysis, and the maximum value of time history analysis and response spectrum method will be selected as the final result. Due to the large number of models used in this study, story drift, which can best reflect the structural stability and safety redundancy, will be used as the only comparison parameter to facilitate the derivation of effective and clear conclusions. Since this is a symmetric 2TSSLB structure, the story drift results of tower A and tower B are similar, and their average values are taken to represent the results of the towers.

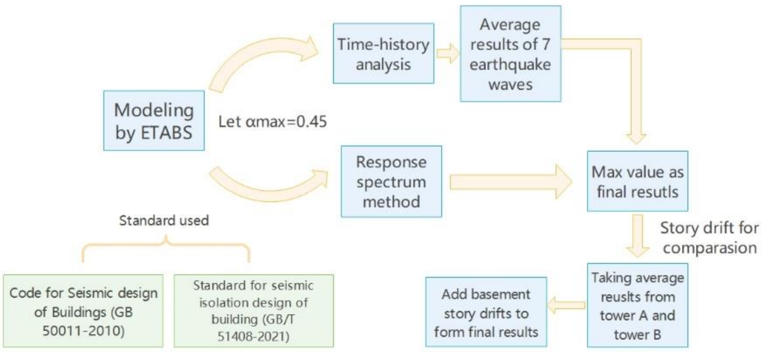

Fig.4 The flow chart of the analyzing progress

Additionally, there are some specific floors that do not participate in the structural comparison.The first one is the top layer of the structure. Due to the fact that the top floor of this structure is a small protruding house, its calculation results do not affect the safety of the main structure therefore, this floor was not considered in the comparative study. The second one is the structural isolation layer. Since the isolation layer does not undertake any building function, the parameters of the isolation layer only need to meet the requirements of the code, and will not participate in the comparison of structural results.

Moreover, high-strength concrete C85 is adopted for all structures, with its shear modulus G=15975Mpa, elastic modulus E=38340MPa and standard compressive strength value Fck=53.4Mpa.The utilization of high-strength concrete allows the structure to be smaller in size, thus to better fulfill the building's function.

IV. RESULTS

A. *Condition of 2TSSLB with 14 levels*

Figure 5[23] and Figure6[23] show the story drift of M1-14[24], M2-14[24] and M3-14[23] in the X and Y directions.

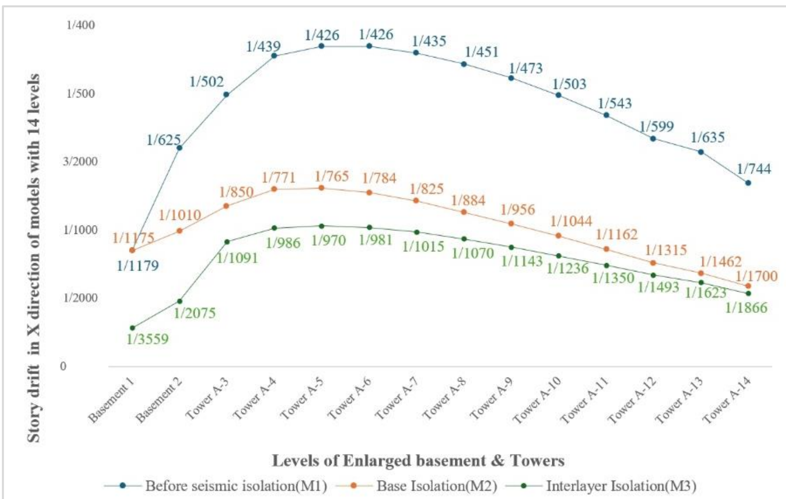

Fig.5 The story drift in X direction of models with 14 levels, adapted from[23]

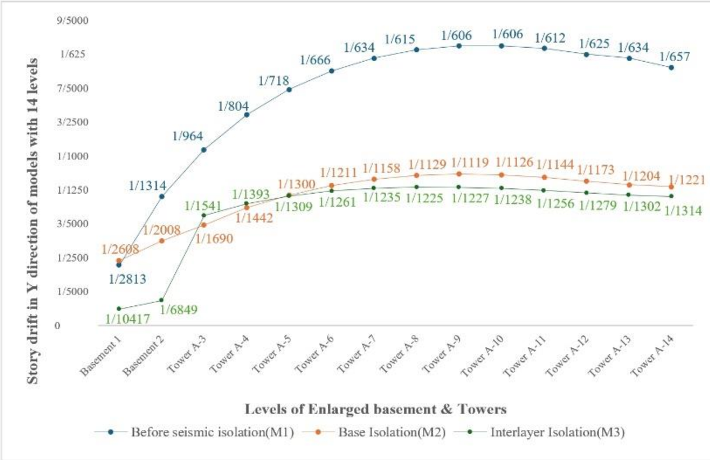

Fig.6 The story drift in Y direction of models with 14 levels, adapted from[23]

As can be seen from the figures, all the isolation schemes (M2-14 and M3-14) greatly reduce the story drift of this 2TSSLB[23]. Compared with the story drift of the base-isolated structure (M2-14), the story drift of the interlayer isolated structure (M3-14) is 22.6% less in the X direction, 14.3% less in the Y direction, thus averaging 18.5% less in both directions.

It's worth noting that the story drift reduces significantly in the level "basement 1" and "basement 2" of M3-14 the interlayer isolated structure. This is because in order to install a seismic isolation layer on top of the enlarged basement, the isolation supporting piers must be installed in the first two levels within the basement, which indirectly increases the stiffness of the level "basement 1" and "basement 2". Therefore, the safety redundancy increases on corresponding floors[23].

B. *Condition of 2TSSLB with 11 levels*

The story drift of M1-11, M2-11 and M3-11 in X and Y directions are shown in Figure 7 and Figure 8.

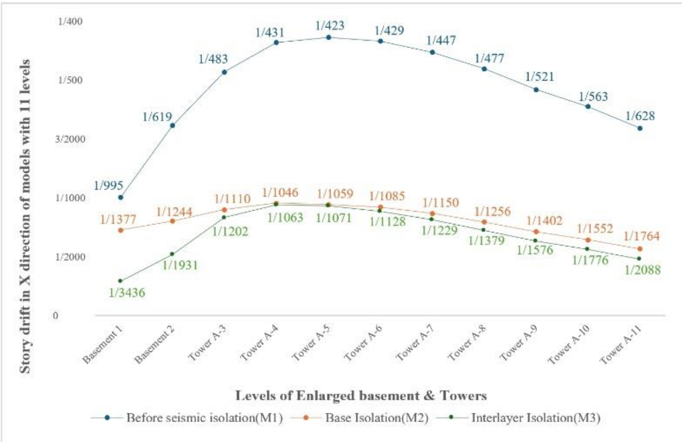

Fig.7 The story drift in X direction of models with 11 levels

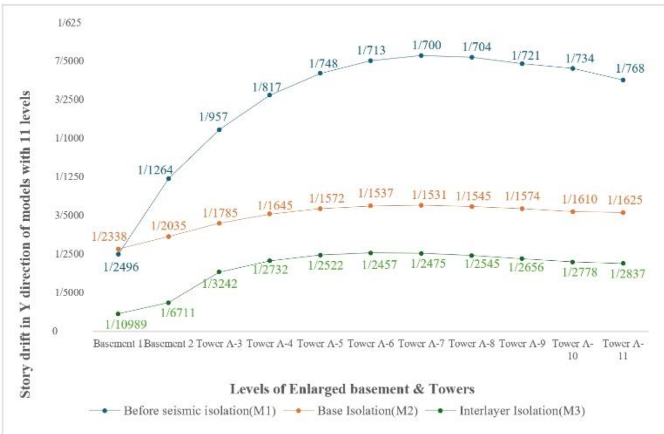

Fig.8 The story drift in Y direction of models with 11 levels

As the figure shows, both the base isolation scheme and the interlayer isolation scheme(M2-11 and M3-11) significantly decrease the story drift. The story drift of interlayer isolated structure (M3-11) is average 14.9% lower in X direction, average 46.5% lower in Y direction, and average 30.7% lower in both directions than that of base isolated structure (M2-11).

C. Condition of 2TSSLB with 8 levels

The story drift of M1-8, M2-8 and M3-8 in X and Y directions are illustrated in Figure 9 and Figure 10.

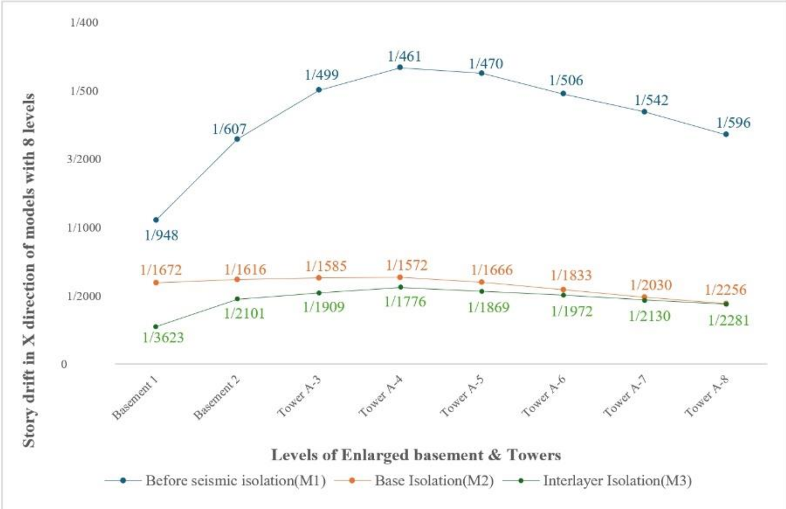

Fig.9 The story drift in X direction of models with 8 levels

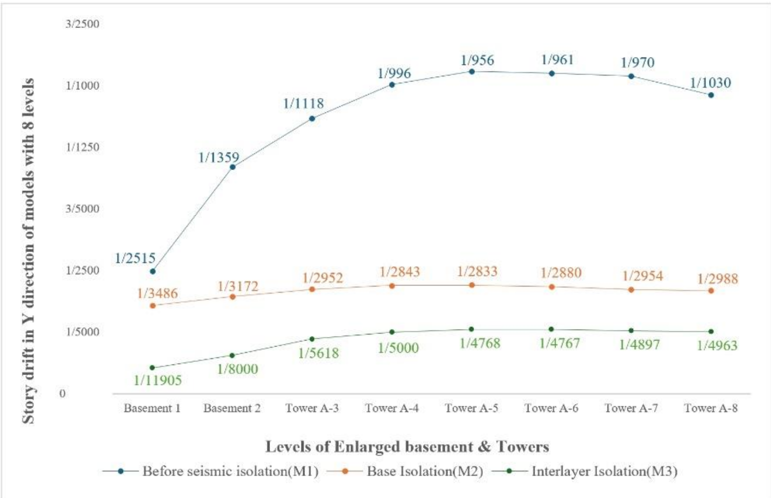

Fig.10 The story drift in Y direction of models with 8 levels

Similarly, it can be seen from the figure that the story drift of the structure is greatly reduced after the application of isolation techniques, including both base isolation and interlayer isolation. Among them, the effect of M3-8 with interlayer isolation technology has superior performance. The story drift of M3-8 is average 16.14% lower in X direction, average 47.66% lower in Y direction, and average 31.9% lower in both directions than that of M2-8 using base isolation.

V. CONCLUSIONS

This study compared the story drift of 2TSSLB using base isolation and interlayer isolation schemes at different heights, which are 14, 11, and 8 stories. The height-to-width ratios of the tower (excluding the isolation layer and the protruding small house at the top) are 4.56, 3.59, and 2.61, respectively. The study reached the following conclusions:

- For 2TSSLB structures with different heights (the height-to-width ratio of the tower varies from 2.61 to 4.56), after the application of base isolation or interlayer isolation technology, their story drift decreases significantly, which proves the effectiveness of isolation technology for such structures at different heights.

- The use of an interlayer isolation scheme with isolation layers set on the top of the enlarged basement (the podium building) for 2TSSLB structures of different heights (the height-to-width ratio of the tower varies from 2.61 to 4.56) yields better results than the base isolation scheme.
  Specifically, the story drift obtained by the interlayer isolation scheme(M3) is lower than that of the base isolation scheme(M2): 1) For the 14 story 2TSSLB, the average story drift of M3-14[23] is 18.5% smaller than that of M2-14[24]. 2) For the 11 story 2TSSLB, the average story drift of M3-11 is 30.7% smaller than that of M2-11. 3)For the 8 story 2TSSLB, the average story drift of M3-9 is 31.9% smaller than that of M2-9
- When designing this kind of 2TSSLB, priority can be given to the scheme of interlayer isolation in order to improve structural safety redundancy. In addition, it is also necessary to consider the challenges of isolation bearing maintenance and economic factors.

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