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SEER-IPLAT: THE ISOLATED PLATFORM FOR SEISMIC MITIGATION

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Abstract:—This paper presents finite element study of a four-storey steel frame building under Pomona earthquake. Time history of the earthquake ground motion was used to investigate the seismic response of the prototype building that was not designed for any earthquake resistance. The building was designed according to BS 5950: 2000 under vertical load only. A newly proposed seismic isolation platform, namely Seer-iPlat was tested for its feasibility and functionality in mitigating the seismic threat. The system was a modification of existing base isolation technique into isolating only each respective floor instead of the whole building. Such method if proven to be efficient would be beneficial in rehabilitation of existing or older building such as museums, hospital surgery room, and sensitive operational center. As the existing ductility design or seismic isolation approach seemed to be requiring more complicated effort in implementation particularly for existing building, Seer-iPlat would resolve this problem. From the analysis results, it was clearly revealed that by installing Seer-iPlat, the column axial force, storey shear and moment was reduced significantly by 63.2, 67.0 and 71.2 percent respectively. Therefore, it has been proven that Seer-iPlat was effective enough in rehabilitation of existing building in terms of seismic threats.

Keywords:—base isolation, isolation platform, seismic, seismic rehabilitation, steel frame building

I. INTRODUCTION

Seismic design code provisions such those contained in Eurocode [1] and International Building Code [2] provide fundamentally two types of structural earthquake designs. Firstly, the conventional ductile structural design. Higher ductility is achieved by structural system possessing larger capacity to deform into its nonlinear region without failure. This is achieved by allowing certain minimal structural damage during earthquake excitations. While the energy of ground shaking is absorbed by these minor cracks spread throughout non-critical region within the building, possible collapse is avoided. Other term for such ductility design is strong column weak beam design philosophy. It is always desirable for structures to suffer beam failure instead of column during severe ground motion. Thus, more stringent reinforcement detailing is often provided at column intersections, allowing plastic hinge to be formed along adjacent beam. Nevertheless, the actual failure mechanism may not always follow such intention in reality. The occurrence of non-structural element such as infill wall may impede the beam element to fail as it should [3]. When this happens, those supporting columns will still be hinging due vast energy being built-up.

Engineers often faced a repetitive dilemma in finalizing their seismic design procedures. A flexible structure will be transmitting lesser acceleration due to the higher flexibility of the structure in absorbing ground movement. However, such behavior requires the engineers to compromise the inter-storey drift response. On the other hand, a rigid structure stands firm during ground motion. Although the inter-storey drift problem is minimized, the ground acceleration will be transferred or sometimes amplified when moving up the building. The second type of earthquake mitigation design is called the structural control concept. One of the methods among this concept is the base isolation approach. The basic theory underlying this method is to decouple the superstructure or building from the severe ground movement. Such attempt is made possible by introducing an isolation layer between the base of building and supporting foundation beneath. Over the past decades, development of elastomeric rubber bearing as base isolator [4 to 6] had contributed to the practicality of seismic base isolation.

Nevertheless, both the seismic mitigation approaches presented earlier are meant for newly designed buildings which are to be constructed. Rehabilitating existing building and their structural counterparts by either providing ductility design or base isolation technique require not only extensive analysis procedure, but also relatively complicated implementation. Taking for example, an existing building needs to be lifted up by jacking before the isolation system is inserted. Thus, a method is proposed in this study to reduce the seismic effects of building structural system by providing an innovated isolation platform (Fig.1) at each floor throughout the building, instead of isolating the whole superstructure itself. The system is named Seer-iPlat. Seer refers to the name of the research group of Structural Earthquake Engineering Research and iPlat simply denotes isolation platform.

It was anticipated that the market of Seer-iPlat would be vast. Unlike the conventional seismic base isolation technique that requires isolating the whole superstructure from ground movement, such product could be standardized in size to accommodate loading of internal floors only. Therefore, there was no implication in determining the quantities of rubber bearing used, and also location of them beneath the platform. However, before the product is being developed further or studied extensively particularly for its manufacturing purpose, the feasibility of such proposal needs to be identified prior to any further research indication. At least, the efficiency of such system could be proven first in seismic mitigation approach. This therefore forms the fundamental requirement that this paper addresses.

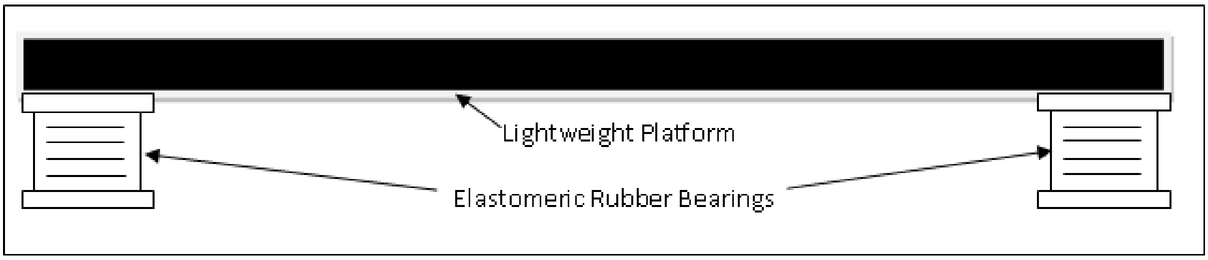

Figure 1. Seer-iPlat: The seismic isolated platform

II. RESEARCH SIGNIFICANCE

This paper investigates the feasibility in providing seismic mitigation of building structural system by proposing to seismically isolate each respective floor. Such application would be beneficial to protect artifacts within museum, hospital surgery room, and special equipment room for sensitive operational buildings. Among few benefits demonstrated by the seismic isolation platform over conventional base isolation system is the standardization of rubber bearing sizing. In addition to that, implementation as well as installation onto existing building is relatively straightforward and easier. This would contribute to effective seismic rehabilitation and mitigation of older buildings.

III. METHODOLOGY

This study adopted mainly the finite element analysis to investigate the possibility in isolating only the floor level of each floor of a four-storey building, as shown in Fig. 2. The building structural components comprised a single-bay frame having width of 8.0m. Spacing among each storey level was 4.0m high. The frame was assumed to be internal frame which supported two spans of slab of 8.0m in length, too. The structural elements of the building consisted primarily steel elements. Designed in accordance to British Standard BS 5950: 2000 [7], the structure elements are listed in Table 1. The demand-over-capacity ratios of all structural steel components were kept below 1.0, with no-earthquake loading being considered for selection of the element sizes.

Only self-weight of the structure was taking into consideration as the total mass for all analysis cases. This self-weight was accumulated from the total weight induced by the weight of concrete floor at each floor. Considering the length of 8.0m in both direction supported by the internal frame, the total vertical loading acting on all respective floors was 38.4N/mm. Meanwhile, the loading at roof level was taken only as half of the former value, contributing to 19.2N/mm.

Time history analysis using the ground motion record of Pomona earthquake (Fig. 3 to Fig. 5) was performed onto the normal building system and also the frame having isolation platform at each level (Fig. 6). The purpose of conducting the time history analysis was to obtain the dynamic response of structure under earthquake excitation. The frame element was used to define all structural elements, while the platform was defined by concrete property. Meanwhile, nonlinear link was used to model the Seer-iPlat.

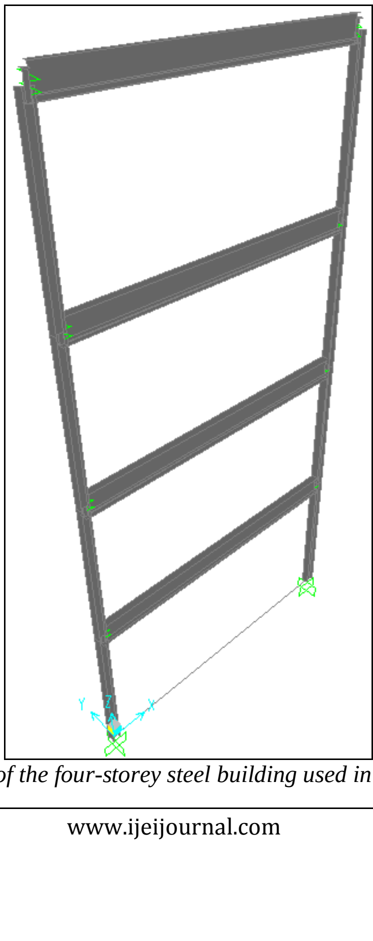

Figure 2. Illustration of the four-storey steel building used in finite element analysis

Table 1. Structural steel elements of the building

Items No.	Items	Steel Section	Capacity Ratio
1	4th storey beam	UB 457 x 191 x 98	0.186
2	3rd storey beam	UB 457 x 191 x 98	0.295
3	2nd storey beam	UB 457 x 191 x 98	0.284
4	1st storey beam	UB 457 x 191 x 98	0.309
5	4th storey column	UC 203 x 203 x 71	0.314
6	3rd storey column	UC 203 x 203 x 71	0.458
7	2nd storey column	UC 203 x 203 x 71	0.583
8	1st storey column	UC 203 x 203 x 71	0.609

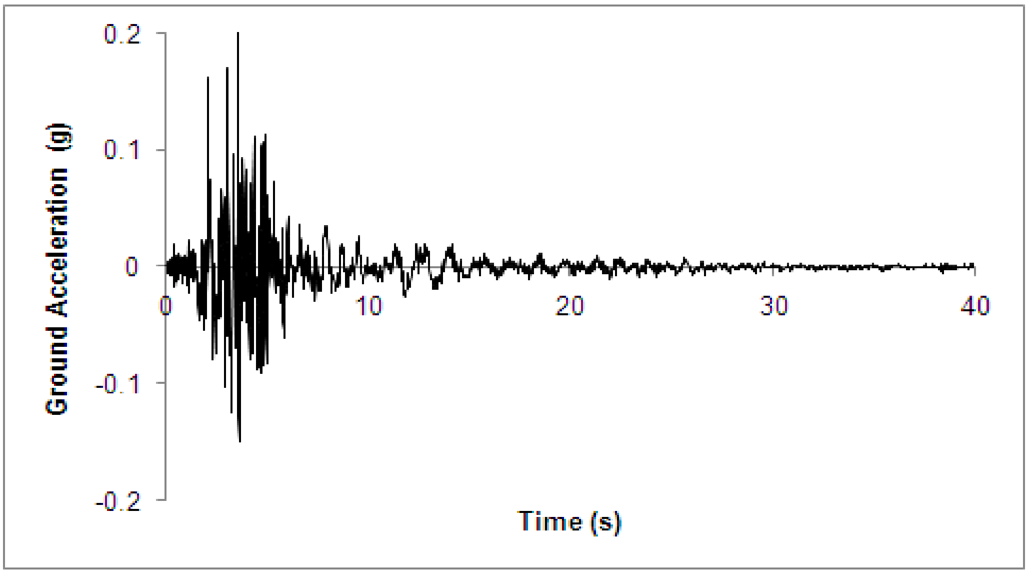

Figure 3. Pomona earthquake ground acceleration time history

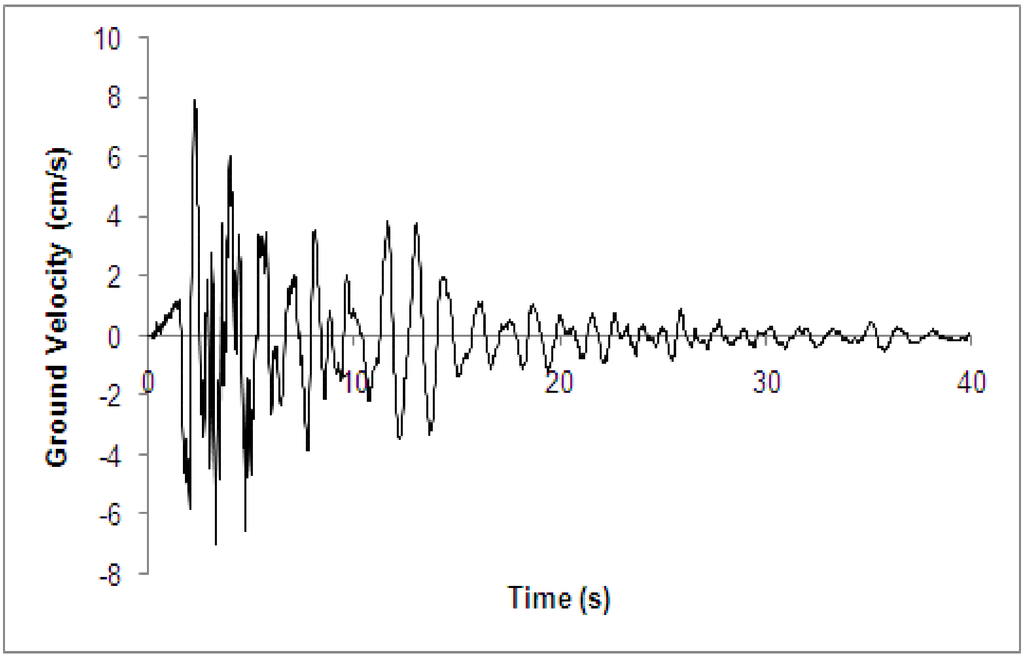

Figure 4. Pomona earthquake ground velocity time history

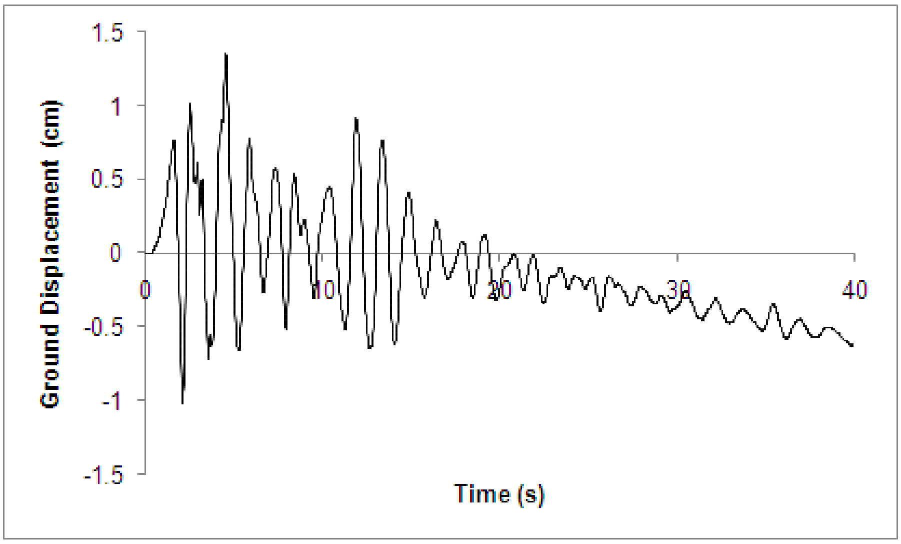

Figure 5. Pomona earthquake ground displacement time history

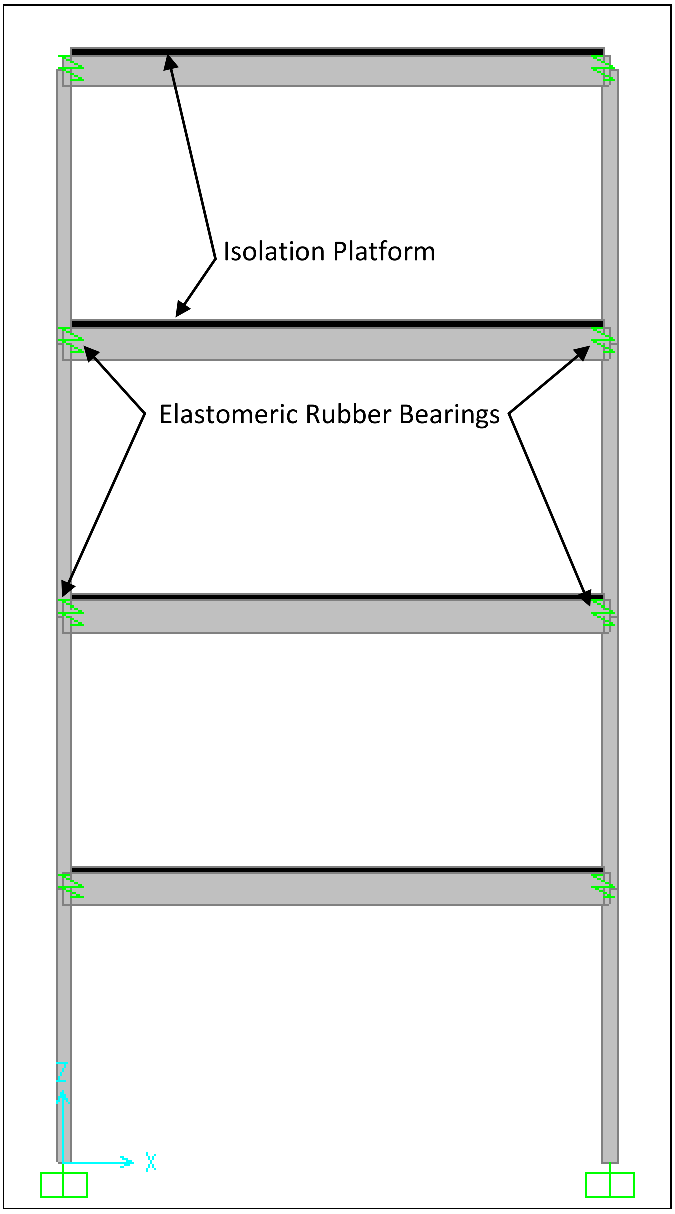

Figure 6. Steel frame of the four-storey building with isolation platform at each floor

IV. RESULTS AND DISCUSSION

Under excitation of Pomona ground motion, the internal forces within critical structural elements were investigated and presented in Figure 7. Internal forces within the structural elements for the building system under Pomona time history in terms of column storey axial, storey shear and moment were obtained and analyzed for the building structural system with and without isolation platform.

The hypothesis was that by providing isolation platform (i.e. Seer-iPlat), the internal forces of the steel structural frame for the building would be observed to have significant reduction.

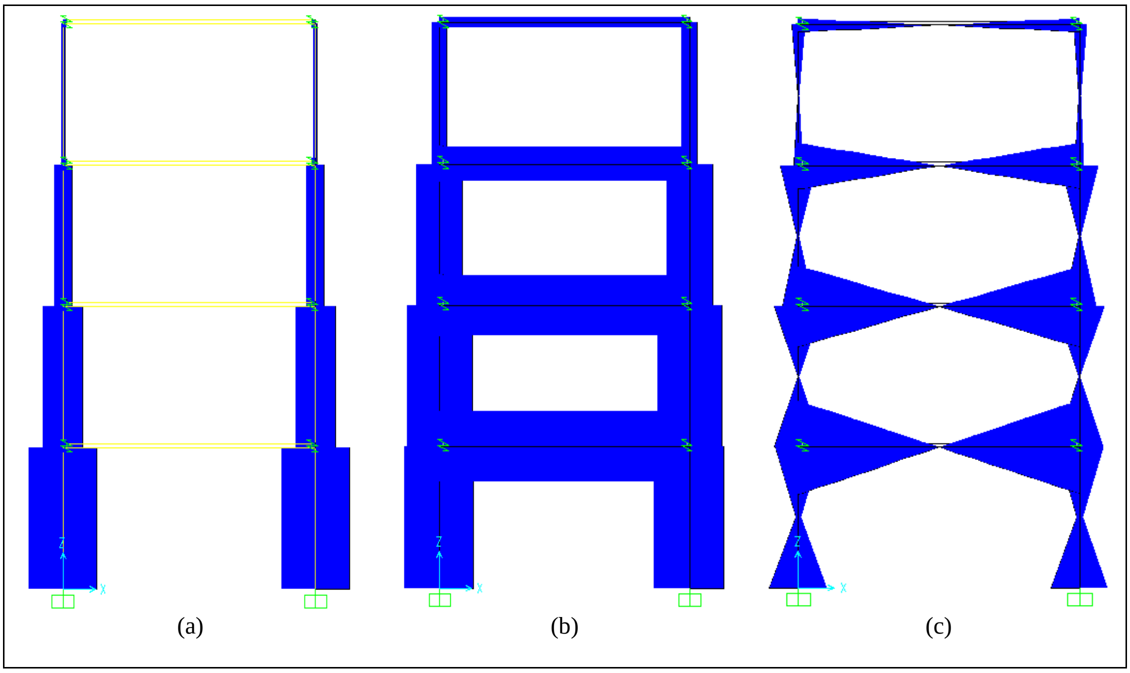

Figure 7. Internal forces of structural elements under Pomona earthquake in terms of axial (a), shear (b) and moment (c)

Comparison between column shear force along each storey between building with and without isolation platform is denoted in Fig. 8. Theoretically, a four-storey building would transfer its weight including self-weight and all other loading to the foundation through vertical load carrying members. In most cases where no shear wall is provided, column members act as primary vertical load carrying elements. In the event of seismicity, the lateral swaying response of the building will then be resisted by these columns. For a conventional base isolated building, it is widely proven theoretically that by decoupling the building from ground movement, the base shear demand due to such ground displacement is impeded.
Interestingly, this study revealed that by isolating the floor level at each storey (i.e. by installing Seer-iPlat at each respective floor), the axial force transferred to column was noted to have decreased significantly particularly at the higher storey level. Such response would contribute to lesser structural capacity demand for column members, thus contributing to more economical structural detailing. The maximum reduction percentages of column axial forces were 63.2, 61.0, 60.4 and 61.5 percent for 4th, 3rd, 2nd and 1st floor respectively.

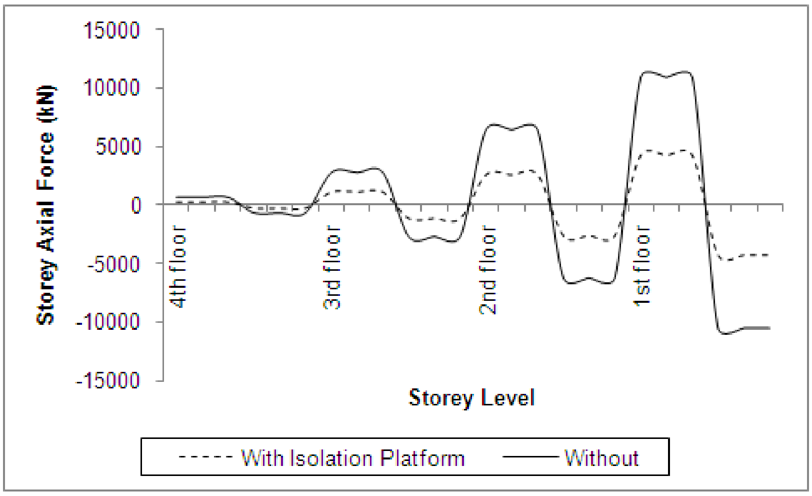

Figure 8. Column storey axial forces between building with and without isolation platform

Significant reduction in storey shear was also observed for the building structural system comprising isolation platform. Shown in Fig. 9, the pattern of storey shear reduction was similar to the column axial force. Compared to the building without isolation platform, the storey shear with isolation platform was reduced by 67.0, 59.4, 60.2, and 63.7 percent from the 4th to 1st storey respectively.

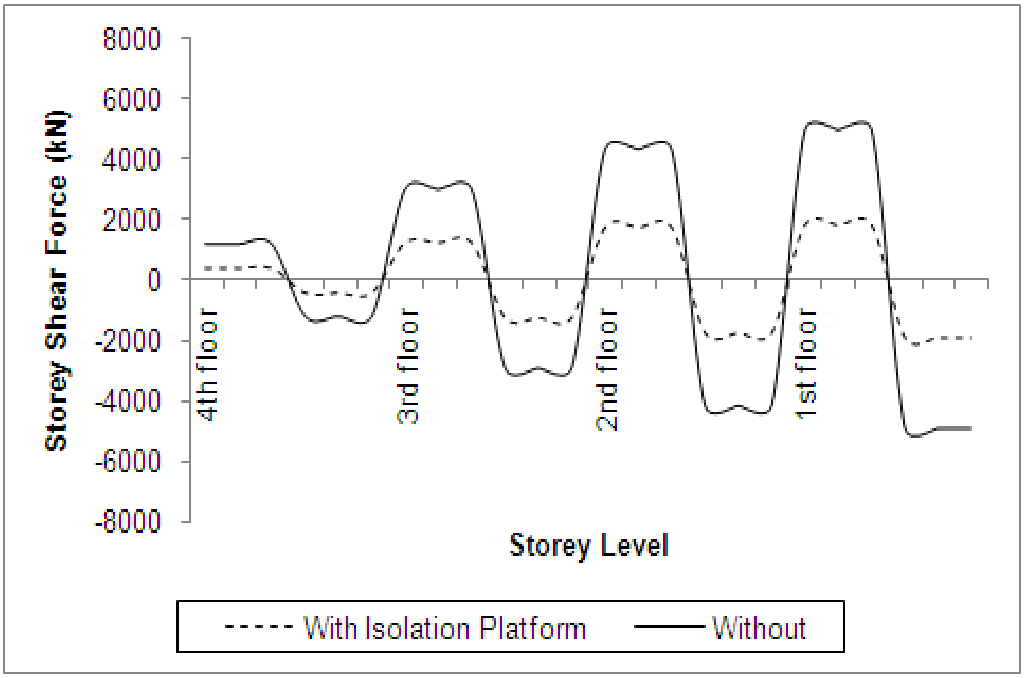

Figure 9. Column storey shear between building with and without isolation platform

Distribution pattern of storey moment forces along the height of column were noted to be different to the previous two types of internal forces, as shown in Fig. 10. Changes from sagging moment to hogging moment were obviously observed. Nevertheless, these moments were also reduced by providing isolation platform at each floor. The maximum percentage of reduction was 71.2, detected in 4th storey. Throughout the remaining three stories, the internal moments were remarkably decreased by 58.3, 60.6, and 60.3 percent from 3rd to 1st floor correspondingly.

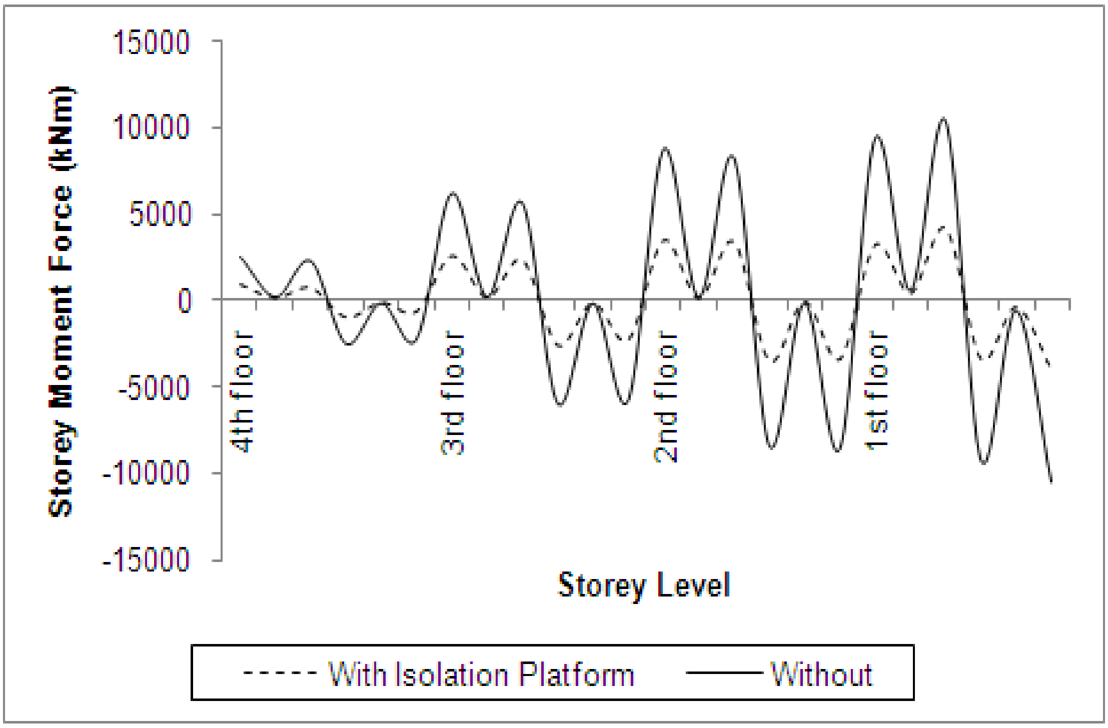

Figure 10. Column storey moment forces between building with and without isolation platform

V. CONCLUSION

In this study, time history analysis of a four-storey steel building was performed using finite element analysis under Pomona earthquake ground motion data. This paper investigated the feasibility of applying a newly proposed seismic isolation platform, namely Seer-iPlat that was installed at each corresponding floor to reduce the seismic impact. As there are no guidelines currently available in the field of knowledge to either design or analyzing such system, it was noted in this study that the proposed system was able to reduce internal force demand due to seismic incident onto important vertical load carrying members. Significant decrement of column axial forces, shear and moment had proven the workability and efficiency of the proposed system to be further studied and researched in laboratory testing as seismic mitigation approach for existing or older buildings such as museum, hospital and sensitive operational center.

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REFERENCES

1. CEN 1998. Eurocode 8: Design of Structures for Earthquake Resistance - Part 1: General Rules, Seismic Actions and Rules for Buildings, 2003, British Standards Institution, London.
2. International Code Council. 2009 International Building Code. Illinois, 2009, International Code Council, United States of America.
3. Lopes, M. S., and Bento, R. Seismic behaviour of dual systems with column hinging, Earthquake Spectra, 2001, 17(4), pp. 657-678.
4. Naeim, F., and Kelly, J. M. Design of Seismic Isolated Structures - From Theory to Practice, 1999, John Wiley & Sons, Canada.
5. Sunaryati, J. Behaviour of Steel Structures with Base Isolator under Low Intensity Earthquake Effect, Ph.D Thesis, 2008, Universiti Teknologi Malaysia, Malaysia.
6. Adnan, A., Tiong, P. L. Y., Sunaryati, J., Ghazali, M. Z. M., and Malek, K. A. Seismic Base Isolation of Steel Frame Structure by Hollow Rubber Bearings, Gazi University Journal of Science, 24(4), pp. 841-853.
7. British Standards Institution. Structural Use of Steel Work in Building, Part 1, Code of Practice for Design in Simple and Continuous Construction: Hot Rolled Sections, 2000, British Standards Institution, London.