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SOIL TYPE DEPENDENCY ON THE SEISMIC PERFORMANCE OF RC PRECAST GOVERNMENT RESIDENTIAL BUILDING

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ABSTRACT

Malaysia is known to have less seismic activities as it is located in the intraplate region and is far from major plate boundary faults. Besides, Malaysia also experiences frequent tremors and has recorded a devastating tsunami due to the active seismic activities in neighboring countries. The latest occurrence of earthquake in Ranau on June, 5 2015 that had caused casualties and damages to properties, triggered Malaysia to take immediate actions to deal with all the issues. Following that, the national seismic code and National Annex were introduced in 2015 and 2017 respectively. However, buildings constructed before both documents were established do not consider seismic requirements. This study is conducted to evaluate the seismic performance of the target building and improves it with suitable seismic retrofit methods. A 5-story RC precast government residential building is selected to be evaluated based on the seismic hazard level at Bentong, Pahang with $a_g = 0.106$ g and Lahad Datu, Sabah with $a_g = 0.192$ g considering soil profile models available in Malaysia. Capacity spectrum method is carried out to estimate the performance points based on specific seismic hazard levels with different soil profile models. The seismic performance of the building is then evaluated based on the performance level of plastic hinges formation observed at the performance points. Finding indicates that the target building can survive based on the seismic hazard level at Bentong, Pahang with soil profile model 1 without requiring any seismic retrofitting. Nonetheless, it cannot survive concerning the soil type E of soil profile model 2. For the seismic hazard level at Lahad Datu, Sabah, the target building cannot survive concerning the soil types C, D and E of soil profile model 1 and 2. Seismic retrofit plan is applied to the target building, and the seismic performance of the retrofitted building is re-evaluated. The finding shows that the retrofitted building can survive based on both seismic hazard levels with soil profile models 1 and 2.

Keywords: seismic performance, plastic hinge, pushover, capacity spectrum method, seismic retrofit.

1. INTRODUCTION

Most of the private and government buildings in Malaysia constructed before the establishment of the national seismic code and National Annex in 2015 and 2017 respectively, are seismic-vulnerable due to no consideration of seismic requirements during the design stage. Those buildings also include the government buildings that have been constructed using the Pre-Approved Plan (PAP) designs

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established within 2015 until before May 21, 2018. All the existing buildings are potentially exposed to earthquakes and at risk of experiencing structural damage, which require seismic performance review.

2. TARGET BUILDING SELECTION

For this study, a five-story reinforced concrete (RC) precast government residential building from the PAP design collection that was established in April 2016 is selected as the target building (see Figure 1). This building was designed using MS EN 1992-1:2010 without considering seismic requirements during the design stage. It also has an irregular plan and elevation layout, equipped with cast-in-situ load-bearing RC walls in the X and Y directions. Most of its beams, columns and slabs are precast.

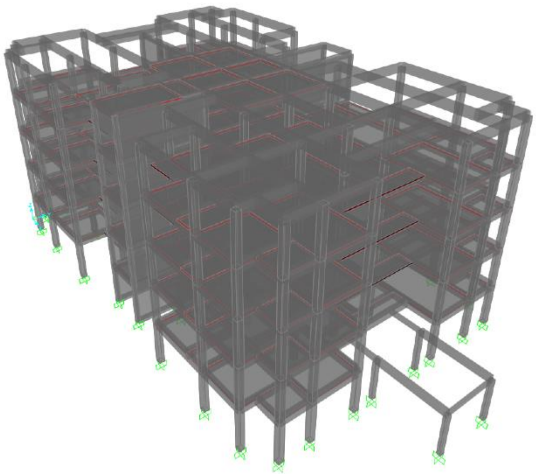
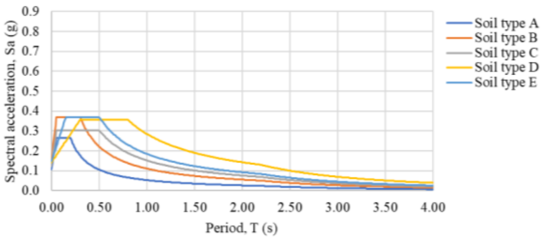


Figure 1: Analytical model of the target building.

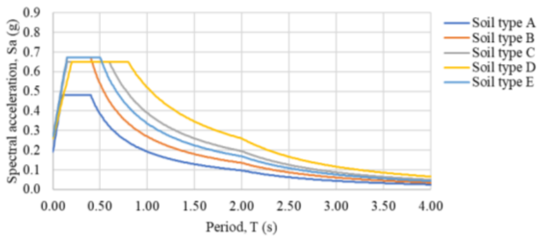
3. METHODOLOGY

Modelling of the target building and seismic analysis are carried out by using the software SAP 2000 v22. The evaluation on the seismic performance of the target building is carried out by using the Capacity Spectrum Method (CSM) of ATC 40 (1996). The limit states for the seismic performance of the target building are determined based on the performance level of plastic hinge (FEMA-356 (2000)) and the column failure mode (JBDPA (2001)). The plastic hinge conditions are observed at the intersection points between the two main components of CSM; the capacity spectrum (obtained from the pushover analysis) and the demand spectrum (represented by the reduced elastic response spectrum).

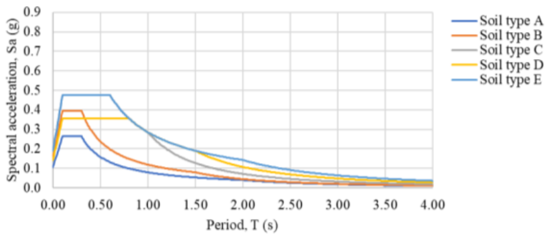
3.1. Provision of the elastic response spectra



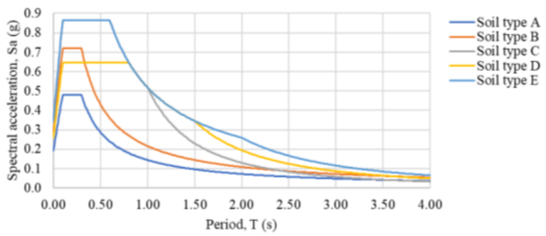
(a) Bentong, Pahang with soil profile model 1.



(b) Bentong, Pahang with soil profile model 2.



(c) Lahad Datu, Sabah with soil profile model 1.



(d) Lahad Datu, Sabah with soil profile model 2.

Figure 2. Elastic response spectra according to the selected locations and soil profile models.

Based on thirty-six site locations randomly selected from the PWD project database, Bentong, Pahang is the site location in the Peninsular region with the highest peak ground acceleration, a_g of 0.106 g with a population density of 63 people/km^2. Meanwhile, Lahad Datu is the site location in the Sabah state with the highest peak ground acceleration, a_g of 0.192 g with a population density of 30 people/km^2. Bentong, Pahang (Peninsular Malaysia) and Lahad Datu, Sabah were selected for this study to define seismic hazard levels. The elastic response spectra as shown in Figure 2 above represent the seismic hazard levels at both locations considering the soil types available in Malaysia.

3.2. Seismic retrofit plan

To improve the seismic performance of the existing building, suitable seismic retrofit methods are chosen and applied to the building. The details of the seismic retrofit plan are as per below:

a) Demolition of the existing parts of the building
b) Retrofitting of the existing columns with RC jacket (RC1 and RC2)
c) Provision of the new RC shear walls (NSW200)
d) Extension of the existing RC walls (RSW200)
e) Provision of the new RC slabs (NS150)
f) Provision of the new steel structures

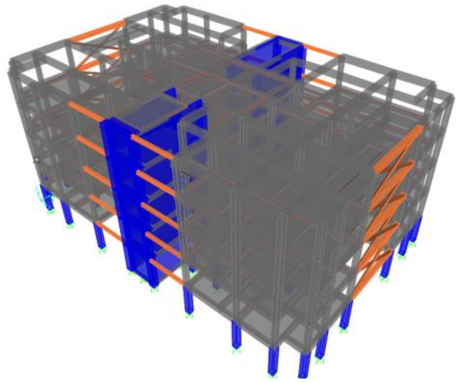
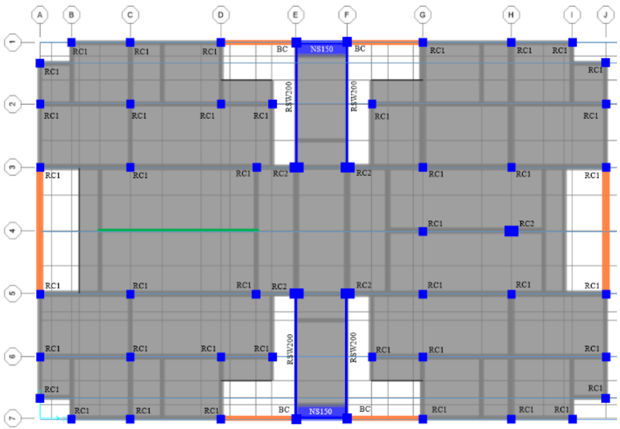
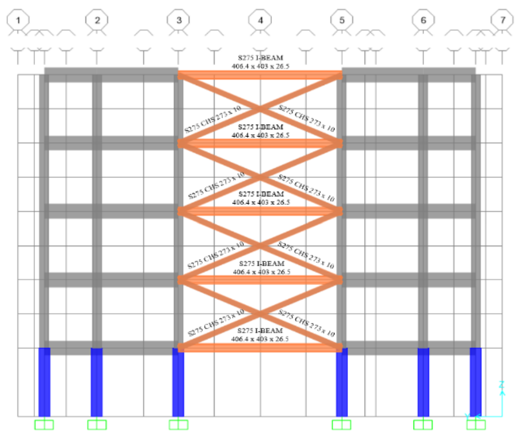


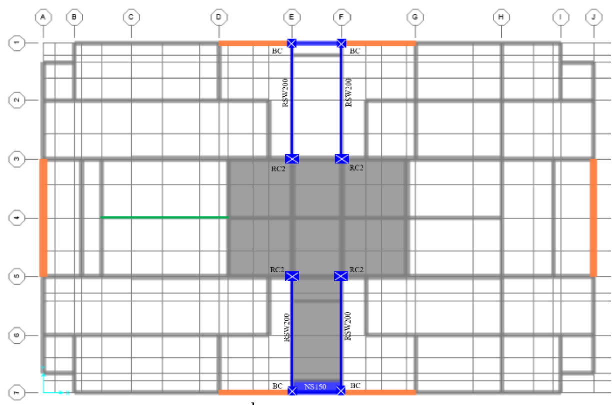
Figure 3. Three-dimensional view of the retrofitted building.



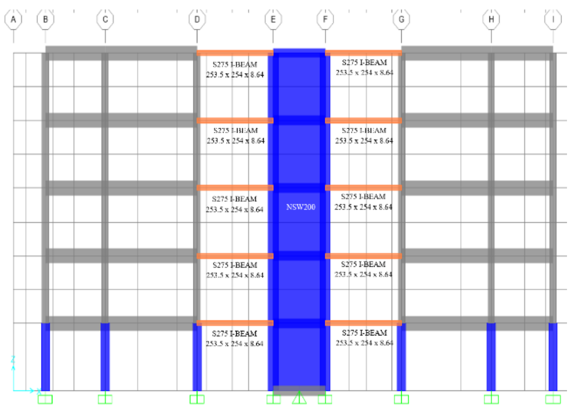
(a) 1st story plan view.



(b) Elevation view at grids A and J.



(c) 5th story plan view.



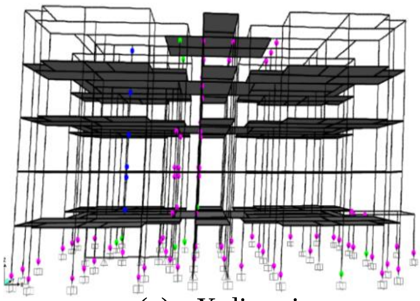
(d) Elevation view at grids 1 and 7.

Figure 4. The locations and arrangement of the retrofitted and new structural members.

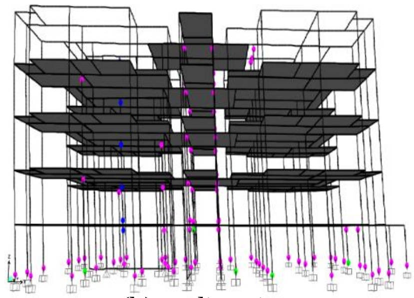
4. RESULTS AND DISCUSSION

The pushover results as shown in Figure 5 demonstrate that the existing building has a weak column-strong beam design and a soft first-story features. Based on the review of the column failure mode according to the JBDPA (2001), most existing columns fail in a shear manner. All of these features should be avoided in building design as they will lead to sudden and global collapse during the earthquake.

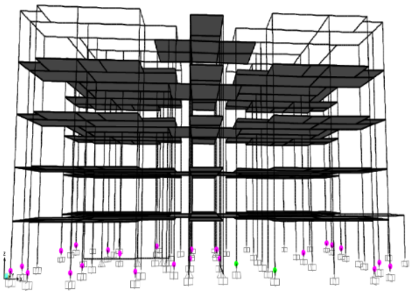
The retrofitted building is subjected to the same procedures used to evaluate the seismic performance of the existing building. Figure 6 shows that plastic hinges with various performance levels are still formed on the first-story columns even after being retrofitted. However, the total number of green plastic hinges at the first story has reduced and appear at a more significant spectral displacement compared to the pushover results of the existing building. The seismic retrofit plan implemented on the existing building is able to delay the formation of plastic hinges and has improved the spectral capacity of the SDOF system in all pushover directions. The review on the failure mode of the retrofitted columns results in a shear manner.



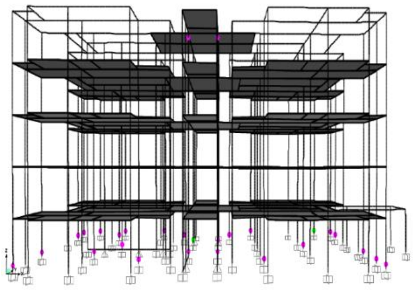
(a) -X direction.



(b) X direction.

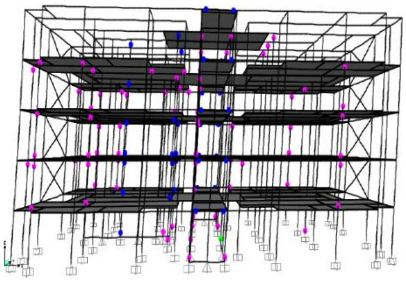


(c) -Y direction.

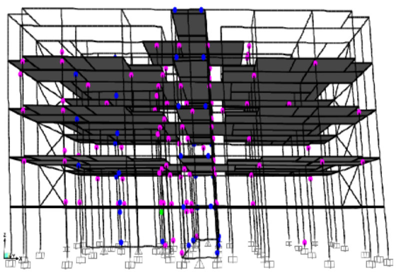


(d) Y direction.

Figure 5. Formation of plastic hinges on structural members of the existing building in different pushover directions.



(a) -X direction.



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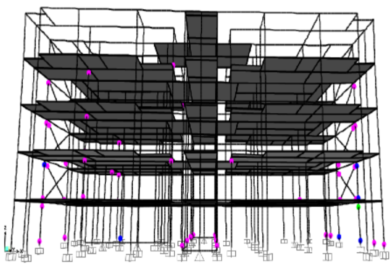
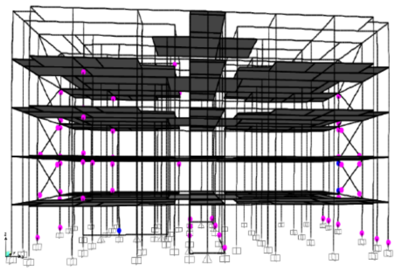
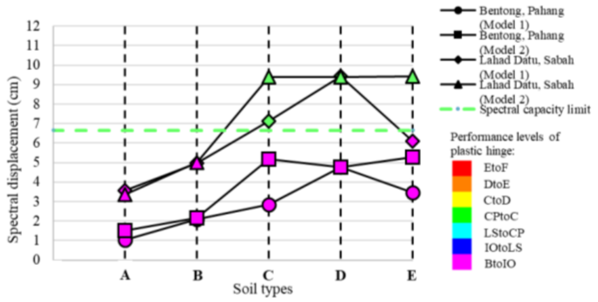


(c) -Y direction.

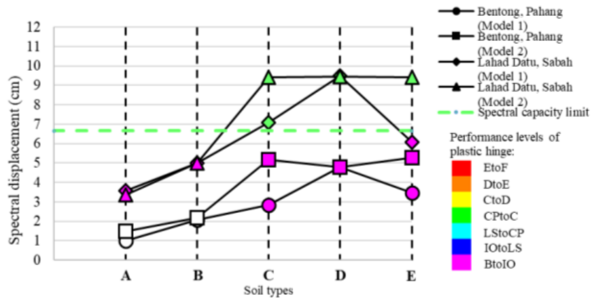


(d) Y direction.

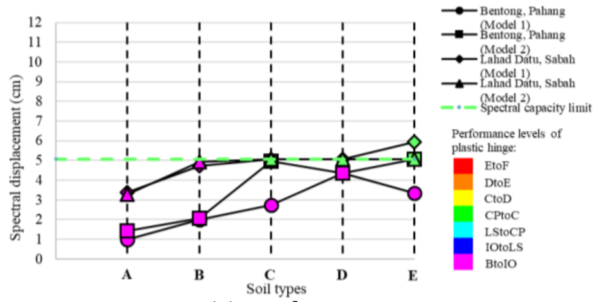
Figure 6. Formation of plastic hinges on structural members of the retrofitted building in different pushover directions.



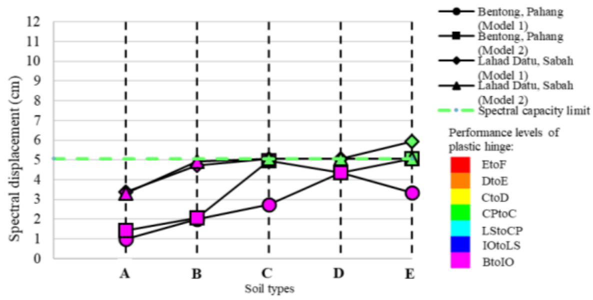
(a) -X direction.



(b) X direction.

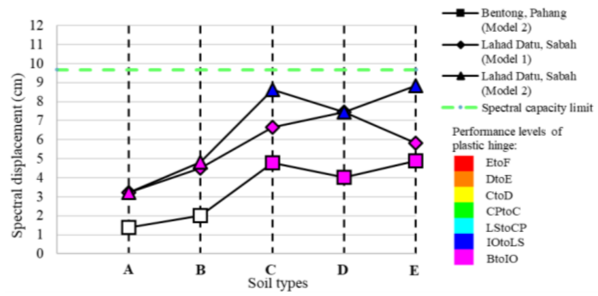


(c) -Y direction.

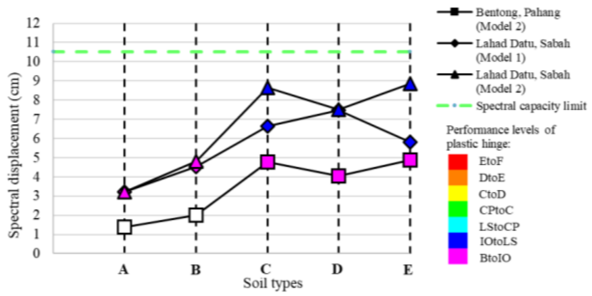


(d) Y direction.

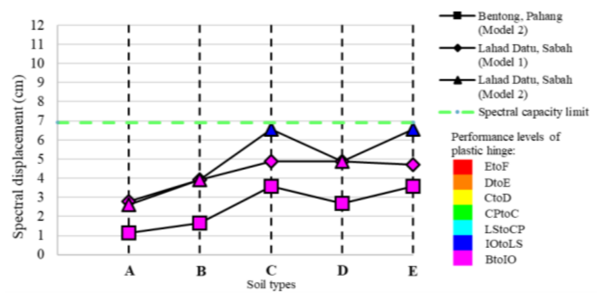
Figure 7. Maximum inelastic displacement of the existing building based on the seismic hazard level at Bentong, Pahang and Lahad Datu, Sabah with different soil profile models in different pushover directions.



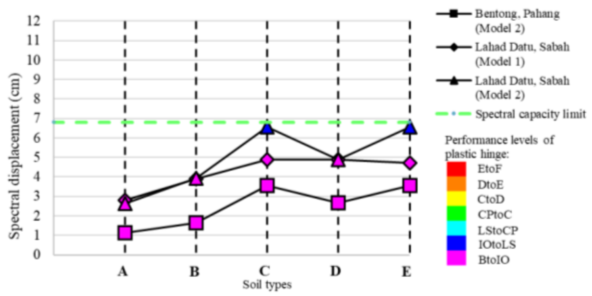
(a) -X direction.



(b) X direction.



(c) -Y direction.



(d) Y direction.

Figure 8. Maximum inelastic displacement of the retrofitted building based on the seismic hazard level at Bentong, Pahang and Lahad Datu, Sabah with different soil profile models in different pushover directions.

Referring to the CSM results of the existing building as shown in Figure 7, based on the seismic hazard level at Bentong, Pahang (Peninsular Malaysia) with soil profile model 1, the existing building can survive during the earthquake under the influence of soil types A, B, C, D and E with the performance level of plastic hinges within Immediate Occupancy (IO) limit observed at most of the performance points. However, the existing building cannot survive during the earthquake under the influence of soil type E for soil profile model 2. Meanwhile, based on the seismic hazard level at Lahad Datu, Sabah with soil profile models 1 and 2, the existing building can survive during the earthquake under the influence of soil types A and B only with the performance level of plastic hinges within IO limit observed at all the performance points. However, the existing building cannot survive during the earthquake under the influence of soil types C, D and E for both soil profile models.

Referring to the CSM results of the retrofitted building as shown in Figure 8, based on the seismic hazard levels at Bentong, Pahang (Peninsular Malaysia) and Lahad Datu, Sabah considering all the soil types of soil profile models 1 and 2, the retrofitted building is able to survive during the earthquake.

5. CONCLUSIONS

From the above outcomes, the seismic performance of the building is significantly affected by the influence of different soil types. The irregularity of the building with the unfavorable features also contribute to the poor seismic performance of the existing building. The proposed seismic retrofit plan manages to improve the seismic performance and the capacity of the existing building to withstand the seismic forces from each direction. However, the plan cannot eliminate the weak column-strong beam, the soft first-story, and the shear column failure mode features.

ACKNOWLEDGEMENTS

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