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SEISMIC EVALUATION AND RETROFITTING OF EXISTING REINFORCED CONCRETE BUILDINGS IN MYANMAR

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ABSTRACT

Myanmar is an earthquake-prone country. Although earthquakes do not kill people, the subsequent collapse of building, for example, can cause human death and economic losses. In this study, hazard maps were initially used to implement an earthquake disaster mitigation strategy. Two cities, in particular, Mandalay and Yangon, were selected to investigate the hazard risk of buildings in the high and low seismic zones. A three-story reinforced concrete (RC) building with brick walls was evaluated by the Japan Building Disaster Prevention Association (JBDPA) standard and the Capacity Spectrum Method (CSM). After evaluating the target building with the JBDPA standard and the CSM, it was cleared that the target building did not meet requirements. Two simple retrofitting methods, RC column jacketing and RC shear wall, were applied in order to retrofit the target building. These two methods are not expensive and they only require the application of a simple technology. After construction of a small number of RC shear walls or increasing the size of selected columns on the 1st story, the building could be designated safe, even in a very high seismic zone. The results showed that we could obtain a satisfactory earthquake-resistant building.

Keywords: Seismic evaluation, Retrofit, Capacity Spectrum Method.

1. INTRODUCTION

Earthquakes are frequent events in Myanmar. The buildings should be resistant to earthquakes to avoid the collapse of the buildings. Myanmar National Building Code (MNBC) was published in 2016. Before 2016, buildings were designed by the international building code like ACI. Although these buildings are more robust than non-engineered structures, the seismic performance of these buildings is uncertain. According to the recent hazard maps, which harmonize with the seismic design forces of MNBC, many cities are in a zone with high seismic activity. When the earthquake struck in high seismic zones, the buildings in those areas can suffer severe damage. It is needed to check the seismic capacity of the buildings before potential future earthquakes happen. In this study, the low-rise building's seismic performance was evaluated by the JBDPA Standard and the CSM method to investigate the hazard risk of buildings in high and low seismic zones. If the seismic performance of the building is deficient, retrofit methods will be proposed.

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2. METEOROLOGY AND TARGET BUILDING

2.1. Meteorology applied in this study

The targeted building was evaluated by two methods: the seismic diagnosis method of the Japan Building Disaster Prevention Association (JBDPA) and the capacity spectrum method (CSM). For the CSM, the author uses the STERA3D program (Saito).

2.2. Design response spectrum by MNBC

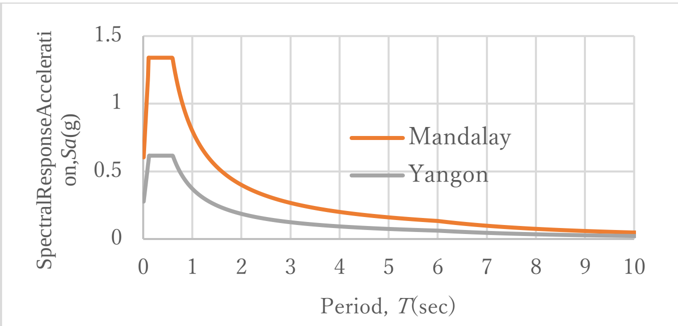

Fig.1. Comparison of design response spectrum of two cities.

In this study, the author produced two cities' design acceleration response spectrum (2% probability of exceedance in 50 years), referring to the MNBC. The soil condition was assumed to be soil type D, which means stiff soil. Figure 1 shows a comparison of the two cities' design response spectrum. The peak spectral response accelerations Sa(g) of Mandalay and Yangon were 1.34 g and 0.6 g, respectively.

2.3. Outline of the structure targeted in this study

A three-story reinforced concrete building with brick walls was used as a case study in this study. The strength of the brick walls was not considered in seismic evaluation because they were designed as non-structural elements. The yield strength of the steel reinforcement was 275.79 N/mm^2, and the design compressive strength of the concrete was assumed to be 17.24 N/mm^2, which is the minimum requirement of MNBC, in this calculation. The areas of the 1st story, 2nd story, and 3rd story were 140 m^2, 152 m^2, and 80 m^2, respectively. The heights of the 1st story, 2nd story, and 3rd story were 3.81 m, 3.5 m, and 3.5 m.

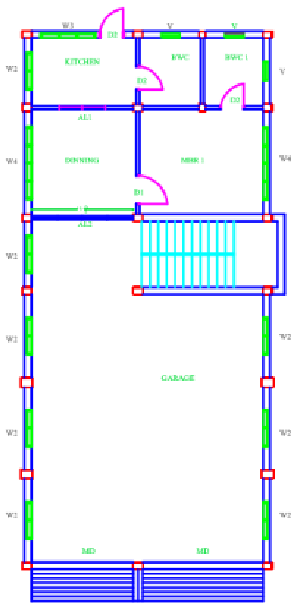
Fig.2. Ground floor plan.

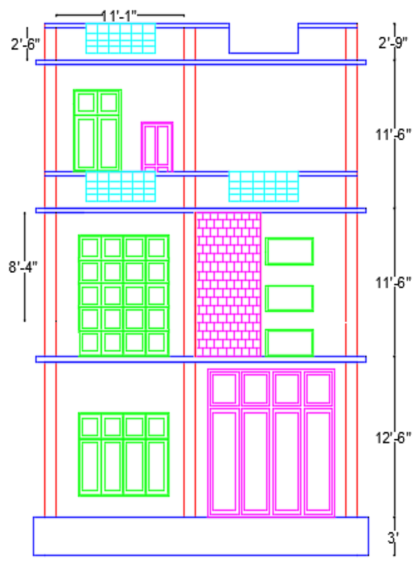

Fig.3. Front Elevation.

3. SEISMIC DIAGNOSIS BY JBDPA SECREENING METHOD

3.1. The results of the second level screening method

In the application process of the JBDPA method, it was found out that all columns in the X-direction and some columns in the Y-direction have a low ductility index F(F=1), although the failure mode of them was flexural. The reasons for these results were that the tensile reinforcing ratio P_t of all columns was higher than 1%, and the axial force acting on those columns was high. Due to the higher P_t ratio, bond splitting failure can occur in the columns. Thus, the author investigated the possibility of this failure type by a more accurate method. AIJ structural design guidelines for reinforced concrete buildings (1994) were used to check the column's bond splitting failure. Results obtained from the AIJ guidelines showed that bond splitting failure might not occur in all columns. Therefore, Pt values were neglected in the JBDPA seismic evaluation, and the Is value of the target building was calculated again in both directions. Figure 4 shows the comparison of I_S and I_{SO} in second-level screening. Only the 1st story required a retrofit.

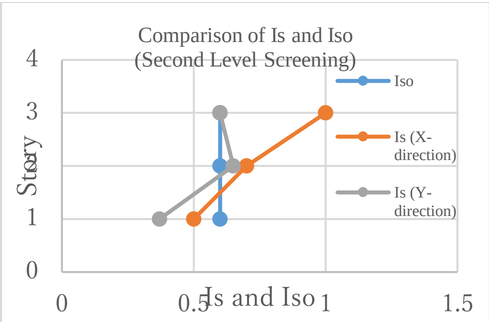

Fig.4. The comparison of I_S and I_{SO}.

4. SEISMIC PERFORMANCE EVALUATION BY CAPACITY SPECTRUM METHOD

4.1. The results of the capacity spectrum method

The seismic response can be predicted as the performance point by the CSM method, as shown in Figures 5 and 6. From the performance points of the structure, demand story drifts for each city were obtained. The limit story drifts of the structure were compared with the demand story drifts for two cities, as shown in Table 1. It was observed that the limit drift on the 1st story was lower than the corresponding demand story drift. Therefore, the target building was unsafe in both high and low seismic zones.

Table 1. Comparison of limit and demand story drifts of the structure.

Story	Mandalay		Yangon		Limit story drifts of the structure
	2% Probability	10% Probability	2% Probability	10% Probability	
	demand story drifts(cm)		demand story drifts(cm)		
1	- (NG)	3.98 (NG)	3.45 (NG)	2.81 (NG)	1.52
2	- (NG)	3.35	2.97	2.4	7.01
3	- (NG)	4.25	3.72	3.04	7.01

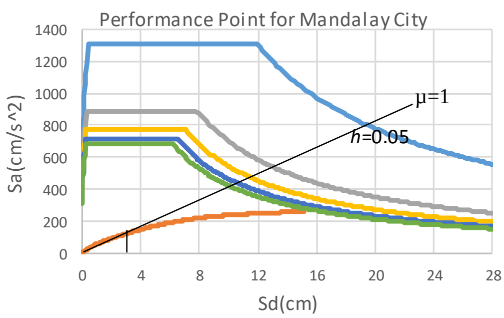

Fig.5. The building's performance point for Mandalay city using the demand spectrum (2% probability).

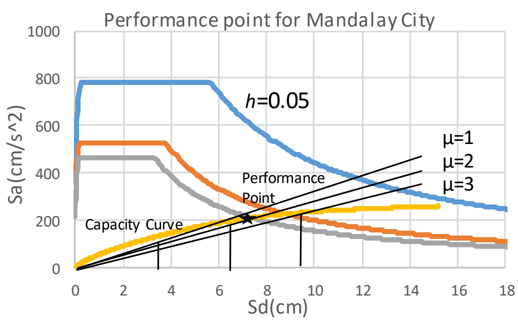

Fig 6. The building's performance point for Yangon city using the demand spectrum (2% probability).

5. RETROFITTING

5.1. Basic concept for retrofitting

The author judged the original building needs a retrofit based on the results shown in the previous chapter. The retrofitting technique is an effective way to minimize the damage caused by earthquakes. Figure 7 shows the retrofit model by installing RC shear walls, and Figure 8 shows the retrofit model by RC column jacketing. The main purpose of seismic retrofitting shown in figure 7 is to upgrade the strength, and that of the other retrofitting shown in figure 8 is to upgrade the ductility of a building to meet the seismic performance demands.

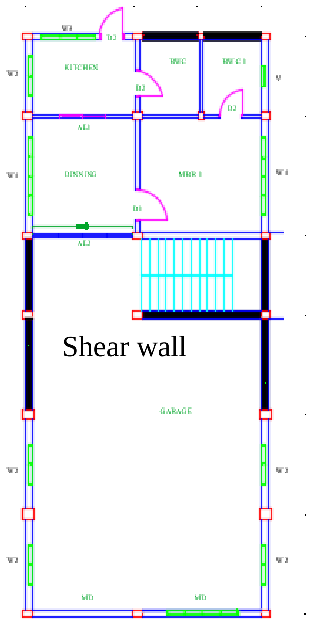

Fig.7. The retrofit model by installing RC shear walls on the 1^{st} story.

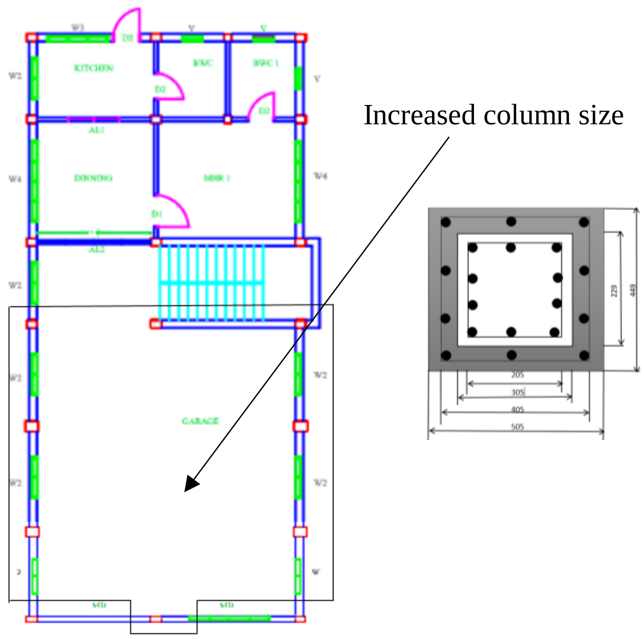

Fig.8. The retrofit model by RC column jacketing on the 1^{st} story.

5.2. Seismic rehabilitation of the structure using RC shear walls

The author suggested installing three RC shear walls in the X-direction, and four RC shear walls in the Y-direction on the 1^{st} story. The thickness of each wall is 200 mm. The compressive strength of concrete and the yield strength of shear reinforcement in the RC shear walls were F_c=18 N/mm^2 and σ_{wy}=294 N/mm^2. Post-installed anchors were placed along with boundary columns and beams of the existing structures to transfer shear forces between the existing structure and infilled shear walls. The 1^{st} story's seismic capacity was upgraded after constructing RC shear walls. Figure 9 shows that the seismic capacity of all stories evaluated by the second level screening of the JBDPA was enough in the longitudinal and transverse directions.

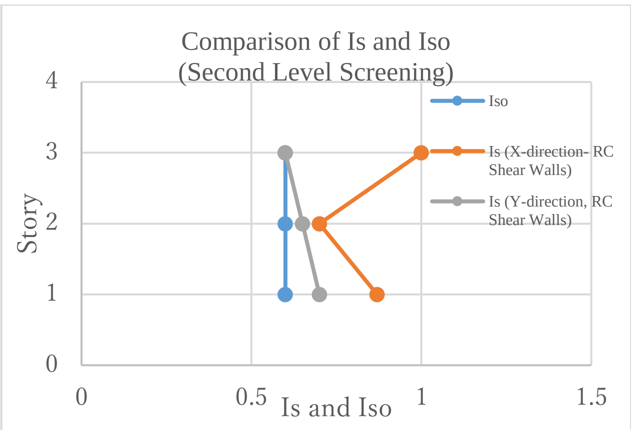

Fig.9. Comparison of I_S and I_{SO} (X and Y direction).

5.3. Seismic rehabilitation of the structure using RC column jacketing

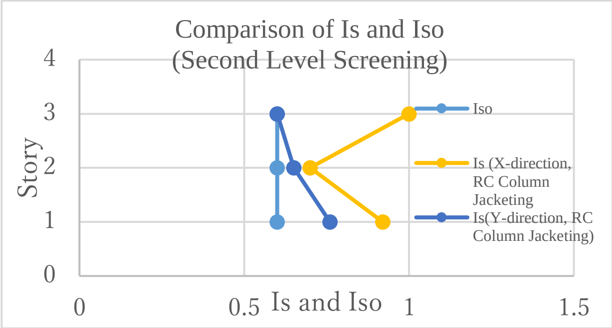

Fig.10. Comparison of I_S and I_{SO} (X and Y direction).

In the 1st story, the existing eight columns were jacketed with reinforced concrete at a thickness of 100 mm. The concrete's compressive strength and the yield strength of tensile reinforcement in the jacketing part of the column were Fc=25 N/mm^2 and σ_y=400 N/mm^2. The seismic capacity of the 1st story was increased using RC jacketing. All stories were determined safe in the second level screening of the JBDPA, as shown in Figure 10.

5.4. Seismic evaluation of the structure by the CSM method (after retrofitting)

After retrofitting the 1st story with RC shear walls and RC column jacketing, the building was evaluated by the CSM method. Figures 11 and 12 show the performance point for the retrofit model with RC shear walls in Mandalay and Yangon cities. It was found out that the seismic capacity of the structure was higher than the requirement, as shown in Table 2. Therefore, the target building was determined to be safe in both high and low seismic zones.

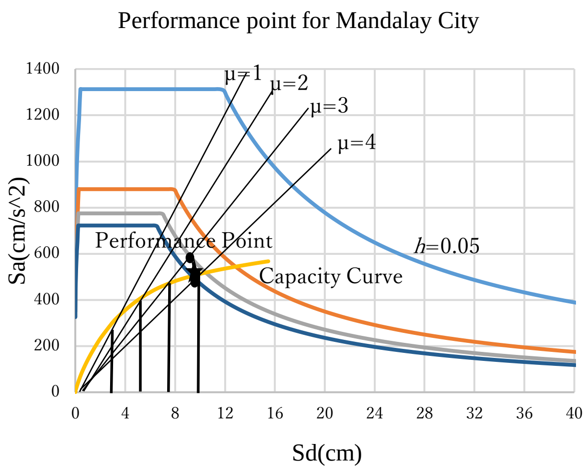

Fig. 11. The building's performance point for Mandalay city using the 2% probability demand spectrum (after retrofitting with RC shear wall).

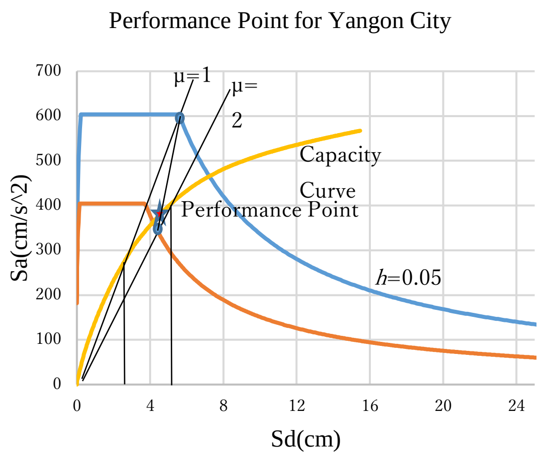

Fig. 12. The building's performance point for Yangon city using the 2% probability demand spectrum (after retrofitting with RC shear wall).

Table 2. Comparison of limit and demand story drifts (after retrofitting with RC Shear Walls).

Story	Mandalay		Yangon		Limited story drifts of the structure
	2% Probability	10% Probability	2% Probability	10% Probability	
	demand story drifts(cm)		demand story drifts(cm)		
1	0.66	0.47	0.37	0.28	1.52
2	5.31	3.07	2.48	2.08	7.01
3	6.99	3.84	3.10	2.59	7.01

Table 3. Comparison of limit and demand story drifts (after retrofitting with RC Column Jacketing).

Story	Mandalay		Yangon		Limit story drifts of the structure
	2% Probability	10% Probability	2% Probability	10% Probability	
	demand story drifts(cm)		demand story drifts(cm)		
1	1.10	0.77	0.77	0.28	1.52
2	5.54	2.86	2.86	2.08	7.01
3	7.72 (NG)	3.64	3.64	2.59	7.01

Table 3 shows the evaluation results of the retrofitted model with the RC column jacketing. Even after retrofitting the 1st story with RC column jacketing, the 3rd story did not meet the requirement for Mandalay. We should increase the column size of the 3rd story. However, the demand story drift is almost equal to limit story drift. The 3rd story can obtain enough seismic capacity by increasing the size of a small number of columns.

6. CONCLUSION

The results of this study were summarized as follow:

- According to the seismic evaluation results by the JBDPA Standard and the CSM, the 1st story of the target building did not have enough seismic capacity for both of Mandalay and Yangon. Retrofitting is needed to increase the seismic performance of this story.
- Two types of the retrofit method were suggested. One is installing RC shear walls, and the other is the RC column jacketing.
- After installing a small number of RC shear walls and increasing the size of selected columns on the 1st story, the building's seismic capacity was increased. The building was considered safe, even in a very high seismic zone. The results showed that we could obtain a satisfactory earthquake-resistant structure.

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