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MODELING OF STRUCTURAL DEFORMATION OF STAFF QUARTERS HOSPITAL RANAU SUBJECTED TO THE 2015 RANAU EARTHQUAKE USING RUAUMOKO 2D

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A B S T R A C T

The 2015 Ranau Earthquake had triggered structural damages on many multi-storey school and residential buildings which were designed as soft-storey mechanism in the area of Ranau, Sabah. Soft-storey building mechanism is a type of reinforced concrete structure that commonly used in construction of multi-storey residential building. In Malaysia, most of the building was designed by referring to British Standard (BS8110) design code of practice where there is no consideration been made on earthquake loading. Thus, the main objective of this paper is to model the structural deformation of selected prototype soft-storey building which is Staff Quarters Hospital Ranau when subjected to the 2015 Ranau Earthquake with PGA=0.12g using Ruaumoko 2D. The modeling result showed that the damages occured at the ground floor beam-column joints, as the weakest points for soft-storey building mechanism. The post-earthquake on-site visual observation on the damages of Staff Quarters Hospital Ranau was also discussed in this paper.

1. Introduction

Earthquake is one of a natural disaster that give a great impact to the world and also to human. Although Malaysia is located at outside of Pacific Ring of Fire and categorized as low-seismic area, however, East of Malaysia especially Sabah is located in moderate seismic area. In June 2015, Sabah was shocked by an earthquake with 6.0 Scale Richter that hit Ranau District (Boh, 2015). The 2015 Ranau Earthquake had triggered structural damages on many multi-storey school and residential buildings which were designed as soft-storey mechanism. Soft-storey building mechanism is a type of reinforced concrete structure that commonly used in construction of multi-storey residential building. Although the design gives a series of functional and aesthetic advantages, severe structural damage and even the collapse of buildings when an earthquake occurs (Teresa, 2012).

2. Problem Statement

High shaking on the ground can lead to the failure of design and damage to the building especially to the building that was designed not to cater for seismic loading (Kay Dora, 2014). Most of the building in Malaysia was designed using British Standard Code of Practice (BS8110) where there is no consideration on seismic loading in the design.

Soft-storey is a multi-storey building with more than one floor that contains an open space at the ground floor level. However, soft storey buildings weak to withstand the lateral loading (Kirac, 2013). It is known as the type of building that has strong beam and weak column design. Thus, recent earthquake that happened in Sabah had caused a few buildings especially soft-storey building were damaged. This is because, when a building structure that have open ground storey and contains several levels will reduce the stiffness and lateral load resistance then lead to collapse when earthquake incident (Bhakti and Harne, 2015). Soft-storey building has less resistance, stiffness and ductility to stand earthquake stress (Hejazil et. al, 2011). The soft storey building cannot resist the resistance during earthquake especially for the first level of the building. During an earthquake, the weak joints at the column will undergo some displacement.

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Hejazil et. al (2011) also stated that during the ground motion happen, the load from the upper stories will be transfered to the first floor then leave a great damage to the first floor. When the lower stories cannot afford to stand the higher load exerted on it, thus it can lead to failure and at the same time damage to human. Thus, the aim of this research is to model the structural deformation of Staff Quarters Hospital Ranau when subjected to the 2015 Ranau Earthquake with 6.0 Magnitude of Scale Ritcher and Peak Ground Acceleration of 0.12g at various time history. Besides that, the post-earthquake on-site visual observation of Staff Quarters Hospital Ranau after 2015 Ranau Earthquake is also discussed in this paper.

3. Research Methodolgy

Figure 1 shows the prototype building for this study. The prototype building selected was the Staff Quarters Hospital Ranau which is categorized as a soft-storey building. The building analysis of the prototype building was carried out using Orion R18 software to obtan the static load analysis. The static analysis output was used as the input data in Ruaumoko 2D program. Table 1 shows the details design data of the prototype building. Figure 2 show the modeled prototype building using Orion R18. Figure 3 and Figure 4 shows the layout of and the front view of the prototype building, respectively.

Figure 1: Selected prototype building – Staff Quarters Hospital Ranau

Table 1: Details of the building

Code of Practice	BS 8110 :1997
Soft storey Details	Ground Floor
Storey Height	4 Storey Building
Beam Dimension	350 x 500 mm
	200 x 500 mm
Slab details	Thickness : 150 mm
Column	350 mm x 350 mm
	320 mm x 320 mm

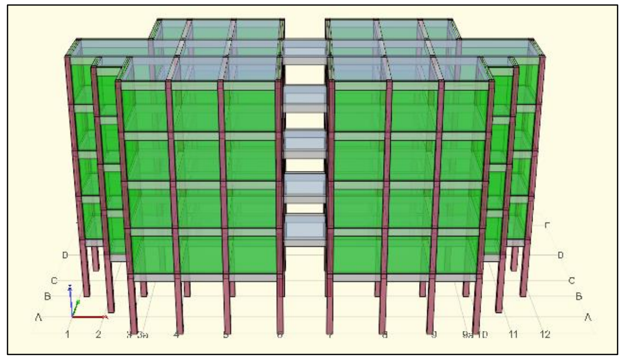

Figure 2: Building modeled using Orion R18

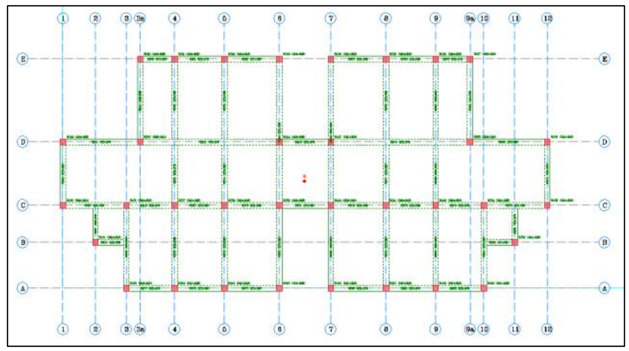

Figure 3: Layout of the prototype building

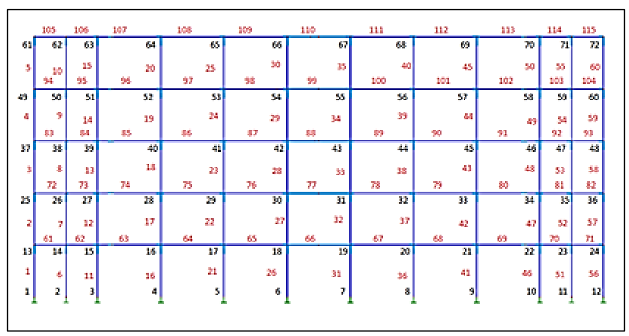

Figure 4: Front view of the prototype building with numbering of node at each elements

Ruaumoko 2D programming was used to carry out the seismic analysis of the building based on the Ranau 2015 earthquake record. The nodes and element in in the building was numbered and a set of data was prepared as a coding that was transferred into Ruaumoko 2D. The Dynaplot program was used to analyse the deformation of the buildings based on the Peak Ground Accleration (PGA) = 0.12g during the 2015 Ranau Earthquake. The analysis was done for every one second during earthquake exerted. The structural deformation and damages of the building were recorded to compare with the on-site visual observation.

4. Result and Discussion

4.1 Structural Deformation of the Prototype Building

The result from Ruaumoko2D programming shows the structural deformation of the prototype building during earthquake as shown in Figure 5. Table 2 shows the maximum lateral displacement of every level and the time of maximum displacement take placed where maximum lateral displacement occurred at 5% damping ratio. As shown in Table 2, the lateral displacement is higher when floor level of a building is increase. Deformation capacity is reasonably high where axial force or strength is low, while at lower floor, deformation is hard to occur because of the present high axial load.

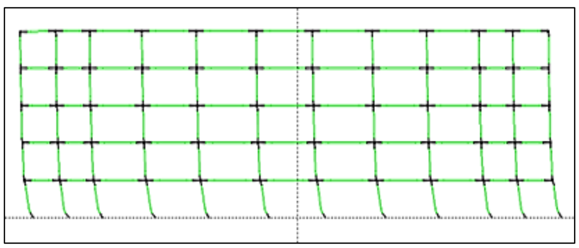

Figure 5: Modeled Deformation of the Prototype Building

Table 2: Maximum Lateral Displacement of Prototype Building

Floor level	Displacement (mm)
Level 1	66.24
Level 2	74.44
Level 3	80.80
Level 4	87.02
Roof	93.25

By using Dynaplot Program which incorporated with Ruaumoko2D Programming, the structural deformation of the prototype building when subjected to PGA=0.12g was obtained. The structural deformations of the prototype building were indicated from the yielding condition. The yielding condition in the building can be categorized in the tension or compression zone. The color-coding of axial yield in the central region of the member is shown in red color for the tension zone, blue color for the compression zone and green color for the safe zone (Carr, 2007). Furthermore, the plastic hinges forming at the joints with positive moments are shown in red and negative moments are shown in blue, while yellow color indicates that the model of the hysteresis loops has a slack region.

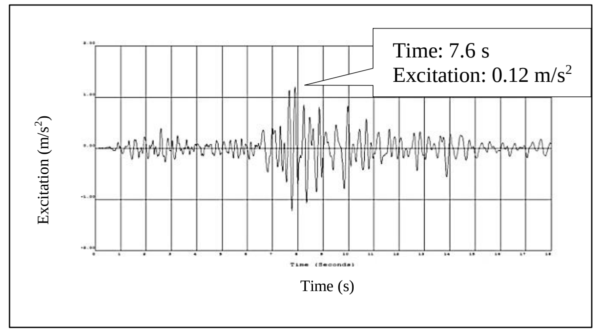

Figure 6: Excitation versus Time for 2015 Ranau Earthquake

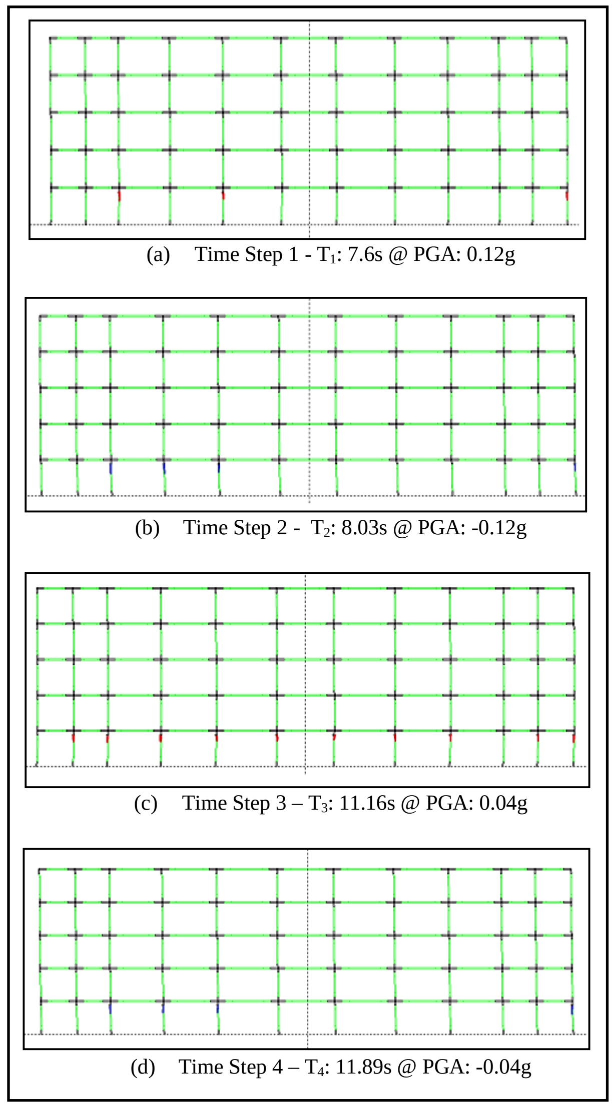

Figure 7: Structural Deformation of the Prototype Building under the 2015 Ranau Earthquake Record at various Time History

Figure 6 shows excitation versus time for the 2015 Ranau Earthquake record. The Peak Ground Acceleration (PGA) 0.12g happened at 7.6 seconds during the 2015 Ranau Earthquake. Figure 7 shows the structural deformation for the prototype building under the 2015 Ranau Earthquake at four selected time history modeled using Dynaplot program. From the modeling, at time step 1 with PGA=0.12g which occurred at 7.6 seconds of time history, the yield condition of the beam-column joints was shown at the first floor level. The beam-column joints yielded in tension moments and are marked with red color in the beams and the columns. The damages were identified at the corners and interior beam-column joints at the first floor of the prototype building. Meanwhile, a plastic hinge was formed with compression moment (marked with blue color) were detected at columns at the first floor of the prototype building at time step 2 (PGA=-0.12g) which was observed at 8.02 seconds time history, more structural damage occurred at the beam-column joint. At time step 3 (T_3 = 11.16s) with PGA=0.04g, severe damage (marked in red color) occurred at almost all columns at the first floor. Finally, at time step 4 (T_4 = 11.89s) with PGA=-0.04g, fhe failure of the column in compression was also observed at the first floor, indicated by the blue color. The modeling results are to be verified with the real damages on-site which is presented in the next sub-section.

4.2 On-Site Visual Observation on the Damages of Staff Quarters Hospital Ranau after the 2015 Ranau Earthquake

As stated before, the soft-storey building mechanism is weak to withstand the earthquake which could lead to damage and failure in structure. The damage mostly happened at the column since it is weak in column. The 2015 Ranau Earthquake has imposed a great impact to many reinforced concrete building including the Staff Quarters Hospital Ranau. A post-earthquake visit to Ranau has been carried out on 15th June 2015, 10 days after the tremor by a group of local researcher. From the visual observation towards reinforced concrete buildings in the area of Ranau and Kundasang, there are a lot of damage recorded after the earthquake. Table 3 contains series of pictures that show the damages of Staff Quarters Hospital Ranau after the earthquake. From these pictures, the damages at the beam-column joints and columns can be seen clearly. The damages were mostly detected at the ground floor of the building and validate the compression and tension failures from Ruaumoko2D modeling which has been illustrated in Figure 7 .

Table 3: Visual Observation of the Prototype Building After Earthquake

Visual Observation	Description of Damages
	The shear crack of end column located at the ground floor and initial spalling of concrete cover was spotted.
	Huge spalling of concrete cover and shear cracks observed at the column located at the ground floor.
	Sspalling of concrete cover and shear cracks observed at the beam-column joint was observed.
	Large cracks in structural elements and beam-column joint. Spalling of the confined concrete inside the column. Fracturing of the longitudinal bars inside the column located at the ground floor.
	Huge crack on the column was observed at the first floor of the building.
	Moderate structural damage; cracks in column and spalling of confined concrete. The reinforcement inside the column can be seen.

5. Conclusions

From the analysis of Ruaumoko2D, it is proved that the soft storey building which has strong beam and weak column design is weak to withstand the lateral loading. Thus, recent earthquake that happened in Sabah had caused moderate to severe damage to a few buildings especially soft-storey building. The open ground storey and weight from upper levels will reduce the stiffness and lateral load resistance then lead to collapse when earthquake strikes. The structural deformation modeling from this study showed that the soft-storey building especially buildings that designed in accordance to British Standard code of Practice (BS8110) where there is no consideration been made on earthquake loading, would have compression and tension failures during earthquake especially for the first level of the building. The on-site visual observation also proved that there were moderate and severe damages in the area of column and beam-column joint of the Staff Quarterd Hospital Ranau after the 2015 Ranau Earthquake.

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