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Rectification of Sabah Stilt House Using Shear Wall Subjected to Earthquake

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Abstract: A moderate earthquake with 6.0-magnitude hit Sabah in 2015 especially in Ranau, Sabah has been labelled as one of the most powerful earthquakes ever in Malaysia. Numerous buildings in Sabah have become defective with the severity level of damages as absolute (non-repairable) in the RC beam-column joints and soft-storey structures. Seismic design and construction requirements were not considered in most buildings in Sabah. Hence, this research is to investigate how to mitigate the effect of earthquake on the low-rise building using a more practical and economical method. A stilt house model is developed using ABAQUS software to determine the behaviour of the stilt, low-rise building subjected to earthquake by constructing shear wall at the short columns support. There are 4 models constructed namely, frame model without shear wall (W1), with shear wall of 100mm (W2), 300mm (W3) and 500mm (W4). The results of seismic response are evaluated and compared. Different length of shear wall affects the displacement and stress of the frame model. As shear wall length increases, the displacement, stress at columns and stress at walls decreases. Thus, adding a shear wall can be used to retrofit stilt houses and a credible way to mitigate damage due to earthquake load for new houses along hill slopes.

Keywords: Sabah earthquake, stilt house, short column, shear wall

1. Introduction

In 2015, a medium 6.0-magnitude earthquake hit Ranau, Sabah and was labelled as one of the most powerful earthquakes ever in Malaysia. Earthquakes hardly occur in Malaysia because of its position quite far from major plate boundary faults. Thus, such medium intensity earthquake occurrence in Ranau can result to substantial damages to the affected areas [1]. No seismic design code was employed to the Malaysian buildings until 2017, after which the Malaysian Annex for Eurocode 8 has been applied for local seismic design. Hence, most of the present structures have not been designed and constructed without considering the seismic loads. Ductile detailing had not been considered and implemented in their construction [1], [2]. Consequently, numerous buildings in Ranau have become defective with the severity level of damage as absolute (non-repairable) in the structural RC beam-column joints and soft-storey buildings [2]. Fig. 1 shows the time history of Ranau earthquake in 2015.

Damage observed in the surveyed RC buildings of Ranau due to the poor quality of construction elements and loose infill walls were 25% and 15% respectively [1], [2]. Due to the inadequate design and construction of RC frame components, these buildings essentially behaved like masonry shear wall structures with a shear-dominant failure mechanism [7]. The vulnerability of the buildings is due to obsolete design codes, poor design practices and enforcement of the code [4]. Most of these buildings are currently in operation but need further evaluation and

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upgrading to minimize seismic damage and improve the safety of life. Most of the buildings with damage level grade 3 and grade 2 are residential houses built with wood and positions near or on the hill [4], [9]. The main causes of the seismic induced damage of the surveyed structures in Ranau are the short column effect (20%) and the plan and elevation irregularity of buildings (30%) [4]. Most of the short column failures that have occurred in the buildings were constructed on inclined slopes where these buildings at the hill slope are built with different heights of columns.

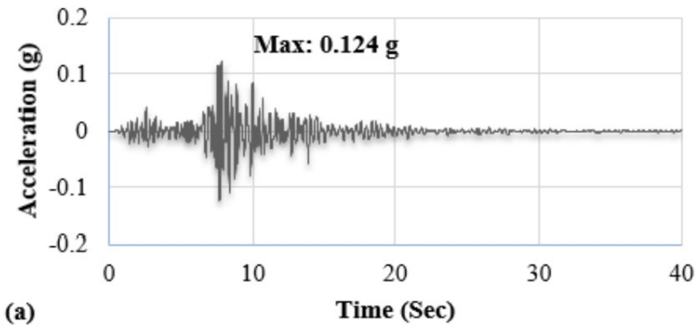

Fig. 1 - Time history of Ranau earthquake [2]

Short columns usually suffer more damage compared to the others. Short column phenomenon normally occurs to structures built on inclined slope that have different heights of first story columns [1]-[3], [8], [12]. It is found that structures with short columns are very vulnerable to seismic action because the short column would be stiffer, has limited flexibility and thus draws a higher bending moment in an earthquake. This type of column also results in more shear force demand since their bending moment arm is short [1], [5].

Several strengthening/retrofitting methods had been carried out. These methods are needed to extend the span in column area, create high strength and ductility in the joints and effectively improve the joint shear strength capacity. The strengthening methods executed have enhanced the energy capacity dissipation and lessened stiffness degradation of beam-column joints. Methods associated to non-seismic design of structural beam-column joints such as the steel dissipation jacket and steel cages have visibly been implemented in the strong column weak-beam concept. Applying external post tension rods and fiber reinforced polymer as one of the retrofitting methods had considerably improved the strength of non-seismic design to 40 %, thus avoiding major brittle shear failure at joints [2]. However, particular care is needed especially for the welded section; wherein the brittle/corrosion failure under elevated number of cycles may occur [2]

In this study, the influence of shear-wall to a low rise building on stilt subjected to earthquake is investigated. Different lengths of shear walls are provided at the shorter lengths of the column to the low-rise building on stilt. The significance of using shear walls can be an alternative to a more practical and economical method to rectify the effect of earthquake on the existing low-rise building on stilt as well as to mitigate new low rise building constructed along slopes [5].

2. Short Column Phenomenon in Ranau Houses

Fig. 2 shows a building on sloping ground which has suffered severe damage due to the short column failure during the Ranau earthquake. It can be observed that all the supporting columns of the building which were about 1 m long failed through shear [1], [4].

Fig. 2 - Stilt house damaged due to short column effect

The side and plan view of this building are shown in Fig. 3(a) and Fig. 3(b) [1]. The wall and roof were made from wood while reinforced concrete was used for the floor beams and columns. Referring to Fig. 3(b), the columns with