International Journal of Civil Engineering and
Geo-Environmental

Journal homepage:http://ijceg.ump.edu.my
ISSN:21802742

PRELIMINARY DAMAGE ASSESSMENT DUE TO 2015 RANAU EARTHQUAKE

T. A. Majid[1*], A. Adnan[2], M. I. Adiyanto[3], M. Z. Ramli[2], T. C. Ghuan[4]

[1] Disaster Research Nexus, School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus, Penang, Malaysia
[2] Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor, Malaysia
[3] Faculty of Civil Engineering & Earth Resources, Universiti Malaysia Pahang, Pahang, Malaysia
[4] Department of Civil Engineering, Faculty of Engineering, Universiti Malaya, Kuala Lumpur, Malaysia

A R T I C L E I N F O

Keywords:

Ranau earthquake
Nonstructural damage
In-situ field investigation
Damage assessment
Sotf-storey

A B S T R A C T

Since December 2004, there was a lot of tremors felt in Malaysia. Most of the tremors occurred due to Sumatra Andaman and Philippine earthquakes. Several local earthquakes in Bukit Tinggi, Pahang also reported in 2007. These events did not caused any damages on buildings. However, on June 5th 2015, a moderate earthquake with magnitude M_w5.9 as reported by Malaysian Meteorological Department was occurred in Sabah, Malaysia around 7:15 am local time. The epicentre was located at 16 km northwest from Ranau and the depth is 54 km beneath the earth. The tremors was felt in Ranau, Kundasang, Tambunan, Pedalaman, Tuaran, Kota Kinabalu, and Kota Belud. The main-shock also followed by several tremors namely as after-shock. For the sake of safety, it is very important to examine the condition of existing buildings shortly after earthquake. Therefore, less than two days after the first event, a reconnaissance mission took action to investigate the damages on buildings. This paper presents the structural damages occurred on reinforced concrete buildings due to 2015 Ranau earthquake. Based on in-situ field observation, it is clear that the columns experienced significant damage compared to beams. This failure mechanism is known as Weak Column – Strong Beam. The damages due to soft-storey mechanism and short column effect also occurred on the reinforced concrete buildings due to the earthquake event.

1. Introduction

Malaysia is surrounded by high seismicity regions at the east, west, and south parts as shown in Figure 1. According to Pappin et al. (2011), these high seismicity regions is strongly associated with the subduction zones between the Eurasian and Philippines plates at the east part. At the west and south parts, high seismicity region is formed by the subduction zones between the Indo-Australian and Eurasian plates. Several earthquakes occurred due to seismic activities in these regions were felt in Malaysian soil, especially after the 26 December 2004 mega earthquake in Aceh, Indonesia. Apart from that, Malaysia also experienced local earthquakes in Bukit Tinggi and Sabah (MOSTI, 2009).

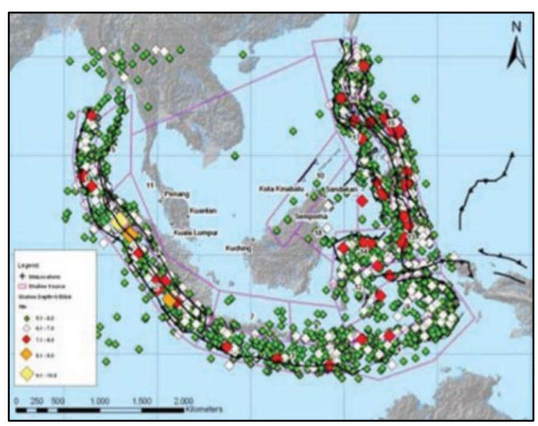

Figure 1: Earthquake events since 1972 to a depth of 50 km (Pappin et al., 2011)

*Corresponding author. Tel: +604-5996201; Fax: +604-5996906
*Email address: taksiah@usm.my

On 5th June 2015, the whole nation was shocked when a moderate earthquake was occurred in Sabah around 7:15 am local time (Adiyanto, 2016). According to the Malaysian Meteorological Department, the epicentre of the M_w5.9 earthquake was located at 16 km northwest from Ranau and the depth is 54 km beneath the earth as shown in Figure 2. Prior to that event, the tremors were felt in Kundasang, Ranau, Tambunan, Pedalaman, Tuaran, Kota Kinabalu, and Kota Belud. A series of after-shock with lower magnitude also occured after the main-shock. A lot of damages had been reported on residential, school, mosque, temple, and commercial buildings. This paper presents the damages on structural elements of reinforced concrete (RC) buildings caused by the 2015 Ranau earthquake. The damages on nonstructural elements can be found in previous paper by Adiyanto et al. (2017).

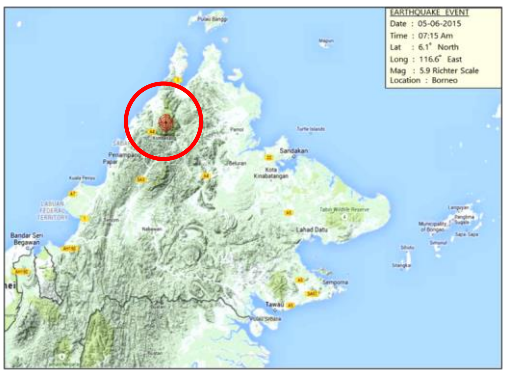

Figure 2: Location of 2015 Ranau earthquake (http://www.met.gov.my/)

2. Investigation Settings

According to Ates et al. (2013), it is important to evaluate the structural performance of buildings shortly after an earthquake event so the status of buildings can be declared either safe for use, need repairing work, or has to be demolished. By referring to FEMA 356 (2000) there are three main structural performance levels namely as Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP). Hence, just two days after the main-shock a technical team took place to investigate the damaged buildings. At that moment, detail inspection was not practical and unsafe due to very active after-shock events. As an alternative, the investigation had been carried out by taking photo, visual observation, and interview with local residents who experienced the tremor. For that mission, a total of 8 sites were investigated.

According to Bayraktar et al., (2013) the structural damages occurred on RC buildings as a result of earthquake action mostly associated with the following reasons:

- Soft-storey failure mechanism
- Weak Column – Strong Beam
- Lack of confinement reinforcement in beams and columns
- Short Columns effect

In addition, wide spacing of transverse reinforcement leads to shear failure, buckling of longitudinal reinforcement, and poor confinement of the concrete core. Similar reasons also reported in previous field observation works (Verderame et al., 2011; Ates et al., 2013; Tapan et al., 2013; Romao et al., 2013).

3. Result and Discussion

For Ranau and surrounding regions, the reference peak ground acceleration, a_{gR} is lies between 80 gals to 100 gals, which is equal to 0.08g to 0.10g, respectively (Adnan et al., 2008). By referring to Eurocode 8 (2004), the ductility class medium (DCM) shall be considered for seismic design of structural system in such regions. In real practice, most RC buildings in Malaysia including Ranau had been designed for gravity load only without any seismic consideration. Therefore, a lot of damages was observed due to 2015 Ranau earthquake. Based on in-situ field investigation, the damages occurred on all 8 sites were typical and can be categorized as follow:

- Damage RC on beams
- Damage on RC columns
- Damage on RC beam-column joints

3.1 Damage on RC Beams

The damage on RC beams due to 2015 Ranau earthquake is presented by Figure 3. It can be clearly observed that the beams only experienced hairline crack which is classified as minor damage. Only some beams experienced spalling of plaster finishing without flexural cracks on its core structure. Most damage occurred on RC beams located at first storey of the building, especially the beams without brick wall beneath it. In other word, the damage occurred on beams which has large opening at its bottom part. This is associated with architectural requirement which is to provide wide space at bottom storey of the building as car park area. Based on in-situ field observation, the cracks were occurred near the beam-column which is also known as critical region. Insufficient steel reinforcement in the critical region of beam may contribute to this damage.

Figure 3: Damages on RC beams due to 2015 Ranau earthquake

3.2 Damage on RC Columns

Based on visual observation during the in-situ field investigation, damage occurred on columns seem to be greater than beams. The damage of columns can be classified into three different levels. The first level is just minor damage where the hairline crack and spalling of plaster finishing occurred on columns as shown in Figure 4. The hairline cracks and spalling of plaster finishing mostly occurred at the top part of the columns, which is near the beam-column joint. The concrete cover and core of the columns is still in good condition.

The second level is associated with significant damage where wider cracks and spalling of concrete cover occurred as shown in Figure 5. As a result, the longitudinal and transverse column reinforcement can be seen. The damages also occurred in the critical regions, which is located at the top and bottom part of the columns. This level of damage is associated with LS performance level, where the interstorey drift ratio is equal to 2% (FEMA 356, 2000). Based on quick observation, it seems that the spacing of confinement or transverse reinforcement within the column’s critical region is not sufficient to resist earthquake load. One of the inspected columns has 250 mm spacing of confinement reinforcement. For gravity load design this spacing might be adequate. However, if seismic detailing is considered the maximum spacing of confinement reinforcement in column’s critical regions with DCM shall not exceed 175 mm (Eurocode 8, 2004).

Finally, the third level can be classified as total damage. At this level the columns were totally broken as shown in Figure 6. The square RC columns originally stand for a single storey residential building built on slope. This condition created soft storey mechanism. In addition, the short column effect also occurred because the height of every column are differ to each other. Due to earthquake action the columns were dislocated from its original position even fully separated from the beam. Lack of confinement reinforcement was observed in the column’s critical regions. The columns experienced spalling of concrete cover, buckling of longitudinal reinforcement, and crushing of concrete core.

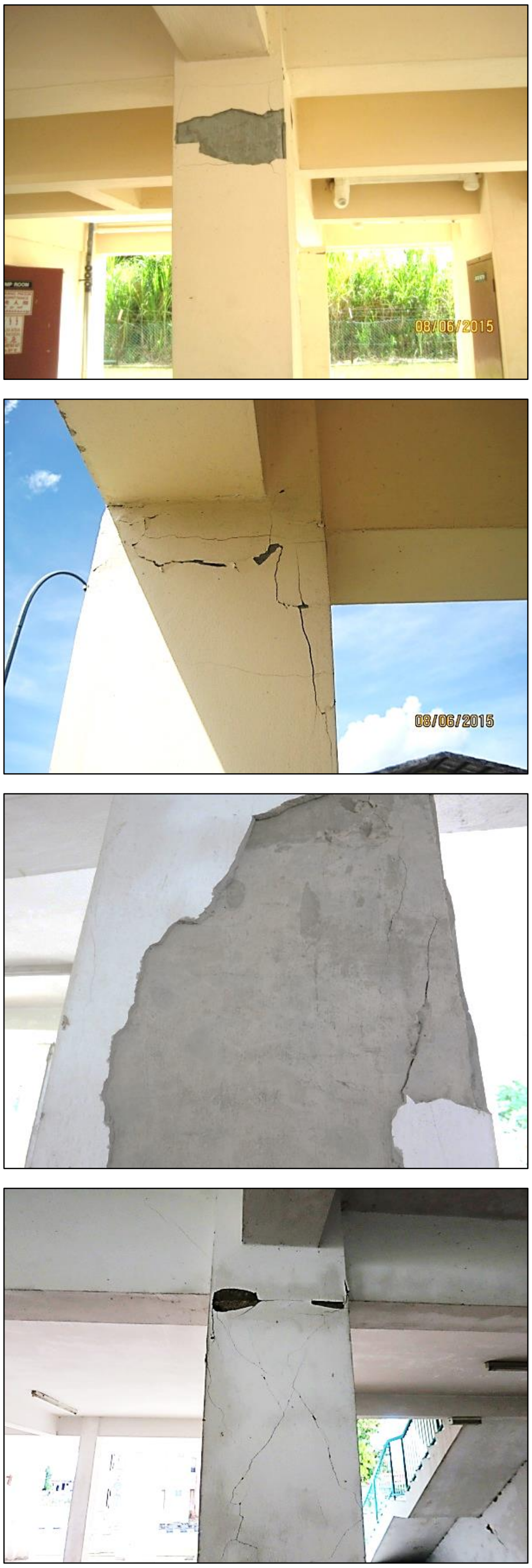

Figure 4: Minor damages on RC columns due to 2015 Ranau earthquake

Figure 5: Significant damages on RC columns due to 2015 Ranau earthquake

Figure 6: Total damage on RC columns due to 2015 Ranau earthquake

3.3 Damage on RC Beam-Column Joints

The M_w5.9 Ranau earthquake also caused damage on the RC beam-column joints as shown in Figure 7. The damages can be classified as significant where severe crack and spalling of concrete cover were occurred. Based on visual field observation, there is no confinement reinforcement within the beam-column joints. Since the inspected buildings were designed for gravity load only this practice is acceptable. However, when it comes to seismic detailing, these beam-column joints did not comply with the seismic provision like Eurocode 8 (2004). In some case, severe crack which originally occurred at the beam-column joints elongated to the critical regions of the columns due to cyclic action of earthquake. This condition caused permanent displacement and the column has no more strength to resist any lateral load caused by after-shocks.

Figure 7: Damage on RC beam-column joints due to 2015 Ranau earthquake

4. Conclusions

Based on in-situ field investigation, it is clear that the RC columns experienced significant damage compared to RC beams. This failure mechanism is known as Weak Column – Strong Beam where the beams remain elastic but columns have to carry all shear forces or compression during earthquake (Bayraktar et al., 2013). The damages were occurred mainly at the bottom storey of RC building. This is associated with the soft-storey failure mechanism due to open space for car park area. Other failure mechanism namely as short column effect also occurred due to the earthquake. Based on visual observation, one of the reason for damage is caused by lack of confinement reinforcement within the critical regions of beam and column.. It can be concluded that the damages and failure mechanism of RC buildings due to 2015 Ranau earthquake is typical as previously reported (Bayraktar et al., 2013; Ates et al., 2013; Verderame et al., 2011; Tapan et al., 2013; Romao et al., 2013). Therefore, it is worth to consider seismic design in medium seismic region in Malaysia as suggested by MOSTI (2009).

References

Adiyanto, M.I. (2016). 'Influence of behaviour factor on seismic design and performance of reinforced concrete moment resisting frame in Malaysia'. PhD Thesis, Universiti Sains Malaysia.

Adiyanto, M.I., Majid, T.A. and Nazri, F.M. (2017). 'Nonstructural damages of reinforced concrete buildings due to 2015 Ranau earthquake'. Proceding of the 3rd International Conference of Global Network for Innovative Technology 2016, Penang, Malaysia, pp.1-6.

Adnan, A., Hendriyawan., Marto, A. and Selvanayagam, P.N.N. (2008). 'Development of seismic hazard maps of east Malaysia'. Advances in Earthquake Engineering Applications, pp. 1 - 17.

Ates, S., Kahya, V., Yurdakul, M. and Adanur, S. (2013). 'Damages on reinforced concrete buildings due to consecutive earthquakes in Van'. Soil Dynamics and Earthquake Engineering, 53, pp.109-118.

Bayraktar, A., Altunisik, A.C. and Pehlivan, M. (2013). 'Performance and damages of reinforced concrete buildings during the October 23 and November 9, 2011 Van, Turkey earthquakes'. Soil Dynamics and Earthquake Engineering, 53, pp.49-72.

CEN. (2004). 'Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings'. European Committee for Standardization, Brussels.

FEMA. (2000). 'Prestandard and commentary for the seismic rehabilitation of buildings, 2000 Edition, FEMA 356'. Building Seismic Safety Council for the Federal Emergency Management Agency, Washington D.C.

Malaysian Meteorological Department (2015) [Online], [Accessed 11th June 2015]. Available from World Wide Web: http://www.met.gov.my/

MOSTI. (2009). 'Seismic and tsunami hazards and risks study in Malaysia'. Final Report, pp. 59 - 142.

Pappin, J.W., Yim, P.H.I. and Koo, C.H.R. (2011). 'An approach for seismic design in Malaysia following the principles of Eurocode 8'. Bulletin Jurutera, pp.22-28.

Romao, X., Costa, A.A., Pauperio, E., Rodrigues, H., Vicente, R., Varum, H. and Costa, A. (2013). 'Field observation and interpretation of the structural performance of constructions after the 11 May 2011 Lorca earthquake'. Engineering Failure Analysis, 34, pp.670-692.

Tapan, M., Comert, M., Demir, C., Sayan, Y., Orakcal, K. and Ilki, A. (2013). 'Failures of structures during the October 23, 2011 Tabanli (Van) and November 9, 2011 Edremit (Van) earthquakes in Turkey'. Engineering Failure Analysis, 34, pp.606-628.

Verderame, G.M., Luca, F.D., Ricci, P. and Manfredi, G. (2011). 'Preliminary analysis of a soft-storey mechanism after the 2009 L'Aquila earthquake'. Earthquake Engineering and Structural Dynamics, 40, pp.925-944