Physical Damages Effect on Residential Houses Caused by the Earthquake at Ranau, Sabah Malaysia

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***Abstract*— Earthquake, the destructive natural disaster had recently stormed East Malaysia. This study aims to identify the physical effects of the earthquake to the building that occurred in Sabah, Malaysia. A survey method had been conducted among 221 citizens in the affected area to meet the requirements of this research objective. The result shows that 68% responded that building cracks had formed on the wall, 48% cracked floor, 23% cracked columns, 10% damages on roof and 8% responded no damages at all while only 2% stated the total collapse of the houses' structures. Researchers have also identified that the impact of the earthquake towards their house yards shows that 55% and 12% responded experienced cracks on ground and landslide respectively, 25% with flood occurrence and 1% are caught with fire. Finally, almost 90% of the respondents are ready to upgrade their house structures. Thus, this research will be continued by developing the retrofitting and strengthening methods for the low rise buildings.**

***Index Terms*—physical damage, earthquake, residential house, questionnaire.**

I. INTRODUCTION

The discharge of energy in the earth crust will create seismic waves that we called it as earthquakes. The process of energy forms during earthquakes can be explained by the elastic rebound theory. It can be explained that as the rocks on adverse sides of fault are deal with force and move, it slowly deform and acquire stress energy until the maximum capacity of stored energy of the crust exceeded. As a result, there will be a sudden movement of crust along the fault, discharge its stored energy and back to their original un-deformed shape.

There are mainly three main types of faults, which are normal fault, thrust fault and strike-slip fault. Normal fault is because of the tension forces between the crust and whichlike they moving away from each other. Thrust fault is because of the compression forces and acting like they pushing each other crust. Next is strike-slip fault is because of the shearing forces between the earth crust.

Liquefaction is another impact from the earthquakes, which lead to the damaged building. It is the behaviour of the soil that loose its strength due to some factors like sand boils, flow failures, ground oscillation and lateral spreads. But for our case study we are focusing on lateral spread because it is liquefaction due to the earthquakes event. Lateral spreads in the involvement of lateral displacement of large, shallow block of soil as a result of liquefaction in a subsurface layer [1]. The combination of gravitational and inertial forces from the earthquakes generates ground movements. Lateral spreads also commonly disturb foundations of buildings because its' location is above or across the failure.

When the ground is shaking violently, medium to low rise buildings, which are not earthquake proof, have more danger of collapsing because they are not flexible. For tall buildings, the ground's rapid motion is dispersed to the reinforcement structure of the buildings. But for low rise buildings, the structure is not designed to resist the earthquake forces. Adding fibres can ameliorate the brittle characteristics of concrete members. When added to the concrete mix as reinforcements, fibres have the potential to increase the bond of the Portland cement paste and the concrete matrix and improve the mechanical properties. Therefore, the inclusion of fibres in concrete reduces the acceleration of shear and flexural crack propagation. Furthermore, the addition of fibre enhances the ductility of the concrete and thereby improves its energy absorption capacity.

A moderate earthquake measuring 5.9 on the Richter scale had occurred in Ranau, Sabah. It had been recorded the most powerful earthquake ever happened in Malaysia, in the last 39 years since 1976. The moderate tremor was the strongest earthquake that surpassed previous records that occurred in 1976, measuring 5.8 on the scale Richter in Lahad Datu, which caused a lot of damage to property and buildings cracks.

It is recorded that four earthquakes had happened in Ranau, first, in 1989 measured at 5.6 Ritcher scale, second in 1991 (5.1 Ricther scale), third in March 2005 (4.1 Ritcher scale) and the fourth in February 2010 (2.6 Ritcher scale). Although Sabah is located outside the Pacific Ring of Fire, a study from Research and Innovation Center of University Malaysia Sabah has found that the area of Kundasang, Ranau, Pitas, Lahad Datu, Kunah and Tawau has the risk of earthquakes. In addition, Director of the center, Prof. Dr. Felix Tongkul, who is also a fellow of the Academy of Sciences Malaysia, stated that Malaysia's position in the neighbouring country that lies on the earthquake fault line caused Malaysia also not spared from the felt of earthquake [2]. Regarding the changes that can be seen after a year of earthquake, Prof Dr Felix Tongkul stated that since the earthquake strucked at Ranau, the government has begun to focus on developing building that has earthquake resistant.

Malaysia had recorded 40 earthquakes in the last 10 years (since 2007) and 37 from it had significantly appeared along earthquake line at Bentong, Pahang. Three earthquakes had occurred at Manjung, Perak and Jerantut, Pahang. The entire event of earthquakes was detected near the area of

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Bukit Tinggi and Janda Baik, which have an outline measuring 15 km width and 70 km long. In addition, Bukit Tinggi and Janda Baik are located above the fault line and it may not surpass tremor measuring 5 Ritcher scale. Therefore, it means that if earthquake occurs at any time it may not damage the structure of the building [3]. This is because there is threshold to make the structure of the building to fail but if the tremor is not achieved the threshold, so the structure will be safe. According to Dr Rosaidi Che Abas, The Meterological Department Director, to date, the earthquakes in Peninsular Malaysia are in the range from 1 to 10 mile below the earth surface.

National Institute of Standards and Industrial Research Institute of Malaysia (SIRIM) is also in the process of designing a code for earthquake resistant building. In addition, through a series of seminars organized by University Malaysia Sabah (UMS) and government agencies, people start too aware of the incident that happened around them [4]. When the design code is completed, it is expected that the design of building after this will have the characteristics of earthquake resistant.

II. Physical Damages Effect of Residential Houses by the Earthquake

Earthquake is a movement of earth plate and keep actively move naturally on its' fault line until today. Land movement or earth settlement can cause damage to the building. The consequence of this event caused many building become defect. But, we also have to take precaution in taking seismic design code for the building that will be built. Even though we make assumption of seismic design code and technology but try not to allow the damage to the building under the maximum considered level of earthquakes although earthquake risk still prevail due to the uncertainty of the next earthquake magnitude [5].

A building might be damaged by the factor of geotechnical deficiency such as fault rupture which causes foundation damage, building differential settlement or soil liquefaction, landslide and damage of retaining wall or by a tilting neighbouring building without enough separation distance [6].

Liquefaction and lateral spreading can occur in many scales, in a range of ways including: total and differential settlements and tilting; the effect of punching settlements of structures with shallow foundations; differential movements of components of complex structures; and interaction of adjacent structures via common foundation soils [7].

According to this discourse, until they are met by vulnerabilities such as an unsafe environment, fragile socioeconomic structures, or lack of disaster preparedness, hazards would remain only as natural phenomena. For example, when a volcano erupts in an uninhabited place, this is only a natural hazard not a disaster. When frequent earthquakes affect settlements in, they do not usually experience these as major disasters because of the country's preparedness and mitigation measures [8].

It is the nature of many construction materials to crack as they aged and as they expand and contract, particularly with exposure to moisture as they get wet and dry out alternately. There are cracks in common areas, such as exterior walls, interior walls at corners of doors and windows, and ceilings (usually in the middle). Crack defect have classified of visible damage to walls. There are having different state in category of damage, and degree of damage. According to the construction theory, the occurrence of wall crack is because of they are overloaded or because the structure has settled or heaved. Vertical and angled crack are usually caused by settlement or heaving [5]. Wall may experience lot of defect due to its non-reinforcement structure. The vibration from the earthquakes makes the bricks vibrate too and cause the adhesive effect of the concrete between the bricks disintegrates and resulting wall defect. From our research area, we find that the two types of wall, which are brick and timber, had suffered failure due to earthquake but with different degree of defect.

Reinforced concrete frame structure system should be designed, as strong columns with weak beams to guarantee the structure system should be a total damage mechanism. Beam subjected to cyclic loading of the type expected in an earthquake, the use of increased flexural reinforcement (positive or negative) might increase the energy dissipation capacity of the member [8]. In an adequately designed lateral load-resisting frame under severe lateral loading, plastic hinges (inelastic zones) will form in the beams rather than in the columns. The moments and shears to which the beams are subjected are a function of the flexural strength of the members; the higher the strength, the greater the imposed loads [9].

The relation of foundation and soil properties can affect the whole structure of a building. Different area contains several types of soil and as a result a proper foundation is needed to setup for the building. Soil amplification factors causing tremors of magnitude bedrock rises during propagated to the ground. Genesis amplification can also lead to poor soil known as liquefaction due to the existence of an increase in pore water pressure and soil [10,11].

III. Result and Discussion

A survey was conducted to Ranau resident on December 2016, six months after the earthquake. The total of 221 respondents consists of female 56.6% and male 43.4% had been involved in the survey. We have collected data for the salary per month of the respondent 27.6% of respondents have salary per month ranging RM 1000 to RM 2499, 16.7% range in RM 2500 to RM 4999, 2.3% which range in RM 5000 to RM 9999 respectively. Majority of the respondents, which is 59.3%, are dwell from agriculture sector since our research area is at Ranau which is the area that is not yet to be industrialized. Other than agriculture sector there is also tourism sector, which is 5.2%, government is 32.6% and construction is 2.2%.

Most of the respondent lives in the house type of non-terrace. They live in the rural area, which is not being in highly developed area. Non-terrace owner has 85.1% and terrace 14.9% for houses type of respondents. From the data, we found that 95.9% are house owners while 4.1% are living in the rented house.

The survey recorded 99% of respondent give the feedback that they are shivered by the incident but 1% of respondent claim that they did not feel the tremor. This is maybe due to the psychological response to vibration exposure above threshold is affecting the function of the situation and type of exposure. It is because some people have different sensitivity of stimuli towards the surroundings. In addition, for an example if the movement of the floor of an underground train were to be transferred to the floor of a building, one would expect a somewhat different response from those standing on that surface. So, considering the relative importance of exposure to earthquake vibration that might only be just above perception of normal person thresholds, perhaps our volcanologists and seismologists should continue monitoring vibration that cannot be felt [12].

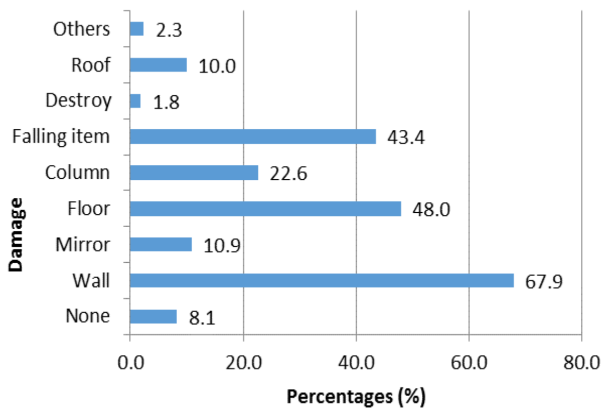

Fig. 1. Types of damage after earthquakes.

Fig. 1 shows the percentage of damaged components of residential building in Ranau. It is shows that wall have the highest percentage of damage due to the earthquake. Since the wall not have reinforcement like beam, slab and column which have the allowed buckling so it more exposed to cracking when the earthquake happened. Moreover, wall is weak in resisting lateral loading that apply on perpendicularly to the wall which is occur during earthquake. Not only that, it might happen due to the settlement of the house foundation. It makes the wall losing its original geometry and therefore cracked occur. In the area of Ranau there are houses that made from wood or combine with concrete and wood. Then when earthquake happen the wall that made from wood become warped. All of the components have been identified from the respondents. Damages in reinforced concrete buildings have happened because of design and construction reasons such as use of insufficiently resistant concrete, the weak reinforcement of soft stories and column beam joints, designs causing short columns, not caring for shear reinforcement and use of strong beam-weak column [13].

Floor experience defect after the earthquakes happen. When the earthquakes occur the ground is displace and cause the floor to move also. Since the floor is fixed because of the suspended slab it cannot withstand the moment to the beam so it cannot support the loading form that resulting crack at floor structure. Moreover, the slab of the stairs also experience defect due to the earthquake vibration. The slab of the stairs happens to cater the loading created from the vibration since the slab is connected from first floor and second floor.

Column is another component of structure that have defect after earthquake event. It is due to the fixed support that cannot move freely when the tremor happens. Column is good in resist vertical loading but weak when it received horizontal loading. It happens when it cannot withstand a certain value of loading so it will form cracks. The cracks commonly form at the joint of the column because the area is enclosed by the highest moment if the column is in fixed support. In addition, some of column have defect at its finishing because the finishing is not well prepared.

The loading from the earthquake to the column cause the column to fail in many ways. There are different types failure with the type of columns, which are short column and long column. Short column will fail directly at the maximum stress that it can withstand but for long column the failure is when it buckles on the application of load. Column is in fixed support and it will act as a portal frame for the whole structure. The tremor from earthquake will produce some frequency and the whole structure will respond to the frequency by moving within its' own frequency. As the building is moving back and forth all items also move together. Fig. 1 also has shown 43.4% of respondent experience items that fall uncluttered inside their house.

Wall has recorded the highest percentages of damaged structure because the wall depends on the brick strength and been fixed on the slab and column. Thus, it cannot withstand higher loading than other types of structures. Unlike beam, column and slab it have reinforcement that can withstand high moment and shear force. In addition, when earthquakes happen the whole structure would be vibrating and cause the wall to vibrate too then the wall cannot withstand the moment created from the displaced columns or beams resulted the wall is cracked. Some of the brick walls have X-mark cracked which means the wall is experience shear failure due to weak load bearing wall. Other than brick wall, timber wall shows that the wall is buckle from the vibration of earthquake cause the timber wall is resisting the load.

Roof has recorded 10% of the damages because it is not fixed at beam or column but only as a pin supported. When earthquake happen the roof only vibrate together since it not fixed supported the moment created from the earthquakes had been eliminated.

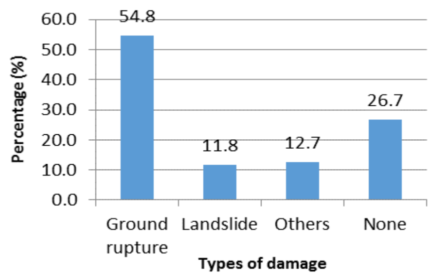

Fig. 2. Damage on house yard.

Fig. 2 shows that 54.8% reported experience soil rupture. It happens when the earth techtonic plate move so resulting the soil rupture. As the earth techtonic plates is move, it create an energy that accumulate and it will release the energy. Effect of the earthquakes makes the section of soil displaced so the result there is liquefaction in a subsurface layer. Furthermore, horizontal displacements on lateral spreads usually ranged up to several metres so it is possible that the ground rupture that form is clearly can be noticed.

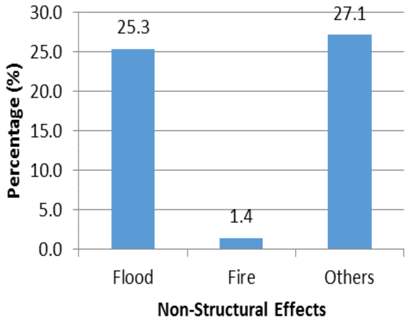

Fig. 3. Non-structural effects after earthquakes.

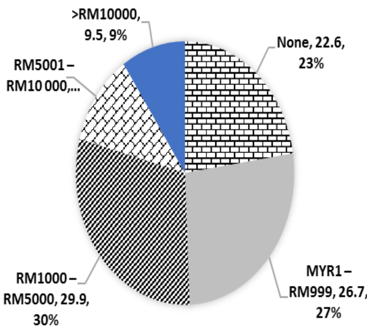

Fig. 4. Estimation loss after the earthquake.

Fig. 3 shows the percentage of non-structural effects to the respondent houses due to the earthquake event. 27.1% shows the defects percentages, which are the mud flood, drainage defect, water supply problem, no electricity, settlement of building. There is analysis to determine the economic flood damages. First is the analysis to the structural damage caused by the flood effects. The degree of structural damage depends on the intensity and magnitude of the flood actions such as hydrostatic and hydrodynamic forces that act to building's resistance by flood.

Next, the economic valuation of the physical damages estimate by the damage estimation in monetary terms will also involve an assessment of the damage to the inventory of the structure [14]. When earthquakes happened the river had leak and cause the water to throw out from its pathway. Riverbanks collapse and cannot hold the water in the river and cause the flood to happen. This failure is due to the ground settlement near the river valley because it loses its' strength due to no suction of water by sandy soil at the river banks because the sand at river bank had become saturated due too much of water pouring inside the voids. Thus, there is no air voids left in the sand at the river banks. As a result the sand loses its bearing capacity and the sand near the river banks settle down cause the flood [1]. This event causes many villagers experience water supply problem because the sediment and debris had been clogged at the water treatment plant. It is recorded 25.3% of respondent had this problem. Furthermore, it is small percentage of respondent that face fire event at their place due to the short circuit that happen during the event.

Fig. 4 shows that the percentage estimation of loss from the respondents. The large of percentage of loss is 29.9%, which is range from RM 1000-RM 5000. This loss can be classified into two major losses, which are structural loss, and non-structural loss. But from our data the major loss is from non-structural loss. Furthermore, from this data we can see the effect of the earthquake to the loss which are varies since the residential building is located at the difference geographical area that have many types of foundation that is suited to the area.

In addition, we expect percentages of estimation loss will be reduced after the implementation of Affordable and Innovative Earthquake Resistance (AIER) system which is that suit for many types of foundation.

Cost-benefit analysis has been used to evaluate the effectiveness of mitigation or retrofit strategies under one hazard or multiple hazards [15]. This is to perform seismic life-cycle cost–benefit analysis. Furthermore, from the recorded data the estimation loss is to make a basis of reference for estimation of the cost of AIER system. The importance of the analysis is to enable house owners to tolerate the cost and benefit of hazard mitigation efforts to target specialized construction practices that are likely to cost effectively mitigate losses [16]. Thus, this method can give the overview from the basic to the top of this implication of application of this system.

From the survey, 91.8% of respondent are willing to make changes of their house structure for application of the AIER system and the extra 8.2% is not willing to do so. Therefore, AIER is relevant and should be applied due to people requests. Moreover, it also environmental friendly since the system use recycled material and it is easily to get the material.

In the hazard mitigation decision making process, other factors involving economic, physiological, and social aspects play an essential role [17]. The perspective of the house owners is to consider the expected goodness that is bigger than cost of retrofit measure. In addition, the decision of the owners' is influenced by many aspects for investing on their houses for future courses and expenses that they have to bare with.

Moreover, the explanation of the system is very important to gain the trust of the respondent and so that they can make decision whether agree or not agree to modified their house. This was explained by [18] how individuals perceive and process information regarding risk with relatively low probability is a dominant factor regarding decision making.

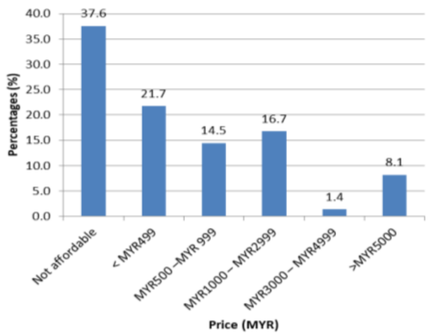

Fig. 5. Estimation cost for the AIER system.

Fig. 5 shows the percentage of the respondents that are willing to expend their money for the application of this system. It is shows that 37.6% of the respondent cannot afford the system. But, 21.7% of respondent is willing to afford the system for less than RM499. There is slightly different in percentage between respondent 14.5% and 16.7% which are agree to expend their money. From this data the price of the system will be known with better material of the system.

There are many aspects need to account for decide the better cost of this AIER system so that it will benefit to both of the parties. Since 37.6% of respondents choose not to afford this product but still there are others respondent are willing to invest their money for the better and safe home. Hence, there is still lot more of research to improve the existing product to make more safe and affordable product.

IV. CONCLUSION

From this research it can be concluded that the physical damages effect on residential houses caused by the earthquake at Ranau, Sabah Malaysia can be reduce by implementing AIER system at the residential houses since analysis of the type of failure and how to overcome such problems had been conducted.

Since the area of Ranau is located on the active fault line and some of the residential was built at the slope area so the application of the rubber foundation still need to be improved because the main problem still cannot be solved because the soil can adrift the foundation in the soil. But, this effect can be reduced by strengthening the joint by applying the bracing to reduce the impact of the earthquakes. Not only that, for the next development it is relevant to account the seismic design into every building in the earthquake potential area.

Further research on best and affordable price and cost for the AIER system can be done by the estimation loss after the earthquake and estimation cost for the AIER system.

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