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ORIGINAL ARTICLE

The Evaluation of Double Story Building Considering Earthquake

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ABSTRACT – Despite being one of the safest countries in the world with shallow earthquake hazards, Malaysia has experienced some minor earthquakes due to its proximity to neighboring countries like Indonesia and Filipina. High seismicity areas surround the nation on the west, south, and east. Furthermore, only about one percent of Malaysia's buildings are earthquake resistant, and Malaysia needs to think of ways to deal with it by constructing more seismic resistance buildings. This research aims to study the implication and cost consequences of the double-story building when an earthquake occurs. In this study, the evaluation of double-story buildings will be investigated by comparing the structural and cost implications of double-story buildings with seismic and without seismic loads. The analysis of an architectural drawing of a typical double-story building will be carried out as part of the research. It is observed that buildings considering earthquake design have more significant structural and cost implications when compared with buildings without considering earthquake design. The study's findings are expected to provide earthquake design criteria for double-story buildings in Malaysia and its neighboring countries to ensure community safety and reduce the structural and cost effects of the construction of double-story buildings with earthquake resistance.

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INTRODUCTION

Earthquakes are one of the most devastating natural disasters on earth. Malaysia is one of the safest countries globally and has very low earthquake hazards because, geographically, it is located at an inactive seismic fault far away from a major plate boundary fault. However, Malaysia has experienced some minor earthquakes due to its proximity to the Philippines and Indonesia, located within the earthquake circle. An earthquake of great magnitude, based on the boundaries of the collision of the bits, can be felt in Malaysia. Hence, Malaysia can be exposed to earthquake risk, whether from local or far-field tremors. The quake felt on the western coast of the Peninsula of Malaysia was triggered by a major earthquake in Sumatra and the Andaman Sea. Furthermore, the local earthquake-affected East Malaysia and some places in Peninsular Malaysia. For Example, in 2007, an earthquake with a magnitude of between 2.7 and 3.5 struck Bukit Tinggi, yet the buildings were not severely damaged [1].

According to the Malaysian Meteorology Department [2], the leading cause of the earthquake was a strike-slip, which was also linked to pressure release caused by earthquakes in Sumatra, Indonesia. Between 1984 and 2007, 35 distant ground motions were recorded in Peninsular Malaysia caused by seismic occurrences in Sumatra. Earthquakes that affected Peninsular Malaysia were originated from Sumatra, particularly from the Sumatra Subduction Zone and the Sumatra Transform Zone [3]. As a result of this massive and extraordinary geological event in 2004, it has disrupted the surrounding plates and altered the terraces of Sundanese land. As a result of the effects, the entire peninsula has been moved to the southwest. Consequently, Peninsular Malaysia has undergone a worse shape change than any other. Thus, the peninsular position of Malaysia is now closer to the epicenter and will experience a more significant impact in the event of an earthquake in the future.

The formation of the earthquake in East Malaysia is different. In the north of Borneo Island, Sabah has suffered 80 earthquakes ranging from 3.3 to 5.0 on the Richter Scale since the 1960 [4]. According to a geologist from Universiti Malaysia Sabah (UMS), most Sabah is exposed to a moderate earthquakes. About seven years ago, on June 5, 2015, the strongest earthquake struck Ranau, Sabah, with a magnitude of 6.0 (Mw) [5]. The state of Sabah has experienced the highest number of ground motions in the country, the majority of which are of local origin and are thought to be caused by several active faults. Now, earthquakes have had a more significant impact in Sabah than in Sarawak or Peninsular Malaysia, owing to the more significant occurrence of local earthquakes in this region. It is worth noting that an earthquake of significant scale can cause severe damage to the property and trigger design engineers' attention [6].

Moreover, just about one percent of buildings in Malaysia are seismically resistant [7] which means considering only gravitational and wind loads. Therefore, design engineers must step outside their comfort zone by designing just for gravity and wind loads to prepare for the coming earthquake. Moreover, previous research on the impact of seismic design consideration on the cost of the material has been limited to different parameters [8]-[9] Thus, this paper investigates the structural implication and cost consequences for a double-story building considering an earthquake in Malaysia. The evaluation of a double-story building will be assessed by comparing the structural and cost implications of double-story buildings with earthquake design and double-story buildings without earthquake design. Hence, this study is beneficial

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to structural engineers in ensuring that the structure can withstand seismic action and is safe to use without being overly expensive.

METHODOLOGY

In this study, two structural modeling of double-story was investigated. For the design simulation, Tekla Structural Designer software was used to simulate the double story building with seismic design and without seismic design, as shown in Figure 1. Table 1 shows the summary of the model specification for both models. All columns and beams size were assumed to be the same for both models and a grade of concrete. Both buildings share a similar plan. A double-story building was designed following [10] for the first model, considering seismic load. Table 2 shows the seismic data that was considered in this study [11]. To ensure that the design is passed to the following stage, the building was designed with the bare minimum requirements. The same building was designed based on Eurocode 2 [12], which does not consider seismic loads.

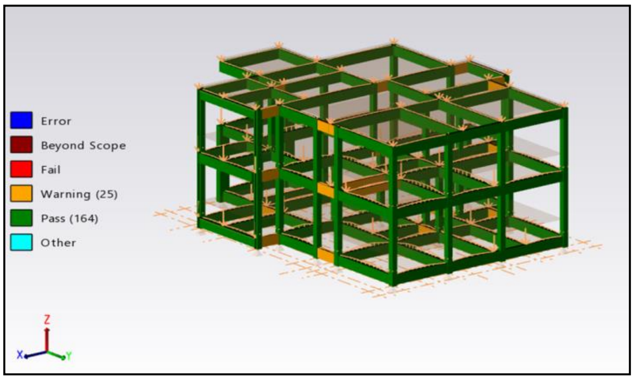

Figure 1. 3D view of double storey building

Table 1. Specification of model

No	Parameters	Capability Values
1	Ground floor (m)	1.5
2	First floor (m)	3.962
3	Roof floor (m)	3.810
4	Slab thickness (mm)	125
5	Size of beam (mm)	250 x 600
6	Size of column (mm)	300 x 300
7	Grade of concrete	C30/37 and C32/40

Table 2. Seismic model description

Description	Parameters
Region	Tawau, Sabah
Referen peak ground acceleration	8.00 %
Sturcutral ductility class	Low
Importance class	II
Imporance factor	1

For the load consideration, there are two types of load applied to the structures, which are horizontal and vertical loads. Vertical loads consist of the structure's self-weighing, dead loads, and live loads. These loads have the same properties as gravity-marked loads. In contrast, horizontal loads, also known as lateral loads, are loads that are perpendicular to gravity forces, which in this case only include wind loads and earthquake loads. Following are specifications of loading values and assumptions, as is customary in Malaysia. As per Malaysian tradition, specifies loading values and assumptions in the following Table 3 are given.

Table 3. Load applied on building

Type of load		Value
Dead load on beams (brick wall)	Roof level	3.6 kN/m
	First level	7.5 kN/m
	Ground level	7.5 kN/m
Dead load on slabs	Roof floor	1.0 kN/m
	First floor	1.5 kN/m
	Ground floor	1.0 kN/m
Live load	Roof floor	0.4 kN/m
	First floor	2.0 kN/m
	Ground floor	2.0 kN/m

The taking-off procedure was used in the final phase to calculate the structural and cost implication for both models. Taking off refers to the process of identifying elements or materials such as the number of rebars, volume of concrete, and weight of steel that produce from the building that can be measured and price. The structural and cost implications of a double-story building with and without earthquake were compared compared. The material cost was determined based on the standard building material price provided by the Jabatan Kerja Raya [13].

RESULT AND DISCUSSION

In this study, both models had undergone structural analysis and model design based on Eurocode 2 [12] (non seismic desin) and Eurocode 8 [14] (seismic design). The structure for the seismic model was classified as important class II, which is in the category of ordinary building. As a result, the building's importance factor equals 1.0, as proposed by Eurocode 8. The magnitude of the dead load, Gk, and the imposed load, Qk, were similar to all models. Furthermore, the size of structural beams and columns was similar to all models, resulting in the similar effective mass of the building, m, and correction factor, λ. Based on the equation proposed by Eurocode 8, the fundamental period of vibration, T1, for all models is equal. The following are the result of the structural cost comparison for both models.

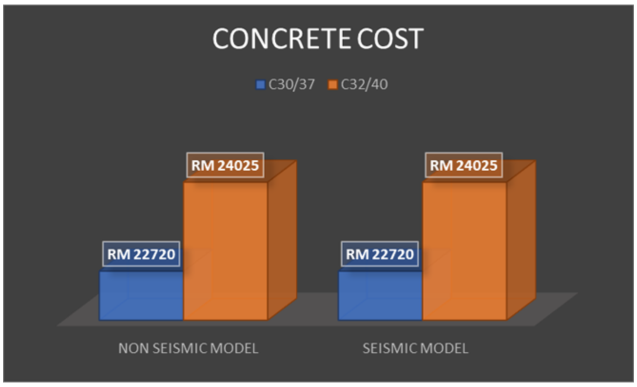

Figure 2. Comparison cost of concrete

Based on the Figure 2, for both models, there are two types of concrete strength which are C30/37 and C32/40. The graph, shows that the volume of concrete required is the same for both models, and the cost of material for concrete was the same. Undoubtedly, to build a building based on seismic load, the cost of concrete is the same as a regular building. So, in conclusion, there is no increment in cost for the amount of concrete required to build a building based on seismic load.

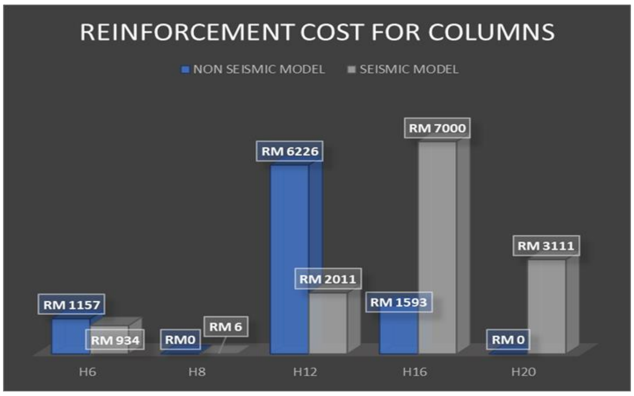

Figure 3. Comparison cost of reinforcement for columns

Figure 3 and Figure 4 show the amount, cost, and type of steel reinforcement for both model designs for beam and column structure. The type of steel reinforcement for columns used for the non-seismic model is H6, H12, and H16, while for the seismic model, the type of steel reinforcement used are H6, H8, H12, H16, and H20. The result obtains shows that the H12 reinforcement cost is the highest for a non-seismic model, which is RM 6226. For the seismic model, the highest cost is for H16 reinforcement, which is RM 7000. The total reinforcement cost for the non-seismic model is RM 8976, while for the seismic model is RM 13062, which is an increment of 45.52 percent. It clearly shows that the cost of reinforcement for the column will increase when subjected to seismic design.

Figure 4. Comparison cost of reinforcement for beams

For the non-seismic model, the type of steel reinforcement for the beam used is H6, H12, H16, and H20, while the type of steel reinforcement for the seismic model is H8, H12, H16, H20, and H25. As a result, it claimed that for the non-seismic model, the highest cost is on steel reinforcement for H12, which is RM 7309. For the seismic model, the highest cost of steel reinforcement is at H16, which is RM 7671. The total cost of steel reinforcement for non-seismic models is RM 9951, while for seismic models, it is RM 12863, which is an increment of 29.26 percent. From here, it was proven that the cost of reinforcement for beams was increasing when taking seismic design into account.

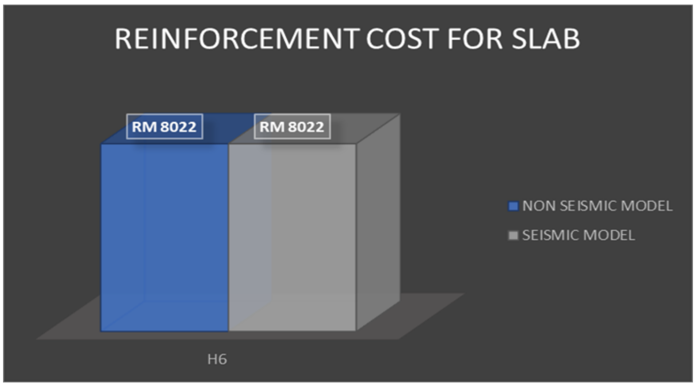

Figure 5. Comparison cost of reinforcement for slab

The Figure 5 shows that the cost for slab reinforcement for both models is the same, as much as RM 8022. The slab is designed to take vertical loads and such a slab may be one-way or two-way. As an earthquake is a horizontal load, therefore, the slab is less impressed but the ability to resist horizontal load by slab-beam-column combination is far better than slab column combination. It concludes that there is no increment in the cost of slab reinforcement for both models.

The result shows that the overall weight of steel reinforcement differs between the two models. For the major structural component, steel reinforcing is increasing by 20 to 50 percent. The result is as expected because the model involving the horizontal load will have the highest value of base shear force [7][15]. It will contribute to a significant bending moment. A structural component like a beam and column that is designed with the highest magnitude of bending moment, leads to increasing the total area of steel required and total area of steel provided [5]. This causes the increment of the number of steel when subjected to seismic design compared to normal design.

CONCLUSION

This research presents the amount of steel reinforcement used and the cost of a double-story building with seismic design and without seismic design in Tawau, Sabah. Two models with and without seismic load had been taken into account. It is important to remember that reinforcement concrete frame structures consist of structural components, including beams, columns, and slabs. Due to the varying forces exerted on these buildings, they all have steel reinforcement of various sizes. Consequently, the total weight of steel reinforcement required in a double-story building for both seismic and non-seismic models is discussed after going through the simulation and receiving the results. The building's cost in this study is based on the result generated from the design analysis of the model and taking off the quantity of the material for the costing.

To obtain analysis and results, a model was designed based on Eurocode 2, which does not account for seismic loads, and another model was designed with seismic loads estimated according to Eurocode 8 using Tekla Structural Designer software. Based on the research findings, the following are some possible conclusions:

a) For models with seismic design, the total mass of steel required increases compared to the model designed without considering the seismic load. From the analysis, it shows that the total mass of steel reinforcement increased by 27.95 percent. The total mass of reinforcement required for constructing a building with a seismic design is more significant than that required for a regular building. This is because the total mass of steel reinforcement required is strongly related to the bending moment and shear force generated by the load imposed on the frame.

b) The total material cost for models with seismic design increases compared to models built without seismic design. These can be proven through the analysis of the results obtained from Tekla Structural Designer software. According to the analysis findings, there is an increment in the cost of steel reinforcement for beams of 29.27 percent, a cost increase for columns of 45.51 percent, and there is no cost change for slabs. This is because buildings with seismic resistance must be designed to withstand dynamic loads, which requires greater quantity of steel reinforcement. As a result, the structure's cost increases.

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REFERENCES

[1] N. Hayati, A. Hamid, and N. Mayuze, “Seismic Assessment of a Full-Scale Double-Storey Residential House using Fragility Curve,” *Procedia Eng.*, vol. 54, pp. 207–221, 2013, doi: 10.1016/j.proeng.2013.03.019.

[2] Meterolological Department of Malaysia, “MetMalaysia: Utama,” *Jabatan Meteorologi Malaysia*. 2019, [Online]. Available: https://www.met.gov.my/.

[3] A. Marto, C. S. Tan, F. Kasim, and N. Z. Mohd.Yunus, “Seismic impact in Peninsular Malaysia,” *5th Int. Geotech. Symp. - Incheon*, no. May, pp. 22–24, 2013, doi: 10.13140/2.1.3094.9129.

[4] S. S. B. Singh, “The Perception Of Primary School Students About The Earthquake In Sabah Malaysia,” pp. 645–652, 2019, doi: 10.15405/epsbs.2019.11.74.

[5] N. Izzati, A. Azman, M. I. Adiyanto, S. Abdul, H. Syed, and A. Adnan, “Steel Reinforcement and Concrete for Multipurpose Hall Building with Seismic Design,” *Int. J. Recent Technol. Eng.*, vol. 8, no. 3S3, pp. 543–547, 2019, doi: 10.35940/ijrte.c1096.1183s319.

[6] A. M. Aly and S. Abburu, “On the Design of High-Rise Buildings for Multi-Hazard : Fundamental On the Design of High-Rise Buildings for Multihazard : Fundamental Differences between,” no. September, 2015, doi: 10.1155/2015/148681.

[7] M. I. Adiyanto and T. A. Majid, “Seismic design of two storey reinforced concrete building in Malaysia with low class ductility,” *J. Eng. Sci. Technol.*, vol. 9, no. 1, pp. 27–46, 2014.

[8] M. I. Adiyanto and T. A. Majid, “Influence Of Behaviour Factor On Seismic Design Of Two Storey Reinforced Concrete Building In Malaysian Seismic Region,” *Aust. J. Basic Appl. Sci.*, vol. 7, no. 8, pp. 411–419, 2013.

[9] M. Z. Ramli, A. Adnan, M. A. A. Kadir, and M. N. A. Alel, “International Journal of Civil Engineering and Cost Comparison for Non-Seismic (EC2) and Seismic (EC8) Design in Different Ductility Class,” vol. 2, no. 2004, 2017.

[10] H. Herrmann and H. Bucksch, “Eurocode 8 - Design of structures for earthquake resistance,” *Dict. Geotech. Eng. Geotech.*, pp. 486–486, 2014, doi: 10.1007/978-3-642-41714-6_51761.

[11] DSM, “Malaysian Standard Malaysia National Annex To Eurocode - Basis of Structural Design,” vol. 2010, 2010.

[12] “MS EN 1992-1-1:2010,” *Chrysanth. Stand.*, 2010.

[13] K. K. R. Malaysia, “Jadual Kadar Kerja Kejuruteraan Awam dan Bangunan Tahun 2021,” p. 138, 2021.

[14] “EUROCODE 8,” vol. 1, no. 2005, 2004.

[15] H. A. Roslan, M. I. Adiyanto, N. S. H. Harith, A. Faisal, and S. M. S. A. Razak, “Impact of seismic design on cost of structural materials for two storey hostel building in Sabah,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 682, no. 1, 2021, doi: 10.1088/1755-1315/682/1/012024.