COST ANALYSIS OF LOW RISE BUILDINGS SUBJECTED TO SEISMIC AND NON SEISMIC ACTION

By

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ABSTRAK

Gempa bumi merupakan fenomena yang membawa impak besar kepada ekonomi dan masyarakat. Malaysia terletak di zon seismik yang rendah ke sederhana, banyak struktur direka mengikut BS 8110 tanpa mempertimbangkan bebanan seismik. Dalam kajian ini, dua bangunan bertingkat rendah iaitu Pra Sekolah dan JKR Cawangan Mekanikal direka semula untuk tahan gempa bumi dengan menggunakan perisian komersil ETABS 2016. Matlamatnya adalah untuk mengenal pasti kos bahan pembinaan meningkat disebabkan oleh beban seismik. Dua model bangunan bertingkat rendah dibangunkan dan direka semula untuk mempertimbangkan beban seismik. Kaedah spektrum tindak balas modal digunkan dalam kajian ini. Parameter bebanan seismik termasuk keadaan tanah, faktor tingkah laku, kelas kemuluran dan pecutan tanah puncak ditentukan mengikut Eurocode 8. Kuantiti bahan seperti jumlah konkrit dan berat tetulang telah ditentukan dengan mengambil kira proses. Keputusan menunjukkan bahawa jumlah konkrit dan keluli bertambah. Selain itu, kos bahan pembinaan meningkat sebanyak 28.35% dan 26.19% untuk Pra Sekolah dan JKR Cawangan Mekanikal. Dalam kajian ini, pelbagai jenis keadaan tanah (Jenis C and D) telah digunakan untuk menilai keseluruhan kuantiti bahan. Keputusan menunjukkan bahawa kuantiti bahan tidak berubah banyak dengan kedua-dua jenis keadaan tanah tersebut.

ABSTRACT

Earthquake is a natural phenomenon that has a greater impact towards the economy and community. Malaysia is located on low to moderate seismic zone, thus almost structures were designed according to BS8110 which does not consider the seismic action. In this study, two existing low rise buildings, namely Pra Sekolah and JKR Cawangan Mekanikal were redesigned for earthquake resistance with the aid of ETABS 2016 commercial software. The aim is to identify the increase in the material construction cost due to the seismic loading. Two low rise building models were generated and redesigned in considering of the seismic loading. The seismic loading was applied to the structure by using modal response spectrum method. The parameter of the seismic load include soil condition, behaviour factor, ductility classes and peak ground acceleration were determined according to Eurocode 8. The material quantities such as concrete volume and weight of reinforcement were determined by taking off process. The results showed that the concrete volume and steel reinforcement increased due to seismic loading. Besides, the material costs increased by 28.35% and 26.19% for Pra Sekolah and JKR Cawangan Mekanikal, respectively. In this study, two different types of soil condition (Type C and D) were used to evaluate the overall material quantity. The two different soil condition showed insignificant change in the material quantities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BS8110	**B**ritish **S**tandard 8110
DCL	**L**ow **D**uctility **C**lass
DCM	**M**edium **D**uctility **C**lass
DCH	**H**igh **D**uctility **C**lass
EC2	**E**urocode 2
EC8	**E**urocode 8
N_{SPT}	**S**tandard **P**enetration **T**est Blow-Count
PGA	**P**eak **G**round **A**cceleration Value

NOMENCLATURES

M_{rb}	Resisting moment in beam
M_{rc}	Resisting moment in column
q_0	Basic value of behaviour factor
ψ_2	Combination coefficient for the quasi-permanent value of a variable action
$v_{s,30}$	Average value of propagation velocity of S waves in the upper 30m of the soil profile at shear strain of 10^{-5} or less
cu	Undrained shear strength of soil
α_u	Multiplier of horizontal seismic design action at formation of global plastic mechanism
α_1	Multiplier of horizontal seismic design action at formation of first plastic hinge in the system

CHAPTER 1

INTRODUCTION

1.1 Background

Earthquake is a natural phenomenon, mainly due to the movement of the tectonic plate around the world. Malaysia is located at non-active seismic fault zone and can be categorised as low to moderate seismicity region. However, Malaysia experienced several tremors due to the earthquake with the magnitude Mw 8.6 which occurred on 28th March 2005 in Nias and 11th April 2012 in Aceh, Sumatra, Indonesia. Besides, a moderate earthquake also occurred in Ranau, Sabah on 5th June 2015 (Sario and Tan, 2015). These phenomena have set the awareness to the relevant authorities on the seismic hazard towards the community.

In Malaysia, most structures were designed according to BS8110 and this particular code does not consider the seismic action in the analysis. As such, only gravitational load and notional are considered in the structural design. Hence, these non-seismic structures may suffer some levels of damage during a local earthquake. Figure 1.1 shows the structural damage after the earthquake event in Ranau, Sabah, Malaysia.

Figure 1.1: Damaged Stilts of a Motel in Ranau Due to Local Earthquake (Sario and Tan, 2015)

Based on the current scenario, the Malaysian Public Works Department (JKR) suggested that it is beneficial to consider the seismic design input for new buildings located in medium-to-high risk earthquake zones (Yuen, 2017). As such, the Eurocode 8 and the National Annex can be used as the design code of practice for earthquake resistance design of structures and able to minimize the damage from the earthquake event. The change from non-seismic to seismic consideration in structural design for area in low to moderate seismicity region may create several new issues to the designer such the selection of seismic force and structural detailing requirement. On the other hand, other stakeholders such as project owners, developers and contractors may put their interest in knowing the change in the construction cost (concrete and reinforcement) due to the incorporation of seismic load in the design.

1.2 Problem Statement

Malaysia is being non-seismic design for the buildings from the beginning. Generally, the anticipated cost for constructing these buildings is well established. However, with the new National Annex for Eurocode 8, some buildings in the near future must be designed by incorporating seismic action and this is particularly true for Sabah (Peak Ground Acceleration, PGA 0.165g). The change in design consideration from non-seismic to seismic loading may affect the design requirements hence changing the detailing of the main structural members. There are several studies focusing on the change of the material cost by comparing the design using BS 8110 and EC 8 but the results are scattered. Moreover, these studies mainly generated simple 2D frame model in the analysis that may not reflect a real building. As such, realistic data on the cost variation cannot be achieved. In addition, to date, no attempt has been made to use real buildings as the model in this type of study. This study aims to provide the relevant stake holders in the construction industry with more reliable data pertaining to the change in the construction material (concrete volume and steel tonnage) due to the incorporation of seismic loading based on constructed building models. This study also investigate the overall material quantities based on different soil condition (Soil C and D). As pervious research only focus the influence of behaviour factor and ductility classes on the overall materials quantities.

1.3 Objectives

The objectives of this research are:

i. To determine the increase in the material quantity of the construction cost due to the incorporation of the seismic loading for two existing buildings.

ii. To evaluate the influence of soil condition on the overall material quantity for two existing buildings.

1.4 Scope of Work

This study were model two existing low-rise buildings that were previously designed based on BS8110. In the seismic design, Eurocode 8 and the Malaysian National Annex were used. The PGA is set to be 0.165g based on the highest value estimated for Malaysia. Moreover, the earthquake loading were applied in the form of response spectrum. The analysis and design were performed with the aid of ETABS Version 17 software. Each structural model were analysed with the different type of soil conditions. Comparisons in terms of the construction material (concrete volume and steel tonnage) between non seismic and seismic design were presented. These quantities are calculated for beams and columns only.

1.5 Significance of Study

The findings from this study can assist industrial player such as project owners, developers, contractors and relevant government agencies to accurately prepare the construction budget, estimate the project cost (tendering) and setting the selling price or rental cost of their properties.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Earthquake events always occurred in countries located near or on the tectonic plate. Malaysia also experienced moderate earthquake event in Sabah due to local fault even though Malaysia is situated relatively far from tectonic plates. In Malaysia, Eurocode 8 is encouraged to be implemented in the design of earthquake resistant building to ensure the safety of structure. The criteria and requirements of the structural seismic design are covered under MS EN 1998-1:2015. This chapter reviews some of the earthquake events worldwide and local, the local design code and past research works pertaining to seismic loading that focuses on cost comparisons.

2.2 Earthquake Event

Earthquake has a greater impact towards the economy and community around the world. In one event, Japan had lost 25000 billion yen (297.8 billion dollars) after the earthquake in Year 2011 (Shrivastava, 2011b) and as a result, the Japan economy shrinks by 1.5%. In 11 March 2011, an earthquake with magnitude of 8.9 Mw occurred near the east coast of Honshu, Japan (Shrivastava, 2011a). It known as 2011 Tohoku Earthquake or 311 Earthquake which is one of the largest earthquakes happened in Japan. Shrivastava (2011a) reported that the 2011 Tohoku Earthquake is the 7th largest magnitude earthquake that generated 10m high tsunami. Other than that, 2011 Tohoku earthquake lead to damage around 110000 building in Japan (Mori, 2016).

On 26 December 2004, one of the powerful earthquakes known as the 2004 Indian Ocean Earthquake and Tsunami occurred in northwest coast of Sumatra, Indonesia (Taylor, 2014). The 9.1 Mw earthquake triggered the tsunami that caused more than 200,000 casualties. Unlike the 2011 Tohoku Earthquake, the 2004 Indian Ocean Earthquake and Tsunami posed greater influence in the loss of life as compared to the damage of infrastructure. Some of the major earthquake events in the past are shown in Table 2.1.

Table 2.1: Seven Major Earthquake Event in the World (Shrivastava, 2011a)

Position	Date	Location	Name	Magnitude,Mw
1	22/5/1960	Valdivia, Chile	1960 Valdivia earthquake	9.5
2	27/3/1964	Prince William Sound, USA	1964 Alaska earthquake	9.2
3	26/12/2004	Sumatra, Indonesia	2004 Indian Ocean earthquake	9.1
4	4/11/1952	Kamchatka, Russia (then USSR)	Kamchatka earthquakes	9.0
5	13/8/1868	Arica, Chile (then Peru)	1868 Arica earthquake	9.0
6	26/1/1700	Cascadia subduction zone, Canada and USA	1700 Cascadia earthquake	9.0
7	11/3/2011	Tohoku region, Japan	2011 Tohoku earthquake	8.9

In the case of Malaysia, Daniell and Vervaeck (2012) reported that the earthquake events mostly occurred in the Sabah area. Besides, Peninsular Malaysia experienced several tremors from the neighbouring country, Indonesia. Although Malaysia is not located in high seismic zone, the earthquake has negative effects towards the structural damage. As the evidence, Figure 2.1 shows the hospital suffered some level of structural damage due to the earthquake occurred in Ranau, Sabah on 5th June 2015.

Figure 2.1: Structural Damage to the column of Hospital Ranau after Earthquake Event (Lim et al., 2017)

2.3 Code of Practice for Seismic Design (Eurocode 8)

The Malaysian National Annex to MS EN 1998-1:2015 (Design of Structures for Earthquake Resistance) was incorporated in the structural seismic design in order to resist the local earthquake effects. Implementation of Eurocode 8 in structural design can ensure the safety of community and develop the sustainable socio-economic in Malaysia (Ahmad, 2017). Malaysian National Annex (2017) for MS EN 1998-1:2015 consist of seismic hazard map of Malaysia which used to classify the seismic zone in Peninsula Malaysia, Sarawak and Sabah as shown in Figure 2.2, Figure 2.3 and Figure 2.4, respectively.

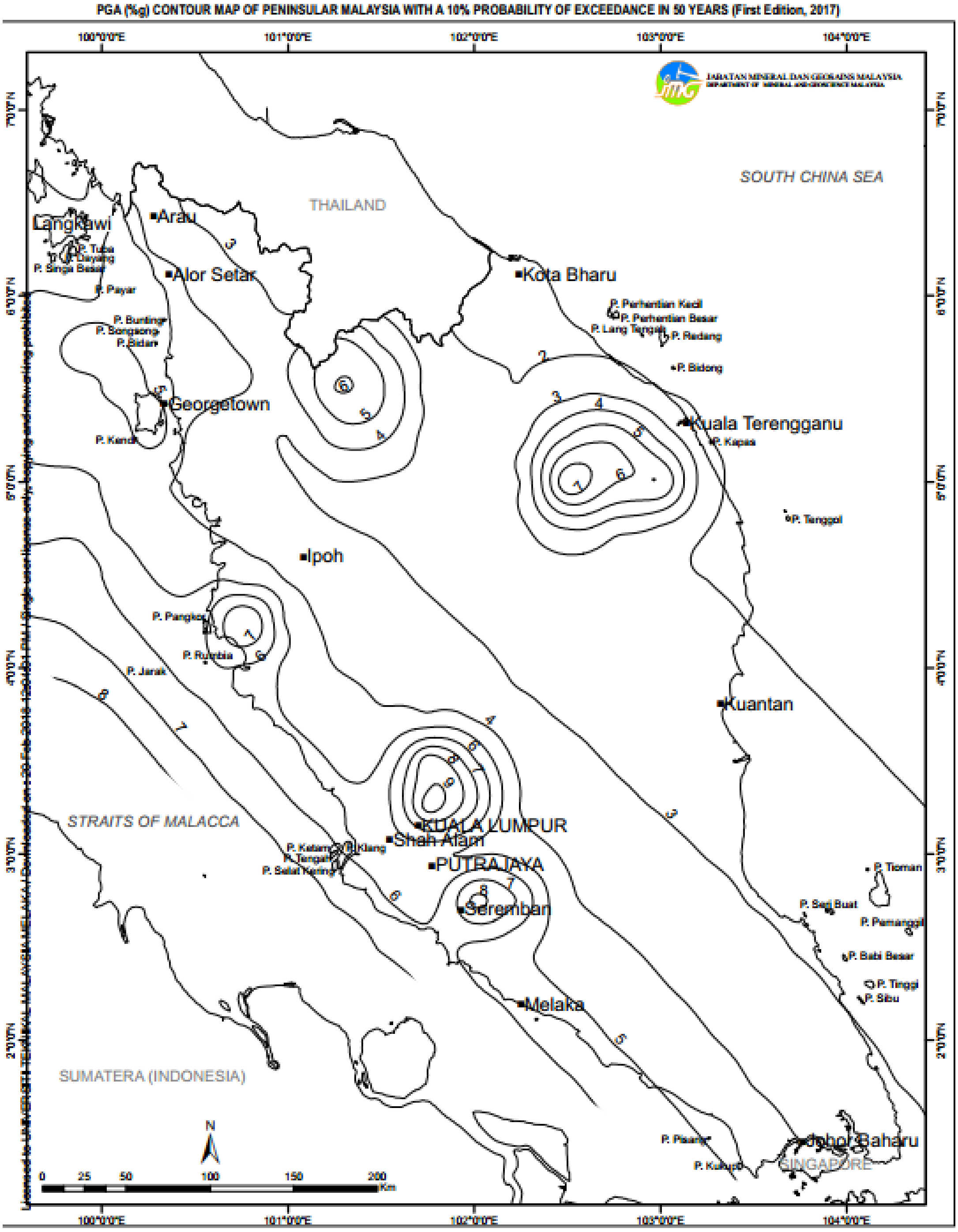


Figure 2.2: Seismic Hazard Map of Peninsular Malaysia (National Annex:2017 for MS EN 1998-1:2015)

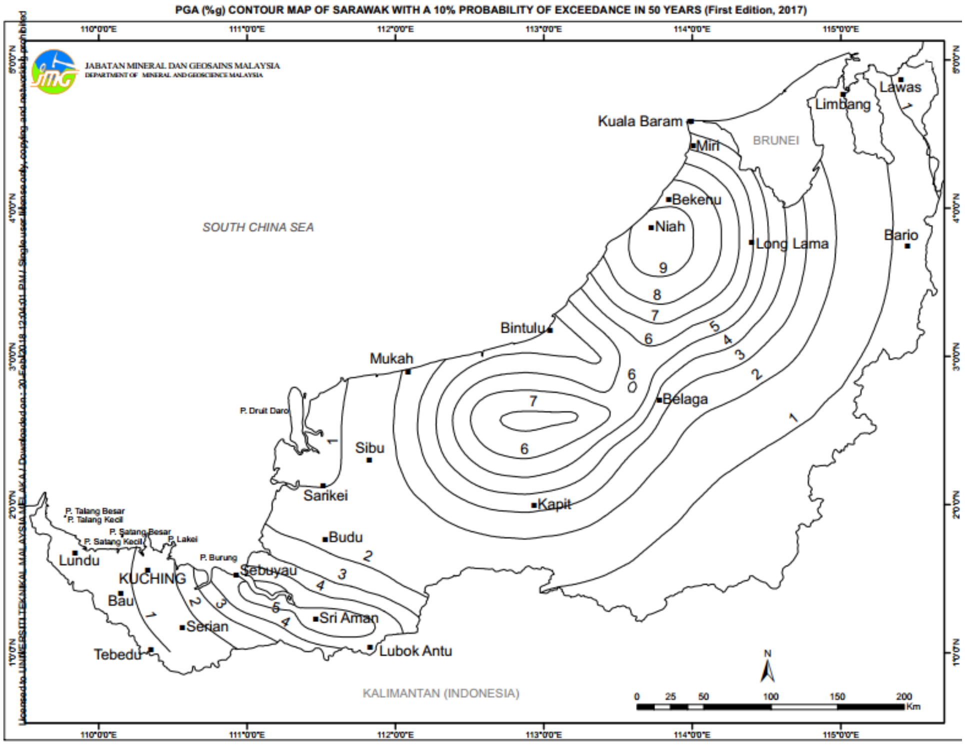


Figure 2.3: Seismic Hazard Map of Sarawak (National Annex:2017 for MS EN 1998-1:2015)

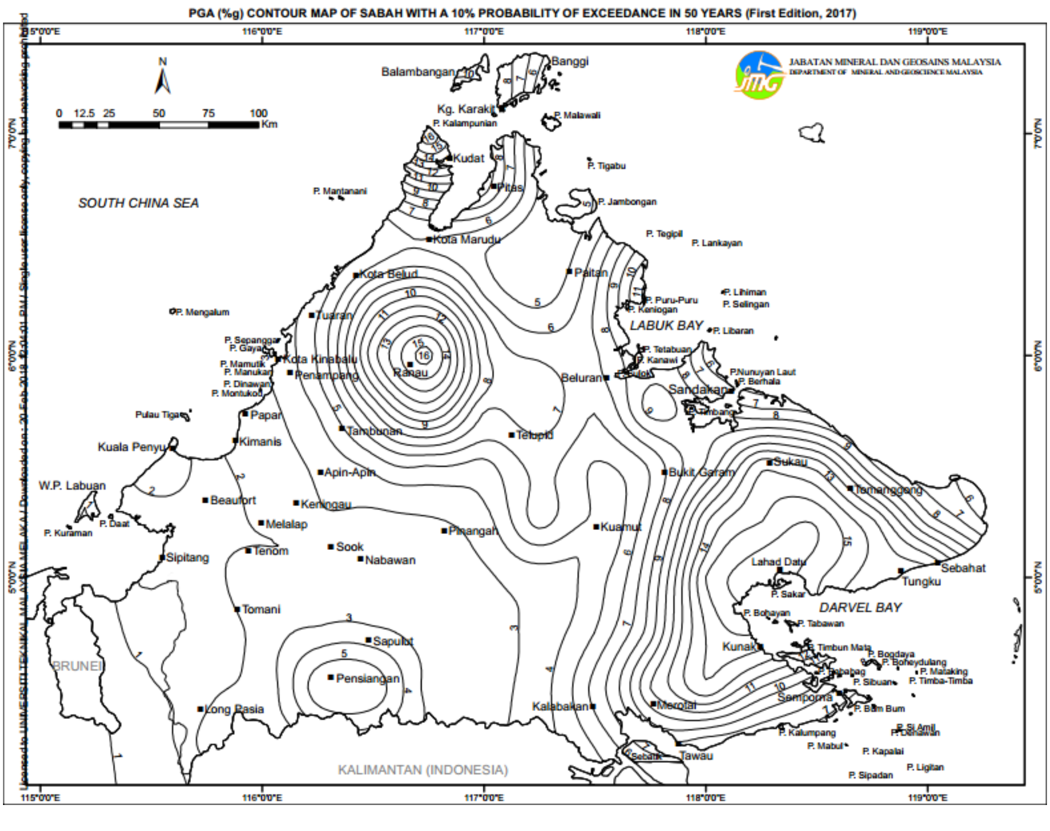


Figure 2.4: Seismic Hazard Map of Sabah (National Annex:2017 for MS EN 1998-1:2015)

Based on the seismic hazard map of Malaysia, it can be seen that the highest estimated PGA value is about 0.08g in Peninsular Malaysia at areas located in Selangor, Negeri Sembilan and Perak. In Sarawak, the highest predicted value is about 0.09g located at Niah area. As for Sabah, the area surrounding Lahad Datu, Ranau and Kudat showed the PGA between 0.14g to 0.16g. The relatively high PGA values reflected that these areas are prone to local earthquake events.

2.4 Method of Seismic Action Analysis

According to Eurocode 8, there are several methods that can be used in the seismic analysis such as lateral force method, modal response spectrum and non-linear methods. Previous research work by Adiyanto and Majid (2013) and Adiyanto and Majid (2014b) used the lateral force method to analysis and design 2-storey reinforced concrete building that is regular in plan and elevation. However, Ramli et al. (2017) used modal response spectrum method. In addition, other researchers performed the non-linear method such as non-linear static and non-linear time history analysis in reinforced concrete structural analysis (Zahid et al., 2017, Sovester and Adiyanto, 2017).

2.5 Horizontal Elastic Response Spectrum

Eurocode 8 categorised the ground condition into ground types A, B, C, D and E. According to Eurocode 8, the type of soil condition can be categorised as shown in Table 2.2.

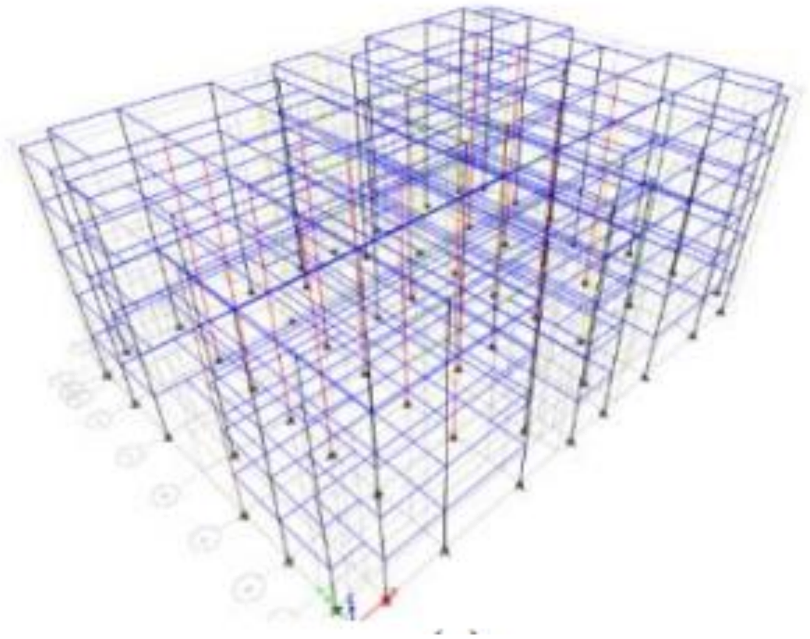
Table 2.2: Ground Types (MS EN 1998-1:2015)

Ground types	Description of stratigraphic profile	Parameters		
		vs,30 (m/s)	NSPT (blows/30cm)	cu (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	-	-
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with vs values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with vs > 800 m/s.			
S1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	-	10 - 20
S2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S1			

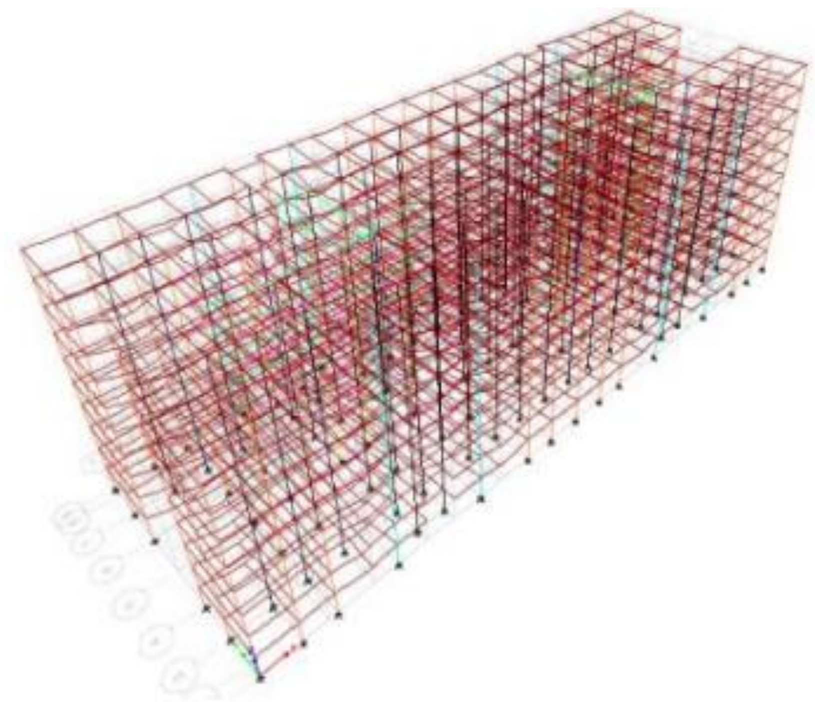
Furthermore, there are two types of horizontal elastic response spectra namely Type 1 and Type 2. Type 1 is adopted if the earthquake surface-wave magnitude, Ms is greater than 5.5 and vice-versa. Different types of ground conditions possessed different parameters of elastic response spectrum (MS EN 1998-1:2015). According to Balendra and Li (2008), buildings in Malaysia were built on soft soil and occasionally subjected to tremors although Peninsular Malaysia located on the stable Eurasian plate. The phenomena occurred due to the far-field effects of earthquake in Sumatra. As such, Ramli et al. (2017) used Type 1 response spectrum and soil D to design the seismic resistant frame model. In another study, Sovester and Adiyanto (2017) also considered Type 1 spectrum with ground type D for investigation of the seismic performance of reinforced concrete structure in Sabah area. Both study considered Type 1 spectrum and soil D according to EN 1998-1:2004 in their investigation.

2.6 Seismic Design Influenced by Ductility Class

Ramli et al. (2017) studied the cost increment between non-seismic design using EC2 and seismic design using EC8 with different ductility class using ETABS commercial software. The material cost was investigated based on the weight of steel reinforcement for beams and columns. The study generated fictitious 5 and 10 storey buildings as shown in Figure 2.5(a) and Figure 2.5(b).



(a)



(b)

Figure 2.5: Models Generated using ETABS showing (a) 5 Storey (b) 10 Storey 3D Frame (Ramli et al., 2017)

The structural seismic design and detailing were based on two different ductility classes and different peak ground acceleration values. The authors analysed building models subjected to PGA of 0.06g for DCL, and PGA of 0.08g and 0.14g for DCM. The results showing the change in the steel (reinforcement) quantities of beams and columns for 5 storey and 10 storey models are shown in Table 2.3 and Table 2.4, respectively. The results showed that incorporating seismic load in the design increased the reinforcement demand in the columns and beams. In the case of 5 storey building, the percentage of reinforcement increased compared to non-seismic design. As the building height increased from 5 storey to 10 storey, the amount of reinforcement also increased approximately 23% and 29% for the same ductility class.

Table 2.3: Quantity of Reinforcement Based on Non-Seismic and Seismic Design for 5 Storey Building (Ramli et al., 2017)

Ductility class	Quantity of reinforcement (tonne)			Increment (%)
	Beam	Column	Total	
EC2	117.0	8.6	125.6	-
EC8 DCL 0.06g	127.5	11.0	138.5	+10.2
EC8 DCM 0.08g	154.0	31.8	185.8	+32.4

Table 2.4: Quantity of Reinforcement Based on Non-Seismic and Seismic Design for 10 Storey Building (Ramli et al., 2017)

Ductility class	Quantity of reinforcement (tonne)			Increment (%)
	Beam	Column	Total	
EC2	962.3	78.7	1041.0	-
EC8 DCL 0.06g	1027.8	361.0	1388.9	+33.4
EC8 DCM 0.08g	1273.9	409.4	1683.3	+61.7
EC8 DCM 0.14g	1274.3	409.5	1683.8	+61.8

Awaludin and Adnan (2016) investigated the material cost of beams and columns for two building models having 3 storey and 8 storey as shown in Figure 2.6 (a) and Figure 2.6 (b), respectively. Comparisons were made based on the changes of the concrete volume and weight of steel reinforcement when the buildings were designed for non-seismic and seismic loading. The seismic loadings were manifested via PGA of 0.06g (DCL), 0.12g (DCM) and 0.4g (DCH).

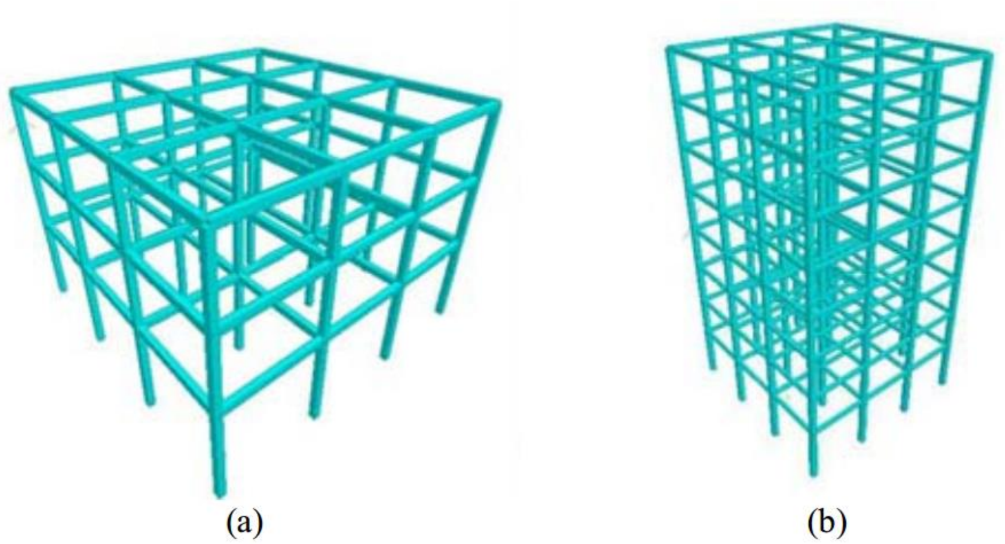


Figure 2.6: Models Generated Using STAAD Pro showing (a) 3 Storey (b) 8 Storey 3D frame (Awaludin and Adnan, 2016)

Table 2.5 shows the total material cost for both buildings. By setting the non-seismic design results as reference, the total cost for the 3 storey DCL and DCM frames increased by 4% and 13% DCM, respectively. Moreover, the cost for the DCH model significantly increased by 68%. Similarly, the 8 storey model showed additional cost of 33%, 36% and 87% for incorporating seismic design based on DCL, DCM and DCH requirements, respectively.

Table 2.5: Total Material Cost for 3 Storey and 8 Storey frame (Awaludin and Adnan, 2016)

Ductility class	Type of frame	
	3 storey	8 storey
Conventional	RM16689.32	RM51718.92
EC8 DCL 0.06g	RM17297.15	RM68699.90
EC8 DCM 0.2g	RM18914.27	RM70757.89
EC8 DCH 0.4g	RM28061.29	RM96720.13

2.7 Seismic Design Influenced by Behaviour Factor

Behaviour factor is defined as the approximation of the ratio of the seismic forces that the structure would experience if its response was completely elastic. Since the factor takes into account the dissipative capacity of the structural system, it varies with the structural typology (Macedo et al., 2019). Adiyanto and Majid (2014a) modelled a fictitious 3 storey general office frame building and investigated the difference in terms of steel reinforcement for column subjected to seismic design with 1.5, 3.0 and 4.5 behaviour factor. The frame model is shown in Figure 2.7.

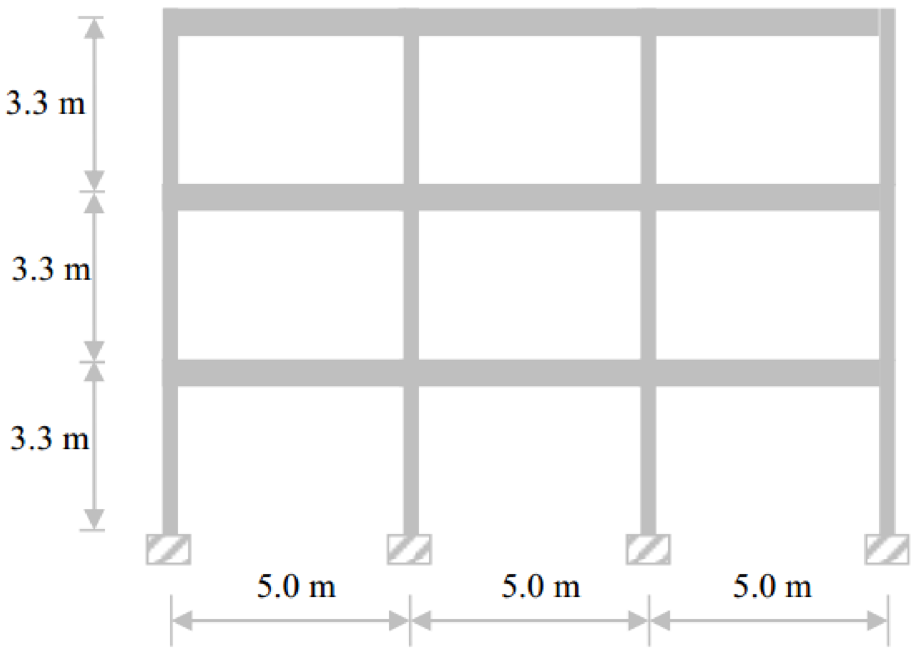


Figure 2.7: Frame Model for General Office Building (Adiyanto and Majid, 2014a)

The authors reported that due to the strong column-weak beam concept, the resisting moment in column, M_{rc} must higher or equal to 1.3 of the resisting moment of beam, M_{rb}. This concept must be considered in order to avoid the formation of plastic hinge in the column of structure. The exterior and interior columns were designed separately because of the different strength of the exterior and interior beams. Figure 2.8 shows the graph of the total weight of steel (flexural and shear) reinforcement for various levels of behaviour factor. The result showed that highest amount of steel reinforcement demand was required for frame with behaviour factor of 1.5 due to the high magnitude of base shear force a shown in Figure 2.8. The total amount of reinforcement decreased at higher behaviour factor as the result of reduced lateral load that in turn, reduced the bending moment for beam design. Strictly speaking, different levels of behaviour factor should not be used for the same model because this factor depends on structural type (frame, ductile wall, frame equivalent dual system, wall equivalent dual system and large lightly reinforced wall), and regularities in plan and elevation (MS EN 1998-1:2015).

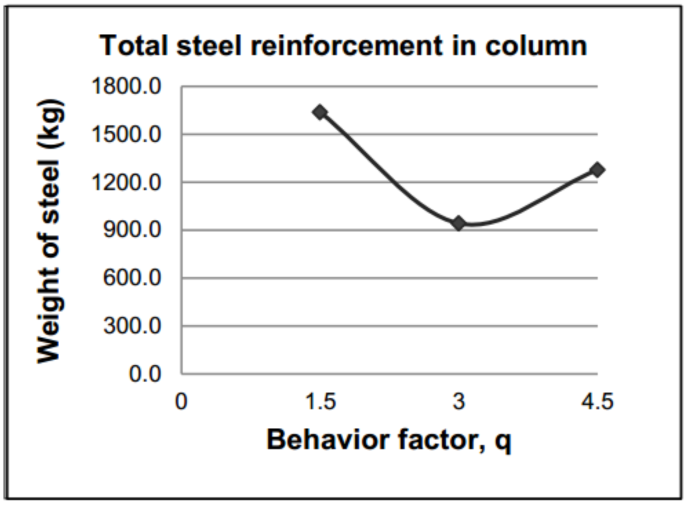


Figure 2.8: Effect of Behaviour Factor on Total Weight of Steel (Adiyanto and Majid, 2014a)

Interestingly, the authors found that the demand for flexural reinforcement was in contrast with the demand for shear reinforcement in column as shown in Figure 2.9. In this case, the weight of flexural reinforcement in interior and exterior columns decreased when the behaviour factor increased due to the reduced moment resistance of the beams. On the contrary, the amount of shear reinforcement for interior and exterior column increased significantly with the behaviour factor due to the requirements for confining the reinforcement set for DCM structure in Eurocode 8.

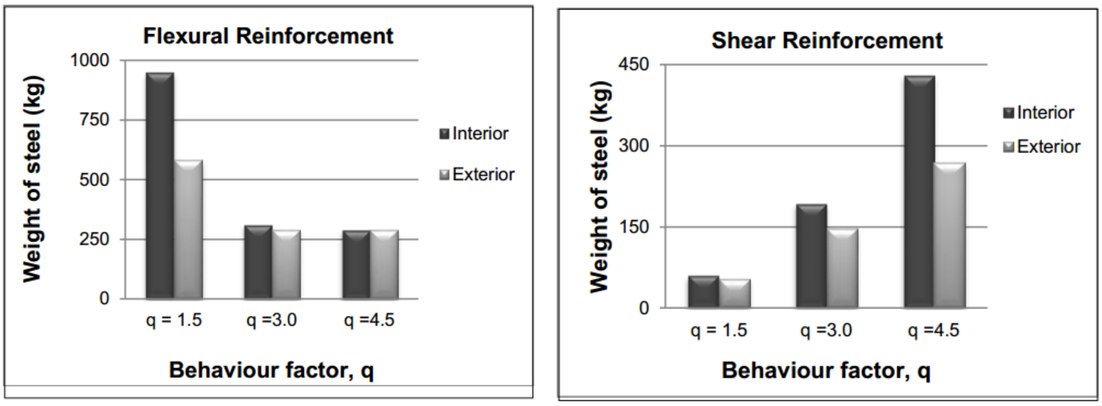


Figure 2.9: Effect of Behaviour Factor on Flexural Reinforcement and Shear Reinforcement (Adiyanto and Majid, 2014a)

Adiyanto and Majid (2013) used the frame shown in Figure 2.10 to investigate the influence of behaviour factor on the material cost. BS 8110 was used for the conventional design whereas Eurocode 8 was adopted to the frame design with behaviour factor set at 1.5, 2.7, 3.9 and 4.5 for medium ductility class. The design considerations and total number of frame used in the design are listed in Table 2.6.

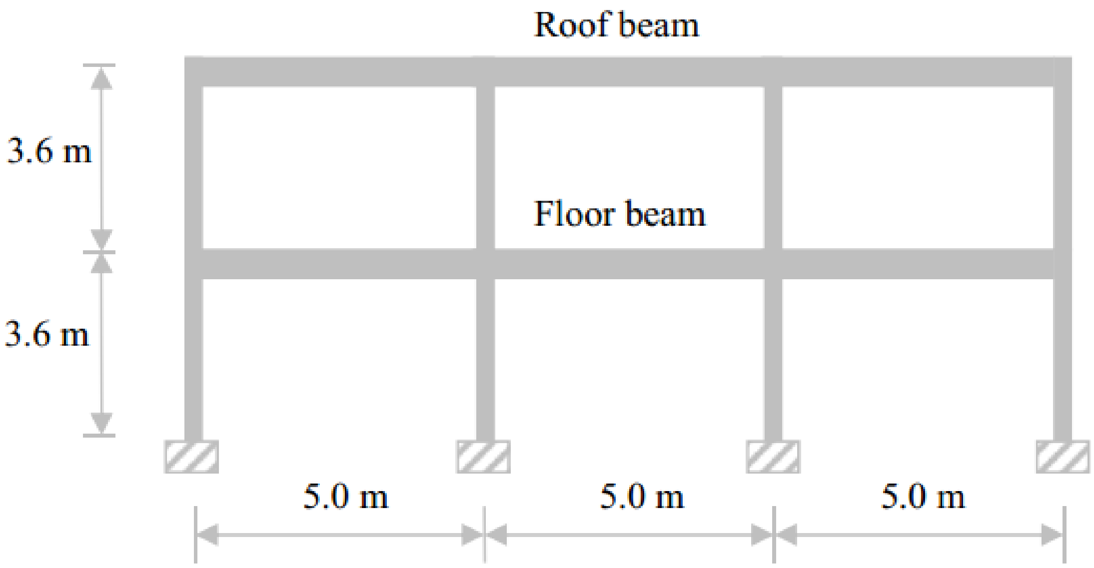
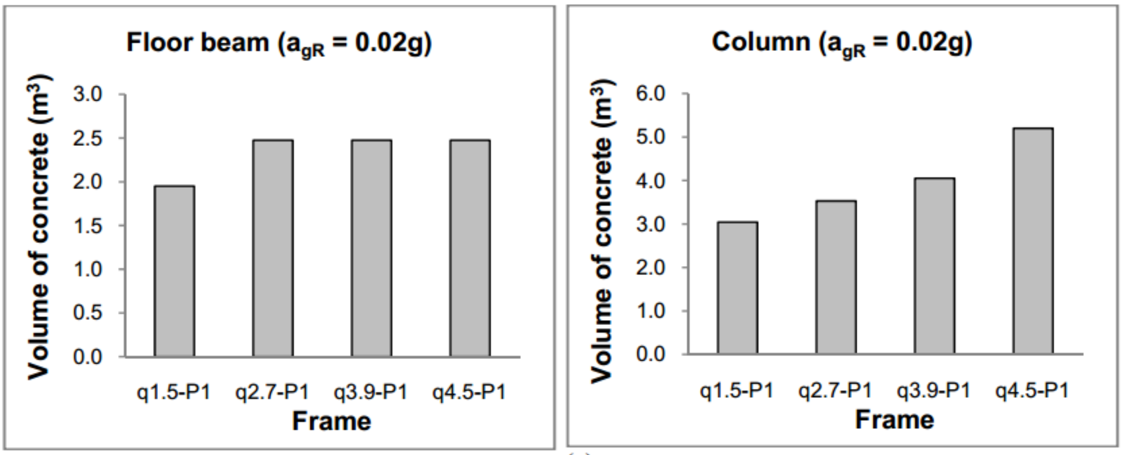


Figure 2.10: Elevation of Reinforced Concrete Frame Model (Adiyanto and Majid, 2013)

Table 2.6: The Design Criteria of Total Frame Model (Adiyanto and Majid, 2013)

No.	Frame	Behaviour factor, q	agR (g)
1	N2BS	-	-
2	q1.5 – P1	1.5	0.02
3	q2.7 – P1	2.7	
4	q3.9 – P1	3.9	
5	q4.5 – P1	4.5	
6	q1.5 – P2	1.5	0.06
7	q2.7 – P2	2.7	
8	q3.9 – P2	3.9	
9	q4.5 – P2	4.5	
10	q1.5 – P3	1.5	0.12
11	q2.7 – P3	2.7	
12	q3.9 – P3	3.9	
13	q4.5 – P3	4.5	

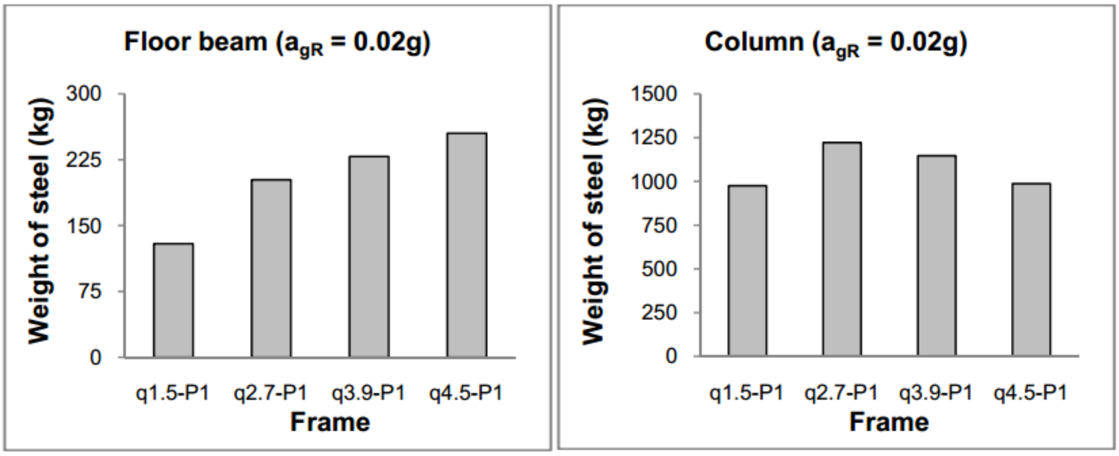
Figure 2.11(a) and Figure 2.11(b) show the results on the changes of concrete volume for column and beam. It can be seen that the total concrete volume of floor beam is relatively constant with the increase in the behaviour factor. This finding is particularly true because the beam size was not affected and remained unchanged. On the contrary, the total concrete volume for column was reported to be influenced by the level of the behaviour factor due to the need of column enlargement to fulfil the maximum reinforcement percentage of 4% ruled by EC8.



(a) (b)

Figure 2.11: Influence of Behaviour Factor on Concrete Volume (a) Beam (b) Column (Adiyanto and Majid, 2013)

The authors also reported that the behaviour factor increased the amount of steel for flexural reinforcement in beam but not in column as shown in Figure 2.12. The finding was associated to the local ductility demand that requires additional reinforcement in the compression zone in order to maintain the same beam size. On the other hand, reduction on longitudinal steel demand was observed for column as shown in Figure 2.12 (b). This result is particularly true when applying the strong column-weak beam concept where the column design is strongly influenced by the beam design and the capacity of the column must be greater than the beam.



(a) (b)

Figure 2.12: Influence of Behaviour Factor on Longitudinal Reinforcement (a) Beam (b) Column (Adiyanto and Majid, 2013)

In addition, Zahid et al. (2017) investigated the seismic performance of 3-storey low-rise building and 18-storey high-rise building with different behaviour factors. Each building consists of five generic models with different value of behaviour factor, as 1, 1.5, 2, 4 and 6. The research found that lateral strength of reinforced concrete buildings decrease as the behaviour factor increases.

2.8 Summary

Based on the previous research, many researchers focused their study on the change of the material cost due to the behaviour factor and ductility class. The 3-D frame models were generated fictitiously without considering the presence of shear wall or lift core and secondary beams. To date, very limited information on the cost comparison study based on real constructed projects can be found in the open literature. In addition, no attempt has been made to investigate the influence of soil type in seismic design to the change in the material cost.

CHAPTER 3

METHODOLOGY

3.1 Overview

Two real low-rise structures were used in this research namely, the Pra Sekolah and JKR Cawangan Mekanikal buildings. The existing structures were previously designed by the engineer according to British Standard, BS 8110. The material quantities for these non-seismically designed buildings were extracted manually from the drawings. In this study, the same buildings models were generated with the aid of ETABS 2016 commercial software and redesigned considering the seismic action based on Eurocode 8. The seismic loading was applied to the structure using modal response spectrum method. Figure 3.1 and 3.2 show the flow of conventional design and seismic design for the buildings. The materials quantity and costs of each structure determined based on non-seismic and seismic design.

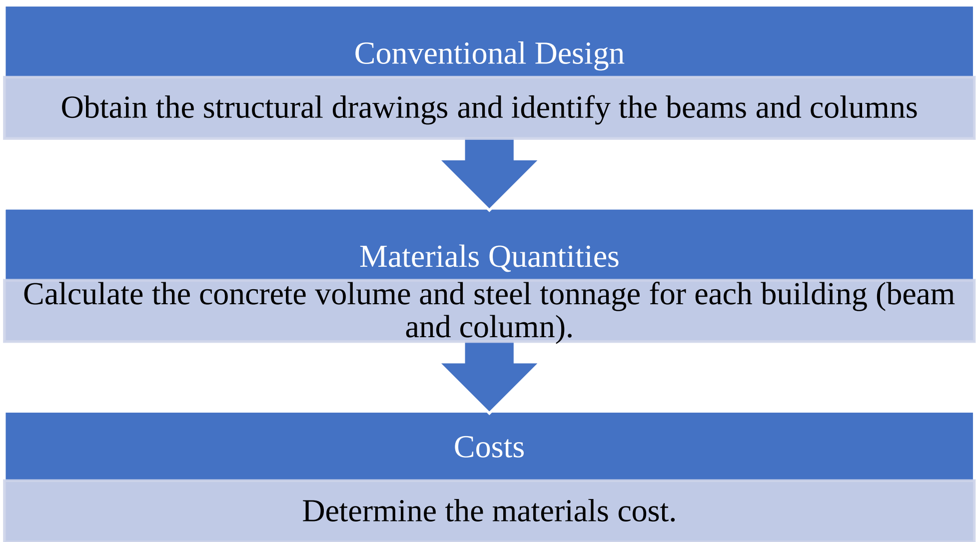


Figure 3.1: Procedure for Determining the Material Cost for Conventionally Designed Buildings

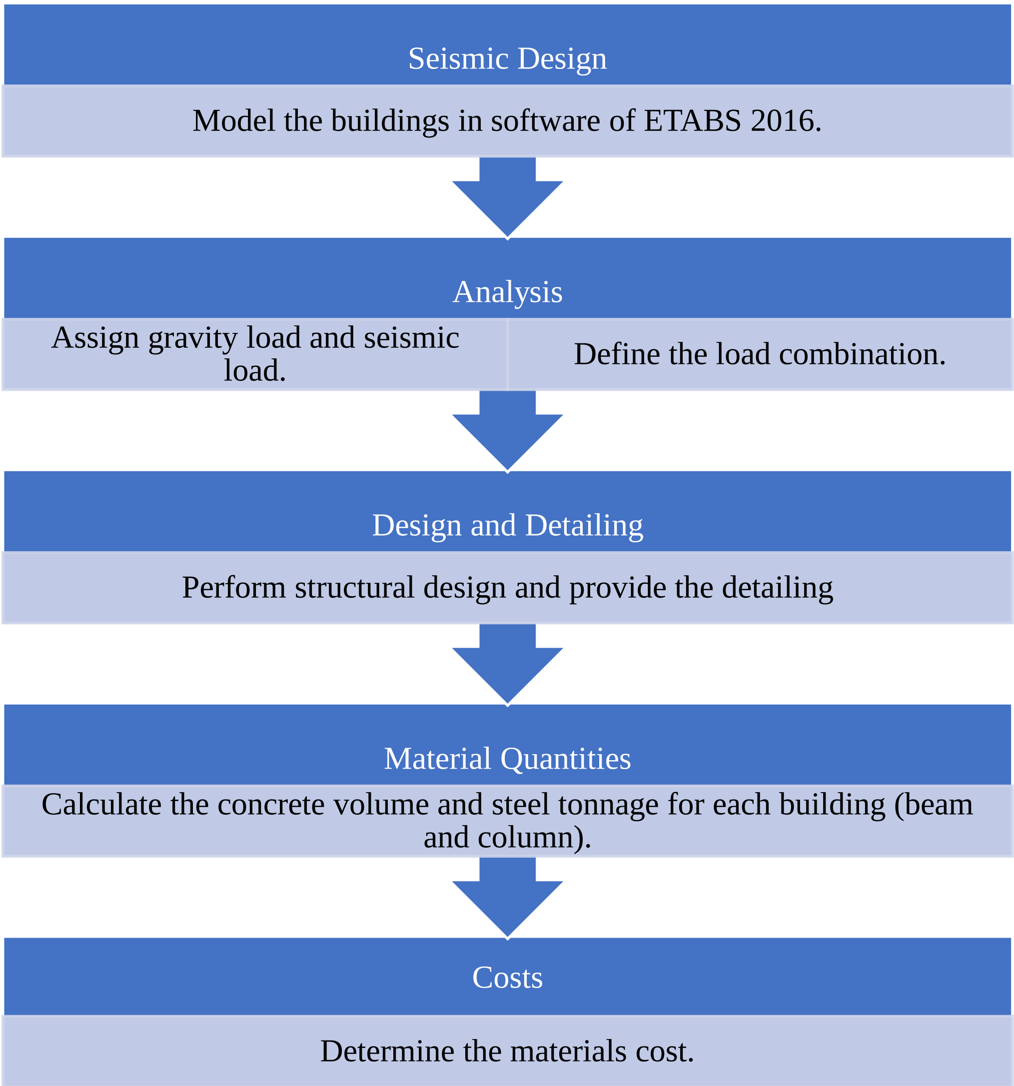


Figure 3.2: Procedure for Determining the Material Cost for Seismically Designed Buildings

3.2 Modelling

Figure 3.3 and Figure 3.4 shows part of the structural drawings (in ACAD format) for Pra Sekolah and JKR Cawangan Mekanikal, respectively. The Pra Sekolah building is a single storey structure with plan dimension of 46.5m length and 15.21m width. On the other hand, the JKR Cawangan Mekanikal building is a three storey structure with plan dimension of 19.1m length and 11m width. The remaining structural floor plan for Pra Sekolah and JKR Cawangan Mekanikal are provided in Appendix A and Appendix B, respectively.

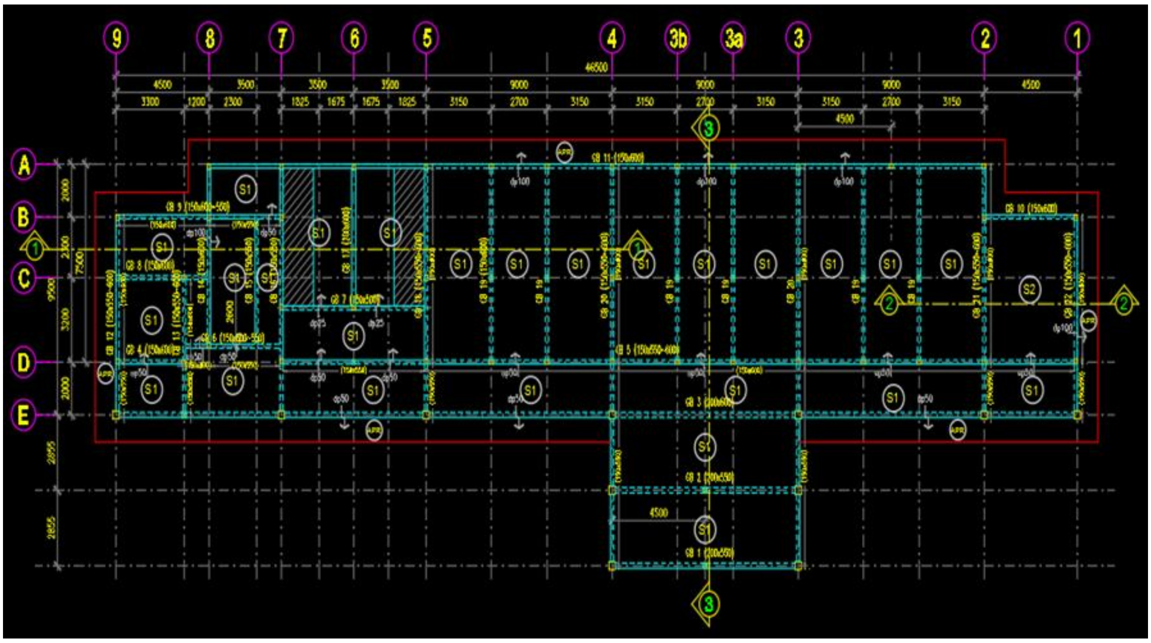


Figure 3.3: Ground Floor Plan of Pra Sekolah

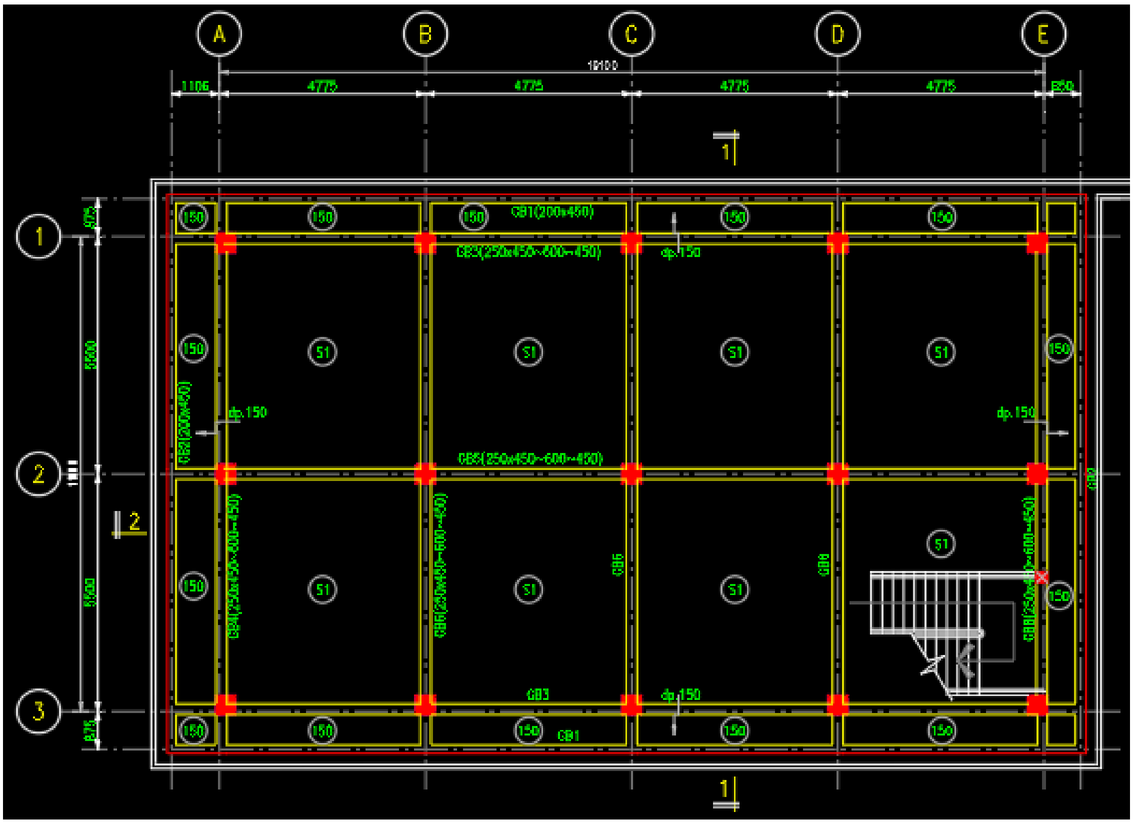


Figure 3.4: Ground Floor Plan of JKR Cawangan Mekanikal