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CONTINUING DEVELOPMENT OF SEISMIC ACTIONS DESIGN STANDARD AND IMPLICATIONS TO ENGINEERING AND ARCHITECTURAL PRACTICES IN MALAYSIA

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ABSTRACT

This paper presents the work of the Technical Committee on Earthquake led by The Institution of Engineers Malaysia (IEM) and sanctioned by the Department of Standards Malaysia (DSM). From the Aceh earthquake event in 2004 to the most recent impact earthquake in Ranau, Sabah, it has been shown that earthquakes are a concern to stakeholders in the local construction industry. And the work of the Technical Committee has been finalized by the completion of the Draft National Annex on Eurocode 8 Design of structures for earthquake resistance, in order to address the needs of the nation. The need for earthquake standards in Malaysia was explained in detail, and the approach adopted was highlighted with emphasis on tackling both distance and local earthquakes, in Peninsular Malaysia as well as Sabah and Sarawak. Ductility is the main consideration in any earthquake-resistant designed structures, and this has to go hand in hand with the types and configurations of structures to be proposed by architects and engineers.

1.0 INTRODUCTION

The watershed events of 26 December 2004 and 28 March 2005 – when two major earthquakes struck the eastern seaboard side of Sumatra, in Banda Aceh and Nias respectively, have literary sent shockwaves throughout the world, but in regional terms, more than 200000 lives have been lost. Malaysia has also experienced a number of casualties (particularly due to the tsunami tidal waves) from the Boxing Day disaster of 2004. Figure 1 below shows two types of seismic zones in the island of Sumatra, i.e. the subduction plates out to the Indian Ocean on west coast side, and the inland fault right along the spine of the island itself.

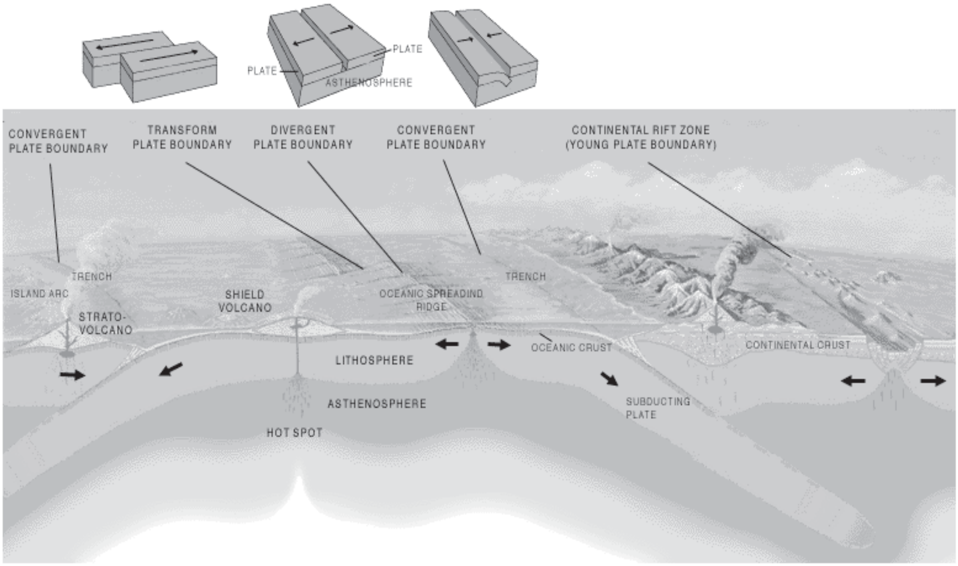


Figure 1. Tectonic boundaries atypical in island of Sumatra

These two earthquakes were felt in Peninsular Malaysia, in which some high rise building structures oscillated quite alarmingly for long periods, sending their occupants fleeing to the ground level. This has raised concern about the safety and vulnerability of existing building structures and the use of current structural design standards which do not specify the need for seismic design in Malaysia.

The Institution of Engineers Malaysia (IEM) took the initiative to study the earthquake issues and published a position paper which was released in 2007. It basically recommended the drafting of a guideline for seismic design for structures which are deemed to be vulnerable, especially to far field effect of earthquake felt from Sumatra.

The formation of a Technical Committee at IEM spearheaded the effort to draft a Malaysian Standard on seismic design, and representation in the committee encompasses stakeholders in the local construction industry. Working groups were formed to tackle various issues of interest and concern, of which the most critical are on determining accurate peak ground acceleration, and to study the vulnerability of building structures. One of the working groups is looking into non-structural components, and it is presently led by a registered practicing architect.

The Technical Committee had decided to adopt the Eurocode 8 standards for earthquake design, ie. EN1998 Part 1, which has also been adopted in UK in 2010 and even in nearby Singapore in 2015. This is in line with the adoption and publication by Malaysia on Eurocode design standards for concrete and steel structures since 2011. Hence, the MS EN 1998 Part 1 is already adopted and published in 2015, while the accompanying National Annex or NA to Eurocode 8 has its draft sent for public comments in February 2016, and now awaiting approval.

Besides highlighting the current status in seismic standard development in Malaysia, this paper also presents the key elements of earthquake engineering insofar as measuring its intensity and to predict the response and behavior of structures. Along the way, some understanding is made on how to ensure such structures can be designed to withstand or to minimize the damages due to earthquake effects.

In the latest development of major seismic activity in Malaysia, on 5 June 2015 a local earthquake of magnitude M6.0 struck at Ranau, Sabah causing a number of deaths and injuries of mountain climbers due to falling rocks and debris in Mount Kinabalu, a mere 50 km away from Sabah State capital Kota Kinabalu. This was a wake-up call to the authorities on the risk of local earthquakes in Malaysia. Hence, there is an urgency to incorporate design for local earthquake into the draft Malaysian Standard, not just focusing on the far distance earthquake culminating from active seismic areas like Sumatra.

1.1 BACKGROUND

The issue of earthquake concern in Malaysia has always tied to those tremors felt from far field seismic effect from nearby Sumatra – just over 350 km away from the major populated areas in Klang Valley and along the west coastal zones in Peninsular Malaysia. Local earthquakes occurred infrequently but are of very low magnitudes, especially in Peninsular Malaysia. The maximum observed seismic intensity so far was VI on the Modified Mercalli (MM) scale (i.e. moderate shaking severity with falling objects). Nevertheless, higher magnitude earthquakes had occurred in parts of East Malaysia, particularly in Lahad Datu area in Sabah, some of them resulted in some damage on properties and even human injuries. The recent 2015 earthquake in Ranau, Sabah was a major local earthquake event with fatalities and some structural damages to buildings.

Besides the local earthquakes, the east coast of Sabah is also affected by large earthquakes originated from over Southern Philippines and in the Straits of Macassar, Sulu Sea and Celebes Sea. The maximum observed intensity so far was VII on MM scale (i.e. strong shaking severity with non-structural damage).

The Institution of Engineers Malaysia (IEM) undertook to draft and publish a position paper which was released in 2007.

In the short term, IEM recommended these initiatives:

i. Urging for the need of more seismic monitoring stations in Malaysia.

ii. Exhorting for the setting up of instrumentation for measuring seismic response of buildings.

iii. Undertake seismic vulnerability studies of existing important buildings or structures, particularly in high risk areas.

iv. Review of current Engineering Design & Construction Standards and Practices.

v. Suggest for the design of highrise buildings to cater for long period vibration. In addition, site specific ground motions are required for consideration in the design of highrise structures of seven (7) storeys and above. This range of building's height is found to be particularly vulnerable to the effects of earthquake.

In the long run, IEM is recommending these courses of actions by various players and stakeholders in the local engineering industry:

i. Develop or adopt a suitable code of practice with necessary modification for the construction industry with regards to seismic design after the review.

ii. Sensitive and Important structures (e.g., hospital, fire and rescue department, police stations, importance bridges, dams, power supplies structures, telecommunication structures, etc) shall be checked for vulnerability when exposed to seismic ground motion.

iii. Introduction of earthquake engineering education curriculum in the universities and other tertiary institutions of higher learning.

iv. Sourcing of substantial rolling research fund for earthquake engineering research and also to include monitoring and risk assessment works.

v. Continuing education for practicing engineers is required in the areas of earthquake engineering in line with the call from the Board of Engineers Malaysia.

2.0 CURRENT SITUATION

2.1 SEISMOGRAPH NETWORK IN MALAYSIA

Seismic wave radiated by a sudden release of energy in the earth will propagate to all direction and will arrive at a certain place depending on its velocity and the distance from the source to the site. If several sensors at different places are operated and detect an approaching seismic waves, then a set of data of arrival time will be obtained. From this record the location of the source can be determined.

The precision of tracing back the source will depend on the quality of the measured data, which has several factors such as: timing system, pointing up the seismic phase, position of the source with respect to the stations, etc., beside the variety of the responses of the ground through which the moving waves have passed.

Figure 2 shows the current locations of seismological stations in both Peninsular and East Malaysia, which were set up and managed by the Malaysian Meteorological Service (MMS), which serves as the national information centre for seismology. MMS provides information, advice and consultation related to earthquake to users such as engineers, architects and planners for socio-economic development of the country. The first few stations were set up and operated in 1979 at Petaling Jaya, Kluang, Ipoh and Kota Kinabalu.

As the need arose, three more stations, one at Kuala Terengganu, and the other two at Tawau and Kuching were installed from 1986 to 1988. To meet the increasing demand for seismological information in the country, five more stations were installed (at Kuala Lumpur, Kudat, Sandakan, Bintulu and Sibu) from 1992 to 1998. Three of the total twelve stations (Figure 2) are equipped with the strong-motion accelerographs, i.e. Sibu, Bintulu and Sandakan – in anticipation of higher intensity of local earthquake felt there.

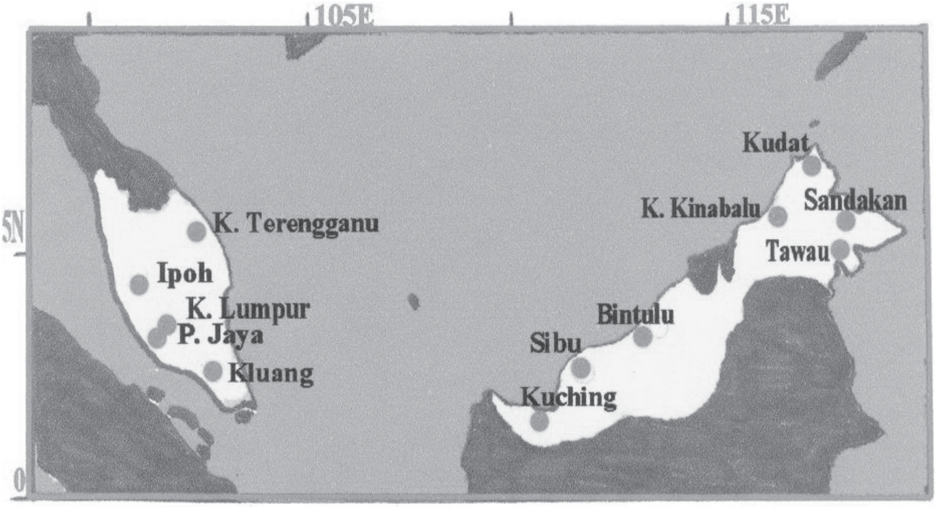


Figure 2. Seismological stations of Malaysia

It has been said that with this network, the MMS has the capability to detect and identify earthquakes which occur in and around Malaysia with some degree of accuracy for the first hour after the event.

There was a strong motion measuring instrument set up near to Kota Kinabalu, which should have recorded some measured Peak Ground Acceleration (PGA) values during the Ranau earthquake in 2015. Unfortunately, the instrument did not provide reliable measurements due to some equipment faults, which the MMD office could not explain.

2.2 THE NEED TO DRAFT A MALAYSIAN NATIONAL STANDARD FOR SEISMIC DESIGN OF BUILDING STRUCTURES

Based on IEM Position Paper's recommendation, a Technical Committee (TC) on Earthquake Design was formed by IEM upon approval of the Department of Standards Malaysia (DSM) and SIRIM in March 2009. In order to be inclusive and transparent, most if not all major stakeholders in the construction industry were invited to send representatives to be members of the TC. They include consultants, academics, contractors, government agencies and others.

Five Working Groups (WG) were formed to study on various aspects as below:

i. Determining peak ground acceleration, seismic response spectrum and seismic mapping for Peninsular Malaysia (WG1);

ii. Vulnerability study of new and existing building structures to seismic actions in Peninsular Malaysia (WG2);

iii. Geotechnical study of ground conditions affecting seismicity and seismic design for structures in Peninsular Malaysia (WG3);

iv. Effect of seismic actions on non structural elements of building structures in Peninsular Malaysia (WG4); and

v. Base isolation methods to minimise adverse effect of seismic actions on building structures in Peninsular Malaysia (WG5)

The work of both TC and WGs have been ongoing since March 2009, and it is being treated very seriously by the Construction Industry Development Board (CIDB) through its commercial arm CREAM, and also by the Ministry of Science Technology and Innovation (MOSTI) through the Malaysian Meteorological Services (MMS). Both agencies have pledged some funding support for the work and activities of the Technical Committee. In 2016, due to the scope of the NA to Eurocode 8 which includes provisions for Sabah and Sarawak, all of the above five Working Groups have re-aligned their scope of work to Malaysia (including Sabah and Sarawak) – not just in Peninsular Malaysia. Further to that, two more Working Groups were formed:

i. Drafting and editing of NA to EC8 (WG6); and

ii. Retrofitting of existing RC structures for earthquake resistance (WG7)

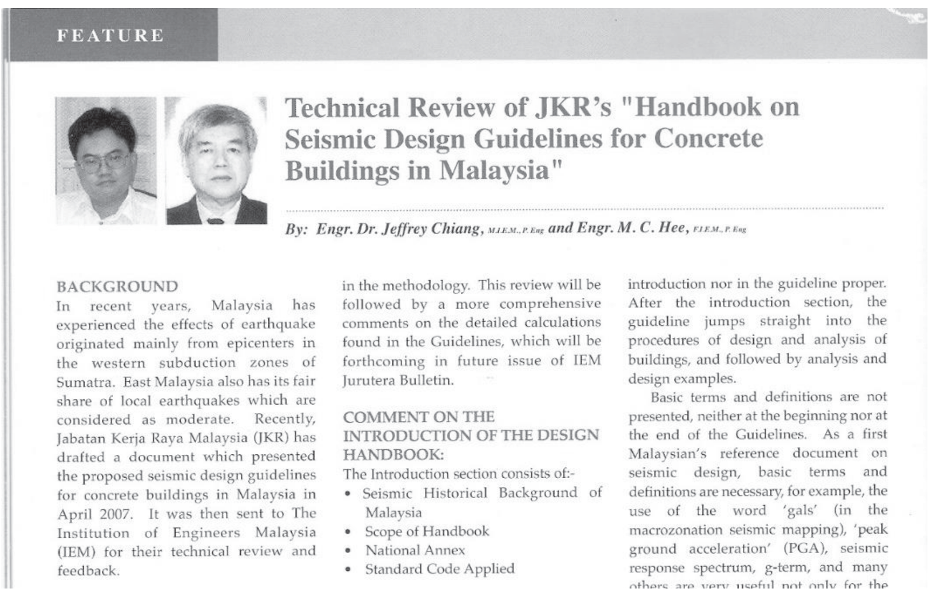
2.3 OUTCOME OF PREVIOUS LOCAL RESEARCH UNDERTAKEN

Universiti Teknologi Malaysia (UTM) has carried out a number of research projects on local earthquakes for the past fifteen years or more, from seismic zone mapping for Malaysia, and the application of local rubber bearing products as base isolators for infrastructural designs. As a well-established public university, substantial funding support was made available to UTM as grants via the Public Works Department or Jabatan Kerja Raya (JKR) and also CIDB.

In 2007, JKR produced a Draft Guidelines on Earthquake Design for Reinforced Concrete Buildings in Malaysia, which is based on the research work undertaken by UTM. In it, design procedures are very much referred to two international earthquake standards, i.e. the American International Building Code (IBC2000), and Eurocode EN1998. IEM was asked to make a technical assessment of the document, and in a technical paper published in 2008 (see Figure 3), two members of the TC commented critically on the Draft JKR Guidelines for Earthquake Design. Basically the guidelines are not acceptable to be adopted for use in the local industry due to its overestimation of the peak ground accelerations, and its full blown seismic design procedures which are straight out of IBC2000 and EN1998, without suitable justifications for Malaysian practices.

Due to that technical assessment by IEM, JKR decided not to release or finalise the document for local industry practice. The TC is of the opinion that the recommended peak ground accelerations (PGA) in the Draft JKR Guidelines is excessive, e.g. for West Malaysia, a PGA of 0.08g – 0.10g was cited, whereas the recorded PGA by MMS (at the height of both Banda Aceh and Nias earthquakes) was in the range of 0.001g to 0.003g. The problem here is that JKR's recommendations are based on research work of UTM, which is very much probabilistic in approach – requiring many recorded data of earthquakes in Malaysia, which is not available. And this approach is very much adopted from research work of Pietersen which has formed the basis of earthquake modelling in North America, i.e. more for near field earthquake, as opposed to far field earthquake effect felt in Peninsular Malaysia.

The TC decided to consult regional panel of international experts who had years of research experience in earthquake engineering. In particular, Professor Nelson Lam of Melbourne University and his team of co-researchers had produced an earthquake prediction model which is widely known as the Component Attenuation Model (CAM) which had been successfully applied in India, and Singapore. The advantage of this model is that it is quite accurate in determining the PGA of regions which either have low to very low earthquake intensity, or do not have sufficient recorded earthquake data. And this fits in very much with the situation here in Malaysia, and even Singapore.



FEATURE

Technical Review of JKR's "Handbook on Seismic Design Guidelines for Concrete Buildings in Malaysia"

By: Engr. Dr. Jeffrey Chiang, M.I.E.M., P.Eng and Engr. M. C. Hee, F.I.E.M., P.Eng

BACKGROUND

In recent years, Malaysia has experienced the effects of earthquake originated mainly from epicenters in the western subduction zones of Sumatra. East Malaysia also has its fair share of local earthquakes which are considered as moderate. Recently, Jabatan Kerja Raya Malaysia (JKR) has drafted a document which presented the proposed seismic design guidelines for concrete buildings in Malaysia in April 2007. It was then sent to The Institution of Engineers Malaysia (IEM) for their technical review and feedback.

in the methodology. This review will be followed by a more comprehensive comments on the detailed calculations found in the Guidelines, which will be forthcoming in future issue of IEM Jurutera Bulletin.

COMMENT ON THE INTRODUCTION OF THE DESIGN HANDBOOK:

The Introduction section consists of:-

- Seismic Historical Background of Malaysia
- Scope of Handbook
- National Annex
- Standard Code Applied

introduction nor in the guideline proper. After the introduction section, the guideline jumps straight into the procedures of design and analysis of buildings, and followed by analysis and design examples.

Basic terms and definitions are not presented, neither at the beginning nor at the end of the Guidelines. As a first Malaysian's reference document on seismic design, basic terms and definitions are necessary, for example, the use of the word 'gals' (in the macrozonation seismic mapping), 'peak ground acceleration' (PGA), seismic response spectrum, g-term, and many others are very useful not only for the

Figure 3. Technical input by IEM into JKR Draft Seismic Design Guidelines

2.4 COLLABORATIONS WITH INTERNATIONAL PANEL OF SEISMIC EXPERTS

It was in September 2009 when the TC had invited Professor Nelson Lam to Malaysia to conduct joint seminars on earthquake design and analysis, based on his research carried out in Melbourne University. In particular, he applied the CAM analytical model in Australia, and it has been found to be reasonably accurate, if applied to Malaysia and Singapore, based on recent published technical papers by his co-researchers in Singapore.

In an interesting development, Professor Nelson had proposed the following:

- Instead of focusing on determining peak ground acceleration (PGA) which is the conventional approach in ultimately calculating for the base shear which is then use to predict the response of building structures to earthquake motion, he proposed the primary objective in studying the peak ground velocity and even peak ground displacement instead – which would give a better perspective in studying the vulnerability of building structures to earthquake.

- Since the far field earthquakes (due to tremors felt from seismic active areas in Sumatra) had proven to be of less threat, he suggested for Malaysian researchers to focus instead on local earthquake or near field earthquake. In particular, in areas in the vicinity of an 80-km long Bentong fault, close to Bukit Tinggi, where recorded earthquakes of low magnitude around M3.5 has occurred. And this study should also be extended across to East Malaysia where there are also some active fault lines. This was carried out in the drafting of the NA to Eurocode 8, which includes proposed PGA values for Sabah and Sarawak which cater for local earthquake events there.

Out of this collaboration with renowned international experts, the TC has organised further activities in 2010, in which Professor Nelson Lam was invited to conduct an extended joint seminar in June 2010 together with Dr Tsang Hing Ho from Hong Kong Univesity. This culminated with an intensive 2-day workshop, in which three invited panel experts (Prof Nelson Lam, Dr Tsang Hing Ho and Dr Kusno Megawati from Nanyang Technological University of Singapore), had provided timely advice, and recommendations in the way forward for Malaysia to undertake seismic studies to the next level.

Dr Tsang Hing Ho was involved in the aftermath study of the Sichuan earthquake devastation in China in 2008, whereas Dr Kusno Megawati has worked closely with both Professor Nelson Lam and Dr Tsang Hing Ho in Hong Kong and also in Singapore on geological mapping for seismic studies.

Further joint research collaboration effort was undertaken in 2011, in the form of a geophone seismic survey exercise which was carried out in Hong Kong. The Technical Committee was invited to send representatives to observe and study the procedure and equipment usage, so that the same exercise can then be adopted in similar survey planned for the Bentong fault and in areas of close proximity. It has to be noted that the Bentong fault is only about 30 to 35 km away from Kuala Lumpur city centre, and earthquake is an event that is very unpredictable in nature – both in its probability of happening and also in its magnitude and devastation which can be inflicted upon nearby occupied structures.

From 2012 to 2016, this group of International Panel seismic experts has collaborated extensively with the Technical Committee through the Working Group WG1 in developing the finalised NA to Eurocode 8, with numerous, briefings, workshops, seminars and symposia held in Kuala Lumpur, Malaysia and even in Kota Kinabalu, Sabah at the end of 2015.

3.0 ANALYSIS AND DESIGN APPROACH FOR SEISMIC ACTIONS IN BUILDING STRUCTURES

3.1 FROM A STRUCTURAL ENGINEER'S PERSPECTIVES

The behaviour of building structures to earthquakes is very much dependent on how they are designed. The following will illustrate the requirement for structures to resist earthquake effects, from a structural engineer's viewpoint.

How do earthquakes affect the structural behaviour of buildings? The illustrations in Figures 4, 5 and 6 depicted this very clearly.

- As inertia forces accumulate downwards from the top of the building, the columns and walls at lower storey experience higher earthquake-induced forces and are therefore designed to be stronger than those in the storey above. See Figure 4.
- Under gravity loads, tension in the beams is at the bottom surface of the beam in the central location and is at the top surface at the ends.
- The level of bending moment due to earthquake loading depends on severity of shaking and can exceed that due to gravity loading. See Figure 5.

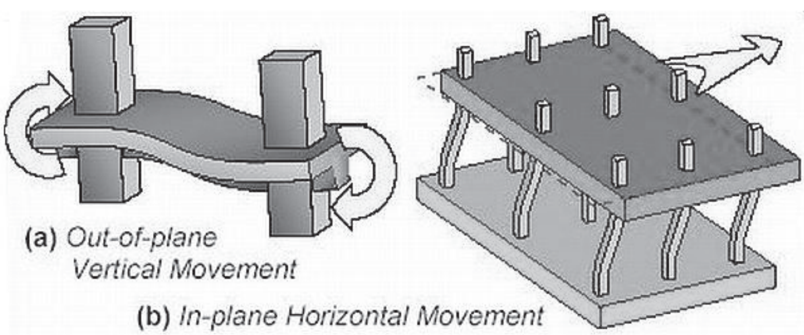


Figure 4. Movements in buildings during earthquake

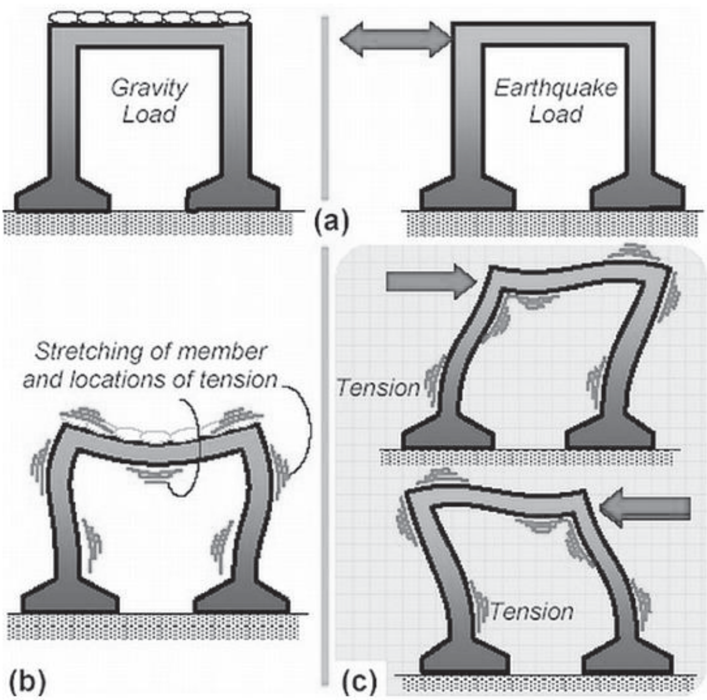


Figure 5. Tensile zones during movement of structures

- Thus, under strong earthquake shaking, the beam ends can develop tension on either of the top and bottom faces.

- Since concrete cannot carry this tension, steel bars are required on both faces of beams to resist reversals of bending moment. See Figure 6.

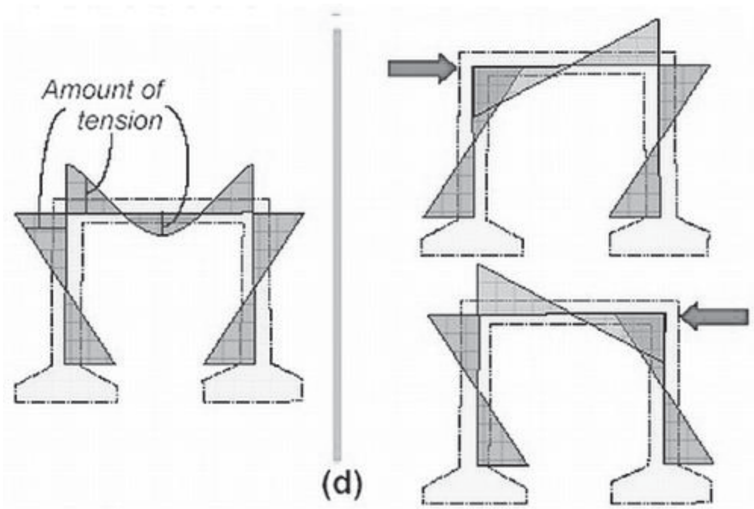


Figure 6. Earthquake shaking reverses tension and compression in members – reinforcement is required on both faces of members

In terms of structural integrity and flow, the matter of strength hierarchy is an important factor.

- For a building to remain safe during earthquake shaking, columns should be stronger than beams, and foundations should be stronger than columns.
- If columns are made weaker, they suffer severe local damage, at the top and bottom of a particular storey.

Conceptual design and planning is the next consideration in resisting earthquakes, especially in determining the size of buildings and their aspect ratios.

- In tall buildings with large weight-to-base size ratio the horizontal movement of the floors during ground shaking is large. See Figure 7.
- In short but very long buildings, the damaging effects during earthquake shaking are many. And, in buildings with large plan area, the horizontal seismic forces can be excessive to be carried by columns and walls. See Figure 7.

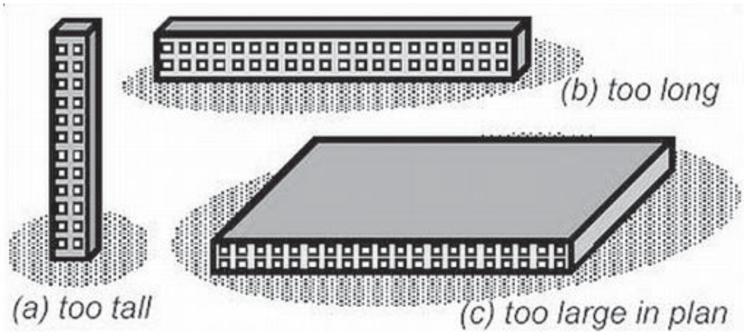


Figure 7. Buildings with one of their overall sizes much larger or much smaller than the other two, do not perform well during earthquakes

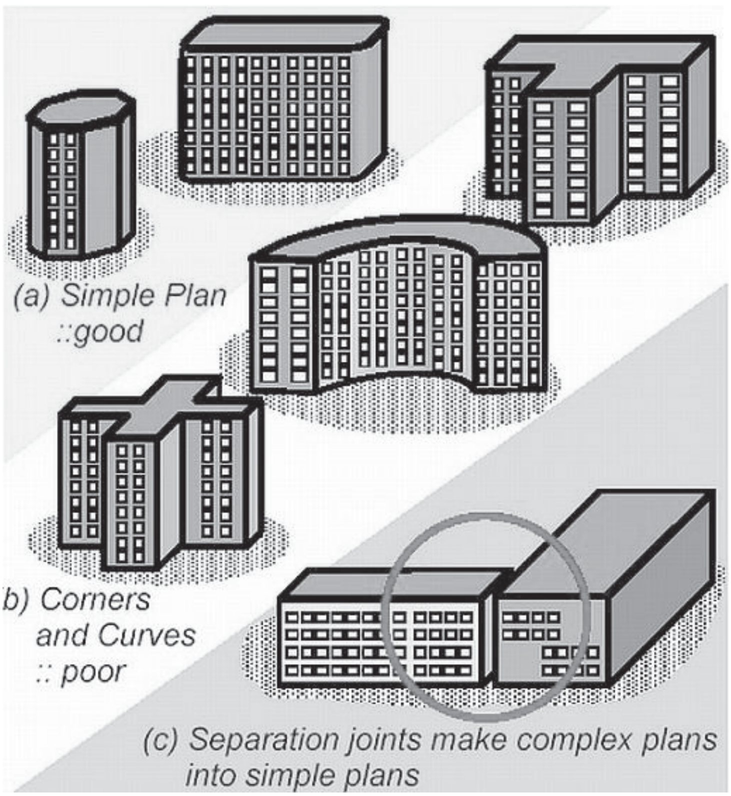
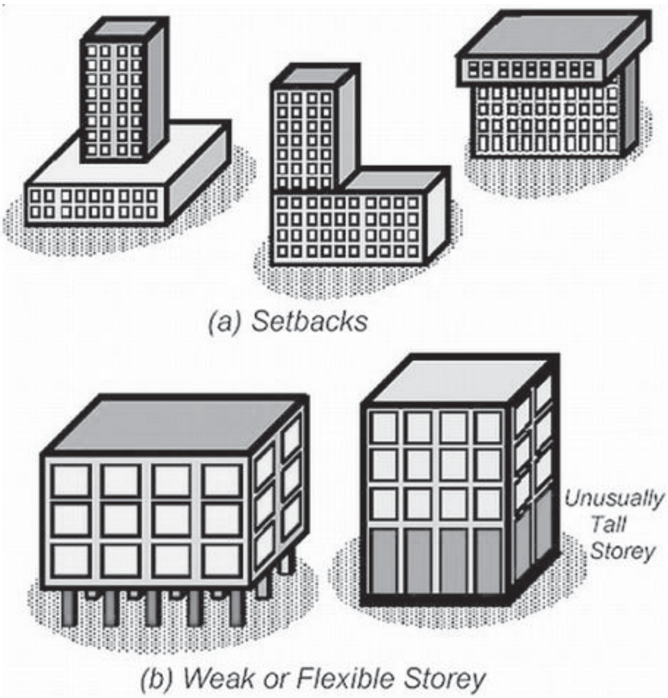


Figure 8. Horizontal layout plays a major role in structural behaviour

- Buildings with simple geometry in plan perform well during strong earthquakes. Buildings with re-entrant corners, like U, V, H and + shaped in plan sustain significant damage. The bad effects of these interior corners in the plan of buildings are avoided by making the buildings in two parts by using a separation joint at the junction. See Figure 8.

- Earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path, any deviation or discontinuity in this load transfer path results in poor performance of building. Buildings with vertical setbacks cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. See Figure 9.



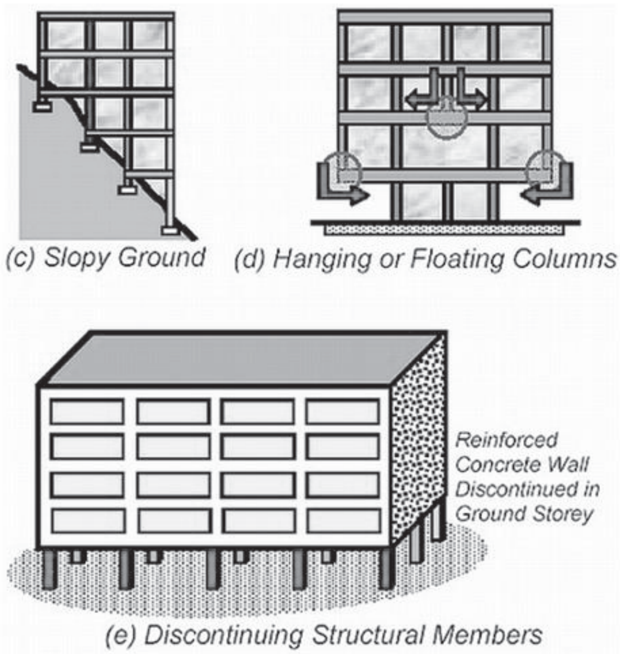


Figure 9. Vertical layout of structures in terms of balanced setback, sufficient rigidity and no sudden deviations in load transfer path will ensure higher seismic resistance

- Buildings on sloppy ground have unequal height columns along the slope, which causes twisting and damage in shorter columns that hang or float on beams have discontinuity in load transfer. See Figure 9.

- Buildings in which RC walls do not go all the way to the ground but stop at upper levels get severely damaged. See Figure 9.

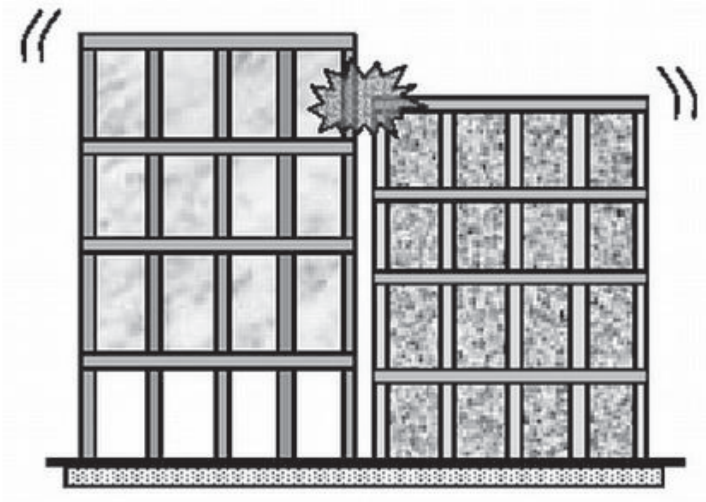


Figure 10. Pounding can occur between adjoining buildings due to horizontal vibrations of the two buildings

Adjacency of buildings play a significant role in minimizing effect of earthquake in damages incurred due to mutual destructive mode. See Figure 10.

- When two buildings are close to each other, they may pound on each other during strong shaking.
- When building heights do not match the roof of the shorter building may pound at the mid- height of the column of the taller one; this can be very dangerous

There are two design approach that can be considered. The conventional approach in seismic design is stated as follows:

- This design approach depends upon providing the building with strength, stiffness and inelastic deformation capacity which are great enough to withstand a given level of earthquake-generated force.
- This can be accomplished by selection of an appropriate structural configuration and careful detailing of structural members, such as beams and columns, and the connections between them.

Alternatively, the designer can adopt the basic approach:

- This design approach is not to strengthen the building, but to reduce the earthquake generated forces acting upon it. This can be accomplished by de-coupling the structure from the seismic ground motion, in the following manner:

- Increase natural period of structures by Base Isolation.
- Increase damping of system by Energy Dissipation Devices.
- Mitigate earthquake effects completely by using Active Control Devices

There is no necessity to go into further details of this approach.

In terms of design philosophy for seismic actions, the severity of ground shaking at a given location during an earthquake can be categorized as minor, moderate and strong., whereby minor shaking occurs frequently; moderate shaking occasionally and strong shaking rarely.

For instance, on average annually about 800 earthquakes of magnitude M5.0 to M5.9 occur in the world while there are about 18 for magnitude range M7.0 to M7.9.

So, should we design and construct a building to resist that rare earthquake shaking that may come only once in 500 years or even once in 2500 years, even though the life of the building may be 50 or 100 years?

The answers to that philosophical question are as follow:

- Engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquake; such buildings will be too robust and also too expensive.
- Instead engineers should make buildings earthquake-resistant; such buildings should resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake.
- Thus, the safety of people and contents is assured in earthquake-resistant buildings, and thereby a disaster is averted. This is a major objective of seismic design codes throughout the world.

Further to that, under minor but frequent shaking, the main members of the buildings that carry vertical and horizontal forces should not be damaged; however buildings parts that do not carry load may sustain repairable damage.

Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts that do not carry load may sustain repairable damage.

Under strong but rare shaking, the main members may sustain severe damage, but the building should not collapse.

For an adequate seismic-resistant designed structure, the keyword that needs to be addressed is – ductility. The severity of damage and response of structures to earthquake can be clearly shown in Figure 11 where ductility is a key factor.

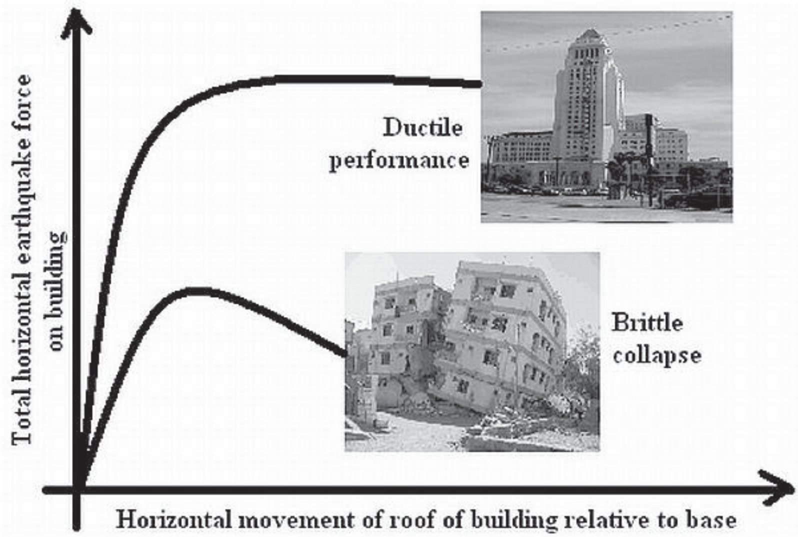


Figure 11. Design concept of ductile performance under seismic action

The correct use of ductile reinforcing (i.e. steel) to ensure ductile performance of reinforced concrete structures, especially at joints and connections, is the mainstay of a good and sound structural design to resist earthquakes.

The correct building components need to be made ductile. The failure of columns can affect the stability of building, but failure of a beam causes localized effect.

Therefore, it is better to make beams to be ductile weak links rather than columns. This method of designing reinforced concrete buildings is called the strong-column weak-beam design method.

Lastly, for a structural engineer to carry out a proper seismic analysis and design of structures, it is very important to adopt the correct methodology, depending on the complexity of the structure and its proximity to seismic active zones. Table 1 summarises the methodology that can be used.

Table.1 Elastic/Inelastic versus Static/Dynamic approach in analysis and design

	Static	**Dynamic**
Elastic (linear) analysis	Lateral Force Method (or Equivalent Static Analysis Method)	Modal Response Spectrum Analysis
Inelastic (non-linear) analysis	Non-linear Static Method (or Capacity Spectrum Method)	Non-linear Time History Analysis

3.2 FROM AN ARCHITECT'S PERSPECTIVES

In view of the likelihood of the TC in recommending the adoption Eurocode 8 EN1998-1:2004 Design of structures for earthquake resistance, as the basis for MS, the TC has farmed out various study topics on Eurocode 8 to the five working groups. The WG4 on non-structural components has commenced by concentrating on materials design. But this should not stop the WG4 on non-structural components to expand its scope into building services like fire fighting, air handling unit, escape and evacuation points, facade design, lighting and air passages, features and layout in minimizing internal damages due to collapse of furniture and fittings, and so forth.

There are definitely a lot more that architects can contribute in ensuring a safe and adequate building design, in resisting earthquakes, even in low seismic zone like Malaysia.

4.0 CONCLUSION

No doubt, Malaysia is considered a low seismic risk zone, and may or may not require a seismic design standard for its building structure design. But two regional earthquakes in 2004 and 2005 had changed the perspective of both public view and concern on the potential structural vulnerability of the local buildings and infrastructures during earthquake events, albeit from far distance effect. Then, the local earthquake happened in Ranau in 2015, which further triggered the concern of authorities and the need for a Malaysian Standards for earthquake design is no longer in doubt.

From the study undertaken to date, and with inputs from international experts, it may be worthwhile to focus attention on local near field earthquake, in particular the Bentong Fault which is reasonably close to Kuala Lumpur city centre. To that, one may add the earthquakes that occurred more frequently in East Malaysia, of which the most recent major event was in Ranau, Sabah in June 2015.

The local authorities have also responded positively to the initiative and effort to draft a national standard for seismic design, by offering financial support to professional institutions like IEM which is taking the lead, besides the usual research grants usually reserved for public universities.

The behaviour of building structures to earthquakes is very much dependent on how they are designed, and various do's and don't's have been illustrated, from the viewpoints of a structural engineer and an architect. It is hoped that with the mutual support and input from both practicing professionals, a national standard on seismic design can be drafted which can then be applied by practicing professionals in the local construction industry.

5.0 ACKNOWLEDGEMENT

The author would like to extend his appreciation to members of the IEM Technical Committee on Earthquake and also to members of the various Working Groups of the TC, who have all contributed to the work of the Technical Committee. Appreciation also go to agencies and institutions who have agreed to provide financial support to the work undertaken by the TC Earthquake. But the major thanks go to the members of the International Panel of seismic experts who have contributed tremendously to the final draft of the NA to Eurocode 8.

6.0 REFERENCES

- Balendra T & Li Z, "Seismic Hazard of Singapore and Malaysia", eJSE International Journal Special Issue, 2008, pp57-63.
- BSI, BS EN 1998-1:2004, "Eurocode 8: Design of structures for earthquake resistance", 230p.
- Chiang, J & Hee MC, "Technical Review of JKR's Handbook on Seismic Design Guidelines for Concrete Buildings in Malaysia", IEM Jurutera Bulletin No. 3, March 2008, pp 26-28.
- Lam N, "2-Day Course on Earthquake Resistant Design and Analysis of Buildings and Structures", The Institution of Engineers Malaysia Course Notes, 23-24 September 2009, 128p.
- Lam N & Wilson J, "Displacement Modelling of Intraplate Earthquakes", ISET Journal of Earthquake Technology, Paper No. 439, Vol 41 No 1, March 2004, pp 15-52.
- Mohd Rosaidi bin Che Abas, "Earthquake Monitoring in Malaysia", Seismic Risk Seminar, Malaysia, September 2001.
- Mustafa Kamal Shuib, "The Recent Bukit Tinggi Earthquakes and Their Relationship to Major Geological Structures", Geological Society Malaysia, Bulletin 55, November 2009, pp 67-72.
- Pan TC & Megawati K, "Estimation of Peak Ground Accelerations of the Malay Peninsular Due to Distant Sumatra Earthquakes", Bulletin of the Seismological Society of America, Vol 92, April 2002, pp1082-1094.
- Quek ST & Pang SD, "2-Day Course on Dynamic Analysis and Earthquake Design of Structures", The Institution of Engineers Malaysia Course Notes, 21-22 April 2009, 156p.
- The Institution of Engineers Malaysia (IEM), IEM Position Document 2005, "Position Paper on Issues Related to Earthquake", 23p.

- **APPENDIX 1**

Mercalli Intensity Scale in Depicting Severity of Ground Shaking Due to Earthquake

- Based on damage and observed effects on people, buildings and other objects – quite subjective and varies from place to place.
- Example, two areas (one densely populated, another sparsely populated) may experience same earthquake magnitude – but the densely populated area has higher intensity due to more damage and loss of lives.
- The Modified Mercalli Scale is used to measure 12 levels of increasing intensity.

Richter Scale in Measuring Earthquake Magnitude

- Measured directly at source, using seismograms and the Richter magnitude M – which is determined from logarithm of amplitude recorded by a seismometer as:
    - $M = \log_{10}(A/A_0)$
    - where A_0 is a constant equal to 0.001mm
    - Note that each whole no increase in M represents a 10-fold increase in measured amplitude

Earthquake probability and return periods

- P_1 = probability that ground motions of a given intensity will be exceeded in any given year
- Return period = inverse of P_1, normally, 500 year return period for seismic resistant design is very common.
- Example: A building is design for y = 50-year occupancy has T = 475 years, using formula

$$P_y = 1 - \left(1 - \frac{1}{T}\right)^y$$

$$P_{50} = 1 - \left(1 - \frac{1}{475}\right)^{50} = 10\%$$