Intricacies of addressing distant and local earthquakes in Malaysia in the official design standard EC8 Malaysia NA

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Abstract

Malaysia is in a unique situation and location in terms of its geographical layout and proximity to the seismic rings of fire. The Peninsular Malaysia experienced distant earthquake effects from the Sumatra's subduction plate boundary to the western shores and random small magnitude local earthquakes within the peninsula. On the other hand, the Eastern Malaysia, which consists of Sarawak and Sabah experienced local earthquakes, in particular higher magnitude of local earthquakes (about M6) in the central and eastern parts of Sabah.

Public concerns were raised in recent years due to a number of key earthquake events in this region, in particular, the Sumatra’s Aceh Earthquake in 2004 and more recently the Sabah's Ranau Earthquake in 2015, both of which have caused lost lives in Malaysia due to tsunami and landslide with rock fall event respectively as a result of earthquakes.

This paper sets out the work done by Malaysian engineers in collaboration with the international panel of earthquake experts in identifying suitable hazard models which can be applied in Malaysian context.

The authors will give an insight into the development of the National Annex (NA) for Malaysia based on Eurocode 8 (EC8), and the responses received from various stakeholders in the local construction industry. Through the sharing of the experiences with notable researchers, the industry will stand to benefit if the guiding principles on public safety are to be maintained steadfastly.

Keywords: seismic, design, local earthquake, distant earthquake, peak ground acceleration, natural period, hazard mapping

INTRODUCTION

The works that have been done in developing the Draft National Annex (NA) to Eurocode 8 (EC8) for Malaysian Standard MS EN 1998 Part 1-1 were carried out by The Institution of Engineers Malaysia (IEM) and were presented in earlier 10th Pacific Conference on Earthquake Engineering, Sydney, 2015 by various authors (e.g. Hee et al. (2015), Tsang et al. (2015), Looi et al. (2015) and Lam et al. (2015)). This paper gives a background view of how the work was initiated, progressed and the responses received or evoked from various stakeholders in Malaysia.

Ideally, the focus of every design standard development is to ensure the adoption and preservation of public safety, and then followed by the national interest at a certain distance away. However, in the case of the Draft NA to EC8 for MS EN 1998 Part 1-1, the stakeholders' vested interests overruled the issue of national interest. Strong and vigorous objections to the Draft NA were brought in during the public comment stage by various stakeholders without prior active involvements in the development of seismic code and most of them were having no technical background in earthquake hazards and seismic design. This appears to be a very interesting development, especially when the National Standards Body in charge of this standard development who seems to agree with this sentiment. This attitude of the organisation in charge is sacrificing public safety to which they are supposed to subscribe to and to uphold.

The issue of earthquake engineering and design standards development seems to be a contentious issue between two groups of interested parties, namely, the earthquake structural engineers versus the seismologist and geoscientist. Both parties have a heavy stake in the development of these standards and each prefers their approach and methodology to be prescribed in these standards. Apparently this is a universal situation, which is also prevalent in other countries besides Malaysia. The exception is Malaysia is situated in a low-to-moderate seismicity region and has no seismic design codes previously. Many if not all engineers and scientists in Malaysia are not well-versed and knowledgeable in ground motion predictions and in other engineering aspects of earthquake. Nevertheless, there are local academics and researchers in Malaysia who have been doing earthquake research with conventional approach adopted in the high seismic region, which is not suitable for a low-to-moderate seismicity region.

THE WORK ON THE NA TO EC8 FOR MALAYSIA

Initially the scope of the Technical Committee (TC) set up for Malaysia earthquake design code was to focus only on the seismic study in Peninsular Malaysia, with the effect of long distance earthquake tremors from Island of Sumatra across the Straits of Malacca. Component Attenuation Model (CAM) by Lam et al. (2000) was found useful in providing matching predictions of the projected peak ground acceleration (PGA) values compared to the measured readings taken from the seismic stations along the west coast of the Peninsular Malaysia and Singapore (Lam et al., 2009).

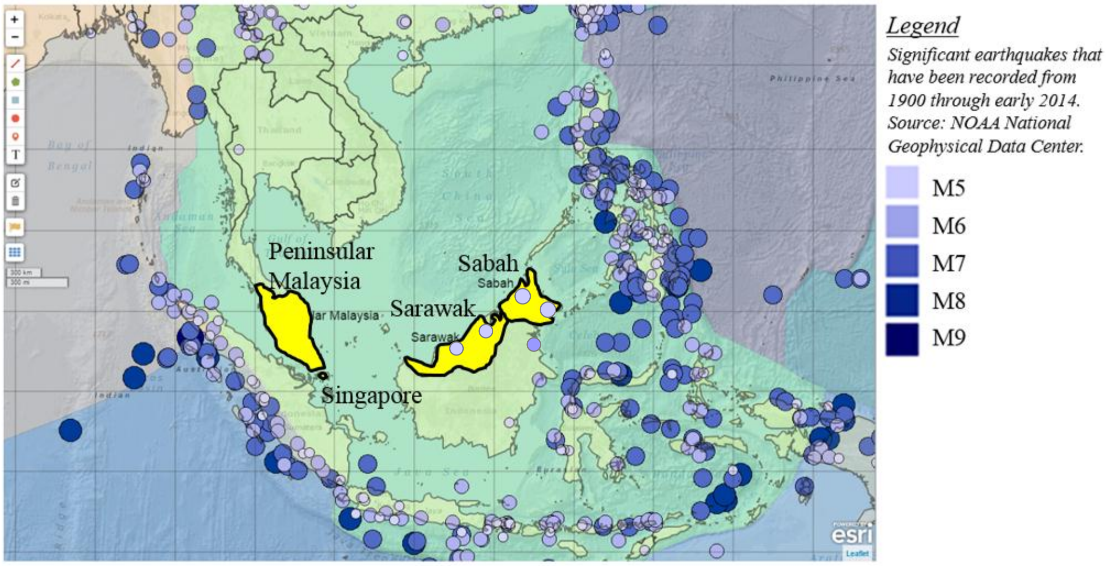
The TC received feedbacks from the stakeholders in East Malaysia (states of Sabah and Sarawak) and the scope of work was expanded to include the whole Malaysia (Peninsular, Sabah and Sarawak). This was achieved by extending the membership of the TC with representatives from Sabah and Sarawak.

The International Panel of Advisors, led by Professor Nelson Lam from The University of Melbourne has proposed practical approaches for Malaysia through his track records of international paper publications in well-respected earthquake engineering journals. One of his remarks in an interview reported in the Jurutera magazine, a monthly Bulletin of the Institution of Engineers Malaysia published in March 2015 (Zarina, 2015) – "Why do we have the perception that destructive earthquakes won't happen in Malaysia? Although the land size is small, you need to have statistical data based on research. Don't wait too long to capture statistics. You must interpret earthquakes because you have smaller land mass." The idea of trading time with space for a country with very limited years of instrumental earthquake reading records was embedded in the development of the draft NA.

1. Potential seismic hazards in Malaysia and the associated response spectrum

The seismicity situation in Malaysia is unique and complex in terms of the potential hazards faced. The country has three distinct regions for seismic consideration – Peninsular Malaysia, Sarawak and Sabah. Peninsular Malaysia is situated in between two tectonic plate boundary along the tectonic area of Sumatra and the Philippines. The long distance effect from the massive earthquake in Aceh, Sumatra in 2004 which resulted in the ensuing tsunami, could be felt by residents in Peninsular Malaysia and Singapore in the obvious swaying of high-rise building structures with no serious structural damage. Nevertheless, the Peninsular is also susceptible to some known local seismic hazards along some mild active faults running along the spine of the Peninsular close to the capital city of Kuala Lumpur.

On the other hand, the state of Sarawak in the Borneo Island across the South China Sea, is far away from distant earthquake disturbances, although there is local earthquakes due to intra-plate seismicity. To further east is Sabah, which is the most seismically active region among the three in Malaysia. Sabah is affected by high regional seismic activity dominated by active faults in surrounding seas of Sabah and the Philippines, and moderate seismicity locally in the central and east. Refer to Figure 1 on the regional seismicity of three key regions in Malaysia.



http://mapmaker.nationalgeographic.org/dFhAVtrGc8lfOt8SXUNWnv/?edit=eVJPruTexDKnLZwb4E7jU6

Figure 1 – Regional Seismicity in Malaysia and its vicinity

The Aceh earthquake in 2004 have been a wake-up call on the seriousness of seismic effect to Peninsular Malaysia. The local earthquake at Ranau Sabah in 2015 has further attracted the attention of engineers and other professionals in geological and seismological studies on the need and importance in data collection. Malaysia has instrumental earthquake records for 38 years (1979 onwards), however the international advisory panel led by Professor Lam advised that the records may not have captured sufficient data in view of the short period of monitoring in a low-to-moderate seismicity region with infrequent earthquake events.

Professor Lam reminded the TC and the Authority that local earthquake events in Peninsular Malaysia must not be ignored. “Hardly can we find local literature about this. All we obtained was a record of tremors in Bukit Tinggi near the capital city of Kuala Lumpur. But in 2013, another earthquake had happened up north in Perak. Bukit Tinggi activity is a local earthquake but it doesn’t mean that it will only happen here. You cannot preclude it from happening elsewhere.” he said (Zarina, 2015).

It is also critical to look into the importance factors especially for lifeline facilities, such as hospitals, schools, fire, police and power stations. The draft NA has considered the importance factors by associating with the return period (RP) where lifeline facilities are to be designed for a 2475 years RP seismic hazard. (See Table 1).

Table 1 – Importance Factor categories based on Design Peak Ground Acceleration (PGA) on Rock Sites for Malaysia

Importance Class	Importance Factor	Recommended Building Categories	Notional design PGA, a_g (g's)	
			Peninsular Malaysia, Sarawak and SW Sabah	CNE Sabah
I	0.8	Minor constructions	0.06 (0.8 x 0.07)	0.10 (0.8 x 0.12)
II	1.0	Ordinary buildings (individual dwellings or shops in low rise buildings)	**0.07 Reference PGA** (notional 475 years RP)	**0.12 Reference PGA** (notional 475 years RP)
III	1.2	Buildings of large occupancies (condominiums, shopping centres, schools and public buildings)	0.08 (1.2 x 0.07)	0.14 (1.2 x 0.12)
IV	1.5	Lifeline built facilities (hospitals, emergency services, power plants and communication facilities)	**0.10 (2475 years RP)**	**0.18 (2475 years RP)**

The draft NA advocates the use of minimum hazard (Lam et al., 2016) to circumvent extremely low PGA values due to insufficient data collected. Single reference PGA value was proposed for the three respective seismic regions in Malaysia, i.e. Peninsular Malaysia with 0.07g, Sarawak and South-western (SW) Sabah with 0.07g, and Central and North-eastern (CNE) Sabah with 0.12g. It should be noted that a single PGA of 0.07g for Peninsular Malaysia, Sarawak and SW Sabah does not generalise the two regions into the same hazard level. The structural engineers are more interested in the response spectral values in the higher period ($T \geq 0.3$ s) as most of the natural period of built structures fall in these range. Figure 2 to 4 show the distinct features of the response spectrum on rock sites, where the slopes in the displacement response spectrum for Peninsular Malaysia and CNE Sabah has implicitly encapsulated the effects of distant earthquakes. A unique hybrid approach was adopted in the modelling of the response spectrum (Looi et al., 2017).

$T \leq 0.3$:	$S_{De}(T) = 16\ T^2 / (0.3 \text{ x } 1.25)$
$0.3 \leq T \leq 1.25$:	$S_{De}(T) = 16\ T / 1.25$
$T \geq 1.25$:	$S_{De}(T) = 16 + 6.7\ (T - 1.25)$

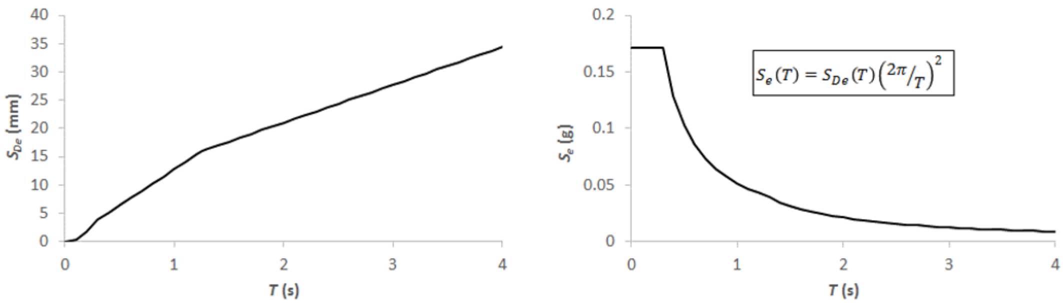


Figure 2 – Response spectrum on rock site for Peninsular Malaysia

$T \leq 0.3$:	$S_{De}(T) = 16\ T^2 / (0.3 \text{ x } 1.25)$
$0.3 \leq T \leq 1.25$:	$S_{De}(T) = 16\ T / 1.25$
$T \geq 1.25$:	$S_{De}(T) = 16$

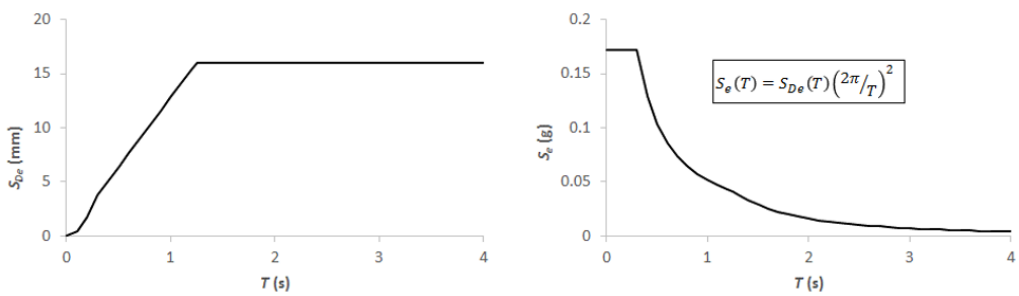


Figure 3 – Response spectrum on rock site for Sarawak and SW Sabah

$T \leq 0.3$:	$S_{De}(T) = 28\ T^2 / (0.3 \text{ x } 1.25)$
$0.3 \leq T \leq 1.25$:	$S_{De}(T) = 28\ T / 1.25$
$T \geq 1.25$:	$S_{De}(T) = 28 + 40\ (T - 1.25)$

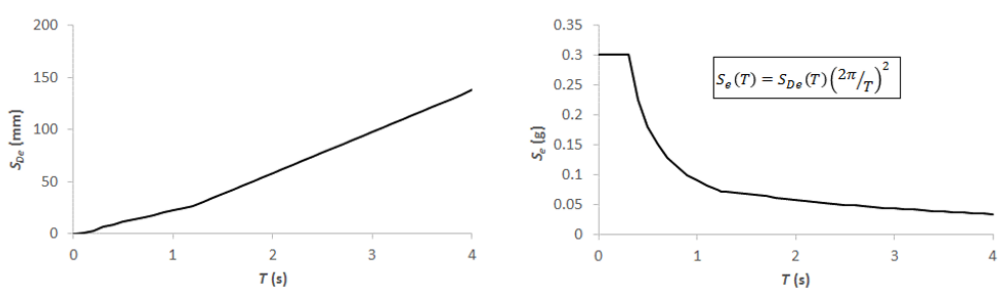


Figure 4 – Response spectrum on rock site for CNE Sabah

When explaining the rationale behind the adoption of the response spectrum model that has been written into the Draft NA, Professor Lam made references to long distance earthquake hazard generated by high seismic sources in the Sumatran Island, and subduction sources offshore of Sumatra and from the Philippines in combination with small and medium magnitude intraplate earthquakes that occur locally. This unique combination of seismic hazard which is not commonly seen in Europe explains the need of specifying a response spectrum model that is different to the standard Eurocode Type 1 and 2 response spectrum models (Lam et al., 2009). For the same reason Singapore has redefined the shape of the response spectrum, neither using EC8 Type 1 nor Type 2 in its provisions Clause 3.2.2.2(2)p Note 1 to allow for long distance seismic hazard affecting the city state. Figure 5 shows the normalised spectrum shape comparison of the proposed response spectrum model for Peninsular Malaysia in the draft Malaysia NA with the generic EC8 for Europe and the Singapore NA.

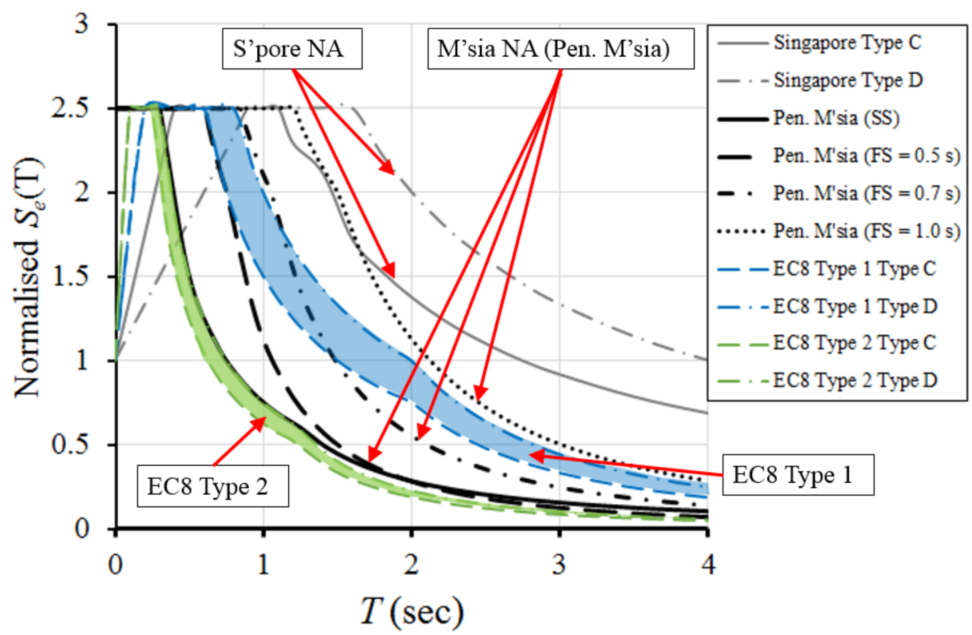


Figure 5 – Normalised spectrum shape comparison of the proposed response spectrum model in the Malaysia NA (Peninsular Malaysia) with the generic EC8 for Europe and the Singapore NA.
(*Note: Stiff Soil (SS) and Flexible Soil (FS) with site natural period)

2. Views sought from well-renowned seismic experts and other stakeholders

A two-day workshop on the proposed seismic analysis methods for regions of low-to-moderate seismicity was held on 10th to 11th April 2017 in Malaysia. This section highlights the views sought from the invited speakers.

Professor Kyriazis Pitilakis is the Vice President of the European Association of Earthquake Engineering (EAEE) and was leading the drafting of Eurocode 8 in relation to geotechnical matters. He concurred with the inability of the current site factor model in the present EC8 to properly address deep site geology was a matter of concern. It is planned to have the next edition of EC8 to be revised to the form (Riga et al., 2016; Pitilakis et al., 2013; Pitilakis et al., 2012) which is consistent with the model proposed by IEM.

Professor Robert Geller (previously attached to Tokyo University) pointed out the great uncertainties of Probabilistic Seismic Hazard Assessment (PSHA) in view of the poor track record of the methodology in terms of predicting earthquake hazards for the future (Stein et al. 2012, 2013; Mulargia et al., 2017). The credibility of the predictions is further compromised in the case of Malaysia where a mere 38 years (year 1979 onwards) of complete instrumental record (Che Abas, 2001; MOSTI, 2009) on a small land area only shows two earthquakes exceeding magnitude 5 (on 12th February 1994 and 1st May 2004) occurring in the Peninsular and Sarawak combined. He advocated the use of common sense as opposed to believing in every details generated by the computer as there was no way we have sufficient information to predict the location of future earthquake occurrence with such a precision. An approach based on averaging global rate of occurrence of earthquakes in tectonically stable regions (Lam et al., 2016) is supported.

For a balanced view, the local researchers were invited to present in the two-day workshop. Professor Azlan Adnan from Universiti Teknologi Malaysia (UTM) and his team presented a seismic hazard map that was generated by conventional PSHA (See Figure 6). A similar approach was undertaken by the Department of Mineral and Geoscience Malaysia in the recent development of hazard map for public comments.

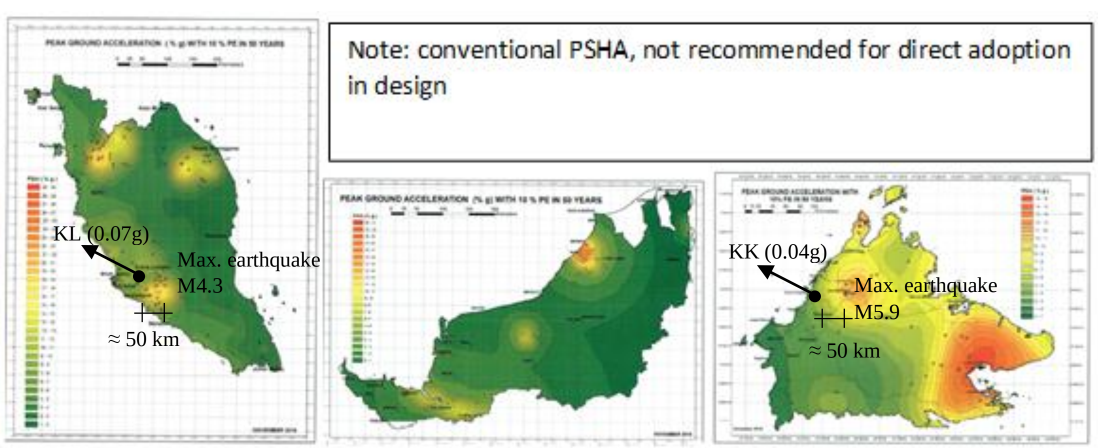


Figure 6: Seismic hazard PGA contours on rock generated by conventional PSHA for the Peninsular, Sarawak and Sabah prepared by local contingent led by Professor Adnan.

In the opinion of the authors, the Malaysia community including the TC who has no prior experience in seismic code writing, should not ignore the advices given by the experienced international experts who have done seismic codification for years. Three critical points are elaborated here based on Figure 6:

1. Malaysia is situated in a low-to-moderate seismicity region. The very limited instrumental data of 38 years (year 1979 onwards) are not adequate to capture sufficient M5 earthquakes locally. The map in Figure 6 done by the local researchers was produced with a database from year 1900 to 2016. It should be exclusively pointed out that the non-instrumental data from 1900 to 1979 is only able to give large magnitude readings which presented a severe bias. The unpredictable spatial distribution of intraplate earthquakes could not be predicted with such good accuracy and hence having unreliable high PGA value hotspots and extremely low value in the "valley" of the contours is never a good practice for a low-to-moderate seismicity region.
2. The very fine interval of 0.01g can only be considered as a scientific exercise but not suitable for design codification purposes. The local researchers have to put more effort and thinking by considering the statistical confidence level in the development of the map, and not just blindly applying probabilistic study.
3. The hazard map in Figure 6 shows a classical example of the uncertain features of PSHA in the low-to-moderate seismicity region with limited data within a limited period of observation. Taking a comparison for Kuala Lumpur (KL) which is about 50 km away from a known source of M4.3 at Bukit Tinggi area, and Kota Kinabalu (KK) which is also about 50 km away from Ranau with M5.9, the PSHA results revealed an unexplainable higher PGA value in KL (0.07g) than in KK (0.04g). Hence, even the seismic hazard contour map is to be adopted as part of the earthquake action code of practice, a minimum hazard value should be added as a clause. It is noted that the New Zealand standard committee has adopted a minimum hazard value for the whole country. Even Auckland is considered as a low seismicity area, the 500-year design Z-factor (PGA) is 0.13 g.

3. The proposed behaviour factor to suit the Malaysia construction industry

A behaviour factor (q) is to be stipulated to account for the capacity of the structure at the member level to withstand seismic forces beyond its notional capacity limits. The elastic spectrum is to be scaled down by a factor of $1/q$ into the design spectrum for linear analysis, from which the displacement shall be multiplied by the displacement behaviour factor q_d. Table 2 shows the recommended and default behaviour factors as adopted in various region and countries.

Table 2 – Recommended and default values of behaviour factor *q* for limited ductile structures

Region/Country	Standards/Codes	Over-strength factor	Ductility factor	Behaviour factor
Malaysia	Proposed *NA to MS*	1.2	1.25	1.5
Europe Singapore	*Eurocode 8* *NA to SS*	1.5	1.0	1.5
Canada	*NBCC*	1.3	1.5	2.0
Australia	*AS1170.4*	1.3	2.0	2.6

Given that the default *q* value stipulated in the National Annex for Singapore is 1.5, which is consistent with the recommendations by Eurocode 8, it was prudent to adopt the same in the Malaysian Draft NA, pending further studies in the future to justify a higher value perhaps. It is noteworthy that a local research study (Chiang et al, 2012) revealed that the mean strength to characteristic strength ratio of thousands of concrete cube tests up to Grade C40 in Malaysia was 1.2. Hence, this justify the recommendation for over-strength factor of 1.2, as shown in Table 2.

4. The views of the Government

In an interview with IEM Jurutera Bulletin publisher in February, 2015 (Zarina, 2015), the then former Senior Director of the Civil and Structural Engineering Branch of the Public Works Department (PWD), Dato' Ir. Dr. Abdul Aziz bin Haji Arshad stated that PWD has been an actively involved in the drafting of the NA to EC8. He cited the need for local practicing engineers to be ready to implement what is required by the law, when the NA to EC8 becomes mandatory for structural design in Malaysia.

Another important consideration cited by Dato' Ir. Dr. Abdul Aziz, is to address the expected increase in cost to incorporate earthquake resistance elements in building and structural designs, by doing comparative studies. These tasks are necessary to convince the various stakeholders in the industry that there is a need to adopt earthquake design in Malaysia.

He concluded by stating the following: "Despite the challenges, our emphasis now is to get the National Annex to Eurocode 8 adopted. In Malaysia, the Eurocode is managed by IEM whereas in the UK, it is the Government that drives it. This is the problem. NGOs like IEM cannot plan for the country. So the Government must drive it. But here in PWD, whether we are ready or not, we have to take the initiative, do our own thinking and give the proper technical advice to the Government. We must be prepared for the probability of major earthquakes happening in the country."

5. The view from the industry (the users)

In the 2015 Earthquake Symposium held in Malaysia, at the end of the consultative forum session, one of the participants in the audience who is a practicing structural engineer made a very poignant comment:

"Consultants in the industry are not well-versed in seismic design as it was never a requirement in the British Standards and was not required in the Uniform Building By-Laws. Therefore, I would like to suggest the Technical Committee to come out with simple procedures which consultants can follow easily. We are not too concern over how the figures of PGA has come about, so long as there were technical merits and justifications for use in the local context, spelt out clearly and logically in the National Annex to Eurocode 8."

CONCLUSION

The views sought from international experts coming from Europe, Japan, Australia and from within Malaysia congregated in organised forums to explain on the intricacies of Eurocode 8 and the draft National Annex for Malaysia, which attempted to cater for distant and local earthquake phenomena. Professor Pitilakis who is one of the lead code drafters of Eurocode 8 was amongst those invited. What has been demonstrated in the workshop is that the draft EC8 NA for Malaysia has incorporated contemporary principles of seismic hazard assessment and site period parameterisation of soil spectrum, taking into account the development of knowledge and practice since the time Eurocode 8 was first developed two decades ago. Particular attention was devoted to the importance of maintaining the following key features in the draft NA by IEM:

(i) A minimum design PGA value of 0.07g for Peninsular Malaysia, Sarawak and SW Sabah (and 0.12g for CNE Sabah) irrespective of the results from PSHA because of considerable modelling uncertainties, particularly in the source zone;

(ii) Response spectrum models are deviated from EC8 Type 1 and 2 because of the need to address both local earthquake and long distance subduction seismic hazard; and

(iii) A site classification and site amplification model which incorporates the site natural period parameterisation as a design parameter (as opposed to only consider the upper 30 m of soil sediments).

It is hope that other countries in the low-to-moderate seismicity regions who have plans to implement seismic design codes can learn from the sharing of the Malaysian experience elaborated in this paper.

Acknowledgement

The international collaboration on the earthquake code EC8 NA for Malaysia with Professor Nelson Lam (The University of Melbourne) and Dr. Hing-Ho Tsang (Swinburne University of Technology, Melbourne) is gratefully acknowledged.

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