Introducing the Paper Series on Structural Eurocodes

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THERE will be a critical change to our construction industry due to the withdrawal of the British Standard in March 2010 (in the European Union), to be replaced by the Eurocodes. The great implications to other non-EU countries such as Malaysia had been the theme of the September 2009 issue of JURUTERA.

In Malaysia, great efforts have been put in to cater for this change. IEM, as a Standard Writing Organisation, has set up Technical Committees for EC 0 (EN1990), EC 1 (EN1991-1-1), EC 2 (1992-1-1), EC 3 (EN1993-1-1), EC 7 (EN1997) and EC 8 (EN1998). Furthermore, IEM has organised seminars and road shows to promote awareness of the Eurocodes.

Public comment for the documents MS EN1990, MS EN1991-1-1 and MS EN1992-1-1 has been completed and the official publication of these standards will follow. Invitation for public comment on MS EN1993-1-1 is expected to open by December 2009.

To further disseminate information on this critical matter, on 7 November 2009, the Standing Committee on Information and Publications endorsed the publication of a series of papers in JURUTERA beginning December 2009. The Paper Series on Structural Eurocodes is devoted to highlighting the issues and development of the Eurocodes in Malaysia.

Structural Eurocodes consist of 10 codes (a total of 58 documents), and their relations are depicted in Figure 1. Besides the structural codes, there are many other related Eurocodes covering the specifications of materials, workmanship and testing. These include EN206-1 (Concrete specification, performance, production and conformity), EN10025 (Specification of hollow sections), EN12390 (testing of hardened concrete), EN12504 (Testing of concrete in structure) and EN13791 (Assessment of *in situ* compressive strength in structures and pre-cast concrete components).

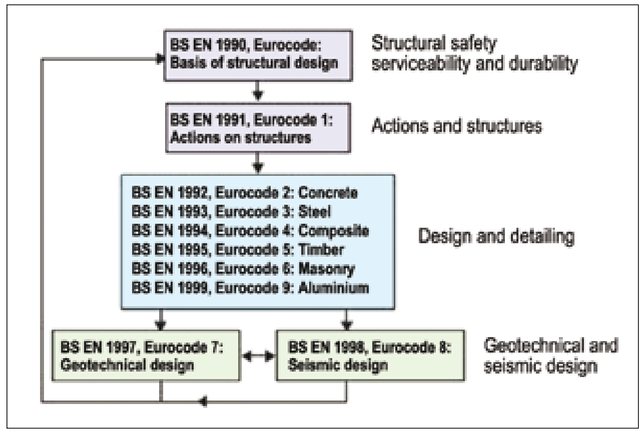

Figure 1: Relationships between various Eurocodes on structures (Source: http://www.eurocode2.info/main.asp?page=1149)

The author has volunteered to coordinate the solicitation of articles for the column. Comments and articles from members are most welcomed. Please direct your input to pub@iem.org.my. ■

This change in design standards for structural design in the UK has major implications in other Commonwealth countries (which include Malaysia) where the design standards used in construction and structural engineering are all adopted from the British Standards. The dilemma faced by Malaysia was deliberated some years ago from 2003, when the date of switchover by the UK was originally 2006 – and then subsequently pushed back twice to 2008 and then finally set in 2010.

BACKGROUND

Many countries in East and Southeast Asia are facing the situation of adapting to the fast pace change in concrete design in accordance to the latest and updated international standards. These international standards are developed and promoted in three main parts of the world. The Americans have their ACI318, while the Europeans are promoting the use of Eurocode EC2, and it is noted that the Asia Pacific region has also come into the picture with the Asian Concrete Model Code ACMC2006, led by developed Asian economies such as Japan and Korea. Hence, smaller developing countries such as Malaysia has to decide on which of these international standards are to be adopted – in view of the phasing out of British Standards BS8110, which is predominantly used in Malaysia as a throwback to its past British colonial influence.

In 2003, The Institution of Engineers Malaysia (IEM) recommended strongly through its Position Paper that, since the UK is adopting Eurocode EC2 in place of BS8110:1997 by 2010, then it is advisable for Malaysia to follow suit. As this is the case for Malaysia to adopt EC2, then this paper will give a brief insight into the workings of the Technical Committee formed in Malaysia, which is looking into developing National Annexes to tackle issues and design aspects in the Malaysian context, such as thin size elements and durability recommendations.

By mid-2009, the Technical Committee has completed the draft National Annexes for EC0, EC1 and EC2, and upon considering the public comments received, they should be published as Malaysian Standards MS EN Eurocode documents. This is on the understanding that these new sets of Malaysian Standards will supersede the existing MS 1195:1991[5], which is essentially a full adoption of BS 8110:1985, which will be withdrawn by BSI in 2010.

IEM POSITION PAPER

The Committee recommended the following actions to be carried out by the proper authority to ensure a smooth transition from BS8110 to Eurocode EC2:

- IEM is to take the lead in drafting and producing the necessary National Annex in line with the full adoption of the Eurocode EC2 as a Malaysian Standards document.
- IEM will also spearhead the task of organising public forums, technical talks and introductory seminars, as part of the awareness campaign to educate and promote the adoption and use of Eurocode EC2 for the construction industry.
- On the implementation side, the Committee recommends to train the trainers, *i.e.* university lecturers and course speakers, by organising short courses on Eurocode EC2.
- IEM would also be taking the initiative to incorporate the use of Eurocode EC2 as design examples and methods in the civil engineering course syllabus at local universities.
- All the stated promotional and awareness activities and campaigns have to be funded by national standards agencies, and IEM will approach Standards Malaysia to provide the necessary financial support to that end.

EUROCODES FOR ADOPTION: CONSIDERATION BY MALAYSIAN ENGINEERS

Besides having to grapple with the understanding and use of Eurocode EC2, designers will also have to make use or refer to two other suites of Eurocodes, *viz.* Eurocode EC0 (Basis of structural design) and Eurocode EC1 (Actions on structures). The reason being, Eurocode EC2 make references to basic fundamentals and assumptions in design provided for in Eurocode EC0, while Eurocode EC1 provides the basis of loadings in the form and terminology of actions as well as the various load combinations required for the design of concrete structures.

Hence, this paper will give further insights into the various issues as identified in the three Eurocodes documents as mentioned. In terms of the naming of the adopted Eurocodes as Malaysian Standards, it is accepted by CEN the following as the titles in the adoption of Eurocodes for Malaysia:

- MS EN 1990:2009 National Annex for Eurocode 0 – Basis of structural design
- MS EN 1991:2009 National Annex for Eurocode 1 – Actions on structures
- MS EN 1992:2009 National Annex for Eurocode 2 – Design of concrete structures

The other structural Eurocodes that are yet to be adopted as Malaysian Standards are as follows:

- EN 1993 Eurocode 3 – Design of steel structures (in the process of being adopted in Malaysia)
- EN 1994 Eurocode 4 – Design of composite steel and concrete structures
- EN 1995 Eurocode 5 – Design of timber structures
- EN 1996 Eurocode 6 – Design of masonry structures
- EN 1997 Eurocode 7 – Geotechnical design (in the process of being adopted in Malaysia)
- EN 1998 Eurocode 8 – Design of structures for earthquake resistance (to be considered for adoption in Malaysia)
- EN 1999 Eurocode 9 – Design of aluminium structures

(To be continued on page 26)

MS EN 1990:2009 NATIONAL ANNEX FOR EUROCODE EC0: BASIS OF STRUCTURAL DESIGN

Under the scope of Eurocode 0, principles and application rules are established, not only for the design of concrete structures but for the whole suite of Eurocodes from EC2 to EC9, in conjunction with Eurocode 1 for actions.

One of the initial issues faced by Malaysian practitioners is the use of different terminology from the British Standards used before. The term 'actions' is used in place of 'loads', and terms such as 'permanent and variable actions' replace the usual 'dead and live loads' respectively.

Another major hurdle that needs to be tackled by Malaysian engineers is the use of cylindrical compressive strength in EC0 as opposed to the cube strength compressive strength test which are used in BS8110. This issue is alleviated somewhat by the use of the two different compressive strengths in the following manner:

C25/30 means a cylinder strength for concrete of 25 MPa which is equivalent approximately to a cube strength of 30 MPa, whereas C30/37 denotes a cylinder strength of 30 MPa to be read in equivalence to a cube strength of 37 MPa.

A common load or action combination for permanent (G_k) and variable (Q_k) actions will also be different in EC0, *i.e.* $1.35G_k + 1.5Q_k$, as opposed to $1.4G_k + 1.6Q_k$ in BS8110.

The various other load combinations recommended in EC0 is a vast change from BS8110 in terms of complexity and coverage. Nevertheless, BSI has managed to influence CEN to modify the BS EN1992 version of the Eurocode EC2, by incorporating some of the common features of alternate floor load combinations in braced and unbraced frames, as found in BS8110. And this has been adopted likewise by the Malaysian Standard in adopting the UK's BS EN1992.

One key feature in Eurocode 0 is the use of conversion factors for characteristic variable actions into representative values. These can be found in Table NA A1.1 of the MS EN1992:2009 in which values for these conversion factors, ψ_0, ψ_1, and ψ_2 for different categories of buildings are presented. For example, category A (domestic, residential areas) requires the following values: $\psi_0 = 0.7$, $\psi_1 = 0.5$, and $\psi_2 = 0.3$.

Note that ψ_0 is a factor used for combination value of a variable action, while ψ_1 is a factor for frequent value of a variable action, and ψ_2 is a factor for quasi-permanent value of a variable action. Hence, these are new considerations designers in Malaysia have to learn, in obtaining design loads according to the Eurocode.

In order to give an idea of the complicated equation for loading combination under ultimate limit state, below is a general equation presented as Eq. 6.10 in EC0, under page 44 of the standards:

$$E_d = \sum \gamma_{G,j}\, G_{k,j} + \gamma_P P + \gamma_{k,1} Q_{k,1} + \sum \gamma_{Q,i}\, (\gamma_{o,i} Q_{k,i}) \quad (1)$$

where,

E_d = design action effect

$G_{k,j}$ = characteristic value of permanent action (previously known as dead load)

P = representative value of pre-stressing action (or force)

$\psi_{0,i}$ = factor used for combination value of variable action (as found in Table NA A1.1)

$Q_{k,i}$ = characteristic value of variable action

γ_P = factor used for combination of pre-stressing action (usually taken as 1.0)

From the above, the normal load combination under ultimate limit state becomes,

$$E_d = \sum 1.35 G_{k,j} + 1.0P + 1.5Q_{k,1} + \sum \gamma_{Q,i}\, (\psi_{o,i} Q_{k,i}) \quad (2)$$

Besides the above issues related to EC0, designers in Malaysia would have to consider structural actions, not in isolation, but also in conjunction with other related effects due to:

- Stability or EQU (which stands for equilibrium)
- Structural or STR
- Geotechnical or GEO
- Accidental design situations
- Seismic design situations

Note that for seismic design situations, there is another Eurocode which takes care of this, which is EN1998:2004 – which is in the process of being studied for adoption in Malaysia too. For the purpose of load combination in EC0, the quasi-permanent value of earthquake action would have to be incorporated into the general equation Eq. 6.10 in EC0.

In the case of serviceability limit state design, the typical load combination required to be considered by Malaysian engineers is as shown,

$$E_d = \sum G_{k,j} + P + Q_{k,1} + \sum \psi_{o,i} Q_{k,i} \quad (3)$$

Again, the various conversion factors ψ_0, ψ_1, and ψ_2 attached to the characteristic variable action Q_k, will again come into play in accordance to either at combined value, frequent value or at quasi-permanent value.

In contrast to the complicated load combination issues faced by Malaysian engineers in understanding EC2, their work in dividing up the uniformly distributed loads on braced and unbraced framed structures is made much easier, as EC2 provisions have been modified somewhat (with the UK's influence) to be in line with that of BS8110. For example, in the case of a subframe analysis of a typical braced continuous beam or slab, the UDL is first assumed to be placed on all spans, and then to be placed at alternate spans – which are specified the same way in both EC2 and BS8110. The only difference is in the allotted load factors used, for both the self-weight (classified as permanent action) and also the live load portion (or variable action).

In BS8110, the unloaded portions have a self-weight with a value of $1.0G_k$, while for the loaded portions, the combined load is given as $1.4G_k + 1.6Q_k$.

On the other hand, in EC 2, the self-weight floor area is upped to $1.35G_k$, while the combined load for the loaded portions is given as $1.35G_k + 1.5Q_k$, as per the factors in ULS.

MS EN 1991:2009 NATIONAL ANNEX FOR EUROCODE EC1 – ACTIONS ON STRUCTURES: PART 1-1: GENERAL ACTIONS, DENSITIES, SELF-WEIGHT, IMPOSED LOADS FOR BUILDINGS

The advantages of adopting Eurocode EC 2 for the design of concrete structures is that more details are given in terms of loading or action requirement, since it is all detailed out in a separate document, as in EC0 and also in EC1 – which points out the types, categories and classifications of actions.

It has to be pointed out that, the code drafters in Malaysia have only looked into Part 1-1 so far. There are other parts to Eurocode EC 1 which will have to be studied later on for likely adoption, and they are:

- Part 1-2: Actions on structures exposed to fire
- Part 1-3: Snow loads (this will most likely not be considered under the Malaysian tropical climate conditions)
- Part 1-4: Wind loads (which will be studied soon)
- Part 1-5: Thermal actions
- Part 1-6: Actions during execution
- Part 1-7: Accidental actions due to impact and explosions
- Part 2: Traffic loads on bridges
- Part 3: Actions induced by cranes and machinery
- Part 4: Actions on silos and tanks

In the case of referral to EC1 is concerned, besides the usual requirements for domestic, residential, commercial, industrial and even storage types of structures, there is also the issue of imposed load reduction for beams and columns – *particularly* for high-rise structures. Malaysian engineers would have to take into consideration that it is unlikely that the same amount of imposed load will be applied at every floor in multiple-storey structures. Hence, it stands to reason that a reasonable reduction is allowed. Depending on conditions, the imposed load can be reduced from 5% to over 30%.

For MS EN 1991:2009 National Annex for EC1, there was a separate Editorial Group formed out of the Technical Committee on EC2, to look into the adherence and conformity of EC0 and EC1 to EC2, which is adopted as MS EN1992. One key difference adopted in the Malaysian National Annex is the imposed load by heavy vehicles (e.g. fire-fighting vehicles) in the vicinity of building structures. This is found in Table NA.2.6 under Category G loading, where the BS National Annex recommended a load range of 30 kN < gross weight of heavy vehicle < 160 kN. This corresponded with a recommended UDL of $q_k = 5$ kPa which is considered low by Malaysian practice. An UDL of not less than 10 kPa would be more reasonable as the gross weight of fire and rescue vehicles used in Malaysia, and the maximum load can go as high as 180 kN.

Hence, this issue has to be noted by Malaysian engineers, and in the Malaysian National Annex on EC1, the Committee has decided to revise Category G loading (for fire and rescue vehicles) to a load range 30 kN < gross weight < 200 kN; using $q_k = 10$ kN/m^2, and Q_k to be stated as "To be determined for specific use (e.g. fire rescue emergency purpose vehicles)".

One additional change is found in Table NA.2.7 where imposed loads are recommended for accessible sloping roof. For Malaysian practice, the basis imposed load $q_k = 0.25$ kPa compared to $q_k = 0.6$ kPa for BS EN1991 National Annex.

CONCLUSION

This brief paper provides a glimpse or a useful insight into the background, and issues faced by local engineers in adopting Eurocodes EC0 and EC1 as two new sets of the Malaysian National Annexes or the Malaysian Standards based on the EN1990 and EN1991. There are many new terminologies and new concepts to be learned by local engineers. Hence, the learning curve is expected to be steep and possibly an acceptable transition period is envisaged for a smooth and transparent switchover from the British Standards to the Eurocodes. It is particularly important to understand fully the base codes EC0 and EC1 which are necessary references for all the following Eurocodes, including EC2 and EC3 for concrete and steel design respectively. ■

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REFERENCES

[1] BSI. 1997. BS 8110-1:1997. *Structural use of concrete: Code of practice for design and construction*. London, UK

[2] BSI. 2002. EN 1990:2002. *Basis of structural design:* London, UK.

[3] BSI. 2003. BS EN 1991:2003. *Action on structures:* London, UK.

[4] BSI. 2004. BS EN 1992:2004. *Design of concrete structures:* London, UK.

[5] SM. 1991. MS 1195:1991. *Structural use of concrete:* Code of practice for design and construction. KL, Malaysia.