Summary Update of Cost Implication on Proposed Malaysian NA for EC8 on Office Buildings and Link Houses

by Ir. Adjunct Prof. M C Hee, Prof. Nelson Lam, Dr Tsang Hing Ho, Engr. Looi Ting Wee Grad. IEM, Engr. Ahmed Zuhal Zaeem Grad. IEM, Ir. Lim Ek Peng.
(Photos and details of authors on page 44.)

In order to understand the implications of earthquake design in Malaysia, a cost study was undertaken by the Working Group 1 of IEM Technical Committee for Earthquake. Since Malaysia would soon adopt Eurocode as the design standard and, with the development of the Malaysian NA to EC8, studying all aspects of earthquake engineering is deemed necessary. Therefore with the introduction of the design spectrum for Malaysia, the cost study is a stepping stone for engineers in understanding the implication of earthquake design guidelines in Malaysia.

GENERAL BUILDING DESCRIPTION

Typical office buildings ranging from 1-storey, 5-stories, 10-stories, 20-stories and 30-stories degenerated into 2 Dimensional buildings for ease and simplicity in analysis (Fig. 1a to Fig. 1e) and typical link houses ranging from 1-storey and 2-stories were used in the study (Fig. 1f to Fig. 1g). Given that the majority of structures built in Malaysia are reinforced concrete, the study limits all the buildings to reinforced concrete. All the buildings were analysed and designed using structural design programme, Midas Gen 2015 and for quantities taking off, Midas DShop was utilised. The office buildings are built out of reinforced concrete of grade C30/37 and the link houses are built out of reinforced concrete of grade C20/25. For reinforcing steel, yield strength of Class B rebar for longitudinal reinforcement and stirrups is utilised. Two models were developed for each type of building. One was subjected to static loading and one was subjected to both static and earthquake loading. The two replicas were analysed and designed on the assumption that they were uncracked. They were subjected to pushover analysis in order to determine whether the sections weare cracked or not. If the buildings fall under cracked sections, the property of the building is assumed cracked, thus reducing the stiffness of all members by 50% as per BS-EN1998-1:2004

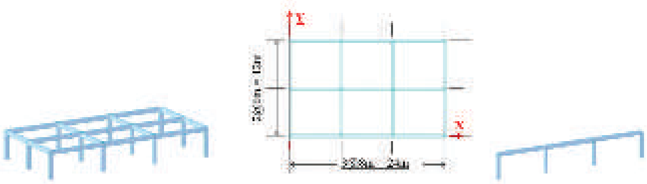

Figure 1a: 1-storey office building degenerated into a 2D model

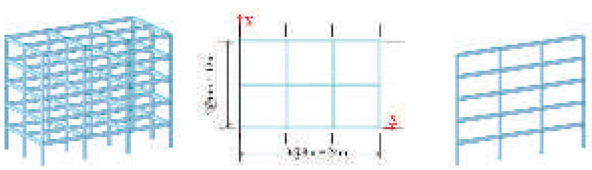

Figure 1b:.5-storey office building degenerated into a 2D model

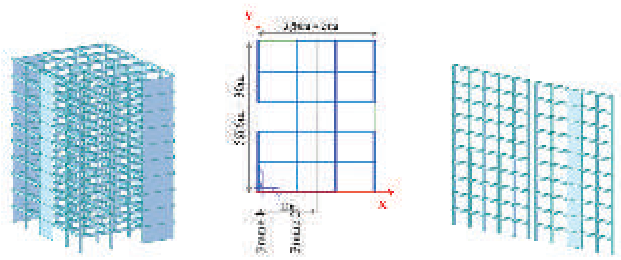

Figure 1c: 10-storey office building degenerated into a 2D model

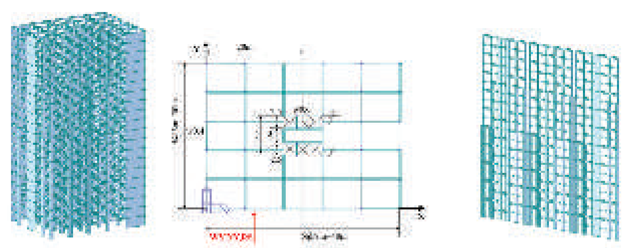

Figure 1d: 20-storey office building degenerated into a 2D model

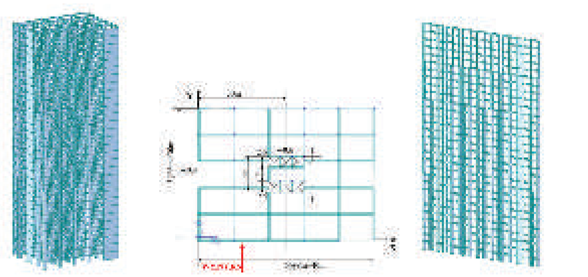

Figure 1e: 30-storey office building degenerated into a 2D model

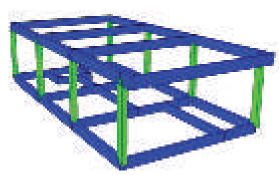

Figure 1f: 1-storey link house

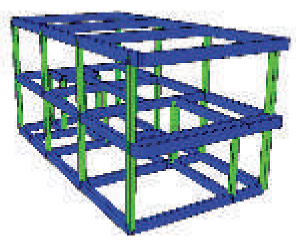

Figure 1g: 2-storey link house

LOADING APPLIED

Each of the office buildings was designed to a uniform building density of 3.4 kN/m3. For link houses, superimposed dead load of 2.5 kPa and a live load of 1.5 kPa was adopted. Wind loads were applied as per BS-EN1991-1-4 2005, with a basic wind speed of 20 m/s inside city. Notional imperfection load was applied, taking maximum inclination of 1/200 for 1 and 2-stories buildings and 1/400 for 5, 10, 20 and 30-stories buildings. This amounted to 0.5% of the ultimate dead and live load for the 1 and 2-stories buildings and 0.25% of the ultimate dead and live load for the 5, 10, 20 and 30-stories buildings. Earthquake loading was also been applied as per the Malaysian hybrid design spectrum of the Malaysian National Annex EC8. All buildings were assumed to be located on stiff soil sites consistent with most Malaysian soil condition. As for computations of the natural period of vibration, which was a function of stiffness and mass of the building, the design seismic mass was formulated using equation 1.

$$m = \sum G_{k,}i + \sum \Psi_{E,j} \ .Q_{k\,j} \qquad (1)$$

where G_k and Q_k the characteristic dead and imposed mass respectively. Ψ is taken as 0.3 taking into account the likelihood that imposed load is not present over the entire structure during the earthquake.

PUSHOVER ANALYSIS AND STIFFNESS REDUCTION

Under the clause 4.3.1 of EC8, the stiffness of the cracked structural elements can be taken as 50% of its original un-cracked stiffness. In order to determine whether the structure is cracked or un-cracked, a pushover analysis is performed. The capacity curve (Fig. 2a) for 1-storey link house gives the maximum displacement in metres of the building against lateral load in kilo Newton. The building experiences its first crack at 360kN (α1). Hence the pushover capacity curve was superimposed over the acceleration displacement response spectrum of Peninsular Malaysia to determine the performance point (Fig. 2b). Since the performance point is above the 1 (which is the first crack), this indicates that the structure has cracked, hence concluding that the building has cracked and the analysis is carried out under cracked section properties. This reduction in stiffness increased the first mode period of the 1-storey link house from 0.25s to 0.35s and the 2-storey building from 0.48s to 0.67s.

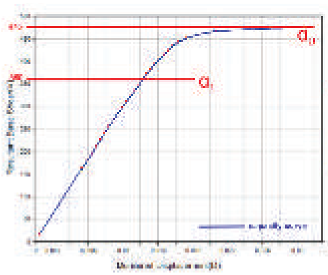

Figure 2a: Pushover capacity curve

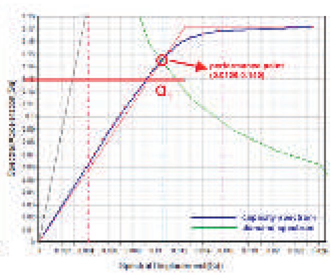

Figure 2b: Pushover demand curve

ANALYSIS AND RESULTS

Cost Estimation is calculated under static load conditions (dead load, imposed load, wind load and notional imperfection load) and under combined static and earthquake load. One standard deviation is calculated with the two samples of 1-storey and 2-storey buildings and applied to the costing to cover uncertainties.

The percentage differences in costs is estimated as shown in Fig. 3a for office buildings and Fig. 3b for link houses. The highest increase in cost is predicted for Sabah (8.1% for a 10-storey office building and 4.8% for 2-storey link house).

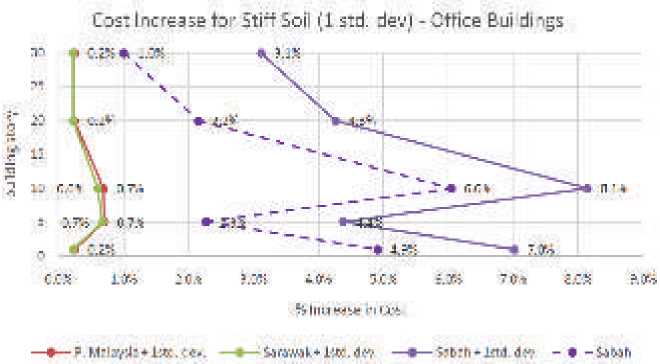

Figure 3a: Preliminary cost estimation for office buildings (Structural building cost) for Stiff Soil

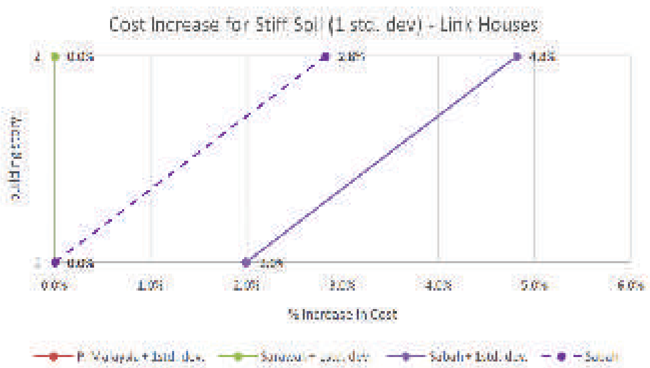

Figure 3b: Preliminary cost estimation for link houses, (structural building cost) for stiff soil

SUMMARY AND CONCLUDING REMARKS

The highest cost estimation (with 1 standard deviation) for Peninsular Malaysia/Sarawak for office buildings is 0.7% and 0.6% respectively for 10-storey office building. The highest increase in cost for Sabah is 8.1% for 10-storey. For Peninsular Malaysia and Sarawak, link houses have no change in the structural cost. For Sabah the cost increases for single and double storey houses are 2.0% and 4.8% respectively.

ACKNOWLEDGEMENT

The authors would like to thank the IEM Earthquake Technical Committee for the technical and financial support given to conduct the research. Valuable intellectual inputs by various participants from EC8 TC are also gratefully acknowledged. ■

REFERENCES

[1] CEN (2004) EN 1998 1. 2004. Eurocode 8: Design of Structures for Earthquake Resistance – Part 1: General Rules, Seismic Actions and Rules for Buildings. European Committee for Standardisation, Brussells.