Development in Seismic Actions Study in Malaysia and Implications to Professional Practice in the Local Construction Industry (Part 2)

by Ir. Assoc. Prof. Dr Chiang Choong Luin, Jeffrey

This is continuation of Part 1 of the Eurocode Series Paper published in the April 2011 issue of JURUTERA on pages 34 to 38.

ANALYSIS AND DESIGN APPROACH FOR SEISMIC ACTIONS IN BUILDING STRUCTURES

(a) From a structural engineer's perspective

The behaviour of building structures to earthquakes is very much dependent on how they are designed. The following will illustrate how and what to do and not to do, from a structural engineer's viewpoint.

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

- As inertia forces accumulate downwards from the top of the building, the columns and walls at the lower storeys experience higher earthquake-induced forces and are, therefore, designed to be stronger than those in the storey above. (See Figure 4).

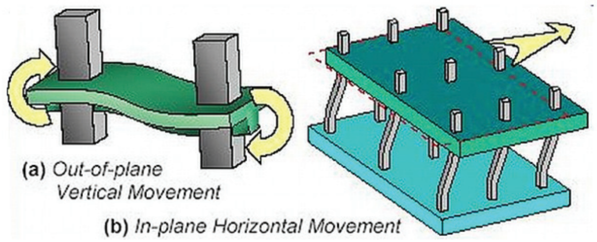

Figure 4: Movements in buildings during earthquake

- Under gravity loads, tension in the beams is at the bottom surface of the beam in the central location and at the top surface at the ends.
- The level of bending moment due to earthquake loading depends on the severity of shaking and can exceed that due to gravity loading. (See Figure 5).
- Thus, under strong earthquake shaking, the beam ends can develop tension on both the top and bottom faces.
- Since concrete cannot carry this tension, steel bars are required on both faces of the beams to resist reversals of bending moment. (See Figure 6).

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.

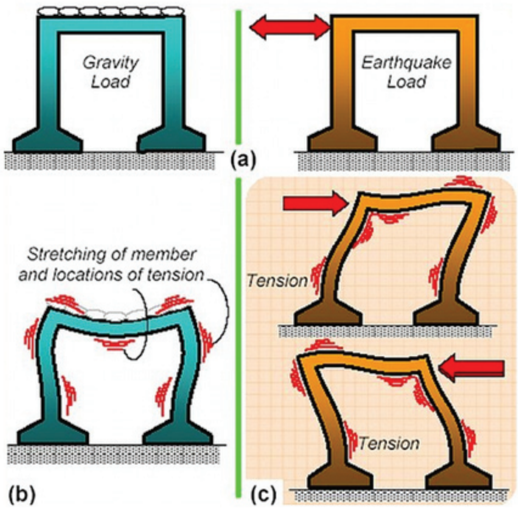

Figure 5: Tensile zones during movement of structures

- If columns are made weaker, they suffer severe local damage, at the top and bottom of a particular storey.

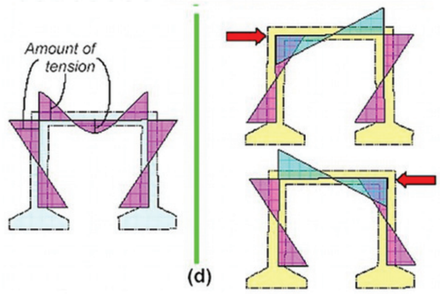

Figure 6: Earthquake shaking reverses tension and compression in members – reinforcement is required on both faces of members

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 a large plan area, the horizontal seismic forces carried by the columns and walls can be excessive. (See Figure 7).

(To be continued at page 36)

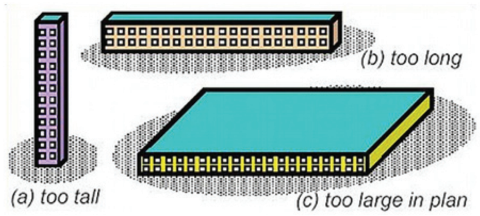

Figure 7: Buildings with one of their overall sizes much larger or much smaller than the other two do not perform well during earthquakes

- Buildings with simple geometry in plan perform well during strong earthquakes. Buildings with re-entrant corners, such as 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 separating the buildings into two parts by using a separation joint at the junction. (See Figure 8).

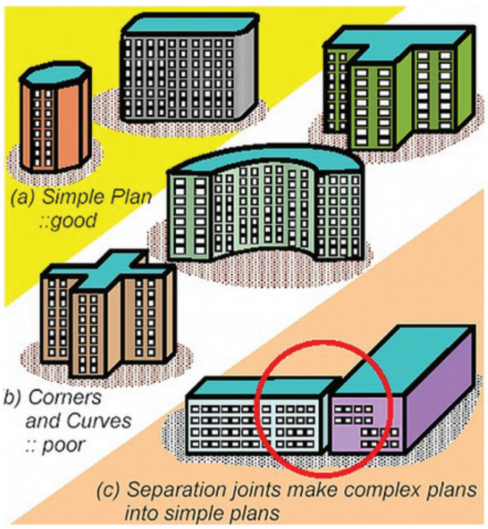

Figure 8: Horizontal layout plays a major role in structural behaviour

- 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 the 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, an end result which is initiated in that storey. (See Figure 9).
- 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 that 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).

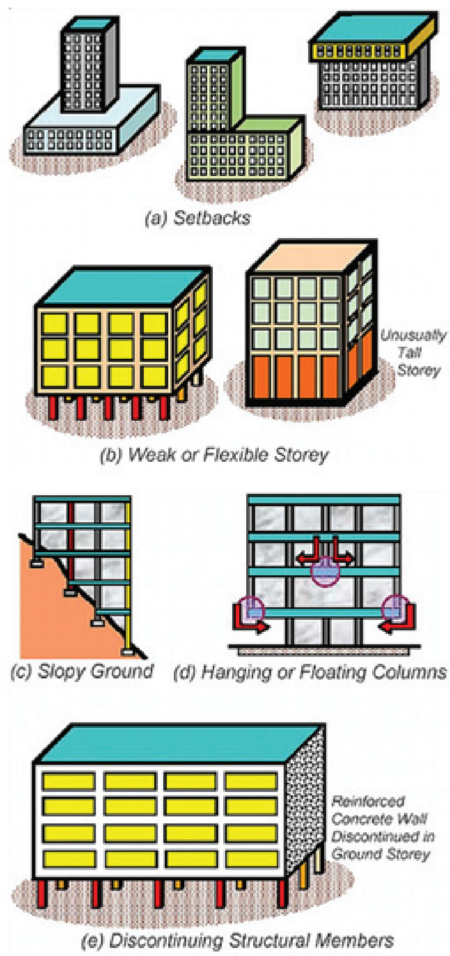

Figure 9: Vertical layout of structures in terms of balanced setback, sufficient rigidity and no sudden deviations in load transfer path will ensure higher seismic resistance

Adjacency of buildings plays a significant role in minimising the effect of earthquake in damages incurred due to a 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.

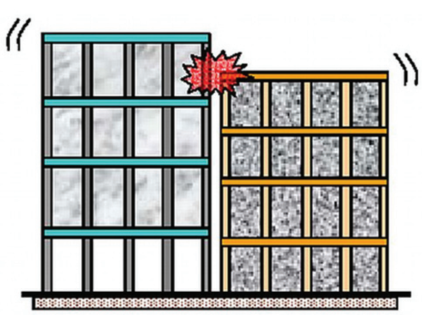

Figure 10: Pounding can occur between adjoining buildings due to horizontal vibrations of the two buildings

(To be continued at page 38)

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

- This design approach depends on 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 the 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.

It is not necessary to go into further details of this approach.

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

For instance, on average, about 800 earthquakes with a magnitude of 5.0 to 5.9 occur in the world annually, while there are about 18 earthquakes with a magnitude range of 7.0 to 7.9.

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 2000 years, even though the life of the building may be 50 or 100 years?

The answer to that philosophical question is as follows:

- 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 a strong earthquake.
- Thus, the safety of people and contents is assured in earthquake-resistant buildings, thereby, a disaster is averted. This is the 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 design structure, the keyword that needs to be addressed is – ductility.

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

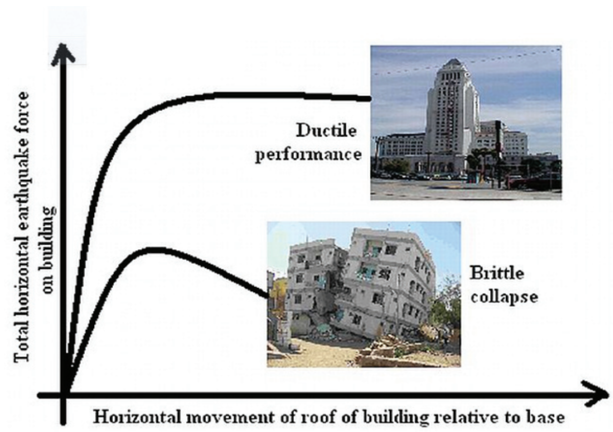

Figure 11: Design concept of ductile performance under seismic action

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

Therefore, it is better to make beams 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.

(b) From an architect's perspective

In view of the likelihood of the Technical Committee (TC) in recommending the adoption of 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 working group (WG) on non structural components has commenced by concentrating on materials design. But this should not stop the WG on non structural components to expand its scope into building services such as fire fighting, air handling unit, escape and evacuation points, facade design, lighting and air passages,

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

features and layout in minimising internal damages due to collapse of furniture and fittings, and so forth.

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

CONCLUSION

No doubt, Malaysia is considered a low seismic risk zone, and may or may not require a seismic design standard for its building structures. But the two regional earthquakes in 2004 and 2005 had changed the perspective of both the public view and concern of the structural vulnerability of local buildings and infrastructures during earthquake events, albeit from far distance effect.

From the study undertaken to date, and with inputs from international experts, it may be worthwhile to focus the attention on local near field earthquake, in particular the Bentong Fault, which is reasonably close to the Kuala Lumpur city centre. To that, one may add the earthquakes that occur more frequently in East Malaysia.

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 such as the IEM, which is taking the lead, besides the usual research grants usually reserved for public universities.

The behaviour of building structures during earthquakes is very much dependent on how they are designed, and the 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.

ACKNOWLEDGEMENT

The author would like to extend his appreciation to members of the IEM Technical Committee (TC) on Earthquake and also to members of the various Working Groups of the TC, who have all contributed to make possible the publication and presentation of this technical paper in its present form. Many thanks also go to agencies and institutions who have agreed to provide financial support to the work undertaken by the TC on Earthquake. ■

REFERENCES:

[1] Balendra T and Li Z, "Seismic Hazard of Singapore and Malaysia", eJSE International Journal Special Issue, 2008, pp57-63.

[2] BSI, BS EN 1998-1:2004, "Eurocode 8: Design of Structures for Earthquake Resistance", 230p.

[3] Chiang, J and 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.

[4] 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.

[5] Lam N and Wilson J, "Displacement Modelling of Intraplate Earthquakes", ISET Journal of Earthquake Technology, Paper No. 439, Vol 41 No 1, March 2004, pp 15-52.

[6] Mohd Rosaidi bin Che Abas, "Earthquake Monitoring in Malaysia", Seismic Risk Seminar, Malaysia, September 2001.

[7] Mustafa Kamal bin Shuib, "The Recent Bukit Tinggi Earthquakes and Their Relationship to Major Geological Structures", Geological Society Malaysia, Bulletin 55, November 2009, pp 67-72.

[8] Pan TC and 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.

[9] Quek ST and 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.

[10] 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 a logarithm of amplitude recorded by a seismometer as:
  - $M = \log_{10}(A/A_0)$
  - where A0 is a constant equal to 0.001mm
  - Note that each whole no increase in M represents a 10-fold increase in measured amplitude

Richter Scale in Measuring Earthquake Magnitude

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

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

$$P_{50} = 1 - \left(1 - \frac{1}{475}\right)^{50} = 100\%$$