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DINCEL STRUCTURAL WALLING

EARTHQUAKE DESIGN & BRICK WALLS

WHY READ THIS DOCUMENT?

The purpose of this article is to highlight the issues brought by new AS1170.4 – 2007 especially for the use of brick walls in buildings.

The previous Earthquake Engineering Design Code AS1170.4 – 1993 was required to be updated to bring it into line with international practices. The revised AS1170.4 – 2007 – Earthquake Design Code is effective from 01st May 2008.

The new standard is prepared jointly by the Australia and New Zealand Standards Committee. The summary of the main changes can be read in the summary document, Reference No: 5 or Reference No: 3.

Readers are recommended to review Reference No: 6 for further information.

CHANGES TO EARTHQUAKE DESIGN

The following are the main changes to the Earthquake Design Engineering Code.

- Soil descriptions changed – harmonised with NZ1170.5 – 2004.
- Earthquake design categories introduced. Structural response factors changed. Ductility detailing currently exist in AS3600, 3700 and 4100 are expected to be amended.
- Load bearing un-reinforced masonry structures not allowed more than 12m to 15m high depending on the soil type. (Refer AS3700 – 2001 Amdt-3, Appendix A-A Table AA3).
- Non-load bearing un-reinforced masonry (URM) is allowed in buildings over 12m provided a separate seismic resistance exists and the URM elements allow the system to effectively resist the earthquake actions (refer Reference No: 2).
- Footings required to be tied to each other for soils less than 250kpa bearing capacity.
- All parts of the structure shall be tied together both in horizontal and vertical planes. This means that the load bearing brick walls must tie to the floor slabs to avoid collapse of the untied walls during an earthquake.

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BRICK WALLS AND EARTHQUAKE DESIGN

The common engineering designs of Australian residential buildings consist of load bearing brick walls or frame structures (i.e. column – slab/beam) with masonry (brick/block) and/or lightweight infill walls for low to medium rise buildings.

The Australian culture for suburban residential home unit construction 10 years ago consisted of a single level of basement and 3 storey walk-ups. This trend has now significantly changed and the number of floors has significantly increased.

The fundamental difference between old and new planning is that we now utilise solar access and cross ventilation principles which results in party walls between adjacent units parallel to each other. This results in long lengths of party walls in living areas without cross walls. However, with the previous planning, nearly all walls utilised for the building are being stabilised by each other to form rigid forms of boxes. Therefore, the current planning results in brick walls with lesser stiffness and stability for earthquake purposes.

The following comments have been made to highlight the significance of the abovementioned planning changes and its effect on the use of brick walls in building structural designs.

The new AS1170.4 – 2007 Clause 5.2 requires:

- All parts of the structure, i.e. floors and walls shall be tied together.
- The stiff components of the building (such as brick, party or partition walls):
  - Shall be designed as part of seismic – force – resisting system, or
  - Separated from structural elements.

The implementation of solar access and cross ventilation provision results in building designs which incorporate long party walls with very little in the way of cross walls to provide lateral restraint. In these instances, if brick walls are tied to the floor slabs as required by AS1170.4 – 2007 for wall stability purposes a conflicting problem is created.

This problem is due to the fact that brickwork and concrete are two dissimilar materials. In particular concrete will shrink and masonry brickwork will grow. The concrete slabs and masonry brick walls are also subject to differential thermal movement (particularly roof slabs). For this reason it is customary to provide a slip joint between the concrete slab and masonry brickwork contact surfaces. The slip joints used for load bearing brick walls typically comprise 2 sheets of galvanised iron packed with grease in between.

The conflicting problem created is that the stability requirement of AS1170.4 – 2007 for the tying of the slab to the wall to prevent a collapse (like a deck of cards) will result in major cracking through the building structure due to the shrinkage or thermal movement of the floor slab compacting against the growth of the masonry brick load bearing walls. In the case where no slip joint is provided the masonry brick load bearing wall will crack at the first adjacent mortar bed joint (i.e. one coarse below the slab soffit and/or one coarse above floor slab).

It is then arguable how much shear resistance the cracked mortar bed joint could offer under an earthquake event.

Reference No: 1 shows a design of brick walls under earthquake conditions. The solution ignores the commonly used proper slip joint (metal strips with grease in between).

It is therefore evident that compliance with AS1170.4 – 2007 for load bearing masonry structures for stability purpose, which will be extremely difficult to achieve, is due to the restraint against differential movement that occurs at the brick wall to floor slab interfaces which will result in cracking of the brick walls at adjacent mortar bed joints. In effect this cracked mortar bed joint becomes a slip joint with questionable resistance against horizontal earthquake shear forces.

Providing a conventional slip joint (metal strips with grease in between) will prevent the cracking in the adjacent horizontal mortar bed joints, but again the slip joint will only provide limited capacity to resist horizontal earthquake shear forces (refer Reference No: 7).

The other common problem of brick party walls is having joints of about 6 metres to 8 metres intervals to avoid cracking of the brick walls. The position of joints will need to be located by structural engineers so the structural integrity of the load bearing brick wall is not compromised during an earthquake.

The new code now also consists of housing external wall and roof, anchorage detail of BCA 3.3.3.3 (b) Acceptable Construction Practice is not adequate for 0.5 kN/m anchorage force.

The use of infill non-load bearing brick walls as non-load bearing walls in association with reinforced concrete frame structures are also problematic as explained in Reference No: 2. The inherent stiffness of the infill walls changes the structural behaviour of reinforced concrete frame structures during an earthquake. This necessitates that the framed structures be designed for much greater loads and bending moments. This very important and complex mechanism is not covered in Australian codes. In fact, the new code refers Australian designers to the New Zealand Earthquake Engineering Code to analyse the cases such as combined stiff infill walls (such as brick) with reinforced concrete frame structures.

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TECHNICAL DISCUSSION

It is an unpractical and unsafe engineering assumption that brick walls under shrinkage and temperature movements, especially when associated with floor slab's actions, will not crack. If the mortar bed has already cracked, no sufficient shear resistance will be available at the mortar joint. The associated crack could occur one or more courses above or below the floor slabs.

The load bearing brick walls should have proper slip joints, however this does not mean that the brick walls will not crack at the mortar joints above or below the floor slabs due to certain reasons (e.g. brick protruding into the floor slab or friction available at the bottom of the brick wall where it sits on the floor slab). The load bearing brick wall will not offer shear resistance to earthquake forces either at the slip joint or at the cracked mortar joint. These walls will not be able to accommodate shear restrains such as lateral restraint ties due to the presence of slip joints. Even if it was possible to place the restraint ties with the presence of slip joints, the same restraints will not offer benefits if the mortar bed at or below the restraint point is cracked.

The worst condition occurs in the absence of pre-compression loading as in the case of non-load bearing walls. These types of walls usually consist of non-mortar bed at the top of the walls to avoid vertical load transfer and to avoid shrinkage and temperature cracking. The cracks at the mortar beds of this type of walls often occur for the following reasons:

1. Supporting slab deflection. Engineers may need to consider edge beams/thickened slab to control this type of cracking.
2. The cracking of the wall above the floor slabs as in the case of load bearing walls due to slab shrinkage and temperature movements or brick growth.
3. The top of the wall having a gap has to be restrained with appropriate lateral restraint ties. However, these lateral restraints against earthquake forces should not restrain the wall movement against brick growth, shrinkage and temperature. If this is not maintained, mortar bed cracking at the restraint point will occur; hence the provision of lateral restraints will be meaningless.

An earthquake may consist of a number of shock waves. This means that at the first shock wave, it is most likely that the majority of mortar beds of brick walls will have cracks if the walls do not fall in the first place. However, even if this was the case there will not be any mechanism to prevent the brick walls falling at the second shock wave as the mortar beds have already cracked, i.e. the presence of masonry ties will not serve any purpose.

Prior to the introduction of cross ventilation building requirements, the wall layout of Australian apartments, townhouses and similar types of buildings used to incorporate closely placed cross walls like boxes to support each other. The new planning of these buildings now consist of wall layouts of very long party walls between each sole occupancy unit or at their façade walls without nearly any cross walls. These types of wall layouts required for cross ventilation planning will be most vulnerable to falling like a pack of cards during an earthquake.

The traditional Australian residential building construction systems consist of either load bearing or column-slab framed structures with non-load bearing masonry concrete/clay brick infill walls. Masonry brick walls are commonly used because of maintenance free façade walls and most importantly due to the market expectation of safe and secure feelings because of solid walls. This reality is still valid for at least the party, corridor, and façade walls of the building. There is a current trend where internal partition walls are being constructed out of lightweight dry walls (i.e. steel/timber with plasterboard facings). Australian buildings, as a result of loss of internal solid partition walls and long party walls without cross walls are more vulnerable to earthquake related falling of brick walls more than ever.

The solution is not to eliminate the cross ventilation planning which is vital for energy efficiency and healthy building interiors but to use walls that can be easily tied to the structure and enhance structural earthquake behaviour simultaneously.

The perfect world does not exist in the construction industry. The brick walls at their mortar joints will crack due to any of the following reasons: brick growth, protruding bricks into the floor slab over, brick walls where it sits on the floor slabs, accidents during construction, and the possibility of having more than one earthquake shock wave.

As explained above, brick walls are most likely to have small or big cracks at mortar beds. Therefore, it is the engineer's responsibility to ensure that all possibilities are accounted for to avoid the walls falling over like a pack of cards and potentially resulting in the loss of human lives during earthquakes.

The question that should be really asked is: "Is it really safe to use brick walls, especially with the current Australian building planning requirements incorporating cross ventilation?"

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SUMMARY AND CONCLUSION

Dincel-Wall eliminates any of the earthquake concerns or design issues associated with brick walls.

- The polymer formwork with recently increased wall polymer thickness offers additional residual capacity against earthquake forces. (Refer Dincel Structural Design Engineering Design Manual).
- The joint's ductility provision complied with 'L' bars at the junction of floor and wall slab.
- The floor slab – wall junction with the 'L' bars are considered as monolithic. The shrinkage and thermal movement of the floor slab will not affect the function or aesthetic look of the Dincel-Walls due to the non-brittle and ductile permanent polymer formwork finish. The floor slab and wall are both compatible to each other unlike the brick walls, hence similar behaviour is maintained. The internal in-built crack inducers of Dincel-Wall articulates the concrete of Dincel-Wall and no shrinkage and temperature movement of the concrete both in the slabs or walls affects Dincel-Wall.

  Therefore, there is no need to provide contraction and/or expansion joints in party walls built with Dincel-Wall (refer Dincel Structural Design Engineering Manual).
- "Will not collapse like a deck of cards".
- Compatibility of material behaviour due to use of concrete in both floor slab and load bearing walls is guaranteed.

Please provide your comments, if any, to burak@dincel.com.au

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REFERENCES

1. Earthquake Performance of Unreinforced Masonry, Residential Buildings up to 15m in Height – C.R. Willis, M.C. Griffith, S.J. Lawrence – March 2007.
2. Roles of Non-Structural Walls in Chi-Chi Earthquake.

   Department of Civil Engineering Chiao-Tung University, Hsingchu, Taiwan.

   Journal of the Chinese Institute of Engineers, Volume 25, No: 4, page 473 – 477 (2002). www.crt.ntust.edu.tw/jcie/pdf/25-4-pdf/473-478.pdf
3. The Australian Building Codes Board. Final Regulation Impact Statement (RIS 2007 – 03) Proposal to Amend The Earthquake Provisions of the Building Code of Australia.
4. Australian Standard AS1170.4 : 2007 Earthquake Design Code.
5. Designing Structures for Earthquake Loadings – by Simon Matthews, ACEA CPD Seminar, Sydney – November 2006.
6. Assessment and improvement of the structural performance of buildings in earthquakes. The New Zealand Society for Earthquake Engineering, June 2006, www.nzsee.org.nz/PUBS/pubs.shtml
7. On the Seismic Capacity of Typical DPC and Slip Joints in Unreinforced Masonry Buildings – Australian Journal of Structural Engineering Vol. SE1, No: 2, 1998 by M. C. Griffith and A. W. Page.

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