CASE STUDY 10:

Building Resilience to Earthquakes in Chile

Image 1: Tie-column reinforcement cages extending from foundations of a new building; these are a key feature of 'confined masonry' construction. *Source: Brzev, Astroza and Yadlin, 2010*[1].

The problem

Hundreds of thousands of people have lost their lives due to the collapse of buildings during earthquakes in the last two decades; billions of dollars of financial loss have also been sustained. Building vulnerability generally results from a lack of understanding of engineering science and poor enforcement of building codes. The problem is most severe in developing countries where populations are growing, towns and cities are expanding and buildings are more vulnerable to damage[2–4].

The science

Scientists have studied the ways in which materials and structures are affected by strong shaking as experienced in an earthquake. By exposing structures to physical forces in the laboratory, and by studying the effects of real-life earthquakes, scientists can see how structural elements like beams, columns and walls behave under earthquake ground shaking, what type of damage they experience and how collapse takes place. This has brought an understanding of how to construct buildings to better withstand earthquakes.

For instance, buildings constructed in the 'confined masonry' style, have been designed to withstand earthquakes better than buildings built with other, more traditional building techniques[5]. 'Confined masonry' buildings are characterized by masonry walls combined with reinforced concrete confining elements, such as tie-column and tie-beam reinforcement cages (Image 1), and, in some cases, concrete bands through walls[6–8].

Building codes with seismic provisions are the most common tool used to put this scientific knowledge into practice. If adequately enforced, seismic building codes result in earthquake-resistant buildings that are less likely to collapse even in severe earthquakes, thus ensuring the safety of inhabitants.

Seismic code provisions are generally based on earthquake hazard maps and are more stringent in high hazard regions and for structures with high importance such as schools, hospitals, fire and police stations, and critical facilities. Building codes are generally updated regularly to incorporate new knowledge and experience gained from major earthquake events.

The application to policy and practice

The South American country of Chile experiences frequent earthquakes which have claimed many lives[9]. Chile has a long history of regulated 'confined masonry' construction practice, starting in the 1930s, after the 1928 Talca earthquake of magnitude 8.0[10].

Seismic design provisions for buildings were first formally laid out in 1940[11]. From the 1960s onwards, the Chilean

1 Brzev S, Astroza M, Yadlin MO. Performance of confined masonry buildings in the February 27, 2010 Chile earthquake. EERI report. Confined Masonry Network, 2010. Available at: http://www.confinedmasonry.org/performance-of-confined-masonry-buildings-in-the-february-27-2010-chile-earthquake [accessed 9 April 2013].

2 Jain SK. Historical developments in India towards seismic safety and lessons for future. Proceedings of the 14th World Conference on Earthquake Engineering, Beijing, China, October 2008.

3 Maqsood ST, Schwarz J. Building vulnerability and damage during the 2008 Baluchistan Earthquake in Pakistan and past experiences. Seismological Research Letters. 2010; 81(3):514-525.

4 Maqsood ST, Schwarz J. Comparison of seismic vulnerability of buildings before and after 2005 Kashmir Earthquake. Seismological Research Letters. 2010; 81(1):85-98

5 Meli R, Brzev S, Astroza M, Boen T, Crisafulli F, Dai J et al for the Confined Masonry Network. Seismic Design Guide for Low-Rise Confined Masonry Buildings. Oakland: Earthquake Engineering Research Institute, 2011. Available at: http://www.confinedmasonry.org/wp-content/uploads/2009/09/ConfinedMasonryDesignGuide82011.pdf [accessed 11 April 2013].

6 *Ibid.*

7 International Association for Earthquake Engineering (IAEE). Guidelines for Earthquake Resistant Non-Engineered Construction. Columbia and Delhi: IAEE, 2004.

8 Chilean Ministerio de Tierras y Colonización. Ordenanza General de Urbanismo y Construcción. Decreto Supremo Nº 1.099 de 1940. Santiago, 1940.

9 Ene D, Crafaleanu I-G. Seismicity and Design Codes in Chile: Characteristic Features and a Comparison with some of the Provisions of the Romanian Seismic Code. Constructii. 2010; 2:69-78.

10 Brzev S, Astroza M, Yadlin MO. Performance of confined masonry buildings in the February 27, 2010 Chile earthquake. EERI report. Confined Masonry Network, 2010. Available at: http://www.confinedmasonry.org/performance-of-confined-masonry-buildings-in-the-february-27-2010-chile-earthquake [accessed 9 April 2013].

11 Chilean Ministerio de Tierras y Colonización. Ordenanza General de Urbanismo y Construcción. Decreto Supremo Nº 1.099 de 1940. Santiago, 1940.

government funded research work into seismic design codes for the country [12] and, in 1997, new building regulations were introduced which gave provisions for all new buildings to be designed and constructed in the 'confined masonry' style [13]. The regulations specify how buildings should be constructed and include standards such as the required strength for clay and concrete masonry units such as bricks and blocks. The regulations include the newest methods and techniques available [14].

The 1997 building regulations have been enforced well, with local authorities requiring that seismic and structural computations in the design of new buildings are verified by an independent professional [15].

Similar examples are seen in other areas of the world, particularly in Pakistan, which is also heavily affected by earthquakes. The new Building Code of Pakistan [10] was prepared after the 2005 Kashmir earthquake; these guidelines move away from the use of traditional adobe structures and adopt 'confined masonry' as the main building typology [16, 17]. More than 400,000 buildings were reconstructed in the affected areas after the 2005 earthquake, using the new code and with the aim to 'build back better' [18]. Other examples include the introduction of the Dhajji Diwari building typology (clay brick confined by small timber elements) in Kashmir [19].

Internationally, 'confined masonry' technology is being promoted by earthquake engineering experts. For instance, the Confined Masonry Network [20] has developed guidelines on seismic design for low-rise constructions, targeting countries where 'confined masonry' is not yet used [21].

Did it make a difference?

Over 200,000 people died in the magnitude 7.0 Haiti earthquake in January 2010 but when a magnitude 8.8 earthquake struck central Chile the next month, on 27th February 2010, only around 300 people lost their lives due to collapsed buildings [23] (Image 2). Well-enforced, science-based seismic building codes have been suggested as a major reason for the low number of casualties in the Chile earthquake [24, 25]. The earthquake was the most severe since the 1930s and produced significant ground-shaking over a large area of the country. Despite this, 'confined masonry' buildings of all sizes performed very well and it is estimated that only about 1% of the total building stock in the affected area was damaged [26]. Similarly in Pakistan, buildings constructed in line with seismic codes have survived several moderate and strong earthquakes over the past five decades with no or only minor damage [27, 28]. In this way, integration of science into building practice can and does save lives and livelihoods.

Image 2: A building with a collapsed ground floor as a result of the February 2010 earthquake in Chile. *Source: Brzey, Astroza and Yadlin, 2010* [22].

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13 Instituto Nacional de Normalizacion (INN). Norma Chilena Oficial 2123.Of 1997. Confined masonry – Requirements for structural design. Santiago: INN, 1997.
14 Ene D, Crafaleanu I-G. Seismicity and Design Codes in Chile: Characteristic Features and a Comparison with some of the Provisions of the Romanian Seismic Code. Constructii. 2010; 2:69-78.
15 *Ibid.*
16 Maqsood ST, Schwarz J. Comparison of seismic vulnerability of buildings before and after 2005 Kashmir Earthquake. Seismological Research Letters. 2010; 81(1):85-98
17 Ministry of housing and public works. Building Code of Pakistan – seismic provisions. Islamabad, 2007.
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21 Meli R, Brzev S, Astroza M, Boen T, Crisafulli F, Dai J et al for the Confined Masonry Network. Seismic Design Guide for Low-Rise Confined Masonry Buildings. Oakland: Earthquake Engineering Research Institute, 2011. Available at: http://www.confinedmasonry.org/wp-content/uploads/2009/09/ConfinedMasonryDesignGuide82011.pdf [accessed 11 April 2013].
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24 *Ibid.*
25 Ene D, Crafaleanu I-G. Seismicity and Design Codes in Chile: Characteristic Features and a Comparison with some of the Provisions of the Romanian Seismic Code. Constructii. 2010; 2:69-78.
26 Brzev S, Astroza M, Yadlin MO. Performance of confined masonry buildings in the February 27, 2010 Chile earthquake. EERI report. Confined Masonry Network, 2010. Available at: http://www.confinedmasonry.org/performance-of-confined-masonry-buildings-in-the-february-27-2010-chile-earthquake [accessed 9 April 2013].
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28 Maqsood ST, Schwarz J. Comparison of seismic vulnerability of buildings before and after 2005 Kashmir Earthquake. Seismological Research Letters. 2010; 81(1):85-98