



Achieving earthquake-safe buildings – an educational initiative for developing nations

A.W. Charleson,

Victoria University of Wellington, Wellington, New Zealand.

ABSTRACT

Building departments in developing nations have a poor track record of achieving new earthquake-safe buildings. Many buildings within their jurisdictions are not expected to perform well in medium- to high-intensity earthquake shaking. To investigate this issue, a survey of construction industry stakeholders in a large Indonesian city revealed how the present undesirable situation can be improved. The key finding was that a lack of knowledge of earthquake design and construction good practice, both in building departments and among the general public, is a significant barrier to achieving earthquake-safe construction.

This paper describes the author's response to this identified need for educational material. It explains how, in collaboration with the international NGO, The World Housing Encyclopedia, 25 short articles outlining principles for achieving earthquake-safe buildings have been written, illustrated and published online. The intent of the articles, written in the first instance for an Indonesian city, is that they also function as templates for other developing nations. After limited contextualization and translation, the articles are ready for in-country dissemination.

After discussing the development of the articles, the paper explains how they are written not for technically competent readers, but rather for the general public. Examples of simple diagrams that convey earthquake-engineering principles are provided, and the strategy and the progress to achieve international dissemination of the articles is outlined.

1.1 Introduction

This paper addresses the current situation where, in many areas of the developing world, new buildings that are unsafe in earthquakes are being constructed. The term 'unsafe' means that the requirements of national codes of practice are not being implemented. This discrepancy between code requirements and what is under construction may begin at the design office, but it is clearly observed on building sites. Any experienced engineer passing-by buildings under construction, be they using reinforced concrete (RC) or structural steel,

can observe deficiencies. For example, in many cities in the seismically-active country of Indonesia, the bending of column ties in RC columns use 90-degree hooks rather than the code-specified 135-degree bends. There is usually also a lack of column confining steel, such as additional ties or stirrups, intended to enable columns to sustain damage but not collapse during a medium-to-large earthquake.

This serious situation was confirmed recently by detailed research in the Indonesian city of Padang (Wardi et al., 2018). Researchers visited the sites of 47 multi-storey buildings under construction. They compared the as-built details with those specified in the appropriate and current Indonesian codes, focussing on a total of 27 reinforcing details. On many, if not most buildings sites, reinforcing details that were crucial for earthquake-safe performance did not comply with the codes.

The current situation of unsafe new buildings is not uncommon internationally (World Bank Group and GFDRR 2015). In numerous countries, high levels of disregard for building regulations are also observed. Unfortunately, this type of non-compliance results in more deaths, casualties and damage in an earthquake. Responding to this situation, this paper reports on one very small step towards a realizing a vision for transforming a country's whole building sector, beginning with education.

The need for an educational initiative became apparent after a 2019 survey of building industry stakeholders in Yogyakarta, Indonesia. One hundred and forty engineers, architects, contractors and building owners were asked, among other questions, to suggest changes that could be made in order to improve building safety during earthquakes (Charleson et al. 2020).

The survey results indicated that the current system for achieving safe buildings was in need of significant improvement. A large percentage of the stakeholders interviewed believed that knowledge and enforcement of building regulations, technical review of construction documents to ensure building safety and adequate technical site inspections were lacking. The most prevalent suggestion was that building departments should take on an educational role. The survey respondents believed that information, including the earthquake hazard, effects of earthquakes on buildings, and building regulations related to building safety should be readily available to all stakeholders, as well as to the staff of building departments themselves.

The series of 25 educational articles described in this paper are envisaged to contribute to a gradual improvement of earthquake safety. Although primarily written for the general public, the articles can also help educate staff of city building departments. However, once the public are more aware that buildings can be designed and built safely against earthquakes, citizens are more likely to have higher expectations of their building departments to be intentional regarding building safety. These articles can therefore be considered a 'bottom up' earthquake risk reduction strategy (Shah 2006). They will support the efforts of current concerned professionals in developing nations who are trying to encourage their fellow citizens, their engineering community, their governmental organizations and their regulators to reduce earthquake risk.

2 RATIONALE FOR AND DEVELOPMENT OF THE ARTICLES

There were two sources of inspiration for how the articles were written and formatted. The first was the typical one-page brochure for home owners and DIYers readily available from the suppliers of building materials, at least in New Zealand. A brochure might outline how to construct a fence or build a deck, and be written and illustrated in such a way as to be easily understood by a DIY person.

The second source of inspiration was the series of 32 short articles titled "Earthquake Tips" (Murty 2005). Written primarily for Indian readers, the 'Tips' are short and concise articles discussing different aspects of earthquake engineering. They are aimed mainly at those involved in building design and construction so they include technical terms. The many simple illustrations help the 'Tips' communicate earthquake-resistant principles effectively. The key features of these two very different publications described above are their conciseness, visual attractiveness and simplicity.

A literature review of publications written for the public related to natural hazards was undertaken and the importance of a simplified message stripped of the usual technical terms for wide acceptance was certainly emphasized (Steward 2017). A summary of the rules that were adhered to during writing the articles included:

- Articles are written for the general public: avoid technical terms.
- Writing must be clear, concise and accurate.
- Aim for high readability: keep paragraphs and sentences short, and avoid uncommon words.
- Each article to be around 500 words long.

Since the anticipated readership of the 25 articles discussed herein is the general public, but not excluding those in the building industry of course, a less technical approach has been taken. This is considered appropriate as the articles were written for a very specific public – the people of Bandung, Indonesia’s third largest city. Over the years, beginning in the 1980s and up to 2020, the author has spent many months in Bandung and visited many other cities in Indonesia as well as in other developing nations. This experience, and especially that of teaching earthquake engineering to architectural and civil engineering students in these countries provided an awareness of the content of the articles. The articles were therefore eventually conceived to answer the main questions that the people of Bandung might have about how to design and build earthquake-safe buildings.

Although the articles are context-specific they feature building materials and attitudes towards construction that are prevalent throughout the developing world. As such, the articles are intended to function as a template that is applicable to many different nations. The intention is that first, the articles will be modified to suit local contexts, including construction materials and methods of both engineered and non-engineered buildings. Then, if necessary, the articles will be translated into local languages for earthquake-affected cities and regions.

Prior to publication, the articles were peer-reviewed by members of the Executive Committee of The World Housing Encyclopedia. The articles are available for free download from its website (Charleson 2022).

3 DESCRIPTION OF THE ARTICLES

The titles of the articles are listed below.

Article 1. Bandung and Earthquakes

Article 2. Avoiding Soil and Foundation Problems during Earthquakes

Article 3. Three Structural Systems to Resist Earthquakes

Article 4. Why Walls Are the Best Earthquake-resistant Structural Elements

Article 5. Are Walls in Buildings Helpful during Earthquakes?

Article 6. How Do Buildings with Reinforced Concrete Columns and Beams Work in Earthquakes?

Article 7. Principles for Earthquake-safe Masonry Buildings

Article 8. Tying Parts of Buildings Together to Resist Earthquakes

Article 9. Local Wisdom and Building Safety in Earthquakes

Article 10. Infill Walls and How They Affect Buildings during Earthquakes

Article 11. A Common Structural Weakness to Avoid: Soft Story

Paper 11 – Achieving earthquake-safe buildings – an educational initiative for developing nations

Article 12. A Common Structural Weakness to Avoid: A Discontinuous Wall

Article 13. A Common Structural Weakness to Avoid: Short Column

Article 14. Preventing a Building from Twisting during Earthquake

Article 15. Why Buildings Pound Each Other during Earthquakes

Article 16. Construction Codes and Standards

Article 17. What to Look for in Building Regulations

Article 18. What to Expect from a Building Designed according to Codes

Article 19. Importance of Checks during the Design of Buildings

Article 20. Importance of Checks during the Construction of Buildings

Article 21. Preventing Damage to Non-structural Components

Article 22. Retrofitting Buildings against Earthquake

Article 23. Advanced Earthquake-Resilient Approaches for Buildings

Article 24. Urban Planning and Earthquake Safety

Article 25. Tsunamis and Buildings

As mentioned previously, it was important for the articles to be both simple and attractive. As well as many photographs illustrating the principles communicated by the articles, simple drawings were also included to clarify descriptions given in the text. Several examples are shown in Figures 1 to 3 below.

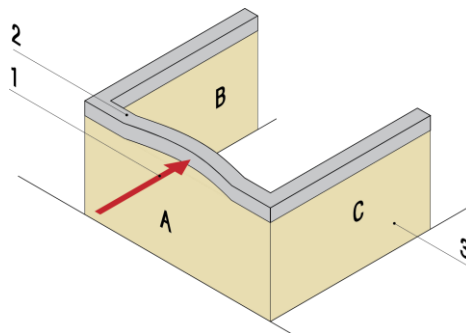


Figure 1. A diagram illustrates how a bond beam distributes seismic forces to return walls.

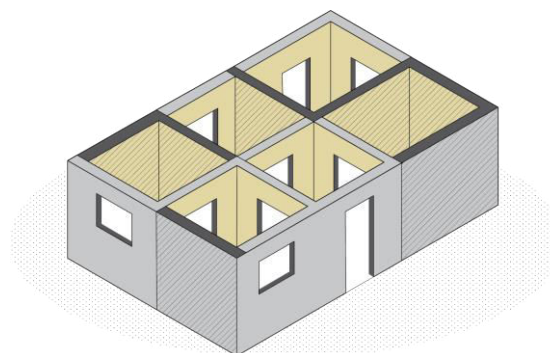


Figure 2. The walls sectioned in black are confined-masonry walls used in non-engineered houses as effective bracing walls due to their lack of penetrations.

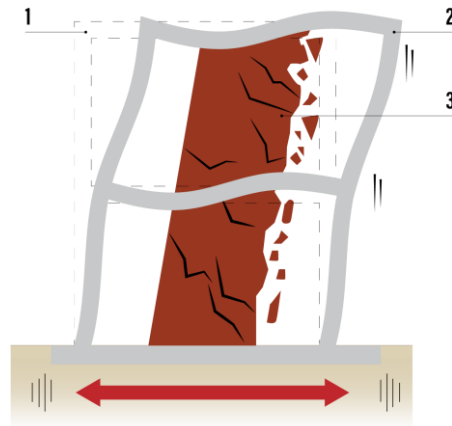


Figure 3. This diagram illustrates how the incompatibility of unseparated stiff unreinforced masonry infills and flexible moment frames leads to earthquake damage.

4 DISSEMINATION OF THE ARTICLES

Having published this educational resource online in 2022, The World Housing Encyclopedia is continuing to seek partners in developing nations to edit them as necessary, then to translate and disseminate them. A partner should possess a strong desire to improve the earthquake-safety of local buildings, be experienced in earthquake-resistant design and construction, be highly reputable and respected, and be in a position of influence in the local building industry. After editing and translating the articles to increase their local relevance, a partner will disseminate them.

Potentially, the most strategic partner is a local or regional building department. Ideally, it would host the local version of the articles on its website, and even make printed copies available for those seeking building permits as well as the general public. Alternatively, a partner might be a government department, a national earthquake society, a consortium of university staff, or a large consulting engineering firm. A partner's input into the final local version of the articles is acknowledged, even by becoming a co-author, and this exposure could raise the partner's public profile. The partner might also offer to answer queries arising from the articles, further strengthening its engagement with the public.

As well as posting the articles on a website and or printing articles for those visiting an office in person, additional dissemination methods are possible. For example, the articles could be published as a series of newspaper or magazine articles. Magazines read by building professionals and building and home owners could be targeted. The articles could also be promoted as teaching resource materials to appropriate professional education and construction training institutions.

At the time of writing this paper the World Housing Encyclopedia has already formed partnerships in India, Indonesia and Serbia, and translations are underway. A recent promotion of the articles by the President of the International Association for Earthquake Engineering (IAEE) to National Delegates of the Association has aroused interest and as a result several other countries, including China, may use the articles.

The introduction to the articles provides guidance to editors modifying articles to suit local contexts and to translators, including:

- Add references particularly relevant to your city or country and remove any that could be unhelpful.
- Replace any images or diagrams with those more appropriate to your local situation and remove any you consider irrelevant.

- Rephrase text as required for your country. Use local place names where appropriate to make articles as specific and as relevant as possible to your city or region. As an example, in Indonesia the phrase “local wisdom” is very popular, but in other countries the term “traditional construction” might be more appropriate.
- Review critically the content of each article to ensure your local version will be fully applicable to your readership. Check that assumptions made in the template articles are valid for you. For example, when discussing how to tie buildings together in Article 8, it is assumed that suspended concrete slabs are present. Yet in some countries, wooden floors are commonly used in conjunction with masonry walls.
- Consider the format in which the articles are to be published. If they are being published as one document, then there is no need to have the introductory footnote in each article. However, that footnote is appropriate when the articles are published, say, as a series in a newspaper or magazine.
- Remember that the articles are specifically written for the general public. The articles therefore are to be understood by ordinary people. In any rewriting and translation, avoid technical terms or jargon. Strive for clarity and readability.

5 SUMMARY

The paper begins by outlining the background to an educational initiative consisting of 25 short articles on earthquake-safe buildings intended to reduce the earthquake vulnerability of buildings in developing nations. It is hoped that by raising public awareness of this topic city building departments will be both encouraged and pressured to take building safety in earthquakes seriously. Then, after the paper describes the rationale for and the development of the articles, they are briefly described. The articles are considered as templates to be edited, translated and then disseminated by local partners in many countries and so information on these processes is provided, including a report on the uptake of the articles internationally at the time of writing the paper.

As with any endeavour like this, the author trusts that over time the vision undergirding this initiative will be further developed, improved and expanded upon for the sake of improved global earthquake-safety. Readers are encouraged to promote this resource where ever it might achieve this aim.

6 REFERENCES

Charleson AW, Wulansari M, Afif N, Salamah H (2021). “Improving building safety in Indonesia through regulatory controls: a survey of building industry stakeholders”. *17th World Conference on Earthquake Engineering (17WCEE)*, September 13th – 18th, Sendai, Paper Number 7c-0003, 10pp.

Charleson AW (2021) “*Earthquake-safe Buildings: A Series of Educational Articles for Developing Nations to Improve the Earthquake Safety of Buildings*”. The World Housing Encyclopedia/EERI, Oakland, USA, 73pp. <https://www.world-housing.net/tutorials/earthquake-safe-buildings>

Murty CVR (2005). “*EARTHQUAKE TIPS: Learning Earthquake Design and Construction*”. Building Material and Technology Promotion Council Ministry of Urban Development & Poverty Alleviation, Government of India New Delhi. <https://www.nicee.org/EQTips.php>

Shah HC (2006). “The last mile: earthquake risk mitigation assistance in developing countries”. *Philosophical Transactions of The Royal Society A: Mathematical Physical and Engineering Sciences*, September 2006, DOI: 10.1098/rsta.2006.1821, pp 2183-89.

Steward IS, Ickert J and Lacassin, R (2017). “Communicating seismic risk: the geoethical challenges of a people-centred, participatory approach”. *Annals of Geophysics*, 60, Fast track 7, 2017: DOI: 10.4401/AG-7593, 17pp.

Wardi S, Sanada Y, Kita M, Tanjung J and Maidiawati (2018). “Current structural details and deficiencies in Indonesian RC buildings: preliminary report on field investigation in Padang City, West Sumatra”. *International Journal on Advanced Science, Engineering and Information Technology*: 8(2), 418-425.

World Bank Group and GFDRR (2015). “*Building regulation for resilience: managing risks for safer cities*”. WBG and GFDRR, Washington D.C., 136pp.

<http://documents.worldbank.org/curated/en/326581468337788007/Building-regulation-for-resilience-managing-risks-for-safer-cities>