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EUROCODE PROVISIONS FOR SEISMICALLY ISOLATED AND OTHER SPECIALLY ENGINEERED BUILDINGS

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This paper considers the changes that might be needed to future generations of the seismic Eurocode, EN1998, to address the needs by 2025 and beyond of designers of buildings which incorporate specially engineered systems to modify seismic response.

In the last 20 years, a great deal of field evidence has been collected on the response to severe seismic ground motions of buildings specially engineered to respond to earthquake shaking. The evidence has been overwhelmingly positive; many hundreds of seismically isolated buildings (see for example Kasai *et al* 2013) have not only survived strong earthquakes with only minor damage and without injury to their occupants, but also have been able to continue functioning normally immediately after shaking has stopped. Field evidence for other types of system has been much more limited, because fewer such buildings have been tested, but for example the Southern Cross Hospital endoscopy building, with an innovative articulated prestressed system, survived the 2011 Canterbury earthquake triumphantly (Pampanin 2012). Not only have specially engineered buildings been successful in ensuring that occupants are safe during an earthquake, but they also address an increasing requirement to provide performance standards which go well beyond addressing safety. Enhanced performance standards for minimising loss and ensuring continued functionality are much harder to meet using conventionally engineered structures.

The current (first generation) edition of Part 1 of EN1998 (hereafter EC8) devotes a chapter to seismically isolated structures, but the chapter falls substantially short of providing a complete set of provisions for designing seismically isolated buildings; Part 2 is much more complete for bridges. However, EC8 currently has no provisions for other technologies such as added damping or articulated structures, and has no procedures for dealing with innovative 'beyond code' structures. Future generations of EC8 will not be able to claim to constitute a complete set of state-of-the-art provisions unless these deficiencies are addressed. The European Association for Earthquake Engineering (EAEE) has set up a Working Group (Booth, 2014) to consider generally how EC8 should develop in future. The Working Group is looking beyond the revision process currently underway to produce a second generation of Eurocodes (including EC8) and has as its main target the third generation of EC8 which might appear in 2025. Specially engineered structures forms an important part of the Working Group's remit; the authors of this paper are both members and set out below their initial ideas on how EC8 might develop in this respect. It is hoped that the paper will stimulate discussion, and the authors invite comments and suggestions.

The authors suggest that by 2025 (i.e. by the time of publication of the third generation of Eurocodes), EC8 needs to incorporate the following aspects in its treatment of specially engineered buildings.

- There is now conclusive evidence that such buildings have the potential to greatly improve building performance in earthquakes. Therefore, EC8 should not just allow such use but actively encourage it.

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- This can be achieved partly by ensuring that the design process is within reach of smaller practices without access to specialist expertise or software.
- More generally, the design process should be as straightforward as possible and should not include unwarranted penalties (such as may apply to some extent in current US codes) compared to requirements for conventional structures.
- This must however be tempered by the absolute need to ensure that safety and reliability are not compromised. Specially engineered structures are by definition 'high technology' and unsafe situations could result if they are employed in situations where the necessary technical resources are not available to design and implement them.
- Comprehensive rules for established technologies are needed. Currently these are considered to include seismic isolation, viscous dampers, hysteretic dampers, frictional dampers, articulated precast concrete and timber structures, steel structures with energy dissipating connections. By 2025, doubtless others will be added to the list. Good model requirements for all these established technologies can be found in US, NZ and other standards and advisory documents, and much of this goal should be achieved by the time the second generation of Eurocodes is published around 2020.
- The code must explicitly allow innovation, and give procedures for 'beyond code' structures, i.e. specially engineered structures employing technologies other than those established technologies for which detailed rules are given. A test for the drafters of EC8 might be to ask – how would a semi active control building be designed to EC8?
- An essential part of the provision for 'beyond code' structures should be to give multiple performance goals which are tailored to the needs of special performance buildings, and which recognise that the goals will (to a variable extent, depending on the project) exceed those of the code-required minimum.
- Design and construction approval procedures need to be established for innovative beyond code structures, possibly including peer review.
- Specially engineered structures often include sophisticated products for response modification and energy dissipation. The relationship between EC8 and the CEN product standards for such devices needs to be sorted out, in a way that still has not been fully achieved in the case of EC8 and the product standard for isolation bearings.

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