THE JOINT AUSTRALIAN EARTHQUAKE LOADING STANDARD: CHALLENGES AND DIRECTIONS

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ABSTRACT:

A committee (BD/6/4) was formed in 1996 to develop a Joint Australian/New Zealand Earthquake Loading Standard with New Zealand facilitating the process. The task of drafting a joint earthquake loading standard has been challenging due to the different levels of seismicity and the significantly different design approaches currently adopted by the two countries. A number of issues have been highlighted including the formatting of standards for building code citation, the interface between the loading standard and the material standards, the selection of the appropriate return periods for different facilities and the associated seismic design forces, the seismic design methodologies and verification procedures. The current draft appears very similar to the existing New Zealand Seismic Standard in both format and approach. Four verification procedures (VP) have been proposed in the draft ANZ, with VP"0" and VP"I" generally appropriate for Australia and VP"II" and VP"III" appropriate for New Zealand. The industry experience in the application of AS1170.4 has been that engineers generally try to find "escape clauses" so that earthquake design loading and the associated design considerations can be minimised or avoided. A preferred situation would be for all structures to be checked for the appropriate earthquake loading and checked to ensure that viable load exist in the structure from roof level to the foundation. Further, the structure should have some deformation capacity and "toughness" so that brittle modes of failure are discouraged. The VP"0" and VP"I" procedures specified in the draft ANZ do little to improve this situation. Clearly, this is a priority issue to be addressed in the development of the Joint Standard.

1. INTRODUCTION

Australia and New Zealand agreed in 1992 to produce joint standards, and where possible to align with international standards (ISO). In addition, there is an initiative to produce unified formats for loading standards consistent with ISO within the APEC countries. In the earthquake loading context, this implies future consistency with ISO3010.

A committee (BD/6/4) was formed in 1996 to develop a Joint Australian/ New Zealand Earthquake Loading Standard with New Zealand facilitating the process. A series of working groups were established to develop a state-of-the-art review in a number of topical areas including: seismic hazard modelling, design methodologies, analysis techniques and non-structural components. Included in this process was a review of other leading international earthquake standards such as the Eurocode 8, Uniform Building Code (USA), the Japanese Seismic Standard and ISO3010. The outcome of the working groups formed the basis of the brief for the preparation of the draft standard. The draft was produced by the New Zealand consultants Beca Carter Hollings and Ferner under contract during the period 1999-2000. Following an internal review involving the working group parties, the draft 'Part 4 : Earthquake Actions' Standard and Commentary (DR00902, DR00903) were issued for public comment in November, 2000, together with the draft 'Part 0: General Requirements' Standard (DR00904) prepared by a separate group. The public comment submissions closed in May 2001 with an overwhelming response and the comments are currently under consideration by the drafting standards committee and the contractor.

The task of drafting a joint earthquake loading standard was known to be challenging. For example, the seismic activities and engineering practices of the two countries are very different. In New Zealand, the seismic hazard level ranges from moderate (Auckland) to high (Wellington), whereas in Australia the seismicity ranges from low to moderate. A viable approach for the development of the joint standard is to adopt a two-tier strategy: one tier for the low-moderate seismic regions and the other tier for the higher seismic regions. This implies that the seismic design approach for Auckland would be similar to some regions in Australia. This clearly poses a challenge since the existing seismic design approaches in the two countries are fundamentally different.

The aim of this paper is to review and discuss contentious issues associated with the draft Joint Australian/New Zealand Earthquake Loading Standard (ANZ) and to compare this draft document with the existing Australian Earthquake Loading Standard (AS1170.4:1993). In general, the draft ANZ appears to be strongly influenced by the existing New Zealand Earthquake Design Standard, and the format appears more complex than AS1170.4 and the notation is not consistent with ISO3010. One other notable difference between the Standards is that the parts referring to "Domestic Structures" and load-bearing masonry buildings in AS1170.4 is not included in the Draft ANZ.

2. FORMATTING OF STANDARDS FOR BUILDING CODE CITATION

Design Standards can be described as the "contact point" between the art and science of engineering and the regulatory framework. The regulatory framework consists of regulations established through acts of parliament. In the context of building construction, these regulations are embodied in design documents such as the Building Code of Australia (BCA).

The BCA calls up standards which are relevant to the design issues being considered, such as the loading and material standards. The Australian Building Control Board (ABCB) has the responsibility to ensure that all designs comply with the BCA, which is usually achieved through a certification process involving bodies such as local governments, registered engineers and registered building surveyors. The ABCB prefers standards to provide "verification methods" or "deemed to satisfy solutions" and discourages clauses which rely on engineering judgement or discretion leading to an open-ended solution. Consequently, the draft standard contains mostly definitive statements as to what needs to be done and the criteria to be satisfied, without involving open-ended professional engineering judgement (as is often associated with performance-based design standards).

The committee reviewing the draft standard has been most uncomfortable with the fact that engineering judgement and "best practice" has been virtually excluded from the standard. It is difficult to codify a huge body of knowledge (i.e. text books, technical papers, computer programs, design aids) and a very complex design and analysis process into a definitive verification procedure. This has also resulted in new state-of-the-art design methodologies such as the "Displacement Based" methods being excluded from the current draft. Ironically, most buildings are founded on soils where engineering judgement on geotechnical issues is absolutely essential for the successful design of the foundation. Following discussions with the ABCB and the New Zealand Building Industry Association (BIA), it is understood that some engineering judgement will be considered for inclusion in the next revision of the draft Earthquake Loading Standard.

3. INTERFACE OF LOADING STANDARDS WITH MATERIAL STANDARDS

The current earthquake loading standard (AS1170.4) addresses earthquake loading, detailing and design aspects. A decision was made very early in the drafting of the ANZ to separate earthquake loading from earthquake design. Earthquake design will form part of the materials standards whilst earthquake loading will be the subject of ANZ. The interface between the material and loading standards is the ductility factor. Ideally, the loading standard should specify the ductility factors for different structural systems, whilst the material standards should specify the detailing and design requirements consistent with these ductility values. However, in the current draft ANZ, the ductility factors have not been specified but instead the user is referred to the appropriate material standards. It is recommended that at least minimum ductility values be specified in the loading standard so that a definitive earthquake load can be obtained without reference to the material standard. Considerable further work is required to re-draft the material standards in both Australia and New Zealand to ensure compatibility and consistency before the earthquake loading standard can be released.

4. LIMIT STATE EARTHQUAKE FORCES AND RETURN PERIODS

The methodology in the draft ANZ for the calculation of the base shear force is similar in format to the existing New Zealand earthquake standard and generally consistent with AS1170.4, and is shown in Fig.1. Some of the significant differences associated with the base shear force calculation are highlighted in this section.

A new normalised response spectrum for Australia has been included in the draft ANZ, and is significantly lower than the current AS1170.4 spectrum. A detailed review and discussion on this issue is provided in the companion paper (Lam, 2001). Soil amplification effects have been accounted for using the method proposed by Crouse (1996) and do not explicitly account for soil resonance effects for very soft and deep soil sites.

$$V = C_d W \qquad (1)$$

where W is the weight of the building and C_d is the lateral design action coefficient defined as follows:

$$C_d = \frac{C_h(T_1) Z R_u S_p}{\mu} \qquad (2)$$

$C_h(T_1) Z R_u$ is effectively the elastic response spectrum and $C_h(T_1)$ is the normalised response spectrum, Z is an acceleration coefficient representing the seismicity, and R_u is a return period factor to adjust the loads for return periods which differ from the standard 500 year return period event. The ratio $\frac{\mu}{S_p}$ is the equivalent to the structural response factor in AS1170.4 where μ is the ductiltiy factor (refer Section 3) and $1/S_p$ con be interpreted as the overstrength factor (and is in the order of 1.5).

Figure 1 Earthquake Base Shear Force Calculation

The appropriate return period for a facility is determined from the 'Part 0: General Requirements' Standard (DR00904) and is dependent on the design working life (i.e. 5, 25, 50 or 100 years) and the function category of the facility. For most structures with a 50 year life, the appropriate design return period is specified as 500 years (Design Category IV). However, the design return period increases to 2000 years for structures with special post-disaster functions such as power stations and designated civilian emergency centres. The ratio of the earthquake load for different return periods compared with the 500 year event are represented by the Return Period Factor in Eq.2 (Ru). An Ru=1.8 has been specified for the 2000 year return period event in Australia, implying that the design base shear force for special facilities is increased by a factor of 1.8, and is considerably higher than the "Importance Factor" of 1.25 currently specified in AS1170.4.

Whether return periods for different function categories should be specified in the 'Part 0 : General Requirements' Standard , or should be specified directly in the BCA, is an even more fundamental issue currently under debate.

5. SEISMIC DESIGN METHODOLOGY

The seismic design procedure to be followed in AS1170.4 is clearly defined in Section 2 of the Standard and is dependent on the following parameters : product of the acceleration coefficient and the site factor (aS), structural classification, structural regularity and structural ductility. The placement of this information in Section 2 ensures that the designer is fully aware of the design procedure to be followed, and importantly directs the designer to the other relevant sections of the standard. In contrast, the current draft ANZ defines a four-tier verification procedure (VP) which is based solely on seismic hazard (refer Table 1). In general, VP"0" and VP"I" are intended for applications in Australia and VP"II" and VP"III" for applications in New Zealand. (Interestingly, the draft ANZ contains clauses which preclude the application of VP"0" and VP"1" in the lower seismic regions of New Zealand). The designer is required to cross-reference a number of sections before the appropriate design procedure is identified (i.e. static or response spectrum analysis). It is recommended in the redraft of ANZ that consideration be given to include all parameters namely seismic hazard, structural regularity and structural ductility, in a table in an early section of the standard to clearly identify the design methodology to be undertaken.

Table 1 Earthquake Design Verification Methods in Draft ANZ

$C_h(0.5)ZR$	Verification Procedure
≤ 0.10	Procedure 0 (No requirement to consider earthquake loading)
0.10 - 0.15	Procedure I (nominal load requirements)
0.15 - 0.35	Procedure II
≥ 0.35	Procedure III

The minimum base shear force recommended for robustness has not been finalised with values ranging from 1% to 2.5% of the seismic weight being suggested. This range of values is grossly below the elastic demands implied by the design elastic response spectrum particularly for short period structures. For example, the Ch(T=0.5)ZR value for Melbourne ranges between 7% and 20% which is greatly in excess of the robustness requirement and hence implies a large ductility demand on the structure.

It should be noted that the majority of structures in Australia will require a verification procedure of "0" or "I" (as defined in Table 1), and hence will only be designed for a nominal base shear force. A preferred procedure would be for all structures to be checked for the base shear force as defined in Fig.1, and thus ensure that viable load paths exist throughout the structure from roof level to foundation. In addition, the designer should identify both the force and the displacement capacity of the structure associated with the likely failure mechanism when subject to excessive lateral load, and ensure that the ductility level assumed in the design is achievable. For example, many low-rise structures in Australia are configured with a "soft-storey" in which case the actual ductility (or displacement) capacity can be very limited. This important consideration is addressed in Eurocode 8 by reducing the ductility factor for irregular structures, but is not specified in AS1170.4 nor in the draft ANZ. These recommendations are considered of vital importance and justify the extra effort and understanding on the part of the Australian design engineer at the initial stage of the implementation.

Finally, the three-tier seismic design methodology recommended for "parts and components" (non-structural components) in the draft ANZ has addressed some of the shortcomings in the existing seismic codes for both Australia and New Zealand. However, the section requires some simplification to improve transparency and user-friendliness.

6. CLOSING REMARKS AND CONCLUSIONS

This paper has highlighted some of the significant issues concerned with the drafting of the ANZ standard, in particular:

- the formatting of standards for building code citation and the need for verification methods which discourage "best practice" and "engineering judgement".
- the absence of explicit provisions for "Domestic" and load-bearing masonry structures.
- the interface between the loading standard and the material standards.
- the selection of the appropriate return periods for different facilities and the associated seismic design forces.
- the seismic design methodologies and verification procedures.

The development of the Joint Seismic Loading Standard between Australia and New Zealand has been challenging due to the different levels of seismicity and the significantly different design approaches currently adopted by the two countries. The current draft appears very similar to the existing New Zealand Seismic Standard in both format and approach. Four verification procedures (VP) have been proposed in the draft ANZ, with VP"0" and VP"I" generally appropriate for Australia and VP"II" and VP"III" appropriate for New Zealand. The industry experience in the application of AS1170.4 has been that engineers generally try to find "escape clauses" so that earthquake design loading and the associated design considerations can be minimized or avoided. A preferred situation would be for all structures to be checked for the appropriate earthquake loading and checked to ensure that viable load exist in the structure from roof level to the foundation. Further, the structure should have some deformation capacity and "toughness" so that brittle modes of failure are discouraged. The VP"0" and VP"1" procedures specified in the draft ANZ do little to improve this situation. Clearly, this is a priority issue to be addressed in the development of the Joint Standard.

7. REFERENCES

AS1170.4 (1993) Standards Association of Australia : "Minimum design loads on structures : Part 4: Earthquake Loads - AS1170.4 and Commentary ".

Crouse CB, McGuire JW (1996). Site response studies for purpose of revising NEHRP seismic provisions. *Journal of Earthquake Spectra*; 12(3): 407-439.

DRAFT ANZ (2000), *Draft Australian/New Zealand Standard for Comment* , Standards Australia and Standards New Zealand Joint Document : DR00902-DR00904, issued 17th November,2000.

Eurocode 8 (1996) *Design Provisions for Earthquake Resistance of Structures.* British Standards Institution. London.

ISO/DIS 3010 (International Organization for Standardization) *Bases for Design of Structures - Seismic Actions on Structures.*

Lam, N.T.K. and Wilson., J.L (2001). "Earthquake Response Spectrum Models for Australia". Proceedings of the annual seminar for the Australian Earthquake Engineering Society, Canberra. This Volume.

Uniform Building Code (1991). International Conference of Building Officials, Whittier, California, USA.