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AN AUSTRALASIAN EARTHQUAKE STANDARD

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An Australasian Earthquake Standard

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1. Abstract

With the increased trade between NZ and Australia and the presence of agreements on removing barriers to this trade, it is timely that the development of common standards be implemented. Such development has been under consideration for some time by both Standards Organisations in New Zealand and Australia. The first task in bring structural standards together is to develop a common basis for our joint structural loading standard, from which common structural material standards can follow.

This paper reviews international earthquake engineering standards, with particular attention to future trends and developments which may be on the horizon. The approach considers earthquake engineering design from first principles and how the essential features of ground response and building response can be brought together and presented in a manner which will most assist the design engineer. Several recommendations are included within the paper which may form the basis of a working brief from which a future earthquake design section of a common loading standard may evolve.

2. Background

Earthquakes are the most devastating natural hazard to life on this planet. Through history they have destroyed cities on every continent. Their destructive power is such that they were long considered as an 'act of god' or supernatural event against which there was no protection. A feature of earthquakes is that although the interval between events may be large, the total destruction that occurs and the suddenness of these events is such that that they remain one of mankind's most feared natural phenomena.

The hazards generated by earthquakes are themselves unique. Damage incurred is instantaneous and in many cases total. These hazards are generally confined to man made structures, although periodically landslides triggered by earthquakes also contribute to this hazard. The dominant role of man made structures also provides an insight into appropriate mitigation measures against earthquake hazard in that it is within man's capability to control the response of such structures to the earthquake attack through the application of sound design techniques. The problem is that, fortunately, destructive earthquakes are rare, and therefore one cannot justify the cost of ensuring all structures are able to withstand such rare events without damage. The engineering approach accepted by most engineering design standards is that damage and repair of structures following rare, extreme events is acceptable, provided collapse is avoided, while the onset of damage during less intense, more common events should be controlled.

3. Developing an Earthquake Design Standard.

This paper has been written with a view to identifying the key components of a future earthquake standard specifically for Australia and New Zealand, but one which could be of international earthquake design standards. The paper has been formatted in four parts as follows:

1. specifying the earthquake response of the site,
2. the building response to that motion,
3. the technical procedures needed to implement such measures, and
4. higher tier code issues which need to be specified elsewhere to provide a suitable framework for the system to operate.

Clauses are generally divided into three parts. The clause **objective (in bold)** some general discussion relating to the background and currently identified future trends (in normal text) and some *action recommendations* (*in italics*), for committee consideration. A summary diagram of the basic elements required for an earthquake design standard is given in Appendix A. A comparison chart in Appendix B shows how the issues discussed in the following sections are implemented by a variety of International Earthquake Design Codes.

4. Prescription of Earthquake Ground Motion.

To identify the parameters required to describe earthquake induced ground motion at a specific site.

4.1. Site Response

{To present the dynamic response characteristics of the site in a manner which is easily interpreted and understood by the designer.}

The dynamic response characteristics of the site are usually published as a response spectrum or plot of motion against period of vibration.

Figure 1 shows typical acceleration and displacement response spectra prepared in this manner. Traditionally, acceleration has been the ground motion parameter most often used to describe the dynamic response. Designers are able to use Newton's Law which give Force equalling the product of seismic mass and spectral acceleration, to determine the base shear resulting from the design motion. Acceleration has now been acknowledged as being somewhat deficient when representing building damage. Proposals are being developed in Canada to include some recognition that velocity, in conjunction with acceleration, causes damage (Heidelbrech 1995). An alternative design procedure based on spectral displacement has also been presented (Priestly 1993).

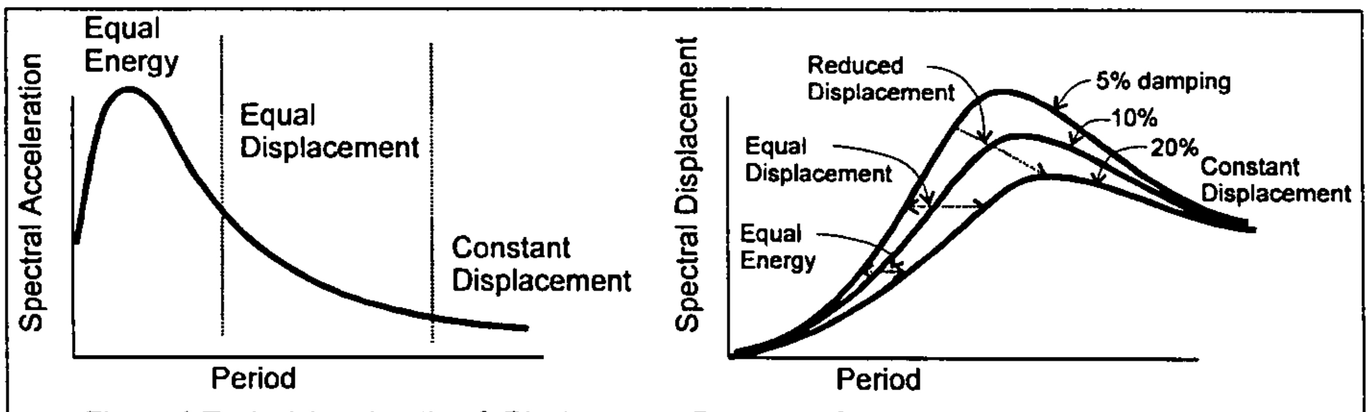

Figure 1 Typical Acceleration & Displacement Response Spectra (from Priestley 1993)

The seismicity of a region encapsulates the expected recurrence interval, the energy content and the spectral response characteristics of earthquakes expected to occur within that region. The proximity of the region to the interface boundary between tectonic plates is now accepted as being a sound means of classifying the response character. Figure 2 (from Walcott 1981) shows the location of these boundaries within the South Pacific. Countries such as **New Zealand, Japan, Indonesia, Chile** and the **Philippines** and regions such as the **western seaboard of the USA and Canada** are close to such boundaries. Earthquakes within such locations can be classified as **interplate earthquakes.** As such they are usually more seismically active, typically experiencing damaging earthquakes every 10 to 20 years. These would generally be centred at a depth of between 10 and 20 km, and range in magnitude between M6 and M7.5, sometimes greater. These events normally have their energy spread across a reasonably broad period range and continue for a significant duration with high intensity ground shaking typically lasting between 10 and 40 seconds. The fractured crustal geology results in rapid energy attenuation characteristics, and in the epicentral zone of severe damage being limited typically to between 20 to 40 km. Conversely, **Australia, central and eastern USA and central and eastern Canada** are away from plate boundaries. Earthquakes in these regions can be classified as **intraplate earthquakes.** Such regions are generally less seismically active, experiencing damaging earthquake less frequently (40 to 100 years). Damaging intraplate earthquakes are often very shallow (<10 km) and of moderate magnitude (< M6). The damage threshold is often much lower (<M4). The damage zone can, however, be equally widespread since there are lesser attenuation properties within the sound rock often present within such regions. Such events will usually have a high short period energy content (<0.3 seconds) but will lack energy within the middle and long period range. Intraplate events will generally be of much shorter in duration (<5 seconds).

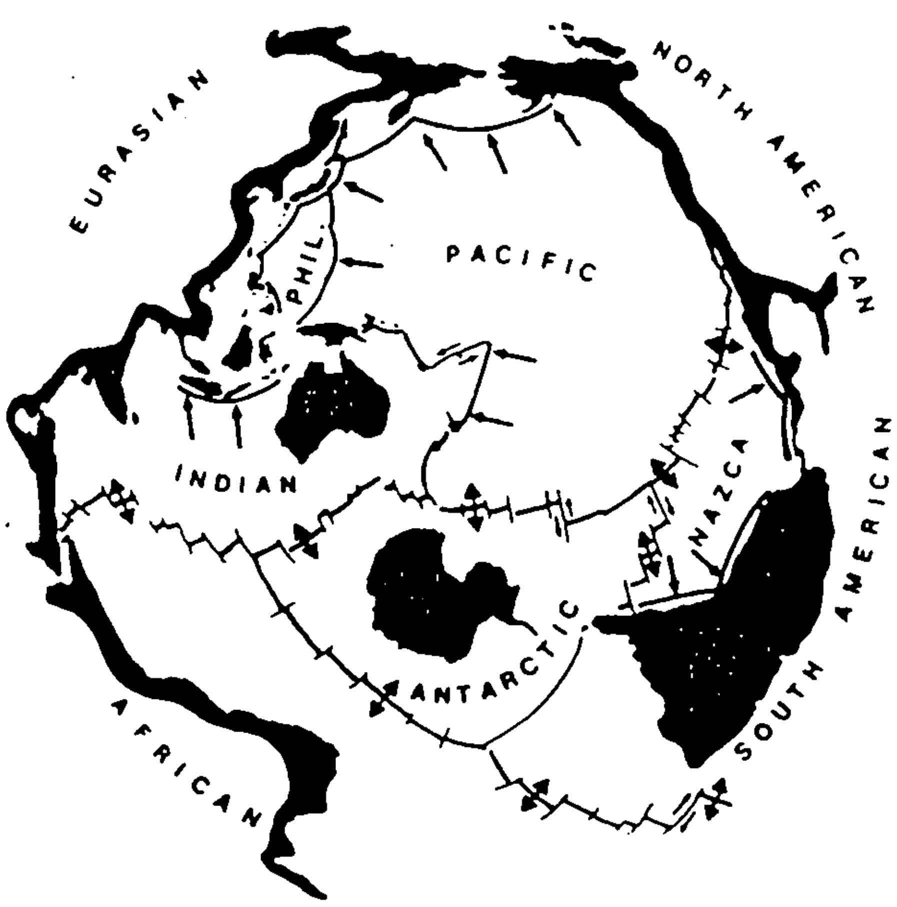

Figure 2: Tectonic Plate Boundaries within the Pacific Rim (from Walcott 1981)

[A future earthquake design standard will include a basic elastic site response spectra, probably based on acceleration, although alternative options should also be investigated. The suite of response spectra should be prepared on a similar basis (say 10% probability of excedence within 50 years).]

4.2. Regional Seismicity (Seismic Zonation Maps)

{To provide a means by which the relative seismicity between regions can be prescribed}

Regional variations in seismicity can be incorporated within seismic hazard zone maps. They will consist of a plot of isoseismal contours which have a specified recurrence interval. One such map will be required for each recurrence interval of interest. Maps of this nature are currently published in most earthquake design standards, including both the NZ Loading Standard, NZS 4203 (SNZ 1992) and the Australian part of the suite of loading standards, AS 1170.4 (SAA 1994). Unfortunately the basis of their derivation is different and will require resolution before a common seismic zonation map is prepared. (see Dowrick et al 1995)

[A suite of seismic zonation maps will be required. These will be country or regionally specific, prepared on a common basis and be based upon a common recurrence interval. National risk adjustment factors may be required needed when the national building control system requires an adjustment from the nominated recurrence interval used to prepare the zonation maps.]

4.3. Soil Amplification Effects

{To allow for the surface soil effects which influence the ability to transmit basement rock ground motion to the surface}

Earthquake motion is the surface manifestation of the strain energy released from the bedrock following rupture. Although such rupture is generally initiated from a point (the epicentre) it commonly expands over a considerable area (the rupture zone), with the released energy waves promulgating from the entire zone. It is quite common for the intensity of surface ground motion to become skewed as the direction of promulgation influences the wavelength of the released energy wave, compressing it in the direction of promulgation. The nature of the soil strata through which these energy waves pass as they travel towards the surface can significantly modify aspects of the ground motion experienced on the surface. Such modifications are accounted for within a soil modification factor. In its simplest form this is simply a linear magnification (or attenuation factor) which scales the site response spectra (as in the UBC and Australian earthquake design provisions). In such cases, the shape of the spectrum is unaltered. New Zealand and the draft of Eurocode 8 develop individual spectra for each soil type which, although more complicated, more accurately reflects real response.

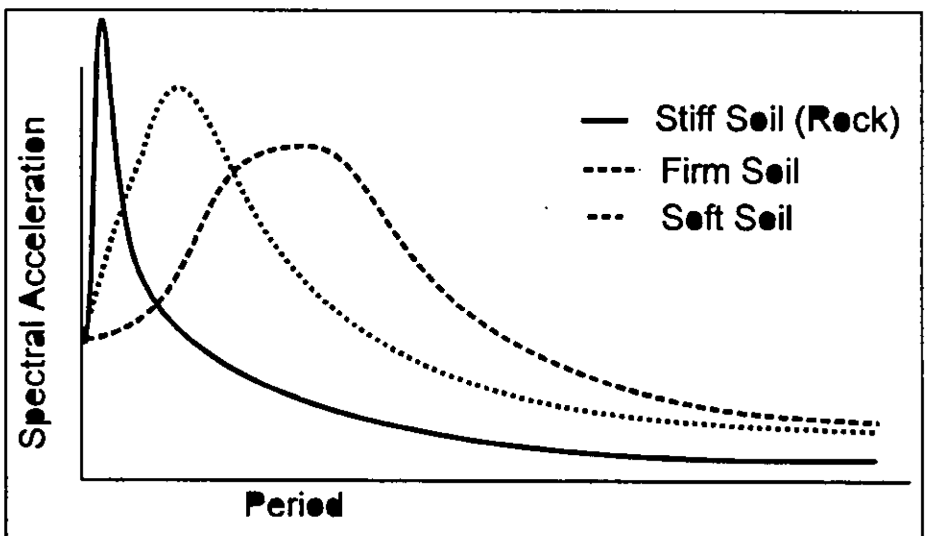

Figure 3: Soil Influence on Site Response

Typically rock and stiff soil sites have a higher short period response with less energy in the longer period range (refer Figure 3). Soft soils typically filter out the short period motions which are lost .to the surface, but they have been known to resonate when excitation is sympathetic with their own natural period. Where surface structures respond in harmony with such resonance, very significant amplification can be expected. In such soils, site specific investigations may be required to ascertain the precise dynamic characteristics of a given site. For code purposes it is common to extend the maximum response plateau beyond the period range where such amplification occurs. This is conservative as it implies such resonance will occur across a broad period range whereas in reality, for a given site, the resonant period range will be narrow but within this band.

A problem remains in specifying the soil parameters from which the soil type is determined. The actual parameter of interest is the shear velocity at which energy waves are transmitted through the soil. Structural design engineers have little understanding of this parameter and it is important that the description of each soil profile also include common descriptors such as soil depth and origin (cohesive or alluvial) to enable the correct selection of soil type.

[Soil modification effects will be included. The attraction of the simple soil factor approach may be negated by the necessity of modifying the basic spectral shape. Investigations of such effects will be required.]

5. Structural Response to Earthquake Motion

{To prescribe procedures and principles which enable the structural response to the earthquake induced ground motion to be applied within the design process.}

The dynamic ground motion described in section 4 only defines the site response. The design engineer is required to translate this motion into the dynamic building response.

The structural form and materials selected to be used within the structure, together with its use and occupancy characteristics will influence this response. Only the form and material are within the control of the designer. The selection of the primary structural system (moment resisting frame, shear wall building or cantilever system) and the construction material (concrete, steel, timber or masonry) heavily influence the characteristics of the structural response to the ground motion.

5.1. Building/Occupancy Importance (Risk Adjustments)

{To modify the design response of different classes of building and/or occupancies to allow for specific performance expectations to be met. }

Whereas the avoidance of collapse and deferral of damage onset is common to all classes of buildings and occupancy groups, some classes have specific enhanced performance expectations which need to be included in the design. A simple method of achieving this is to scale the response spectra in accordance with the building importance. Key post-disaster facilities may be required to remain operational following earthquake attack. Buildings of national importance (eg museum or heritage buildings) may be required to survive undamaged. Those used for public assembly may be targeted as surviving a more severe, longer recurrence period, event. Conversely, temporary buildings or those with low occupancy could be designed for a reduced design event (ie one with a shorter return period). Risk or Importance factors typically range between 1.3 and 0.8.

The building owner may choose a higher level of resistance, in which the design will be based upon the higher level of resistance being equivalent to an event of greater recurrence interval. Care is required to ensure that the correct response parameters are being targeted to achieve the required performance. Increasing the design level event may provide greater security against collapse, but have little effect on the onset of damage threshold. In such cases, it may be more appropriate to limit the level of inelastic response of the structure (ductility) or indeed use passive control devices such as dampers or base isolating mechanisms to control building response.

[A building importance factor, probably in the range of 1.3 to 0.8, is likely to be employed. An investigation of parameters and an appropriate design methodology which directly addresses the onset of building damage (post earthquake operational continuance) should be undertaken.]

5.2. Structural Form and Inelastic Response

{To establish the inelastic dynamic response of the structure following selection of the structural materials and structural form.}

It is common engineering practice to expected building damage (non-recoverable inelastic response) during a design level earthquake attack. The designer must ensure the structure can sustain such damage without collapse. The threshold at which the onset of damage is anticipated is likely to dictate whether the building is stable after the attack. Reductions in the design lateral load level can be justified by accepting some damage during the design event. In such cases the elastic response spectrum can be reduced by a function which relates to the post-elastic capacity of the structural system.

Post-elastic response reduction factors currently vary widely between earthquake standards. In New Zealand a ductility factor, μ, is used as the basis for reduction, with the actual reduction formula including a period dependency to allow for the transition between displacement and energy compatibility. The Australian earthquake standard follows the UBC and uses a structural response factor, R_f. The European approach within Eurocode EC8 applies a structural behaviour factor, q. Both R_f and q are period independent.

In each case, the inelastic response reduction factor is actually a material related parameter, the value of which is heavily influenced by the structural material and the structural form selected for the lateral load resisting system. Quantification of these parameters should therefore rest with the seismic provisions of the respective material standards. Whilst this is in place within the majority of structural material design standards in New Zealand, the international trend is to include the definition of the inelastic response parameters for different structural forms within the earthquake standard.

An important issue is the ability to rationally verify any such reduction factor by test (or other means) to ensure consistency between materials and to allow new systems to be introduced. To facilitate this, there is an increasing trend internationally to derive the inelastic response reduction factor from several material related variables. In New Zealand the ductility factor, μ, is used alone to reflect the structural ductility present, although a structural performance factor, Sp, (= 2/3) adjusts the inelastic structural response spectra to reflect the building damage associated with several inelastic excursions. Strcutural Engineering Association of California (SEAOC) have proposed changes to UBC (Phillips Hamburger 1995) for the 1997 revision which, if adopted, will split the R factor into two parts, namely a ductility reduction component, R_d, and an overstrength component, R_o. EC 8 goes further with a basic behaviour factor, q_o, (ranging from 2.5 to 5) and three modification factors associated with the ductility class, k_d (1 to 0.5), a regularity function, k_r, (1 or 0.8), and a wall modifier, k_w, which aims to address the prevailing failure mode of wall systems.

[A quantifiable inelastic response reduction factor will be required. This will be material and structural form dependent and is likely to be composite in character. The structural behaviour factor contained within EC8 offers a good starting point for

committee considerations, although the emphasis on energy dissipation may require further consideration.]

5.3. Seismic Mass

{To describe the mass present during earthquake attack.}

The use and occupancy of the structure will describe the imposed occupancy load within the structure. The seismic mass is generally considered to be the self weight of the structure plus the arbitrary-point-in-time occupancy load, Q_{APT}. Q_{APT} should be described within the general section of the loading standard. For NZ and Australia this is set at 40% of the nominal live load specified.

[The participating seismic mass, and its relative distribution within the structure will need to be prescribed, although this may be within the general loading provisions rather than specifically for earthquake considerations.]

6. Technical Procedural (Analysis and Design) Issues

6.1. Design Application (Capacity Design - Do nothing)

{To match the level of design complexity with the regional seismicity to an appropriate level of confidence that the structure will satisfy performance expectations under during earthquake attack.}

Earthquake standards which cover regions with a wide range of seismicity should attempt to direct designers to procedures appropriate for their specific conditions. Where seismicity is low and performance expectations normal, no specific earthquake resistant measures may be required. In regions of high seismicity, or where damage control is essential, sophisticated design and analysis procedures (such as capacity design or the provision of passive protection devices such as base isolation systems) may be adopted. Between these extremes, measures may range from applying simple prescriptive detailing rules, to conventional analysis techniques.

It is essential to identify the requirements early in the design process to avoid unnecessary design effort. In Australia, this involves identifying building category based on site acceleration (basic acceleration including site amplification) and the structural performance expectations. Each category is further subdivided to reflect the nature (brittle and inherently ductile) of the materials. The appropriate design procedure for each is then described. This may vary from no action to minimal prescriptive detailing to conventional analysis and design procedures to capacity design or indeed to base isolation.

[A scoping table which relates site seismicity and anticipated building performance is desirable when the scope of the earthquake standard is to be extended to cover a wide range of regional seismicity. The use of building classes to ensure the appropriate analysis and design technique is employed would seem appropriate.]

6.2. Distribution of Earthquake Induced Lateral Loads

{To provide a means whereby the base shear induced from the inertia effect on the seismic mass present is rationally and appropriately distributed over the height of the vertical lateral load resisting systems and magnified to allow for torsional rotational effects.}

Earthquake induced actions within a structure result from the inertial effect created by the motion of the base relative to the mass of the building. While this response is generally dominated by first mode behaviour (refer Figure 4), the influence of higher modes can also be significant and their effect must be included within the design.

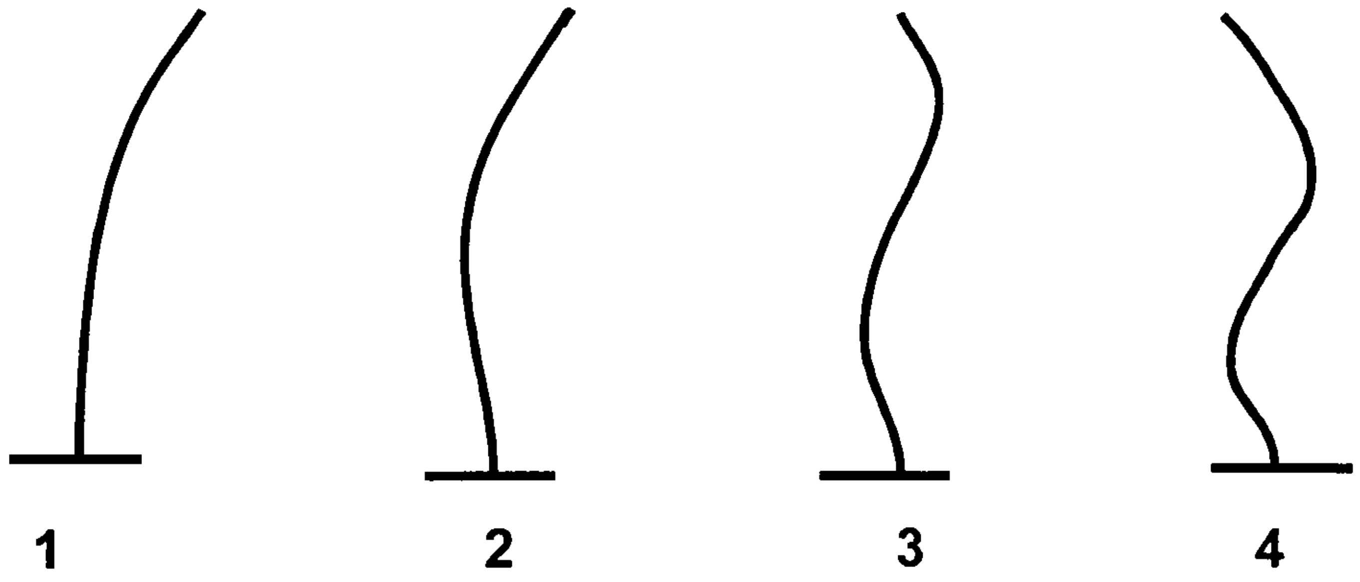

Figure 4 Dynamic Mode Shapes

Higher mode effects are often accentuated by abrupt changes in structural stiffness up the height of the structure. Considerable simplifications can be made within the design process if the structure is **vertically regular,** in which case first mode dominance can be reasonably assumed. Vertically irregular structures, particularly those of moderate or greater height, must specifically consider higher mode effects (using the multi-modal or integrated time history analysis techniques described in Section 6.3).

The distribution of total base shear between the lateral load resisting system and the torsional load resisting system within the structure is a function of its horizontal regularity. When **horizontally regular**, accidental eccentricity may be considered to only amplify the lateral loads of the outside lateral load resisting systems so the analysis can be confined to two dimensions in such cases. For horizontally irregular structures, three dimensional analysis or a greater torsional allowance is required. Preparing clear and unambiguous guidelines to access acceptable levels of horizontal regularly is difficult.

[Regularity, both vertical and horizontal, remains a key issue in accurately predicting the earthquake response of structures. Guidance will be required as to acceptable regularity limits for which simplifying assumptions with respect to the vertical distribution of load apply, and when 3 dimensional analysis is required to address torsion induced by horizontal irregularity.]

6.3. Methods of Analysis

{To prescribe limits within which various methods of analysis can be used to ascertain the earthquake load effects within the structure and to give guidance as to the various analysis methods should be applied and their results interpreted.}

6.3.1. Equivalent Static Method

The equivalent static method of analysis may be used to analyse simple regular buildings only. The dynamic response of such systems is used solely to distribute the total base shear within each frame (usually as an inverse triangulated load pattern), together with an amplification factor to allow for torsional effects. The system is then designed to resist the static loads induced from this distributed load pattern acting at the same time as the associated self weight and long term occupancy loads. Members may be sized and detailed according to the resulting actions, or, if capacity design is required to be employed, as a basis for determining the flexure member capacity, the overstrength capacity of which is used to ensure an appropriate hierarchy of strength.

[The equivalent static method of design should be the preferred option for simple structures. The transparent nature of the analysis provides less likelihood of gross errors being introduced. Guidance will be required as to the appropriate sectional properties (stiffness and member end zone allowance), how accidental torsional effects are to be incorporated, and how deformation compatibility can be assured.]

6.3.2. Multi-Modal Analysis Method

When a more accurate representation of the actual excitation modes of the structure is required, either because of vertical irregularity or for other reasons, the multi-modal can be adopted. The essence of this method of analysis is that the dynamic characteristics of the structure are used to determine the period and shape of each response mode. The contribution from each mode is combined statistically, usually using a sum of squares combination technique. The actions (shear and moment) derived using this procedure more realistically represent the actual response of the structure to the design event. Since the contribution of each mode will not occur simultaneously, the means by which they are combined requires careful attention. (Refer Carr 1995)

[Multi-modal analysis procedures will need to be specified. Guidance is required as to methods of combining the resulting modal effects, with particular reference to the time dependant nature of the resulting action envelopes. Methods by which post-elastic response can be assessed would be helpful.]

6.3.3. Integrated Time History Analysis

Integrated time history analysis techniques have only come into dominance over the last decade with the advent of cheap computer power. The process involves developing a computer model of the structure, usually including both the elastically responding characteristics and their post-elastic parameters. The resulting model, including its appropriately distributed seismic mass, is then subjected to the synthesised ground motion for each time step of the earthquake excitation record being considered.

Issues which require inclusion in any such analysis are the dynamic character and scaling effects of the ground motion, the dynamic interaction between interconnected lateral load resisting elements, and the actual inelastic response of the structural components being modelled. Techniques such as these are most commonly used as checking tools once the structural form has been proportioned in accordance with other methods.

[Integrated time history analysis techniques have become widespread in their use as a means of establishing the onset of damage and thus control within a structure. As such, guidance will be needed as to how to select appropriate input records, and the scaling factors to be applied for a specific site and structural form. Guidance is required as to how to interpret data derived from such analysis and how it should be used in the design process.]

6.4. Displacement Control

{To ensure displacements are appropriately controlled, that the onset of damage is appropriately deferred and that building and component separation distances are sufficient to prevent collision.}

Elastic analysis methods have been discussed in Sections 6.3.1 and 6.3.2. These methods provide useful design information in regard to the distribution of strain (and hence stress) within elements, but give little guidance as to the post-elastic behaviour of the structure which will occur as each element exceeds its elastic limit. Such inelastic response is primarily dictated by the form of the structure, with the post-elastic interstorey drift of framed structures usually being concentrated within the lower third of the building and the rest of the framed building translating predominantly unchanged from its elastic profile. This is in contrast with shear wall or cantilever systems which tend to distribute their overall post-elastic drift reasonably uniformly between participating floors.

Drift control under post-elastic conditions is also required to ensure second-order effects, such as those resulting from displaced gravity actions (P-Δ effects), are inhibited. The quantification of post-elastic drift is notoriously difficult and the limits imposed are therefore somewhat arbitrary. Typical limits of between 1 and 2% of interstorey height have been used within international standards.

Separations between buildings, and between elements within a building, provide a control upon which building clearance and boundary separation are assessed. The potential exists for dynamically unsympathetic responding systems to clash and hammer each other when excited. Impacts of this nature have been observed during recent earthquakes (Mexico 1985) and have resulted in premature structural collapse. Realistic controls of both building and component separation distances will be required within future earthquake codes.

[Post-elastic drift limits will need to be included. The rationale for the imposition of such limits should clearly identified, even if this technical basis for such controls may be somewhat sparse. Guidance will be required to ensure the magnification from the elastic to the post-elastic displacement profile is correctly applied.]

Damage control, and the ability to ensure uninterrupted post earthquake occupancy, are becoming increasingly important performance parameters both for essential facilities and also for reasons of commercial continuity. Where the issue is one of service being maintained, the earthquake design should be based on a less intense event (with a return period of say 20 years) and on designing for a near-elastic structural response which may include the contribution of undamaged, connected, non-structural components. Quantification of the drift limit associated with the onset of such damage is difficult, but should be attempted. Component and structure separation provisions provide an alternative where the elastic drift limits become to stringent.

[Lateral drift limits at which the onset of damage to non-structural elements and components will be required.]

6.5. Non-structural Building Elements & Components

{To provide earthquake induced dynamic actions from which the design of building components and non-structural elements can be designed to attain their required performance.

Damage to non-structural components and elements is most likely to cause building closure following an earthquake attack. Avoidance of the premature onset of such malfunction is increasingly common as a performance criterion. This requires adequate security for the fastening devices used to attach the components and associated parts to the structure, and the provision of adequate clearances or other provisions to ensure that the earthquake induced drift of the structure does not impinge upon the component and render it inoperative.

The earthquake induced motion experienced by a component within the structure will be heavily influenced by the structural response. Resonant effects will occur when the dynamic characteristics of the component coincide with the excitation frequency of the supporting element. This can become complicated because of the high level of uncertainty in determining the supporting frame response both for higher mode effects within the elastic range and for all response within the post-elastic range.

[The earthquake response of non-structural components subjected to more frequent, lower intensity (serviceability level) excitation will need to be included in any future earthquake design standard. Any such solution will include consideration of the dynamic behaviour of the structure, the element within the structure which supports the component and the component itself. It is unlikely that this can be greatly simplified, although all endeavours should be made to develop a simplified procedure if possible.]

7. Higher Level Issues

{To identify issues which are beyond the scope of an earthquake design standard but have an essential input into the successful application of that standard. Such issues would be addressed within either the national building codes or the parent loading standard.}

The proposed objective of the design (protection from hazard, neighbouring buildings, national economic loss, etc.) needs to be clearly defined as these issues are likely to influence several of the controls and acceptable procedures within the earthquake section.

Acceptable design philosophies (Working Stress Design or Limit State Design methodologies) need to be clearly specified. These will apply across the suite of structural standards including the loading and all structural materials standards.

The assignment of particular structural and occupancy classes should apply to all design issues and as such require specification within a higher tier document.

Load combinations will be required for each design state. Such combinations should include recognition that the earthquake response of any system is directly linked to the mass present during the event. The time dependent function of several differing loads will need to be included.

8. Conclusions:

It is quite feasible to prepare a common earthquake design standard for New Zealand and Australia which would be able to accommodate the wide range of seismicity within each country, and the level of design refinement present within the respective design communities. Any such standard could be readily adopted by other regions regardless of the level of their seismicity or their stage of social or economic development.

The essential features of most international earthquake engineering design standards have been identified and discussed. Although there are differences in detail, the overall approach is common, and with refinements could be readily applied to any future code development.

Earthquake engineering design continues to become more refined and focused on assuring the required structural performance is attained. Several new international initiatives have been identified and should be considered for any future standard development.

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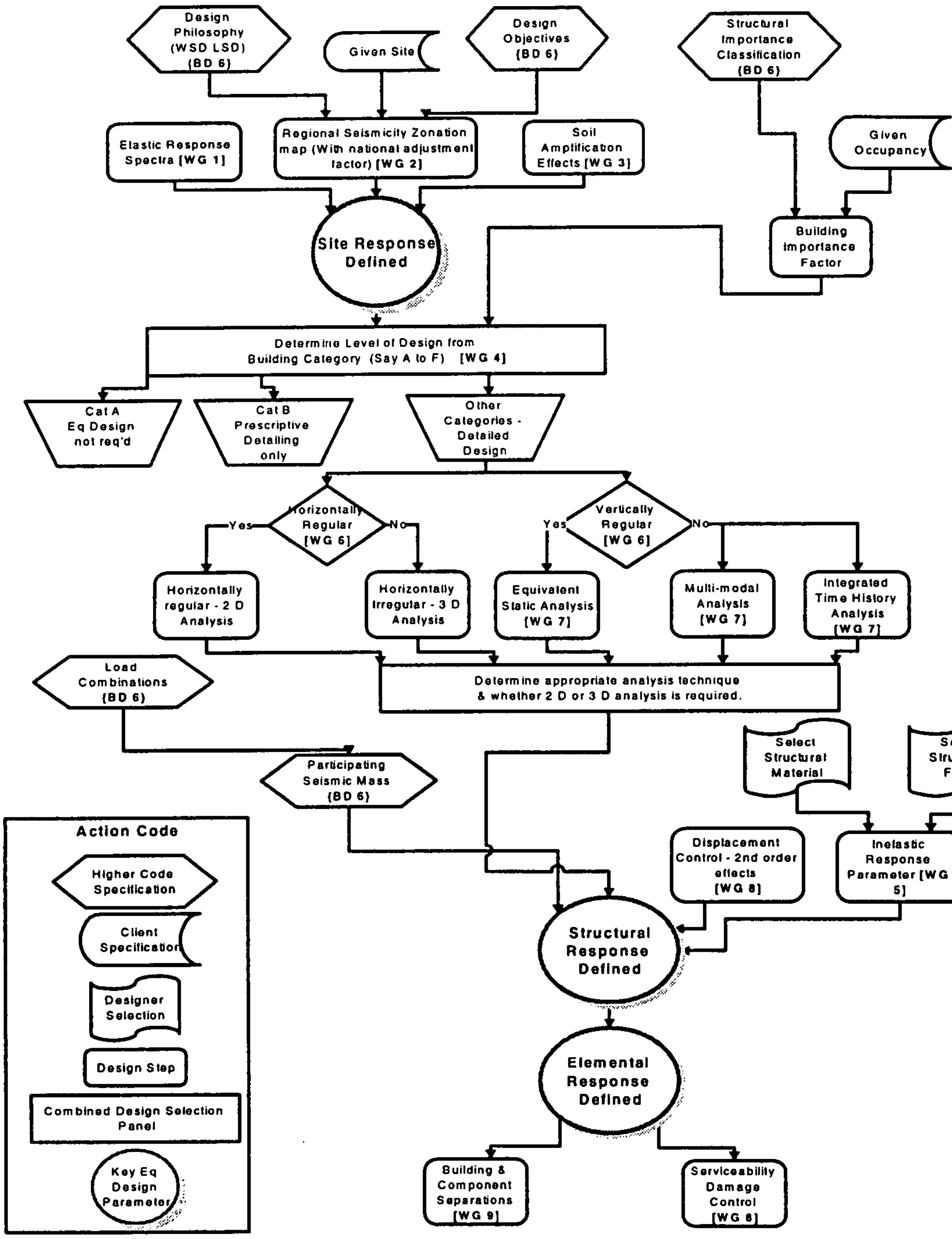
Appendix A:



Proposed Structure for a Common Earthquake Design Standard

Appendix B: Comparison of issues covered in several international earthquake standards

ISSUES	AS 1170 pt 4	NZS 4203	EC8	UBC 1997?	ISO 3010	RECOMMENDATION
<u>BASIC PARAMETERS</u> Elastic Response Spectra	normalised $(1.25S/T^{2/3}) <$ 2.5 eqns and graphs	3 (soil category) 2 segments graphs & tables	parametric 4 segments eqns & tables	parametric 3 segments graphs and tables	parametric $\rho_0(T_c/T)^n < \rho_0$ graphs and tables	parametric country specific eqns, graphs or tables
Zone map return period	10% in 50 years	10% In 50 years	475 yrs	475yrs	not specified	10% in 50 years
Soil Classification	5 classes	3 classes	3 classes	5 classes	not specified	3 classes with both descriptive and shear wave characterisation
Inelastic Structural Response (Seismic resisting system)	R_f (1.5-8.0)	μ and S_p (1.25-6.0, 0.67)	$q = q_0 k_d k_r k_w$ q_0=2-5, k_d=0.5-1 k_r=0.8-1,k_w=0.4-1	$R = R_d R_0$ R_d=1.2-3.4 R_0=1.8-2.5	δ 1/5-1/3 ductile 1/2-1 non-ductile	Use multiple parameter descriptor
Important factor	1-1.25	1-1.3	not specified	1-1.25	not specified	not logical-need to identify objectives
<u>PROCEDURES</u> Levels of design						
nothing	func(aS,bld. type)	not allowed	a < 0.04g	zone 0	not specified	incorporate all design levels
details only	func(aS,bld. type)	not allowed	a < 0.1g	if wind control		in a matrix
conventional design	func(aS,bld. type)	μ related	a > 0.1g	required		as a function of
capacity design	not covered	μ related	?	not required		seismic vunerability and
special design	not covered	?	?	?		type of building

ISSUES	AUS	NZ	EC8	UBC	ISO	RECOMMENDATION
TECHNICAL PROCEDURES						
Seismic mass	$G + \psi_c Q$	$G + \psi_u Q$	$G + \varphi \psi_{21} Q$	$G + x Q$		$G + \psi_c Q$
Structural regularity criteria	Yes	Yes	Yes	Yes		Define by examples and diagrams
Torsional Provision	Yes	Yes	Yes	Yes		Include but review
Methods of analysis						
Equivalent static	Cat B, irregular Cat C or above, regular	H<15m regular T<2.0sec irregular T<0.45 s	(i) regular in plan and elevation (ii) limited class with T< 2			
Modal	Cat D or above, irregular	outside equivalent static limits	outside equivalent static limits			
Time history	optional	outside equivalent static limits	outside equivalent static limits			
Design methods	WSD & LSD	LSD	LSD	WSD & LSD	LSD	Mainly LSD but allow WSD
Displacement control						
P-δ	m>0.1	not required for T<0.45s H<15m and T<0.8s $\mu < 1.5$	m >0.1	m >0.1		include but review
Damage limit	0.015 h	0.02h for H< 15m 0.015h forH<30m	0.015h to 0.008h	0.025h forT<0.7s 0.020h for T>0.7s		include but review
Separation (Storey drift)	Δ_e (3R/8)	$\mu \Delta_e$	$q_d \Delta_e \gamma_I$	$0.7 R_d R_0$		include but review

An Australasian earthquake standard
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