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STANDARDS NEW ZEALAND

PAEREWA AOTEAROA

New Zealand Standard

Structural design actions

Part 5: Earthquake actions – New Zealand Commentary

NZS 1170.5 Supp 1:2004

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New Zealand Standard

Structural design actions

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PREFACE

This Commentary is intended to be read in conjunction with NZS 1170.5:2004 referred to here as the "Standard." It is intended to provide background to the various provisions in the Standard, to suggest approaches that may satisfy the intent of the Standard, and if appropriate, describe differences between this and previous editions of the Standard. References are provided for further reading and these are given at the end of each section of the Commentary.

Commentary Clauses are not mandatory.

Clause numbering of the Commentary is identical to that of the Standard except that Clauses are prefixed with the letter '**C**'. A cross-reference such as 5.4.1.2 refers to that Clause in the Standard, while C5.4.1.2 refers to the corresponding commentary Clause. Commentary is not provided to all Clauses in the Standard. Some commentary Clauses do not have a corresponding Clause in the Standard.

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Structural design actions – Earthquake actions – New Zealand Commentary

(Supplement to NZS 1170.5:2004)

SECTION C1 SCOPE AND GENERAL

C1.1 SCOPE

The Standard applies to structures and parts of structures within the scope of AS/NZS 1170.0, however, certain types of structure are specifically excluded. The main reason for the exclusions is that the Standard is written around the performance of building-type structures and civil structures, tanks containing liquids, retaining walls, etc. that will not necessarily behave in a similar fashion under earthquake loading. Some of these structures may be outside the scope of AS/NZS 1170. While for these structures the hazard factor maps in the Standard may give an appropriate indication of the seismicity of the location, the design earthquake to be used and the methods for determining the period of the structure given in the Standard may be inappropriate and give invalid answers. For these types of structures special studies may be required to evaluate the seismicity of the precise location, the appropriate design earthquakes, the behaviour of the structure and appropriate design criteria and detailing.

The Standard draws attention to the fact that the prediction of the effects of an earthquake on soil, e.g. liquefaction, is outside its scope and that the advice of appropriate experts should be sought for these considerations.

C1.2 DETERMINATION OF EARTHQUAKE ACTIONS

E_u and E_s are required for use in AS/NZS 1170.0 and this Clause sets out the general principles for determining these forces.

C1.3 LIMIT STATES

The expected performance of structures during earthquake shaking is assumed in setting the provisions of this part as follows.

Serviceability limit state

Functional requirements for the serviceability limit state are assumed to be met if the structure or part can continue to be used as originally intended without the need for repair (SLS1) or can remain operational or continue to be occupied as appropriate (SLS2). Amd 1 Sep '16

Ultimate limit state

Functional requirements for the ultimate limit state are assumed to be met if:

(a) People within, and adjacent to the structure are not endangered by the structure or part.

(b) Displacements of the structure are such that there is no contact between any parts of a structure for which contact is not intended, or between separate structures on the same site, if such contact would damage the structures or parts to the extent that persons would be endangered, or detrimentally alter the response of the structure(s) or parts, or reduce the strength of structural elements below the required strength.

(c) The structure does not deflect beyond a site boundary adjacent to which other structures can be built or collision between the structure and any adjacent existing structures cannot occur.

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(d) There is no loss of structural integrity in either the structure or part.

C1.4 SPECIAL STUDIES

Special studies may be carried out to justify variations from specific provisions given in this Standard. Guidance on the expectation of special studies and how they are expected to be undertaken are given in AS/NZS 1170.0 Appendix A. Such studies are to be undertaken in a manner consistent with the principles outlined in the Standard. The minimum requirements elsewhere in the Standard (i.e. not addressed by the special study) will still apply unless they too are subjected to a specific special study themselves. (For example a site specific seismic hazard study may result in a design spectrum different from that published in the Standard, but the minimum design base shear provisions will still apply unless they too are subjected to a specific study.)

Examples of special studies and minimum requirements affecting them are:

(a) The development of site specific design spectra is to include consideration of the subsoil conditions at that site, specific distances from that site to known faults etc. and to engage a uniform hazard approach and prescribed departures from that approach so that both the background seismicity and the minimum hazard factors of 0.10 in Northland and 0.13 elsewhere need to be considered.

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(b) The determination of a lateral force coefficient of an item of mechanical plant with consideration of the actual mass distribution of the item and the post-yield characteristics of both the plant and its points of fixity.

(c) The behaviour and response of rocking structures, taking into account the flexibility of fixing points and actual mass distribution within the system.

(d) Determination of maximum material strains for a specific detail shall be capable of dependably sustaining the deformations resulting from the design level event and having sufficient reserve capacity to contribute to a resistant system when subjected to deformations resulting from a very rare (2500-year return period) event.

C1.5 REFERENCED DOCUMENTS

NZS

1170.5:2004 Structural design actions –Part 5: Earthquake actions – New Zealand

3101:2006 Concrete structures Standard Parts 1 and 2 (Amd 1 Sep '16)

4203:1992 General structural design and design loadings for buildings

4671:2001 Steel reinforcing materials (Amd 1 Sep '16)

AS/NZS

1170.0:2002 Structural design actions –Part 0: General principles

AS

1289-2000 Methods of Testing Soils for Engineering Purposes

ASTM

D1586-99 Standard test method for penetration test and split-barrel sampling of soils

D2166-00 Standard test method for unconfined compressive strength of cohesive soil

D2850-95 Standard test method for unconsolidated-undrained triaxial compression test on cohesive soils

ISO

2394:1998 General principles on reliability for structures

SECTION C2 VERIFICATION

C2.1 GENERAL REQUIREMENTS

The underlying objectives of this Standard are that buildings achieve a level of performance during earthquakes so that:

(1) Frequently occurring earthquake shaking can be resisted with a low probability of damage sufficient to prevent the building from being used as originally intended; and

(2) The fatality risk is at an acceptable level.

Objective 1

This objective is intended to limit both the number of times the loss of amenity is likely to occur and the cost of damage repair over the life of a building. It is verified by consideration of the serviceability limit state (SLS).

For a building of normal usage and importance, frequently occurring earthquake shaking is assumed to be that which has an annual probability of exceedance of approximately 5%. That is it might be expected to be exceeded approximately twice during a 50-year design life for a building. For other usage, importance, or design lives, the annual probability of exceedance is adjusted as indicated in AS/NZS 1170 Part 0.

Two levels have been defined for the SLS, namely SLS1 and SLS2 (refer AS/NZS 1170.0 and C2.4).

At the SLS2 level it is expected that there will be a low risk of failure of systems within importance level 4 buildings that would render them unable to undertake the roles for which the importance level has been assigned.

Objective 2

Internationally, an accepted basis for building code requirements is a target annual earthquake fatality risk in the order of 10^{-6} (ISO 2394:1998). In design terms it is generally accepted that fatality risk will only be present if a building fails, i.e. collapses. The maximum allowable probability of collapse of the structure, or part of the structure, is then dependent on the probability of a person being killed, given that collapse has occurred. This conditional probability will be dependent on structural type and other factors and is likely to be in the range 10^{-1} to 10^{-2} (indicative probabilities have been proposed as part of the FEMA 2001 project and are reported in Ref. 5). Acceptable annual probabilities of collapse might therefore be in the range 10^{-4} to 10^{-6}. These values are inclusive of any collapses that might arise from design and construction errors (ie lack of compliance with the provisions of this Standard and the NZBC) which from experience will be the major contributors to collapses that do occur. Amd 1 Sep '16

Given the current state of knowledge of the variables and the inherent uncertainties involved in reliably predicting when a structure will collapse, it is not currently considered practical to either analyse a building to determine the probability of collapse or base a code verification method around a collapse limit state. It is therefore necessary to adopt a different approach for the purposes of design.

It is possible to consider a limit state at a lower level of structural response, at a level where structural performance is more reliably predicted, and one that is more familiar to designers and then rely on margins inherent within the design procedures to provide confidence that acceptable collapse and fatality risks are achieved. In this Standard this limit state is referred to as the ultimate limit state (ULS).

It is an expectation of this Standard that under the ULS there will be a high degree of reliability of achieving the strength and ductility values that are assumed and therefore consequently there will be a very low risk at the ULS of:

(a) Structural collapse;

(b) Failure of parts and elements which would be life threatening to people within or around buildings;

(c) Failure of parts or elements whose function is critical for the safe evacuation of people from the building.

The ULS for buildings of normal use (importance level 2) is typically based around earthquake motions with a return period of 500-years (10% probability in an assumed 50-year life). For such buildings it is considered that application of the generally accepted ULS principles in combination with the 500-year return period motions will lead to a risk of collapse that will be acceptable and in line with internationally recognised levels. For importance level 3 and 4 buildings the probability of collapse and thus loss of life are reduced in recognition of the more serious consequences. Again this is in line with international practice.

However, two exceptions to the relative link between the ULS and an acceptable collapse risk arise. They are:

(a) In areas of low seismicity; and

(b) For materials and structure configurations where there is little reserve beyond the ULS.

In areas of low seismicity the levels of shaking with even a 1000-year return period are not particularly severe and well below those that might typically be associated with the generally accepted concept of a moderate earthquake. It is an additional objective of this Standard that the risk of collapse in moderate earthquake shaking, for all buildings of importance level 2 or greater, should be acceptable irrespective of the return period of the moderate earthquake motions. This is particularly relevant to Auckland where the consequences of poor performance could be large.

For the purposes of this Standard moderate earthquake motions have been taken to be those associated with a magnitude 6.5 earthquake (at an 84 percentile confidence level i.e. median plus one standard deviation) occurring 20 km from the building site under consideration. The adoption of this scenario event to govern the minimum motions for the ULS leads to a minimum hazard factor Z of 0.13. For the Northland regional council area, the lowest seismicity region in New Zealand, the distance is increased to 30 km, reducing the minimum hazard factor Z to 0.10. The expected uniform hazard spectral response from this earthquake (magnitude 6.5 at 20km) is shown in Figure C2.1 together with the estimated 500-year return period hazard estimates for Auckland. It is apparent that the uniform hazard spectral values lie well below the spectral estimates for the moderate earthquake. Also shown are the 500-year return period uniform hazard results for Wellington. In contrast these values are well above the moderate earthquake shaking estimates.

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In order to achieve an acceptable risk of collapse during moderate earthquake shaking in low seismic areas it is necessary to raise the design actions above those that might be expected if a uniform risk was applied across the whole of New Zealand. In this Standard this has been achieved by setting a minimum level of design load (i.e. hazard) that should be considered with the ULS for low seismic areas. The assessment of the minimum level adopted is described in C3.1.4.