AS/NZS 1170.0 Supplement 1:2002

Structural design actions—General principles—Commentary (Supplement to AS/NZS 1170.0:2002)

Standards Australia

STANDARDS NEW ZEALAND Paerewa Aotearoa

AS/NZS 1170.0 Supp 1:2002

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AS/NZS 1170.0 Supplement 1:2002

Structural design actions—General principles—Commentary (Supplement to AS/NZS 1170.0:2002)

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PREFACE

This Commentary was prepared by the Joint Standards Australia/Standards New Zealand Committee BD-006, General Design Requirements and Loading on Structures, as a Supplement to AS/NZS 1170.0, *Structural design actions*, Part 0: *General principles*. This Commentary supersedes in part AS 1170.1—1989, *Minimum design loads on structures*, Part 1: *Dead and live loads and load combinations* and in part NZS 4203:1992, *Code of practice for general structural design and design loadings for buildings (Vol. 2)*.

This Commentary incorporates Amendment No. 1 (November 2003). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The Commentary provides background material for and guidance to the requirements of the Standard.

The clause numbers of this Commentary are prefixed by the letter 'C' to distinguish them from references to the Standard clauses to which they directly relate. Where a Commentary to certain clauses is non-existent, it is because no explanation of the Clause is necessary.

The intention is that the AS/NZS 1170 series of Standards will be applied by a suitably qualified professional.

The AS/NZS 1170 series sets out the basic procedure for the structural design of structures. Other Standards that provide engineered solutions for particular situations (e.g., house framing) may be based on the methods given in these Standards. The AS/NZS 1170 series includes clauses that contain an element of engineering judgement. This reflects the fact that engineering is a creative activity based on science applied with art and skill.

ACKNOWLEDGEMENT

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SECTION C1 SCOPE AND GENERAL

C1.1 SCOPE

This Commentary is intended to be read in conjunction with AS/NZS 1170.0:2002. It explains the provisions of and, in some cases, suggests approaches that may satisfy the intent of the Standard. Commentary Clauses are not mandatory. Lists of references are also given for further reading.

The Standard (AS/NZS 1170.0) has been revised as a joint Australian/New Zealand Standard. It specifies the basic procedure for the structural design of structures including buildings. Other documents may be relevant for the details of building design (e.g., design of fire escapes) that are not needed for the design of the structure.

The Standard incorporates the fundamentals of the limit states method and enables the designer to confirm the design of a structure. The intention is that confirmation establishes the ability of the proposed structure to resist known or foreseeable types of action appropriate to the intended use and design working life of the structure.

The determination of structural resistance is covered by the Standards for design of materials.

Much of the philosophy and some of the text (for example, most of the definitions and notation) are drawn from ISO Standards, including ISO 2394, ISO 3898, ISO 4356 and ISO 8930.

The general principles given in the Standard are relevant to the design of any structure. However, the information may not be sufficient for some structure types because their design is more complex (due to the inherent behaviour of the structure) or involves loadings that are not covered (type of action or load case), or other Standards give design criteria.

Structures and structural elements should be designed so that they are suited for their intended use during the design working life.

ISO 2394 states the following:

'In particular, they shall fulfil, with appropriate degrees of reliability, the following objectives:

(a) They shall perform adequately under all expected actions.

(b) They shall withstand both extreme actions and frequently repeated actions occurring during their construction and anticipated use.

(c) They shall have structural robustness.'

These three objectives enunciate the serviceability, ultimate and fatigue, and progressive collapse (structural robustness) aspects of design.

SPECIAL STUDIES

Where methods or information used in a design are outside the scope of the Standard justification would normally be required for approval under building regulations. This would require a 'special study'. A special study is a means of establishing information for use in design that is not specifically stated in the Standard. This may include information varied from or not included in the Standard (see Appendix A and its Commentary). The results of such special studies are outside the scope of the Standard.

Special studies may be carried out at the initiative of the designer for any building, subject to satisfying the requirements of the appropriate authority. Appendix B covers testing as part of a special study.

Appendix CA gives additional information on actions not covered, including—

(i) movement effects;

(ii) construction loads; and

(iii) accidental actions.

OTHER STRUCTURE TYPES

The following publications give information useful or necessary for the design of the structures indicated:

(A) HB77 for bridges.

(B) AS 4678 for earth-retaining structures.

(C) AS 3995 for lattice towers and masts, including electrical transmission structures.

(D) AS 3962 for marinas.

(E) AS 3826, ISO 2394 and ISO 13822 for assessment of existing structures.

(F) AS 2159 for piling.

(G) AS/NZS 4676 for utility services poles.

(H) AS 1418 for cranes.

(I) AS/NZS 1576 for scaffolding.

(J) AS 3610 for formwork.

(K) AS 2156.2 for walking track structures.

The design of chimneys may require the use of specialist publications.

Off shore structures require additional information on winds, waves, currents and earthquake.

High-risk structures that require special reliability consideration (such as dams) are generally covered by the special requirements of the regulatory authorities responsible for them.

C1.2 APPLICATION

C1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Commentary:

AS
1418 Cranes (including hoists and winches)

2156 Walking tracks
2156.2 Part 2: Infrastructure design

AS

2159	Piling—Design and installation
2327	Composite structures
2327.1	Part 1: Simply supported beams
3610	Formwork for concrete
3826	Strengthening existing buildings for earthquake
3962	Guidelines for marinas
3995	Design of steel lattice towers and masts
4040	Methods of testing sheet roof and wall cladding
4040.3	Part 3: Resistance to wind pressures for cyclone regions
4678	Earth retaining structures
HB77	Australian bridge design code

AS/NZS

1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
1576	Scaffolding
1576.1	Part 1: General requirements
4673	Cold-formed stainless steel structures
4676	Structural design requirements for utility services poles

ISO

2394	General principles on reliability for structures
3898	Bases for design of structures—Notations—General symbols
4356	Bases for the design of structures—Deformations of buildings at the serviceability limit states
8930	General principles on reliability for structures—List of equivalent terms
10137	Bases for design of structures—Serviceability of buildings against vibration
13822	Bases for design of structures—Assessment of existing structures

Other documents are detailed in Clause C4.3 and Appendix CZ.

C1.4 DEFINITIONS

The definitions are drawn from or based on ISO 2394 and ISO 8930 except for those for design capacity, load, proof testing and prototype testing, which are not defined in those Standards.

C1.5 NOTATION

The notation used in AS/NZS 1170.0 follows the guidelines given in ISO 3898. The same notation is used in this Commentary together with the following:

P-Δ = load and deflection effects (second order analysis).

SECTION C2 STRUCTURAL DESIGN PROCEDURE

C2.1 GENERAL

The use of this Standard within the regulatory framework in Australia and New Zealand differs and the Standard includes clauses that are specific to these countries. Reference is made to the Building Code of Australia for Australia and to Section 3 for New Zealand.

The clauses include the determination of appropriate levels of environmental actions for a particular structure and the appropriate materials design Standards.

Materials design Standards include the following:

AS

1720	Timber structures
1720.1	Part 1: Design methods
2159	Piling—Design and installation
2327	Composite structures
2327.1	Part 1: Simply supported beams
3600	Concrete structures
3700	Masonry structures
4100	Steel structures
4678	Earth retaining structures

AS/NZS

1664	Aluminium structures
1664.1	Part 1: Limit state design
4065	Concrete utility services poles
4600	Cold-formed steel structures
4673	Cold-formed stainless steel structures
4676	Structural design requirements for utility services poles
4677	Steel utility services poles

NZS

3101	Concrete structures standard
3101.1	Part 1: The design of concrete structures
3404	Steel structures standard
3404.1	Part 1: Steel structures standard
3603	Timber structures standard
4223	Glazing in buildings
4230	The design of masonry structures
4297	Engineering design of earth buildings

C2.2 ULTIMATE LIMIT STATES

Where other actions than those given in the Standard are relevant to the design of the structure, the following additional steps should be added to the procedure given in Clause 2.2 before the structure is analysed:

(a) Determine values for any other applicable actions.

(b) Determine combinations for any other applicable actions.

This would be the subject of a special study.

C2.3 SERVICEABILITY LIMIT STATES

The selection of the serviceability criteria and their limits is outside the scope of the Standard. Some advice is given in Appendix C. Selection of criteria for serviceability may require a special study.

Where other actions than those given in the Standard are relevant to the design of the structure, the following additional steps should be added to the procedure given in Clause 2.3 before the structure is analysed:

(a) Determine values for any other applicable actions.

(b) Determine combinations for any other applicable actions.

SECTION C3 ANNUAL PROBABILITY OF EXCEEDANCE (FOR NEW ZEALAND USE ONLY)

C3.1 GENERAL

C3.2 IMPORTANCE LEVELS

The 'importance level' of a structure is related to the consequences of failure and is reflected in the acceptance (explicit or implicit) of the probability of exceeding a limit state.

C3.3 DESIGN WORKING LIFE

The 'design working life' is a reference time period expressed in years. It is a concept used to select the probability of exceedance of different actions. This does not mean that when the design working life is reached the structure will fail; nor does it mean that the design working life has to correspond exactly with the intended useful life the designer has in mind or with the durability of the construction materials.

C3.4 ANNUAL PROBABILITY OF EXCEEDANCE

The annual probability of exceedance depends on the chosen notional 'importance level' and on the 'design working life' of the structure. Once the 'importance level' and the 'design working life' are determined for a structure, the annual probability of exceedance of an action is obtained from the Clause.

For each probability, design values are given in the Standards for environmental actions (e.g., AS/NZS 1170.2). ISO 2394 suggests that specific material factors may also be specified by the material design Standards for varying importance levels.

Importance factors previously given in wind and earthquake loading Standards are now covered by the variation provided for in Tables 3.1 and 3.2.

Calibration of loading and materials design Standards is usually carried out for 'normal structures', for which a design working life of 50 years is assumed. A 10 percent probability of exceedance in the life of the structure is commonly accepted for calibration. Thus, for wind and earthquake applied to normal structures, an annual probability of exceedance of 1/500 is specified. Adjustment is provided for other design working lives to provide relatively constant levels of safety against failure of the structure within the respective working lives. This provides for the safety of the structure as a function of its importance to the community.

For design working lives of less than 25 years, an annual probability of exceedance equal to that for 25 years is required. This provides for a level of personal safety that may be expected by an individual using the structure.

SECTION C4 COMBINATIONS OF ACTIONS

C4.1 GENERAL

The combinations of actions given in Section 4 are for use with limit state structural design Standards. They do not cover all relevant actions and combinations. Further combinations of actions may be given in structural design Standards for specific materials (for example, combinations for prestressing forces are given in concrete design Standards) or may be determined by further investigation using Appendices A and B.

Actions, environmental influences and, in many cases, the expected properties of a structure vary with time. These variations are considered by selecting design situations. Each design situation represents a certain time interval with associated hazards, conditions and relevant structural limit states. Separate checking is carried out for each design situation through the use of combination expressions.

Combinations of actions The combinations of actions given in the Standard are the most commonly used combinations for Australian and New Zealand conditions. Whilst they are similar in form to those used in the American Load and Resistance Factor Design (LRFD) methods, they are also consistent with ISO 2394. The principle used in the establishment of combinations of actions is that each combination represents a particular design situation and, for a particular combination, the reliability is consistent for changes in the relative magnitudes of the actions involved.

It should be noted that the combinations of actions are expressed in terms of actions and not action effects. Superposition of action effects is permissible when the structural behaviour is linear. Where non-linear material and/or geometric behaviour is under consideration, the actions in a combination should be combined before analysis is carried out. The format chosen for representing the combinations (i.e., square brackets to indicate a function) is intended to suggest that the effects of the actions are not necessarily directly additive.

In most of the combinations, in addition to the permanent actions, one of the variable actions takes on an extreme value while other variable actions assume values related to their ‘arbitrary-point-in-time’ values. In these combinations, the design situation is treated as a transient one and recognizes that a lower probability exists that a second extreme action will be experienced in that same period of time.

The values of arbitrary-point-in-time wind and earthquake actions are low and these actions are neglected in combinations involving extreme transient actions.

The factors used with imposed actions (e.g., ψ_c, ψ_s, ψ_ℓ) reflect different aspects of the variability of the action being considered (arbitrary-point-in-time, short-term, long-term).

Where a special study (Appendix A) is used to establish design values for an action, the factors for appropriate combinations should be determined as part of the study. The variability of the loads derived should be taken into account when determining the factors used in the combinations.

C4.2 COMBINATIONS OF ACTIONS FOR ULTIMATE LIMIT STATES

C4.2.1 Stability

The structure and its parts are required to be designed to prevent instability due to overturning, sliding or uplift. For each type of potential instability, a mechanism, consistent with the potential instability should be assumed. In considering overturning, moments should be taken about the centroid of the area over which a supporting bearing pressure is likely to act.

To evaluate the stability limit state, it is necessary to separate those parts of the loads that provide stabilizing effects from those that produce destabilizing effects. In particular, permanent actions need to be separated into—

(a) that part of the weight of the structure that provides stability and is factored as in Clause 4.2.1(a); and

(b) that part of the weight of the structure that can assist in de-stabilizing the structure and is factored as in Clause 4.2.1(b).

The above enables the calculation of the stabilizing effects ($E_{d,stb}$) and destabilizing effects ($E_{d,dst}$). These are considered together in Clause 7.2.1.

For example, consider the cantilever shown in Figure C4.1, in which the weight of the back span is G_1, the weight of the overhang is G_2, the imposed action on the back span is Q_1, the imposed action on the overhang is Q_2, and the design capacity of the anchorage at point B is R_B. Overturning about point A is under consideration.

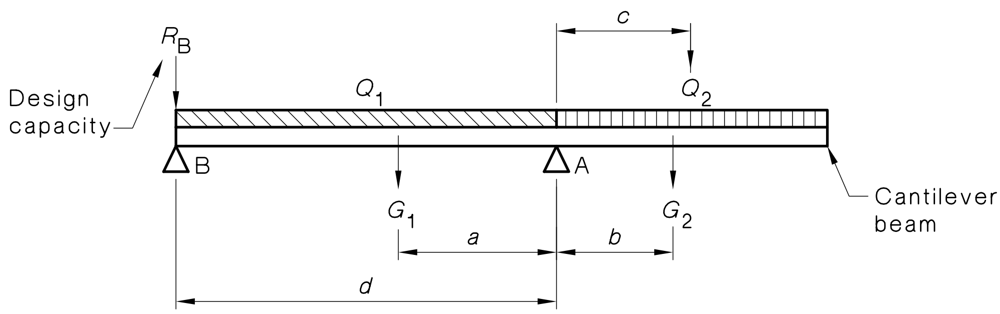

FIGURE C4.1 EXAMPLE OF STABILITY CONSIDERATIONS FOR AN ANCHORED CANTILEVER

Stabilizing effects include the weight of the back span G_1, but not the imposed load in the back span (imposed action might be removed at any time). Thus Clause 4.2.1(a) gives:

$E_{d,stb} = 0.9\ G_1 \times a$

Destabilizing effects include the weight of the overhang G_2, and the imposed action on the overhang Q_2 (imposed action might indeed reach its ultimate value). Thus Clause 4.2.1(b) gives:

$E_{d,dst} = (1.2\ G_2 \times b) + (1.5\ Q_2 \times c)$

Then Equation 7.1 gives: $E_{d,stb} + R_B \geq E_{d,dst}$ which gives:

$(0.9\ G_1 \times a) + (R_B \times d) \geq (1.2\ G_2 \times b) + (1.5\ Q_2 \times c)$

For design situations covering uplift effects (e.g., buried tanks) use $0.9G$ with the appropriate factored actions given for earth pressure and ground water in Clause 4.2.3.

C4.2.2 Strength

Permanent action The factor for permanent action (1.2) is based on the assumption that permanent action has a coefficient of variation of approximately 10 percent. There are situations where this cannot be assumed. A conservative estimate of the permanent load must then be made, or alternatively, that part of the permanent action should be treated as an imposed action. For the cases where the permanent action reduces the effect of other actions (e.g., stability limit state), a factor of 0.9 is given. Careful assessment of the permanent action is required for this situation, and only that part of the permanent action that cannot be removed from the structure should be taken into account.

The factors on long-term installed machinery in Table 4.1 are those that are appropriate for a permanent action. They are included to cover the situation where installed machinery is likely to be replaced within the expected design working life and the weight of the replacement machinery is less certain.

Imposed action Imposed actions usually consist of two components: a sustained component (which remains relatively constant within a particular occupancy, e.g., usual furniture and people) and an extraordinary component (which arises from the extreme clustering of people or objects). For some materials (e.g., timber) the duration of the imposed action is important (see Table 4.1 for long-term and short-term factors).

Parts of the imposed action that tend to reduce the action effect should be taken as zero in the calculation of that particular action effect.

Impact effects Where impact is a design consideration, the effects should be considered as part of imposed action, i.e., substitute (Q + Impact) for Q in the relevant combinations.

Wind action For wind action (W_u), the factor of 1.0 is relevant for the wind forces including quasi-static and dynamic effects as given in AS/NZS 1170.2. Where wind action is derived using other Standards or methods or from wind tunnel tests, other load factors may be required. Expert advice should be sought in these cases.

Earthquake action For earthquake action, attention is drawn to the fact that in design for earthquake resistance ductility is an important design criterion for determining the level of action.

C4.2.3 Combinations for snow, liquid pressure, rainwater ponding, ground water and earth pressure

This Clause gives factors for use with the combinations using the notation S_u for both stability and strength limit states.

Use of these combinations requires the consideration of the design situation or situations in which the load can be considered to occur. For example, if the duration of an action can be taken as a very small proportion of the life of the structure, then combination with other independent short-term extreme events is not relevant.

ITEMS (b) and (c) When liquid pressure is well defined in terms of height and density it is treated similarly to a permanent action. This is not appropriate when the liquid pressure includes dynamic effects.

ITEM (d) The maximum rainwater ponding action, given the assumptions stated in AS/NZS 1170.1, is regarded as having a low variability and is given the same factor as for a permanent action.

ITEM (e) Ground water action, given the assumptions stated in AS/NZS 1170.1, is also regarded as being well defined. It is given the same factor as a permanent action.

ITEMS (f) A combination factor of 1.0 is appropriate for use with earth pressures determined in accordance with AS 4678. For earth pressures determined using other methods, the load factor of 1.5 has been proposed with some hesitation. The design should allow for the possibility of imposed actions occurring and for a surcharge being added (permanent action).

C4.2.4 Combinations of actions for fire

This combination has been derived using the same principles as for strength limit states (see Clause C4.2.2). The fire load is assumed to be an extreme action. Therefore, other loads (G and Q) can assume their arbitrary-point-in-time values. Note that this is a combination relevant for use in a fire test situation.

C4.3 COMBINATIONS OF ACTIONS FOR SERVICEABILITY LIMIT STATES

Serviceability requirements vary considerably from structure to structure. Some of the serviceability problems arise from unspecified effects such as temperature change and moisture movements.

It is not possible for this Standard to specify or even list all causes that affect serviceability. The Standard has, therefore, listed a number of actions, some of which are factored for short-term and long-term effects. It is the responsibility of the designer to anticipate the situations that are likely to occur and to select the proper combinations to be used for checking each likely situation.

Typical combinations for deflections include the following:

(a) For short-term loading conditions:

- (i) $[G, W_s]$
- (ii) $[G, \psi_s Q]$
- (iii) $[G, \psi_\ell Q, W_s]$
- (iv) $[G, \psi_\ell Q, E_s]$
- (v) $[G, \psi_\ell Q, S_s]$

(b) For long-term loading conditions:

- (i) $[G]$
- (ii) $[G, \psi_\ell Q]$
- (iii) $[G, \psi_\ell Q, S_s]$

where S_s is the serviceability load for the actions covered in Clause 4.2.3 with a combination factor of 1.0.

The ψ factors account for the probability that imposed actions for the serviceability limit states will be less than the extreme values given in AS/NZS 1170.1 (see Clause C4.1).

The combinations of actions for short-term effects reflect the probable load situations that will occur during transient design situations. The combinations for long-term effects reflect the probable load combinations that will occur during persistent design situations. The applicable value for variable actions is an estimate of the average load expected over the design working life of the structure.

Analyses for the derivation of some of the load factors in Table 4.1 are provided in the following reference:

PHAM, L. and DAYAH, R.H., 'Floor Live Loads', Proceedings of the 10th Australasian Conference on the mechanics of structures and materials, Adelaide 1986.

C4.4 CYCLIC ACTIONS

AS 4040.3 gives requirements for fatigue testing under wind loading.

SECTION C5 METHODS OF ANALYSIS

C5.1 GENERAL

This Section sets out the general principles on which methods of analysis should be based. It does not give detailed methods due to the variability of the possible structural situations and the large range of available described methods.

A method of analysis is based on a model that describes the behaviour of a structure. The model will incorporate a set of assumptions about the behaviour of the material of the structure and the variation of its geometry and material properties. Some of these models are incorporated in the materials design Standards and some are found in technical publications.

In some cases no reliable model of structural behaviour will be available for some part of the design process. Therefore, testing may be necessary to validate the model used or to supplement an existing model (see Appendices A and B).

Standards on wind actions and earthquake actions indicate when dynamic analyses are required. Situations where P-Δ effects need to be evaluated are given in both materials Standards and the Standard for earthquake actions. Materials Standards provide guidance on the assumptions about material behaviour that may be used in the methods of analysis. The conditions under which upper or lower bound methods may be used may also be given in these Standards.

C5.2 STRUCTURAL MODELS

Static analysis Modelling for static actions is normally based on an appropriate choice of the force versus deformation relationships of the members and their connections. Effects of displacements and deformation should be considered in the context of ultimate limit states (including static equilibrium) if they result in an increase of the effects of actions by more than 10 percent. The formation of mechanisms, second order effects and local buckling should be considered for the strength limit states.

In general the structural analysis models for serviceability limit states and fatigue may be linear. Where departure from linear elastic behaviour is assumed in analysis, the effect of the resulting deformations on serviceability should be considered.

Dynamic analysis When dynamic actions may be considered as quasi-static, the dynamic aspects of actions are considered either by including them in the static values or by applying equivalent dynamic amplification factors to the static actions. For some equivalent dynamic amplification factors, the natural frequencies have to be determined.

In some cases (e.g., for crosswind vibrations or seismic actions) the action effects may be determined by carrying out a modal analysis based on linear material and geometric behaviour. For regular structures, where only the fundamental mode is relevant, an explicit modal analysis may be substituted by an analysis using equivalent static actions, depending on mode shape, natural frequency and damping.

In some cases, the dynamic aspects may be expressed in terms of time histories or in the frequency domain, for which the structural response may be determined by appropriate methods.

Modelling for fire actions Where structural analysis for fire design is performed, it should be performed using appropriate models for the fire situation (e.g., fire within or outside the structure) including thermal and mechanical actions. The changes in structural behaviour at elevated temperatures should not be overlooked.

Design for fire has broader connotations than just structural behaviour (the subject of this Standard) and must also cover life-safety aspects, e.g., evacuation times for occupants, smoke control, and the effect of active protection systems (see relevant building regulations).

Consideration should be given to the stability of external or boundary walls during and after fire. Structural analysis should cover the possibility where complete external wall panels could collapse outwards as a result of fire. Such walls falling outwards represent a high level of risk to people and property, and measures should be taken to control this risk.

SECTION C6 STRUCTURAL ROBUSTNESS

C6.1 GENERAL

A structure should be designed and constructed in such a way that it will not be damaged by events like fire, explosion, impact or consequences of human errors, to an extent disproportionate to the original cause. The potential damage may be avoided or limited by use of the following:

(a) Avoiding, eliminating or reducing the hazards which the structure may sustain.

(b) Selecting a structural form that has a low sensitivity to the hazards considered.

(c) Selecting a structural form and design that can survive adequately the accidental removal of an individual element or a limited part of the structure or the occurrence of acceptable localized damage.

(d) Avoiding as far as possible structural systems that may collapse without warning.

The design should provide alternate load paths so that the damage is absorbed and sufficient local strength to resist failure of critical members so that major collapse is averted. The materials design Standards usually contain implicit consideration of resistance to local collapse by including such provisions as minimum levels of strength, continuity, and ductility. Connections for example should be designed to be ductile and have a capacity for large deformation and energy absorption under the effect of abnormal conditions.

C6.2 LOAD PATHS

C6.2.1 General

The existence of load paths in the structure will provide a measure of robustness to the structure.

C6.2.2 Minimum resistance

This requirement provides for a degree of resistance to lateral loads. It is envisaged that in most cases this requirement may be satisfied by a simple check to establish that lateral loads from specified actions (e.g., wind) exceed the loads given here.

C6.2.3 Minimum lateral resistance of connections and ties

As for Clause 6.2.2, in most cases this clause would be easily checked or resolved by appropriate detailing.

C6.2.4 Diaphragms

Floor and roof diaphragms are required to transmit forces in their plane from walls or roof elements to lateral load-resisting elements such as shear walls or bracing systems. A system of struts and ties may be used. Where floor slabs or ceiling structures are used as diaphragms, they should be capable of withstanding local concentrations of forces that occur around openings or connections.

C6.2.5 Walls

Where friction forces are relied upon in a connection (such as between a wall and a floor slab), proven values of the coefficients of friction should be used in evaluating the limiting resistance. Provisions for limiting the amount of slip should be considered.

SECTION C7 CONFIRMATION METHODS

C7.1 GENERAL

This Section sets out the test that the design must pass to be in accordance with the Standard.

The confirmation methods given in Section 7 relate to calculation methods. They are a specific set of descriptions that separate desired states of the structure from undesired states. For other methods (e.g., prototype testing) special studies are required (see Appendices A and B).

C7.2 ULTIMATE LIMIT STATES

C7.2.1 Stability

Stability limit states provide checks on limiting equilibrium of the structure or parts of the structure. Loss of equilibrium can result in uplift, sliding or overturning.

The component (ϕR), which is the design capacity of the structural component, is relevant when only part of a structure is checked for instability. The value of (ϕR) may be found using the appropriate materials design Standard.

C7.2.2 Strength

Strength ultimate limit states include the following:

(a) Attainment of the maximum resistance capacity of sections, members or connections by rupture (in some cases affected by fatigue, corrosion, and similar) or excessive deformations.

(b) Transformation of the structure or part of it into a mechanism.

(c) Sudden change of the assumed structural system to a new system (e.g., snap through).

The effect of exceeding an ultimate limit state is almost always irreversible and the first time that this occurs it causes failure.

For simplicity, a state prior to structural collapse may be considered as an ultimate limit state, e.g., reduced structural system following an accidental action.

C7.3 SERVICEABILITY LIMIT STATES

Serviceability limit states include:

(a) Local damage (including cracking), which may reduce the utility of the structure or affect the efficiency or appearance of structural or non-structural elements; repeated loading may affect the local damage (e.g., by fatigue).

(b) Unacceptable deformations that affect the efficient use or appearance of structural or non-structural elements or the functioning of equipment.

(c) Excessive vibrations that cause discomfort to people or affect non-structural elements or the functioning of equipment.

In the cases of permanent local damage or permanent unacceptable deformations, exceeding a serviceability limit state is irreversible and the first time that this occurs it causes non-conformance.

Where a serviceability limit state is reversible, non-conformance may be specified as the point at which the limit state is reached, an amount of time that it is exceeded, a number of times it is exceeded, a combination of these or some other relevant criteria. These cases may involve vibrations, temporary local damage (e.g., temporarily wide cracks) or temporary large deformations. The design criteria are generally expressed in terms of limits for acceptable deformations, accelerations or crack widths.

The set of serviceability limits given in Appendix C is restricted to limits on acceptable deformations and vibrations in particular situations.

APPENDIX CA

SPECIAL STUDIES

Generally, structural design is carried out in accordance with the procedures set out in the appropriate Standards. This Appendix covers the situation where during the use of the Standard, it becomes apparent that AS/NZS 1170.0 or those Standards being used with it (e.g., AS/NZS 1170.2, Wind actions) are not sufficient.

There are cases where part or parts of the procedure may be inappropriate due to the following:

(a) The situation is not covered adequately by the Standards.

(b) Numerical data given in the Standard do not reflect accurately the actual situation.

(c) Use of the Standard leads to very conservative and uneconomical solutions.

At this point, the designer may choose to—

(a) make reference to another text (e.g., a text book on wind design);

(b) use collected data, see Appendix B (e.g., wind speeds at the site of the structure);

(c) carry out testing to establish factors used in design, see Appendix B (e.g., wind tunnel tests); or

(d) carry out testing to confirm the design, see Appendix B (proof or prototype).

It is expected that building authorities will require that the use of such information be justified as it is outside the scope of the Standard. Therefore, this part of the design process is termed a Special Study.

Generally, information gained using Item (a) is itself based on testing, but may also be based on rigorous mathematical analysis or long experience by the construction industry.

Special studies may also be used to justify variation of the requirements given in the Standard.

ACTIONS

Actions for which values are not given in the Standard are those for which values are not known or those that cannot be assigned combination factors. Where there are uncertainties in the specification of or the structural implications of an action, a reliability analysis cannot be performed and, therefore, load factors cannot be assigned. Proper calibration of combination factors could be performed for specific cases where such information is known.

Some of the actions listed in Paragraph (b) may not affect the strength of the member or the structure if sufficient ductility is available. However, these actions may need to be considered for serviceability.

Attention is drawn to the following actions for which specific recommendations are not given in the various parts of the series of Standards:

(a) *Movement effects* Actions on structures resulting from expansion or contraction of materials of construction, such as those due to creep, temperature or moisture content changes and also those resulting from differential ground settlement, should be allowed for where appropriate. Some information on thermal variation resulting from weather is given in Appendix CZ.

(b) *Construction loads* Special loading conditions, which may arise during construction and which adversely affect the requirement for strength, stability and serviceability, should be taken into account. Unusual load paths may be called into play in the partially completed structure, which may need special investigation. Combinations relevant during construction include all actions specified in the Standard. For environmental actions (such as wind, snow, temperature, earthquake) less extreme events may be appropriate. Loads due to the stacking of building materials or the use of equipment during construction or loads that may be induced by floor-to-floor propping should be taken into account. Some construction loads are given in AS/NZS 1576.1 and AS 3610.

(c) *Accidental actions* Accidental actions include explosions, collisions, fire, unexpected subsidence of subgrade, extreme erosion, unexpected abnormal environmental loads (flood, hail, etc.), consequences of human error and wilful misuse. It is impractical to design for all accidental actions as they are very low probability events. However, precautions should be taken to limit the effects of local collapses caused by such actions, that is, to prevent progressive collapse (see Section 6 and its commentary).

(d) *Hail impact* Design for hail impact is hampered by the lack of sufficient information on the level of risk. Data is being gathered on the occurrence of hail of large size.

APPENDIX CB

USE OF TEST DATA FOR DESIGN

CB1 GENERAL

CB1.1 Scope

Appendix B should be used in the context of Appendix A. It sets out general principles for use of data from observation and testing in structural design. A consistent protocol is provided for establishing information that can be used in the design process. It is the intention of the committee that this information should be referenced by the materials design Standards in order to provide consistency in the use of testing.

The method given is general in nature in order to cover all types of action, all design parameters and all material types. Therefore, it cannot cover all requirements for some specific situations and test specifications may need to refer to other sources such as materials design Standards for further details.

CB1.2 Reliability

This is the performance objective. It is important to maintain the reliability of the design regardless of the path used to achieve it.

A calculation model should be set up, where possible, covering the relevant range of the variables and clearly indicating the unknown coefficients or quantities that should be evaluated from the tests. If this is not possible, a set of preliminary tests should be carried out to establish such a model.

CB1.3 Use of test data

Generally, the use of data is expected to replace only a small part of the overall process. For example, data may be used to derive the drag coefficient for an unusual roof shape, or to assess the strength of the heel connection in a truss. It is, therefore, important to identify very clearly which part of the design process is being replaced.

The Committee anticipates that other parts of this suite of Standards and other material design Standards will provide additional rules appropriate for their situations (e.g., wind tunnel test, load test for timber, steel etc.).

CB1.4 Modelling

To prepare for testing, the limit state under consideration should be clearly defined.

An appropriate test rig should be designed and boundary conditions defined.

Possible failure modes should be considered and possible structural behaviour during the test and at failure investigated.

Any eccentricities not inherent in the design of the structure or element, or not resulting from typical loading in service, should be avoided. Care should be exercised to ensure the testing system and the loading arrangements do not create inadvertent restraints on the unit under test. The conditions during testing may differ from the actual conditions in use and these should be accounted for. Among these are the following:

(a) Size effects.

(b) Time effects.

(c) Boundary condition effects.

(d) Environmental effects (humidity, temperature, etc.).

(e) Workmanship (test specimen versus production sampling).

Specimens for testing should be evaluated for appropriate properties (e.g., geometrical properties, material variations) or drawn using appropriate sampling methods from a defined representative population of known properties.

CB1.5 Report

This is a check list of items that should be reported so that the assessor can decide whether the proposed use of data is acceptable.

CB2 PROOF TESTING

CB3 PROTOTYPE TESTING

APPENDIX CC

GUIDELINES FOR SERVICEABILITY LIMITS

The values given in Appendix C of the Standard are not appropriate in all cases and, therefore, can not be normative.

Design methods are based on the probable maximums for loads and probable minimums for materials strengths. Calculations will only give a guide to the likely deflections and, once constructed, the actual loads experienced together with the actual strengths or stiffnesses of materials will greatly influence the outcome.

Useful guidelines for determining where serviceability becomes critical may be obtained from ISO 4356 and ISO 10137 (for vibration considerations).

APPENDIX CD

FACTORS FOR USE WITH AS 1170.4—1993

This Appendix is provided as an interim measure until the revision of AS 1170.4—1993 is completed, to enable AS 1170.4—1993 to be used in conjunction with AS/NZS 1170.0.

The provision of annual probabilities of exceedance for earthquake necessitates the use of a probability factor. Also the importance factor has to be removed.

APPENDIX CE

FACTORS FOR USE WITH AS 1170.3—1990

This Appendix is provided as an interim measure until the revision of AS 1170.3—1990 is complete to enable AS 1170.3—1990 to be used in conjunction with AS/NZS 1170.0.

The provision of annual probabilities of exceedance for snow necessitates the use of a probability factor.

A1

APPENDIX CF

ANNUAL PROBABILITY OF EXCEEDANCE (FOR AUSTRALIAN USE ONLY—STRUCTURES FOR WHICH DESIGN EVENTS ARE NOT GIVEN)

CF1 GENERAL

The structural design actions Standards (AS/NZS 1170 series) can be used within a number of different legislative frameworks. Typically, legislation will give legal weight to some regulations. The regulations reference the structural design actions. Some examples are as follows:

(a) *Most Australian buildings* State government legislation calls for all building under the local government jurisdiction to comply with the provisions of the Building Code of Australia (BCA). The BCA in turn references AS/NZS 1170:2002 (all parts) and provides the design events (in terms of annual probability of exceedance) for wind, earthquake and snow ultimate limit states.

(b) *Mine structures in WA* The Mines Act calls for mine structures to resist the loads given in AS 1170. In this case, the Standard must provide its own annual probability of exceedance for wind, earthquake and snow ultimate limit states events.

(c) *Structures for statutory bodies* Such structures may include publicly owned services, public buildings, communications structures, power transmission and distribution structures, roads, etc. (requirements differ from State to State). In many cases, these structures are exempt from the provisions of the BCA.

In the cases described in examples (b) and (c) above, the regulations do not contain the design events (in terms of annual probability of exceedance) for wind, earthquake and snow ultimate limit states. In order to provide the appropriate design framework for engineers performing the structural design for these types of facilities, there must be a parallel set of probabilities to give designers the criteria they need.

Appendix F of AS/NZS 1170.0 is only used where the normal legislative and regulatory framework **does not** establish the design events (in terms of annual probability of exceedance) for wind, earthquake and snow ultimate limit states. It is 'Normative'.

Appendix F is intended to deliver the same design criteria as those given in the BCA for equivalent structures (as published in Amendment No. 11 to the BCA, July 2002) except that for high consequence structures the annual probability has been adjusted to a more logical range similar to that used in New Zealand. The criteria given are minimum criteria and can be exceeded if other considerations make it appropriate to use a more conservative design.

The Appendix uses a two-step process to determine the design events as follows:

(i) *Step 1* Determine importance level of the structure (Table F1).

(ii) *Step 2* Identify the design events (in terms of the annual probability of exceedance) for wind, earthquake and snow ultimate limit states (Table F2) using the design working life and the importance level of the structure.

A1

CF2 IMPORTANCE LEVELS

The four importance levels in Table F1 reflect the importance levels for equivalent buildings in the BCA. This Table is drafted in more generic terms to give it wider applicability. Both the BCA tables and Table F1 are based on the relative magnitude of risk to life in extreme events. Where it is possible to consider multiple uses for the structure, then the highest applicable importance factor is used for design. This is appropriate and conservative. Such structures would include those that provide sole access or would be required to provide access where the design event occurred, that is, the design event for the more important structure.

The background of the importance levels is as follows:

(a) Importance level 1 is for structures that present a much lower than normal risk to life and property. Such structures will be minor, isolated, rarely contain people and not required as part of normal infrastructure. They are almost expendable.

(b) Importance level 2 covers most structures. This is the 'normal' level and is the default level into which most structures will fall. In the BCA, it includes domestic housing and structures intended to contain reasonable numbers of people under normal operations. Such structures are not designed to contain large numbers of people and activities in them should not be associated with post-disaster functions or hazardous substances. A number of industrial applications may fall into this category.

(c) Importance level 3 is for structures that may house large numbers of people. The risk to life and property is much more significant in these types of structures, and the design event will reflect the higher reliability required for the safety of the larger number of people that may be in them. For example, the BCA (Guide) suggests 5000 people in total or 300 concentrated in one area. Many public buildings fall into this category. (For structures covered by the BCA, the Guide to the BCA includes a Table covering what structures fall into each importance level, which has the same numbers as the USA Standard, ASCE 7.)

(d) Importance level 4 is for structures that, directly or indirectly, may pose a very substantial risk to life. These types of structures include structures that support immediate post-disaster response and recovery functions. These can include essential infrastructure such as hospitals, emergency water supply head-works, emergency power generation facilities, essential communications and transportation links. This classification also includes potentially hazardous activities. Where containment of hazardous substances is involved (such as radioactive materials or highly toxic chemicals), then structural failure may have significant community health impacts. An importance level 4 should be attached to these structures.

(e) Importance level 5 is for structures that must be considered on a case-by case basis. The paragraphs below headed 'catastrophic consequences and very long design lives' give guidance where a more conservative approach is indicated by the magnitude of the effect of a failure in a large event.

The normative clauses of the Standard do not contain examples, but Table F1 indicates the characteristics of the functions performed in structures that fall into each of the importance levels.

CATASTROPHIC CONSEQUENCES AND VERY LONG DESIGN LIVES

For some structures, the magnitude of the loss would justify a full risk analysis. Structures with a very long design working life also would require a risk analysis. A full risk analysis may lead to annual probabilities of exceedance lower than those given in Appendix F.

Such structures are almost exclusively of major importance to the community. They might include extreme hazard facilities whose failure would potentially affect a large region or a large number of people (e.g., a major dam or a hazardous chemical facility close to a major city).

A1

CF3 DESIGN EVENTS

AS/NZS 1170.2, *Wind actions*, AS/NZS 1170.3, *Snow and ice actions* and AS 1170.4, *Earthquake loads* (as modified by Appendix D of AS/NZS 1170.0) each require designers to determine the annual probability of exceedance of ultimate limit states design events. For cases in Australia that do not have this information provided in statutory regulations, the information may be drawn from Table F2.

The design event is influenced by both the required reliability and the planned lifetime of the structure, as follows:

(a) The required reliability is indicated by the importance level. Structures with a very high importance level will require a 'high reliability'. This will be reflected in generally lower probabilities of exceedance for the ultimate limit states design event.

(b) The longer a structure is in place, the greater the chance of experiencing an event of a given intensity. Conversely, if a structure has a short design life, then it will have a lower probability of experiencing a serious event. The paragraphs at the end of Paragraph CF2 give guidance where a more conservative approach is indicated by the choice of a very long design working life.

Table F2 combines the importance level and the design working life to give a design event for each action being considered. The design events are specified in terms of the annual probability of exceedance for each of non-cyclonic wind, cyclonic wind, snow and earthquake actions.

The normal design working life assumed is 50 years. The values for 25 years are included to allow for a reduction in loads for structures with short design working life compared to normal structures. A shorter design working life might be relevant for structures such as mining installations where the mine has a predictable life. For retractable structures, the design working life for wind should be the total time the structure is extended and exposed to the wind.

The values for structures of a temporary nature are given in order to provide consistent design values across a number of temporary situations. For example, design may be required for structures in situations where construction is continuing and the structure is in place for only a couple of weeks. Such structures are unlikely to be required to be importance level 4. The values for 5 years are included to allow a reduction in the loads for importance level 1 structures. This would primarily be of relevance for primary produce structures.

The values for 6 months or less cover structures constructed for a short-term purpose (for example, a grandstand for a single event). Some allowance has been made to account for the common re-use of components used for such structures and the resulting level of inspection of the component parts. A lower annual probability of exceedance should be considered where components are to be used for a total cumulative design working life of more than 15 years.

The main reason for the lower probabilities for cyclonic wind is that any structures with lower design loads may provide a source of flying debris during a cyclone and, therefore, increase the damage to other structures. It is acknowledged that in cyclone areas, the wind speeds expected outside the cyclone season are much lower than those specified in the Standard, but the committee could not rely on supervision being of a level to ensure that a temporary structure would be demolished when intended (for example, in the case of a bankruptcy).

The values for construction equipment relate to the 6 months values for importance level 2.

APPENDIX CZ

ADDITIONAL LOAD INFORMATION

CZ1 MOVEMENT EFFECTS

Movement effects include internal strain effects associated with foundation settlement, prestress, welding, shrinkage, creep, and similar. The detailed specification of these effects is beyond the scope of the Standard. Information for the assessment of temperature effects is given below.

Many structures can accommodate the expansion or contraction of construction materials due to temperature or moisture content changes without giving rise to any significant action effects. Analyses for movement effects are necessary only in a few specific circumstances such as restrained concrete roofs.

Further information is available in the following references:

COONEY, R.C. and KING, A.B., '*Serviceability Criteria for Buildings*, Study Report SR14', Building Research Association of New Zealand, 1988.

RUSCH, H., JUNGWIRTH, D. AND HILSDORRF, H.K., '*Creep and shrinkage—Their Effect on the Behaviour of Concrete Structures*', Springer-Verlag, New York, 1983, 284 pp.

CZ2 THERMAL VARIATIONS

CZ2.1 General

Designers may use the following information to account for action effects in the structure resulting from a temperature profile differing from that at the time of construction. This information does not take into account the effects of rapid temperature changes from fires nor does it cover the situation of design at elevated temperatures.

CZ2.2 Structure type and influences

A temperature profile may exist in a structure at any given time. The form and variation of the temperature profile depends upon the nature of the heating and the properties and form of the structure. The temperature profile and its effects may be any one or all of the following:

(a) A uniform temperature causing overall expansion or contraction.

(b) A uniform temperature gradient causing bowing.

(c) A residual non-linear temperature profile, which may cause a self-equilibrating stress system within the structure.

Where the structure forms the interior of a building, it may be assumed to be at a uniform temperature equal to the current internal temperature of the building.

Where the structure is heated or cooled by some industrial process, temperatures should be calculated from reliable knowledge of that process. Material properties at the operating temperatures should be considered.

Where the structure is exposed to the environment, the temperature profile depends on the changes in meteorological conditions. The principal factors are ambient temperature, solar radiation and wind speed combined with the nature and orientation of the surface (e.g., colour), degree of exposure, and nature of the structure.

CZ2.3 Temperature data

Maximum uniform temperatures occur on days of simultaneous low wind speed, high solar radiation, and high average air temperature. Maximum temperature gradients occur on days of simultaneous low wind speed and high solar radiation, which start with a cold morning and develop into a hot afternoon. In the absence of more exact local information from the Commonwealth Bureau of Meteorology, the data given in Table CZ1 may be used to compute extreme temperatures in a structure exposed to the environment. The extreme temperatures given in Table CZ1 have been derived from Bureau of Meteorology data and represent extreme events with an annual probability of exceedance of 0.04 (1/25).

Minimum temperatures occur just before dawn after re-radiation of heat to a clear night sky. An exposed surface temperature of −5°C may be used in the absence of exact local information.

CZ2.4 Combination factor

The combination factor of 1.25 may be used where thermal action is computed from the temperature information given in Table CZ1. This factor may not be suitable for other types of thermal actions such as those due to industrial processes or to fire.

TABLE CZ1

EXTREME AUSTRALIAN TEMPERATURES IN STRUCTURES EXPOSED TO ENVIRONMENT

Region	A	B	C
Shade temperatures			
Seasonal range of mean dry bulb temperature (°C)	11	11	17
Highest temperature excess above summer mean (°C)	14	22	19
Lowest temperature depression below winter mean (°C)	17	14	17
Extreme temperature range (°C)	42	47	53
Temperature and radiation effects:			
For maximum uniform temperature			
Max. external air temperature (°C)	35	37	42
Min. external air temperature (°C)	26	22	21
Average wind speed (km/h)	7	7	7
Irradiance at noon (watts/m^2)	1 070	1 025	1 090
For maximum differential temperature			
Max. external air temperature (°C)	31	28	38
Min. external air temperature (°C)	12	13	14
Average wind speed (km/h)	5	5	5
Irradiance at noon (watts/m^2)	1 020	1 040	1 100

LEGEND:

A = Australian North Coastal Region—within 400 km of nearest coast north of 25°S

B = Australian South Coastal Region—within 400 km of nearest coast south of 25°S including Tasmania but not including land ≥1000.0 m above sea level

C = Australian Interior Region—more than 400 km from nearest coast

NOTE: The values in the Table are based on an annual probability of exceedance of 0.04.

Further information is available in the following references:

HIRST, M.J.S., ‘Design values for thermal loading of concrete roofs’, *American Concrete Institute Journal*, Nov./Dec. 1984.

PRIESTLY, M.J.N. and BUCKLE, I.G., ‘*Ambient Thermal Responses of Concrete Bridges*’, RRU Bulletin No. 42, National Roads Board, 1979, 83 pp.

THURSTON, S.J., ‘*Thermal Stresses in Concrete Structures*’, Civil Engineering Report 78-21, University of Canterbury, 1978.

PRAKASH, R., '*Temperature Distributions and Stresses in Concrete Bridges*', ACI Proceedings, Vol. 83 No. 4, 1986, pp.588-596.

ELBADRY, M. and GHALI, A., '*Thermal Stresses and Cracking of Concrete Bridges*', ACI Proceedings, Vol. 83 No. 6, 1986, pp. 1001-1009.

AMENDMENT CONTROL SHEET

AS/NZS 1170.0 Supp 1:2002

Amendment No. 1

REVISED TEXT

SUMMARY: This Amendment applies to the Appendix CF (new).

Published on 28 November 2003.

Standards Australia

Standards Australia is an independent company, limited by guarantee, which prepares and publishes most of the voluntary technical and commercial standards used in Australia. These standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth government, Standards Australia is recognized as Australia's peak national standards body.

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