2 DEFINITIONS

2.1 General. The following terms are defined for general use in this Code. Specialized definitions appear in individual sections:

ADMIXTURE. A material other than portland cement, aggregate, or water added to concrete to modify its properties.

AGGREGATE. Inert material which is mixed with portland cement and water to produce concrete.

ANCHORAGE. See Section 5. Also, the means by which the prestress force is permanently transferred to the concrete.

BEAM. An element subjected primarily to loads producing flexure.

BONDED TENDON. Prestressing tendon that is bonded to concrete either directly or through grouting.

CAPACITY DESIGN. In the capacity design of earthquake resistant structures, elements of the primary lateral load resisting system are chosen and suitably designed and detailed for energy dissipation under severe deformations. All other structural elements are then provided with sufficient strength so that the chosen means of energy dissipation can be maintained.

COLUMN. An element subjected primarily to compressive axial loads.

COMPOSITE CONCRETE FLEXURAL MEMBERS. Concrete flexural members of precast or cast-in-place concrete elements or both, constructed in separate placements but so interconnected that all elements respond to loads as a unit.

CONCRETE. A mixture of portland cement or any other hydraulic cement, sand, coarse aggregate and water.

CONCRETE, STRUCTURAL LIGHTWEIGHT. A concrete containing lightweight aggregate and having a unit weight not exceeding 1850 kg/m^3. In this Code, a lightweight concrete without natural sand is termed "all-lightweight concrete", and lightweight concrete in which all sand consists of normal weight is termed "sand-lightweight concrete".

CONCURRENCY. The occurrence of simultaneous seismic actions along both principal axes of the structure.

CONSTRUCTION JOINT. An intentional joint in concrete work detailed to ensure adequate strength and serviceability.

CURVATURE FRICTION. Friction resulting from bends or curves in the specified prestressing tendon profile.

DEFORMED REINFORCEMENT. Reinforcing bars conforming to NZS 3402P.

DEVELOPMENT LENGTH. The embedded length of reinforcement required to develop the design strength of the reinforcement at a critical section (see 5.3).

DIAPHRAGM. A horizontal member composed of a web (such as floor or roof slab) or a horizontal truss which distributes horizontal forces to the vertical resisting elements.

DUCTILE FRAME. A structural frame possessing ductility (refer NZS 4203).

EFFECTIVE PRESTRESS. The stress remaining in the tendons after all calculated losses have been deducted, excluding the effects of superimposed loads and the weight of the member; stresses remaining in prestressing tendons after all losses have occurred excluding effects of dead load and superimposed load.

EMBEDMENT LENGTH. The length of embedded reinforcement provided beyond a critical section.

EMBEDMENT LENGTH, EQUIVALENT. The embedded length of reinforcement which can develop the same stress in the reinforcing as that which can be developed by a hook or mechanical anchorage.

END ANCHORAGE. Length of reinforcement, or a mechanical anchor, or a hook, or combination thereof, required to develop stress in the reinforcement; mechanical device to transmit prestressing force to concrete in a post-tensioned member.

ENGINEER. The Local Authority's principal Engineer who shall be registered under the Engineers Registration Act 1924 and who is the holder of a current annual practicing certificate; his deputy or assistant appointed by the Local Authority to control the erection of buildings, or the registered engineer appointed by the Highway or Railway Authority to control the erection of bridges.

JACKING FORCE. In prestressed concrete, the temporary force exerted by the device which introduces the tension into the tendons.

LOAD:

LOAD, DEAD. Includes the weight of all permanent components of a structure, for example, for buildings – includes walls, partitions, columns, floors, roofs, finishes and fixed plant and fittings that are an integral part of the structure.

LOAD, DESIGN. Combinations of factored loads used in design as set out in NZS 4203 or other appropriate loadings code. In seismic design the design load may be either the factored loads or the load resulting from the capacity design procedure depending on the case being considered.

3.5 Principles and requirements additional to 3.3 for the analysis and design of structures subjected to seismic loading

3.5.1 *Methods of design*

3.5.1.1 To provide minimum resistance for the appropriate combination of gravity and seismic loads specified by NZS 4203 or other appropriate loading code, design methods shall be used which are applicable to the structural systems as follows:

(a) Ductile structures resisting seismic loading and undergoing inelastic displacements are required to dissipate energy by ductile flexural yielding in specified localities of the structure. Ductile structures shall be subject to capacity design as defined in Section 2. Adequate ductility and hysteretic dissipation of seismic energy may be considered to have been provided for, if all primary earthquake resisting elements of such structures are designed and detailed in accordance with this Code

(b) Structures of limited ductility are assumed to have low inelastic deformation demand and are designed to resist seismic loads derived with the use of larger structural type factors, as specified in NZS 4203 or other appropriate loading code. Member strength is determined either with capacity or strength design procedures according to Section 14

(c) Elastically responding structures are not expected to develop inelastic deformations while resisting the largest seismic loads specified by NZS 4203, or other appropriate loading code. Accordingly they may be designed to conform to 3.3 and are exempt from the seismic requirements for detailing for ductility.

3.5.1.2 For structures subjected to seismic loading, the alternative method of design, given in Appendix B, shall not be used.

3.5.1.3 Wherever the requirements of a capacity design procedure apply, the maximum member actions to be expected during large inelastic deformations of a structure shall be based on the overstrength of the potential plastic hinges.

3.5.1.4 The interaction of all structural and non-structural elements which, due to seismic displacements, may affect the response of the structure or the performance of non-structural elements, shall be considered in the design of that structure.

3.5.1.5 Consequences of failure of elements that are not a part of the intended primary system for resisting seismic forces shall also be considered.

3.5.1.6 Floor and roof systems in buildings shall be designed to act as horizontal structural elements, where required, to transfer seismic forces to frames or structural walls.

3.5.1.7 Structural systems and design methods, other than those covered in this Code, may be used only if it can be shown by analysis or experiment, based on accepted engineering principles, that adequate strength, stiffness and ductility for the anticipated seismic movements have been provided for.

3.5.2 *Seismic loading*

3.5.2.1 In the derivation of the lateral seismic loading, to be considered with the appropriately factored gravity load, the structural type factor S, the structural material factor M, specified by NZS 4203 or other approved codes, shall be used. The same structural type factor S shall be substituted in all relevant equations of the additional seismic requirements of this Code.

3.5.2.2 Where modified capacity design procedures are used, the appropriate factors for member overstrength, dynamic moment and shear magnification shall be used to determine the design actions on members.

3.5.2.3 In considering the concurrency of seismic effects in two-way horizontal force resisting systems the following requirements shall be satisfied:

(a) Columns and walls, including their joints and foundations, which are part of a two-way horizontal force resisting system, shall be designed, in accordance with the requirements of NZS 4203, for concurrent effects resulting from the simultaneous yielding of all beams or diagonal braces framing into such columns or walls from all directions at the level under consideration and as appropriate at other levels

(b) When the design actions on columns, walls or foundations have been derived from capacity design procedures with appropriate magnifications for dynamic, concurrency and other extreme seismic effects, the intent of 3.5.2.3 (a) may be deemed to have been satisfied if components of such two-way framing systems are designed separately for the maximum actions so derived for each of the principal directions of the seismic loading

(c) Bridge members shall be designed for any additional forces resulting from seismic actions along both major axes of the structure concurrently, such as those due to friction or shear stiffness of devices intended to prevent horizontal movement in a direction perpendicular to that being considered.

3.5.3 *Assumptions and methods of analysis*

3.5.3.1 In determining the minimum strengths for members, designed for the maximum effects of factored static loads determined by elastic analysis, or for effects derived from dynamic analysis, as permitted by NZS 4203 or other appropriate loading code, the strength reduction factors specified in Section 4 shall be used.

3.5.3.2 Structures classified in 3.5.1.1 (a), such as ductile frames composed of beams and columns with or without shear walls, and also cantilever or coupled shear walls and bridge piers, shall be assumed to be forced into lateral deformations sufficient to create reversible plastic hinges by actions of a severe earthquake.

(b) The requirements of Section 14, wherever the actions that could be transmitted by the superstructure at the top of the foundations are equal or larger than those which would result from the application of lateral earthquake loading to the superstructure corresponding with $SM = 1.6$.

3.5.12.5 *Rocking foundations.* When special studies are carried out to the satisfaction of the Engineer, structural walls may be assumed to limit the seismic loads induced in the structure by rocking with their foundations, provided that:

(a) The vertical design loads on the foundations are determined from factored gravity loads together with overstrength contributions of adjacent slabs, beams and other elements which may be yielding during the rocking of the wall system, and having regard to all accelerations induced in the superstructure during rocking

(b) The lateral design load acting simultaneously with the vertical forces, in accordance with 3.5.12.4 (a), are determined from special studies.

3.5.12.6 *Lateral forces on retaining walls and piles.* Particular attention shall be given to forces that might develop against retaining walls and piles during earthquakes.

3.5.12.7 *Uplift forces.* Uplift forces that may act on foundation pads during earthquakes, shall be considered to ensure that, when necessary, adequate flexural tension reinforcement is provided in the top of isolated footing pads or in other localities of continuous or combined footings or rafts, where under gravity load compression stresses would prevail. Such reinforcement shall not be less than 0.001 times the gross sectional area of such a pad.

3.5.13 *Structures incorporating mechanical energy dissipating devices.* The design of structures incorporating flexible mountings and mechanical energy dissipating devices is acceptable provided that the following criteria are satisfied:

(a) The performance of the devices used is substantiated by tests

(b) Proper studies are made towards the selection of suitable design earthquakes for the structure

(c) The degree of protection against yielding of the structural members is at least as great as that implied in this Code relating to the conventional seismic design approach without energy dissipating devices

(d) The structure is detailed to deform in a controlled manner in the event of an earthquake greater than the design earthquake.

3.5.14 *Secondary structural elements*

3.5.14.1 Secondary elements are those which do not form part of the primary seismic force resisting system, or are assumed not to form such a part and are therefore not necessary for the survival of the building as a whole under seismically induced lateral loading, but which are subjected to loads due to accelerations transmitted to them, or due to deformations of the structure as a whole. These are classified as follows:

(a) Elements of Group 1 are those which are subjected to inertia loading but which, by virtue of their detailed separations, are not subjected to loading induced by the deformation of the supporting primary elements or secondary elements of Group 2

(b) Elements of Group 2 are those which are not detailed for separation, and are therefore subjected to both inertia loadings, as for Group 1, and to loadings induced by the deformation of the primary elements.

3.5.14.2 Group 1 elements shall be detailed for separation to accommodate deformations $\nu\Delta$ and Δ_p. Such separation shall allow adequate tolerances in the construction of the element and adjacent elements, and, where appropriate, allow for deformation due to other loading conditions such as gravity loading. For elements of Group 1:

(a) Loading E_p used in the design shall be that specified in NZS 4203

(b) Analysis may be by any rational method

(c) Detailing shall be such as to allow ductile behaviour and in accordance with the assumptions made in the analysis. Fixings for precast units shall be designed and detailed in accordance with 3.5.15.

3.5.14.3 Group 2 elements shall be detailed to allow ductile behaviour and in accordance with the assumptions made in the analysis. For elements of Group 2:

(a) Additional seismic requirements of this Code need not be satisfied when the design loadings are derived from the imposed deformations $\nu\Delta$, specified in NZS 4203, and the assumptions of elastic behaviour

(b) Additional seismic requirements of this Code shall be met when plastic behaviour is assumed at levels of deformation below $\nu\Delta$

(c) Inertia loading E_p shall be that specified by NZS 4203

(d) Loadings induced by the deformation of the primary elements shall be those arising from the level of deformation $\nu\Delta$, specified in NZS 4203 having due regard to the pattern and likely simultaneity of deformation

(e) Analysis may be by any rational method, in accordance with the principles of elastic or plastic theory, or both. Elastic theory shall be used to at least the level of deformation corresponding to and compatible with one-quarter of the amplified deformation, $\nu\Delta$, of the primary elements, as specified in NZS 4203