NZS 4219:1983

Specification for

SEISMIC RESISTANCEOF ENGINEERING SYSTEMS IN BUILDING

AMENDMENTS NO1&2
APPENDED

NEW ZEALAND STANDARD

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NEW ZEALAND STANDARD

Specification for

SEISMIC RESISTANCE OF ENGINEERING SYSTEMS IN BUILDINGS

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COMMITTEE REPRESENTATION

This Standard was prepared under the supervision of the Building and Civil Engineering Sectional Committee (38/–) for the Standards Council, established under the Standards Act 1965. The committee consisted of representatives of the following:

Association of Consulting Engineers of New Zealand
Building Research Association of New Zealand
*Department of Scientific and Industrial Research
Housing Corporation of New Zealand
Institution of Professional Engineers New Zealand
*Ministry of Works and Development
Municipal Association of New Zealand
New Zealand Contractors Federation
New Zealand Counties Association
*New Zealand Institute of Architects
New Zealand Manufacturers' Federation
New Zealand Master Builders' Federation
New Zealand Timber Merchants' Federation

The Seismic Resistance of Building Services Committee (38/13) was responsible for the preparation of the Standard and consisted of representatives of the following organizations in addition to those marked with an asterisk (*) above:

Earthquake and War Damages Commission
New Zealand Electricity Department
Post Office

In addition to the above representation Mr F. Blackwell was co-opted to assist in the committee's work.

RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

- NZS 3404:1977 *Code for design of steel structures (with commentary)*
- NZS 4203:1976 *Code of practice for general structural design and design loadings for buildings*

BRITISH STANDARDS

- BS 1387:1967 *Steel tubes and tubulars suitable for screwing to BS 21 pipe threads*
- BS 1775:1964 *Steel tubes for mechanical, structural and general engineering purposes*
- BS 3601:1974 *Steel pipes and tubes for pressure purposes – carbon steel with specified room temperature properties*

AUSTRALIAN STANDARDS

- AS 1111:1972 *ISO metric hexagon commercial bolts and screws*
- AS 1250:1975 *Rules for the use of steel in structures*

NATIONAL FIRE PROTECTION ASSOCIATION (USA)

- NFPA 13:1972 *Installation of sprinkler systems*

SHEET METAL INDUSTRY FUND OF LOS ANGELES

- SMACNA 1976 *Guidelines for seismic restraints of mechanical systems*

The users of this Standard should ensure that their copies of the above mentioned New Zealand Standards or of overseas standards endorsed as suitable for use in New Zealand are the latest revisions or include the latest amendments. Such amendments are listed in the annual SANZ *Catalogue* which is supplemented by lists contained in the monthly magazine *Standards* issued free of charge to committee and subscribing members of SANZ.

FOREWORD

This Standard makes recommendations to enable engineering systems in buildings to be designed and installed to withstand damage comparable with damage caused to the structure and other building elements by earthquake induced forces.

Recent investigations have shown that buildings may not be usable after an earthquake because of damage to essential services and other non-structural elements even though the structure may have suffered only modest damage. In addition to life safety hazards, heavy financial losses have resulted from direct damage to equipment, consequential fires, and water leakage.

The second part of the Standard is set out in a clause and commentary format. The information contained within this Section and that in Appendix A, extracted from NZS 4203:1976, should be adequate for most normal installations. Relatively flexible equipment with an amplified response has shown the greatest propensity to damage and requires special care in assessing the loading. The information included for the design of fixings and supports is intended only for minor components related to specific items of equipment and should not be used to size primary or secondary structural elements of the building for which the appropriate materials codes should be consulted.

Examples of the application of information in Part 2 are appended as Appendix B. These are not intended to be exhaustive, nor are they the only interpretations of the information given.

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Director, Standards Association of New Zealand, Private Bag, Wellington.

NEW ZEALAND STANDARD

Specification for
SEISMIC RESISTANCE OF
ENGINEERING SYSTEMS IN BUILDINGS

1 GENERAL

1.1 Scope

1.1.1 This document sets out the installation, design and restraining requirements for engineering systems in buildings. Each system is dealt with separately as listed in the table of contents.

1.1.2 Individual items of equipment exceeding 20% of the total deadweight of the floor on which it is located, or individual items of equipment exceeding 10% of the total deadweight of the structure, shall be subject to a special study.

1.1.3 Seismic requirements for the design and operation of lifts and the securing to the building structure of lift machinery, standby, and related equipment, are detailed in the Power Lift Rules 1980. These rules are issued by the Marine Division of the Ministry of Transport.

1.1.4 Equipment essential to the building operation shall be included even though not permanently fixed to the building, but portable equipment is excluded.

C1.1.4 The object of this subclause is to ensure that essential equipment such as that for life safety, fire fighting, and emergency lighting, is adequately protected. This will include attention to fixing ancillary equipment such as batteries or small fuel tanks.

1.2 References

1.2.1 In this Standard, the word 'shall' indicates a requirement that is to be adopted in order to comply with the Standard, while the word 'should' indicates a recommended practice.

1.2.2 Subject to 1.2.1, clauses prefixed by 'C' printed in italic type are intended as comments on the corresponding mandatory clauses.

1.2.3 Where any other standard named in this Standard has been declared or endorsed in terms of the Standards Act 1965, then:

(a) Reference to the named standard shall be taken to include any current amendments declared or endorsed in terms of the Standards Act 1965, or

(b) Reference to the named standard shall be read as reference to any standards currently declared or endorsed in terms of the Standards Act 1965 as superseding the named standard, including any current amendments to the superseding standard declared or endorsed in terms of the Standards Act 1965.

C1.2.3 The date at which amendments or superseding standards are regarded as 'current' is a matter of law depending upon the particular method by which this standard becomes legally enforceable in the case concerned. In general, if this is by contract, the relevant date is the date on which the contract is created, but if it is by Act, regulation or bylaw, then the relevant date is that on which the Act, regulation or bylaw is promulgated.

1.2.4 The full titles of reference documents cited in this Standard are given in the 'List of related documents' immediately preceding the Foreword.

1.3 Definitions

1.3.1 For the purpose of this Standard the following definitions shall apply:

ANCHOR. The device used to connect the equipment to the building, foundation or ground.

BRITTLE COMPONENT. A component which lacks ductility.

BUILDING CLASS. A classification of buildings to allow for their importance to the community,
- CLASS I Essential facilities which should not be rendered non-functional due to earthquakes.
- CLASS II Important buildings which should be restored to service as soon as possible typically designed as "public buildings".
- CLASS III Buildings not in Class I or II. Examples of Class I and II buildings are given in NZS 4203.

CONNECTION. The component used to transmit earthquake forces between parts of equipment or equipment and the building (see ANCHOR).

DESIGN LOAD. The assessed maximum load due to earthquake and other effects used to proportion and size component parts of equipment.

DUCTILITY. The ability of equipment or component to undergo repeated and reversing inelastic deflections beyond the point of first yield while maintaining a substantial proportion of its initial maximum load carrying capacity.

DUCTING. Sheet metal or other enclosure for air, gas, smoke or vapour distribution or extraction from building.

ELASTIC DESIGN. A design method in which all components are proportioned to remain elastic.

EMERGENCY POWER AND LIGHTING. Electric power and lighting service pertaining to safe egress or the containment of hazardous substances.

EQUIPMENT. Any item, part or component of a service falling within the scope of this Standard as defined in 1.1.

EQUIPMENT DISPLACEMENT. The estimated maximum relative movement between items of equipment or between equipment and the building elements under condition of earthquake loading.

EQUIVALENT STATIC FORCE ANALYSIS. A method of analysis using static forces to simulate the effects of earthquake ground motion.

FIXING. See ANCHOR.

FLEXIBLY MOUNTED EQUIPMENT. Equipment constructed or fixed on mounts with a period of vibration greater than or equal to 0.10 s or as defined under the relevant clauses.

GEOMETRICAL PROPERTIES. The dimensional properties of components and member sections which affect stability under earthquake load.

HAZARDOUS SUBSTANCE. A substance which, if released, could cause injury to the building occupants, either directly or as a consequence of some secondary effect, such as fire or explosion.

HORIZONTAL LOADING OR DEFLECTION. The horizontal component of the earthquake induced loading or deformation.

INTERSTOREY DISPLACEMENT. The design relative movement between successive floors measured parallel to the lower floor.

INSERT. A pre-made fixing set in concrete.

INELASTIC DESIGN. A design philosophy which provides for controlled yielding.

LONGITUDINAL BRACING. Bracing in systems of pipework or ductwork providing restraint to movement in the direction of the pipe or duct run.

LUMINAIRE. Lighting fixture.

NON-SPECIFIC EQUIPMENT. Equipment not made for a given location in a particular building.

NON-STRUCTURAL FIXINGS. Fixings not forming part of the main building system load transmission.

PLANT. See EQUIPMENT.

POSITIVE FIXING. A fixing in which components are held in place in such a manner that permanent relative movement cannot take place without exceeding the yield of one or more parts.

PROPRIETARY EQUIPMENT. Equipment intended for general use in any building and forming part of the supplier's normal product range.

RESILIENT MOUNT. A mount designed to support equipment but isolate the transmission of vibration to or from the structure.

RIGIDLY MOUNTED EQUIPMENT. Equipment constructed or fixed in such a manner that the first mode period is less than 0.05 s.

SEISMIC LOADING. The design load on the building or equipment due to earthquake effects.

SEISMIC RISK CATEGORY. A means of classifying equipment and services based on importance and effect of failure in an earthquake.

SERVICES. The fixed component parts of a building engineering system (see also EQUIPMENT).

STRENGTH DESIGN. A design procedure in which the working loads are multiplied by a factor appropriate to their uncertainty and members are proportioned using their yield strength or crippling strength.

VERTICAL LOADING. The vertical component of the earthquake induced loading.

WORKING STRESS DESIGN. A design procedure in which members are proportional using working loads and the allowable stresses. Allowable stresses are determined by dividing the yield stress or crippling load by a factor.

1.4 Symbols

1.4.1 In this Standard, symbols shall have the following meanings:

C_p Seismic design coefficient for equipment (NZS 4203)

F_p Seismically induced horizontal force or equipment (NZS 4203)

Ft_f Tensile stress in bolt

Fu_w Nominal tensile strength of welding electrode (table 1)

Fv_f Shear stress in bolt

F_y Material yield stress (table 1)

Fy_f Yield stress of fastener (table 1)

f_n Resultant direct stress normal to throat of weld (table 1)

f Sum of shear stresses in weld in plane of throat (table 1)

fy, Ultimate tensile strength of stud material (table 1)

K_p Equipment support stiffness *(C2.2.7)*

M_p Equipment mass *(C2.2.7)*

P Maximum applied tension load in fixing (2.11)

P_u Ultimate pullout load of insert or anchor (2.11)

T Material thickness (table 3 and clause 2.6)

T_p Fundamental period of equipment

V Maximum applied shear load

$V\mu$ Ultimate tensile strength of shear cone in concrete

2 REQUIREMENTS

2.1 Building layout and design

2.1.1 The arrangement of engineering systems within the building shall allow for earthquake effects. The location, construction and fixing shall be such as to reduce possible life and injury hazards and shall protect property from damage commensurate with that required for the structure.

C2.1 Building layout and design

C2.1.1 Consideration must be directed to the role played by engineering systems in the protection of life and property and safe egress from the building, as well as the seismic resistance of the services and their component parts. The basic concepts of a building layout should be examined with the effect of an earthquake on the particular building. The following points are of special significance:

(a) The provisions for egress from the building, especially casualty clearing. Lifts may provide means of casualty clearance from upper levels but they could be out of action for a period after a major earthquake.

(b) The location of heavy plant at high level. This not only adds to the earthquake loading but also requires some main reticulation pipes and electric power to run the full height of the building, requires pumps for water, and makes the changing of plant or temporary replacement difficult.

(c) The operation of fire protection, emergency power and lift services should be checked for post earthquake operation.

(d) The seismic resistance of public utility services both to reduce the probability of damage and to provide for connection of temporary alternative services. Vehicle access, main pipe connections, the position of shut-off valves, meters, risers and main reticulation are all important. These services must be clearly identified.

(e) Fires may result from earthquake damage; kitchens and boiler rooms are potential high risk areas. These rooms should be located so that egress from the building will not be blocked by fire or smoke.

(f) Where gas or other hazardous substances may leak into occupied buildings it may be an advantage to install seismically operated shut-off valves.

(g) A close liaison between the services, the structural and the architectural designers is needed from the beginning of the job if earthquake resistance and the job in general is to be cost effective and well engineered.

(h) Broken glazing and failure of external walls, partitions, ceilings and doors can affect the operation of emergency services such as fire suppression and smoke venting and should be allowed for in the building design.

(j) The effect of heavy equipment on the structure and other building components should be considered. Heavy equipment breaking loose is a potential source of injury and building damage.

(k) Leakage of contents of pipes and vessels should be prevented from damaging equipment required to be operated immediately following an earthquake.

(m) Electric power supply sub-stations, main a.c. switchboards and the emergency standby power plant located below ground floor level introduces a potential hazard where there is a risk of flooding as a result of an earthquake. For most buildings broken mains are also likely causes of localized flooding. In either case, floors below ground level can easily be flooded to the stage where power plant is not only unserviceable but cannot be put back into service until it has been totally dismantled and cleaned. Modern high-rise buildings are so dependent on electric power for their operation that such potential hazards should be avoided if at all possible, even at the expense of floor space in some more desirable area of the building.

2.2 Earthquake loading. Earthquake loading shall be in accordance with NZS 4203.

C2.2 Earthquake loading

NZS 4203 procedure is intended for all elements of a normal building. To assist in its application to engineering installations the relevant clauses of NZS 4203 are summarized in Appendix A.

Occasionally the method described above may not model the system sufficiently accurately and a special analytical or experimental study may be required to derive appropriate loadings. Such instances are expected to be few and largely confined to special installations. Such studies shall be based on accepted methods of seismic analysis.

When an item of equipment whose mass is a significant proportion of the building mass and it is tuned to one of the building modes, interaction effects can occur and building and equipment should be considered together.

The response of equipment on the ground will be determined by its dynamic properties and the earthquake ground motion. The motion of equipment at higher levels in the building will be influenced by the building motion as it responds to the earthquake. If the equipment is tuned to the building and has little damping very high forces can result.

The equipment period may be assessed by experiment from:

$$T_p = 2\pi \sqrt{\frac{M_p}{K_e}}$$

where, T_p = *fundamental period (s)*

M_p = *equipment mass (kg)*

K_e = $\dfrac{\textit{Applied force (N)}}{\textit{Displacement (m)}}$

K_e *may be determined by applying a static horizontal force to the equipment. The force and deflection are recorded. The force should preferably be equivalent to the design static force applied at the centre of gravity.*

For guidance only typical first mode periods of equipment are:

Cooling tower	*0.45 s*
Water chiller	*0.40 s*
Pump set	*0.32 s*
Centrifugal fan	*0.45 s*
Free standing switchboard	*0.08 to 0.2 s*

These periods can vary over a wide range and must be used with extreme caution. Where possible measured or calculated values should be used. If the above values are used the period must be confirmed by site measurement and the earthquake loading adjusted accordingly.

2.3 Proprietary equipment. Proprietary equipment is equipment of standard manufacture not intended for a specific building, system, or position within a building. Proprietary equipment shall be manufactured and fixed in place to withstand seismic loadings in accordance with NZS 4203 without malfunction or damage.

Where the final application is unknown, a minimum C_p coefficient shall be used, which is the largest value obtained from NZS 4203 for the particular item.

C2.3 Proprietary equipment. *This clause is intended to provide for standard catalogued equipment. Where the type of occupancy or function of the building is not known, an importance factor I (see NZS 4203) of 1.6 should be used. More exact calculations can then be made when determining the fixings.*

2.4 Loading combinations. The equipment earthquake loads shall be applied in accordance with NZS 4203.

2.5 Building deformation. The building deformation shall be assumed to be in accordance with NZS 4203.

C2.5 Building deformation. *Provision should be made for a minimum displacement of three times the sum of the computed deflections or a minimum value of 0.004 times the height. This is based on twice the building separation requirement to allow for the movement to be taken up by services crossing the separation space.*

2.6 Inter-storey displacement. The inter-storey displacement shall be assumed to be in accordance with NZS 4203.

C2.6 Inter-storey displacement. *Inter-storey deflections measured between two successive floors parallel to the lower floor are limited to 0.01 of the storey height (0.57°) which unless more detailed calculations are made should be used for services installations. This is the maximum value for buildings designed to NZS 4203; when more precise values are calculated using the code lower values may be expected.*

2.7 Design principles. The earthquake resistant design of building services installations shall follow the same general principles as the earthquake resistant design of buildings and structures to NZS 4203 and appropriate materials codes with regard to ductility and the avoidance of brittle failure or buckling.

Steel members shall be proportioned for adequate strength and stiffness in accordance with the provisions of NZS 3404 using either the strength design method or the alternative (working stress) method.

C2.7 Design principles. *A large number of buildings and structures are designed to a relatively low seismic factor and their earthquake resistance is very dependent on post yield ductility. On the other hand, for many building services installations it will be more appropriate to secure equipment to withstand essentially elastically the earthquake design load, particularly where the operation of the equipment would be impaired by misalignment due to yielding of fixings in an earthquake. However, even in these cases the overall ductility of the installation should be considered in order to avoid a "sudden death" type of failure if the design earthquake load is exceeded.*

In a capacity check of earthquake resistant structures energy dissipating elements or mechanisms are chosen and suitably designed and detailed. All other structural elements are then provided with sufficient reserve strength capacity to ensure that yielding is confined to the chosen areas. A capacity check is most readily carried out in association with the strength method of design.

In the strength method of design, bending moments and forces in members are determined assuming elastic behaviour under the design loads. The member sizes are then proportioned so that their strengths are not exceeded under these ultimate moments and forces. In addition some parts of the structure are further increased in strength so that a premature collapse mechanism will not form under the action of ultimate loads.

In the working stress method bending moments and forces in members are determined assuming elastic

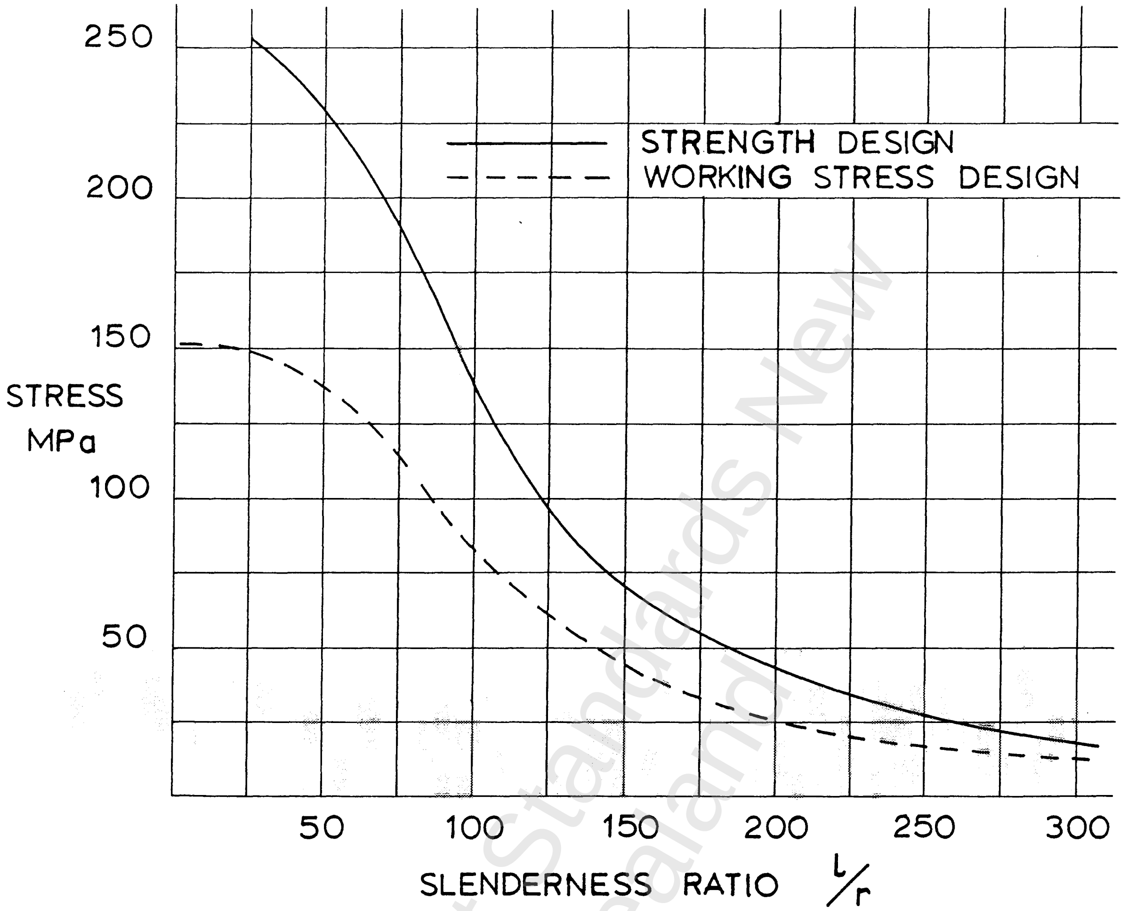


Fig. 1 MAXIMUM PERMISSIBLE STRESS IN STRUTS – MATERIAL STRESS (F_y) 250 MPa

NOTE (1) For other F_y refer to AS 1250:1981, NZS 3404:1977.
(2) For excentrically loaded struts refer to AS 1250.

behaviour under the design loads but, unlike strength design, working stress bases design on working loads and stresses. These allowable working stresses are the member ultimate strengths divided by a design factor.

The working stress approach does not therefore lend itself readily to an appreciation of the installations likely response to earthquake, so probable collapse mechanisms and the like can be appreciated and avoided. The alternative method is therefore unsuitable for capacity design requirements.

2.8 Allowable stress. Fixing brackets and small stands and supports shall be designed using the allowable stresses in table 1 or fig. 1.

C2.8 Allowable stress *Under earthquake conditions yielding will almost certainly occur unless high seismic factors of the order of 1 g or more are used. However, provided the installation has been designed to yield in specified regions so that damage is controlled and collapse mechanisms are avoided, the use of low seismic factors may be quite adequate. Yielding, whether it be tensile, compression or hinging, or some combination, absorbs energy and thus has the beneficial effect of damping the earthquake response of the installation.*

Where stands supports, and the like, become a significant structure in their own right they should be designed in accordance with NZS 4203 and relevant loadings codes.

2.9 Geometric properties

2.9.1 Members shall be proportioned to prevent local buckling and instability in the walls of round and square tubes, flange outstands, webs, and stiffeners. The requirements described herein refer to the more common structural members likely to be used for the support of services and equipment. The base document is NZS 3404 for fabricated sections or materials not covered.

2.9.2 *Section parameters for elastic design.* Where a member or portion of a member is unlikely to yield or form plastic hinges under earthquake loading, the criteria for elastic design apply.

2.9.3 *Effective cross-section.* The effective cross-section shall be calculated by deducting from the gross sectional area:

(a) The cross-sectional areas of excessive plate widths which exceed those given in table 2 or table 3 or both

(b) The sectional area of all holes in the section: For compression members rivet or bolt holes may be ignored. For a countersunk hole an equivalent diameter may be used.

Table 1 ALLOWABLE STRESSES (1)

	Ultimate strength design	Fy = *250 MPa*	*Working stress design*	Fy = *250 MPa*
BEAMS				
Round square and rectangular bars bent around axis of minimum strength	1.25 F_y	313	0.75 F_y	188
All other beams	1.10 F_y	275	0.66 F_y	165
Beams bent around axis of maximum strength (2)	0.75 F_y	188	0.45 F_y	112
Compressive stress	1.00 F_y	250	0.60 F_y	150
Shear stress based on web area	0.60 F_y	154	0.37 F_y	92
Average	0.75 F_y	188	0.45 F_y	112
Bearing stress	1.25 F_y	313	0.75 F_y	188
TENSION MEMBERS				
Average tensile stress	1.00 F_y	250	0.60 F_y	150
Bearing in tension members	1.25 F_y	313	0.75 F_y	188
CONNECTIONS				
Bolts, rivets, pins (3)				
tensile stress	1.00 Fy_f	240	0.60 Fy_f	144
shear stress	0.55 Fy_f	132	0.33 Fy_f	80
bearing stress (4)				
Bolt load places part in tension	2.25 F_y	262	1.35 F_y	337
Bolt load places part in shear	3.50 F_y	875	2.10 F_y	525
Welds (7)				
Butt complete penetration (5)	1.67 F_y	417	1.0 F_y	250
incomplete penetration	0.83 Fu_w	207	0.50 Fu_w	125
Fillet (6)	0.55 Fu_w	137	0.33 Fu_w	82

Symbols: F_y yield stress

Fy_f yield stress of fastener

Fu_w nominal tensile strength of electrode

NOTE (1) The use of this table is dependant on the compliance with the geometrical properties clause.
(2) Further details including other stresses are given in NZS 3404 and AS 1250, which should be consulted for major and structural components.
(3) Stresses are for bolts to AS 1111.
(4) Area is obtained by multiplying bolt shank diameter by plate thickness.
(5) F_y is the minimum value pertaining to the components being joined.
(6) Stress is calculated on maximum design throat thickness.
(7) Welds subjected to a combination of stresses shall comply with

$$\sqrt{(f_n^2 + 3f_v^2)} \leqslant 0.57\, Fu_w$$

where f_n is resultant direct stress normal to throat thickness, f_v is vector sum of shear stresses in plane of throat thickness and Fu_w is the nominal tensile strength of the electrode.

Table 2 SECTION PARAMETERS FOR ELASTIC DESIGN

Flange and plate outstands	
Maximum projection of plate or flange beyond its connection to a web or other line of support:	
Flanges and plates in compression with unstiffened edges	16 *T*
Flanges and plates in compression with stiffened edges including I sections, box sections and plates with continuously stiffened edges	16 *T*
Flanges and plates in tension	20 *T*
Flanges and plate, unsupported width	
Where a plate is connected to other parts of a built-up member along lines generally parallel to the longitudinal axis the maximum width between any two adjacent lines of connection or support shall not exceed:	
For plates in compression not stress relieved	35 *T*
Other plates	50 *T*
Plates in uniform tension	60 *T*
Circular hollow sections	
Round tubes used as struts or beams shall have their geometrical properties calculated from the outside diameter, *D*, and the tube thickness, *t*, provided that the tubes are supplied to one of the following Standards – BS 1387, BS 3601, grade 22 or 27, BS 1775	

NOTE This table is based on a material yield stress, F_y, of 250 MPa. For all other materials refer to AS 1250 and NZS 3404.

2.9.4 *Section parameters for regions of yielding*

2.9.4.1 Parts of members where yielding or plastic hinges form shall be proportioned as in table 3. For further details refer to NZS 3404.

Table 3 SECTION PARAMETERS FOR PLASTIC DESIGN

Compression outstands
Flanges, web stiffeners at plastic hinges or other compression elements or compression outstands. Maximum projection beyond outermost point of attachment shall be 8.6 *T*.
Unsupported widths
Distance between adjacent parallel lines of attachment of any compression flange or element shall not exceed 32 *T*.
Webs in shear
Depth of web shall not exceed 70 *T* (*T* = web thickness).
Lateral restraints
If the applied moment exceeds 0.85 of the maximum moment capacity at least one supporting web or gusset shall be provided. The spacing of supports shall not exceed 60 r_y where r_y is the radius of gyration about the longitudinal axis.
Web stiffening
Web stiffening shall be provided at plastic hinge points where: The applied load exceeds 150 *Aw*. *Aw* is the web cross-sectional area. Where the shear capacity of the web, V_y = 137.5 *Aw*, is exceeded, web stiffeners or doublers shall be provided to carry that portion of the force which exceeds the shear capacity of the web. Web stiffeners are to be provided at the point of application of concentrated load when the web crippling will occur opposite the compression flange.

NOTE (1) This table is based on a material yield stress, F_y, of 250 MPa; for other materials to NZS 3404.
(2) The yield stress of steel used in plastic regions should not exceed 360 MPa.

2.10 Brittle components

2.10.1 Brittle components should be designed to either have twice the breaking strength of the seismic force as determined under the loadings clause or to have twice the yield strength of some adjacent intermediary energy dissipator.

2.11 Fixings

2.11.1 Equipment shall be positively restrained and shall not rely on friction effects alone.

Where services and equipment are fixed to non-structural elements of the building such elements shall be checked to verify that their load carrying capacity is adequate.

2.11.2 Post-drilled anchors shall be of a type that expands on tensioning the bolt or shall have an *in situ* proof loading to the design earthquake loading carried out on a representative sample of bolts.

Holding down bolts, embedments and inserts should have greater capacity than the equipment to which they are attached.

Allowable loads on embedded bolts are given in table 5.

Allowable loads on post-drilled anchor bolts are given in table 4.

Minimum edge distances are given in table 6.

2.11.3 Fixing methods for lightweight equipment are given in table 7. This table can be used for minor items where a more detailed study is not justified.

2.11.4 The maximum stresses in bolts are given in table 1.

2.11.5 When a bolt to AS 1111 is subjected to combined tension and shear the following expressions shall apply. For strength design:

$$\left(\frac{Fv_f}{133}\right)^2 + \left(\frac{Ft_f}{240}\right)^2 \text{ shall not exceed unity.}$$

For working stress design:

$$\left(\frac{Fv_f}{80}\right)^2 + \left(\frac{Ft_f}{144}\right)^2 \text{ shall not exceed unity.}$$

Where Fv_f = Shear stress in bolt (MPa)

Ft_f = Tensile stress in bolt (MPa)

Embedments subjected to combined stress shall comply with the following:

$$P^{4/3} + V^{4/3} \leqslant V_\mu^{4/3}$$

Where P = maximum applied tension load.

V = maximum applied shear load.

V_μ = ultimate tensile strength of shear cone in concrete and may be taken as equal to the 28 day strength.

C2.11 Fixings

C2.11.1 Although significant vertical accelerations have been measured there is no general agreement on their magnitude, consequently friction effects cannot be relied upon to hold equipment in place.

C2.11.2 Holding down fixings should maintain a tight coupling between the equipment and floor. A yielding fixing could result in shock loading and subsequent failure. It is preferred that when possible the part attached to the bolt yields first to prevent this. A suggested design criterion is; the insert embedment length is calculated on the basis of 80% of the 28 day design strength of the concrete and that the inset shall have at least 30% higher yield strength than the component part to which it is fixed. There are times when it may be preferable for the bolts to yield first; in such cases the effect of a loose fixing should be considered.

Locking nuts on fixings. *Nuts on fixings for rotating or oscillating machines which may work loose during normal operation should be locked in position to prevent shock loading on an already loose fixing during an earthquake. The locking device selected will depend on the fixing, but a locking type washer will normally be adequate.*

C2.11.3 For combined stresses in bolts other than to AS 1111, NZS 3404 should be consulted.

Table 4 ALLOWABLE LOAD ON POST-DRILLED ANCHOR BOLTS

Anchor bolt size	*Minimum depth of embedment*	*Maximum tension load*
	mm	*kN*
M10	40	3
M12	50	5
M16	60	7
M20	60	9

NOTE (1) This table applies only to anchors which expand on tightening the bolt or are to be proof loaded after installation.
(2) This table does not preclude the use of higher loads where the anchor performance and concrete quality can be substantiated.
(3) Design pullout load may be taken as twice the tension.
(4) Minimum spacing 12 bolt diameters.
(5) Minimum edge distance 6 bolt diameters.

Table 5 ALLOWABLE LOAD ON EMBEDDED BOLTS

Bolt size	*Minimum embedment*	*Shear load*	*Tension load*
	mm	*kN*	*kN*
M6	65	2	1.5
M10	75	5	4
M12	100	8	7
M16	125	13	12
M20	150	19	18
M24	180	34	33

NOTE (1) Minimum spacing 12 bolt diameters.
(2) Minimum edge distance 6 bolt diameters.
(3) Concrete 28 day strength 20 MPa.

Table 6 MINIMUM EDGE DISTANCES

Nominal diameter of fastener	*Sheared or hand flame-cut edge*	*Rolled plate, machine flame cut, sawn or planed edge*	*Rolled edge of a rolled section*
mm	*mm*	*mm*	*mm*
10	20	18	12
12	24	22	16
16	28	24	20
20	32	28	24
24	42	38	32

2.12 Fixings for lightweight equipment

2.12.1 Where services and equipment are fixed to non-structural elements of the building, such elements shall be checked to verify that their load carrying capacity is adequate.

2.12.2 For minor items of equipment where a more detailed study is not justified, fixings to table 7 may be used.

Table 7 FIXING METHODS FOR LIGHTWEIGHT EQUIPMENT

Load	*Screw in 25 mm thick wood*	*Screw in 50 mm thick wood*	*Through bolt and washer in wood*	*Through bolt in steel*
kN				
4.5		16 dia.		
4.0				M10
3.5	NOT RECOMMENDED	(1.5 kN)	M12	
3.0		12 dia.		
2.5				(4.5 kN)
			(3 kN)	
2.0		(1.5 kN)	M10	
1.5		24 *ga*	(1.75 kN)	M6
1.0			M6	
	24 *ga*	(1.5 kN)		
0.5	(510 N)	10 *ga*		
	10 *ga* (380 N)	(670 N)	(900 N)	(2 kN)

NOTE (1) Figures in the table are minimum bolt or screw size.
(2) Figures in parentheses are allowable shear per bolt or screw.
(3) *ga* is wood screw gauge.

2.13 Flexible mountings

2.13.1 Flexibly mounted equipment is equipment which has a period of vibration equal to or greater than 0.10 s.

2.13.2 Flexibly mounted equipment shall be positively restrained under the seismic loads to prevent failure of the mounts by

(a) keying columns and applying adhesive to the anti-vibration mat; or

(b) holding down bolts; or

(c) using captive type anti-vibration mounts; or

(d) using positive stops or snubbers.

Service connections shall be flexible and should not form part of the restraining mechanism.

C2.13 Flexible mountings

C2.13.1 There are two broad categories of flexible mounting used on building equipment:

(a) Resilient pads used to reduce the transmission of relatively high frequency noise and vibration and sometimes seismic response. They should provide a

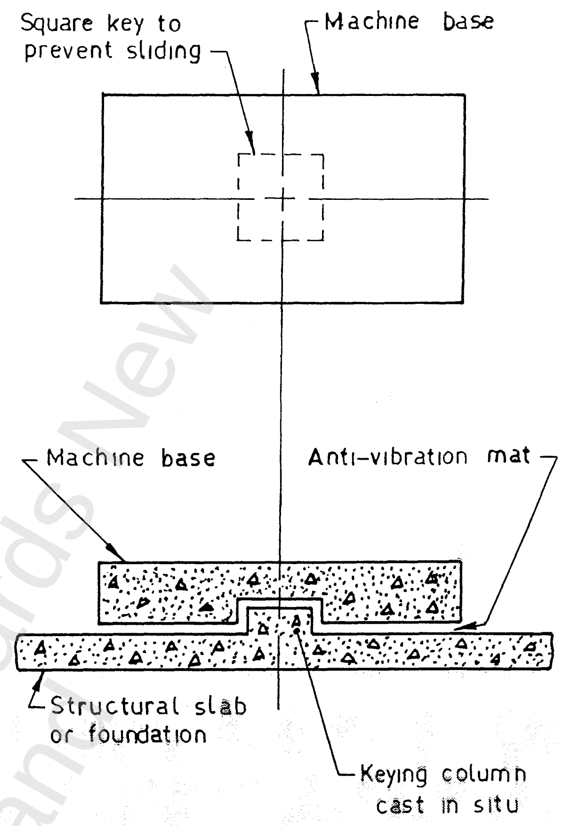


Fig. 2 SHEAR CONNECTION BY KEYING COLUMN

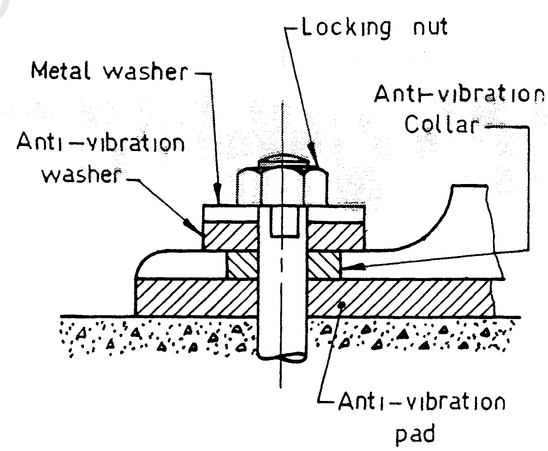


Fig. 3 RESILIENT MOUNTING

natural frequency of greater than 15 Hz. For equipment with a ratio of base to height of centre of gravity greater than 3, holding down arrangements may not be necessary, but a shear connection should be provided. This may take the form of a keying column set in the foundation as shown in fig. 2. An adhesive should be applied between the pad and the equipment and the pad and the floor. Where the equipment has a base width to height of centre of gravity ratio less than about 3, a resilient mounting such as shown in fig. 3 may be used. A pad washer and collar are necessary to prevent shock loading. The pad washer should be of the same thickness and compressed by the same amount as the main supporting pad when tightening the locknut

(b) *Anti-vibration mounts: Anti-vibration mounts used to reduce the transmission of vibration from the equipment to the structure have often failed during earthquakes. Heavy inertia bases increase the seismic forces for which isolators must be designed.*

Rubber mounts of the captive type which are unable to be pulled apart and are of sufficient strength provide an adequate restraining system.

Steel spring and air bag mounts should be fitted with positive stops or snubbers to limit excessive movement. Such stops should be positioned clear of normal operating displacements and should have surfaces resiliently coated to reduce shock loading.

C2.13.2 It is recommended that, where doubt exists as to the capability of a mount to withstand the horizontal loading, confirming tests should be carried out or snubbers fitted.

2.14 Tanks and vessels

2.14.1 Large freestanding tanks or elevated tanks on separate towers shall be designed as separate structures.

For essential services, where pipework integrity is uncertain (possibly due to passage through unstable ground), the normal tank draw-off location should be some distance above the bottom of the tank, but with an additional valved connection near the bottom.

C2.14 Tanks and vessels

Pressure tanks, tanks holding highly viscous fluids and completely filled tanks with lids can be considered to respond as a rigid mass, provided the lid is fixed. There are no hydrodynamic effects to consider.

Open topped tanks and partially filled tanks with lids experience hydrodynamic phenomena associated with the surface waves set up by an earthquake. The coefficients given in NZS 4203 take this into account for smaller tanks likely to be found in buildings.

A vertical tank on the ground should be designed for cantilever beam action due to lateral forces, combined with other stresses as applicable. Consideration should be given to the tie-down stresses around the periphery of the tank, horizontal shear at the base, overturning at the tank footing and the compression buckling of the tank shell. The footing should be sized so that there is no theoretical net tension between the footing and supporting ground. Resistance to sliding should be developed by positive means without dependence on friction between tanks and supporting pad.

For horizontal tanks on the ground the stresses in the saddles and the base footings should be considered. The soil pressure in the transverse direction due to overturning may be critical. The resultant of forces should always fall within the middle third of the footing pad.

Where thin walled tanks are likely to collapse at the bottom seam and rupture pipe connections, ovalling of the tank sides at the top may also take place. Hot water cylinders without rigid insulation can be damaged using a simple strap.

To enable compliance with 2.1.1 the loss of liquids could be contained by ponding of the contents of the tank in specially made shallow containers or by extending the walls, whichever is applicable, of areas such as the plant room or flat roof and arranging for a controlled discharge from there, by means of downpipes to drains or otherwise outside the building. This method would be particularly applicable to water, but may not be safe for other liquids especially when they are flammable or corrosive.

The relative movement of the tank and interconnected pipework has resulted in the failure of the pipe connections to the tank or adjacent fittings. Such pipes should be fixed to move with the tank allowing the relative displacement to be taken up by flexible, less highly stressed sections of the pipe.

2.15 Flues and stacks

2.15.1 Freestanding flues and stacks not attached to the building shall be designed as separate structures in accordance with NZS 4203.

2.15.2 Stacks constructed inside buildings shall allow for inter-storey deflection under seismic loading without damage (see 2.6) except that heavy stacks which may alter the intended behaviour of the structure shall be effectively separated from the building.

2.15.3 Horizontal flues shall be braced against transverse and longitudinal sway and shall be designed to prevent slip joints and other flexible connections being pulled apart. Such bracing shall be provided at least once on each length. Provision shall be made for relative movement between plant structure and structural elements.

C2.15 Flues and stacks

C2.15.1 Flues and stacks should be located in a position accessible for inspection over the whole height to check for damage after an earthquake.

C2.15.2 Light steel insulated and uninsulated stacks have performed better than masonry and refractory lined stacks and should be used wherever possible. Unreinforced masonry should be avoided. Masonry and refractory lined stacks should have provision for inspection particularly where a fire hazard could result from large cracks or damaged liners.

C2.15.3 Stacks are continuous beams and if supported or guyed will respond as propped cantilevers. Modelling them as a point load on a cantilever will not accurately determine the fundamental period of the stack and if in doubt an assessment should be made of possible tuning with the building response and the stack possibly analysed as flexibly mounted.

2.16 Piping systems

2.16.1 The seismic force for pipework shall be determined at a midpoint between seismic braces with the pipes taken as full.

2.16.2 Pipes carrying toxic and flammable liquids and gases, acids, alkalis or other hazardous substances up to 200 mm nominal bore (nb) shall be fixed against seismically induced movement, as follows:

(a) Bracing shall be provided at not more than 12 m intervals

(b) At least one brace shall be provided to limit longitudinal movement

(c) Transverse bracing for one pipe section may also act as longitudinal bracing for the pipe section connected perpendicular to it if the bracing is installed within 600 mm of the elbow or tee

(d) Gas piping shall be provided with at least one transverse brace per length at a maximum of 6 m centres and a longitudinal brace at a maximum of 12 m for all pipes above 25 mm nominal bore

(e) Where sway bracing is provided by struts they shall have a slenderness ratio of length to radius of gyration not exceeding 200 unless specifically designed

(f) Seismic restraints may be omitted from the following:

(1) Pipes containing hazardous substances less than 25 mm nominal bore

(2) Fire sprinkler and other fire service pipes less than 50 mm nominal bore

(3) Piping in boiler and mechanical equipment rooms less than 50 mm nominal bore

(4) All other piping less than 65 mm nb

(5) All piping suspended by individual hangers 300 mm or less in length from the top of the pipe to the bottom of the hanger support.

2.16.3 Pipes not covered by 2.16.2 need only be braced at the points of connection of branch pipes, connections to equipment, and where the free swaying of the pipe may damage other building elements.

2.16.4 Provisions for pipes greater than 200 mm nb shall be determined by special study.

C2.16 Piping systems. *The categories used may need to be extended to cover other services where a high degree of seismic resistance is required to protect life or property.*

Pipe services over 200 mm nominal bore although not unknown are unusual in most buildings and because of the possible damage from escaping fluids should command special attention although the principles laid down in this Section would still apply. Damage from escaping fluids from fractured pipes invariably far exceeds the cost of repairs to the pipe.

Experience has shown that small pipes with relatively low mass and high flexibility are not generally damaged except where attached to large masses or to more than one structural system. Highly stressed points at fittings, branches and connections can be avoided by anchoring the pipe to ensure that movement is taken over a greater length of pipe. To provide bracing on all pipework is not therefore justified.

Branch pipes should not be anchored to the building if the mains are allowed to sway.

A rigid piping system should not be fastened to two dissimilar parts of a building that may respond in a different mode during an earthquake – for example, a wall and a roof. Where a connection is necessary between two structural systems, it should be provided with adequate flexibility and be as close to ground level as possible. Bellows type expansion joints are usually unsuitable.

Offsets, bends and loops provide the best means of crossing seismic joints. Where thermal expansion joints are of the sliding or bellows type, suitable limit stops shall be provided to prevent the joint pulling apart.

Whenever possible, risers should be supported at a point or points above the centre of gravity of the riser. Lateral guides should be provided at the top and bottom of the riser and at intermediate points not exceeding 10 m centres.

Pipes should never be supported by each other, but spreaders may be provided at appropriate intervals to separate adjacent pipes where contact may occur during an earthquake. Where pipes are supported by a common rack or trapeze system, it shall be braced to withstand the seismically induced forces of the combined piping system.

Fire protection systems installed in accordance with the seismic requirements of NFPA 13 are acceptable for this Standard.

Piping and conduit installed within partitions should be tied to the same structural elements as the partition system.

Acid waste piping systems such as glass, plastics, asbestos cement and cast iron are not covered by this clause. Due consideration should be given to the special properties of these materials, such as brittleness and the probable type and consequences of failure considered when providing fixings.

Sleeves large enough to allow for anticipated differential movements and lined with a vibration damping material should also be provided through walls and floors.

Pipes should be designed to provide for adequate flexibility between different structural systems, such as walls and floors, by using a flexible pipe layout incorporating bends, or by flexible jointed braces to prevent damage from lateral displacement.

Where pipes enter a building through the foundation, provision should be made for relative movement between the pipe and building.

2.17 Water service

2.17.1 Water distribution pipes and tanks essential for the continued functioning of the building should be designed and located to facilitate repairs.

2.17.2 Tanks and pipes shall be located so that any fracture or leakage would result in minimal water damage and would not affect safety operations. Except for fire services pipe joints shall not be located over electrical equipment.

C2.17 Water service

C2.17.1 The potential importance of water stored on site and available after an earthquake should be considered in Class I and Class II buildings.

In Class I buildings where water is essential to continued operation, the quantity and security of on-site storage should be carefully assessed. Provision should be made for the delivery of water by mobile tanker, and where possible, supplies should be available from two independent sources. In addition to normal restraints, tanks, pipes and pumps should be located for reasonable access and provided with bypass connections and isolating valves suitably labelled.

Isolating valves should be in easily accessable locations and should be provided for main branches at each floor in multi-storey buildings.

Some judgement will be necessary as to the importance of the water service and the potential property damage.

C2.17.2 Small quantities of water stored in a building could be important after a major earthquake when the local authority supply is likely to be disrupted.

Many important Class I buildings are unable to function without a supply of water, and although such buildings would be a high priority for delivery by mobile tankers limited access and manpower may make this difficult in the immediate post-earthquake period. The use of larger site storage, the provision of water from at least two independent sources and the connection of pumps to standby power supplies should all be considered.

2.18 Steam service. All steam plant and equipment shall be constructed and installed to withstand the earthquake loading and shall be installed to enable safe shutdown.

C2.18 Steam service. *Pressure vessels designed to Statutory Regulations are unlikely to fail in an earthquake. Hazards, however, can arise from fractured pipe connections or malfunction of controls. Provided that reasonable precautions are taken to ensure a failsafe system it is only necessary to ensure that the equipment is fixed in place to withstand the earthquake loading.*

In earthquakes where the electric power, water and fuel systems may fail or sustain damage, the plant should be shut down safely by the isolation of the fuel or the operation of the normal safety controls, or both.

2.19 Gas service. Installations with a consumption exceeding 50 m^3/h should be fitted with seismic shut-off valve. This gas supply pipe passing from the ground into the building shall be designed to withstand the highest credible value of the seismic deflection of the building without rupture. See clause 2.5.

C2.19 Gas service. *In fixing appliances and accessories, gas operated cooking and laundry equipment, gas cylinders and meters should not be overlooked.*

Spigot and socket joints in flues, pushed together, require additional restraint.

Gas isolating valves and seismically operated valves should be located in an accessible position outside the building, preferably close to the entrance. Such valves should be clearly identified and where seismically operated valves are installed a list of connected appliances and their location should be affixed or located nearby.

Seismic shut-off valves should be set to operate with a horizontal acceleration of 2 m/s^2. These devices are not recommended where numerous small appliances are used, because of the danger of gas leakage going undetected when the service is restored.

Where possible, gas mains should be run external to the building. Mains should not be located in ceiling spaces.

2.20 Fuel service

2.20.1 For Class I buildings that require fuel for electric power or other essential operations, sufficient fuel should be stored on site for the immediate post-earthquake period, or where fuel cannot be stored, dual fuel equipment with storage of the secondary fuel should be considered.

2.20.2 The installation shall be designed to reduce fire and other hazards from earthquake damaged equipment.

C2.20 Fuel service

C2.20.1 The point of delivery should allow easy access following an earthquake. An enclosed rear yard would not normally be as suitable as a street filling point because of debris.

C2.20.2 The risk of fire following an earthquake can be reduced by:

(a) Locating fuel burning equipment where it is accessible to facilitate fire fighting

(b) Storing a minimum of fuel above ground and in buildings

(c) Reticulation of fuel, particularly gas, outside the building

(d) By the use of ductile (steel) flues and chimneys rather than brittle masonry and brick construction

(e) Where small underground pipes run from storage tanks they should be installed inside larger diameter pipes that pass through the foundations.

2.21 **Hazardous substances.** General guidance can only be given for the precautions necessary for hazardous substances.

C2.21 **Hazardous substances.** *The ultimate in protection and restraint will frequently interfere with normal functional use. Typical hazardous substances encountered in building services are battery acid, compressed gas installations, cleaning fluids and solvents, heat transfer oils, hot water, flue/exhaust gases, and refrigerants. The following precautions will reduce the seismic hazard:*

(a) Install pipework, tanks and equipment in accordance with the recommendations of this Standard

(b) Store heavy items at floor level instead of high shelves. Restrain items kept on shelves

(c) Label containers and pipes to indicate contents, using standard codes

(d) Hold only small quantities where possible

(e) Have accessible and identifiable isolating valves and alarms.

2.22 Ducting

2.22.1 For ducting:

(a) Positive fixings shall be used to support ducting

(b) Ducting in ceiling spaces shall be installed with a clearance of 150 mm from vertical hangers from the ceiling or suspended fittings, unless both ceiling and ducting are provided with transverse bracing or unless the hanger length to the top of the duct does not exceed 200 mm

(c) Registers and grilles shall have positive fixings to the ducting, wall opening or ceiling support system.

2.22.2 For installations where the failure of the service or where toxic fumes or gases may be released, an installation complying with the details in the publication *Guidelines for seismic restraints* (SMACNA), shall be deemed to comply with this Standard.

C2.22 Ducting

C2.22.1 Damage to ducting in most installations will present no particular hazard, but precautions must be taken to prevent freely suspended ducts from damaging building elements such as ceilings or causing a hazard by falling.

C2.22.2 Ducting supports must not come apart during earthquakes; open hooks and some slotted connections would be unacceptable. Split pins, bolts and nuts with spring washers and welded connections provide positive fixings.

2.23 **Heat producing appliances.**

Permanently installed appliances which operate at elevated temperatures shall be so constructed and fixed that they will remain safe in the event of damage by an earthquake.

C2.23 **Heat producing appliances.** *Fixed appliances rather than portable appliances should be used wherever possible.*

Where interruption of the energy source could give rise to a fire hazard (immediately or on reinstatement of the service), it should shut down and require manual restarting. The shutting down operation can be provided by a fuse, an automatic shut-off valve, or a seismically triggered device, but should operate if the appliance has been or is likely to be seriously damaged.

2.24 Electrical distribution

2.24.1 Electrical reticulation in the form of cable or busbar and together with associated ducting, conduit, or similar supporting methods, shall be designed and installed to allow relative movement of the building, or electrical apparatus to which it is connected, or both, without damage to the electrical reticulation apparatus or building.

C2.24 Electrical distribution

C2.24.1 Electrical apparatus such as transformers, switchboards and control cubicles should be securely anchored to the floor or to the structure of the building or both, and braced where necessary to resist lateral forces.

Flexible braided connections or equivalent multistranded conductors should be used in place of rigid copper busbars wherever relative movements may occur between switchboard components.

Care must be taken to ensure the strength of the busbar system against short circuit forces and hence its rated short circuit capacity is not reduced by this procedure.

Where it is necessary to cross building seismic joints with cables, the crossing should occur at the lowest possible floor. All crossings shall be designed for flexibility to provide horizontal and vertical movement at the joint.

At an entry point at foundation level or where crossing a seismic joint, a sleeved joint should be included to allow relative movement and take the strain off heavy cables. Additional draw-in boxes with slack conductors should be provided in long conduit runs to avoid tensioning of the conductors.

Motors subject to damage by low service voltages after an earthquake should be provided with a starter incorporating undervoltage trips.

Electrical cubicles and switchboards should:

(a) Have any loose components contained within, for example, batteries, positively restrained with straps, bars, bolts, and similar devices

(b) Have hinged or sliding doors fitted with top and bottom catches as lift-off panels may fall on live terminals during earthquakes

(c) Have frame and construction designed to withstand earthquake forces

(d) Be protected from damage from adjacent plant and building components by the adequate fixing of the latter items or other means

(e) Have modular and plug-in elements positively restrained

(f) Not contain mercury switches or other gravity-operated devices if their incorrect operation during an earthquake would cause serious danger to life or property.

In some cases electrical equipment has been damaged in the same way as mechanical equipment. Tall equipment such as control cubicles, transformers, switchboards and rotating equipment have overturned when these items were not bolted to the building structure. Many cubicles have performed better than surrounding partition systems owing to the use of rigid conduit. The failure of distribution conduit has been due mainly to the failure of the particular ceiling, wall or floor which supported that conduit.

2.25 Luminaires

2.25.1 All fastenings including those for detachable accessories (such as diffusers, light controllers) shall be of a positive locking type designed to prevent disconnection under earthquake loading.

2.25.2 Where recessed or surface mounted on suspended ceilings, luminaires shall be positively clamped to the ceiling suspension main runners (T-rails) or to cross runners having the same carrying capacity. Clamping shall be by means of screws and nuts or locking type clamping devices.

2.25.3 Suspended luminaires with a mass exceeding 10 kg shall have two supports attached to a suitable structure. Each support, which need not be in tension, shall be capable of supporting the luminaire weight.

2.25.4 Surface mounted luminaires shall be mounted on the structure by at least two fixings.

C2.25 Luminaires

C2.25.1 Suspended luminaires including those in ceiling systems have frequently fallen in past earthquakes. Falling objects are a serious hazard and promote panic and therefore justify extra attention.

C2.25.2 When forming part of a suspended ceiling system the whole system must be considered as the one entity.

C2.25.3 Freely suspended luminaires can have large displacements due to the pendulum action and should be fixed or restrained to prevent impact with the building or other equipment.

C2.25.4 The supports for heavy suspended luminaires may be in addition to the normal fixings to say the ceiling grid and may take the form of wires fixed to the structure. They should have a minimum of slack to reduce shock loading.

2.26 Emergency electrical supply

2.26.1 Emergency power generating sets should be located for easy access away from positions where flooding may occur.

The set shall be securely fixed to the structure or floor slab. The building enclosure and installation shall comply with NZS 4203.

2.26.2 The use of resilient mountings should be avoided where possible. Where they are used they shall comply with this Standard.

2.26.3 Service connections, radiators, control panels and starting batteries shall be fixed to resist earthquake forces.

2.26.4 Battery installations shall be designed and fixed to withstand earthquake forces and remain fully functional.

2.26.5 The fuel supply shall comply with 2.20.

C2.26 Emergency electrical supply

C2.26.1 Auxiliaries such as batteries, control cabinets, fuel tanks and radiators shall be mounted to resist earthquakes and connected through adequately flexible connections.

C2.26.2 The installation of standby generators isolated from the main building structure will reduce the transmission of vibration through the building and may eliminate the need for resilient mounts.

C2.26.3 Where resilient mountings must be provided they should employ restraining devices or snubbers and connection piping should be arranged to reduce potential damage to fuel, cooling water, and exhaust lines. All service lines should be kept as short as possible, compatible with providing adequate flexibility.

C2.26.4 Battery installations should comply with the following requirements:

(a) All batteries in racks should be securely strapped or otherwise constrained to prevent movement and withstand equivalent loads

(b) Have cabinets securely fixed in place in accordance with this Standard

(c) Have batteries positively restrained within the cabinet

(d) Sufficient slack should be allowed in connections for any likely movement.

2.27 Communication systems

2.27.1 Cubicles, control panels, cabling, and the like, should be designed and installed generally in accordance with the requirements for electrical, equipment and distribution section.

2.27.2 Aerial systems should be designed with consideration to the effects of earthquakes as well as the normal wind and other loads.

2.28 Control systems

2.28.1 Control systems shall be designed and installed to withstand the induced seismic forces and relative displacement.

2.28.2 Consideration shall be given to the effect of an earthquake on the reliability and safety of the control system.

C2.28 **Control systems.** *The effect of control system failure should be examined to reduce the likelihood of hazards to the occupants or consequential damage to the building and its contents. As no rules can be laid down, judgement will be needed in each case.*

2.29 Ceiling-suspended equipment and equipment in ceiling voids

2.29.1 Equipment including luminaires, air distribution grilles, diffusers and other fittings not exceeding 10 kg mass shall be positively fixed to the ceiling suspension system or the building structure, but not supported by the ceiling panels or tiles. Separate equipment supports are not necessary if the equipment is adequately fastened to the ceiling grid and the grid can withstand the earthquake loading from the equipment.

2.29.2 Ceiling mounted equipment exceeding 10 kg mass shall be fixed in accordance with 2.2 to 2.14, where the ceiling is designed to move under earthquake loadings equipment supports should allow for this. Where additional supports not normally under tension are used they should not allow the equipment to drop more than 100 mm.

2.29.3 Services and equipment installed in ceiling voids shall be braced to prevent damage to the ceiling suspension system.

2.29.4 Where the distribution service, duct, pipe or cable is supported separately from the ceiling and ceiling mounted fittings, a suitable flexible connection shall be used. Where service connections (ducts, pipes or cables) are supported from the structure or ceiling separately from the suspended equipment or fixtures, a flexible connection shall be used.

C2.29 Ceiling systems

C2.29.1 Suspended ceiling systems including equipment must be considered as the one entity and cannot be treated separately. NZS 4203 requires that a vertically upwards force is allowed for with ceiling systems.

C2.29.2 Rigid connections should be provided between ceiling areas separated by linear diffusers, which may be unable to withstand the loads imposed by the ceiling system and can result in the progressive failure of the whole ceiling.

The requirement for flexible connections does not imply the need for flexible electrical cords in such instances.

APPENDIX A

RELEVANT EXTRACTS FROM NZS 4203

A1 This Appendix includes a summary of the more frequently used relevant clauses and information from NZS 4203, including Amendments No. 1 and No. 2, for the convenience of users of this Standard. NZS 4203 should be referred to for further details.

The relevant clauses of NZS 4203 are 1.3.2, 1.3.3, and 3.6.

A2 The seismic load on any item of equipment is determined from the formula:

$$F_p = C_p W_p \qquad \text{(1A)}$$

where F_p = Seismic force at centre of gravity of equipment

W_p = Normal operating weight

C_p = Coefficient determined as:

either,

(a) $C_p = IC_{p\max.}$

I = Importance factor taken from table 4 of NZS 4203

$C_{p\max.}$ = Coefficient taken from table 9 of NZS 4203

C_p may be modified by multiplying by the following factors:

$\frac{5}{6}$ for seismic Zone B

$\frac{2}{3}$ for seismic Zone C

and/or $\dfrac{K_p \text{ at level } h_x}{K_p \text{ at level } h_n}$ (Clause 4.3.9.4)

where K_p is determined as follows:

K_p is the larger of 1.5 or $1.5K_x$

where $K_x = \dfrac{h_x}{h_{cg}}$

h_x = height being considered

h_{cg} = height of centre of gravity of building

h_n = height of top of building

(b) C_p may be determined by the method given in NZS 4203, 3.4.9.2(b). This method is more comprehensive.

Table A1 (table 4 of NZS 4203)

IMPORTANCE FACTOR *I*

Class	*Description*	*I*
I	Essential facilities required to be completely functional immediately after a seismic disaster	1.6
II	Public buildings not included in class I	1.3
III	All other buildings	1.0

Points to note about the various seismic force factors are:

(i) Class I Buildings: *Essential facilities can become non-functional because of secondary damages to the building or to equipment, and special attention should be given to this in design. Typical essential facilities that should remain functional after an earthquake include:*

Ambulance centres.

Designated civilian emergency centres and civil defence centres.

Fire stations.

Hospitals and medical facilities having surgery and emergency treatment areas.

Major electricity supply substations.

Police stations.

Radio and television facilities.

(ii) Class II Buildings: *Typical buildings that should be designed as "public buildings" include:*

Courts.

Buildings used as record depositories or for the storage of historic, artistic, or literary treasures.

Central and local government centres.

Communication centres that are not essential facilities.

Defence establishments.

Hospitals and medical facilities that are not essential facilities.

Places of restraint and other buildings to which the public are directed by law.

Post Offices.

Prisons.

Public utility service centres and storage facilities.

Schools, universities, technical institutes, and the like.

Table A2 (Part of table 9 of NZS 4203)

SEISMIC FORCE FACTORS FOR PARTS AND PORTIONS OF BUILDINGS

Item	*Part or portion*	*Direction of force*	C_p *max.*	R_p	C_p *min.*
6	(b) Multi-storey buildings				
	S_p equal to 1.0		0.3		0.3
	S_p equal to 1.2		0.4		0.4
	S_p greater than 1.2		0.6		0.6
7	Towers not exceeding 10% of the mass of the building. Tanks and full contents, not included in item 8; chimneys and smoke stacks and penthouses connected to or part of the building except as provided for by clause 3.4.5:	Any horizontal			
	(a) Single-storey buildings where the height to depth ratio of the horizontal force resisting system is:				
	(i) Less than or equal to 3		0.2		0.2
	(ii) Greater than 3		0.3		0.3
	depth ratio of the horizontal force resisting system is:				
	(i) Less than or equal to 3		0.3		0.3
	(ii) Greater than 3		0.5		0.5
8	Containers and full contents and their supporting structures, pipelines, and valves:	Any horizontal			
	(a) For toxic liquids and gases, spirits, acids, alkalis, molten metal, or poisonous substances, including containers for materials that could form dangerous gases if released:				
	(i) Single-storey buildings		0.6	2.0	0.5
	(ii) Multi-storey buildings		1.3	2.0	0.9
	(b) For sprinkler systems:				
	(i) Single-storey buildings		0.5	1.5	0.3
	(ii) Multi-storey buildings		1.0	1.5	0.6
	(c) Other:				
	(i) Single-storey buildings		0.3	1.0	0.2
	(ii) Multi-storey buildings		0.7	1.0	0.4
9	Furnaces, steam boilers, and other combustion devices, steam or other pressure vessels, hot liquid containers; transformers and switchgear; shelving for batteries and dangerous goods:	Any horizontal			
	(i) Single-storey buildings		0.6	2.0	0.5
	(ii) Multi-storey buildings		1.3	2.0	0.9
10	Machinery; shelving not included in item 9; trestling, bins, hoppers, and such like; other fixtures:	Any horizontal			
	(i) Single-storey buildings		0.3	1.0	0.2
	(ii) Multi-storey buildings		0.7	1.0	0.3
11	Lift machinery, guides, and such like; emergency standby equipment.	Any horizontal	0.6		0.6
12	Connections for items 8 to 11 inclusive shall be designed for the specified forces provided that the gravity effects of dead and live loads shall not be taken to reduce these forces.				
13	Suspended ceilings including attached equipment, lighting and attached partitions, see clause 3.6.5.	Any horizontal	0.6		0.6

Fig. A1 SEISMIC ZONES

APPENDIX B

EXAMPLES IN DESIGN

This section of the Standard is intended to be illustrative of the information in Section 2, Requirements. It is not exhaustive nor is it intended to contain the only interpretation of the data contained therein. The solutions are based on ultimate strength design where applicable.

Example 1

Given 7500 kg hot water boiler on top of a 12 storey uniform Class III building in Zone A. Mass of floor = 100

Required Size of bracket and holding down bolts

Solution Check mass ratios

$$\frac{M_p}{M_{floor}} = \frac{7500}{100 \times 10^3} \times 100 \quad \ldots\ \text{Clause 1.1.2}$$

$$= 7.5\ \%\ (<20\ \% - \text{OK})$$

$$\frac{M_p}{M_{building}} = \frac{7500 \times 100}{12 \times 100 \times 10^3} \quad \ldots\ \text{Clause 1.1.2}$$

$$= 0.625\ \%\ (<10\ \% - \text{OK})$$

Earthquake loading

$$F_p = IC_{pmax}.W_p \quad \ldots\ \text{Clause 2.2.and Appendix A}$$

$$= 1.0 \times 1.3 \times 7500 \times 9.8 \times 10^{-3}$$

$$= 95.5\ \text{kN}$$

Tension load per side fixing
Moments about A

$$\text{Tension force} = \frac{95.5 \times 1050}{1550}$$

$$= 65\ \text{kN}$$

Fixing by M20 embedded bolts

Allowable load/bolt = 18 kN . . . . table 5

$$\text{Bolts per side} = \frac{65}{18}$$

$$= 3.6$$

Use 2 brackets with 2 bolts each

Brackets from rolled steel angles;
Use two bolts per bracket;
Minimum bolt spacing = 12 x diameter . . . . table 4
= 12 x 20
= 240 mm

Edge distance = 28 mm (sawn edge) . . . . . . table 6
Length of bracket = 320 mm.

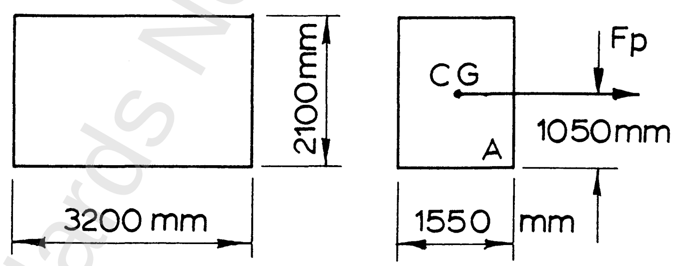
Try 70 x 70 x 8 rolled steel angles

$$f_b = \frac{M}{Z}\ \text{Bending stress about X–X}$$

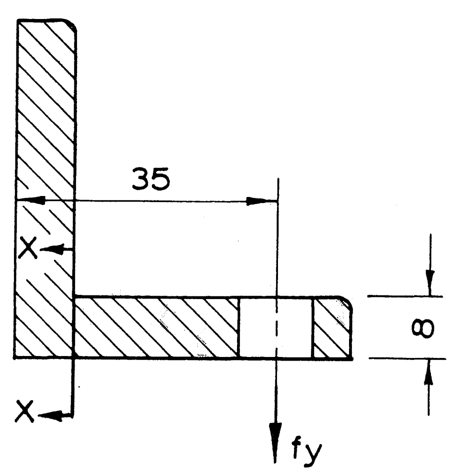
$$= \frac{(35-8-10^{-3} \times 65/2 \times 10^3 \times 6}{320 \times 10^{-3} \times 8^2 \times 10^{-6}}$$

$$= 257\ \text{MPa} <313\ \text{MPa} - \text{OK}) \quad \ldots\ \text{table 1}$$

(continued)



Example 1



Example 1

(Example 1 continued)

Force for bracket to yield

$$f_y = \frac{F_y Z}{(35-8)10^{-3}}$$

$$= \frac{250 \times 10^6 \times 0.320 \times 8^2 \times 10^{-6}}{(35-8)10^{-3} \times 6}$$

$$= 31.6 \text{ kN}$$

Bolt pullout = 18 x 2 x 2
= 72 Kn

Assume bolt yield is about twice the maximum load
Then Force for bracket yield < Bolt pullout. Clause C2.11.2

So bracket yields first.

Weld shear

Throat thickness t $= \frac{8}{2}$

Area $= 320 \times \frac{8}{2} \times 10^{-6}$

$= 1800 \times 10^{-6}\ \text{m}^2$

Allowable load $= 1800 \times 10^{-6} \times 13.7 \times 10^6$ . . . table 1
$= 248$ kN

Example 2

Given 150 mm wet riser, 38 kg/m in uniform 10 storey, Class III building, located in Zone B

Required Horizontal seismic force at all supports

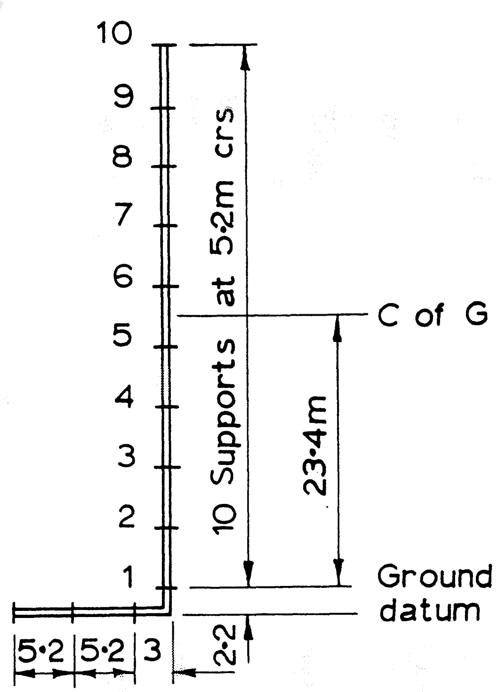
Solution Fundamental frequency of pipe vibration is approximately 6 Hz therefore provide flexible mount

C_p = 1 . . . . NZS 4203, table 9, item 8(b)(ii)
x $\frac{5}{6}$ . . . . Zone B
x 1 . . . . Class III
x 2 . . . . Flexible
= 1.67

Multiply by height correction factor as determined below

$W_p = 38 \times 9.8 \times 5.2 \times 10^{-3}$
$= 1.9$ kN

Floor	$kx = \frac{h_x}{h_{cg}}$	k_p	$\frac{k_{px}}{k_{p10}}$	C_p	F_p(kN)
Ground 1	0	1.5	0.5	0.8	1.5
2	0.22	1.5	0.5	0.8	1.5
3	0.44	1.5	0.5	0.8	1.5
4	0.67	1.5	0.5	0.8	1.5
5	0.89	1.5	0.5	0.8	1.5
6	1.11	1.7	0.6	1.0	1.9
7	1.33	2.0	0.7	1.2	2.2
8	1.56	2.3	0.8	1.4	2.7
9	1.78	2.7	0.9	1.5	2.9
10	2.00	3.0	1.0	1.7	3.2



Example 2

(Example 2 continued)

NOTE– The fundamental frequency of vibration of pipes can be determined from the following equation:

$$f = \frac{\pi}{2\ell^2}\sqrt{\frac{EI}{m}}$$

Where ℓ = unsupported or unbraced length
E = modulus of elasticity of pipe material
m = mass of full pipe per unit length
I = moment of inertia of pipe section

Simple calculation for floor 6:

Height of centre of gravity $= \frac{\Sigma mh}{\Sigma m}$

$h_{cg} = \frac{45\ mh}{10\ m}$

$= 4.5\ h$

$h_6 = 5\ h$

$k_x = \frac{h_x}{h_{cg}}$

$= \frac{5\ h}{4.5\ h}$

$= 1.11$

$k_{px} = 1.5 \times k$

$= 1.5 \times 1.11$

$= 1.7$

$k_{p10} = \frac{1.5 \times 9}{4.5}$

$= 3.0$

$\frac{k_{px}}{k_{p10}} = \frac{1.7}{3.0}$

$C_p = 1.67$

$\frac{C_p \times k_{px}}{k_{p10}} = 1.67 \times \frac{1.7}{3.0}$

$= 1.0$. table above

Example 3

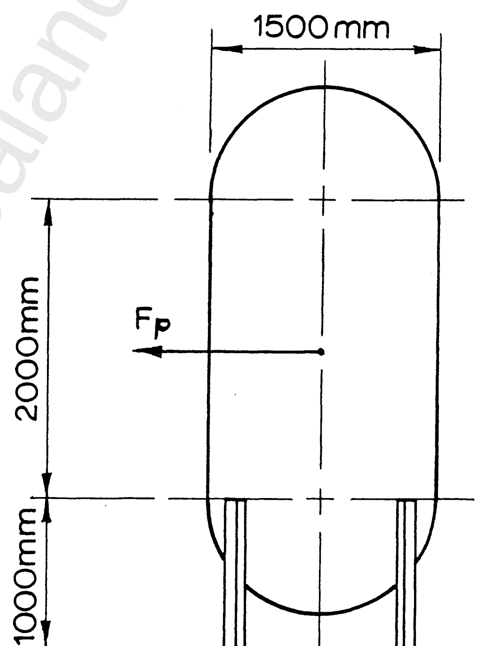
Given Pressure tank at ground level in Class III building located in Zone A. Support by 4 unbraced RHS legs bolted to the floor with cast-in anchor bolts. Weight of full tank is 45 kN.

Required Size of legs and holding down bolts

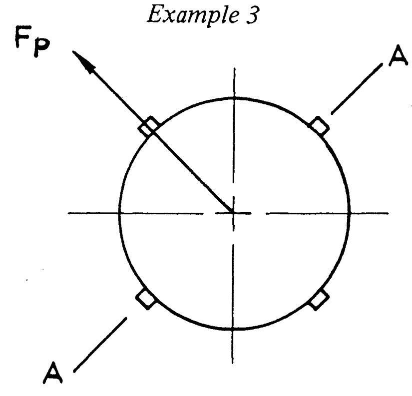
Solution Design based on flexible mounting (0.1< Period <2.0)

C_p = 0.6 . . . . NZS 4203, table 9
x 1 . . . . Zone A
x 1 . . . . Class III

(continued)



Example 3



Example 3

(Example 3 continued)

x 2 . . . . Flexible

$= 1.2$

$W_p = 45$ kN

$F_p = C_p W_p$

$= 1.2 \times 45$

$= 54$ kN

Moments about A–A

Compression load = 0.9D + E . . . . Refer NZS 4203, 1.3.2.3

$$= 0.9 \times \frac{45}{4} + \frac{54 \times (1+2/2)}{2 \times 1.5/2}$$

$= 82.1$ kN

Try 51 x 51 x 3.2 RHS

$A = 591 \text{ mm}^2$

$r = 19.2$ mm

$$\frac{\ell}{r} = \frac{1}{19.2 \times 10^{-3}}$$

$= 52$

Allowable stress = 226 MPa fig.1

$$\text{Actual stress} = \frac{82.1 \times 10^3}{591 \times 10^{-6}}$$

$= 139 \times 10^6$

$= 139$ MPa (<226 MPa – OK)

Bolt size:

Pullout load not reduced by gravity effects . . . NZS 4203, table 9, Item 12

$$\text{Load} = \frac{54\ (1+2/2)}{2 \times 1.5/2}$$ . . . . . Moments about A–A

$= 72$ kN

Use three M24 bolts per leg . . . . table 5

Check flexibility

$$T = 2\pi \frac{M_p}{K_p}$$

$$K_p = \frac{\text{applied force}}{\text{displacement}}$$

Assume legs cantilever beam, one fixed, the other end free but guided.

Displacement under load P

$$= \frac{P\,\ell^3}{12\,EI}$$

Four legs under load W_p

$$\text{Displacement} = \frac{W_p\,\ell^3}{48EI}$$

$$\therefore\ K_p = \frac{48\ EI}{\ell^3}$$

$$M_p = \frac{W_p}{g}$$

$$\therefore\ I = \pi^2 W_p\,\ell^3$$

(Example 3 continued)

and T = 0.1 sec

W_p = 45×10^3 N

ℓ = 1 m

E = 200×10^9 Pa

g = 9.8

$\therefore$ I = 1.89×10^{-6} m^4

Minimum size for rigid fixing:

89 x 89 x 4.9 RHS.

Example 4

Given A ventilating fan on top of a multi-storey Class III building Zone B. Mass of the fan motor and base is 500 kg. The fan is mounted on spring mounts to isolate 90 % of vibration. Mounts are not restrained. Fan speed is 900 RPM

Required Horizontal force and displacement of the fan if:
(a) unrestrained mounts are used
(b) movement limiting snubbers are used.

Solution For this fan to give 90% vibration isolation the mounts will have a natural frequency of about 5 Hz. Assume mounts have the same stiffness in the vertical and horizontal directions. Rocking mode is neglected.

(a) Horizontal force unrestrained:

C_p = 0.7 . . . . NZS 4203, table 9, Item 10(ii)

x 1 . . . . Class III

x 5/6 . . . . Zone B

x 2 . . . . Flexible

= 1.2

W_p = $500 \times 9.81 \times 10^{-3}$

= 4.9 kN

F_p = C_pW_p

= 1.2 x 4.9

= 5.9 kN

Approximate peak displacement:
from vibration theory

$$f_n = \frac{15.8}{d_n}$$

d = 10 mm

where

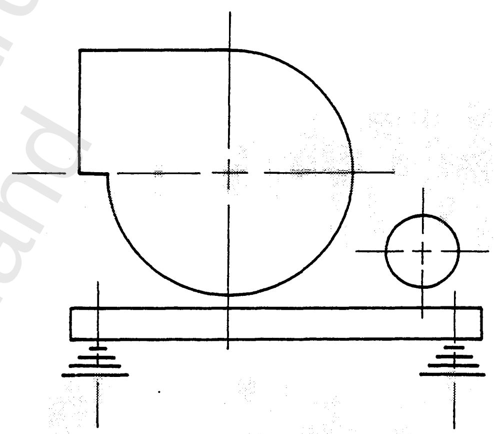
f_n = natural frequency 5 Hz

d_n = static deflection

Stiffness k = $\frac{500 \times 9.81}{0.01}$

= 490 500 N/m

Horizontal stiffness = vertical stiffness



Example 4

(Example 4 continued)

Static deflection under earthquake design load

$$\text{deflection} = \frac{\text{load}}{\text{stiffness}}$$

$$= \frac{5900}{490\,500}$$

$$= 0.012 \text{ m}$$

$$= 12 \text{ mm}$$

(b) Horizontal force, restrained

C_p = 0.7 . . . . NZS 4203, table 9, Item 10(ii)
x 1 . . . . Class III
x 5/6 . . . . Zone B
x 1 . . . . Restrained
= 0.58

W_p = 4.9 kN

F_p = C_p x W_p
= 0.58 x 4.9
= 2.9 kN

Displacement: The displacement will be determined by the snubber; a clearance of 12 mm would be typical, i.e., 6 mm deflection from centre position.

NOTE – This should be increased if shock loading is likely to result from contact with the snubber.

Example 5

Given A thin-walled water tank with fixed lid and full mass of 800 kg on top of a multi-storey Class III building with height:depth ratio greater than 3, located in Zone A

Required Seismic bracing system without penetrating the safe tray

Solution Hydrodynamic effects and friction between the base of the tank and the safe tray are disregarded. Assume the mass ratio falls within the limits of Clause 1.1.2.

Horizontal force:

C_p = 0.5 . . . . NZS 4203, table 9, Item 7(b)(ii)
x 1 . . . . Zone A
x 1 . . . . Class III
= 0.5

W_p = $8000 \times 9.8 \times 10^{-3}$
= 78.4 kN

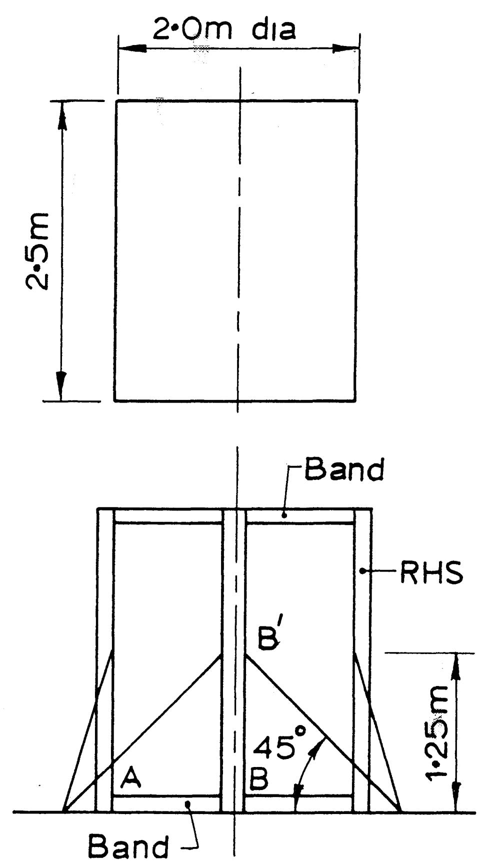
F_p = C_pW_p
= 0.5 x 78.4
= 39.2 kN

Assume full load transmitted through the top and bottom bands.

Moments about A

$$\text{Tension in band} = \frac{39.2 \times 1.25}{2 \times 2.5} = 9.8 \text{ kN}$$

(continued)



Example 5

(Example 5 continued)

Moments about B

Tension in wire $= \dfrac{9.8 \times 2.5 \times \sqrt{2}}{1.25}$

$= 27.7$ kN

Select a 12 mm diameter rod

$f_t = \dfrac{27.7 \times 10^3 \times 4}{\pi \times 12^2}$

$= 245$ MPa (<250 MPa – OK)

Allowable stress is 250 MPa . . . . table 1

Compression in BB' $= \dfrac{27.7}{\sqrt{2}}$

$= 19.6$ kN

RHS Beams

Bending moment of centre $= 9.8 \times 1.25$

Select a 102 x 102 x 4.0 RHS

$Z = 47.5 \times 10^3$ mm^3

$A = 1540$ mm^2

$r = 39.5$ mm

$f_b = \dfrac{M}{Z}$

$= \dfrac{9.8 \times 10^3 \times 1.25}{47.5 \times 10^{-6}}$

$= 258$ MPa (<313 MPa – OK)

Allowable bending stress is 313 MPa . . . . table 1

$f_c = \dfrac{19.6 \times 10^3}{1540 \times 10^{-6}}$

$= 12.72$ MPa

$\dfrac{\ell}{r} = \dfrac{1.25}{39.5 \times 10^{-3}}$

$= 31.6$

Allowable stress is 240 MPa . . . . table 1

Check combined stress

$\dfrac{f_{ac}}{F_{ac}} = \dfrac{31.6}{240}$

$n = 0.13$ (<0.15 – OK) Use simplified rule AS 1250, Section 8

$\dfrac{f_{ac}}{F_{ac}} + \dfrac{f_{bcx}}{F_{bcx}} + \dfrac{f_{bcy}}{F_{bcy}} \leqslant 1$

$\dfrac{31.6}{240} + \dfrac{258}{313} + \dfrac{0}{313} \leqslant 0.96 < 1$ (OK)

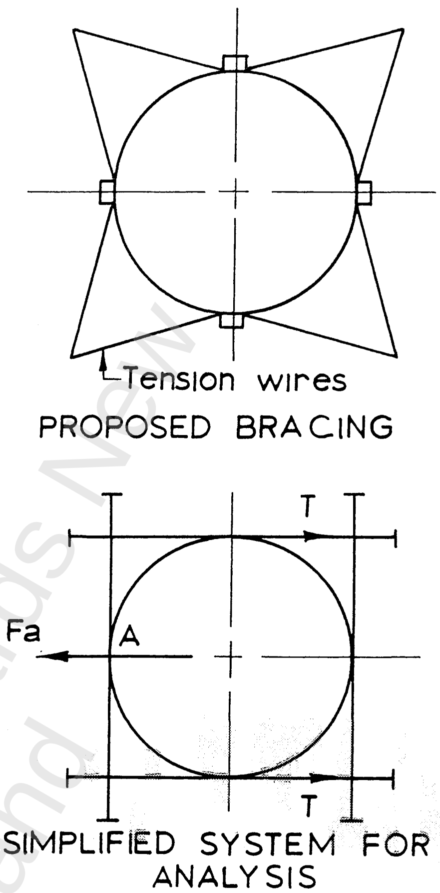
Top and bottom bands

NOTE – The bearing stress on the tank must be kept low to avoid local buckling. Assume band is 50 mm x 6 mm flat

Tension load = 9.8 kN

Select 50 mm x 6 mm flat

(continued)



Example 5

(Example 5 continued)

Stress $f_t = \dfrac{9.8 \times 10^3}{50 \times 6}$

$= 32.66$ MPa

Allowable stress = 250 MPa . . . . table 1

Weld RHS to band

Assume 5 mm fillet

Stress $f_w = \dfrac{9.8 \times 10^3}{2 \times 50 \times 5/\sqrt{2}}$

$= 27.7$ MPa (<137 MPa – OK)

Allowable stress = 137 MPa . . . . table 1

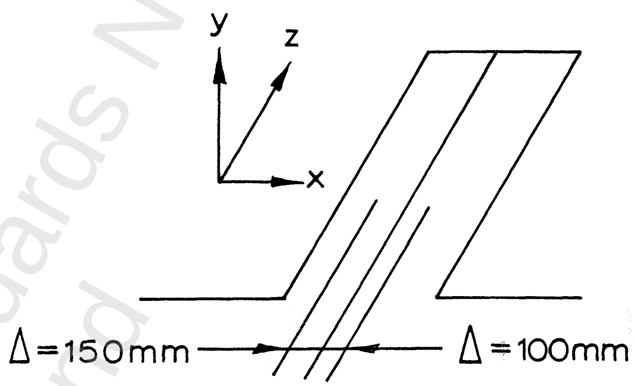
Example 6

Given A pipe loop crossing a seismic break; the computed deflections of the building structure on each side of the seismic break are 150 mm and 100 mm respectively.

Required The movement to be taken up by a pipe loop crossing the break

Solution Total deflection = 150 + 100
= 250 mm

NOTE– Computation in the x direction only is shown. Simultaneous deflection in the y and z directions must also be allowed for.



Example 6

Example 7

Given A ceiling-mounted suspended air conditioner with a mass of 350 kg in an occupied space on the 7th floor of a 10-storey uniform Class III building in Zone B.

Required The size of supports for:
(a) an unbraced system with rigid connection to the building
(b) a cross-braced system with pin joint connections

Solution

Reduction in coefficient C_p for building height

Height of centre of gravity of building as a proportion of total = 0.5

$K_n = \dfrac{h_n}{h_{cg}}$

$= \dfrac{1.0}{0.5}$

$= 2$

K_p at top $= 1.5\ K_n$

$= 3$

$K_x = \dfrac{h_x}{h_{cg}}$

$= \dfrac{0.7}{0.5}$

$= 1.4$ (Underside of 8th floor)

(Example 7 continued)

K_p at h_x = $1.5\ K_x$

= 2.1

$\frac{K_p \text{ at } h_x}{K_p \text{ at } h_n} = \frac{2.1}{3.0}$ . . . . NZS 4203, Clause 3.4.9.2

= 0.7

(a) Unbraced:

C_p = 0.7 . . . . NZS 4203, table 9, Item 10(ii)

x 5/6 . . . . Zone B

x 1 . . . . Class III

x 0.7 . . . . height factor

x 2 . . . . flexible mounting

= 0.82

W_p = 350 x 9.8

= 3.43 kN

F_p = C_pW_p

= 0.82 x 3.43

= 2.8 kN

Load per support = $\frac{2.8}{4}$

= 0.7 kN

Try 38 x 38 x 2.6 RHS

I = 0.0728×10^4 mm^4, Z = 3.82×10^3 mm^3 r = 14.3 mm, A = 357 mm^2)

Bending stress

$f_{bx} = \frac{M}{Z}$

$= \frac{0.7 \times 10^3}{3.82 \times 10^3 \times 10^{-9}}$

= 183 MPa (<allowable stress of 313 MPa)

NOTE– Direct stress is insignificant.

Check period

Stiffness K = $\frac{12\ EI}{^3}$

(Assume supports cantilever beam is fixed at one end free but guided at the other)

Period t = $2\pi\sqrt{\frac{M_p}{K}}$ $M_p = \frac{350}{4}$

$= 2\pi\sqrt{\frac{350 \times 1^3}{4 \times 12 \times 203 \times 10^9 \times 7.28 \times 10^{-12}}}$

= 0.14 sec (flexible)

(b) Braced

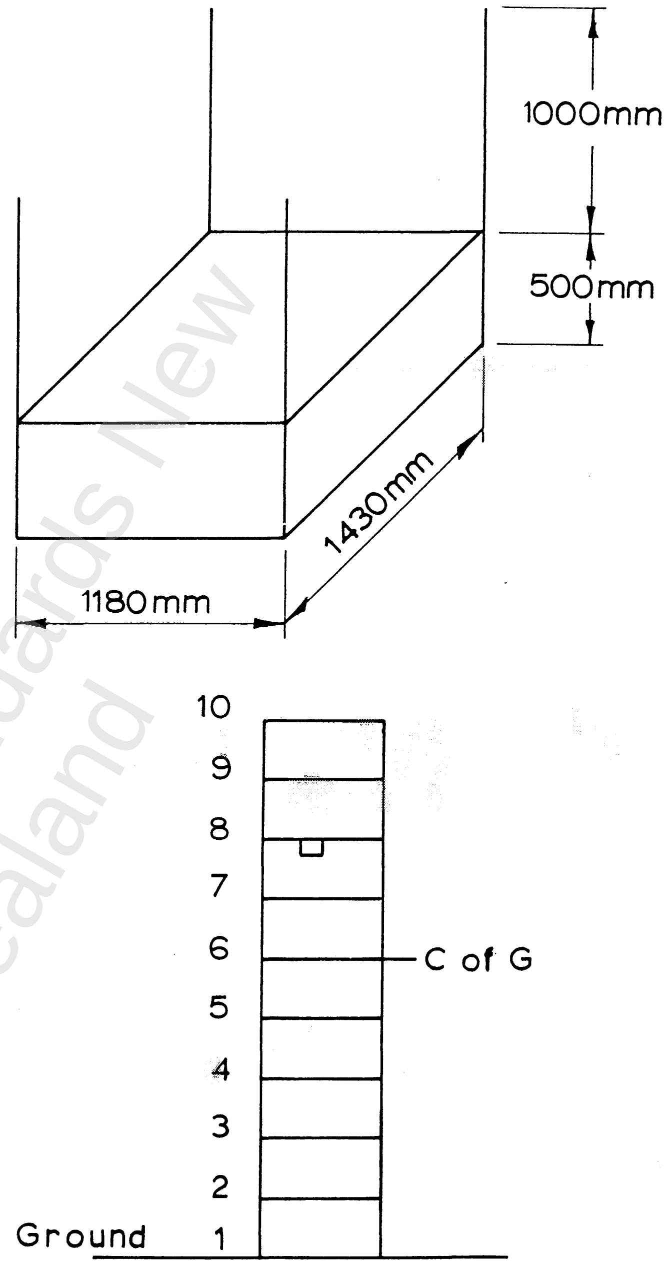
Assume rigid support

Braces take tension load only

C_p = 0.7 . . . . NZS 4203, table 9, Item 10(ii)

x 5/6 . . . . Zone B

(continued)



Example 7

(Example 7 continued)

x 1 . . . . Class III

x 0.7 . . . . height factor

$= 0.41$

$W_p = 350 \times 9.8$

$= 3.43$ kN

$F_p = C_p W_p$

$= 0.41 \times 3.43$

$= 1.41$ kN

Assume half the load is carried by each end frame

$F_p = 0.7$ kN

Dead load $= \dfrac{0.9 \times 350 \times 9.8}{2}$ . . . . NZS 4203, Clause 1.3.2.3

$= 1.54$ kN

Load in BC $P_{BC} = \dfrac{0.7}{\cos\theta}$ . . . . . .Resolving horizontally

$= 0.92$ kN

Load in AB $P_{AB} = \dfrac{0.7 \times 1.25 - 1.54 \times 1.18/2}{1.18}$

Moments about C

Load in CD $P_{CD} = \dfrac{0.9 \times 1.25 + 1.51 \times 1.18/2 - 1.18 \times 1.18 \sin\theta}{1.18}$

Moments about A

$= 0.91$ kN

Member	Max. Load kN	Allowable Stress MPa	Min. Area mm²	Size MSL	Actual Stress MPa
BC	0.92	250	3.68	25x25x2.6	3.9
AB	0.285	250	0.11	25x25x2.6	0.12
CD	0.91	250	3.64	25x25x2.6	3.8

Check period using strain energy

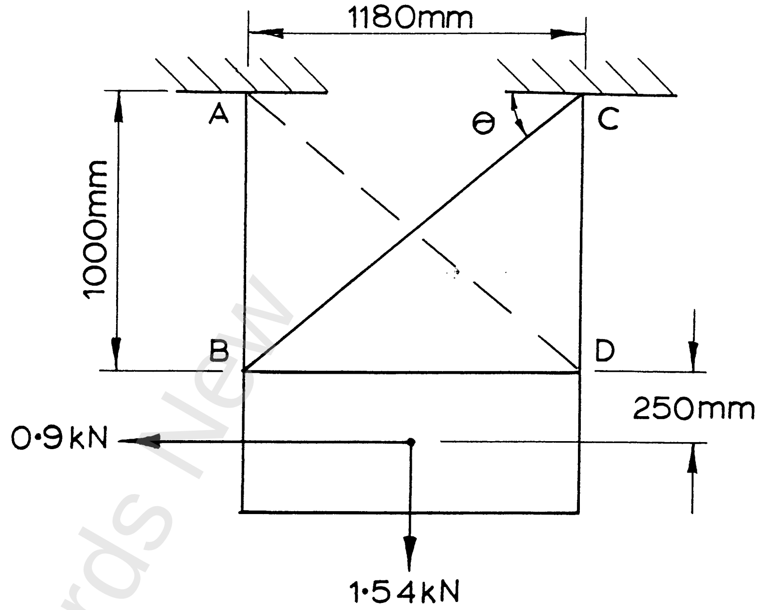
Member	Load	Area (x10⁻⁴)	Length	$\frac{p^2 L \times 10^4}{A}$ (x10⁴)
AB	0.64	2.6	1	0.15
BC	0.38	2.6	1.55	0.86
CD	0.21	2.6	1	0.17

$\Sigma \dfrac{P^2 L}{A} = 1.18 \times 10^4$

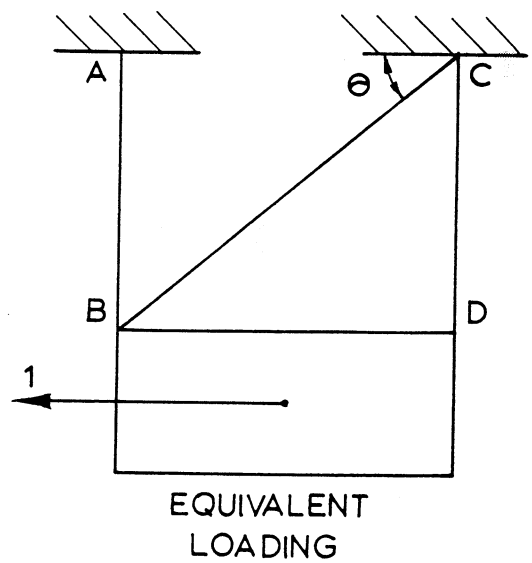
$1 \times \dfrac{\Delta}{2} = \Sigma \dfrac{P^2 L}{2\,AE}$

$\Delta = \Sigma \dfrac{P^2 L}{AE}$

(continued)



Example 7



Example 7

(Example 7 continued)

x 1 . . . . Class III

x 0.7 . . . . height factor

= 0.41

W_p = 350 x 9.8

= 3.43 kN

F_p = C_pW_p

= 0.41 x 3.43

= 1.41 kN

Assume half the load is carried by each end frame

F_p = 0.7 kN

Dead load = $\frac{0.9 \times 350 \times 9.8}{2}$ . . . . NZS 4203, Clause 1.3.2.3

= 1.54 kN

Load in BC $P_{BC} = \frac{0.7}{\cos\theta}$ . . . . . . Resolving horizontally

= 0.92 kN

Load in AB $P_{AB} = \frac{0.7 \times 1.25 - 1.54 \times 1.18/2}{1.18}$ Moments about C

Load in CD $P_{CD} = \frac{0.9 \times 1.25 + 1.51 \times 1.18/2 - 1.18 \times 1.18 \sin\theta}{1.18}$ Moments about A

= 0.91 kN

Member	Max. Load kN	Allowable Stress MPa	Min. Area mm^2	Size MSL	Actual Stress MPa
BC	0.92	250	3.68	25x25x2.6	3.9
AB	0.285	250	0.11	25x25x2.6	0.12
CD	0.91	250	3.64	25x25x2.6	3.8

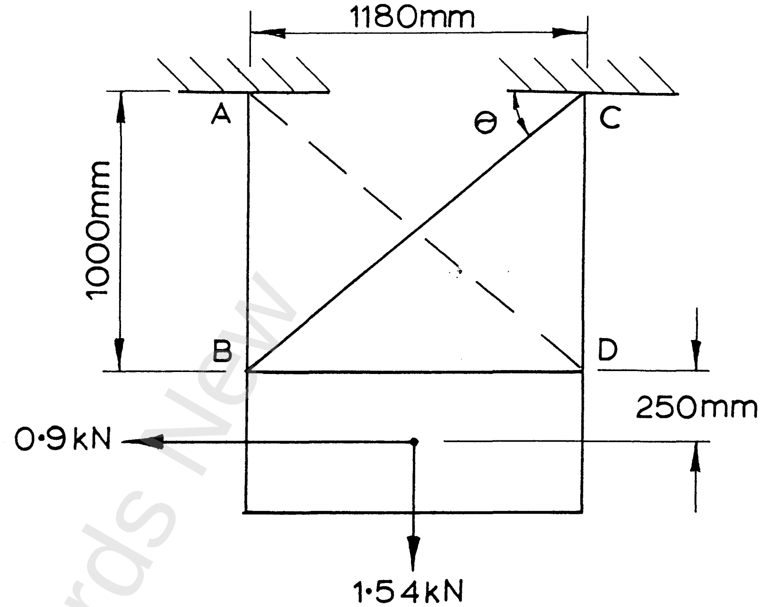
Check period using strain energy

Member	Load	Area ($\times 10^{-4}$)	Length	$\frac{p^2 L \times 10^4}{A}$ ($\times 10^4$)
AB	0.64	2.6	1	0.15
BC	0.38	2.6	1.55	0.86
CD	0.21	2.6	1	0.17

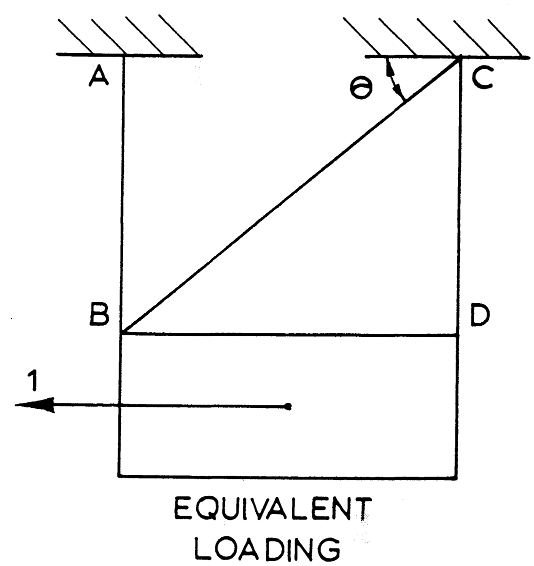
$$\Sigma \frac{P^2 L}{A} = 1.18 \times 10^4$$

$$1 \times \frac{\Delta}{2} = \Sigma \frac{P^2 L}{2\,AE}$$

$$\Delta = \Sigma \frac{P^2 L}{AE}$$



Example 7



Example 7

(continued)

(Example 7 continued)

x 1 . . . . Class III

x 0.7 . . . . height factor

$= 0.41$

$W_p = 350 \times 9.8$

$= 3.43$ kN

$F_p = C_p W_p$

$= 0.41 \times 3.43$

$= 1.41$ kN

Assume half the load is carried by each end frame

$F_p = 0.7$ kN

Dead load $= \dfrac{0.9 \times 350 \times 9.8}{2}$ . . . . NZS 4203, Clause 1.3.2.3

$= 1.54$ kN

Load in BC $P_{BC} = \dfrac{0.7}{\cos\theta}$ . . . . . .Resolving horizontally

$= 0.92$ kN

Load in AB $P_{AB} = \dfrac{0.7 \times 1.25 - 1.54 \times 1.18/2}{1.18}$

Moments about C

Load in CD $P_{CD} = \dfrac{0.9 \times 1.25 + 1.51 \times 1.18/2 - 1.18 \times 1.18 \sin\theta}{1.18}$

Moments about A

$= 0.91$ kN

Member	Max. Load kN	Allowable Stress MPa	Min. Area mm²	Size MSL	Actual Stress MPa
BC	0.92	250	3.68	25x25x2.6	3.9
AB	0.285	250	0.11	25x25x2.6	0.12
CD	0.91	250	3.64	25x25x2.6	3.8

Check period using strain energy

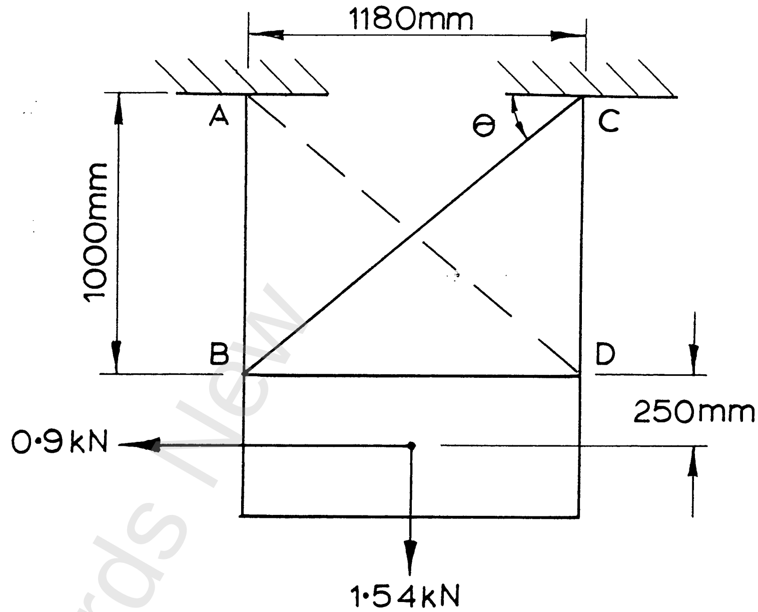
Member	Load	Area $(\times 10^{-4})$	Length	$\frac{p^2 L \times 10^4}{A}$ $(\times 10^4)$
AB	0.64	2.6	1	0.15
BC	0.38	2.6	1.55	0.86
CD	0.21	2.6	1	0.17

$$\Sigma \frac{P^2 L}{A} = 1.18 \times 10^4$$

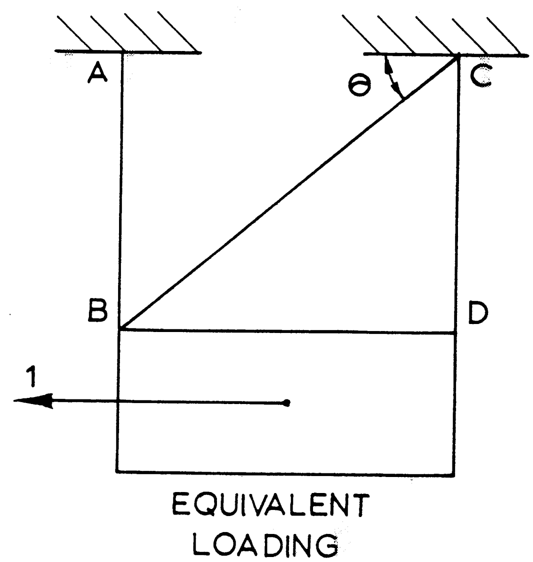
$$1 \times \frac{\Delta}{2} = \Sigma \frac{P^2 L}{2\,AE}$$

$$\Delta = \Sigma \frac{P^2 L}{AE}$$

(continued)



Example 7



Example 7

(Example 7 continued)

$$= \frac{1.18 \times 10^4}{200 \times 10^9}$$

$$= 1.3 \times 10^{-8}$$

$$K = \frac{1}{\Delta}$$

$$K_p = 2K$$

$$= \frac{2}{\Delta}$$

$$= 154 \times 10^6 \text{ N/m}$$

$$T_e = 2\pi\sqrt{\frac{M_p}{K_p}}$$

$$= 2\pi\sqrt{\frac{350}{154 \times 10^6}}$$

$$= 0.0095 \text{ sec (Rigid)}$$

Example 8

Given Oil supply daily service tank 3000 kg total mass on a low cross-braced stand at the top of a multi-storey Class I building in Zone A

Required To determine suitable sizes for the legs and cross braces.

Solution

C_p = 1.3 . . . . NZS 4203, table 9, Item 8(a)(ii)
x 1.6 . . . . Class I
x 1 . . . . Zone A
x 1 . . . . Assume rigid mounting
= 2.08

$$W_p = 3000 \times 9.8$$

$$= 29400 \text{ N}$$

$$F_p = C_p W_p$$

$$= 2.08 \times 29.4$$

$$= 61.15 \text{ kN}$$

Assume stand is pin-jointed and that cross bracing will only take loads in tension.

Consider one end frame

$$P = \frac{61.15 \times 0.75}{2.x\ 15}$$

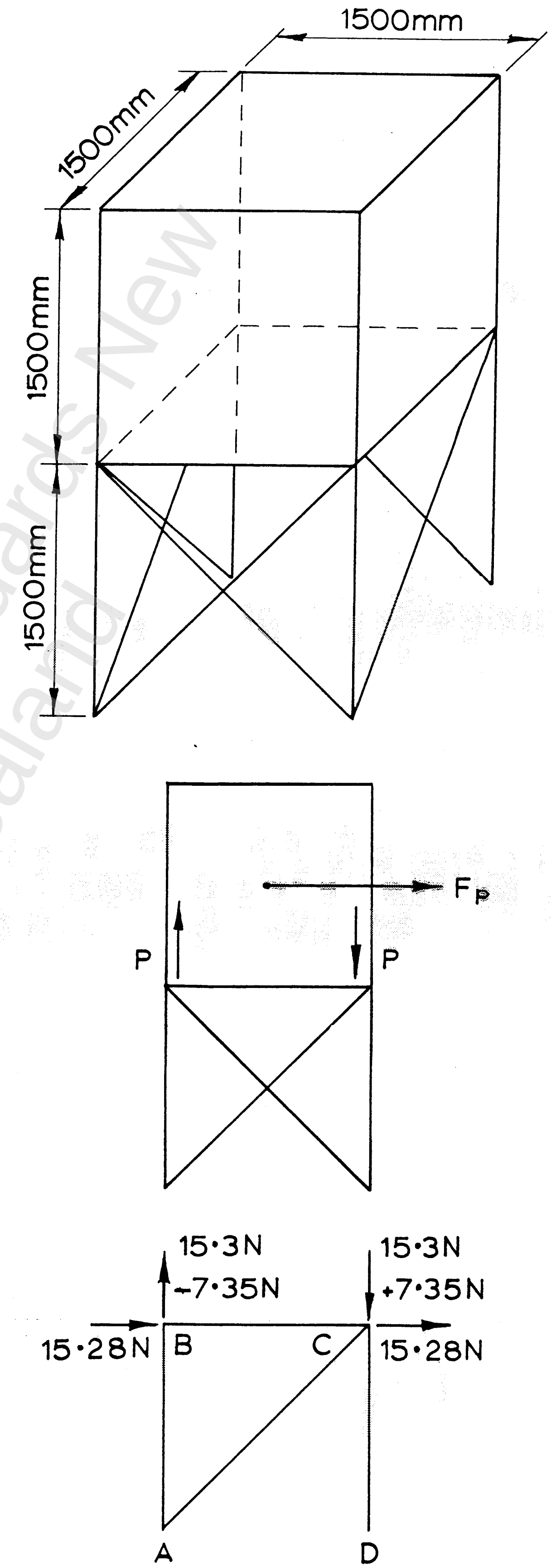
$$= 15.3 \text{ kN}$$

Gravity load on each corner support

$$= \frac{3 \times 9.8}{4}$$

$$= 7.35 \text{ kN}$$

(continued)



Example 8

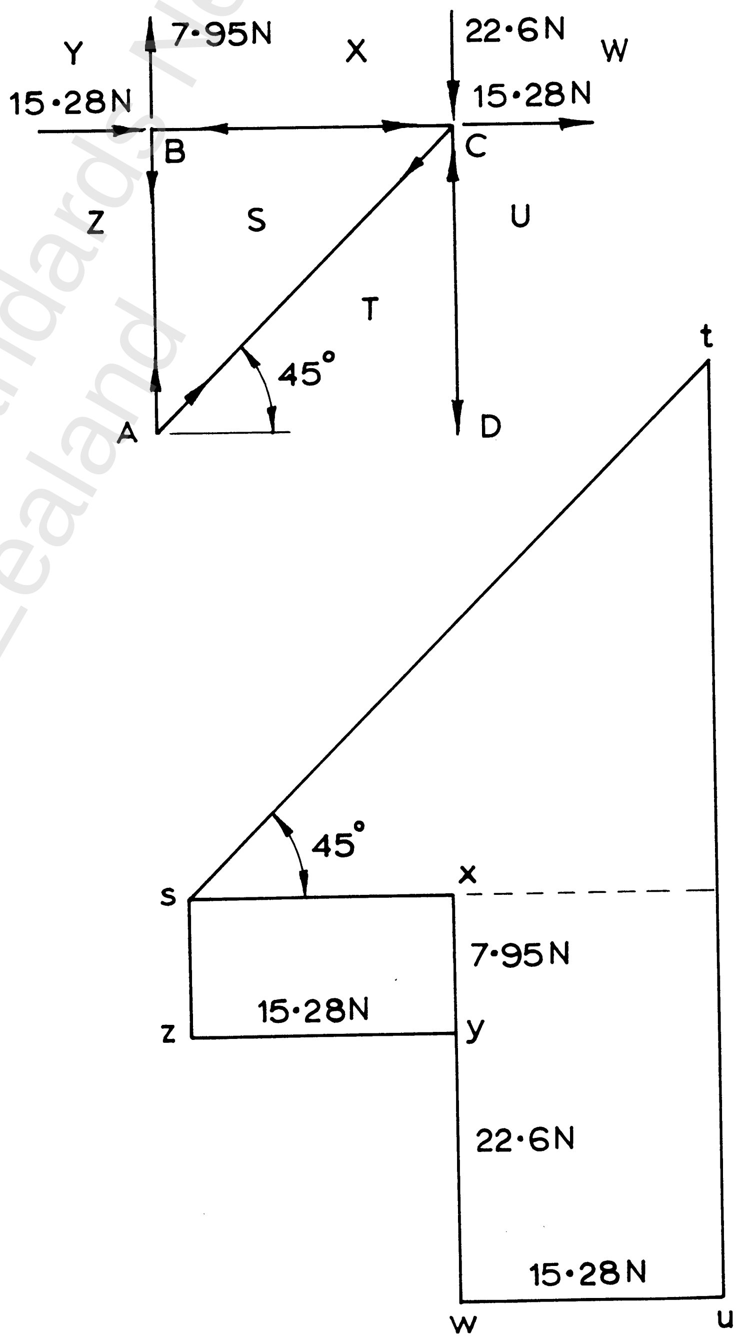
(Example 8 continued)

Member	Tension (T) Comp (C)	Load (kN)	Length (m)	Radius (cm)	Allowable Stress (MPa[1])	Minimum Area (cm^2)	Size	Actual Area (cm^2)
AB	T	7.95	1.5	–	250	–	50 x 50 x 5L	–
AC	T	43.27	2.12	–	250	1.73	40 x 5FL	2.0
CD	C	53.2	1.5	1.5	125	4.26	50 x 50 x 5L	4.80
BC	C	15.3	1.5	1.5	125	1.22	50 x 50 x 5L	4.80

(1) Allowable stress from table 1 and fig. 1

AB is of the same material as CD to allow for reversal in load. BC is of the same material as AB for fixing tank and convenience in manufacture.

Force in member AB = sz = 7.95 T
Force in member AC = st = 2 x 15.28 x$\sqrt{2}$ = 43.2 T
Force in member CD = ut = 22.6 + 2 x 15.28 = 53.2 C
Force in member BC = sx = 15.28 C



Example 8

NEW ZEALAND STANDARD

NZS 4219:1983

Pr AA

Specification for SEISMIC RESISTANCE OF ENGINEERING SYSTEMS IN BUILDINGS

AMENDMENT No. 1

August 1990

EXPLANATORY NOTE - Amendment No. 1 corrects the omission of fire sprinkler pipes from the provisions for piping systems, corrects errors and updates related documents.

APPROVAL

Amendment No. 1 was approved on 17 August 1990 by the Standards Council to be an amendment to NZS 4219:1983 pursuant to the provisions of section 10 of the Standards Act 1988.

RELATED DOCUMENTS

Delete the referenced New Zealand, British and Australian Standards and **substitute** the following:

"NEW ZEALAND STANDARDS

NZS 3404:- - - -	The steel structures code
Part 1:1989	New Zealand amendments to AS 1250:1981 (with commentary)
Part 2:1989	Sections 12, 13, 14. Means of compliance (with commentary)
NZS 4203:1984	Code of practice for general structural design and design loadings for buildings

BRITISH STANDARDS

BS 1387:1985	Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads
BS 3601:1987	Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes
BS 6323:Parts 1 to 8:1982	Specification for seamless and welded steel tubes for automobile, mechanical and general engineering purposes

AUSTRALIAN STANDARDS

AS 1111:1980	ISO metric hexagon commercial bolts and screws
AS 1250:1981	The use of steel in structures"

(Amendment No. 1, August 1990)

Table 2 SECTION PARAMETERS FOR ELASTIC DESIGN

In the last line, **delete** "BS 1775" and **substitute** "BS 6323".

(Amendment No. 1, August 1990)

2.16 Piping systems

Delete the first paragraph of 2.16.2 and **substitute**:

"Pipes carrying toxic and flammable liquids and gases, acids, alkalis or other hazardous substances, and fire sprinkler and other fire service pipes, up to 200 mm nominal bore (nb) shall be fixed against seismically induced movement as follows:"

(Amendment No. 1, August 1990)

APPENDIX A

Table A2
SEISMIC FORCE FACTORS FOR PARTS AND PORTIONS OF BUILDINGS

Under item 7, after (a) (ii), **add** the following line:
"(b). Multi-storey buildings where the height to"

Under item 8, in the second line, **delete** the comma after "structures" and **substitute** a semi-colon.

(Amendment No. 1, August 1990)

APPENDIX B

Example 3
On page 29, two-thirds down the page, **delete** the equation:

"$T = 2\pi \frac{M_p}{K_p}$" and **substitute** "$T = 2\pi \sqrt{\left(\frac{M_p}{K_p}\right)}$"

(Amendment No. 1, August 1990)

APPENDIX B

Example 7
On page 34, three-quarters down the page, **delete** the equation:

"Stiffness $K = \frac{12EI}{3}$" and **substitute** "Stiffness $K = \frac{12EI}{\ell^3}$"

On page 35 in the upper diagram, **delete** the horizontal force "0.9 kN" and **substitute** "0.7 kN".

On page 35, halfway down the page **delete** the equation for "load in CD" and **substitute** :

"$P_{CD} = \frac{0.7 \times 1.25 + 1.54 \times 1.18/2 - 0.92 \times 1.18 \sin\theta}{1.18}$"

(Amendment No. 1, August 1990)

(c) 1990 STANDARDS COUNCIL
STANDARDS ASSOCIATION OF NEW ZEALAND
WELLINGTON TRADE CENTRE,
181-187 VICTORIA STREET
WELLINGTON 1

NEW ZEALAND STANDARD NZS 4219:1983

Specification for
SEISMIC RESISTANCE OF ENGINEERING SYSTEMS IN BUILDINGS

Pr Gratis

AMENDMENT No. 2

July 1992

EXPLANATORY NOTE – This Amendment applies when this Standard is used as a Verification Method that is referenced in Approved Document B1 Structure – General, to the New Zealand Building Code. The Amendment need not apply when this Standard is used under the Model Building Bylaw system which remains in operation until 31 December 1992.

To ensure receiving advice of the next amendment to NZS 4219:1983 please complete and return the amendment request form.

APPROVAL

Amendment No. 2 was approved in July 1992 by the Standards Council to be an amendment to NZS 4219:1983 pursuant to the provisions of section 10 of the Standards Act 1988.

(Amendment No. 2, July 1992)

2.19
Delete the clause.

(Amendment No. 2, July 1992)

STANDARDS NEW ZEALAND
WELLINGTON TRADE CENTRE, 181-187 VICTORIA STREET
WELLINGTON 1

REQUEST FOR ADVICE OF NEXT AMENDMENT

Please fill in the request for the next amendment to this New Zealand Standard and mail to Standards New Zealand, Private Bag, Wellington.

If this request slip has not been returned SNZ has no record that you wish to be advised of future amendments to this Standard.

To confirm that the next amendment has been requested, enter details of despatch:

REQUEST FOR NEXT AMENDMENT

NZS 4219:1983
Amendment No. 3

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