NZS 3109:1997

Incorporating Amendment No. 1 and No. 2

New Zealand Standard

Concrete construction

Superseding NZS 3109:1987

NZS 3109:1997

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COMMITTEE REPRESENTATION

This Standard was prepared by the Concrete Construction Committee (P 3109), for the Standards Council established under the Standards Act 1988.

The Concrete Construction Committee consisted of representatives of the following organizations:

Association of Consulting Engineers New Zealand
Building Research Association of New Zealand
Cement and Concrete Association of New Zealand
Institution of Professional Engineers New Zealand
New Zealand Contractors Federation
New Zealand Master Builders Federation
New Zealand Ready Mixed Concrete Association

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AMENDMENTS

No.	*Date of issue*	*Description*	*Entered by, and date*
1	August 2003	This amendment is a result of NZS 3104:2003 being published. This fully revised Standard no longer refers to 'grades of concrete'. The terminology is now Normal Concrete, Special Concrete and Prescribed Mix Concrete. This amendment applies to Sections 1, 6 and 9 of NZS 3109.	Incorporated in this edition.
2	March 2004	Amended to provide for reinforcing steel manufactured to AS/NZS 4671:2001.	Incorporated in this edition.

NZS 3109:1997

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NEW ZEALAND STANDARDS

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Part 1:1995	The design of concrete structures
Part 2:1995	Commentary on the design of concrete structures
NZS 3104:1991	Concrete production – High grade and special grade
NZS 3108:1983	Concrete production – Ordinary grade
NZS 3112:- - - -	Methods of test for concrete
Part 1:1986	Tests relating to fresh concrete
Part 2:1986	Tests relating to the determination of strength of concrete
Part 4:1986	Tests relating to grout
NZS 3113:1979	Chemical admixtures for concrete
NZS 3114:1987	Concrete surface finishes
NZS 3121:1986	Water and aggregate for concrete
NZS 3122:1995	Portland and blended cements (General and special purpose)
NZS 3123:1974	Portland pozzolan cement (type PP cement)
NZS 3125:1991	Portland-limestone filler cement
NZS 3421:1975	Hard drawn mild steel wire for concrete reinforcement
NZS 3422:1975	Welded fabric of drawn steel wire for concrete reinforcement

Amd 2 Mar ’04

JOINT AUSTRALIAN/NEW ZEALAND STANDARDS

AS/NZS 1554:- - - -	Structural steel welding
Part 3:2002	Welding of reinforcing steel
AS/NZS 4671:2001	Steel reinforcing materials

Amd 2 Mar ’04

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AMERICAN STANDARDS

ACI SP-47	Durability of concrete
ASTM A820-90	Specification for steel fibers for fiber reinforced concrete
ASTM A497-95	Steel welded wire fabric, deformed for concrete reinforcement
ASTM C42-94	Obtaining and testing drilled cores and sawed beams of concrete
ASTM C309-95	Liquid membrane-forming compounds for curing concrete
ASTM C1116-95	Fiber-reinforced concrete and shotcrete
ASTM C1152-90	Test method for acid-soluble chloride in mortar and concrete

AUSTRALIAN STANDARDS

AS 1012:- - - -	Methods of testing concrete
Part 14-1991	Method of securing and testing cores from hardened concrete for compressive strength
AS 1311-1987	Steel tendons for prestressed concrete – 7-wire stress-relieved steel strand for tendons in prestressed concrete
AS 1313-1989	Steel tendons for prestressed concrete – Cold worked high tensile alloy steel bars for prestressed concrete
AS 1478-1992	Chemical admixtures for concrete
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BRITISH STANDARDS

BS 4486:1980	Hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete
BS 5896:1980	High tensile steel wire and strand for the prestressing of concrete

OTHER PUBLICATIONS

Building Industry Authority. New Zealand Building Code Handbook and Approved Documents, 1992.

Cement and Concrete Association of New Zealand, TR 3, 1991. Alkali aggregate reaction – Minimising the risk of damage to concrete.

Lewis, R.K. and Blakey, F.A. 1969. The interpretation of core strength results. CSIRO.

The Concrete Society (U.K.) Technical Report No. 11, 1987.

NEW ZEALAND LEGISLATION

Building Act 1991
Building Regulations 1992

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

FOREWORD

The objectives of this revision are to:

1. Update NZS 3109 in the light of the recently published NZS 3101 Concrete Design Standard.

2. Structure the revised NZS 3109 in a form which is compatible with the building control regime established under the Building Act 1991.

3. Reflect the developments in materials and practices which have occurred since the last revision of this Standard.

REVIEW OF STANDARDS

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6020.

NEW ZEALAND STANDARD

CONCRETE CONSTRUCTION

1 GENERAL REQUIREMENTS

1.1 Scope and application

1.1.1
This Standard provides a means of compliance with the construction requirements for structures designed in accordance with NZS 3101. This Standard may also provide minimum requirements for the construction of reinforced concrete, unreinforced concrete, prestressed concrete or a combination, in elements of any building or civil engineering structure designed on any other basis.

1.1.2
For the production of concrete, compliance with this Standard is satisfied through compliance with NZS 3104. Amd 1 Aug '03

1.2 Interpretation

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*" are comments, explanations, summaries of technical background, recommended practice or suggest approaches which satisfy the intent of the Standard. They relate to the corresponding mandatory clauses where present. They are not to be taken as the only or complete interpretation of the corresponding clause nor should they be used for determining in any way the mandatory requirements of compliance within this Standard. The Standard can be complied with if the comments are ignored.

1.2.3
Cross-references to other clauses or sub-clauses within this Standard quote the number only, for example ".... slump required by 6.8.1".

1.2.4
Where this Standard contains non-specific or unqualified requirements (such as where provisions are required to be acceptable, adequate, applicable, appropriate, relevant, satisfactory, suitable or the like,) or where it refers to work complying with drawings and specifications other than those prepared in accordance with NZS 3101 then these do not form parts of the means of compliance with construction requirements for structures designed in accordance with NZS 3101 as a verification method for compliance with the New Zealand Building Code.

C1.2.4
Where the non-specific or unqualified requirements of 1.2.4 are applied, then such application is treated as an alternative solution to the New Zealand Building Code and needs to be to the satisfaction of the territorial authority.

1.3 Construction review

1.3.1
All stages of construction of a structure or part of a structure within the scope of this Standard shall be adequately reviewed by a person who, on the basis of experience or qualifications, is competent to undertake the review and who can verify that the design intent is being interpreted correctly. That person is referred to in this Standard as the construction reviewer.

C1.3.1
NZS 3101 requires that the extent of review to be undertaken shall be nominated by the design engineer, taking into account those materials and workmanship factors which are likely to influence the ability of the finished construction to perform in the predicted manner.

The construction reviewer may be required, as a condition of a building consent, to certify that he or she believes on reasonable grounds that either all, or specified parts, of the concrete work has been completed to the extent required by that building consent.

1.3.2
A decision or approval of the construction reviewer which provides an outcome which differs from the requirements of NZS 3101 is outside the scope of NZS 3109 as a means of compliance with the construction requirements of designs in accordance with NZS 3101.

C1.3.2
When the decisions or approvals described in 1.3.2 are then the work affected will be treated as an alternative solution to the New Zealand Building Code and needs to be to the satisfaction of the territorial authority.

2 DEFINITIONS

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

ANCHORAGE, (when referring to prestressing). A device or provision enabling the prestressing tendon to impart and maintain the prestress in the concrete.

BATCH. The unit of concrete which results from a single operation of mixing of materials.

CHARACTERISTIC STRENGTH OF TENDONS. A guaranteed value of the tensile strength of the tendon below which not more than 4 % of the test results shall fall.

COMPRESSIVE STRENGTH OF CONCRETE. The crushing resistance of cylindrical specimens of concrete, prepared, cured and tested in accordance with the standard procedures prescribed in sections 3, 4 and 6 of NZS 3112: Part 2. This is denoted by the symbol f'_c.

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

CONSTRUCTION REVIEWER. A person who is nominated by the owner of the works being constructed and who, on the basis of qualifications and experience, is competent to perform the particular function being nominated in this Standard. Where necessary, this may include an appropriate level of structural design competence or may involve referring questions to the design engineer as defined in NZS 3101. The actions of the construction reviewer shall at all times promote compliance with the performance criteria of the New Zealand Building Code.

DEVIATION. Difference between a particular size or position and the corresponding nominal size or position.

DRAWINGS AND SPECIFICATIONS. The documents on which a building consent under the Building Act has been granted including all conditions to which the building consent is subject.

FALSEWORK. The structure which supports the formwork, associated access ways and the placed concrete.

Amd 1 Aug '03

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

LOWER CHARACTERISTIC YIELD STRENGTH, (of reinforcing steel). The value of yield strength below which not more than 5 % of the production tests in each size falls, denoted by the symbol f_y (refer AS/NZS 4671). Amd 2 Mar '04

MICROALLOYED BARS. Grade 500 reinforcing bars that are cooled in air from rolling temperature and derive their high strength properties substantially from the alloy content of the steel. Amd 2 Mar '04

PLANT SUPERVISOR. The person suitably experienced in the manufacture and quality control of concrete and approved by the engineer to the plant in accordance with NZS 3104 to exercise supervision of all aspects of plant operations.

POST-TENSIONING. A method of prestressing in which the tendons are tensioned after the concrete has attained sufficient strength.

PRESTRESSED CONCRETE. Concrete in which stresses are induced which counteract, to a desired degree, the stresses resulting from external loads.

PRETENSIONING. A method of prestressing in which tendons are tensioned before the concrete is placed.

Amd 1 Aug '03

QUENCHED AND SELF-TEMPERED BARS. Grade 500 reinforcing bars that are partially water quenched from rolling temperature and derive their high strength properties substantially from modified microstructures resulting from heat treatment. Amd 2 Mar '04

READY MIXED CONCRETE. Concrete conforming to the requirements of NZS 3104 delivered to the site ready mixed.

REINFORCED CONCRETE. Concrete containing steel reinforcement, and designed on the assumption that the 2 materials act together in resisting forces.

SAMPLE, REPRESENTATIVE. A sample of a batch of concrete taken as prescribed in 3.4.3 of NZS 3112: Part 1.

SAMPLE, SNATCH. A sample taken as prescribed in 3.4.2 of NZS 3112: Part 1.

SAMPLING, RANDOM. Sampling by a procedure in which all of the concrete from which the selection is to be made has an equal chance of being sampled, that is, sampled without bias, such as by the use of tables of random numbers or by other well established methods. ➤

SAMPLING, SELECTED. Sampling after the concrete has been sighted (for example, on the basis of some visible feature prompting a check test) or the predetermined sampling of a particular batch prompted by the desire to have further information about such particular batch.

SLUMP, NOMINATED. The nominal slump value that the concrete is required to have at the time of its placing.

SPECIFIED COMPRESSIVE STRENGTH of concrete. A singular value of strength normally at age 28 days unless stated otherwise, denoted by the symbol f'_c which classifies a concrete as to its strength class for purposes of design and construction. It is that level of compressive strength which is required to be equalled or exceeded by a high proportion of the concrete concerned.

STIRRUPS OR TIES. Lateral reinforcement formed of individual units, open or closed, or of continuously wound reinforcement usually placed perpendicular or at an angle to longitudinal reinforcement. The term "stirrups" is usually applied to lateral reinforcement in horizontal members and the term "ties" to those in vertical members.

Amd 1 Aug '03

TENDON. A steel element or group of elements such as wire, cable, bar or strand used in tension in a concrete member or structure to impart prestress to the concrete.

TOLERANCE. The sum of the limits accepted for the deviation concerning a particular size, shape or position. Thus, except in asymmetrical cases, the tolerance is twice the deviation.

TRANSFER. In prestressed concrete, the operation of transferring the tendon force to the concrete.

UNBONDED TENDONS. Tendons which are not bonded to the concrete either directly or through grouting. They are usually wrapped in a protective and lubricating coating to ensure that this condition is obtained.

3 REINFORCEMENT

3.1 Notation

D Diameter of former pin, mm

d_b Bar diameter, mm

d_i Minimum diameter of bend, mm

f_y Lower characteristic yield strength of non-prestressed reinforcement, MPa

3.2 Steel reinforcement

3.2.1

Amd 2 Mar '04

Reinforcing bars shall conform to AS/NZS 4671, Grade 300E or Grade 500E except that the use of Grade 250N or Grade 500N is permitted where specifically indicated in the drawings and specifications. The use of Grade 500L bars is not permitted.

Amd 2 Mar '04

C3.2.1

If it is intended on a particular project to vary this Standard by permitting reinforcing bars manufactured to standards other than AS/NZS 4671, then the effects on properties of heating by gas torch, by grinder cutting or by welding will need to be considered.

3.2.2
Welded wire fabric shall be composed of hard-drawn mild steel only, which conforms to NZS 3421. The finished fabric shall comply in other respects with NZS 3422.

3.3 Hooks and bends

3.3.1
The minimum diameter of bend measured on the inside of the bar for hook and bends of main reinforcing bars and of stirrups and ties shall be as given by table 3.1.

Table 3.1 – Minimum radii of reinforcement bends

f_y (MPa)	Bar type	Bar diameter, d_b (mm)	Minimum diameter of bend, d_i (mm)	
			Plain bars	**Deformed bars**
300	Stirrups and ties	6-20	$2d_b$	$4d_b$
or		24	$3d_b$	$6d_b$
500	All other bars	6-20	$5d_b$	$5d_b$
		24-40	$6d_b$	$6d_b$

NOTE –
Where deformed bars are galvanized before or after bending, the minimum bend diameter shall be:
(i) $5d_b$ for bar diameters of 16 mm or less
(ii) $8d_b$ for bar diameters of 20 mm or greater.

Amd 2 Mar '04

Amd 2 Mar '04

3.3.2
Details of the standard hook, bend and stirrup or tie are given in figure 3.1.

3.3.3
Spiral reinforcing shall consist of evenly spaced circular spirals tied to and in contact with the longitudinal bars.

3.3.4 *Bending*
Except as provided in 3.3.8, all bars shall be bent cold. Proper bending tools shall be used, thus guarding against notching of bars. Amd 2 Mar '04

3.3.5
Bars partially embedded in concrete to be field bent shall be bent only in accordance with this Standard, except as shown on the drawings and specifications or permitted by the construction reviewer.

3.3.6
The inside diameter of bends in welded wire fabric, plain or deformed, for stirrups and ties shall not be less than 4 wire diameters for deformed wire larger than 7 mm and 2 wire diameters for all other wires. Bends with inside diameter of less than 8 wire diameters shall not be less than 4 wire diameters from the nearest welded intersection.

3.3.7
Where plain bars are to be used in an application which requires the bars to be de-bonded from the surrounding concrete, such as dowel bars, then the cut ends of such bars shall have their circular cross-section maintained and not be distorted such as can occur with guillotining.

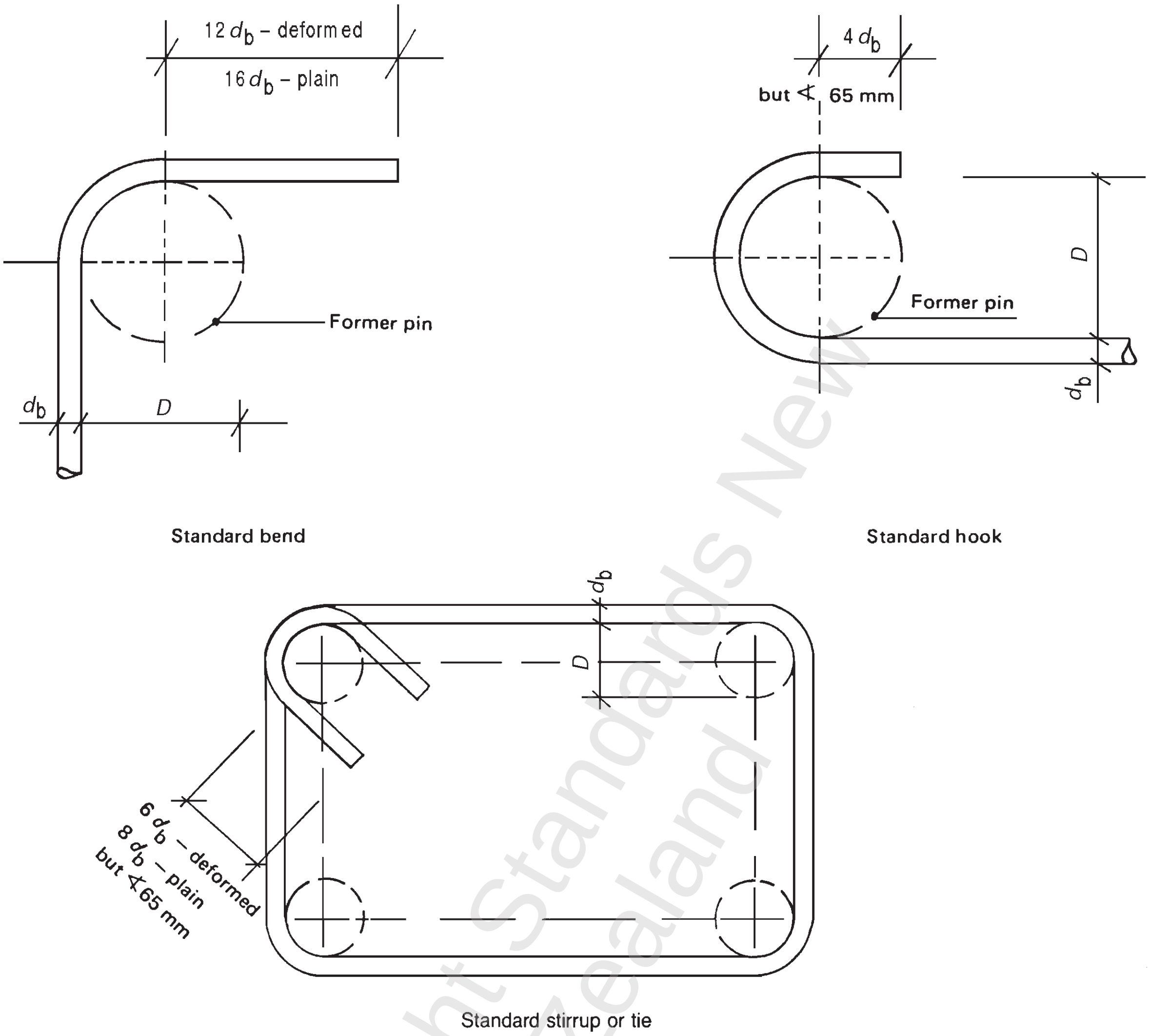


Figure 3.1 – Standard bend, hook and stirrup

3.3.8

Grade 300E and Grade 250N quenched and self-tempered bars that have been bent and which are required to be straightened or re-bent may be re-bent once only in accordance with 3.3.1, 3.3.2 and 3.3.4. Grade 500 quenched and self-tempered bars shall not be straightened or re-bent.

Where microalloyed Grade 500E or Grade 500N bars that have been bent are required to be straightened or re-bent, the bar shall be heated to 750 ± 75°C (cherry red heat) over the length of the bend and are to be bent at that temperature in accordance with 3.3.1 and 3.3.2. Such heated bars shall be permitted to air cool to ambient temperature with protection from accelerated cooling by wind, rain or similar influences.

Any re-bending, may only take place in the plane of the original bend, and shall not bend the bar past the original straight position. Re-bending shall be carried out using smoothly applied force in a continuous action, not using impact loads and using a bending tool that avoids causing surface damage.

Amd 2 Mar '04

The surface of all re-bent areas is to be inspected after completion of re-bending and if cracking of bars is found, those bars shall be rejected.

3.4 Surface condition of reinforcement

Steel reinforcement at the time concrete is placed shall be free from any material or surface condition which may adversely affect bonding capacity or other performance requirements.

C3.4
Surface contaminants such as loose, flaky rust, loose mill scale, concrete laitance mud, oil or other coatings and windblown chloride or other salts may all have a detrimental effect. Tightly adhering mill scale or surface rust do not have a detrimental effect.

3.5 Supporting and fixing of reinforcement

3.5.1
Reinforcement shall prior to commencement of concrete placement, be placed, supported and secured against displacement in accordance with the tolerances stated in 3.9.

Metal supports and tie wires to the reinforcing shall not extend into the cover concrete.

Reinforcement shall be supported by appropriate proprietary chairs or spacers, or tied up with wire, such that the durability and strength of the structure is not compromised. Cementitious spacers shall at least match the quality of the concrete being cast and shall have a minimum compressive strength of 40 MPa.

C3.5.1
For concrete members where surface finish is important, the selection of reinforcement support shall reflect the required finish.

For guidelines on selection and positioning of reinforcement support, reference should be made to U.K. Concrete Society Report CS 101 'Spacers for reinforced concrete', November 1989.

3.5.2
Welding of crossing bars shall not be permitted for assembly of reinforcement unless carried out in accordance with AS/NZS 1554.3. Amd 2 Mar '04

3.6 Spacing of reinforcement

3.6.1
The clear distance between parallel bars in a layer shall be not less than the nominal diameter of the bars nor less than 25 mm.

3.6.2
The nominal maximum aggregate size shall not be larger than 3/4 of the minimum clear distance between individual reinforcing bars or bundles of pre-tensioning tendons or post-tensioning ducts.

3.6.3
Where parallel reinforcement is placed in 2 or more layers in beams the bars in the upper layers shall be placed directly above those in the bottom layer with the clear distance between layers not less than 25 mm nor the nominal diameter of the bars.

3.6.4
The clear distance limitations between bars shall also apply to the clear distance between a contact lap splice and adjacent splices of bars.

3.7 Splices in reinforcement

3.7.1 *General*
Splices in reinforcement shall be made only in the positions and manner as indicated on the drawings and specifications.

3.7.2 *Welded splices*

3.7.2.1
Welded splices shall only be permitted where the drawings and specifications set out the performance criteria.

3.7.2.2
Amd 2 Mar '04 Welding, including tack welding shall meet the requirements of AS/NZS 1554.3, and shall not be closer than $3d_b$ from the commencement of bends or that part of bar which has been bent or bent and re-bent.

C3.7.2.2
Designers should avoid the need to weld reinforcing steel if possible as:

(a) Where butt jointing is required there is a good range of coupling devices available. Lapping, particularly of smaller bars, may also be an option;

(b) Tack welding of stirrups or ties to main bars may result in a reduction in capacity of the main bar, either through metallurgic changes, or the generation of notches due to undercut if the required procedures are not followed;

(c) Where welds are required to provide lightning protection, care should be taken to choose a route through non-critical members.

The designer's written approval should be obtained for any welding as what seems to be an unimportant weld to a site operative could affect a critical member.

Amd 2 Mar '04 *The above cautions apply to all grades of steel.*

3.7.3 *Splicing spiral reinforcing*
Spirals shall not be lap-spliced but may be welded to develop the full tensile strength of the spiral bar following the requirements of 3.7.2.1 and 3.7.2.2. Alternatively, splices shall be achieved by an extra half turn of spiral bars (or 48 diameters if governing) plus terminating the spiral bar with at least a 135 $^{\circ}$ bend and a leg of 8 diameters directed towards the core of the member.

3.8 Cover

3.8.1
Reinforcement shall be positioned in the formwork in accordance with the tolerances of 3.9(c) and 3.9(d) to provide the minimum concrete cover thickness as shown on the drawings and specifications.

C3.8.1
Cover is measured from the outside of the stirrup hoop, spiral or tie to the exterior surface of the concrete.

Concrete cover thickness requirements will vary with different concrete strengths and specifications.

3.8.2
Where concrete is cast on or against ground and compacted in accordance with section 7, the minimum cover for a surface in contact with the ground shall be 75 mm or 50 mm if using a damp-proof membrane between the ground and the concrete to be cast.

3.9 Tolerances for reinforcement

Unless tighter tolerances are specified the following tolerances shall apply:

(a) Bending tolerances:

(i) Cranks stirrups and ties where:
member depth is less than 200 mm .... +0, –5 mm
member depth is 200 mm or more .... +0, –10 mm
(ii) Other steel .... +0, –15 mm
(iii) Length of straight bars .... +0, –15 mm
(iv) Length of straight bars where length fitment is not critical .... +20 mm

(b) Tolerances on bar spacing/position (to be read in conjunction with (c) below)

(i) Spacing of main bars in beams and columns .... ±10 mm
(ii) Distance between layers of main steel except it shall not be less than 25 mm .... ±5 mm
(iii) Distance between bars along the face of walls or slabs .... ±20 mm
(iv) Spacing of stirrups or ties in beams and columns .... ±20 mm
(v) Longitudinal position of splice .... ±30 mm

(c) Tolerances on concrete cover relative to the values shown on the drawings and specifications

(i) In slabs and walls .... +10, –0 mm
(ii) In beams and columns .... +10, –0 mm
(iii) At ends of members .... +25, –0 mm

(d) *Large bars.* For bars of diameter greater than 20 mm, the tolerances in (a), (b) and (c) above shall be increased by 5 mm except that where the stipulated value is zero there shall be no change.

C3.9
Where tighter tolerances are specified, the minimum requirements of this Standard as a means of compliance with the construction requirements of NZS 3101 will be exceeded.

There are no permitted reductions in the concrete cover dimensions.

For the tolerances applicable to prestressing tendons and ducts, refer to 4.5.

3.10 Fibre reinforcement

> ***C3.10***
> *This clause is outside the scope of this Standard as a means of compliance with NZS 3101.*

3.10.1
Steel fibre reinforcement shall be manufactured in accordance with ASTM A820.

3.10.2
Polypropylene fibre reinforcement shall be manufactured in accordance with ASTM C1116.

3.10.3
Alkali resistant glass fibre reinforcement shall be manufactured in accordance with ASTM C1116.

4 PRESTRESSING MATERIALS

4.1 Care of materials

4.1.1
All wire, strand, alloy and steel wire bars, anchors, couplers, ducts and similar items shall be adequately packed, handled and stored and maintained in a dry state, free from damage. A light coating of rust on tendons will be allowed, but no flaking rust, or pitting which is visible to the naked eye is acceptable. This requirement applies until the tendons are permanently protected against corrosion in the concrete member or structure.

4.1.2
Wire and strand shall be delivered from the manufacturer in coils of sufficiently large diameter to ensure that it runs off straight.

4.2 Test certificates

All wire, strand or bars shall be tested and shall comply with the test criteria given in AS 1311, AS 1313, BS 4486 or BS 5896 as applicable. Test certificates, including the stress/strain or load/extension plots, complying with the relevant supply Standard shall be supplied by the manufacturer for all wire, strand and bars to be used in the work, and copies shall be made available for inspection to the construction reviewer if required.

> ***C4.2***
> *Test certificates and particularly the stress/strain or load/extension plots of the material to be used are required for the realistic determination of tendon extensions under 8.4.2.*

4.3 Material specifications

4.3.1 *High tensile steel wire*
All high tensile wire, shall comply with the requirements of AS 1311 or BS 5896. All wire shall be stress relieved, and may be stabilized to reduce relaxation under stress. The wire may be either plain or indented, but shall not be crimped.

4.3.2 *High tensile steel strand*

4.3.2.1
The strands shall be of seven wire cross-section complying with all requirements of AS 1311 or BS 5896. Acceptance tests shall be made on the fabricated strands rather than the individual wires used to make up the strand.

4.3.2.2
Any strand in which the helix of wires is only loosely bound or has "destranded" shall be rejected, except that some destranding of the portions outside the anchors will be permitted.

4.3.3 *Cold worked high tensile alloy steel bars*

4.3.3.1
Cold worked high tensile alloy steel bars used as tendons shall comply with AS 1313 or BS 4486.

4.3.3.2
Bars shall be handled to avoid kinking. Bars which have been kinked to a local radius less than 50 bar diameters shall not be incorporated in the structure. Any irregularities in straightness of less severity shall be corrected before the bars are incorporated in the structure.

4.3.4 *Ducts for post-tensioned grouted tendons*

C4.3.4
The type of ducting used and the condition of its surface has a marked influence on the level of frictional resistance and consequent reduction of tendon forces, along the length of the tendon away from the end being stressed. Typical values for the friction coefficients are given in the commentary on the Concrete Design Standard NZS 3101, but there can be substantial variations from these stated values. The values adopted should be verified during the stressing operations.

4.3.4.1
Tendon ducts shall be formed by casting in either permanent or removable formers. Permanent duct formers shall be of semi-rigid corrugated metal or plastic, capable of being curved where necessary to a radii given in the post-tensioning manufacturer's information.

Smooth rigid tube shall be used only where detailed as such on construction drawings and specifications. The ducts shall be non-reactive with concrete, tendons and grout (for example, aluminium, or aluminium coated duct formers shall not be used). Removable formers shall be of rubber or other suitable material which shall be withdrawn when the concrete has hardened. In either case, the cross-sectional area of the core of the duct shall be at least twice the cross-sectional area of the steel in the tendon.

4.3.4.2
Duct formers, whether permanent or removable, shall prevent the ingress of cement paste during concreting. A grouting inlet and vent shall be provided for each duct at every high point of each tendon profile, at each end, and elsewhere at intervals of not more than 30 m. All inlets shall permit the grouting nozzle to be tightly attached, so that no pressure or grout is lost. All inlet and air vents shall be capable of being sealed against the loss of water or grout under the maximum grout pressure likely to be applied. All inlet and air vent tubes shall be not less than 6 mm inside diameter. Midspan and low point vents may be installed provided they can be accessed for being sealed.

4.3.4.3
Duct formers shall be delivered, stacked, stored and placed inside the formwork in a clean and dry condition, free from defects, damage, dirt and loose rust or scale. The voids shall be maintained in a clean dry condition until grouted.

4.3.5 *Protection materials for post-tensioned unbonded tendons*

C4.3.5
Suitable materials for use as protective coating against corrosion are bitumastics, asphaltic mastics, greases, wax, epoxy resins, or plastics. It is particularly important that the whole length of tendon should be protected, since a bare spot on a coated tendon is especially susceptible to electrolytic corrosion. The minimum coating thickness will depend on the particular coating material selected.

Suitable wrapping materials are plastics, fibreglass, metal and impregnated and reinforced paper.

4.3.5.1
Unbonded tendons, which are to be left permanently free to move longitudinally relative to the surrounding concrete, shall be coated against corrosion and wrapped for slippage and protection of the coating.

C4.3.5.1
For tendons comprised of strand which require the use of grease for corrosion protection, it is important that the individual wires of the strand be parted in such a way as allow a complete coating of all wires including the central king wire.

4.3.5.2
The coating material shall be continuous over the whole length of tendon to be protected, and shall be thick enough to ensure full continuity and effectiveness with sufficient allowance for variations in application. If the coating material is removed at anchorages, this portion of the tendon shall be protected from corrosion after the anchorage is installed. The coating material shall have the following properties. It shall be:

(a) At all times free from cracks and not become brittle or fluid over the entire anticipated range of temperatures. In the absence of specific requirements this temperature range shall be taken as –20 °C to 70 °C.

(b) Chemically stable for the life of the structure;

(c) Non-reactive with the surrounding materials such as concrete, tendons or wrapping;

(d) Non-corrosive or corrosion inhibiting;

(e) Impervious to moisture, non-absorbent, and not capable of forming a stable emulsion with water.

4.3.5.3
The wrapping shall be continuous over the entire zone to be unbonded and shall prevent the intrusion of cement paste and the loss of coating material during the casting operations. The wrapping shall have sufficient tensile strength and water resistance to resist damage and deterioration during transit, storage at the site, during installation and concrete placement.

4.3.6 *Tendon anchorages*

C4.3.6

The term anchorage is normally taken to include the unit bearing against or bonded to the concrete, together with the positive grips holding the individual tendons in or against the unit, including any special treatment to the ends of the tendons, and together with any concentration reinforcement surrounding the anchor. Anchorages may be either "stressing end" where the jacking pressure is directly applied, or "dead end" where jacking pressure is not and usually cannot be applied.

Unless friction in the tendon is to be measured by the use of a jack at the non-stressing end, it may be possible with the construction reviewer's approval to substitute a "dead end" for a "stressing end" anchor provided it can be shown that an acceptable level of prestressing force can be obtained throughout the full length of the tendon.

4.3.6.1

Anchorages shall conform to and be fixed in accordance with the manufacturer's details, specifications and accepted practice. Every type of anchorage together with any concentration reinforcement provided shall be capable of transferring to the concrete a prestressing force of not less than 110 % of the specified characteristic strength of the tendon without diminishing the strength of the tendon at any point. Anchorages shall be perpendicular to the line of the tendon and straight for a minimum length of 1.1 m. After completion of stressing and locking-off operations, anchorages shall be permanent and positive and shall not permit any further draw-in of the tendon. The amount of draw-in during anchorage shall be measured and shall lie within a nominated range stipulated by or agreed to by the designer, based on the results of previous actual experience, and allowance shall be made for such draw-in in determining tendon extensions corresponding to jacking loads.

4.3.6.2

The drawings and specifications will normally identify the location of "stressing end" and "dead end" anchorages. If not so identified, it shall be assumed that all anchorages are of the "stressing end" type.

The requirements for "dead end" anchorages shall be consistent with 4.3.6.1.

4.3.6.3

Where post-tensioned unbonded tendons are to be used, the anchorages and tendons shall be shown to satisfy 3 additional test requirements as follows. The test assembly shall consist of a length of tendon with an anchorage fitting at each end. The test loading shall be applied to each fitting by the test apparatus in the same manner as it would be applied in the structure. The 3 additional test requirements are:

(a) In a static test to failure the total elongation of a new test assembly shall not be less than 2.5 % measured over not less than a 3 m gauge length;

(b) A new test assembly shall withstand without failure 500,000 cycles from 60 % to 66 % of its specified characteristic strength;

(c) A new test assembly shall withstand without failure at least 50 cycles of loading corresponding to the following percentages of its specified characteristic strength:

$$60 \pm \frac{600}{(L + 30)} \quad \text{(Eq. 1)}$$

where

L is the length in metres of the tendon to be used in the structure.

C4.3.6.3
In structures subjected to earthquake loading the effects of reversal of loading, repetitive loading and possible adverse notching effects by the anchor on the tendon should be investigated to ensure that anchorage failure will not occur. Hence special tests are recommended for anchorage assemblies for unbonded tendons, which are left permanently free to move longitudinally relative to the surrounding concrete. It should be noted that in the case of unbonded tendons complete reliance is placed on the anchorage to hold the tendon force for the whole life of the structure, whereas for pre-tensioned or grouted post-tensioned tendons the bond between the concrete and steel will maintain much of the tendon force, if not all, in the event of an anchorage failure. Therefore, it is particularly important to prevent anchorage failure of unbonded tendons, since such failure is catastrophic and is extremely dangerous due to the large release of energy. The test requirements apply to all unbonded tendons used in seismic zones even if the design calculations indicate that the tendons are not required in the structure for earthquake resistance. The percentage elongation requirement from a static test is included because it is important that the anchorage used does not damage the tendon and lead to failure at a small elongation. For the cyclic load tests, one cycle involves a change from the lower load to the higher load and return to the lower load. Generally the tests are conducted on full scale tendon and anchor fittings but for cyclic load tests only, systems with multiple strands, wires or bars may be tested using a small capacity prototype tendon that will duplicate the behaviour of the full scale tendon including anchorage. Generally the small capacity tendon when used should have not less than 10 % of the strength of the full scale tendon. The test data from the assemblies should be sufficient to ensure that the combinations of tendon and anchorage meet the specifications. It is not necessary to require tests on samples taken from the material being used for the specific project; tests from lots made to the same specification should be sufficient.

4.3.7 *Couplers*
The provisions with regard to anchorages given in 4.3.6, where relevant, apply equally to couplers. Couplers shall be capable of transferring 110 % of the specified characteristic strength of the tendon.

4.4 Cleaning and cutting of tendons and welding near tendons

4.4.1
All prestressing tendons for grouted post-tensioned or pre-tensioned construction, at the time of incorporation in the structural member, shall be free from loose mill scale, loose rust, paint, grease or other harmful matter which may affect bond performance. Tendons which will be unbonded in their service condition shall be free of harmful surface coatings before the wrapping and protective coating is applied, and the wrapping and protective coating shall be undamaged when the tendons are concreted into the structure.

4.4.2
All cutting to length and trimming of ends shall be done by mechanical or abrasive means unless gas cutting is carried out as provided in this clause. Gas cutting is not permitted in post-tensioning work.

Cutting by gas flame may be done only if authorised by the construction reviewer. If gas cutting is permitted, there shall be an excess of oxygen in the flame and care shall be taken to ensure that the flame does not come in contact with the anchorage or with other stressed tendons.

C4.4.2
The preferred method of cutting tendons is by use of a high speed flexible carborundum disc or hydraulic or mechanical shears. During cutting it is important not to apply heat to any part of the anchor or stressed tendon, or to impair the anchoring efficiency in any way. Heat resistant shields should be used to safeguard these points. When bar tendons are gas cut, a heat resisting shield should be placed over the nut and adjoining bar. When they are cut by disc or saw, a liberal amount of water should be used to dissipate the heat.

4.4.3
Welding shall not be carried out on or near high tensile tendons nor shall welding current be earthed through them or weld spatter be allowed to fall on them, except that portions not subject to stressing loads may be welded to assist placing operations provided that the work is executed in such a manner that no damage is caused to the stressed portion of the tendon.

C4.4.3
The requirements of this clause must be strictly enforced. Even the smallest amount of weld spatter deposited on tendons is sufficient to induce premature failure. Any welding currents passing through tendons can lead to failure, particularly should any arcing occur. Where welding is sanctioned to assist placing of the tendon, then the anchorage and that part of the tendon subject to high levels of stress must be completely protected and screened during the welding operation by use of a generous cover or wrapping of non-combustible material. Welding should be a least 500 mm clear of any portion at a tendon which is tensioned or to be tensioned.

4.5 Positioning of tendons and ducts

4.5.1 *Tendon location*

4.5.1.1
The tendons or ducts shall be accurately located and maintained in position both vertically and horizontally. The method of supporting and fixing the tendons, or the ducts or duct formers, in position shall be such that they will not be displaced by heavy and prolonged vibration, by pressure of the concrete being placed, by workers, or by construction traffic.

C4.5.1.1
In deciding the locating method it should be remembered that any deviation of the tendons from their correct position when the prestressing force is applied will not only alter the stress distribution throughout the cross-section but also cause the member to adopt a profile different from that anticipated in the design.

In drawings defining post-tensioned tendon profiles, dimensions will normally be given to the centreline of the tendon duct and the allowance made for the eccentricity of the tendon in its duct should also be given on the drawings. Where the stated values of eccentricity allowance do not apply to the tendons and ducts used, an appropriate adjustment will be required. The action to be taken should be resolved with the construction reviewer.

4.5.1.2
The tendons, ducts or duct formers shall be suitably tied to secondary reinforcement or located by withdrawable through-shutter bolts, precast concrete blocks or similar means.

4.5.1.3
The secondary reinforcement shall be properly braced and supported so that it forms a rigid cage and is able to support prestressing tendons during concreting.

4.5.2 *Pre-tensioned construction*

4.5.2.1
In pre-tensioned construction the means of locating the tendons shall not give rise to excessive friction when the tendon is being stressed. Stressed pre-tensioned tendons shall be supported at intervals along the bed to ensure that tendons do not sag or become displaced during concreting.

4.5.2.2
Pre-tensioned tendons shall be located and held within a tolerance of 5 mm from their specified position except that where the error in location reduces cover the tolerance is reduced to 3 mm.

C4.5.2.2
There may well be cases in large dimension or partially pre-tensioned members where it would be appropriate to allow a relaxation of the stipulated tolerances. In such cases the designer should state such requirements on the drawings.

4.5.3 *Post-tensioned grouted construction*

4.5.3.1
The joints in the ducting shall be properly tight and sealed with a suitable tape to ensure that they are grout proof.

4.5.3.2
Duct location at construction joint faces shall be sufficiently separated to enable connections to duct extensions to be effectively sealed by circumferential taping or by use of supplementary compression seals.

4.5.3.3
Ducting shall be placed to the profile detailed in a smooth curve and shall be supported at close intervals to prevent the duct floating during concreting. At anchorage locations the duct shall be perpendicular to the bearing surface of the anchor head and straight for a minimum distance of 1.5 m.

C4.5.3.3
If the tendons are not inserted into their ducts before being placed inside the forms, a semi-rigid tube or equivalent stiffener should be inserted inside each duct to provide sufficient rigidity to enable the duct to be placed to the correct smooth profile.

4.5.3.4
Ducts shall be placed in the required location within a vertical tolerance of 5 mm or h/30, whichever is the larger, where h is defined as the perpendicular distance to the nearer of the 2 extreme concrete surfaces as seen in a side elevation of the member. Duct location horizontal tolerance shall not exceed 10 mm in beams and 30 mm in slabs. All tendon anchorages shall be located with a tolerance of 5 mm from the specified position.

C4.5.3.4
The tolerance alternative of h/30 is incorporated to recognize that in deep members, provided that the tendon is not at extreme eccentricity, the tendon location is less critical. It should be noted, however, that near mid-depth of deep sections where large tolerances are allowed by the h/30 criteria, sharp changes in cable profile or direction are not acceptable (see 4.5.3.3).

4.5.3.5
At any tendon coupler care shall be taken that the axes of the 2 lengths of tendon are truly coincident through the coupler, and that wobble in the tendon is not increased by the use of couplers. Ducts shall be enlarged as necessary to contain the couplers, and care shall be taken in positioning the coupler relative to the enlargement of the duct, to ensure that there is adequate freedom of movement to permit the required tendon extension. The enlargements in the ducts for couplers shall still provide the minimum amount of concrete cover as specified.

4.5.3.6 *Water soluble oil*
Any tendon to be grouted may be protected from rust and the frictional properties improved by coating the tendons with a water soluble oil approved by the construction reviewer. After stressing and before grouting, the oil solution shall be removed by continuous flushing of the ducts with water and air agitation until little further oil solution is detected in the flushing medium.

C4.5.3.6
Where water soluble oil has been used to inhibit corrosion, it is not essential that every last trace of oil be flushed from the duct prior to grouting. In most cases 10 complete changes of flushing water can be considered an adequate level of cleanliness. This may be determined on a time basis derived from the volume of the duct and an appropriate measurement of the rate of discharge of the flushing water.

4.5.4 *Post-tensioned unbonded construction*
Special care shall be taken to ensure that the wrapping is undamaged. If the wrapping is damaged, the tendon shall be recoated with corrosion protection and the damaged portion of the wrapping replaced and sealed. The tendon shall be placed to the profile detailed in a smooth curve and shall be supported at close intervals. The tendons shall be placed within a vertical tolerance of 5 mm or h/30, whichever is the larger, where h is defined as in 4.5.3.4. Duct location horizontal tolerance shall not exceed 10 mm in beams and 30 mm in slabs.

C4.5.4
See C4.5.3.4.

5 FORMWORK, EMBEDDED ITEMS AND CONSTRUCTION JOINTS

5.1 Design of formwork

C5.1
The Australian Standard AS 3610 is a useful reference for design, detailing and propping.

5.1.1
Formwork shall be used wherever necessary to support and confine the concrete and shape it to the requirement dimensions. Joint and linings shall be sufficiently tight to prevent loss of water from the concrete.

5.1.2
Formwork shall be securely fixed and braced and have sufficient strength and rigidity to support in safety all loads arising during construction and to maintain the specified dimensional tolerances.

5.1.3
Positive means of adjustment shall be provided to ensure that formwork is secured in its correct position.

5.1.4
Formwork shall be fabricated in a manner permitting its easy removal without damage to the concrete. Where metal accessories are used they shall be constructed to be wholly or partially removable without damage to the concrete. Any embedded portion shall terminate not less than twice its minimum dimension from the concrete surface but in no case less than the specified cover requirements. Resulting cavities shall be filled with cement mortar and the surface left sound, smooth, even and uniform in colour.

5.1.5
Earth cuts shall not be used as forms for vertical surfaces unless required or permitted by the drawings and specifications.

5.1.6
Formwork release agents shall not be permitted to contact reinforcement, embedded items or hardened concrete against which fresh concrete is to be placed.

5.1.7
In computing vertical loads not less than the actual weight of concrete shall be assumed. Formwork and falsework shall be designed in accordance with sound engineering principles for the pressure of fresh concrete and for superimposed construction loads anticipated according to the method and rate of concrete placing proposed.

5.1.8
Strutting shall be carried down to construction sufficiently strong and stable to afford the required support.

5.1.9
Provision shall be made during formwork construction or erection to permit the removal of deleterious materials prior to the commencement of concreting.

5.1.10
Allowance shall be made for the redistribution of forces in the falsework resulting from the prestressing of structures which are still dependent on the falsework for support. Redundancies of the structural system and curvatures resulting from the post-tensioning action shall be taken into account.

5.2 Surface finish

In addition to the requirements of this Standard the formwork shall comply with the provisions of NZS 3114 applicable to the class of surface finish specified.

C5.2

The surface finish achieved is influenced by the following aspects of construction:

(a) Formwork rigidity;

(b) Formwork lining;

(c) Formwork joint details;

(d) Formwork release agents;

(e) Adequacy of compaction;

(f) Uniformity of concrete, including cement content, cement supply, concrete mix proportions and workability and curing;

(g) Stripping time interval.

5.3 Tolerances

The tolerances required by tables 5.1 and 5.2 are the least strict which will ensure that structures designed in accordance with NZS 3101 will meet the minimum requirements of the New Zealand Building Code. For structures designed on a basis other than NZS 3101, the minimum requirements of the New Zealand Building Code may be exceeded where these tolerances are applied. Specific tolerances are to be specified where tolerances affect the seating of members on supports or where accumulated tolerances over a series of elements may affect aspects such as joint sealing or structural connections.

Figures 5.1, 5.2 and 5.3 indicate how tolerances are to be measured.

C5.3

Tighter tolerances may need to be specified to meet objectives other than those of NZS 3101. Such tolerances will be outside the scope of this Standard as a means of compliance with the New Zealand Building Code. To avoid or lessen technical and legal arguments, it is advisable that tolerances be specified. The specified tolerance level will influence materials, construction techniques and labour and, consequently, costs. Selecting an unnecessarily strict level of tolerance will increase construction costs with no corresponding benefits. In many cases only certain dimensions are critical. A rational approach is to have tight tolerances only where necessary.

Tables 5.1 and 5.2 indicate 2 different standards of accuracy.

(1) Precast components

To forestall difficulties in erection, it is advisable the tolerances for manufacture of precast work be at reasonably high level. It is believed the tolerances listed could be described as "good quality" work and should be achieved at reasonable cost.

The differential camber between adjacent precast units after installation assumes there may be selection of units to ensure that units having large and small cambers are not alongside each other.

(2) In situ work

If a particular project requires special tolerances for construction, the specifier will need to write their own requirements for tolerances in lieu of table 5.2.

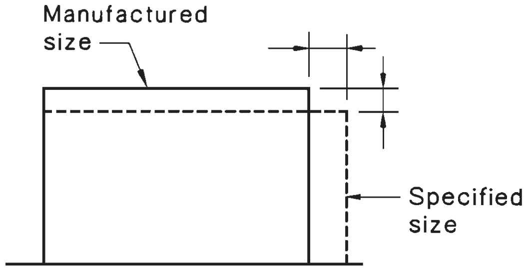
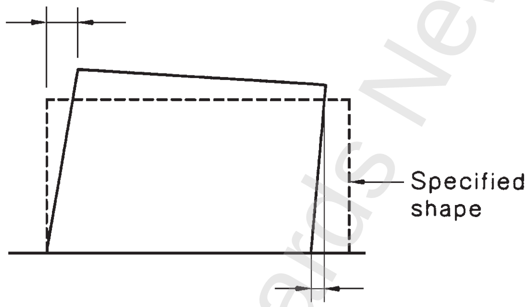


Figure 5.1 – Tolerances in linear dimensions



NOTE – Out-of-squareness may affect measurement of tolerances in linear dimensions.

Figure 5.2 – Tolerances in angular dimensions

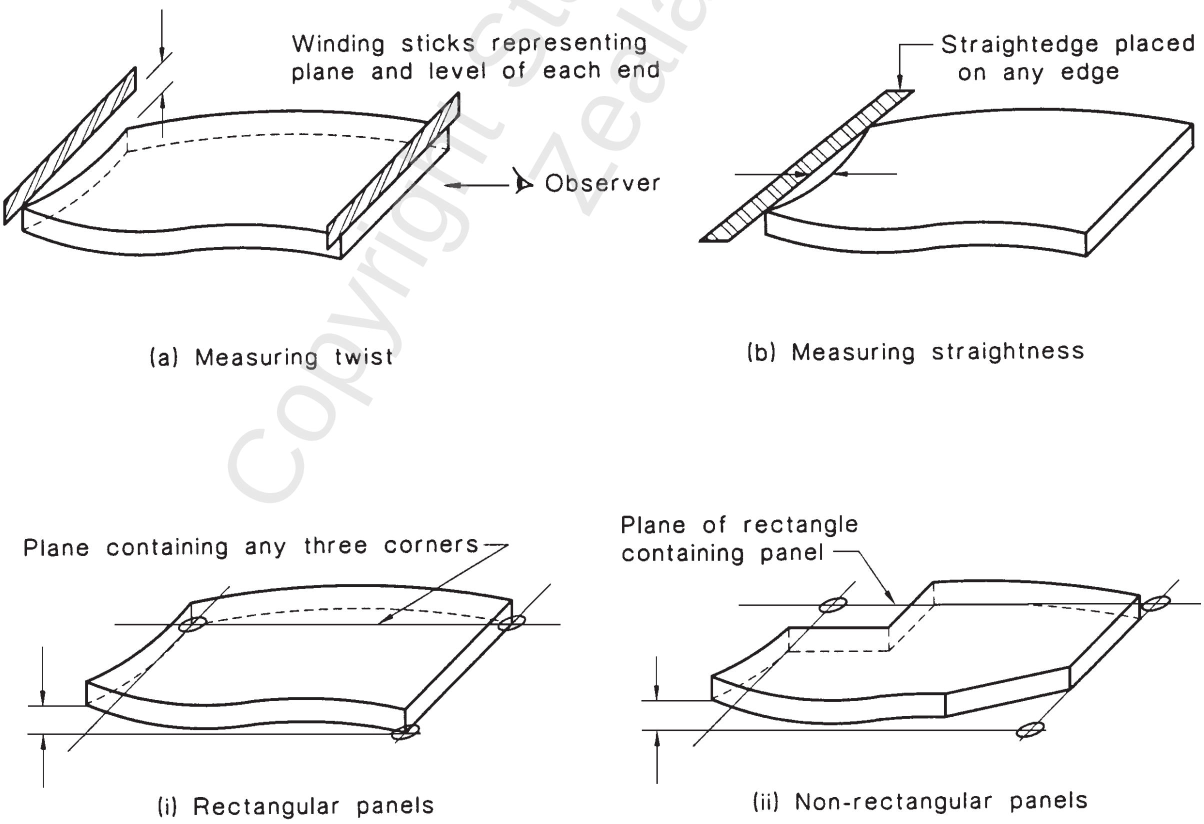


Figure 5.3 – Tolerances in profile

5.3.1 *Precast components including tilt slab*

Tolerances for precast components including tilt slab construction shall be in accordance with table 5.1.

C5.3.1

Information on tolerances in tables 5.1 and 5.2 has been partially drawn from Guidelines for Use of Structural Precast Concrete, Australian Standards AS 3600 and AS 3610, PCI Architectural Precast Concrete, ACI Manual of Concrete Practice and experience on the use of the previous NZS 3109 tolerance values.

The worst possible algebraic combination of tolerances is statistically unlikely but where it does occur, assembly problems may result. It may be impractical to specify tolerances to avoid this possibility and the use of details to accommodate generous tolerances is preferable.

When checking squareness using a 3:4:5 triangle, the longest side is to have a length error less than 1.25 times the allowable deviation for the shortest side of the triangle.

5.3.2 *In situ construction*

Tolerances for *in situ* construction shall be in accordance with table 5.2.

Table 5.1 – Tolerance for precast components

Tolerance classification	Description			Acceptable deviation, (mm)
Linear dimensions	Dimensions of flat panels	Panel length or width	< 3 m	± 5
			≥ 3 m < 6 m	± 8
			≥ 6 m	± 12
		Panel thickness at any location		± 5
		Openings length or width		± 5
	Dimensions of units other than flat panels	Cross section overall dimensions and dimensions of parts such as webs, ribs or flanges	< 600 mm	± 5
			≥ 600 mm < 1500 mm	± 8
			≥ 1500 mm	± 10
		Length, critical dimensions of abutting members or ledge support		± 5
		Length non-critical (*L* in metres)	*L* < 6 m	± 8
			6 m ≤ *L* < 12 m	± 15
			L ≥ 12 m	± 20
	Features in all units	Location of core holes, ducts or similar		± 12
		Width or depth of grooves		± 3
		Location of grooves and fastenings for window frames, door frames and similar features		± 5
		Location of grooves or strips for flashings		± 8
		Location of electrical outlets and similar features		± 12
		Other requirements		As specified(1)
		Irregular curved or unusual shapes		As specified(1)
		Position of individual connecting bolts, bolt holes, projecting metal or other devices in any associated group (e.g. the joint of 2 precast units), with respect to their position in the group		± 3
		Longitudinal location of any individual or any group of bolts, bolt holes, projecting metal or other devices, with respect of its true position in the unit in which the group is cast		± 8
		Weld plates	Lateral	± 20
			Surface depth	± 5
		Inserts	Lateral	± 12
			Surface depth	± 5
		Handling devices		± 12
Angular dimensions	Squareness of corners	Measured over shorter side, *B*	*B* < 3.0 m	± 5
			3.0 m ≤ *B* < 6.0 m	± 8
			B ≥ 6.0 m	± 12
Profile	Straightness of edge		≤ 12 m	*L* /1000 but not < 3
			> 12 m	± 15
	Flatness of surface camber	Check requirements of NZS 3114(2)		
		Variation from average camber for units when units are in place and up to 2 months after manufacture	*L* < 3.0 m	± 5
			3.0 m ≤ *L* < 6.0 m	± 8
			6.0 m ≤ *L* < 12.0 m	± 12
			12 m ≤ *L* < 15.0 m	± 15
			L > 15.0 m	As specified
	Warp	Up to 5 m diagonal		± 5
		Over 5 m diagonal		± 10
	Twist per metre width in 3 m length			± 10

NOTE –
(1) Specific requirements needed in project documentation.
(2) NZS 3114 has specification requirements relating to the use of the surface.

Table 5.2 – Tolerances for *in situ* construction

Tolerance classification	Description			Acceptable deviation, (mm)
Linear dimensions	Foundation	Dimension on plan		± 20
		Level variation of foundation top a) To receive *in-situ* construction b) To receive precast concrete c) To receive masonry		 ± 12 + 0, – 12 + 3, – 10
		Cross sectional dimensions a) Width of formed footing b) Width of footing cast against soil c) Depth of footing where D = footing section depth		 ± 12 (1) + 75, – 12 (1) ± 5 % D
	Super-structure	Length or height	< 3 m	± 5
			≥ 3 m < 6 m	± 12
			≥ 6 m	± 15
		Cross section thickness	< 150 mm	± 5
			≥ 150 mm < 300 mm	+ 10, – 5
			≥ 300 < 900 mm	+ 12, – 10
			> 900 mm	+ 15, – 12
		Openings length or width		± 5
		Cross section dimensions of parts such as webs, ribs or flanges	< 600 mm	± 5
			≥ 1500 mm	± 12
	Features	Diameter or side dimensions of core holes, ducts or similar		± 3
		Width or depth of grooves		± 2
		Location of grooves and fastenings for window frames, door frames and similar features		± 3
		Location of grooves or strips for flashings		± 5
		Location of electrical outlets and similar features		± 12
		Other requirements		As specified (2)
		Irregular curved or unusual shapes		As specified (2)
		Position of individual connecting bolts, bolt holes, projecting metal or other devices in any associated group (e.g. the joint of 2 precast units), with respect to their position in the group		± 3
		Longitudinal location of any group of bolts, bolt holes, projecting metal or other devices, with respect of its true position in the unit in which the group is cast		± 12
		Weld plates	Lateral	± 20
			Surface depth	± 5
		Inserts	Lateral	± 12
			Surface depth	± 5
Profile	Position	Position on plan or in elevation (distance to nearest reference line)		± 10
		Level of bearing surface		± 5
		Level difference to nearest upper or lower surface	h < 3 m	± 10
			3 m ≤ h < 6m	± 12
			6 m < h <12 m	± 15
	Straightness			L (mm) / 500
		Differential camber between adjacent floor units	L < 3 m	5
			3 m ≤ L < 6 m	8
			6 m ≤ L < 12 m	12
			12 m ≤ L < 24 m	20
			L ≥ 24 m	30
	Flatness of departure from 3 m template		NZS 3114 requirements	
	Plumbness	Element		h / 400 or 10 mm
		Structure	h > 12 m	25

NOTE –

(1) Minus (–) deviation not permitted if resulting in infringement of concrete cover requirements. The practicality of steel fixing in a foundation may govern its overall dimensional size.

(2) Specific requirements needed in project documentation.

5.3.3 *Foundation position*

Position on plan – within 2 % of width but not more than 50 mm for general construction and 12 mm for masonry.

5.3.4

Where tolerances are not stated in the drawings and specifications for any individual structure or feature thereof, permissible deviations from established lines, grades and dimensions shall be determined by appropriate application of the tolerances listed in tables 5.1 and 5.2.

5.4 Removal of forms and shores

5.4.1

Formwork shall be removed without shock or vibration and in such a manner as to permit the concrete to take the imposed stresses gradually. Formwork shall not be removed until the minimum periods set down in table 5.3 have elapsed except as provided by 5.4.2.

C5.4.1

Tables of minimum striking times for soffit and vertical formwork, *Construction Industry Research and Information Association Report No 67, 1977, uses as a basis:*

(a) The concrete section;

(b) Cement type;

(c) Placing temperature;

(d) Formwork thermal conductance;

(e) Ambient temperature;

(f) Required strength to avoid damage;

(g) Required strength 33 % f'_c;

(h) Required strength 66 % f'_c.

Information contained in AS 3610 provides additional helpful data.

These or similar factors should be taken into account when considering the use of shorter stripping times than those specified in 5.4.

5.4.2

When strength of concrete is the main consideration, the stripping time given in table 5.3 may he reduced if it is shown by field-cured tests that a compressive strength has been attained of twice the stress to which the member will be subjected at the time of stripping.

5.4.3
Concrete members shall not be assumed capable of supporting any superimposed loading when the minimum stripping time has elapsed and the construction supports have been removed, nor capable of supporting the design live load until the concrete has reached its design strength.

5.4.4
Nothing in this clause shall prevent longer stripping times than those given by table 5.3.

> ***C5.4.4***
> *Where colour control is important, it is advisable to strip forms early, subject to the limitations of 5.4.*

5.4.5 *Removal of formwork supports from reinforced members in multi-storey structures*

5.4.5.1
In multi-storey structures, the number of storeys, including the lowest storey, which are to remain supported by formwork at any one time and the maximum spacing of the formwork supports in any storey, shall be calculated on the basis of the relevant properties of the concrete in each floor at that time and the interaction between the formwork supports and the concrete structure.

5.4.5.2
Where removal of formwork supports from a storey will result in the floors above being supported mainly by formwork and suspended concrete construction, all supported and supporting floors and beams shall be checked by calculation for cracking and deflection under the resulting loads. Removal of formwork supports from that storey may then be permitted only if the magnitude of the cracks and deflections so calculated will not impair the strength or serviceability of the complete structure. No undisturbed supports or backprops shall be removed within 2 days of the placing of any slab directly or indirectly supported by such supports.

5.5 Embedded sleeves, conduits and pipes
Sleeves, conduits, pipes, cores or other penetrations shall not be cast in concrete unless they are stipulated on the drawings and specifications or, if not so stipulated, they are approved by the construction reviewer.

Table 5.3 – Minimum formwork stripping times – *in situ* concrete

Formed surface	Classification	Hot conditions > 20 °C	Average conditions ≤ 20 °C > 12 °C	Cold conditions ≤ 12 °C > 5 °C
Beam and slab soffits	Forms	4 days	6 days	8 days
	Supporting members (shores or backprops)	12 days	18 days	24 days
Vertical faces	Finishes F6, F5, F4 (see Note 1)	1 day	2 days	3 days
	Finishes F3, F2, F1	9 hours	12 hours	18 hours
	A minimum of 2 days applies to the stripping of vertical faces where frost damage is likely.			

NOTE –

(1) Finish references are from NZS 3114.

(2) The stripping times for beam and slab soffits for members cured in conditions less than 5 °C shall be increased by half a day for each day on which the daily average temperature was between 2 °C and 5 °C, or by a whole day for each day on which the daily average temperature was below 2 °C.

(3) Temperatures shall be taken as the average of the maximum and minimum air temperatures for a day.

5.6 Construction joints

5.6.1 *General*
Construction joints shall be formed in locations shown on the drawings and specifications or, where the locations are not defined, at positions of low shear stress as approved by the construction reviewer. In beams, slabs and columns, construction joints shall be made horizontal or vertical. Where during a continuous concreting operation it becomes necessary in an emergency to stop placing concrete before a section is completed, bulkheads shall be placed at right angles to the long axis of the section, the concrete squared up to this bulkhead and the resulting joint treated as a construction joint.

5.6.2 *Methods of construction*

5.6.2.1
For horizontal joints, the surface of the concrete may be prepared by green cutting (using high velocity air/water jets or vigorous wire brushing) to remove all laitance and inferior surface concrete after the concrete has hardened sufficiently to prevent loosening of any aggregate which is not removed. The time during which green cutting is feasible may be extended by the application of a surface retarder.

C5.6.2.1
Scabbling of hardened concrete to produce a construction joint surface can crack or loosen coarse aggregate particles and thus reduce the shear strength of the concrete in the plane of the joint. Whilst the texture dimensioned in 5.6.3 is necessary for a joint subject to stress, methods of surface preparation which avoid scabbling are preferred.

5.6.2.2
For other than horizontal joints a retarder shall be used to prepare the joint. Immediately on removal of the formwork the surface shall be prepared in a similar manner to horizontal joints. Alternatively, the treatments mentioned above may be omitted and the surface prepared immediately prior to placing the new concrete by scabbling or sandblasting and washing to produce a clean new surface free from all laitance and weak or damaged concrete.

5.6.2.3
Care shall be taken to avoid damage to the edges of the surface and to the aggregate forming the surface of the joint. Surfaces shall be in a saturated condition prior to placing of the fresh concrete but all standing water shall be removed before concreting commences. Immediately before placing concrete, the surface shall be restored to a bright clean condition free of laitance.

5.6.3 *Types of joint*
Construction joints shall be one of the following basic types:

(a) Type A construction joints shall be used only in areas of low shear stress, and shall be prepared as specified in 5.6.2.

(b) Type B construction joints shall be made at locations indicated on the drawings and specifications where it is necessary to develop shear friction across the joint. The surface of cast concrete shall be prepared by one of the methods specified in 5.6.2. Concrete is placed against previously hardened concrete where the interface for shear transfer is clean, free of laitance, and intentionally roughened to a full amplitude of not less than 5 mm.

(c) Type C construction joints shall incorporate shear keys or steps as detailed on the drawings and specifications. The surface of the joint shall be prepared as specified in 5.6.2.

C5.7 *Seatings for precast units*
Attention is drawn to the need to specifically design seatings for precast units. Details should be given in the drawings and specifications.

6 SUPPLY OF CONCRETE

6.1 Materials and limitations

Materials for concrete and grout shall comply with the relevant requirements of NZS 3104 but shall if specified be subject to the following limitations:

(a) Chlorides:
The calculated total chloride content of concrete based on measurements of acid soluble chloride content arising from aggregate, mixing water and admixtures expressed as mass of chloride ion per unit volume of concrete shall be limited as follows:

Prestressed concrete .... 0.50 kg/m^3

Reinforced concrete
(i) Located in a moist environment or exposed to chloride .... 0.80 kg/m^3

(ii) Located in a dry or protected from moisture environment .... 1.6 kg/m^3.

Test procedures for determining the acid soluble chloride content shall conform to ASTM C1152.

(b) Sulphate:
Sulphate content of concrete as placed, expressed as the percentage by mass of acid-soluble SO_3 to mass of cement shall not be greater than 5.0 %.

(c) Other salts
Other salts shall not be added to concrete unless it can be shown that they do not adversely affect durability.

C6.1
To reduce the risk of reinforcement corrosion, 6.1 effectively precludes the use in reinforced as well as prestressed concrete of:

(a) Sea water;

(b) Some unwashed beach sand in which chloride accumulates may have concentrations which exceed that permitted by 6.1. It is advisable to check that sand from marine sources does not have unacceptable chloride levels;

(c) Accelerating admixtures containing calcium except in above-ground dry situations.

6.2 Specification and manufacture of concrete

Concrete to which this Standard applies shall be:

(a) Specified as Normal (N) or Special (S) or Prescribed Mix (P) in accordance with NZS 3104 together with:

(i) The specified compressive strength;

(ii) Nominal maximum aggregate size;

(iii) Workability;

(iv) Method of placement; and

Amd 1 Aug '03 (v) Any additional requirements associated with Special Concrete.

(b) Manufactured in accordance with NZS 3104.

C6.2
Where high early strength and specific quantities of air entrainment are required, then the concrete should be specified as a Special Concrete to include these requirements along with any other (if any) special requirements.

6.3 Concrete mixes

The following descriptions apply:

(a) Normal Concrete mixes shall be selected from the standardized strength list: N 17.5, 20, 25, 30, 35, 40, 45 and 50 MPa;

(b) Prescribed Mix Concrete shall be selected from the following restricted strength list: P 17.5, 20 and 25 MPa;

(c) Special Concrete mixes shall be specified to identify the special performance parameters required together with specified testing and compliance tolerances;

(d) Mixes over 50 MPa characteristic strength at 28 days shall be considered to be Special Concretes.

C6.3
The introduction of the term 'Special Concrete' was considered necessary to be able to describe mixes that are often project-related, requiring special characteristics, particular materials or higher strengths. Concretes in harmful environments are likely to need special materials which will lead them to be classified as Special Concretes.

The specifier is required to specify the special parameters required for the concrete and to describe a method by which a producer is required to demonstrate performance.

It will also be necessary to develop a sampling and testing compliance regime for Special Concretes.

It may be appropriate to use strength testing at alternative times rather than the normal 28-day period.

Generally Normal Concretes are based on GP cement and Special Concretes may well use either GP or GB cements.

Prescribed Mix Concrete which uses prescriptive-based quantities may use GP or limestone filler cement. Amd 1 Aug '03

7 CONCRETE PLACING, FINISHING AND CURING

7.1 Performance requirements

7.1.1 *Handling, placing and compaction of concrete*
Concrete shall be transported, handled, placed and compacted so as to:

(a) Prevent segregation or loss of materials;

(b) Produce a monolithic mass between planned joints or the extremities of members, or both;

(c) Completely fill the formwork to the intended level, expel entrapped air, and closely surround all reinforcement, tendons, ducts, anchorages and embedments; and

(d) Provide the specified finish to the formed surfaces of the member;

(e) Ensure there is no contamination of the concrete;

(f) Ensure that the transporting, handling, placing and compaction of the concrete is complete before setting reactions have passed the point which prevents the concrete from attaining its potential fully cured properties.

7.1.2 *Finishing of unformed concrete surfaces*
Unformed concrete surfaces shall be finished to achieve the specified:

(a) Dimensions, falls, tolerances, or similar details relating to the shape and uniformity of the surfaces;

(b) Cover from the surfaces-to reinforcement, tendons, ducts and embedments; and

(c) Texture of the surface.

7.1.3 *Curing and protection of concrete*

7.1.3.1
Concrete shall be cured continuously for a period of time that ensures that the design requirements for strength and serviceability are satisfied.

7.1.3.2
Freshly cast concrete shall be protected from the effects of rain, running water and freezing or drying prior to hardening. During the initial curing period the concrete shall be protected from freezing or drying.

7.2 Unfavourable conditions

7.2.1
Concrete shall not be placed on frozen ground, nor shall concrete be placed in unfavourable conditions as defined in 7.2.2 which may be detrimental to the quality and finish of the concrete in the structure unless adequate precautions have been taken.

7.2.2
Unfavourable conditions shall be deemed to include low temperatures (below 5 °C with temperature descending, or below +2 °C with temperature ascending), excessively hot dry conditions, excessively wet conditions, or any conditions making it impracticable to work and finish the concrete adequately.

C7.2.1 & C7.2.2

General

New Zealand has a temperate climate and does not generally suffer from the extremes of cold or heat prevailing in some other countries. In some cases extraordinary measures such as heating water and aggregates in a cold climate, or the use of refrigerated water in hot climates, could be beneficial.

Cold weather concreting

Precautions that may be taken in unfavourable cold conditions referred to above, including the following:

(a) Use of air entrainment;

(b) Use of lower slump concrete;

(c) Use of an approved accelerating admixture;

(d) Use of water reducers;

(e) Increased cement content;

(f) Protection of aggregates against frost;

(g) Use of hot water or heated aggregates;

(h) Avoidance of placing concrete on a frozen subgrade;

(j) Protecting the surface of the freshly placed concrete from frost until the strength of at least 3.5 MPa has been achieved – this is usually a period of not less than 2 days. When a considerable proportion of the design strength must be attained before it is safe to remove the formwork, protecting of the concrete should continue until strength test cylinders stored beside the part of the structure concerned indicates such strength has, in fact, been attained.

Hot weather concreting

High temperatures result in more rapid hydration of cement, and hence early stiffening of the concrete, greater mixing water demands, increased evaporation of mixing water, reduced strengths, and larger volume changes; and greater chances of plastic cracking. A maximum concrete temperature of 30 °C should be considered a reasonable practical upper limit, and efforts should be made to keep it at lower levels. Precautions that will reduce the temperature of the concrete placed include:

(a) Elapsed time between mixing and placing should be minimized;

(b) Exposure to the hot sun of mixers and agitators while waiting to be unloaded should be minimized;

(c) Mixer drums should be painted in heat-reflecting colours;

(d) Use concrete with the lowest possible cement content consistent with strength require-ments;

(e) Use suitable retarding admixtures;

(f) Avoid excessive mixing;

(g) In severe conditions, sprinkle stockpiles to give cooling by evaporation;

(h) If pumps are to be used, paint the pipelines white;

(j) Wet forms, reinforcing, subgrade and surrounding areas by spraying with water shortly before placing;

➤

(k) Speed up placing;

(m) Use fog sprays shortly after placement;

(n) Give prompt curing and protect exposed surfaces from drying out;

(o) Take care to maintain temperature and moisture conditions for strength test specimens required in standard test methods.

Temperature rise in mass concrete due to heat of hydration of cement. In each concrete pour, the temperature rise resulting from the heat of hydration of cement, being largely adiabatic, can be considerable, leading to relatively large volume contraction and tension in the hardened concrete as it eventually cools. The degree to which volume changes are acceptable in the structure are to be taken into account at the design stage, and acceptable temperature rises determined by the designer. Should special concrete making and placing methods (such as limiting the height of the lift, time interval between pours, embedding of cooling pipes) be required to control the temperature rise in the concrete, these are to be included in the job specification. Thermal shock to exposed concrete surfaces can result if the formwork is stripped off while the heated concrete is still at a temperature considerably above that of the surrounding air.

7.3 Preparation for concreting

7.3.1
Immediately before any concreting is commenced, it shall be ensured that all dirt, shavings, sawdust, dried mortar and other refuse has been removed and that construction joint faces have been prepared in accordance with 5.6.

C7.3.1
Appropriate means of cleaning in preparation for concreting include brushing or washing with a hose.

7.3.2
The inside of timber forms shall be wetted with clean water immediately prior to placing concrete unless the forms have been coated with purpose made form dressing applied in accordance with the manufacturer's directions and approved by the construction reviewer. No form dressing other than water shall be applied after placing reinforcement in the forms. In all cases surplus water (and form dressing) shall be removed before concrete is placed.

7.4 Handling and placing

7.4.1
The discharge, final placement and vibration of concrete shall be completed within 1 hour 30 minutes after the introduction of the cement to the aggregates or of the mixing water to the cement and aggregates or such other period as may be approved by the construction reviewer.

C7.4.1

Segregation can occur from using an uncohesive concrete and impacting the flow of such concrete onto reinforcing steel or formwork sides. It is preferable to use a drop chute or pump hose lowered within the formwork to reduce the incidence of impacting in this case.

Where impacting on steel or formwork can be avoided and a cohesive mix is used, direct placing without using a drop chute or pump hose can occur.

7.4.2

The addition of water to the mixed concrete at the site is strictly forbidden except under the controlled circumstances detailed in 6.8.2 for ready mixed concrete and the addition of water or any other material after discharge from the mixer or agitator truck is prohibited.

7.4.3

Concrete in deep sections shall be placed in layers not over 0.5 m deep and each layer shall be compacted in place by methods which will not cause the ingredients to segregate.

7.4.4

Vibration shall not be used to transport concrete along the forms.

7.4.5

Surfaces shall be free from voids caused by stone pockets. Where necessary, vibration shall be supplemented by hand spading to secure these results.

7.4.6

A succeeding layer shall not be placed unless re-vibration and reworking causes the concrete of the preceding layer to become plastic. Where delays have been too great for the foregoing to be complied with, the surface of the concrete shall be treated as for a construction joint.

C7.4.6

It is important to ensure that exposed faces of a preceding layer have been protected, if necessary, from moisture loss by wind, sum and low humidity. These factors are dependent on weather conditions.

7.5 Concrete placing under water

Any method of placing concrete under water shall ensure that no intermixing of concrete and water, segregation or wash out occurs.

C7.5

Detrimental effects on the concrete are avoided only if the concrete is discharged at a point below the surface of the previously placed concrete. Placement by concrete pump or through a tremie are the safest methods provided the discharge point is buried throughout the discharge period, and failure in this respect is disastrous. It is important in under water placement of concrete to keep careful records of the concrete placed and the corresponding wet concrete surface level so that the depth of the discharge point can be correctly located and adjusted as the work proceeds. Water levels should be adjusted (by pumping if necessary) as work proceeds to prevent the development of a hydraulic head across the wet concrete.

7.6 Compaction

7.6.1 *Vibrators to be used*
Unless approved otherwise by the construction reviewer, compaction of all concrete, including floor slabs, shall be carried out principally by the use of vibrators. Immersion vibrators shall be used in all sections for which their use is practicable and shall be supplemented by platform or screed type vibrators where satisfactory surfaces cannot be obtained with the immersion type alone. In general, form vibrators shall be used when sections are too small for the immersion type.

7.6.2 *Vibrators*
Vibrators shall be capable of transmitting to the concrete not less than 8000 cycles of vibration per minute. The vibration of immersion and form vibrators shall be sufficiently intense to cause the concrete to settle readily into place and to positively affect the concrete over a radius of at least 20 times the diameter of the vibrator and to a depth of 150 mm for slabs. A sufficient number of vibrators shall be employed so that, at the required rate of placement, vibration throughout the entire volume of each layer of concrete, and complete compaction are achieved. At least one extra vibrator shall be on hand for emergency use.

7.6.3 *Internal vibration*
Shall be applied at points uniformly spaced not farther apart than the radius over which the vibration is visibly effective. Vibrators shall be applied close enough to the forms to effectively vibrate the concrete at the formed surface.

7.6.4 *Form vibrators*
Shall be attached to or held on the forms in such a manner as to effectively transmit the vibration to the concrete and shall be raised in lifts as filling of the forms proceeds, each lift being not more than the height of concrete visibly affected by the vibration. They shall be placed horizontally at distances not greater apart than those through which the concrete is visibly affected.

7.6.5 *General*
Irrespective of the method of application, vibration of the concrete shall be such that expulsion of entrapped air and settlement of the concrete is visibly evident over all areas of the surface and shall be maintained until this action ceases and until coarse aggregate at the surface is embedded. Vibration shall not be prolonged beyond the time at which this condition is reached. However re-vibrating after a delay following the first compaction and immediate prior to initial set is permissible.

> ***C7.6.5***
> *Vibration immediately prior to initial set leads to an improvement to the concrete by reducing plastic shrinkage movements.*

7.7 Finishing (including finishes)

7.7.1
The surface finish of unformed surfaces shall comply with the provisions of NZS 3114 applicable to the class of surface finish specified.

7.7.2
Immediately after compaction, the surface of the concrete shall be screeded by straight-edge or vibrating screed to the specified profile within the tolerances specified in 5.3. Screeding shall be carried out with a minimum of working to avoid concentration of excess sand/cement paste at the concrete surface.

7.7.3
Final finishing, including floating and trowelling, shall be delayed until any water sheen has disappeared from the surface and the concrete is sufficiently stiff to prevent concentration of fine material at the surface.

C7.7.3
The timing of surface finishing is critical. If attempted too soon, excess finer material is brought to the surface and dusting and crazing may occur subsequently. If attempted too late, extra work is necessary which delays coverage of the area, accentuating the problem and in some cases the specified surface finish is not achieved. The correct timing depends on the cement content and workability of the concrete, its initial temperature and ambient weather conditions. Timing ceases to be critical if final finishing by early age grinding (at 2 to 7 days) is carried out.

7.7.4
No work shall be carried out on any area where there is free surface water. Application of dry cement or sand to absorb free water is not permitted.

7.7.5
Minor surface defect repairs such as fins, ledges, plastic cracks up to 12 mm depth, blowholes and tie holes shall be carried out as specified in NZS 3114.

C7.7.5
When repairs by patching are required on finishes F3, F4 and F5 as prescribed in NZS 3114, it is important that colour and texture be considered. A trial area is recommended prior to full scale repairs.

7.7.6
Structural defects such as chipping, spalling, honeycombing and cracking (other than plastic cracking up to 12 mm deep) shall not be repaired without written approval by the construction reviewer.

C7.7.6
Need for repair as described within this Standard arises primarily from construction actions. It does not consider repair options for damage arising from other causes, e.g. fire, explosion, overloading, earthquake, deterioration, settlement etc. Such work is considered to require specific project investigation and specification. The execution of repair works in these fields requires specialist expertise and is outside the scope of this Standard.

7.7.7
Prior to any repairs, all contaminants and cracked or otherwise unsound concrete shall be removed to produce a clean sound surface with aggregate exposed.

7.7.8
An appropriate repair method shall be selected and receive the approval of the construction reviewer prior to executing the work. Repair materials are to match as closely as possible the properties of the concrete being prepared.

C7.7.8
Typical systems are dry pack mortar, plaster or concrete replacement. It is recommended that proprietary pre-packed products be used where possible, since these products generally have proven strength and shrinkage properties.

Most cement based systems will require the surface of the concrete to be dampened down prior to repair applications and will require effective protection against damage and moisture evaporation after installation.

The method must take into account the accessibility of the repair and the skill of the available work force.

7.8 Curing and protection

7.8.1 *General*
From immediately after placement, concrete shall be protected from premature drying, excessively hot or cold temperatures and mechanical injury, The concrete shall be maintained with minimal moisture loss for the period necessary for hydration of the cement and hardening of the concrete as defined in 7.8.4.

C7.8.1
Curing concrete is a very important part of the building process because all useful properties such as strength, water tightness, wear resistance and volume stability improve with age as long as conditions are favourable for continued hydration of the cement. The improvement is rapid at early ages but continues more slowly for an indefinite period. Two conditions are required:

(a) The presence of moisture;

(b) A favourable temperature.

Evaporation of water from newly placed concrete can cause the hydration process to stop. Loss of water also causes concrete to shrink, thus creating tensile stresses at the drying surface which may result in cracking. Hydration proceeds relatively slowly when temperatures are low. The necessary duration of curing is dependant upon the type of cement, mix proportions, required strength, size and shape of the concrete mass, weather and future exposure conditions. This period may be a month or longer for lean concrete mixes. Since all the desirable properties of concrete are improved by curing, the curing period should be as long as practicable in all cases, but especially for concrete made with cements with slow strength gain characteristics.

7.8.2 *Unformed surfaces*

For concrete surfaces not in contact with the forms, one of the following procedures shall be applied on completion of concrete finishing operations as soon as it is possible to do so without damaging the surface:

(a) Ponding or continuous sprinkling;

(b) Application of absorptive mats or a layer of sand and maintaining continuously wet;

(c) Continuous application of a mist spray;

(d) Application of a membrane forming curing compound conforming to AS 3799 or ASTM C309. Curing compounds shall not be used on any surface against which additional concrete or other material is to be bonded, unless positive measures are subsequently to be taken to remove it completely from such surfaces. Effective methods include sandblasting and scabbling.

(e) Covering with an impermeable sheet such as polyethylene in a manner to prevent undue loss of water from the concrete.

7.8.3 *Formed surfaces*

Immediately after loosening or removing forms in contact with concrete surfaces, the concrete shall be cured by one of the methods specified in 7.7.2 for the curing of unformed surfaces until the end of the prescribed time by 7.8.4.

7.8.4 *Length of curing period*

When mean temperatures exceed 10 °C, curing shall be continued for at least 7 days, except where otherwise noted on the drawings and specification. When temperatures are less than 10 °C the length of the curing period shall be nominated by the construction reviewer.

> ***C7.8.4***
> *The various Exposure Classifications of NZS 3101 have differing curing requirements. If the designer designates that concrete is in an A1 or A2 exposure zone, then curing may be reduced to 3 days.*

7.8.5 *Accelerated curing processes*

Appropriate accelerated curing processes may be employed at the discretion of the construction reviewer.

> ***C7.8.5***
> *Typical methods of accelerated curing include low pressure steam curing, the application of heat or the use of admixtures.*

8 PRESTRESSING: STRESSING AND GROUTING

8.1 Concrete strength at transfer

8.1.1

The drawings and specifications shall clearly define both the specified compressive strength, f'_c and the strength at transfer and the level of prestress required for the particular components of the work.

8.1.2
Stressing of tendons in post-tensioned construction or the release of tendons in pre-tensioned construction shall not be undertaken until the concrete has attained the specified compressive concrete strength at transfer as determined from field cured compression test results. In the case of low pressure steam curing, provisions shall be made for field specimens to be cured in similar conditions to those applied to the main concrete. In the case of curing by applied heat, the construction reviewer shall approve a suiable method to be used so that the concrete in the test specimens shall follow the same time-temperature conditions as the main concrete within ±2 °C, once the temperature has become steady.

8.2 Stressing equipment

8.2.1
Prestressing steel shall be tensioned by means of hydraulic jacks. Other mechanical apparatus for applying prestress shall be subject to the approval of the construction reviewer but such other mechanical apparatus is outside the scope of this Standard.

8.2.2
The stressing equipment shall enable the jacking force to be measured by a dynamometer or hydraulic pressure gauge to an accuracy of ±3 %, in the range between 60 % and 80 % of the specified characteristic strength of the tendons on which it may be used. The calibration of load measuring equipment shall be tested and certified by a suitably qualified independent testing authority at intervals not exceeding 6 months.

8.2.3
The tensioning apparatus shall not induce excessive secondary stresses or torsional effects on the tendon, concrete or on the anchorage.

8.3 Stressing procedure

8.3.1
Prior to commencement of prestressing operations, the construction reviewer shall approve:

(a) The curing of test cylinders as required by 8.1;

(b) That the prestressing equipment has a current calibration certificate as required by 8.2.2;

(c) The calculations and measurements required by 8.4;

(d) Measurements of tendon draw-in, as provided in 8.7.3;

(e) Grout materials and grouting sequence as provided in 8.8.

8.3.2
Stressing shall be carried out in such a manner that the stress in the tendons increases at a constant rate and the transfer of this force to the concrete occurs gradually.

8.3.3
After tensioning and anchoring, the load in the tendons shall be as close as practicable to that specified. In no case shall the maximum jacking force applied to a tendon during tensioning exceed 80 % of its specified characteristic strength.

8.4 Method of measurement

8.4.1

The level of prestressing force applied shall be measured either from jack pressure or load on a calibrated gauge with allowance for friction loss in jack, or by the use of a calibrated dynamometer. It shall be checked by measuring tendon elongation.

8.4.2

Calculations shall be made to determine tendon extension corresponding to each particular tendon type and force, tendon length and profile for the methods, material and equipment intended for use on the site. Such calculations shall make allowance for draw-in at anchor grips, elongation correction due to initial stress, and

(a) *For pre-tensioning*. Rotation and displacement of the anchorage abutments under load and elongation of abutment anchor rods;

(b) *For post-tensioning*. The frictional resistance due to wobble and curvature.

Elongation calculations shall use data from the stress/strain curve supplied by the manufacturer for the specific tendon material which is to be used. Alternatively, the results of test samples may be used.

C8.4.2

Elongation correction due to initial stress

It is usual when commencing tensioning operations to impose a nominal stress in the tendon in order to take up irregularities and slackness so that a reasonable starting point is made for measuring elongation. A correction shall be applied to the total elongation observed to compensate for this initial tensioning of the tendon. Provided that the frictional resistances in the duct are reasonably uniform, and therefore that it is reasonable to assume that the losses per unit length are constant, the correction to the measured elongation may be calculated by plotting on a graph the force readings as abscissae and the measured extensions as ordinates; the intersection of the curve with the y-axis when extrapolated gives the correction value as shown in figure 8.1.

Draw-in at anchor grips

Any movement of the tendon as the anchor grips are driven home will result in some loss of stress in the tendon. The allowances made for the amount of the "draw-in" movement at anchor grips should be checked and confirmed by measurements on site.

Losses due to friction in post-tensioning

The design will have taken into account all losses of prestress that may occur during tensioning operations due to friction between the prestressing tendons and the surrounding concrete, ducts, or any fixture attached to the tendons or the concrete. In post-tensioning systems there will be movement of the tendon relative to the surrounding duct during the tensioning operation, and if the tendon is in contact with either the duct, or spacers if provided, friction will cause a reduction in the prestressing force as the distance from the jack increases. In addition a certain amount of friction will be developed in the jack itself and in the anchorage through which the tendon passes. Friction in the jack and anchorage may vary in proportion to the jack pressure, and win vary considerably between systems; they shall be ascertained for the type of jack, the particular jack, and the anchorage system to be used. Friction in the duct due to unintentional and intentional changes in direction may be calculated using the method given in NZS 3101.

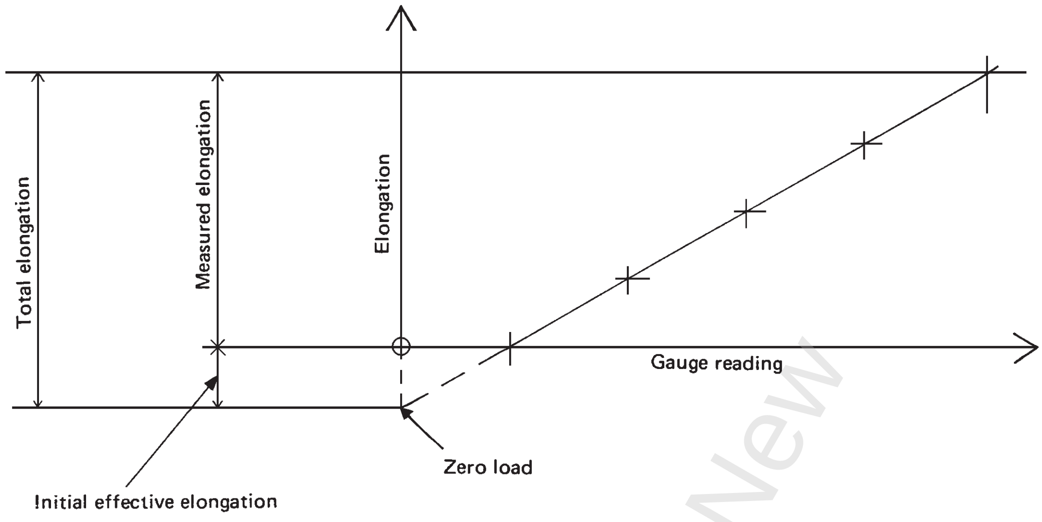


Figure 8.1 – Elongation correction

8.4.3 *Friction testing*

At the commencement of work on a project where required by the construction reviewer, verification measurements shall be made in sufficient number to reliably check the values of the parameters used in the above calculations. Where necessary, the calculations shall be modified to incorporate the measured values. The test for post-tensioned tendons requires that readings at both active and passive anchorages be taken. This may be done either by employing jacks at both anchorages, or by relocating the jack used at the active anchorages and using it to read the residual load at the passive anchorage. The total measured elongation and the forces at both anchorages shall be used to derive true values of the frictional parameters between tendon and duct.

C8.4.3

In selecting representative tendons for friction testing, it is important to recognize that good correlation with calculations cannot normally be obtained on short tendons (less than 30 m). Often the loss due to friction is smaller than the variation permitted in the stressing force. Representative tendons should, therefore, be as long as possible.

8.4.4

Particulars of the required elongation of the tendons and of the jack pressure or total force requirement shall be provided together with such other details as apply from those stated in 8.4.2.

C8.4.4

The responsibility for providing information on elongation, jacking load and other factors has not been defined in this Standard and should therefore be covered in the "Special Conditions of Contract". In most circumstances the calculations would be prepared by the specialist prestressing contractor and checked by the contract supervisor, so that agreement is reached between the parties on the specific criteria which will be used to control the operation. Supervisory staff must have on hand, prior to commencement of stressing, details of the agreed criteria for each different type of tendon or layout geometry used.

8.4.5

The cause of any discrepancies between measured and calculated extensions which exceeds 5 % in pre-tensioning and 8 % in post-tensioning shall be ascertained and corrected.

8.5 Multi-tendon stressing

8.5.1

Single element tensioning may be used on pretensioned construction, but only on post-tensioned construction in the special case of flat slabs where the tendons comprise not more than four parallel elements anchored individually in line.

8.5.2

The several elements forming a post-tensioned tendon shall be tensioned simultaneously to induce equal loads in each element. In the event of breakage or loss of prestress of one or more elements when a large number are being tensioned, or in individual wires in a stranded tendon, the total prestress force shall be maintained, but the stress in any individual tendon shall not be increased by more than 3 %. If the loss of steel area exceeds 3 %. The situation falls outside the scope of this Standard.

> ***C8.5.2***
>
> *Where the loss of steel area exceeds 3 % further measures may need to be taken to ensure that the objectives of the design are met.*

8.6 Deflected tendons in pre-tensioned members

Where tendons are deflected in a pre-tensioned member, the stressing shall be carried out in such a manner as will ensure that the tendons are uniformly stressed and that the deflecting and holding devices are secure. Differences in force along any deflected tendon within a member shall not exceed 5 %. Tendons and deflecting devices shall be released in such a pre-determined order that allowable concrete stresses are not exceeded.

8.7 Transfer of prestress in pre-tensioning

8.7.1

The tendons shall be slowly slackened concurrently. In general, this shall be by means of movable anchor plates which shall be released smoothly in one direction only so that their full force is transferred symmetrically to the unit before any tendon is cut. Jacking the anchor plates or individual tendons by applying further load prior to slackening, for instance to remove chocks, will only be permitted if the total additional strain in tendons is less than 0.07 % of the free length clear of the end of the concrete.

8.7.2

It is not permissible to transfer prestress by cutting individual tendons in sequence.

> ***C8.7.2***
>
> *It must be emphasized that the cutting of individual tendons in sequence is not acceptable in that individual tendons are released violently, and the uncut tendons in the sequence become progressively and more dangerously overloaded as the operation proceeds. One method for the release of prestress consists of the gradual application of heat well clear of the concrete, concurrently and uniformly to all pre-tensioning wires or strands in the units cross-section. As their temperature rises, the stressed tendons yield and relax, thereby slowly transferring their load to the prestressed concrete element. This method requires very careful supervision. Where tendons are few in number and preferably in a single layer, consideration may be given to such a method subject to confirmation that the design objectives will continue to be met.*

8.7.3 *Tendon draw-in on release*

If required by the construction reviewer, representative measurements shall be made of the draw-in of tendons on transfer as follows:

The sample tendons shall be marked within 100 mm of the concrete end face on the jacking side, and measured relative to that face before and after transfer of prestress to determine the amount of draw-in. If any individual tendon draws in more than 4 mm, or the average draw-in for a group of 10 or more tendons exceeds 2 mm, then the results shall be referred to the construction reviewer for a decision on the acceptability of the results.

C8.7.3

The amount of tendon draw-in on transfer of prestress and the corresponding length of tendon from the end face needed to transfer the full prestressing force to the concrete) will be of greater concern to the designer in the case of shorter, thin units such as floor and deck slabs or cladding panels; but is less likely to be important in the longer, deep pretensioned units. Thus the need to carry out the provisions of this clause will vary from job to job. Where provision is made in a contract for such testing, then consideration should be given to a reduced frequency of testing or its deletion altogether once an acceptable continuing standard has been established for the particular materials and processes being used.

The 2 mm and 4 mm allowable limits for draw-in of tendons on release are values appropriate to normal conditions. Some strand manufacturers appear to be using a lubricant in the drawing process which has the consequences of (a) reducing the bond strength, and (b) inhibiting the modest corrosion that would otherwise have enhanced the bond strength. Average draw-in values of 5 mm and the occasional value of 8 mm to 10 mm have been experienced. The corresponding transfer length of about 2 m has very serious consequences, particularly for the shorter pre-tensioned units. Strand made from indented wire is available and is recommended to overcome the possibility of excessive draw-in.

8.8 Grouting of bonded post-tensioned tendons

8.8.1 *General*

After post-tensioned tendons have been fully prestressed and anchored, every duct shall be grouted so that the tendon is effectively protected against corrosion over its entire length.

8.8.2 *Sequence*

Grouting may be carried out on any tendon immediately after it has been stressed, or on a series of tendons after they have been stressed, provided that grouting of any tendon is carried out within one month of finally stressing that tendon, or as approved by the construction reviewer.

8.8.3 *Materials*

Grout shall be made of Type GP Portland cement and water as specified for concrete. Admixtures that improve the workability or reduce water content for the same workability may be used if approved by the construction reviewer. The proportions of the materials shall be based on the results of adequate tests made prior to the commencement of the work, and the grout shall have a minimum compressive strength of 15 MPa at 7 days determined from test cylinders moulded, cured and tested in accordance with section 5 of NZS 3112: Part 4. No admixture which contains any components consisting partly or wholly of chlorides, nitrates or sulphides shall be used. Grout shall not bleed or segregate.

8.8.4 *Flow time*

The flow time of the grout shall be measured with a standard flow cone in accordance with section 3 of NZS 3112:Part 4 and shall be between 18 and 22 seconds unless an admixture is used to improve workability, when the required flow time may be reduced to 15 seconds.

8.8.5 *Bleeding*

The amount of bleeding of the grout shall be determined as described in section 4 of NZS 3112: Part 4 and shall not exceed 2 % of the initial volume 3 hours after mixing.

Bleed water shall be re-absorbed after 24 h. This shall be confirmed using a disposable non-absorbent vertical cylinder approximately the same diameter as the cable or a short length of cable duct sealed at its lower end. The quantity of grout used shall be not less than 1.5 litres and the cylinder shall be covered and left undisturbed during the test.

8.8.6 *Plant*

8.8.6.1

Grout shall be mixed with mixer capable of producing a homogenous grout free of lumps or segregated particles. The pump capable of delivering the grout at a pressure of at least 800 kPa, and fitted with a reliable pressure gauge. Grout pressure shall not exceed 1000 kPa and the pump shall be fitted with a pressure release bypass to restrict it to this value.

8.8.6.2

The grout shall pass through a filter with mesh size not greater than 1.5 mm. The mixer capacity shall be such that a whole duct can be grouted without interruption.

8.8.7 *Procedure*

8.8.7.1

If ducts are unsheathed, they shall be flushed through with water immediately before grouting to minimize absorption of water from the grout by the concrete. The water shall then be removed by compressed air. After a period of frost, the presence of ice in the duct shall be eliminated before grouting. Injection of grout shall be from the anchorage at the lower end of the tendon if a choice exists, so that as far as possible the grout is pumped uphill.

8.8.7.2

Grout shall not be used more than 30 minutes after first mixing.

8.8.7.3

As clean grout issues from each vent pipe in turn, and there is no appearance of air bubbles, the vent shall be sealed. Grout shall be allowed to issue from the final outlet until the required flow time (see 8.8.4) is reached. When all the vents have been sealed, pressure shall be built up to at least 350 kPa and the inlet shall be sealed before the nozzle is disconnected .

8.8.7.4

Where tendons are heavily draped or vertical, special precautions shall be taken to prevent bleed water accumulating at the high points of the duct.

8.8.7.5

In the course of grouting work, should grout leakage or interconnection of ducts occur, then the grouting operation on the affected ducts shall be completed as quickly as possible. Water pressure tests shall be carried out on the remainder of the ducts in the cross-section after the grouted ducts have set, to establish the location and seriousness of any leakage.

C8.8.7.5

Water pressure testing for interconnection of ducts

Water pressure testing for duct leakage or interconnection of ducts should consist of the filling of the ducts with clean water, sealing off vents and drains as air is expelled, followed by the application of pressure in excess of the proposed grouting pressure and sealing off at that level. A drop of pressure of more than 10 % in 5 min indicates leakage and the possibility of interconnection, but does not give a reliable measure of the seriousness of the problem in that volume loss corresponding to this pressure drop is very small. Where such a pressure drop occurs, then water injection at grouting pressure should be resumed and maintained. Should an outflow of water from the mixing bowl or reservoir be detected, then serious interconnection or leakage can be regarded as established and a check should be made at all vents and drains of adjacent ducts and at concrete surfaces to identify leakage paths.

8.8.7.6

The procedure used when grouting is resumed shall ensure that interconnected ducts are grouted in sequence and as quickly as possible. In addition, for the balance of the construction work, duct placement, sealing and concreting procedures shall be reviewed and improved to eliminate interconnection. Water pressure testing shall be continued until it is established that satisfactory results are being consistently maintained.

8.9 Completion of all post-tensioning

If after completion of stressing the tendons extend outside the surface of the concrete, they shall be cut off, and the recess containing the anchor shall be filled with sand/cement mortar or other material approved by the construction reviewer so as to provide 40 mm of cover to all steel parts of anchor or tendon. Plaster of paris, epoxy resin or any corrosion-inducing material shall not be used for this purpose.

8.10 Safety precautions

In dealing with the large forces involved in prestressing, accidents can happen (and have happened) unless strict precautions are taken to prevent them. Some points that should be noted during stressing operations are given as follows:

(a) Stressing operations shall be supervised by an experienced supervisor;

(b) Pressure gauges or load cells must be accurate and carefully watched during stressing, together with the extension;

(c) Where the prestressing system in use has a pump separate from the jack, the pump shall be clear of the jack, out of the direct line of action of the tendons;

(d) Persons assisting in the stressing operations shall not stand behind or walk behind the jacks or anchorages, nor be permitted to walk on pre-tensioning beds during stressing;

(e) Only the minimum number of persons needed during the work shall be permitted near the stressing operations. All others, including any member of the general public, shall be excluded;

(f) Substantial barriers shall be placed directly in line and behind jacks and anchorages;

(g) Vibration from hammering near a stressed tendon shall be avoided;

(h) Adequate warning signs shall be displayed at times at danger points during the stressing operations;

(j) Unenclosed tendons in excess of 4 m between the point of anchorage and the commencement of a unit shall be adequately dampened to prevent "snaking" in the event of tendon failure or slip.

9 CONCRETE ASSESSMENT

9.1 Production assessment and control

The concrete manufacturing process shall follow the sampling, testing and control requirements of NZS 3104.

9.2 Project assessment

Where required by 6.3 or by the specifier, a system of assessment of concrete in a specific project or part of a project shall be instigated with the agreement of both the manufacturer and client, except that sampling and testing of concrete for slump, air content and strength shall follow the provisions of NZS 3104.

C9.2

It should be noted that trial mixes are likely to be needed with Special Concrete in order to establish performance guidelines suitable for compliance.

The statistical control methods of sampling in NZS 3104 may not result in samples of concrete being specifically taken from the project under consideration unless site mixing is being used. Where testing for a project or part of a project is specifically required, then this should be specified. The working of 9.2 can therefore be required by either the use of Special Concrete or by the need for the consultant to receive test results specifically for the project or parts of it.

9.3 Project sampling

Where the designer, construction reviewer or general contractor have reason to doubt the quality of a batch of concrete supplied, then selected representative samples of the fresh concrete shall be taken in accordance with NZS 3112: Part 1. The compression strength results shall be judged against the representative sample limits set out in 9.4.1.

C9.3

It is emphasized that when this action is required, the sampling and preparation of samples for testing must be done strictly according to NZS 3112: Part 1. It is preferable to request the concrete supplier to sample and prepare the samples under the observation of the party requesting the check on concrete quality. The concrete supplier must under the terms of NZS 3104 have technicians experienced in the testing procedures of NZS 3112.

9.4 Strength and special parameters

9.4.1 *Rejection limits*

Normal Concrete from a single test result:

Representative sample: $0.85\,f'_c$ or $f'_c - 3.5$ MPa
(whichever is the greater)

Snatch sample: $0.80\,f'_c$ or $f'_c - 4.5$ MPa
(whichever is the greater)

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Special Concrete:

Strength:	As for Normal Concrete
Special parameters:	Limits to be set by specifier in accordance with 9.2.

9.4.2 *Slump*

Slump testing at time of delivery shall be conducted in accordance with NZS 3112: Part 1.

For the acceptance of the concrete represented the results of the slump shall have a value within the tolerance limits stated in table 9.1.

Table 9.1 – Tolerances for nominated slump

Nominated slump (mm)	**Tolerance for snatch sample** (mm)
60 or less	±20
70 – 110	±30
Greater than 110	±40

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9.4.2.1

Where the slump of the concrete as delivered is less than specified and the concrete is less than one hour old, a limited addition of water by the concrete supplier shall be permitted, subject to the following:

(a) Special Concrete has not been specified;

(b) The amount of water added shall be limited to increase the slump to the nominated value, and shall under no circumstances exceed 10 litres per cubic metre of concrete;

(c) After the water addition the mixer bowl shall be turned at a minimum of 30 revolutions at mixer speed;

(d) The slump shall be re-measured and the amount of added water recorded on the concrete delivery docket.

9.5 Concrete liable for rejection

9.5.1

When concrete is liable for rejection under 9.3 the location and extent of the affected concrete shall be identified and assessed.

9.5.2

No further concrete shall be placed where it would prejudice the removal of the concrete in question.

9.5.3

The constructor or concrete supplier shall, if disputing the test results, arrange to have confirming tests made from hardened cores taken from the concrete in question. Such cores shall:

(a) Be a minimum of three sound specimens;

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(b) Be of appropriate diameter consistent with the maximum size of aggregate used in the concrete;

(c) Where possible, avoid damage to reinforcement;

(d) Before sampling, receive prior approval from the designer ensuring positions for sampling do not cause unsatisfactory weakening of the structure;

(e) Be tested in accordance with NZS 3112: Part 2 Section 9.

C9.5.3
Prior to determining the extent and operation of obtaining samples, reference should be made to the Cement and Concrete Association publication "Concrete Core Testing".

9.5.3.1
The results shall be evaluated in accordance with Concrete Society (UK) Report 11. Amd 1 Aug '03

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