NZS 3109:1987

Incorporating Amendment No. 1 and 2

New Zealand Standard

Concrete construction

NZS 3109:1987

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AMENDMENTS

No.	*Date of issue*	*Description*	*Entered by, and date*
1	22.7.83	The amendment is issued to avoid conflict with the concrete production Standards NZS 3104 and NZS 3108. Other changes are made which have been recommended as a result of experience during the use of NZS 3109 and also to avoid conflict with NZS 3101: 1982 *The design of concrete structures*.	Incorporated in this edition
2	26.6.87	Updates references to related documents and removes some anomalies.	Incorporated in this edition

NEW ZEALAND STANDARD

Specification for CONCRETE CONSTRUCTION

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COMMITTEE REPRESENTATION

This standard was prepared under the supervision of the Concrete Industry Sectional Committee (31/–) for the Standards Council, established under the Standards Act 1965. The committee consisted of representatives of the following:

*Association of Consulting Engineers of New Zealand
Building Research Association of New Zealand
*Department of Scientific and Industrial Research
Harbours Association of New Zealand
*Ministry of Works and Development
*Municipal Association of New Zealand
New Zealand Concrete Masonry Association
New Zealand Concrete Research Association
New Zealand Counties Association
*New Zealand Institution of Engineers
*New Zealand Master Builders Federation
*New Zealand Portland Cement Association
New Zealand Prestressed Concrete Institute
*New Zealand Ready Mixed Concrete Association
New Zealand Universities

The Concrete Construction Committee (31/11) was responsible for the preparation of the standard and consisted of representatives of the following organizations in addition to those marked with an asterisk (*) above:

New Zealand Institute of Architects
New Zealand Institute of County Engineers

RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

NZS 1900:----	*Model building bylaw –*
Chapter 9: 1985	*Design and construction*
NZS 3101:----	*The design of concrete structures*
Part 1: 1982	*Code of practice for the design of concrete structures*
Part 2: 1982	*Commentary on the code of practice for the design of concrete structures*
NZS 3104: 1983	*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 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: 1974	*Portland cement (ordinary, rapid hardening and modified)*
NZS 3123: 1974	*Portland pozzolan cement*
NZS 3402P: 1973	*Hot rolled steel bars for concrete reinforcement*
NZS 3421: 1975	*Hard drawn mild steel wire for concrete reinforcement*
NZS 3422: 1975	*Welded fabric of drawn steel wire for concrete reinforcement*
NZS 4702: 1982	*Metal arc welding of grade 275 reinforcing bar*

OVERSEAS STANDARDS

American Concrete Institute

ACI SP-47	*Durability of concrete*
AS 1012:----	*Methods of testing concrete –*
Part 14-1973	*Method of securing and testing cores from hardened concrete for compressive strength or indirect tensile strength*
ASTM C42—84a	*Obtaining and testing drilled cores and sawed beams of concrete*
ASTM C309—81	*Liquid membrane-forming compounds for curing concrete*
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*

FOREWORD TO 1980 EDITION

This Standard is a revision of the technical requirements of NZS 1900: Chapter 9.3A and is a means of compliance with general bylaw requirements which are set out in the revised Chapter 9.

The provisions of this Standard have been extended to cover the construction requirements of prestressed concrete and NZS 3101 covers the design requirements of prestressed concrete. Upon publication of these two documents, NZSR 32: 1968 was superseded.

Reference is made in the document to:

NZS 3104	Concrete production – High grade and special grade
NZS 3108	Concrete production – Ordinary grade

The production of concrete complying with one or other of the above Standards ensures compliance with the relevant requirements for supply of fresh concrete given in this Standard.

FOREWORD TO 1987 EDITION

The 1987 edition of this Standard incorporates Amendments No. 1 and No. 2 to the 1980 edition.

Amendment No. 1 was published concurrently with the concrete production Standards, NZS 3104 and NZS 3108 and was issued primarily so as to avoid conflict with those Standards. Amendment No. 2 brings up to date the references to related documents.

NOTES

NEW ZEALAND STANDARD

Specification for CONCRETE CONSTRUCTION

1 GENERAL REQUIREMENTS

1.1 Scope and application

1.1.1 This Standard provides minimum requirements for the construction of reinforced concrete, unreinforced concrete, prestressed concrete or a combination, in elements of any building or civil engineering structure; and provides a means of compliance with the construction requirements of NZS 1900: Chapter 9.

1.1.2 For the production of concrete, compliance with the relevant grades of this Standard is satisfied through compliance with one (or other) of the following Standards:

NZS 3104	Concrete production – High grade and special grade
NZS 3108	Concrete production – Ordinary grade

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 clause 1.2.1, clauses prefixed by "C" are intended as comments on the corresponding mandatory clauses. These commentary clauses are grouped at the end of each section.

1.3 Inspection

1.3.1 All structural concrete work shall be inspected by the person responsible for the design or by a competent representative nominated or approved by him. Such inspection shall establish that the design is being interpreted correctly and that the works are being carried out generally in accordance with the standards specified.

2 DEFINITIONS

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

ANCHORAGE 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 percent 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 normally denoted by the general symbol f_c.

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

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

ENGINEER SUPERVISOR. The professional engineer (or architect), his deputy or authorized representative, nominated on behalf of the owner to supervise the works.

NOTE – This is in distinction from the Engineer defined in bylaw requirements as exercising overall authority and who is the controlling local body's engineer.

FALSEWORK. The system of struts, ties and bracing which supports the formwork, associated accessways and the placed concrete.

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

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.

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

REINFORCED CONCRETE. Concrete containing reinforcement, and designed on the assumption that the two 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 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. The term "stirrups" is usually applied to lateral reinforcement in horizontal members and the term "ties" to those in vertical members.

TARGET MEAN STRENGTH. The mean strength for which the concrete mix has been designed.

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 Metal reinforcement

3.1.1 All reinforcement other than ties, stirrups, spirals, welded wire fabric and wire strands and high strength alloy steel bars for prestressing tendons shall be deformed unless otherwise approved by the engineer supervisor.

3.1.2 Reinforcing bars shall conform to NZS 3402P, unless otherwise approved by the engineer supervisor.

3.1.3 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.

3.2 Hooks and bends

3.2.1 The minimum diameter of bend measured on the inside of the bar for hooks and bends of main reinforcing bars and of stirrups and ties shall be as given in table 1.

3.2.2 Details of the standard hook, bend and stirrup or tie are given in fig. 1.

3.2.3 Spiral reinforcing shall consist of evenly spaced circular spirals tied to the longitudinal bars.

3.2.4 *Bending.* All bars shall be bent cold, unless otherwise permitted by the engineer supervisor. Proper bending tools shall be used, thus guarding against notching of bars.

3.2.5 No bars partially embedded in concrete shall be field bent, except as shown on the plans or permitted by the engineer supervisor.

3.3 Surface condition of reinforcement

3.3.1 Metal reinforcement at the time concrete is placed shall be free from loose flaky rust and mill scale, loose concrete, laitance, mud, oil or other coatings which adversely affect bonding capacity.

3.4 Fixing of reinforcement

3.4.1 Reinforcement shall be accurately placed, adequately supported and secured against displacement prior to ordering concrete placement.

3.4.2 Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the engineer supervisor. Metal supports and tie wires to the reinforcing shall not extend into the cover concrete. Any concrete spacers used to aid the positioning of the reinforcement shall be of comparable strength to adjacent concrete and of a quality and surface finish consistent with the required surface finish of the member.

3.5 Spacing of reinforcement

3.5.1 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.

3.5.2 The nominal maximum aggregate size shall not be larger than three fourths of the minimum clear distance between individual reinforcing bars or bundles of pre-tensioning tendons or post-tensioning ducts. Where parallel reinforcement is placed in two 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.

3.5.3 In walls and slabs other than concrete joist construction, the principal reinforcement shall be spaced not further apart than three times the wall or slab thickness, nor more than 450 mm.

3.5.4 In spirally reinforced and tied compression members, the clear distance between any longitudinal bars when viewed from the face shall be not less than one and a half times the nominal bar diameter, nor less than 40 mm.

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

3.5.6 The clear distance between pretensioning steel at each end of the member shall be not less than four times the diameter of individual wires nor three times the diameter of strands. Closer vertical spacing and bundling of strands may be permitted in the middle portion of the spans.

3.6 Splices in reinforcement

3.6.1 *General*

3.6.1.1 Splices in reinforcement shall be made only in the positions and manner as indicated on the drawings or specification or as authorized by the engineer supervisor.

3.6.2 *Lapped splices*

(a) *Lap lengths.* The length of lapped splices, where not drawn or specified, shall be in accordance with table 2. Splice lap lengths shall be increased by 100 % for plain round steel. If more than 50 % of beam bars are lapped at any one location, the required lap lengths shall be increased by 30 %.

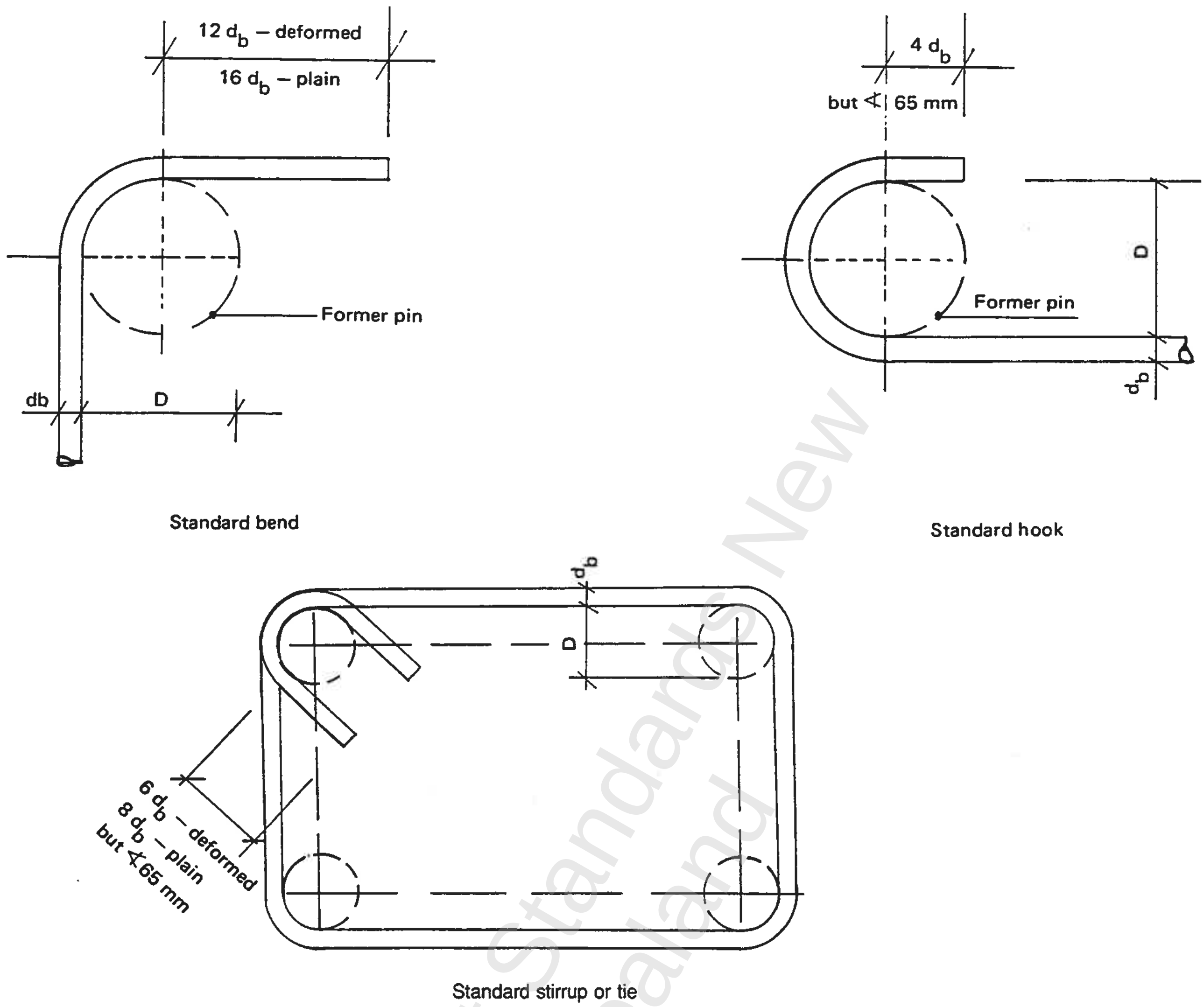

Fig. 1 STANDARD BEND, HOOK AND STIRRUP

Table 1 MINIMUM FORMER PIN DIAMETERS 'D' FOR BENDING REINFORCING BARS
(Refer also to figure 1)

Bar size	*Main steel*		*Stirrups and ties*			
	Grade 275	*Grade 380*	*Grade 275*		*Grade 380*	
			Round	*Deformed*	*Round*	*Deformed*
6	30	48	12	24	24	48
10	50	80	20	40	40	80
12	60	96	24	48	48	96
16	80	128	32	64	64	128
20	100	160	40	80	–	–
24	120	240	–	–	–	–
28	140	280	–	–	–	–
32	192	320	–	–	–	–
40	240	400	–	–	–	–

NOTE – In the case of stirrups and ties:
(1) Minimum bend diameters for deformed bars are twice those for plain round bars.
(2) Where the main bar size is greater than the minimum former pin diameter, the main bar size will govern.
(3) Grade 380 steel is not recommended for stirrups and ties.

Table 2. SPLICE LAP LENGTHS FOR DEFORMED STEEL
(in millimetres)

Bar designation	*Grade 275 steel*	*Grade 380 steel*
D10	390	580
D12	470	700
D16	620	930
D20	770	1160
D24	960	1390
D28	1200	1660
D32	1470	2030
D40 and over	Lapped splices not permitted unless approved by the engineer supervisor.	

(b) *Bundled bars.* Lengths of splices of bundled bars shall be as shown on the drawings.

(c) *Contact laps.* Only contact lapped splices, in which the spliced bars must not be further apart than the bar diameter over the length of lap, shall be used in beams and columns.

(d) *Non-contact laps.* Individual bars spliced by non-contact lapped splices in walls and floor slabs shall not be spaced transversely further apart than 20 % of the required lap length nor 150 mm.

(e) *Lapped splices in welded smooth wire fabric.* Lapped splices shall be so made that the overlap measured between outermost cross wires of each fabric sheet is not less than the spacing of cross wires plus 50 mm nor less than 150 mm, except when shown otherwise on the drawings.

(f) *Offset laps in beams and columns.* Where main bars are offset, the slope of the inclined portion of the bar with the axis of the member shall not exceed one in six, and the portions of the bar on each side of the offset shall be parallel to the axis of the member.

3.6.3 *Welded splices*

(a) Welded splices must be capable of developing the full tensile strength of the bar.

(b) Grade 275 bars (to NZS 3402P) may be welded providing the welding meets all the requirements of NZS 4702.

(c) Grade 380 bars (to NZS 3402P) may not be welded except with the approval of the engineer supervisor. He shall be satisfied prior to approval that the welding technique and control (preheating, electrode type, storage and other factors) have been demonstrated by tests to produce welds that have the required mechanical and metallurgical properties. Such established technique and control shall be maintained for the duration of the welding operation.

3.6.4 *Other splice methods*

3.6.4.1 Various mechanical connections to butt joint bars are available. They shall not be used without the approval of the engineer supervisor.

3.6.5 *Splicing spiral reinforcing*

3.6.5.1 Spirals shall not be lap-spliced but may be welded to develop the full tensile strength of the spiral bar. 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° bend and a leg of eight diameters.

3.7 Cover

3.7.1 The values of *minimum* cover defined in table 3 shall be provided for reinforcing bars, prestressing tendons or ducts. Permitted tolerances on these values are given in clause 3.8.1(c).

3.8 Tolerances for reinforcement

3.8.1 Unless otherwise specified by the engineer supervisor, tolerances relative to dimensions for reinforcing steel shall be as follows:

(a) Bending tolerances:
(1) Cranks, stirrups and ties
where member depth is less than 200 mm
+0, -5 mm
where member depth is 200 mm or more
+0, -10 mm
(2) Other steel . . . . +0, -15 mm
(3) Length of straight bars .... +0, -15 mm

(b) Tolerances or bar spacing:
(1) Spacing of main bars in beams and columns ±10 mm
(2) Distance between layers of main steel ±5mm
(3) Distance between bars along the face of walls or slabs . . . . ±20 mm
(4) Spacing of stirrups or ties in beams and columns .... ±20mm.

(c) Tolerances on cover relative to the values given in table 3 or as otherwise specified:
(1) In slabs and walls . . . . +10, –0 mm
(2) In beams and columns . . . . +10, –0 mm
(3) 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.

NOTE – For the tolerances applicable to prestressing tendons and ducts, reference should be made to 4.5.

Table 3 MINIMUM COVER (mm)

Position	*Component*	*Type of reinforcement*	*Cast in-situ*	*Precast*
Not exposed to the weather nor in contact with the ground	Beams and columns	Principal reinforcement	40	35*
		Prestressing tendons or ducts	40	30
		Secondary reinforcement including stirrups, ties and spirals	25	20*
	Walls, slabs, panels and ribs	Reinforcing bars and prestressing tendons or ducts	20†	15†
	Shells and folded plate members	Reinforcing bars and prestressing tendons or ducts	20*	20*
Exposed to the weather or in contact with the ground	Beams and columns	Principal reinforcement	50	40
		Prestressing tendons or ducts	50	40
		Secondary reinforcement including stirrups, ties and spirals	40	30
	Walls, slabs, panels and ribs	Reinforcing bars	35†	30†
		Prestressing tendons or ducts	30	25
	Shells and folded plate members	Reinforcing bars and prestressing tendons or ducts	35†	30
Cast against and permanently exposed to the ground	All components	Reinforcing bars and prestressing tendons or ducts	75	–

* The designer may stipulate less for small bars (see NZS 3101).
† For all bars greater than 20 mm increase cover by 10 mm.

NOTE –
(1) In harmful environments, including seawater, the cover given in the table shall be increased by 10 mm.
(2) In pretensioned prestressed concrete construction the cover adjacent to the tendon anchorage length shall not be less than three diameters of the respective tendon.

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

4.2.1 All wire, strand or bars shall be tested and shall comply with the test criteria given in the relevant standard specification. Test certificates shall be supplied by the manufacturer for all wire, strand and bars to be used in the work, and made available to the engineer supervisor if required.

4.3 Material specifications

4.3.1 *High tensile steel wire*

4.3.1.1 All high tensile wire, including 8 mm diameter wire, shall comply with the requirements of BS 5896. In the reverse bend test, the radius of jaws for 8 mm diameter wire shall be 25 mm. 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 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 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*

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, capable of being curved where necessary to a radius of 4 m. Smooth rigid tube may be used subject to the approval of the engineer supervisor where force transference by bond is not of primary importance. 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 in general 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 grout during concreting. An approved type of 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 vent tubes shall be not less than 6 mm inside diameter.

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*

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.

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 °

(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 and during installation and concrete placement.

4.3.6 *Tendon anchorages*

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 the specified characteristic strength of the tendon without diminishing the strength of the tendon at any point. 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 lie within a range nominated, 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 requirements for "dead end" anchorages shall be consistent with the above clause.

4.3.6.3 Where post-tensioned unbonded tendons are to be used, the anchorages and tendons shall be shown to satisfy three 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 three 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 3m 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:

$$60 \pm \frac{600}{(L+30)} \qquad (1)$$

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

4.3.7 *Couplers*

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

4.4 Cleaning, cutting and welding of 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 performance bond. 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 means. Cutting by gas flame may be done only if authorized by the engineer supervisor. 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.

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.

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 workmen, or by construction traffic.

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.

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.

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 two 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.

4.5.3.5 At any tendon coupler care shall be taken that the axes of the two 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 Any tendon to be grouted may be protected from rust and the frictional properties improved by coating the tendons with an approved water soluble oil. After stressing and before grouting, the oil shall be removed by continuous flushing of the ducts with water until little further oil is detected in the washing water.

4.5.4 *Post-tensioned unbonded construction*

4.5.4.1 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 clause 4.5.3.4. Duct location horizontal tolerance shall not exceed 10 mm in beams and 30 mm in slabs.

COMMENTARY

C4 PRESTRESSING MATERIALS

C4.2 Test certificates

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

C4.3.4 Ducting

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 code NZS 3101, but there can be substantial variations from these stated values. The values adopted should be verified during the stressing operations.

C4.3.5 Protective coatings and wrapping

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.

C4.3.6 Anchorages

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.

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

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 engineer supervisor'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.

C4.3.6.3 Unbonded tendon anchorages

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 percent 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.

C4.4.1 A film of rust is not necessarily harmful and may improve bond. It may, however, also increase the stress loss due to friction along the length of the tendon.

C4.4.2 Cutting of tendons

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, an asbestos 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.

C4.4.3 Welding near tendons

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.

C4.5.1 Tendon location

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 engineer supervisor.

C4.5.2 Tendon tolerances (pre-tensioning)

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 his requirements on the drawings.

C4.5.3 and C4.5.4 Tendon tolerances (post-tensioned)

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).*

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.

C4.5.3.6 Water soluble oil

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 ten 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.

5 FORMWORK, EMBEDDED ITEMS AND CONSTRUCTION JOINTS

5.1 Design of formwork

5.1.1 Formwork shall be used wherever necessary to support and confine the concrete and shape it to the required dimensions. Joints 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.

Table 4 PERMISSIBLE DEVIATIONS
Values to be adopted unless specified otherwise

Component	*Dimension*	*Tolerance*
	m	*mm*
1. PRECAST UNITS (except special units)		
(a) Length dimensions*	$L<3.0$	±6
	$3.0<L<6.0$	±10
	$6.0<L<12.0$	±15
	$L>12.0$	±25
(b) Cross-sectional dimensions*	$L<2.0$	±5
	$L>2.0$	±10
(c) Straightness	$L<3.0$	±5
	$3.0<L<6.0$	±10
	$6.0<L<12.0$	±15
	$12.0<L<24.0$	±20
	$L>24.0$	±30
(d) Skewness (where *L* is the diagonal of the rectangle)	$L<3.0$	±8
	$3.0<L<6.0$	±10
	$6.0<L<10.0$	±15
	$L>10.0$	±0.0015 *L*
(e) Camber: Variation from average camber for units up to two months after manufacture.	$L<3.0$	±5
	$3.0<L<6.0$	±8
	$6.0<L<12.0$	±12
	$12.0<L<24.0$	±20
	$L>24.0$	±30
2. SPECIAL UNITS (where close tolerances are necessary)		
(a) Length and height*	L or $h<3.0$	±3
	L or $h<3.0$	±5
(b) Thickness overall*		±3
(c) Deviation from square (difference in length between two diagonals)	$L<4.0$	0.0015 *L*
	$L>4.0$	6
3. IN SITU CONSTRUCTION– Foundations		
(a) Position on plan		2 % of width but not more than 50
(b) Dimension on plan		±30
(c) Level variation of top face		±25
(d) Level variation of bottom face		±40
(e) Variation in depth (d)		±0.05 d

*On occasions, it may be necessary to limit oversize, for example, +0, –10.

Component	*Dimension*	*Tolerance*
	m	*mm*
4. IN SITU CONSTRUCTION – Superstructure (including erection of precast components)		
(a) Position on plan or in elevation (distance to nearest reference line)		±10
(aa) Level of bearing surfaces for timber or masonry		±5
(b) Length and height of component	$L<0.5$	±10
	$0.5<L<1.5$	±12
	$1.5<L<3.0$	±15
	$3.0<L<10.0$	±20
	$L>10.0$	±0.002 L
(c) Cross-sectional dimensions	$L<0.5$	±10
	$0.5<L<1.5$	±12
	$L>1.5$	±15
(d) Straightness	$L<3.0$	±10
	$3.0<L<6.0$	±15
	$6.0<L<10.0$	±20
	$L>10.0$	±30
(e) Skewness (where L is the diagonal of the rectangle)	$L<3.0$	10
	$3.0<L<6.0$	15
	$6.0<L<10.0$	20
	$L>10.0$	0.002 L
(f) Level difference to the nearest upper or lower surface	$h<3.0$	10
	$3.0<h<6.0$	12
	$6.0<h<12.0$	15
	$12.0<h<20.0$	20
(g) Differential camber between adjacent precast floor units	$L<3.0$	5
	$3.0<L<6.0$	8
	$6.0<L<12.0$	12
	$12.0<L<24.0$	20
	$L>24.0$	30
(h) Floor or deck surface levels – departure from 3.0 m template		6
5. POSITION TOLERANCES (distance to nearest reference line)		
(a) Weld plates		±25
(b) Inserts		±12
(c) Handling devices		±75
(d) Flashing reglets		±6
(e) Flashing reglets at edge of panel		±4
(f) Reglets for glazing gaskets		±2
(g) Groove width for glazing gaskets		±2
(h) Electrical outlets, hose bibs, etc.		±2
(j) Openings and blockouts		±6

NOTE –

(1) In item (h) the value applies prior to removal of supporting shores. Surface profiles will incorporate any precamber allowance stipulated by the designer to counteract dead load and long term deflections.

(2) The attention of detailers is drawn to the fact that the requirements for tolerances for embedded items and blockouts vary considerably and should be subject to specific consideration.

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 20 mm. 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.

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 without permissible stress or deflections being exceeded.

5.1.9 Washout openings shall be provided at the bottom of all concrete lifts in each column or wall and shall be of adequate size and spacing for their purpose.

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

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

5.3 Tolerances

5.3.1 Where tolerances are not stated in the specifications or drawings for any individual structure or feature thereof, permissable deviations from established lines, grades and dimensions shall be determined by appropriate consideration of the tolerances listed in table 4.

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. Unless otherwise approved by the engineer supervisor, formwork shall not be removed until the minimum periods set down in table 5 have elapsed. When strength of concrete is the main consideration, the stripping time given in table 5 may be reduced if the engineer supervisor is satisfied by field-cured tests that a compressive strength has been attained of twice the stress to which the member will be subjected. 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.

Nothing in this clause shall prevent the engineer supervisor, at his discretion, lengthening stripping times from those given by table 5.

5.5 Embedded sleeves, conduits and pipes

5.5.1 *Conduits and pipes.* Sleeves, conduits or other pipes shall not be embedded in concrete unless they are of such size and location as not to impair unduly the strength or fire resistance properties of the construction. Subject to this requirement the following shall apply:

(a) Sleeves, conduits or other pipes embedded in concrete shall not be of materials whose physical or chemical properties may render them harmful to concrete.

(b) Sleeves, conduits or other pipes passing through floors, walls or beams may be considered as replacing structurally in compression the displaced concrete provided they:

(1) Are not exposed to rusting or other deterioration;

(2) Are of uncoated or galvanized iron or steel of an approved thickness;

(3) Have a nominal inside diameter not exceeding 50 mm; and

(4) Are spaced not less than three diameters on centres.

(c) Sleeves, conduits and pipes other than those merely passing through may be embedded in floors, walls, or beams provided that the effect of this embedment has been allowed for in the design of the structure and provided that their size and location has been indicated on the approved plans.

(d) Unless otherwise agreed by the engineer supervisor, pipes which will contain liquid, gas or vapour may be embedded in structural concrete under the following additional conditions:

(1) The temperature of the liquid, gas or vapour shall not exceed 65 °C

Table 5

REMOVAL OF FORMWORK

Items from which formwork is to be removed	*Minimum stripping time**
Sides of beams, walls and columns	12 hours
Slabs in beam and slab construction (props to be left under slabs of span over 2 m)	4 days
Removal of props from slabs of span over 2 m in beam and slab construction	10 days
Beams, soffits and slabs of span exceeding 5 m	18 days

* For each day in which the mean temperature falls below 10 °C add half a day to the minimum stripping time, except that a whole day should be added for each day in which mean temperature falls below 2 °C.

(2) The maximum pressure to which any piping or fittings shall be subjected shall be 1.4 MPa above atmospheric pressure

(3) Unless otherwise agreed by the engineer supervisor, immediately prior to concreting, all pipes and fittings shall be subjected to a leakage test in which:

(i) The testing pressure above atmospheric pressure shall be 50 % in excess of the pressure to which the pipes anf fittings may be subjected in service but not less than 1 MPa; and

(ii) The test pressure shall be held for 4 h with no drop in pressure except that which may be caused by air temperature.

(4) Pipes carrying liquid, gas or vapour which is explosive or injurious to health shall again be tested as specified in paragraph (3) herein after the concrete has hardened

(5) No liquid, gas or vapour, except water not exceeding 30 °C nor 140 kPa pressure above atmospheric shall be placed in the pipes until the concrete has thoroughly set

(6) In solid slabs the piping, except for radiant heating and snow melting, shall be placed between the top and bottom reinforcement.

(7) The concrete covering of the pipes and fittings shall be not less than 25 mm

(8) Reinforcement with an area equal to at least 0.2 % of the area of the concrete cross-section shall be provided normal to the piping

(9) The piping shall be so fabricated and installed that it will not require any cutting, bending or displacement of the reinforcement from its proper position

(10) No liquid, gas or vapour which may be injurious or detrimental to the pipes, shall be placed in them

(11) Drain pipes and other piping designed for pressures of not more than 7 kPa above atmospheric pressure need not be tested as required in paragraph (3) herein, but shall nevertheless be subjected to such leakage tests as are prescribed in any other statutory enactments, regulations, or requirements to which the structure is subject.

5.6 Construction joints

5.6.1 *General.* Construction joints shall be formed in locations shown on the drawings or, where the locations are not defined, at positions of low shear stress as approved by the engineer supervisor. In beams, slabs and columns, construction joints shall be made horizontal or vertical unless otherwise approved. 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 ravelling of the aggregate. The time during which green cutting is feasible can be extended by the surface application of an approved retarder.

5.6.2.2 For other than horizontal joints an approved 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.* Contruction joints shall be one of the following basic types:

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

Type B construction joints shall be made at locations indicated on the drawings 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 clause 5.6.2. The extent of treatment shall be such as to produce a roughened or broken surface to a depth of approximately 3 mm above and below the average level.

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

COMMENTARY

C5 FORMWORK

C5.2 Surface finish

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.*

C5.3 Tolerances

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.

Table 4 is proposed with three different standards of accuracy in mind.

1. Precast concrete work *(except special units).*

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.

2. Special units.

These tolerances apply where necessary and only outline dimensions are indicated. It is likely further dimensions and tolerances should be detailed on the drawings.

3. In situ work.

On the basis that a high degree of accuracy is not necessary.

If table 4 is not suited to a particular project, the specifier will need to write his own requirements for tolerances.

As mentioned in table 4 the values listed are those assumed to be applicable unless otherwise specified. If precast units are to be classified as "special units" this should be stated.

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 placed next to each other.

NOTE – The tolerances are derived from the findings of FIP/CEB commissions.

C5.4 Removal of forms and shores

Striking times of formwork. *Tables of curing periods to achieve given strengths. CIRIA Report No. 67 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

These or similar factors should be taken into account by the engineer supervisor when considering requests for approval to use shorter stripping times than those specified in 5.4.

C5.6 Construction joints

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 clause 5.6.3 is necessary for a joint subject to stress, methods of surface preparation which avoid scabbling are preferred.

6 CONCRETE : SUPPLY

6.1 Concrete strength

6.1.1 Concrete mixes shall be proportioned to be workable and capable of being thoroughly consolidated by the means of compaction available and produced to provide an average compressive strength in compliance with table 7 for the specified strength of concrete f'_c. Refer to section 9 of this Standard for procedure for the evaluation of compressive strength.

6.1.2 Drawings or specifications or both defining any project shall clearly identify the specified strength of concrete f'_c for which each part of the structure is designed.

6.2 Production standards

6.2.1 Concrete used in construction shall be either made on the site, or supplied ready mixed, or supplied in the form of precast products. Site mixed concrete production shall comply with NZS 3104 or NZS 3108 as appropriate. Ready mixed concrete and concrete used in the production of precast products off the site shall comply with NZS 3104.

6.2.2 *Concrete grades*

6.2.2.1 Concrete production shall be denoted by grades according to the standard of production employed. The grades shall be designated as follows:

ORDINARY GRADE denotes site mixed concrete conforming to the standard of production prescribed for ordinary grade in NZS 3108 and for a specified strength up to but not exceeding 20 MPa.

HIGH GRADE denotes concrete either site mixed, or factory made, or supplied ready mixed conforming to the standard of production prescribed for high grade in NZS 3104 for a specified strength up to but not exceeding 40 MPa. The concrete mix design criteria for high grade production depend on the availability of a satisfactory record of production test results. Clause 6.10.2.1 and table 7 set out these alternative requirements depending whether or not there are production records available.

SPECIAL GRADE denotes concrete either site mixed or factory made or supplied ready mixed conforming to the standard of production prescribed for special grade in NZS 3104 for a specified strength up to but not exceeding 50 MPa.

6.3 Cement

6.3.1 Cement used shall comply with NZS 3122 or NZS 3123. For normal circumstances the cement used shall be ordinary portland cement (type O), except that with the approval of the engineer supervisor rapid hardening portland cement (type RH) may be used.

NOTE – NZS 3122 and NZS 3123 as well as the two cements type O and type RH mentioned in 6.3.1 cover modified portland cement (type M) and portland pozzolan cement (type PP). Designers and specifiers are advised that type RH is not always available and type M and type PP only if special arrangements have been made with the cement manufacturers.

6.3.2 Aluminous cement (or high alumina cement) shall not be used in any structural components of the project.

6.4 Aggregate and water

6.4.1 Aggregate and water shall comply with NZS 3121.

6.4.2 The nominal maximum aggregate size shall not exceed the specified concrete cover on reinforcement, nor exceed 75 % of the clear lateral space between adjacent reinforcement (disregarding laps); provided that where a cover of 20 mm is applicable on slab reinforcement, the maximum nominal size of aggregate may be 19 mm.

6.5 Admixtures

6.5.1 The use of admixtures shall be subject to the approval of the engineer supervisor. Chemical admixtures covered by NZS 3113 shall comply with that Standard.

6.5.2 *Air entrainment.* Where concretes are air entrained, the maximum target entrapped plus entrained air contents shall conform to table 10.

6.6 Chlorides

6.6.1 The calculated total chloride content of concrete based on measurements of chloride content arising from aggregate, mixing water and admixtures expressed as chloride ion as a percentage by weight of cement shall be limited as follows:

Prestressed concrete .... 0.06 %

Reinforced concrete

(a) located in a moist environment and exposed to chloride .... 0.10 %

(b) located in a moist environment but not exposed to chloride .... 0.15 %

(c) above-ground building construction where concrete in service will remain dry permanently .... 1.50 %

Unreinforced concrete .... 1.50 %

6.7 Concrete in harmful environments

6.7.1 Where concrete will be in wet or saline situations, aggressive soil or groundwater, or in contact with harmful industrial materials or processes, appropriate measures shall be specified to ensure the durable integrity of the structure. If harmful conditions are found to exist which are not adequately covered by the specification, the engineer supervisor shall order appropriate measures.

6.8 Slump

6.8.1 The slump of the concrete shall be kept to a value consistent with satisfactory placement and compaction using the equipment approved for the work.

6.8.2 The 'nominated slump' for the concrete used shall not exceed the value stated for the corresponding type of work in table 6 unless otherwise specified or authorized by the engineer supervisor.

6.9 Minimum requirements to be nominated

6.9.1 Technical requirements defining the concrete required shall be stipulated by the designer in respect of the following:

(a) Specified strength for the concrete at 28 days (6.1.1)

(b) Minimum acceptable grade of production (6.2.2)

(c) Any restrictions or requirements for durability in harmful environments where applicable (6.7)

(d) Nominal maximum aggregate size if other than 19 mm (6.4)

(e) Whether the concrete may be placed by pump.

NOTE – Where items have not been specified in the contract documents, the requirements shall be subject to the approval of the engineer supervisor.

6.9.2 The constructor shall submit for approval by the engineer supervisor his proposals for concrete supply in respect of the following:

A (1) *If site produced.* Details of plant, equipment, sources of materials, supervision and performance record of mixes if available, or proposals to establish mix designs.

(2) *If ready mixed supply.* The name of the supplier, location of plant, evidence of performance record and grading, or if no evidence of performance or grading is available, the requirements of A(1) above.

B The proposed methods of concrete distribution to various parts of the work and the proposed methods of compaction. In particular, whether placing by pump is proposed.

C The nominal maximum aggregate size proposed for respective sections of the work (where not otherwise specifically governed under the provisions of preceding 6.4.2 and 6.9.1).

D The nominated slump values for various parts of the work.

E Any proposed admixture.

F Early strength requirements in relation to construction programme (for example, removal of shores, prestressing and so on).

6.10 Quality standards for production

6.10.1 *General.* Prior to commencement of the supplying of concrete, the constructor shall produce evidence to the satisfaction of the engineer supervisor that the concrete mixes proposed for the project are adequately designed and that the production standards nominated can be achieved consistently.

Table 6 MAXIMUM VALUES FOR NOMINATED SLUMP

Type of construction	*Maximum nominated slump*
	mm
Walls and components less than 200 mm thick, columns and beam junctions	120
Floor slabs cast on the ground	80
Heavy mass construction	80
Other concrete members	100

Table 7 MINIMUM PRODUCTION STANDARDS

	No performance record								*With a performance record*													
	Ordinary Grade		*High Grade*						*High Grade*						*Special Grade*							
Specified strength MPa	17.5	20	17.5	20	25	30	35	40	17.5	20	25	30	35	40	17.5	20	25	30	35	40	45	50
Coefficient of variation*	22	20	17.5	17	16	15	14	13	15.5	15	14	13	12	11	12.5	12	11.5	10.5	10	9.5	9	8.5
Minimum target mean strength MPa †	31	35	27.5	30.5	36.5	43	49.5	55	25	27.5	33.5	40	45.5	51	22	24.5	30.5	36.5	42.5	48.5	54	59.5

* The coefficient of variation tabulated is:

(a) In the case of no performance record, the value assumed in calculating the minimum target strength
(b) In the case of high grade or special grade with a performance record, the maximum value that will qualify for performance, subject to the provisions of 6.10.3.1. Also the least value can be used in the calculation of the target mean strength.

† To ensure a high probability that the mean of each group of 30 or more results, exceeds the cautionary limit of table 11 the designed target strength should be greater by a small margin than the minimum target mean strength tabulated above.

6.10.2 *Minimum production standards*

6.10.2.1 Table 7 defines criteria required to be assumed for mix design purposes at each strength level for:

(a) Ordinary grade production.

(b) Production with no previous history or an unacceptable record of performance.

(c) High grade production with an established and acceptable record of performance.

(d) Special grade production with an established and acceptable record of performance.

6.10.3 *Evidence of compliance*

6.10.3.1 *Performance record.* Evidence required to establish the standard of production shall include data from one or more previous test series, each of not less than 30 sets of compression test results from the same plant, using the same materials and representative of current production practice.

For any such test series tendered as evidence, the mean strength and the best estimate over-all production coefficient of variation shall be determined in accordance with section 10 of NZS 3112: Part 2 and shall be reviewed as follows:

Identify in table 7 the column headed by the nominated production standard and by the specified minimum strength for that test series. Check the derived strength parameters against the values in the identified column, that is:

(a) That the calculated mean strength of the test series is not less than the tabulated target mean strength and

(b) That the best estimate overall production coefficient of variation is not greater than the tabulated value.

6.10.3.1.1 Test series need not be from concrete of the same specified minimum strength as required in the work, but if such is the case and higher strength concrete is required, then additional evidence shall be provided to demonstrate that the concrete constituents have the characteristics needed to consistently achieve the higher target mean strengths required.

6.10.3.1.2 Where evidence, including that from 30 or more sets of production compression tests, is not available or not satisfactory to the engineer supervisor, then the coefficient of variation and the target strengths listed under no performance record in table 7 shall apply as minimum values. In the particular case when special grade production cannot be assured to the satisfaction of the engineer supervisor the corresponding high grade criteria shall be considered and applied where warranted.

6.10.3.2 *Mix design.* Evidence shall be provided to the satisfaction of the engineer supervisor that each concrete mix proposed has a target mean strength in compliance with the requirements of table 7 for the appropriate plant grading and specified strength.

6.11 Change of mix

6.11.1 When the constructor wishes to change, in a manner likely to reduce its mean strength, a mix design which the engineer supervisor has approved as specified in 6.9.2 or altered as provided in 9.5.6.3, the engineer supervisor's approval shall first be obtained. Approval shall be based on the evidence of the most recent test results from such mix, not less than 30 in number, that the proposed change is consistent with the requirements of table 7 in respect of target mean strength and variability for the specified strength.

COMMENTARY

The specified strength of concrete f'_c should be one (or more) from a standardized series of strengths adopted for structural design purposes (see NZS 3101). This series is as follows:

$$f'_c = 17.5, 20, 25, 30, 35, 40, 45, 50 \text{ MPa}.$$

C6.4 Aggregate

For low and medium strength concrete it is normally economical to use the largest nominal maximum aggregate size consistent with reinforcement spacing and cover, member dimensions and finishing requirements. A relative reduction of drying shrinkage coefficient also results. However, use of large nominal maximum sized coarse aggregate may increase the cost of supply, handling, placing and finishing. Aggregate larger than 19 mm may not be readily available.

C6.6 Chlorides

To reduce the risk of reinforcement corrosion, this clause effectively precludes the use in reinforced as well as prestressed concrete of:

(a) Sea water
(b) Most unwashed beach sand
(c) Accelerating admixtures containing calcium chloride except in above-ground dry situations.

C6.7 Concrete in harmful environments

(a) There are conditions such as wear, good long-term appearance or low maintenance cost where it is advisable to have a quality of concrete mix rather better than would be determined only on account of strength. These could occur in floors subject to wear, thin sections, ornamental or architectural concrete, reinforced piles and all sections with less than 20 mm cover.

In these cases it is recommended that the specified strength be not less than 35 MPa for non-air entrained concrete and 25 MPa for air entrained concrete.

(b) Where the service conditions of concrete are known or suspected to be aggressive it is recommended that the strengths shown in table 8 should be specified. The specifier is also advised to consult, for further information, ACI SP-47 Durability of concrete.

Additional measures to improve the durability of concrete in harmful environments include:

(1) Particular attention to compaction and placing techniques to achieve dense concrete.

(2) Increased cover to reinforcement.

(3) Use of pozzolan, special aggregate or special admixtures.

(4) Increase of concrete strength.

C6.8 Slump

The slump test is a simple method of determining the consistency or "wetness" of the concrete. It is a test subject to quite a degree of experimental error.

The uniformity of slump values is usually more important than the mean value and it is not possible to make simple rules for good practice regarding slump, without creating serious anomalies.

Generally the higher the slump of concrete, the greater is its workability and ease of compaction, the more prone it is to segregation in handling and the greater is the tendency to cracking. Concrete produced at greater than the designed slump, where this is due to an increase in water content, will generally lose strength at a rate of 1 to 2 MPa per 25 mm of slump increase.

Concrete which has slump values which are extremely variable is likely to have zones of incomplete compaction and excessive colour variations and have unformed surfaces which are difficult (and unlikely) to finish properly. Provided the concrete is well designed and manufactured to a uniform slump, and suitable handling, compacting and finishing methods appropriate to the slump of the concrete being used are employed, good work can be achieved even at high slump values.

Slump tends to decrease with time. The crucial slump is that at the time of placement of the concrete. Consequently the slump at the mixer may be required to be set at a higher level than the nominal slump in order to compensate for slump reduction during the delivery process.

C6.9.1 (e) Concrete pumping

Where it is proposed that concrete should be placed by pumping, it will be for the reason that concrete transportation and handling costs are favourable, or because there

Table 8

CONCRETE IN HARMFUL SITUATIONS – RECOMMENDED MINIMUM SPECIFIED STRENGTH MPa

Situation		*Indicates footnote applies*	*Concrete section and cover to reinforcement*			
			Unreinforced or steel cover 60 mm or over		*Steel cover under 60 mm but not under 40 mm*	
			Air entrained	*Non-air entrained*	*Air entrained*	*Non-air entrained*
Sulphur bearing soil or groundwater in concentrations as under						
SO_3 % in mass	SO_4 in ppm					
0.10 to 0.20	200 to 360		30	40	30	40
0.20 to 0.50	360 to 1200	*	35	50	35	50
above 0.50	above 1200	*	45	60	45	60
Seawater and spray			30	40	35	50
Fresh soft water and fresh carbonated water with excess unbuffered CO_2						
Submerged continuously			25	35	30	40
Subject to differential hydrostatic pressure			30	40	35	50
Fresh water, not soft, and without unbuffered CO_2						
Submerged continuously in still water			20	30	25	35
Submerged intermittently or in running water			25	35	30	40
Subject to differential hydrostatic pressure			25	35	30	40

* Concrete that is especially sulphate-resistant shall be used, as made with either an approved cement with low susceptibility to sulphate attack or with an approved admixture having the specific property of improving sulphate resistance significantly.

NOTE – Where the attainment of these strengths is uneconomic owing to failure of coarse aggregate, a cement content of 400 kg/m³ should be used.

would otherwise be difficulty in respect of access. Because it is in the interests of all concerned that buildings be constructed as economically as possible consistent with adequate quality standards being achieved, proposals to place concrete by pump should receive serious consideration. There are, however, some disadvantages which include:

1 Possible requirement to strengthen formwork or scaffolding

2 Possible mix design adjustments to limit maximum aggregate size, increase sand content and increase workability, any one of which will increase water content.

The extent of necessary adjustment in respect of item 2 is dependent on a number of factors including the height and horizontal distance to be pumped, the quality and state of maintenance of the pump and pipe line, the diamete.

the pipe line and the presence of bends, tapers and a flexible section for concrete distribution. Easy pumping situations require small adjustments but difficult pumping situations may require significant adjustments which materially reduce the quality of the concrete.

Extra costs of formwork and concrete materials will reduce the economic advantages leading to the proposal, but the other disadvantages increase the degree of drying shrinkage and increase the difficulty of achieving a dense finish on an unformed surface. The probability of achieving lower standards of workmanship and inherent lower abrasion resistance are both consequences of the use of pumped concrete.

If the additional potential shrinkage is significant, it can often be accommodated by appropriate detailing (for example, use of heavier reinforcement or closer joint spacings) so that this also is often a further economic factor.

Placement of concrete in floors by pumping reduces the quality which can be achieved. The designer should, therefore, decide whether the proposed service in terms of environment, traffic and general wear and tear are such that suitable quality can be achieved with pumped concrete, or whether its use should be prohibited.

C6.10.3.2 Mix design

For concrete produced as specified in 6.10.2.1(b), evidence that the mean strength of the proposed concrete mix is adequate is a matter of judgment for the engineer supervisor. If data exist for the materials and the w/c strength relationship is established for the cement, a rationally designed concrete mix may suffice. With unknown materials or with a mix differing markedly from established mixes, a programme of trial mixes will be necessary and the engineer supervisor will probably require margins of strength which relate to the volume of data from the proposed mix design.

7 CONCRETE PLACING, FINISHING AND CURING

7.1 Unfavourable conditions

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

7.2 Preparation for concreting

7.2.1 Immediately before any concreting is commenced, all formwork shall be carefully examined to ensure that all dirt, shavings, sawdust, dried mortar and other refuse has been removed by brushing or by washing with a hose or other approved means and that construction joint faces have been prepared in accordance with 5.6. The inside of timber forms shall be wetted with clean water immediately prior to placing concrete unless the forms have been coated with an approved form dressing. No form dressing other than water shall be applied after placing reinforcement in the forms. In all cases surplus water (or form dressing) shall be removed before concrete is placed.

7.3 Handling and placing

7.3.1 All concrete shall be conveyed from the mixer, or from the agitator or truck mixer, to the place of final deposit as rapidly as is possible by methods which shall prevent segregation. The addition of water to the mixed concrete at the site is strictly forbidden except under the controlled circumstances detailed in NZS 3104 for ready mixed concrete and the addition of water or any other material after discharge from the mixer or agitator truck is prohibited.

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. Vibration shall not be used to move concrete along the forms. Surfaces shall be free from voids caused by stone pockets. Where necessary, vibration shall be supplemented by hand spading to secure these results. Fresh concrete shall not be placed upon the preceding layer after an interval exceeding 45 min, or such other time interval as the engineer supervisor may determine in the circumstances. A succeeding layer may not be placed unless revibration 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.

7.4 Concrete placing under water

7.4.1 Where it is necessary to place the concrete under water, special notice in writing shall be given to the engineer supervisor who may impose such conditions and control as he considers necessary.

7.4.2 Any method of placing concrete under water must ensure that no intermixing of concrete and water occurs. This is avoided only if the concrete is discharged at a point below the surface of the previously placed concrete.

7.5 Compaction

7.5.1 *Vibrators to be used.* Unless approved otherwise, compaction of all concrete, including floor slabs, shall be carried out principally by the use of immersion 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.

7.5.2 *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 500 mm 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.

7.5.3 *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.

7.5.4 *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.

7.5.5 *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.

7.6 Finishing (including finishes)

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

7.6.2 Immediately after compaction, the surface of the concrete shall be screeded by straight-edge or vibrating screed to the specified grade 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.

7.6.3 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.

7.6.4 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 Curing and protection

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

7.7.2 *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 curing compound conforming to ASTM C309 *Specification for liquid membrane-forming compounds for curing concrete.* Curing compounds shall not be used on any surface against which additional concrete or other material is to be bonded, or unless positive measures are subsequently to be taken such as sandblasting, scabbling, or other effective means, to remove it completely from areas which are to receive bonded applications.

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

7.7.3 *Formed surfaces.* For concrete surfaces in contact with the forms, immediately after loosening or removal of the forms, the concrete shall be cured until the end of the prescribed time by one of the methods specified in 7.7.2 for the curing of unformed surfaces.

7.7.4 *Length of curing period.* When mean ambient temperatures exceed 10 °C, curing shall be continued for at least seven days, except that concrete containing rapid hardening cement shall be cured for at least three days. At lower temperatures, appropriately longer periods shall be used at the discretion of the engineer supervisor.

7.7.5 *Accelerated curing processes.* As an alternative to the processes specified above accelerated curing of the concrete may be adopted using one of the following methods:

(a) *Low pressure steam curing.* Where this method is used, the temperature of the enclosure shall not exceed 50 °C within 5 h after casting and the maximum temperature shall not exceed 80 °C.

(b) *Curing by application of heat.* If applied heat (hot water, hot oil or electricity) is used for accelerated curing, the temperature of the concrete shall not rise at a rate greater than 10 °C per hour to a maximum of 65 °C. A device or devices to the approval of the engineer supervisor shall be used to ensure that at all times the temperature of the concrete is within ±5 °C of a specified temperature or of a nominated time–temperature curve after steady conditions have been reached. Provision shall be made for protection of the surface of the concrete so that loss of water is not harmful.

COMMENTARY

C7 CONCRETE PLACING, FINISHING AND CURING

C7.1 Unfavourable conditions

(a) 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.*

(b) Cold water concreting. *Precautions that may be taken in unfavourable cold conditions referred to above, include the following:*

(1) *Use of air entrainment*

(2) *Use of lower slump concrete*

(3) *Use of an approved accelerating admixture*

(4) *Use of water reducers*

(5) *Increased cement content*

(6) *Protection of aggregates against frost*

(7) *Use of hot water or heated aggregates*

(8) *Avoidance of placing concrete on a frozen subgrade*

(9) *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 two days. When a considerable proportion of the design strength must be attained before it is safe to remove the formwork, protection 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.*

(c) 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:*

(1) *Elapsed time between mixing and placing should be minimized.*

(2) *Exposure to the hot sun of mixers and agitators while waiting to be unloaded should be minimized.*

(3) *Mixer drums should be painted in heat-reflecting colours.*

(4) *Use concrete with the lowest possible cement content consistent with strength requirements.*

(5) *Use suitable retarding admixtures.*

(6) *Avoid excessive mixing.*

(7) *In severe conditions, sprinkle stockpiles to give cooling by evaporation.*

(8) *If pumps are to be used, paint the pipelines white.*

(9) *Wet forms, reinforcing, subgrade and surrounding areas by spraying with water shortly before placing.*

(10) *Speed up placing.*

(11) *Use fog sprays shortly after placement.*

(12) *Give prompt curing and protect exposed surfaces from drying out.*

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

(d) 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.*

C7.4 Concrete placing under water

Tremie 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 underwater 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.*

C7.6 Finishing (including finishes)

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 permitted.

C7.7 Curing and protection

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:

1. *The presence of moisture.*

2. 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 or when the curing temperature is low. For rich mixes, especially if high early strength cement is used, a few days curing may be sufficient. 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 of slow strength gain characteristics.

C7.7.5 Accelerated curing

In the case of low pressure steam curing the entry points for steam, type of covers, and exposure can have the effect of a variation in temperature along a casting bed. Judgment is required in placing field cured test specimens so that their curing has some similarity to that of the main concrete. In the case of curing by applied heat, preliminary work is necessary to establish a suitable mix and a time–temperature arrangement that will give a 95 % probability that for prestressed concrete the required release strength can be achieved. Then a suitable method must be used to ensure that the field cured specimens follow the same time-temperature conditions as the main concrete.

8 PRESTRESSING : STRESSING AND GROUTING

8.1 Concrete strength at transfer

8.1.1 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 minimum concrete strength at transfer as determined from field cured compression tests results. Provision shall be made in the case of low pressure steam curing, that the curing of the field specimens is similar to the curing conditions of the main concrete, and also in the case of curing by applied heat, that a suitable method to be approved by the engineer supervisor shall 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 Stresssing equipment

8.2.1 Prestressing steel shall be tensioned by means of hydraulic jacks or other approved mechanical apparatus.

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 plus or minus 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 an independent testing authority at intervals not exceeding six 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 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.

8.3.2 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.

8.4.3 At the commencement of work on a project where required by the engineer supervisor, 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.

8.4.4 The supervisor in charge of the stressing operation shall be provided with particulars of the required elongation of the tendons and of the jack pressure or total force requirement together with such other details as apply from those stated in clause 8.4.2. (See commentary clause C8.4.4)

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 pre-tensioned 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 matter must immediately be referred to the engineer supervisor.

8.6 Deflected tendons in pre-tensioned members

8.6.1 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.

8.7.3 If required by the engineer supervisor, 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 engineer supervisor for his decision on the acceptability of the results.

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 engineer supervisor.

8.8.3 *Materials.* Grout shall be made of ordinary 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 engineer supervisor. 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 seven days determined from test cylinders moulded, cured and tested in accordance with section 5 of NZS 3112: Part 4. In no case shall the water cement ratio by weight exceed 0.50 and preferably it should be below 0.45. No admixture which contains any components consisting partly or wholly of chlorides, nitrates, or sulphides shall be used.

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 s unless an admixture is used to improve workability, when the required flow time may be reduced to 15 s.

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 three hours after mixing, or a minimum of 4 % of the volume.

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 L and the cylinder shall be covered and left undisturbed during the test.

8.8.6 *Plant.* Grout shall be mixed with an approved mixer and 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.

8.8.6.1 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 min after first mixing.

8.8.7.3 As clean grout issues from each vent pipe in turn, with no 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.

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

8.9.1 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 mortared over so as to provide 40 mm of cover to all steel parts of anchor or tendon. Plaster of paris or other corrosion-inducing material shall not be used for this purpose.

COMMENTARY

8 PRESTRESSING : STRESSING AND GROUTING

C8.1 Concrete strength at transfer

The drawings should clearly define both the specified strength f'_c *and the strength of transfer required for the particular components of the work.*

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 fig. 2.*

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 will 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 the concrete design code, NZS 3101.*

C8.4.3 Friction testing. *In selecting representative tendons for friction testing, it is important to recognise 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.*

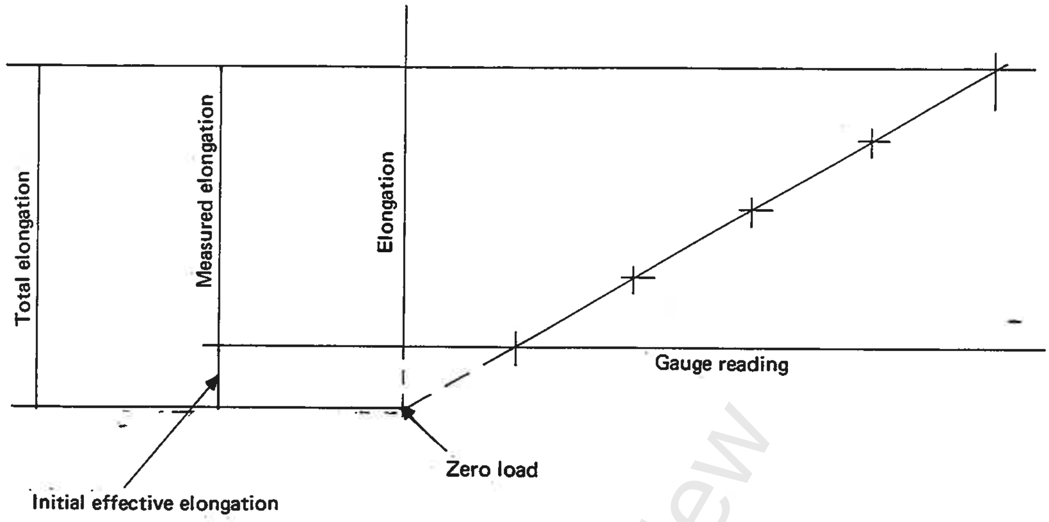

Fig. 2 ELONGATION CORRECTION

C8.4.4 Stressing details. *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 or vice versa, 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.*

C8.7 Release of prestress by heating

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. A method used in some overseas countries 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 the approval of the engineer supervisor.

C8.7.3 Tendon draw-in on release. *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.*

NOTE – The 2 mm and 4 mm allowable limits for draw-in of tendons on release are values appropriate to normal conditions. At the present time 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 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 now available and is recommended to overcome the possibility of excessive draw-in.

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.*

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 and only carried out with the approval of the engineer supervisor.

(h) Adequate warning signs shall be displayed at all 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 ACCEPTANCE TESTS DURING CONSTRUCTION

9.1 General

9.1.1 Tests shall be carried out during construction to check the compliance of the concrete with this specification for the particular parameters stipulated for the work. The tests required shall be carried out in accordance with the methods specified in NZS 3112: Parts 1 and 2 by persons properly trained in the techniques required. Proposals for location of sampling and frequency of testing shall be submitted to and subject to the approval of the engineer supervisor.

9.2 Sampling procedure

9.2.1 *Location.* Samples shall be taken in accordance with section 3 of NZS 3112: Part 1 as directed by the engineer supervisor.

9.2.2 *Types of sample*

9.2.2.1 *Random samples.* Samples taken on a random basis may be either random representative samples or random snatch samples as defined in section 2. Only the results of tests from random samples shall be incorporated in a series from which the best estimate overall production coefficient of variation is to be calculated.

9.2.2.2 *Selected samples.* Samples taken on a selected basis may be either selected representative samples or selected snatch samples as defined in section 2. Samples on a selected basis may be taken when:

(a) There are reasons to doubt the quality of a particular batch or batches of concrete.

(b) There is doubt as to the consistency of the concrete throughout an individual delivery, for example, undue variation between the start and finish of a delivery.

(c) The engineer supervisor seeks assurance about the quality of concrete in a specific part of the structure and directs that tests be taken on the concrete being placed in that area.

Under category (c), provided that the operator responsible for batching and mixing the concrete has no knowledge of the intention to sample that particular mix, the sample may be treated as a random sample. In all other circumstances the results of tests taken on selected samples shall be checked for compliance with the rejection limits only of table 11.

9.3 Slump tests

9.3.1 *Frequency of test.* A slump test shall be made immediately concreting is commenced and at all times when compression test samples are taken and at such other times when directed by the engineer supervisor.

9.3.2 *Procedure.* Slump tests shall be carried out in accordance with section 5 of NZS 3112: Part 1.

9.3.3 *Evaluation.* For acceptance of the concrete represented, the results of slump tests shall have a value within the tolerance limits stipulated in table 9 as appropriate to the type of sampling adopted. Concrete which fails to comply within the tolerance limits will be liable for rejection at the discretion of the engineer supervisor.

Table 9 MAXIMUM TOLERANCES FOR NOMINATED SLUMP

Nominated slump	*Tolerance*	
	Representative sample	*Snatch sample*
mm	*mm*	*mm*
60 or less	±20	±30, −20
80	±20	±30
100	±30	±40
120	±30	±40

9.4 Air content tests for air entrained concrete

9.4.1 *Frequency and location of test.* Where air entrained concrete is used on the work, air content tests shall be carried out when directed by the engineer supervisor.

9.4.2 *Procedure.* Air content tests shall be carried out in accordance with section 9 of NZS 3112: Part 1.

9.4.3 *Evaluation.* For acceptance of the air entrained concrete represented, the result of an air test shall have a value within the tolerance limits stipulated in table 10 as appropriate. Concrete which fails to comply within the tolerance limits will be liable for rejection at the discretion of the engineer supervisor.

9.5 Compression tests

9.5.1 *General.* A compression test result is the average value obtained by testing a set of specimens made from one sample of concrete. Compressive strength shall be determined from specimens moulded, cured, capped where necessary, and tested in accordance with sections 3, 4 and 6 of NZS 3112: Part 2.

9.5.2 *Tests for acceptance of concrete*

9.5.2.1 *Curing.* In the case of tests which are being carried out for the acceptance of concrete and evaluation according to the procedures set out in 9.5.8, the test specimens shall be cured by one of the methods described in 3.5.1 or 3.5.2 of NZS 3112: Part 2 and tested at age 28 days.

9.5.2.2 *Number of test specimens.* A set of test specimens shall consist of three specimens made from one sample of concrete, except that when the number of tests exceeds 20 and the mean within-test coefficient of variation of the test series as calculated by the method described in section 10 of NZS 3112: Part 2 is less than 4 % then the number of specimens per set may be reduced to two.

9.5.2.3 *Frequency of test.* Each day during the manufacture and placing of concrete, unless otherwise directed by the engineer supervisor, for each 50 cubic metres of concrete or part thereof produced, one sample shall be taken for the preparation of compression test specimens for evaluation for acceptance of the concrete. When early age or field cured tests are required, they shall be additional to the above requirements.

9.5.2.4 *Identification of tests.* A record shall be kept for every sample taken for the preparation of compression test specimens for acceptance of the concrete. Such samples shall be numbered consecutively. Immediately after removal from their moulds, the test cylinders shall be clearly marked in waterproof crayon with the sample number together with an agreed code relating to the works in order to facilitate subsequent identification of the specimens at the testing laboratory.

9.5.3 *Tests at ages other than 28 days.* Tests at an age less than 28 days shall be taken in addition to the standard 28 day tests if required by the engineer supervisor when it is deemed necessary to assess the strength of the concrete at an early age, for example, at the outset of the job if little is known about the strength of the concrete or under conditions stated in 5.4.1. The relationship between such test results and 28 day strengths shall be resolved in consultation between the engineer supervisor and the constructor and confirmed by testing.

9.5.4 *Field cured tests.* Sets of compression test specimens may be taken for field curing when it is necessary to determine or check times of operations such as stripping of formwork, stressing, or handling of precast units. In these cases test specimens shall be cured as specified in 3.5.3 of NZS 3112: Part 2.

Table 10 AIR CONTENTS IN AIR ENTRAINED CONCRETE

Nominal maximum aggregate size	*Maximum target air content*	*Tolerance limits for target air content*
mm	%	
Mortar	10	±3%
9.5	8	±2%
13.2	7	±1.5%
19.0	6	±1.5%
26.5	5	±1.5%
37.5	4.5	±1.5%
50	4	±1%
75	3.5	±1%

9.5.5 *Test reports.* Reports on concrete testing shall be made available by the constructor to the engineer supervisor and copies sent to the supplier at regular intervals, but not less frequently than weekly. These reports shall include:

Supply source (concrete)
Mix identification and specified strength
Location in structure
Batch or truck number, where applicable
Time and date concrete mixed
Time specimens prepared
Slump of concrete
Time and date laboratory curing commenced
Time and date specimen tested
Compressive strength to nearest 0.5 MPa
Any relevant comments on the fractured specimen, including obvious segregation, lack of compaction, large aggregate particles, soft aggregate particles and contaminants.

9.5.6 *Evaluation of compression test results.*

9.5.6.1 *Acceptance of data.* All individual specimen strength test values in the analysis shall be retained except in one of the following cases:

(a) In the event of one specimen of the test set showing clearly discernible evidence of faulty moulding, curing or testing, it shall be excluded when determining the test result.

(b) When more than one specimen is manifestly defective as described in (a) the test result shall be discarded. Test values shall not be discarded solely by reason of scatter in the test set.

In the event that the within–test coefficient of variation derived from at least 12 consecutive test results exceeds 5 %, the whole testing procedure shall be critically reviewed to reduce the test variation.

9.5.6.2 *Evaluation of single results.* Single compression test results shall be considered in sequence as they come to hand, and evaluated against the criteria of table 11, which are dependent on the type of sampling employed.

When the value for a single result is less than the relevant criterion, the concrete so represented is liable to rejection at the discretion of the engineer supervisor. The structural designer shall be immediately informed (see 9.5.7).

NOTE – In table 11 the rejection limits are as follows:

(1) For a test result from a representative sample: $0.85 f'_c$ or $f'_c - 3.5$ MPa whichever is the greater.

(2) For a test result from a snatch sample: $0.80 f'_c$ or $f'_c - 4.5$ MPa whichever is the greater.

Table 11 ACCEPTANCE CRITERIA

	No performance record								*With a performance record*													
	Ordinary grade		*High Grade*						*High Grade*						*Special Grade*							
Specified strength MPa	17.5	20	17.5	20	25	30	35	40	17.5	20	25	30	35	40	17.5	20	25	30	35	40	45	50
Overal Coefficient of variation	22	20	17.5	17	16	15	14	13	15.5	15	14	13	12	11	12.5	12	11.5	10.5	10	9.5	9	8.5
(a) Rejection limit, single result. Grounds for rejection of concrete.																						
Representative sample, MPa	15	17	15	17	21.5	26.5	31.5	36.5	15	17	21.5	26.5	31.5	36.5	15	17	21.5	26.5	31.5	36.5	41.5	46.5
Snatch sample, MPa	14	16	14	16	20.5	25.5	30.5	35.5	14	16	20.5	25.5	30.5	35.5	14	16	20.5	25.5	30.5	35.5	40.5	45.5
(b) Cautionary limit to be equalled or exceeded by the mean of any consecutive group of 6 or more consecutive results. Grounds for correction of the mix.																						
Random representative sample or random snatch sample, MPa	25	29	23.5	26.5	32.5	39	44.5	50	22	24.5	30.5	36.5	42	47.5	20	22.5	28	34	39.5	45.5	51	56.5
(c) Cautionary limit to be equalled or exceeded by the mean of the results of each series of consecutive tests (after a minimum of 30 results has accumulated). Grounds for correction of the mix.																						
Random representative sample or random snatch sample, MPa	29.5	33.5	26.5	29.5	35	41.5	48	53.5	24	26.5	32.5	39	44	49.5	21.5	24	29.5	35.5	41.5	47.5	53	58.5

9.5.6.3 *Evaluation of groups of test results from random samples.* Only those test results which are derived from random sampling shall be considered in the following analyses. The results of tests on selected samples shall be evaluated as provided in 9.5.6.2:

(a) *Mean strength of groups of six or more test results.* If the mean strength of any consecutive group of six or more results of consecutive tests on random representative samples or random snatch samples is less than the corresponding cautionary limit value given in table 11, materials, mixing and testing procedures and site practices shall be examined. If the cause of the low mean value is not found and corrected, the engineer supervisor, in the light of the evidence available to him, may order prompt action to increase the average strength to not less than the corresponding value in table 7 for minimum target mean strength.

(b) *Mean strength of groups of thirty or more test results.* If, for a series (comprising a minimum number of 30) of results of consecutive tests on random representative samples or random snatch samples, the mean strength is less than the corresponding cautionary limit value given in table 11, materials, mixing and testing procedures and site practices shall be examined. If the cause of the low mean value is not found and corrected, the engineer supervisor, in the light of the evidence available to him, may order prompt action to increase the average strength to not less than the corresponding value in table 7 for minimum target mean strength.

(c) *Assessment of variability of supply based on the coefficient of variation calculated from groups of 30 or more test results*. When thirty or more consecutive test results have been obtained, the best estimate of the coefficient of variation shall be determined from all results to date in accordance with section 10 of NZS 3112: Part 2. If the best estimate of the coefficient of variation is significantly† greater than the values given in the appropriate column of table 11, the results of the group shall be considered, together with previous test results on the same mix which have been made available. The best estimate of coefficient of variation shall be calculated from the combined results. The production shall be graded accordingly and if regrading is necessary the mix designs shall be adjusted to give the required minimum target mean strength.

† For a single group of 30 results, a tolerance may be applied of 1½ % for high grade and 1 % for special grade.

9.5.6.4 *Review of corrective action.* Where corrective action to a mix design has been taken as provided in 9.5.6.3, such action may be reviewed as provided in 6.11 under the following conditions:

(a) The group of results, on the evidence of which a review of corrective action is proposed, shall be at least 30 in number. Data from concrete produced prior to the production which gave rise to corrective action shall be excluded from such a group.

(b) If the group under review comprises more than one test series as prescribed in 9.5.6.5 in which the only difference is in cement content or water cement ratio, the data may be combined after having been adjusted on the basis of an established and agreed relationship between water cement ratio and strength.

(c) Any adjustment made on the basis of such evidence shall ensure that the minimum target mean strength, shown in table 7 will be equalled or exceeded, and shall be subject to the approval of the engineer supervisor.

9.5.6.5 *Termination of test series.* The accumulation of a series of strength test results shall be terminated and a new collation and analysis begun only when significant deliberate changes in concrete production occur, for example, changes in material or mix proportions used or in plant control personnel or methods. It is the responsibility of the concrete producer to provide advice to the engineer supervisor when such changes are made. Failing the receipt of such advice the analysis shall proceed on the basis of a continuing series.

9.5.7 *Concrete liable to rejection.* When concrete is liable to rejection under 9.5.6.2, the location and extent of the concrete so represented shall be assessed and identified. No further concrete shall be placed where it would prejudice the subsequent removal of the concrete in question unless authorized by the engineer supervisor. The constructor, if he disputes the test result, may arrange to have confirmatory tests made of hardened cores of concrete from that part of the structure in question. Cores shall be located and cut to the approval of the engineer supervisor to ensure the minimum possible damage to any reinforcement and without significant weakening of any structural element. The procedure used in testing the cores shall be in accordance with section 9 of NZS 3112: Part 2. Not less than three sound specimens shall be tested for any one suspect area or structural element. The concrete so represented shall be deemed to be structurally adequate provided that:

(a) The average strength resulting from the tests of the cored specimens is not less than 0.85 f'_c or f'_c – 3.5 MPa, whichever is the greater and

(b) No single specimen test result is less than 0.8 f'_c or f'_c – 4.5 MPa, whichever is the greater.

COMMENTARY

C9 CONCRETE ACCEPTANCE TESTS DURING CONSTRUCTION

C9.1 General

If proper procedures are not followed, test results can be disputed. Obviously potential problems from this source can be largely avoided by having sampling and testing carried out by a TELARC registered laboratory.

The cost of testing is usually specified to be included in the price in building contracts. The contingency element of such allowance may be removed if routine testing operations are scheduled and measured for payment.

In order to ensure compliance with the requirements of NZS 3112: Parts 1 and 2 for testing work on site, it is important to ensure that all requisite equipment and facilities are on hand, and that the testing work is undertaken by trained personnel.

C9.2 Sampling

Snatch samples, either random or selected, may be taken at any place on site as directed by the engineer supervisor, for example, at the delivery end of a pumpline. Note that compression test results from "selected" samples are evaluated from single results only. Results from "random" samples are examined more comprehensively and as a consequence random sampling is to be preferred.

Random representative samples (which are to be identified with a "batch" of concrete) should be taken from the discharge chute of the site mixer or agitator truck or truck mixer.

C9.5.6 Acceptance compression tests

(a) General

Samples for compression tests are required to be taken regularly. The greater the number of test results, the more confidence there can be that undesirable changes in strength or variability have not taken place. Four procedures for the evaluation of the strength of concrete from samples taken at the site are detailed in the Standard:

(1) By the study of tests singly and comparing with the rejection limits in table 11.

(2) By comparing the mean strength of a group of six or more consecutive test results from random samples with the cautionary limits in table 11.

(3) By comparing the mean strength of a group of thirty or more consecutive test results from random samples with the cautionary limits in table 11.

(4) By comparing the coefficient of variation derived from thirty or more consecutive test results obtained from random samples with the values given in table 11.

With controls of the types (2) (3) and (4) above there is risk that warnings will occasionally arise from satisfactory production and occasionally a deterioration in production will not immediately sound a warning.

(b) Rejection criteria

Concrete liable for rejection is covered by 9.5.6.2 and 9.5.7 and table 11. Rejection is based upon single test results only and not on account of the average of a series of test results being considered substandard. Rejection applies only to that concrete which the single test result represents. In practice the need to consider the rejection of concrete should be very infrequent.

(c) Cautionary limits for six or more results

As work proceeds it is important to detect if there has been a change in the characteristics of the materials, or, in the level of control, or an error of judgment in the mix design. For this purpose, the mean of six or more consecutive test results has been introduced, to be used as a warning indication that the required target strength is not being achieved.

The values for six or more consecutive results listed in table 11 are set at a level aimed at giving a reasonable balance between the interests of the purchaser and the concrete producer. It should be recognized, however, that the cautionary limits have been set at a level such that the mean could be below the cautionary limit when, in fact, the results could be part of a complying series.

For this reason the engineer supervisor should examine other evidence that may be available to him, such as the producer's own tests, or site tests from other works over the same period for the same mix.

However, if the mean of six consecutive test results is below the appropriate level, it is a warning, and the engineer supervisor is entitled to act upon it and to direct a change in mix design. It is a matter for his judgment. If the decision is to await further tests before directing a change then the series is a continuing one, but the mean of the series will need to improve if direction for improvement is to be deferred further.

(d) Thirty or more results

When a group of thirty results can be assembled, there is opportunity to check that the best estimate of the overall coefficient of variation from site tests is in reasonable conformity with the appropriate value in table 11 on the evidence of production tests that was submitted as means of compliance. At thirty results it is also required that certain minimum mean strengths be achieved. If the mean strength and variability at n=30 or more are not acceptable to the engineer supervisor, amendments may be ordered to the level of control or the mix design, even though a substantial volume of concrete with that mix design has complied with the set of six or more and has already been accepted.

However, it should be noted that a reliable assessment of variability can only be made from a large number of tests and even at n=100, the possibility of error is not unappreciable. Variation determination at n=30, or more, is chosen, because it is considered that thirty is the least number of tests that could give a reliable assessment of variability. But at this number the results can be misleading and a tolerance is recommended of 1 % in the case of Special Grade and 1.5 % in the case of High Grade. The greater the number of tests the more reliable will be assessment of variability, so that, if tests are continued beyond 30, there should be a continuous series, unless the first results were, say, more than twelve months old, or when there has been some change in production when a new series should be started at that age.

C9.5.7 Concrete liable to rejection

In determining the course of action to be taken the engineer supervisor should check with the designer as to whether the strength attained may nevertheless be deemed sufficient for the location concerned, or whether it is required to be removed from the structure.

Although the testing of cores is unlikely to resolve a question of concrete quality to the satisfaction of all parties, better judgments may be made if all concerned are thoroughly informed as to the background technology. References should be made to Australian Standard AS 1012, ASTM C42 and The Concrete Society Technical Report No. 11 CSIRO The interpretation of core tests. *A review by Lewis and Blakey.*

Alternatively, full scale testing may be possible for some structures, and non-destructive tests such as the Schmidt hammer tests may provide further evidence on which to make judgment.

10 REPAIR OF CONCRETE

10.1 Minor surface defects

10.1.1 The repair of fins, ledges, plastic cracks up to 12 mm depth, blowholes and tie holes shall be carried out as specified in NZS 3114.

10.2 Structural defects

10.2.1 Chipping, spalling, honeycoming and cracking (other than plastic cracking up to 12 mm deep) shall not be repaired without the written authority of the engineer supervisor, who shall specify the method of repair which may be employed utilizing one of the following:

(a) Dry packing

(b) Mortar replacement using:

(1) Plaster

(2) Gunite

(c) Concrete replacement

(d) Epoxy bonded mortar or concrete

(e) Epoxy mortar

Repairs shall be carried out as soon as is practicable to the satisfaction of the engineer supervisor.

10.2.2 All contaminants and weak, cracked or otherwise unsound concrete shall be removed or cut away to a clean sound surface with aggregate exposed.

10.3 Methods of repair

10.3.1 Dry pack mortar shall be used for holes with square or re-entrant edges of depth greater than their least surface dimension.

The concrete to be repaired shall be saturated but surface dry. Dry pack mortar comprising three parts of fine sand to one part of cement with sufficient water to achieve cohesion without plasticity shall be rammed into place. Dry pack mortar shall be cured for seven days.

10.3.2 *Repair by plaster and gunite.* Repair using plaster may be permitted where the depth of repair is in the range 10 to 40 mm. Repair by gunite may be permitted where the depth of repair is in the range 10 to 150 mm. The area shall be prepared with square edges. The work shall be carried out by the experienced craftsmen in accordance with the best trade practice. Plaster and gunite repairs shall be cured for seven days.

10.3.3 *Repair using concrete* may be permitted when the depth of repair exceeds 100 mm. The bottom and sides of the area shall be cut square and the top shall slope upwards towards the surface. Formwork for concrete replacement shall be arranged to put a surcharge of pressure on all joints with existing concrete by overfilling with concrete. The consequent projections should be removed after 24 h and after curing the surface treated as for surface defects.

10.3.4 *Epoxy bonded mortar or concrete.* Mortar or concrete replacement may be bonded to the existing concrete by epoxy resins recommended for this purpose by their manufacturer. Such work shall be carried out in accordance with the instructions of the resin manufacturer.

10.3.5 *Epoxy mortar.* Shallow repairs may be carried out using epoxy resin mortar comprising clean sand bonded with suitable epoxy resin. Such work shall be carried out in accordance with the instructions of the resin manufacturer.

10.4 Cracked concrete

10.4.1 Cracked concrete may be repaired by epoxy resin injection. Cracks of some age may include foreign material, which should be removed as far as possible.

COMMENTARY

C10 REPAIR OF CONCRETE

C10.2 The need for repair may arise from deficiencies in design, detailing, materials or workmanship; from damage caused by explosion, fire, impact overloading, earthquake or foundation settlement, or on account of deterioration caused by environmental attack not foreseen by the specifier. The engineer supervisor must satisfy himself as to the cause of the defect to ensure that the repair will be adequate having regard to future service conditions. If the proposed repair includes patching and the finish specified is either F3, F4 or F5 as prescribed in NZS 3114, the architect should be consulted, as precise matching of the original work in terms of colour and texture is seldom achieved. If possible, the repair should include treatment of a suitable area of surface so that an acceptable feature may be created. Before the repair of cracking is carried out, it is particularly important that the cause of the cracking has been correctly diagnosed and removed.

C10.4 Full development of bond strength is unlikely, with other than recently developed cracks. The repair of cracks by epoxy resin injections should be carried out only by companies and personnel fully experienced in such work.

Specification for
CONCRETE CONSTRUCTION

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AMENDMENT No. 1

July 1992

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

APPROVAL

Amendment No. 1 was approved in July 1992 by the Standards Council to be an amendment to NZS 3109:1987 pursuant to the provisions of section 10 of the Standards Act 1988.

(Amendment No. 1, July 1992)

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2 DEFINITIONS

2.1
Delete the note to the definition of "ENGINEER SUPERVISOR".

(Amendment No. 1, July 1992)

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3 REINFORCEMENT

3.1.1
In lines 3 and 4 **delete** the words "unless otherwise approved by the engineer supervisor,".

3.1.2
In line 2 **delete** the words "unless otherwise approved by the engineer supervisor".

3.2.4
In line 1 **delete** the words "unless otherwise permitted by the engineer supervisor".

3.2.5
In lines 2 and 3 **delete** the words "or permitted by the engineer supervisor".

3.6.1.1
In line 3 **delete** the words "or as authorized by the engineer supervisor".

3.8.1
In line 1 **delete** the words "by the engineer supervisor".

(Amendment No. 1, July 1992)

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5 FORMWORK, EMBEDDED ITEMS AND CONSTRUCTION JOINTS

5.5.1
In the first sentence of item (d) and in item (d) (3), **delete** the words "Unless otherwise agreed by the engineer supervisor".

(Amendment No. 1, July 1992)

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6 CONCRETE: SUPPLY

6.8.2
In lines 3 and 4 **delete** the words "or authorized by the engineer supervisor".

(Amendment No. 1, July 1992)

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7 CONCRETE PLACING, FINISHING AND CURING

7.7.5
In item (b), in the second sentence, **delete** the words "to the approval of the engineer supervisor".

(Amendment No. 1, July 1992)

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8 PRESTRESSING: STRESSING AND GROUTING

8.1.1
In the second sentence, **delete** the words "to be approved by the engineer supervisor".

(Amendment No. 1, July 1992)

8.8.2

In line 5 **delete** the words "or as approved by the engineer supervisor".

(Amendment No. 1, July 1992)

Specification for
CONCRETE CONSTRUCTION

AMENDMENT No. 2

March 1993

EXPLANATORY NOTE – Amendment No. 2 is issued to maintain consistency with NZS 3101 in which changes have been made to reinforcing steel requirements resulting from changes of steel grades in the 1989 revision of NZS 3402. Provision is also made for the use of Portland-limestone filler cement to NZS 3125:1991.

APPROVAL

Amendment No. 2 was approved on 8 March 1993 by the Standards Council to be an amendment to NZS 3109:1987 pursuant to the provisions of section 10 of the Standards Act 1988.

RELATED DOCUMENTS

Delete "NZS 3104:1983" and **substitute** "NZS 3104:1991"

Delete "NZS 3122:1974 *Portland cement (ordinary, rapid hardening and modified)*" and **substitute:**

"NZS 3122:1990 *Portland cement (ordinary, rapid hardening, moderate heat and sulphate resisting)*"

Add "NZS 3125:1991 *Portland-limestone filler cement*".

Delete "NZS 3402P:1973 *Hot rolled steel bars for concrete reinforcement* "and **substitute:**

" NZS 3402:1989 *Steel bars for the reinforcement of concrete.*"

Add "ASTM A497-86 *Welded deformed steel wire fabric for concrete reinforcement.*"

(Amendment No. 2, March 1993)

2.1

Delete the defined term "ANCHORAGE PRESTRESSING" and **substitute** "ANCHORAGE (when referring to prestressing)."

Add the following definition:

"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 NZS 3402)."

(Amendment No. 2, March 1993)

3.1.2

Delete "NZS 3402P "and **substitute**" NZS 3402."

(Amendment No. 2, March 1993)

3.1.3
In line 1, after "Welded" **add** "smooth".

Add a new clause:

"3.1.4 Welded deformed wire fabric shall conform to NZS 3422 or ASTM A497."

(Amendment No. 2, March 1993)

Table 1
Delete the table and **substitute** the following:

"Table 1 MINIMUM FORMER PIN DIAMETERS 'D' FOR BENDING REINFORCING BARS (mm)

(Refer also to figure 1)

Bar size	*Main steel* f_y = 300 or 430 MPa	*Stirrups and ties* f_y = 300 or 430 MPa	
		Round bars	*Deformed bars*
mm			
6	30	12	24
10	50	20	40
12	60	24	48
16	80	32	64
20	100	40	80
24	144	72	144
28	168	84	168
32	192	96	192
40	240	120	240

Delete NOTE (3) to Table 1.

(Amendment No. 2, March 1993)

Table 2
Change the column headings to the following:

Bar designation	*Lower characteristic yield strength*	
	f_y = 300 MPa	f_y = 430 MPa

(Amendment No. 2, March 1993)

3.6.3
Delete items (b) and (c) and **substitute**:

"(b) Welds shall not be made closer than 10 bar diameters from any bend.

(c) Bars manufactured to NZS 3402 may be welded providing the welding meets the requirements of NZS 4702. Appropriate account shall be taken of the process of manufacture.

(d) Bars which do not conform to NZS 3402 shall not be welded except with the approval of the engineer supervisor. He shall be satisfied prior to approval that the welding technique and control (preheating, electrode type, storage and other factors) have been demonstrated by tests to produce welds that have the required mechanical and metallurgical properties. Such established technique and control shall be maintained for the duration of the welding operation."

(Amendment No. 2, March 1993)

3.8.1
In item (b), line 1, **delete** "or" and **substitute** "on".

(Amendment No. 2, March 1993)

6.3.1
Delete the clause and note and **substitute** the following:

"6.3.1 Cement used shall comply with NZS 3122 (Portland cement), or NZS 3123 (Portland-pozzolan cement), or NZS 3125 (Portland-limestone filler cement). The use of any cement other than ordinary portland cement (NZS 3122, Type O) shall be subject to the approval of the engineer supervisor.

NOTE –

(1) Designers and specifiers are advised that rapid-hardening portland cement (NZS 3122, type RH) is not always readily available and that the supply of moderate-heat portland cement (NZS 3122, type MH), sulphate-resisting portland cement (NZS 3122, type SR), and/or portland-pozzolan cement (NZS 3123, type PP) normally requires prior arrangements to have been made with the cement manufacturer.

(2) Where a minimum cement content is specified, the granting of any approval for the use of a portland-limestone filler cement should clearly identify whether the same figure still applies; in the case of marine structures, and for any other circumstance where the durability of contained reinforcement is seen to be at special risk from the prevalence of a high-chloride environment, it is recommended that the contribution to the "cement content" deriving from the presence of the limestone filler component be discounted.

(Amendment No. 2, March 1993)

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