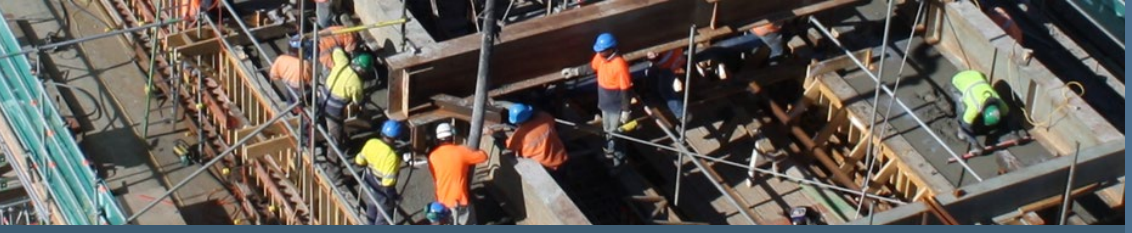

CCANZ TECHNICAL REPORT

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concrete answers

TR 15 Specifications for Concrete Production and Concrete Construction

A New Zealand Guide

(Second Edition 2013)

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SCOPE

This document has been developed to show how specification matters might be dealt with. It utilises, as the primary Standards for compliance, the New Zealand Standard NZS 3109:1997 *Concrete Construction* (including amendments No. 1 and No. 2) in conjunction with NZS 3104:2003 *Specification for Concrete Production* and NZS 3114 *Specification of Concrete Surface Finishes*.

Any specification needs to define the term "Construction Reviewer" used in clauses 3.3.5, 5.5, 5.6.1, 7.4.1, 7.7.6, 7.7.8, 7.8.4, and 7.8.5 of NZS 3109. In this specification the Engineer to the contract has been defined as the "Construction Reviewer".

While generic aspects of workmanship are covered in NZS 3109 the specifics relating to slab construction are not included.

For special floor applications an alternative approach is for the designer to provide outline requirements for the performance of the floor but the actual design, detailed specification, and construction is passed to the specialist flooring contractor.

Some clauses within the specification have a line in the left margin. This indicates that the information supplied within the clause is reasonably well defined in NZS 3109 and if a slimmer specification is required these clauses could be deleted.

INTRODUCTION

The specification for a concrete slab on ground project would typically be divided into the following parts:

- Site works
- Drainage
- Sub-grade preparation
- Sub-base construction
- Concrete slab construction.

The purpose of this specification is to provide typical clauses for the parts dealing either with the construction of the concrete slab, or the parts which affect this construction. It is not appropriate to include a copy of this document in a project specification, nor to refer to it as a standard specification, since each clause will have to be reviewed as to its relevance.

This guide specification does not include clauses related to general requirements such as order of works, setting out, records, inspections, etc., nor does it cover requirements for clauses of the work not directly related to concrete.

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1. GENERAL

1.1 Reference Documents

1.1.1 New Zealand and Australian Standards

The following Standards are referred to and form a part of this specification to the extent indicated in the appropriate clause:

NZS 3104:2003	Specification for Concrete Production
NZS 3109:1997	Concrete Construction
NZS 3114:1987	Specification for Concrete Surface Finishes
NZS 3121:1986	Specification for Water and Aggregate for Concrete
NZS 3122:2009	Specification for Portland and Blended Cements (General and Special Purpose)
AS/NZS 4671:2001	Steel Reinforcing Materials
AS 1478.1:2000	Admixtures for Concrete
AS/NZS 3582:2002	Supplementary Cementitious Materials for use with Portland and Blended Cement, Part 3: Amorphous Silica
AS 3582	Supplementary Cementitious Materials for use with Portland and Blended Cement Part 1:1998 Fly Ash Part 2:2001 Slag – Ground Granulated Iron Blast-Furnace
AS 3799:98	Liquid Membrane-Forming Curing Compounds for Concrete

1.1.2 American Society for Testing and Materials (ASTM)

C 171-03 Standard Specification for Sheet Materials for Curing Concrete is referred to, and forms part of, this specification to the extent indicated in the appropriate clause.

1.2 Construction Reviewer

In terms of NZS 3109, the Construction Reviewer shall be (…..)

Commentary: *The name of the Construction Reviewer should be specified, typically this would be the Engineer to the contract and this specification is based on this assumption*.

1.3 Quality Assurance

It is the Contractor's responsibility to ensure that the construction works complies in all respects with the drawings and specification. The Contractor shall advise the Engineer in writing, as to the name of the Contractor's suitably qualified representative responsible for quality control. Quality control records shall be stored in an orderly manner on site, and be available for inspection at any time. Upon completion of the works the Contractor's quality control

representative shall provide a statement that work has been conducted by suitably qualified persons, and in accordance with the drawings, specification, and any contract instructions.

The quality control records shall include Memorandums for building construction work (also referred to as 'record of works') for all Restricted Building Work. Record of works forms shall identify the Licensed Building Practitioner's name, License Class and particular work carried out/supervised. It shall also include all checklists developed to demonstrate compliance with this specification.

1.4 Protection of the Slab from the Elements

Commentary: *In this clause the designer should outline guidance on the level of protection the slab should be provided from the elements. The best protection is achieved if the building envelope is constructed before the ground slab. Probably the most common causes of dissatisfaction with a slab on grade is random cracking, and the most prevalent reason for these cracks are plastic shrinkage or restrained early thermal contraction. The risk of these occurring is significantly reduced if the slab is constructed after the building envelope. If the slab needs to be constructed first, it is strongly recommended that anti-evaporation sprays and early entry saw are used (see section 8 and 10).*

1.5 Design of Floor

Commentary: *In some instances the design of the floor is nominated as the responsibility of a Specialist Supplier. A common example is Post Tensioned floors. Only include this section if the design is to be done by others. This section should include comments on:*

- *The ground conditions*
- *The design loads*
- *The need to submit drawings for approval*
- *Requirements at joints (i.e. armouring of free joints)*
- *Documentation required*
- *PS 1 and Memorandums from Licensed Building Practitioners.*

2. CONCRETE SUPPLY

2.1 Concrete Required

The concrete for the various elements of the slab shall contain the specific types of materials listed in Table 2.1.

Table 2.1: Summary of concrete materials

Element	Specified Compressive Strength	Type	Maximum Aggregate Size	For Special Concrete Refer to Clause:
Floor slab in warehouse	35 MPa	Normal	19 mm	Not Applicable
Floor slab containing shrinkage compensating admixtures	35 MPa	Special	19 mm	2.3

Commentary: *Fill out table as appropriate.*

2.2 Normal Concrete

Normal concrete shall be used in the locations specified in Table 2.1. The concrete shall be produced in accordance with NZS 3104 from a plant possessing a current Certificate of Audit consistent with the Grade of concrete specified. The Contractor, Concrete Placer, and Concrete Supplier shall determine the appropriate slump of the concrete to achieve the desired workability consistent with the method of placement being utilized.

2.3 Special Concrete

For concrete specified as Special in Table 2.1;

(a) The concrete shall be supplied by a plant possessing a current Certificate of Audit.

(b) Unless modified elsewhere all Special concrete shall, as a minimum, meet the requirements of Normal concrete as specified in NZS 3104.

(c) The following additional requirements shall apply.

Commentary: *The reasons for specifying special concrete could include, but is not limited to, specifying any of the following examples presented below. Note there is also a requirement for the specifier to record the methods of conformance testing required. This has been provided in section 12.3.*

Special Concrete Example - Use of Cements other than GP

The cement used in the mix shall be (….) conforming to section 2.9.2. Batching records shall record the cement type. Conformance testing shall be in accordance with 12.3 of this specification.

Commentary: *An example could be the specification of early strength cements, HE cement. This is typically used where early age strengths (up to 3 days) are required. Rather than specify the cement type a more specific special*

requirement could be the strength required at the specific early age. In this case the specification would record the strength required, when the test would be conducted, and how the samples will be cured.

Special Concrete Example Strengths Greater than 50 MPa

The concrete grade shall be (.....) MPa. Conformance testing shall be in accordance with 12.3 of this specification.

Commentary: *For testing and commentary on this refer to 12.3.*

Special Concrete Example Air content for Freeze Thaw Resistance

The fresh concrete shall have an air content of (.....)%. Conformance testing shall be in accordance with 12.3 of this specification.

Commentary: *Refer section 12.3 for testing.*

Special Concrete example Use of SCM such as Fly ash, Amorphous Silica and GGBS

The concrete shall include (.....)% Fly Ash as a proportion of the total cementitious component. The fly ash shall conform with section 2.9.2.

Or

The concrete shall include (.....)% Amorphous Silica as a proportion of the total cementitious component. The Amorphous Silica shall conform with section 2.9.2.

Or

The concrete shall include (.....)% GGBS as a proportion of the total cementitious component. The GGBS shall conform with section 2.9.2.

The Concrete Supplier shall produce either computerised batch data or a QA system to provide assurance that the SCM has been added to all batches.

Special Concrete Example Use of Aggregates Greater than 37.5 mm

The concrete shall include a minimum (....) kg of aggregate of minimum nominal size 37.5 mm. This shall be verified by inspection of the batching records.

Commentary: *Typically minimum aggregate sizes are specified as a way of controlling drying shrinkage or reducing heat of hydration. A better approach might be to specify the minimum total aggregate content and maximum water content. Be wary that the mix design has to match the equipment used to transport the concrete to its final site and the placing and finishing equipment.*

Special Concrete Example Steel Fibre Reinforced Concrete

The concrete shall include (.....) kg of steel fibre of product name (.....) supplied by (.....) and tensile steel strength of (.....) MPa.

The Concrete Supplier shall produce either computerised batch data or a QA system to provide assurance that the steel fibres have been added to all batches.

Commentary: *Steel fibres in New Zealand are from many sources. While there are many from reputable international companies many others are bought in simply because they are cheap and resemble one of the major supplier's brands. It is preferable that the designer engages with the steel fibre manufacturer to determine the most*

appropriate solution and then specifies the solution. Preference should be given to suppliers who can support their claims through independent (CE) testing.

Special Concrete Example Use of Specified Shrinkage Values

The concrete shall have a maximum 56 day drying shrinkage value of (…..) microstrain when tested in accordance with AS 1012.13.

Prior to the concrete being used on site, the concrete shall be tested from a batch of concrete produced to the mix design and slump to be used in the contract. Testing shall be carried out in accordance with AS 1012.13.

Commentary: *The contractor must be aware that shrinkage testing takes 63 days from sampling through to final testing and is relatively expensive. In New Zealand, shrinkage testing of mixes is not a standard procedure. The shrinkage test does not show the designer the shrinkage that will be exhibited in practice. The factors in AS 3600 may be used to estimate what the in-place shrinkage might be. In order of priority the drying shrinkage will be driven by:*

(a) *The type of aggregate – this can alter shrinkage from a low of around 600 microstrain using Auckland basalt to 1,200 microstrain using some of the lower North Island greywackes.*

(b) *The volume of aggregate in the mix – this acts as a restraint to the shrinkage of the paste. An increase in total aggregate content can reduce the total shrinkage.*

(c) *Water content – for a given cement content increasing the water will increase the shrinkage. The amount of increase will depend on the cement content but 15 litres per m^3 will increase shrinkage by around 50-100 microstrain.*

(d) *Size and grading of aggregate does not itself decrease shrinkage except that it allows the use of leaner mixes with greater aggregate content.*

Special Concrete Example - Maximum Water to Binder Ratio

The concrete shall have a maximum water to binder ratio of (…..).

The manufacturer shall state how they monitor water content in the mix. In particular how they assess sand moisture and the control and measurement of wash-down and temp water. Production records shall be provided to confirm compliance.

Commentary: *When specifiying a water to binder ratio, ensure that the expected strength from this requirement matches the specified strength. Be aware that tolerances in measuring moistures in aggregates may mean that the accuracy within which water can be measured in the mix may be ±10 litres.*

2.4 Chloride Content

The total chloride content in Normal and Special concrete shall not exceed the limits specified in Clause 6 of NZS 3109 and chloride salts or chemical admixtures, formulated with greater than 0.1% by weight of chloride, shall not be added to any steel reinforced concrete.

Commentary: *NZS 3109 specifies total chloride content of concrete based on measurements of acid soluble chloride content arising from aggregate, mixing water, and admixtures expressed as mass of chloride ion per unit volume of concrete as follows:*

- *Prestressed concrete* *0.5 kg/m^3*
- *Reinforced concrete in dry or protected environment* *1.6 kg/m^3*
- *RC in moist environment or exposed to chlorides* *0.8 kg/m^3*

The restriction of 0.1% by weight of chloride comes from 3.14.1.1 of NZS 3101. Strictly it only applies to exposure classifications B1, B2 or C. The last sentence may be deleted if required in exposure classification A1 or A2. Refer to NZS 3101 for exposure classifications.

Literature shows that the life expectancy of a concrete structure is not particularly sensitive to the background chloride levels within the limits provided above. It is therefore usually appropriate to demonstrate compliance with the above clauses by calculating the total chloride levels from test results from the individual components. However, for important structures in exposure classification (such as bridges) it is appropriate to require acid soluble chloride testing of the proposed mix prior to commencement of the first pour to verify calculations.

2.5 Sulphate Content

The sulphate content in Normal and Special concrete shall not exceed the limits specified in Clause 6 of NZS 3109.

Commentary: *NZS 3109 specifies a maximum sulphate content, expressed as the percentage by mass of acid soluble SO_3 to mass of cement, of less than 5%.*

2.6 Workability of Concrete Mix

The selection, proportioning and mixing of the concrete materials shall be such as to produce a mix which works readily into corners and angles of the forms, and around reinforcement, but without permitting the material to segregate or excess free water to collect on the surface.

2.7 Consistency of Delivered Slump

The slump of the concrete at time of delivery shall be consistent and within the tolerances specified in Table 9.1 of NZS 3109.

2.8 Cement and Cementitious Materials

2.8.1 Cement for Normal Concrete

Cement for Normal concrete shall comply with the requirements of NZS 3122: Type GP – General Purpose Portland Cement.

Prior to the commencement of the project, a statement regarding the proposed cement to be used shall be provided stating:

- That all testing required by NZS 3122 (both mandatory and reportable) has been conducted and complies with NZS 3122.
- The source of the cement.
- The frequency of testing complies with Australian Technical Infrastructure Committee Table A1.
- That samples for testing have been obtained at point of dispatch from a New Zealand facility.
- Testing has been conducted by an IANZ accredited laboratory.

- The statement shall be provided by the Plant Engineer (as defined by NZS 3104) responsible for the mix design of the supplying ready mixed concrete plant, and supported by evidence if requested.

Commentary: *Plants which are audited by the NZRMCA Plant Audit Committee and/or use either Golden Bay Cement or Holcim Cement will comply with the above frequency of testing of cement.*

2.8.2 Cement and Supplementary Cementitious Materials for Special Concrete

Where required by Clause 2.3, cements and supplementary cementitous materials shall comply with the following:

(a)	Type GP -	General Purpose Cement	NZS 3122:2009
(b)	Type GB -	General Purpose Blended Cement	NZS 3122:2009
(c)	Type HE -	High Early Strength Cement	NZS 3122:2009
(d)	Amorphous silica		AS/NZS 3582:2002 Part 3
(e)	Fly Ash		AS 3582:1998 Part 1
(f)	GGBS, Ground Granulated iron Blast-furnace Slag		AS 3582:2001 Part 2

Commentary: *NZS 3122 also covers Type LH (Low Heat Cement.), Type SL (Shrinkage Limited Cement). However, these are not commonly used in New Zealand and therefore not included in the list. Typically low heat concretes would be achieved with the use of supplementary cementitious materials, and shrinkage limitation would be achieved using water reducing/shrinkage reducing admixtures.*

2.9 Aggregates

Aggregates shall comply with NZS 3121.

Commentary: *NZS 3121 provides requirements for grading, cleanness limits for deleterious materials, and sampling. Alkali aggregate reaction is incorporated into this specification by a limit on the total alkali content of the concrete as specified in 2.4. A Cement & Concrete Association of New Zealand publication '*Alkali Aggregate Reaction – Guidelines on Minimising the Risk of Damage to Concrete TR 3*' will help specifiers to understand the practical issues raised by this phenomenon.*

2.10 Water

Water shall be free from matter which in kind and quantity will prevent the achievement of the durability requirements of the Building Code. Water quality shall be consistent for all concrete supplied in a pour, and shall not adversely influence the workability and placing characteristics of the concrete. Water shall meet the requirements of NZS 3121.

Commentary: *Most plants in New Zealand use recycled water which is desirable from an environmental perspective, and permitted within NZS 3104.*

2.11 Chemical Admixtures

Chemical admixtures, where utilised in Normal concrete, or specified directly or indirectly for Special concrete in 2.3, shall comply with the requirements of AS 1478.

2.12 Attendance at Pre-pour Meeting

The Concrete Supplier and Concrete Placer shall attend a meeting organised by the Contractor prior to the pouring of the first concrete slab.

Commentary: *A pre-pour meeting is recommended to ensure that everyone understands the performance requirements and risk management strategies. The probable characteristics of the concrete mix and how the placing and finishing characteristic may vary from common concrete mixes should be discussed.*

3. EQUIPMENT

3.1 General

Dependable and sufficient equipment that is appropriate and adequate to meet the approved plan and schedule for the work specified shall be furnished by the Contractor. It shall be assembled at the site of the work in sufficient time before the start of placing to permit thorough inspection, calibration, adjustment of parts, and the making of any repairs that may be required.

Commentary: *The range of equipment suitable for use in constructing slab on grade is wide and varied. This section has been written in this form so as not to restrict the use of equipment which the contractor owns, nor with which the contractor is familiar; or to restrict innovation.*

The conditions of tendering should include the requirement that details of the intended equipment to be used are to be provided.

3.2 Maintenance

The approved equipment shall be maintained in good working condition. It shall be checked regularly for wear, setting and calibration. If not up to the required standard, the equipment shall be repaired or replaced prior to its continued use on the project.

3.3 Pumping Equipment

Equipment for pumping concrete shall be capable of safely and efficiently pumping concretes with slumps as low as 80 mm with mixes based on a maximum aggregate size specified in Table 2.1.

Commentary: *Pumping concrete is a common construction method. To avoid the situation where the concrete mix is designed for the capability of the pump, rather than using an appropriate capacity pump to place the correct type of concrete, minimum requirements have been specified. This has been done in terms of the concrete slump and maximum aggregate size the pump can efficiently handle. In most instances the maximum aggregate size will be 20 mm. The slump value specified in this clause should, in no instances, be interpreted as a desirable slump. The delivered slump of pumped concrete will typically have slumps considerably greater than 80 mm. The specification of an 80 mm slump is to provide a degree of confidence that the pump will be able to operate with low slumps if slump loss was to occur.*

4. FORMWORK

4.1 Comply with NZS 3109

The design, surface finish, tolerances and stripping times shall comply with NZS 3109, unless modified in this section.

4.2 Forms to be Rigid

Forms shall be of steel or seasoned, dressed timber planks. The forms shall be rigid to ensure they do not deform when concrete is placed and vibrated.

4.3 Tolerances for Slab Edge Formwork

Forms shall be free of warps, bends or kinks, and the tolerances of the top surface of the form shall ensure compliance with the finished floor tolerances specified in section 13.

4.4 Formwork Where Dowels or Ties Bars are Used

Where dowels or tie bars are required in construction joints, the forms shall allow for their insertion and for rigidly supporting them in the correct alignment.

4.5 Quality Control of Forms

Formwork shall be set and checked prior to placing the concrete and the setting of the forms shall be approved by the Contractor before any concrete is placed. Records of the quality control shall be kept and be available for inspection if requested.

Commentary: *The Contractor's Supervisor should check the forms for alignment, continuity and rigidity. Any problems should be rectified before approval is given to place concrete.*

4.6 Care when Removing Forms

Forms shall be removed without damaging the concrete, dowel bars or tie bars. Bars or other tools shall not be used as a lever against the concrete in removing the forms.

Commentary: *The appropriate time for the stripping of forms will vary according to the environment and the type of concrete used. NZS 3109 provides good guidance on appropriate stripping times. These may require modification in special situations, e.g. very thick slabs, when heat of hydration considerations necessitates the use of insulated forms. The use of blended cements may also influence form stripping times.*

4.7 Repair of Damage

Any damage to the concrete occurring during form removal shall be repaired promptly by an approved method, at the Contractor's expense.

5. SUB-BASE

5.1 Excavation

The site shall be excavated to the levels shown on the drawings. All top soil shall be removed from under concrete work and shall be kept separate from the excavated subsoil.

5.2 Disposal of Materials

All excavated material shall become the property of the Contractor except where otherwise provided. Remove from site as the work proceeds.

5.3 Sub-grade Preparation

The sub-grade shall be solid and compacted to receive the sub-base and concrete. The sub-grade shall be inspected and approved by the Construction Reviewer before any backfilling with sub-base.

Commentary: *To ensure that the slab can perform satisfactorily throughout its intended service life, the full support offered by the sub-grade should be fully assessed and evaluated before the sub-base is placed upon it.*

Problems can arise if the condition of the sub-grade varies from hard to soft as this site condition can lead to variable support and subsequent differential settlement when in service. Variable materials need to be removed and replaced with uniform backfill product to avoid the risk of differential settlement.

5.4 Sub-base

The sub-base shall comprise of continuously graded granular materials with not more than 5% passing a 2.2 mm sieve and with 100% passing the 63 mm sieve. The material should be suitably graded to permit compaction. The material shall have sufficient crushing resistance to ensure that the grading limits are maintained after compaction.

The sub-base shall be free of foreign matter, waste concrete and other debris at all times.

Commentary: *The specified maximum aggregate size assumes that the sub-base thickness is at least 150 mm deep.*

5.5 Compaction of Sub-base

The sub-base shall be compacted to ensure that it is free from movement under compaction equipment, and does not weave under the weight of a laden concrete truck. Wheel track depths of less than 5 mm shall be recorded after loading with a laden concrete truck.

Commentary: *The sub-base layer is provided for several reasons including:*

- *Providing a clean working platform.*
- *Providing a surface which will not puncture any vapor barrier.*
- *Providing support for construction traffic.*

- *Transferring loads from the floor slab to the sub-grade.*

Of these purposes, the last is probably the least onerous requirement. The design thickness of the slab is only marginally influenced by the load spreading ability of the sub-base, and therefore its presence is often ignored in design. Satisfactory performance under construction traffic is typically a satisfactory indicator of adequate performance. Wheel track depths of less than 5 mm after proof loading with a concrete truck is normally an indicator of adequate compaction. Other methods of ensuring adequate compaction would be to specify that sub-base materials shall be compacted to say 95% of New Zealand Standard compaction.

5.6 Finished Sub-base Surface

The surface of the sub-base should be closed, flat, level, and shall be free of material likely to puncture the underlay membrane. Sand maybe used for closing the surface, however any residual layer of sand on the surface shall be less than 5 mm thick.

Commentary: *Modern laser controlled construction equipment can place materials such as granular materials to very tight tolerances and it should be possible to restrict the maximum thickness of the sand blinding layer to no more than 5 mm. Thickness in excess of this will lead to unacceptable tracking under construction traffic loads.*

5.7 Tolerances of Sub-base

The finished surface of the sub-base shall be surveyed on a 3 m grid to determine the sub-base level. The finished surface shall be within +0, -10 mm of the datum for the bottom of the slab. Records of the survey shall be kept by the Contractor and shall be available for inspection if requested.

Commentary: *In some instances a 3 m grid maybe considered overly onerous and should be modified appropriately. Tight tolerances are desirable to ensure that the friction coefficient under the slab is kept as low as possible. To avoid disputes over the volume of concrete used, the payment schedule should make it clear who will cover the cost if the sub-base is constructed to the extremes of the acceptable tolerances.*

5.8 Maintenance of Sub-base

The sub-base shall be maintained in a smooth, compacted condition in conformity with the required profile and level, until the concrete is in place.

5.9 Sub-base Preparation when Vapor Barriers not Used

In situations where the concrete is placed directly on top of the sub-base, the sub-base shall be dampened (but not saturated) and kept damp prior to placing concrete.

Commentary: *This section is not applicable when concrete is placed directly over an impermeable material (e.g. polythene vapour barrier) or a material of relatively low permeability (e.g. bituminous sealed surface or lean-mix concrete).*

5.10 Inspection of Sub-base

The Construction Reviewer shall be advised at least one working day in advance of covering the sub-base. The Contractor is to make available to the Construction Reviewer all records showing site tests on the sub-grade and sub-base together with survey data to confirm levels are in accordance with the design.

6. UNDERLAY MEMBRANE

6.1 Underlay Membrane

The underlay membrane shall be flexible, polymeric film, nominally 0.25mm thick and manufactured from suitable high-quality ingredients satisfying the requirements of the New Zealand Building Code.

Commentary: *Note, if no underlay membrane is necessary, these clauses will not be required. Typically an underlay membrane is specified to control moisture transmission and to reduce sub-base friction.*

6.2 Storage

The underlay shall be delivered to the site in suitable protective packaging. The packaging, handling and storing of the underlay shall ensure that it is not punctured, torn, or otherwise damaged at any time. The underlay material shall have sufficient resistance to sunlight and associated radiation, so that its specified properties are unaffected by its exposure.

6.3 Laying

The underlay shall be laid over the levelled and compacted sub-base. Sheets of a maximum practical width shall be used to suit the layout and be arranged such that overlaps face away from the direction of concrete placement. The sheets shall be lapped as recommended by the manufacturer, but not less than 150 mm.

6.4 Repairing of Membrane

The membrane shall be inspected after laying and before the concrete is placed. Any punctures or tears shall be patched and sealed.

7. PLACING AND FIXING REINFORCEMENT

7.1 Reinforcement Materials

Reinforcement shall comply with AS/NZS 4671. All reinforcement shall be ductility class E and manufactured using the micro alloy process, unless noted otherwise on the drawings.

7.2 Quality Control – Reinforcement Traceability

As a quality control procedure, checklists shall be provided for each structural element to ensure traceability of reinforcement. The list shall identify:

- Reinforcing detailing sheets
- Source of reinforcement
- Method of reinforcement manufacture
- Ductility class
- Reinforcing batch numbers
- Mill certificate for batch numbers
- Concrete docket numbers
- Location of element in structure

Commentary: *Reinforcement is an important aspect of most reinforced concrete structures and therefore traceability of reinforcement is desirable. The mill certificates should demonstrate compliance with AS/NZS 4671 for each cast. Typically it would be expected that for a reinforcing manufacturing plant which has an established quality record that three tests would be made per cast (a maximum of 50 tonnes) where experience with the reinforcement supplier is low, random testing to confirm the mill certificates should be requested.*

7.3 Compliance with NZS 3109

The detailing of hooks and bends, surface condition of reinforcement, spacing and fixing of reinforcement, splices, cover and placing tolerances, shall comply with NZS 3109 unless modified in the drawings or this specification.

7.4 Dowels

Dowels shall be of the type shown on the drawings. Where steel bars are used they shall be one-piece, straight, plain, round/square steel bars complying with the requirements of AS/NZS 4671, and of the sizes shown in the drawings. They shall be saw-cut to length prior to delivery to the site, and the ends shall be square and free from burrs.

Commentary: *It is desirable that dowels should allow both for longitudinal and transverse movement. There are proprietary systems which can provide for two directional movement.*

7.5 Tie Bars

Tie bars shall be deformed bars complying with AS/NZS 4761, and of the size shown in the drawings.

7.6 Reinforcement Shall be Placed on Chairs

Reinforcement shall be provided in the locations shown in the drawings and shall be placed and securely held in its correct position by the use of approved supports.

Commentary: *The practice of laying reinforcing fabric on the sub-base and hooking the reinforcing into position after concrete is placed is not acceptable. Also unacceptable is working the fabric in from the surface of the concrete, as both of these methods provide no assurance that the reinforcement will end up in a true plane, at the required level.*

7.7 Supports

The supports shall be adequate to withstand construction traffic and shall be sufficient in number and spacing to maintain the reinforcement in its correct position during the concrete placing operation. Cementitious spacers shall at least match the quality of the concrete being cast and shall have a minimum compressive strength of 40 MPa.

8. PLACING AND FINISHING

8.1 Planning and Pre-pour Meeting

The Concrete Placer shall attend the pre-pour meeting organised by the Contractor as specified in 2.13.

8.2 Placing Team

All concrete shall be placed and finished by appropriately skilled and trained personnel. Restricted building work shall be supervised or completed by a Licensed Building Practitioner.

Commentary: *Quality assurance in commercial concrete construction is normally achieved through a series of inspections. However, a Licensed Building Practitioner Class – Foundations exists which incorporates the demonstration of many of the skills required to successfully place concrete. One of the areas of practice of this license class is to demonstrate competency of the construction of concrete foundation walls and concrete slabs on ground.*

8.3 Inspection Prior to Pouring

The Contractor shall give at least one working day's notice of intention to place concrete in any area, to enable the area to be inspected by the Construction Reviewer prior to commencement of placing.

Unless approval is given by the Construction Reviewer, no concrete shall be placed in that section of the works. Any concrete placed without authorisation may require removal from the works at the Contractor's expense. All inspections shall be documented.

8.4 Compliance with NZS 3109

All placing and finishing shall comply with NZS 3109 unless modified in this specification.

8.5 Placing and Finishing Tolerances

The tolerances for finishing and placing shall be as specified in Section 13.

8.6 Slump

The slump of the concrete at time of delivery shall be consistent, and within the tolerances specified in Table 9.1 of NZS 3109.

8.7 Addition of Water

Water may be added to the concrete as delivered only by the Concrete Supplier within the restriction provided in 2.9.3.1 of NZS 3104.

8.8 Limitation on Placement of Concrete

When the possibility of heat, wind, rain, or low humidity could prevent the requirements of this specification being met, the Contractor shall take appropriate precautions to ensure compliance with this specification.

Commentary: *Most contractors see rain as the only impediment to pouring concrete. However, most cases of cracking arise from hot and/or windy conditions causing premature drying of the top surface or plastic cracking. See Section 8.9*

8.9 Elimination of Plastic Shrinkage Cracking

Where there is a risk of plastic shrinkage cracking, the Concrete Placer shall apply an anti-evaporation agent or fog mist the concrete surface after screeding and any floating operation, to prevent excessive evaporation of water from the concrete surface.

8.10 Placing

8.10.1 Working Face

The concrete shall be placed so that its working face is generally vertical, and normal to the direction of placing. It shall be placed uniformly over the width of the slab and in such a manner as to minimize segregation.

8.10.2 Walking on the Concrete

Workers shall not be permitted to walk on the concrete during placing with boots coated with soil or other deleterious substances.

8.10.3 Hand Spreading

Hand spreading of concrete shall be done with shovels, or rakes with blades. Vibrators or rakes with tynes shall not be used.

Commentary: *Vibrators or tyned rakes must not be used to spread concrete as they may cause segregation of the concrete mix.*

8.10.4 Construction Joints

Concrete placing shall be carried out continuously between forms and/or construction joints and in such a manner that a plastic concrete face is maintained. Where their location is shown in the drawings, construction joints shall neither be relocated nor eliminated without approval. Where no construction joints are shown in the drawings, their location shall be approved before work starts.

Commentary: *The proper location of construction joints, which are also free joints, is critical to the functioning of the slab. The Contractor should consult the designer before giving any approval to the relocation of construction joints or the inclusion of new ones.*

8.11 Compacting

8.11.1 Compaction

All concrete, including that adjacent to forms or existing concrete, shall be compacted by mechanical vibration through the use of internal vibrators and/or vibrating surface screeds as detailed herein.

Commentary: *The method of compaction to be employed is dependent on the pavement thickness. A guide to the most appropriate method can be summarised as follows:*

- *For pavements over 200 mm thick, surface vibration may not be sufficient to compact the concrete over its full depth, and internal vibration is required.*
- *Internal vibration should be used adjacent to all construction joints and edges.*

8.11.2 Slabs Less Than 200 mm Thick

Pavements up to 200 mm thick may be compacted using an immersion vibrator complying with NZS 3109, vibrating beam, vibrating truss screed, vibrating screed, or laser screeds. The method selected shall ensure that the specified surface tolerances are achieved. Internal vibrators shall be used to supplement the compaction adjacent to the side forms and at construction joints.

Commentary: *Hand held vibrating screeds are only suitable for domestic slabs and should not be considered vibration for commercial slabs.*

8.11.3 Slabs Greater than 200 mm thick

Pavements greater than 200 mm thick shall be compacted using immersion vibrators complying with NZS 3109.

8.11.4 Requirements for Vibrating Beams

Vibrating beams shall incorporate double beams made of extruded aluminium or steel, or metal-shod timber sections with edges at least 75 mm wide. They shall be at least 300mm longer than the width of the strip being compacted, and equipped with handles to allow the assembly to be drawn over the concrete surface from outside the forms.

8.12 Floating

Commentary: *This specification has been developed on the assumption that the floor will, as a minimum, be power floated. This would be the norm for most floors but in some instances, such as when an exposed aggregate finish is specified, floating would not be necessary and section 8.12 could be deleted.*

8.12.1 Power Floating

Floating shall be undertaken using powered mechanical equipment.

8.12.2 Commencement of Floating

Floating shall not commence until all surplus water is removed or evaporated from the surface of the concrete, and the surface is sufficiently hard to resist displacement under the action of the float.

Commentary: *It is important that power floating is not commenced until the concrete has stiffened sufficiently. The time interval before the initial power floating can commence depends on the concrete mix and the weather.*

8.12.3 Regular Pattern

Floating shall be undertaken in a regular pattern over the entire surface of the concrete.

8.13 Finishing

8.13.1 General

Finishing operations comprising leveling, floating, trowelling and texturing, shall commence following compaction of the concrete, and shall be completed as soon as possible with due diligence.

8.13.2 Addition of Water

The addition of water to the surface of the concrete to assist in finishing operations shall not be permitted. However, in hot weather or dry, windy conditions the application of water to the surface in the form of a fog, or fine mist spray, or the spraying of the surface with an approved aliphatic alcohol shall be permitted.

Commentary: *Spraying with aliphatic alcohol immediately after initial finishing will limit evaporation of water and reduce plastic shrinkage cracking in hot weather conditions.*

8.13.3 Schedule of Required Finishes

The finished surface shall be as specified in Table 8.1.

Table 8.1: Schedule of required finishes

Element	Surface Finish	Specification Clause	Proprietary Surface Products
Floor slab in warehouse	U3, Trowelled	8.12	
Hardstand area outside of warehouse.	U5, Shallow texture	8.13	

Commentary: *The specification covers the following potential surface finishes. If other finishes are required, appropriate specification clauses will need to be developed;*

- *Nil, i.e. float finish only, suitable if the floor will be covered.*
- *Trowelled, the most common for internal warehouse floors.*
- *Shallow texture (broomed) the most common for exterior slabs requiring texture for skid resistance.*

8.14 Trowelling

8.14.1 General

Where a trowelled finish is specified in Table 8.1, the requirements of 8.14 shall apply.

8.14.2 Equipment

Trowelling shall be undertaken using approved powered mechanical equipment.

Commentary: *A power trowel is similar to a power-float but fitted with small individual steel trowel blades. The small blades can be slightly tilted during trowelling operations. This clause shall not prevent the use of hand trowelling to finish the surface along edges, and small areas unable to be covered by mechanical equipment.*

8.14.3 Commencement of Trowelling

Trowelling shall commence after the surface has been power floated. Trowelling shall not commence until the surface is sufficiently hard to resist displacement under the action of the trowel.

Commentary: *The power trowelling is commenced when the excess moisture brought to the surface by initial power-floating has largely evaporated and the concrete has lost its stickiness. The waiting time before power trowelling also depends on both the concrete mix and the weather. A practical test to check the readiness for each trowelling operation is to place the palm of the hand on the concrete surface. If mortar sticks to the palm when the hand is taken away from the surface, the concrete is not ready for trowelling. If trowelling is started too early, the trowel blades will leave ridges.*

8.14.4 Tilting of Trowelling Blades

The blades of the trowel shall be tilted such that maximum pressure is applied without leaving ridges on the surface of the concrete.

Commentary: *The first power trowelling of the slab is undertaken in a systematic pattern with the trowel blades set at a slight angle (the angle depends on the concrete stiffness but as large a tilt as possible to suit the surface should be used). If the tilt on the blades is too great, the concrete surface will be marked.*

8.15 Shallow Texture

8.15.1 General

Where a shallow texture finish is specified in Table 8.1, the requirements of 8.15 shall apply.

8.15.2 Commencement of Finishing

Texturing shall not commence whilst the condition of the concrete is such that the surface could be torn and coarse aggregate particles displaced, or whilst there is free water on the surface.

8.15.3 Broom Texturing

The whole surface of the slab shall be broomed in a direction perpendicular to the direction of placing or as shown in the drawings. Brooms shall be at least 500 mm wide with bristles of natural material, nylon or flexible wire. The broom shall be drawn across the full width of the slab in a series of overlapping strokes. The marks in the slab surface shall be uniform in appearance and approximately 2-6 mm in depth without disfiguring marks.

Commentary: *For most slabs, no additional force other than the self-weight of the broom need be applied to the surface. To improve traction in ramped or inclined areas, a coarser texture can be achieved by applying extra force to the broom.*

8.16 Early Entry Sawing

Where early entry saw cuts are specified on the drawings, all equipment required for cutting shall be on site prior to the commencement of the final finishing operation.

8.17 Protection of the Environment

All wash water associated with concrete shall be managed as stipulated in the New Zealand Ready Mixed Concrete Association's publication "Safe Environmental Guidelines - On Site Management of Concrete Washwater".

9. CURING

9.1 General

The concrete shall be cured by protection against loss of moisture for a period of not less than seven days from the completion of the finishing operations. Curing shall comprise initial curing followed by final curing.

Commentary: *Properties of concrete such as strength and wear resistance improve with age as long as conditions are favorable for continued hydration of the cement. The improvement is rapid at an early age, but continues more slowly thereafter. Evaporation of water from newly-placed concrete can cause the hydration process to stop. It follows that concrete should be protected so that moisture is not lost during the early hardening period.*

9.2 Equipment shall be on Site

Before concrete placing commences, all equipment needed for adequate curing of the concrete shall be on hand and ready for use.

9.3 Sides to be Cured

The sides of panels exposed by the removal of forms shall be cured by one of the methods detailed herein. This shall commence within one hour of removal of forms.

9.4 Initial Curing

Immediately after the finishing operations have been completed and until the membrane, sheet, or water curing has been applied, the surface of the concrete shall be kept continuously damp by means of a water fog or mist applied with approved equipment.

Commentary: *The use of a sprayed film of aliphatic alcohol is not a part of the curing process, it is simply a temporary moisture-retention facility for use during placing and finishing operations.*

9.5 Final Curing

9.5.1 Contractor to Determine Method

The final curing shall be either water curing complying with 9.6, membrane curing complying with 9.7, or impermeable sheet curing complying with 9.8. The Contractor shall determine the most appropriate method consistent with this specification, and obtain approval where specified.

9.5.2 Quality Control

The Contractor shall monitor the curing process and compliance with this specification. Records of the quality control shall be kept and be available for inspection if requested.

9.6 Water curing

9.6.1 General

As soon as possible after the finishing operations have been completed and the concrete has set sufficiently to prevent marring the surface, the forms and entire surface of the newly-laid concrete shall be prevented from drying by the continuous application of a mist spray, or by ponding. Where approved by the construction reviewer, the slab maybe covered with Hessian mats which are kept continuously wet for the specified curing time.

Commentary: *The use of Hessian may result in slight shade variations in the colour of the concrete. In most industrial situations this would be of no consequence, however if the appearance of the floor is a prime consideration, extra care should be taken to ensure curing is as even as possible.*

9.6.2 Hessian Mats

When permitted, Hessian mats shall have sufficient width, after shrinkage, to cover the entire width and faces of the concrete slab. Provision shall be made to securely anchor the mats to ensure that they remain in place in windy conditions. The mats shall overlap each other at least 150 mm. The mats shall be saturated before placing and shall be kept continuously wet and in intimate contact with the slab edges and surface for the duration of the required curing period.

9.7 Sprayed Membrane Curing

9.7.1 Approval to use Membrane Curing

The Contractor shall obtain approval to use any curing compound from the Construction Reviewer. The request for approval shall include a statement on compliance with 9.7.2, the compatibility it has with any subsequent specified treatment, and the potential for discolouration. Membrane curing shall not be used where the surface will be painted, coverings are adhered to the surface, or where the covering supplier requires specified moisture readings in the concrete prior to the application of the product.

Commentary: *If floor slab coatings are specified, the compatibility of the coating with the curing compound needs to be determined. For some floor coverings, the manufacturer will require confirmation that the surface is appropriately dry before the covering is applied. Typically this is determined using a hygrometer. When curing membranes are used it can take a very long time before the slab sufficiently dries to accept the covering.*

9.7.2 Membrane curing materials

Liquid membrane-forming curing compounds shall comply with the requirements of AS 3799 or ASTM C 309.

Commentary: *Of the many different forms of liquid membrane-forming curing compounds available, the wax-based emulsions and chlorinated rubber types are preferred and recommended. Recent research has shown that special safety precautions are necessary for the use of chlorinated rubber compounds. A fugitive dye is suitable to visually check that the slab has been sprayed.*

Most of the silicate type agents are used for surface hardening and are not curing membranes. Before using as a curing membrane ask for proof they meet the requirements of AS 3799 or ASTM C 309. However, they generally are then compatible with many of the various surface finishes used.

Wax-based curing compounds are generally efficient in terms of moisture retention, but can provide a slippery surface. For this reason, it is recommended that they not be used when the slab is to be subject to early foot or vehicular traffic.

9.7.3 Application

On completion of initial curing the entire exposed surface of the concrete, including edges, shall be uniformly coated with the approved membrane curing compound applied in accordance with the manufacturer's recommendations.

9.7.4 Spread evenly

The curing compound should be sprayed uniformly at the rate recommended by the manufacturer to achieve compliance with AS 3799.

Commentary: *Where chemically compatible with individual curing compounds, the use of coloured fugitive dyes are effective in providing for a visual check of uniform coverage.*

9.8 Impermeable Sheet Curing

Commentary: *It is common to get some shade variation in the colour of the concrete when using sheet curing. When not acceptable, this method of curing should be deleted from the specification.*

9.8.1 Impermeable Sheet Materials

Impermeable sheet materials shall comply with the requirements of ASTM C171.

9.8.2 Application

On completion of initial curing and for the remainder of the curing period, the moistened concrete surfaces shall be covered with approved impermeable curing sheets. The curing sheets shall be in pieces large enough to cover the entire width and edges of the slab. Adjacent sheets shall overlap not less than 500 mm and the lapped edges securely tied or weighted down along their full length to prevent displacement or billowing by wind. Sheets shall be folded down over the side of the pavement edges, continuously weighted, and secured. Tears and holes appearing in sheets during the curing period shall be repaired immediately.

Commentary: *The most commonly used impermeable covering is waterproof plastic sheeting, such as clear polyethylene or its equivalent. The sheeting should be placed as soon as the condition of the concrete is such that the surface will not be marked or damaged.*

10. JOINTS

10.1 Types of Joints

Commentary: *This specification refers to four types of joints, defined below:*

- *Free joint- a joint designed to open up as shrinkage occurs without any restraint across the joint.*
- *Tied joint- either the reinforcement is continuous through the joint, or when used as a construction joint, bars (tie bars) are used to tie each side of the joint together.*
- *Isolation joint- these isolate the slab from other elements, typically other structures.*
- *Construction joints.*

10.2 General

All joints shall conform to the details, and shall be constructed in the locations shown in the drawings.

10.3 Free Joints

10.3.1 As specified on drawings

Free joints shall be as specified on the drawings. Where proprietary systems are used they shall be installed in accordance with the manufacturer's recommendations.

Commentary: *For industrial application where heavy loads or pallet stackers are used it is recommended that free joints have steel armoured edges and are dowelled. Many very good proprietary systems are available. Where the joints are not trafficked, or where they will only be crossed by pneumatic tires, then need to amour the edges can be omitted.*

10.3.2 Dowels to be Accurately and Securely Positioned

Where specified, dowels shall be placed across joints where indicated in the drawings. The dowel system shall be precisely aligned and securely held parallel to the surface of the finished slab during placing and finishing operations. The method used to hold dowels in position shall be sufficiently rigid to ensure that individual dowels do not deviate by more than 3 mm in 300 mm from their specified alignment.

10.3.3 Dowel Tolerances

Unless specified otherwise by the dowel manufacture, the vertical and horizontal tolerances shall not be exceeded the lesser of 5% of the slab thickness; or ±10 mm.

10.3.4 Spacing of Dowels

The spacing of dowels in longitudinal construction joints shall be as indicated on the drawings. Dowels shall be omitted when the centre of the dowel would be occurring within 200 mm (horizontally) of a transverse free joint.

10.4 Isolation Joints

10.4.1 General

Isolation joints shall be formed by means of an approved preformed bond breaker.

10.4.2 Location

Isolation joints shall be formed about structures and features that project through, into or against the slab, using joint filler of the type, thickness and width as indicated, and installed in such a manner as to form a complete, uniform separation between the slab and the element to be isolated.

10.5 Tied Joints

Commentary: *Tied joints can be constructed in numerous ways including:*

- *construction joints incorporating tie bars,*
- *saw cuts, which can be early entry or cut with diamond blades,*
- *proprietary crack inducers, with reinforcement through joint,*
- *tooled joint in reinforced slab.*

The following clauses give recommendations for generic systems. It assumes that the types of joints will be shown on the drawings, and if saw cutting is specified the drawings will indicate if early entry or diamond blade saw cutting is to be used.

10.5.1 Tied Joints as Shown on Drawings

The location and type of tied joints shall be as shown on the drawings. Tied joints shall be constructed in accordance with Clause 10.5.

10.5.2 Tied Joints Constructed by Diamond Blade Saw Cutting

Sawn tied joints shall be constructed by sawing a groove not less than 3 mm and not more than 5 mm in width for a depth of quarter the slab depth unless shown otherwise on the drawing.

The time of sawing shall be varied, depending on weather conditions, and shall be such as to prevent uncontrolled cracking of the pavement. Sawing of the joints shall commence as early as possible, typically within 24 hours, and be commensurate with the concrete having hardened sufficiently to permit cutting without excessive chipping, spalling or tearing.

A chalk line or other suitable guide shall be used to mark the alignment of the joint. The saw cut shall be straight from edge to edge of the panels and shall not vary more than 10 mm from the true joint alignment.

Commentary: *These joints are designated as tied joints so in no circumstances should the reinforcement through the joint be cut.*

10.5.3 Tied Joints Constructed by Early Entry Saw Cutting

Early entry sawn joints shall be created as early as possible after initial set of the concrete without raveling of the joint. The depth of the cut shall be the greater of 25 mm or one eighth of the slab thickness.

Commentary: *Early entry saws ensure that saw cuts are in place immediately after finishing. These provide a degree of protection against random cracking due to restrained early thermal contraction. There is a limited window of opportunity for these types of saw cutting hence the requirement in 8.16 that the saws are on site before the start of the final finishing operation.*

10.6 Construction Joints

Construction joints shall conform to NZS 3109, type B, unless notified otherwise. Their location shall be as shown on the drawings, or if not shown, agreed in advance with the Construction Reviewer.

10.7 Joint Sealing

Commentary: *This section assumes that the joints which require sealing are indicated on the drawings. It is important to note that the sealing of free and tied joints is very different. The reinforcement crossing a tied joint is expected to remain elastic and therefore movement across the joint is small. For tied joints the joint can simply be filled with the sealant. When free or isolation joints require sealing, specific design of the dimensions of the sealant is required. For these joints it is important that a bond breaker is used to ensure that the sealant does not stick to the bottom of the joint (it should stick only to the sides) and to avoid excessive demands on the sealant the sealing process should be delayed as much as possible to avoid large movement demands on the sealant due to shrinkage of the concrete.*

10.7.1 Seal Joints as Shown on Drawings

The location and type of joints requiring sealing shall be as shown on the drawings.

10.7.2 Widening of Tied Sawn Joints Requiring Sealing

After expiration of the curing period and immediately prior to joint sealing operations, an 8-10 mm groove for the joint sealer shall be sawn to a depth of 20 mm in the top of sawn joints. Where multiple cuts are necessary to saw the groove to the specified dimensions, the groove shall be washed out between successive saw cuts so that a check can be made of the alignment over the joint edge. The sides of the sawn groove shall be parallel.

10.7.3 Sealant Installation in Tied Joints

Immediately before the installation of the sealer, the joints shall be thoroughly cleaned so that the entire joint space is free from concrete, dirt, dust and other materials. The joint shall be filled with (…..) sealant applied in accordance with the manufacturer's recommendations.

10.7.4 Sealant Installation in Free Joints

The dimensions and details of the sealing of free joints shall be as shown on the drawings. A bond breaking tape shall be provided at the bottom of the joint to ensure that the sealant only adheres to the sides of the joint. The sealant shall be installed (…) days after the completion of curing of the slab.

Commentary: *Specific design of the joint sealant is required so this specification assumes that the details will be provided on the drawings.*

11. PROTECTION OF CONCRETE SLABS

11.1 General

Concrete slabs shall be protected against all damage prior to final acceptance of the work.

11.2 Construction Traffic

Irrespective of age, trafficking of pavements by tracked or solid-wheeled construction equipment shall be permitted only if protective matting, steel plates, or timbers are placed under their wheels or tracks.

12. TESTING AND ACCEPTANCE OF CONCRETE

12.1 General

The finished floor tolerances shall be in accordance with Section 13, and the concrete shall be tested for compliance with the specification in accordance with this section.

12.2 Compression Testing of Normal and Special Concrete

12.2.1 Testing in Accordance with NZS 3104

For both Normal and Special concrete, the Concrete Supplier shall conduct all tests required by NZS 3104 for Normal concrete. The results of tests shall be recorded and be available on request. The Concrete Supplier shall also be able to demonstrate compliance with Section 2 of this specification.

Commentary: *Clauses 2.3 and 2.9.2 in Section 2 relate only to Special concretes. Testing to NZS 3104 ensures that:*

- *Aggregates are test for grading and cleanliness per 100-300 m^3.*
- *Sands are tested every 50-150 m^3.*
- *Total alkali content is less than 2.5kg/m^3.*
- *Compression tests of one test (2-3 cylinders) per 75m^3 up to 15,000 m^3 per annum and over this volume, one test per 250 m^3.*
- *Slump testing, as a minimum with each compression test.*
- *Air content tests, one a day to once a week.*
- *Monthly results monitored by the plant engineer.*
- *Annual audit of plant by independent engineer (for plants with audit certificate).*

Random testing to NZS3104 will not however guarantee that the concrete supplied to your project is sampled and compression tested. Where this is considered desirable this needs to be specified as indicated in 12.2.2.

12.2.2 Schedule of Supplementary Testing

In addition to the testing provided in 12.2.1, representative samples of fresh concrete shall be taken on site in accordance with NZS 3112:Part 1 for compression strength testing and slump testing in the locations and frequency defined in Table 12.1.

Table 12.1: Frequency of onsite compression testing

Element	Sample and Test Frequency

Floor	One test per ?? m^3

All personnel conducting tests shall be adequately trained having satisfied the requirements of New Zealand Qualification Authority unit standard 12019 - Carry out Routine Tests on Concrete.

Testing shall be in accordance with NZS 3112.

A compression test shall comprise of three cylinders of the same batch of concrete. A compression test result, as specified in 9.4 of NZS 3109, shall be the average of the three cylinders.

Commentary: *Only use the above clause if you require tests above that specified in NZS 3104 or specifically want tests on your concrete.. Tests carried out by untrained personnel may not be recognised by the concrete supplier. If the customer opts to carry out a testing programme under their own auspices, the work must be done in strict accordance with the relevant documents or else the results could be challenged or rejected by the supplier. As an alternative, the client could delegate these responsibilities to an INZ (TELARC) accredited laboratory.*

The customer may, at his or her discretion, request that samples be taken from their concrete for testing to determine its strength. This work may or may not be charged for by the supplier as it is, strictly speaking, in addition to the normal testing programmes as defined in NZS 3104.

12.2.3 Rejection Criteria

The assessment of test results shall be in accordance with 9.4 and 9.5 of NZS 3109.

12.3 Testing of Special Concrete

Commentary: *The test requirements for special concrete need to be linked to the criteria requested in Section 2.3 of this specification. It is recommended that the testing required build upon what would normally be specified for Normal concrete.*

12.3.1 Additional Test for Special concrete

In addition to the testing specified in 12.2.1 or 12.2.2, the following tests shall be conducted.

Commentary: *Any other requirements regarding the sampling and testing of concrete over and above that contained in NZS 3104 for Normal concrete, should be specified. The clause needs to be linked to 2.3 and should contain details of sampling and testing frequency. The following are some examples linked to those given in 2.3.*

Use of Cements Other Than GP

Commentary: *12.2.2 would necessitate some compression test results and 2.3 requires batching records document the type of cement used. This may be sufficient in many cases. If a performance criteria was set rather than the type of cement, the following would need to be placed in this section:*

- *How and when the concrete will be tested.*
- *How the samples will be cured.*
- *What will be the conformance criteria.*

Strengths Greater Than 50 MPa

Commentary: *As the concrete supplier may not have a performance record for concretes over 50 MPa, it is desirable to specify the testing required. A possible solution could be to specify the following:*

Representative samples of fresh concrete shall be taken in accordance with NZS 3112 every (.....) cubic metres with a set of four cylinders. One to be broken at seven days and three at 28 days.

All personnel conducting tests shall be adequately trained having satisfied the requirements of New Zealand Qualification Authority unit standard 12019 - Carry out Routine Tests on Concrete.

Testing shall be in accordance with NZS 3112.

The target strength for a set of 30 consecutive tests shall be (.....) MPa. The cautionary limit for six tests shall be (.....) MPa. If the mean strength of any consecutive set of six tests is less than the cautionary limit, the mix design, batching and cylinder testing shall be reviewed.

A compression test shall comprise of three cylinders tested at 28 days, from the same batch of concrete. A compression test result, as specified in 9.4 of NZS 3109, shall be the average of the three cylinders. The rejection limit for concrete shall be in accordance with 9.4 and 9.5 of NZS 3109.

Commentary: *For strengths greater than 50 MPa the specifier may need to liaise with the manufacturer's plant engineer as to the Sd value used to set target strength and COV requirements for monitoring purposes. Monitoring concrete by way of mean strengths and test variation gives an engineer greater control of concrete quality than relying only on rejection limits.*

Air Content for Freeze Thaw Resistance

Testing shall be carried out initially every 20 m^3 until three consecutive tests show an air content within 1.5% of target. Then air tests shall be carried out every 75 m^3.

Tests shall be in accordance with NZS 3112.

Use of SCM such as Fly Ash, Amorphous Silica and GGBS

Commentary: *No tests are specified above the tests specified for Normal concrete. If additional testing is required it should be specified here.*

Use of Aggregates Greater Than 37.5 mm

Commentary: *No tests are specified above the tests specified for Normal concrete. If additional testing is required it should be specified here.*

Fibre Reinforced Concrete

Commentary: *No tests are specified above the tests specified for Normal concrete. If additional testing is required it should be specified here.*

Use of Specified Shrinkage Values

Commentary: *It is assumed that shrinkage tests will be conducted on a trial mix, and once an acceptable mix has been determined, conformance testing will be limited to monitoring batching records. If shrinkage testing is to form*

part of the conformance requirements it would need to be specified here. It should be noted, however, that shrinkage tests take a considerable amount of time and therefore have little use as a conformance test.

12.3.2 Rejection Criteria for Special Concrete

Commentary: *The criteria for rejection of the concrete will depend on the reasons for specifying Special concrete. The criteria against which concrete will be rejected should be specified in this clause.*

12.4 Rejection Criteria

In addition to the criteria set in 12.2.3 and 12.3.2, where appropriate, hardened concrete shall be liable to rejection if any of the following defects occur:

- It is porous, segregated or honeycombed.
- The reinforcing steel has been displaced from its correct location.
- Inserts and other items embedded in the concrete have been displaced from their specified position.
- The concrete work can be shown to be otherwise defective.

12.5 Concrete That is Liable to Rejection May Be Permitted

Concrete that is liable to rejection may be permitted to be retained on the basis of satisfactory results being obtained from one or more of the following:

- An appraisal of the statistical information related to the concrete strength.
- A structural investigation.
- Additional tests (such as outlined in NZS 3109).
- Approved remedial work.

12.6 Rejected Concrete

Where concrete work has been finally rejected it shall be removed to the extent determined, and replaced in accordance with Clause 14.

13. CONSTRUCTION TOLERANCES

13.1 Outline

Commentary: *The surface tolerances and profile of the floor need to reflect the planned use of the floor. Typically floor regularity is controlled in two ways- flatness (i.e. bumpiness), and levelness. There are several ways in which these variables can be measure and evaluated. It is important, regardless of the method used, that appropriate limits are set. Generally the tighter the tolerances the more expensive the construction method.*

Following NZS 3109 and a U3 finish (trowelled) in NZS 3114 would provide surface tolerances of level +/- 10 mm and gradual deviations of 5mm measured over a 3 m length. Note this requirement is often modified to be +/- 3 mm measured using a 3 m straight edge.

The TR 34 produced by the UK Concrete Society specifies different tolerances for different floor classifications. FM 1 has the tightest tolerances and FM 3 the least restrictive. Levelness is measured by levels taken on a 3m grid, and flatness by elevational distance over a 600mm length. This is typically measured by specialist equipment.

In the US, ACI 302 provides an evaluation method using a F number system. Two numbers are determined using a machine, the floor flatness FF and floor levelness FL.

In this specification it has been assumed that New Zealand Standards will be used, with some modification. If either the TR 34 or the ACI 302 method is used, then appropriate clauses will need to be developed.

13.2 General

Following completion, the finished surfaces of the various sections of the pavement shall be tested for conformance to the grades, lines and levels shown in the drawings, and for surface smoothness by the methods detailed hereunder.

13.3 Surface Levels

The finished surface of the slab measured on a 3m grid coinciding with the grid used for the sub-base shall conform to the levels, grades and cross sections shown in the drawings to the extent that:

(a) All points shall be within +/- (…..) mm of the level specified in the drawings.

(b) The difference in level between adjacent grid points shall be less than (…..) mm.

(c) 95% of the results from (b) shall be less that (…..) mm.

Commentary: *Note the above clause assumes that the floor is supposed to be flat. It will need to be modified if the floor is to be constructed to a specified fall. NZS 3109 specifies that the limit on (a) is +/-10 mm but provides no tolerance or acceptance criteria associated with these clauses. TR 34 specifies that 100% of the levels of (a) should be within +/- 15 mm. Items (b) and (c) are not a requirement of NZS 3109 but have been taken from TR 34. TR 34 specifies limits of 4.5 mm, 8 mm, and 10 mm for item (b) for FM 1, FM 2, and FM 3 floors respectively. For item (c) these limits are 7.0 mm 12.0 mm, and 15 mm.*

Consideration should be given as to whether to use this clause rather than rely on the clauses relating to surface flatness and slab thickness.

13.4 Surface Flatness

The finished surfaces of the various sections of the pavement shall not deviate from the testing edge of an approved 3 m straightedge by more than (.....) mm. Refer to NZS 3114.

Commentary: *The requirements of NZS 3114 give acceptance criteria for an individual point. There are however, no criteria for what proportion of measurements exceeding the limit might be considered acceptable. Some American specifications provide for financial effects for exceeding or not meeting the flatness specification. The American F number system has been specified on many slabs as it provides a statistical measure of a slab's flatness and levelness. However, this does not measure close to joints or slab edges which will be of interest to an end user. This would require separate acceptance criteria.*

13.5 Remedial Works

Where the tolerances of this specification are not achieved, the Contractor shall submit for approval, the proposed remedial work.

14. REMOVAL AND REPLACEMENT OF DEFECTIVE AREAS

14.1 Defective Pavement Areas

Slab areas outside the tolerances specified in Section 13, and areas rejected in accordance with Clause 12.4 shall be considered as defective pavement areas.

14.2 Removal and Replacement

The Contractor shall submit the proposed remedial works for approval. Where the suggested remedial works is not approved, defective slab areas shall be removed and replaced as specified herein with pavements of the thickness and quality required by this specification.

14.3 Jointing to Existing Pavement

Jointing of the replacement concrete to the existing concrete shall be by an approved method.