



CCANZ TECHNICAL REPORT

TR 10

**Specifying Concrete for
Performance**



Third Edition 2013

Acknowledgements

THE CEMENT & CONCRETE ASSOCIATION OF NEW ZEALAND WISHES TO THANK THE FOLLOWING FOR THEIR CONTRIBUTION TO THE ORIGINAL PUBLICATION.

- Peter Smith - Spencer Holmes Limited
- David Barnard - Consultant
- Sue Freitag - Opus International Consultants Limited
- Andrew Dallas - Allied Concrete Limited
- David Whittaker - Beca
- Malcolm Thomson - Firth Industries Limited
- Derek Chisholm - New Zealand Concrete Society

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TR 10

ISSN: 1171-4204

ISBN: 978-0-908956-33-3

ISBN: 978-0-908956-34-0 (online)

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Specifying Concrete for Performance

1. INTRODUCTION

A concrete industry forum held to identify issues that needed resolving to progress the development of the industry, highlighted a need for performance-based specifications to facilitate the introduction of innovative solutions. Some attendees expressed the view that often the prescriptive approach did not work, and that there was no clarity in what was expected. This confusion led to unacceptable solutions being offered to the client.

Performance specifications can provide clarity on the outcome expected. In response to these and other views, a focus group/working party was established to develop guidelines for the use of performance-based specifications for concrete. The group intended to produce model specifications and guidelines for the use of performance-based specifications for marine concrete and for concrete floors, but the technology involved is complex and still evolving, and consequently such documents could be both unwieldy and quickly outdated. Instead, this document has been prepared to describe the present capabilities and limitations of performance based specification, and to provide relevant references for readers who may wish to adopt a performance-based approach to specification.

There is no compunction on a specifier to use any performance specification published as part of this compendium document. A list of relevant overseas documents is given in the reference section at the back of the publication. Any one of these documents may form the basis of a specification, at the discretion of the specifier. Most of the documents can be downloaded from the CCANZ website.

Recent amendments to *NZS 3109: Concrete Construction (2003 & 2004)*, *NZS 3104: Specification for Concrete Production (2003)* and *NZS 3101 Concrete Structures Standard* have also highlighted the need for this document.

Specifiers need to be aware that any concrete defined with performance criteria other than strength, (or for concrete with strengths in excess of 50 MPa) is considered as 'special concrete' in NZS 3104.

2. WHAT IS A CONCRETE PERFORMANCE SPECIFICATION, AND WHY USE ONE?

The required properties of concrete can be specified in several different forms. A prescriptive specification prescribes the mix design and method of placement and curing. A performance-based specification prescribes the required properties of the concrete but does not say how they are achieved.

It is usual to nominate concrete properties by calling for a nominated slump and specified strength. Specifying slump and strength is the simplest form of performance-based specification, and can be appropriate when strength is required for adequate performance in its own right. However this approach does not always provide a desirable outcome to the client, as strength may not be the most appropriate property to measure or assess 'fitness for purpose'. For example, concrete's chloride resistant properties may be more important than its compressive strength for marine durability, and floor flatness and levelness may be more important than compressive strength for a high rack warehouse. Performance-based specification can also include such properties, and this is seen as its greatest potential.

There are several advantages in using a performance-based specification. Some of these advantages are:

- The client can nominate specific properties of the end product that are important to them (other than strength) and thus ensure a more relevant outcome.

- Specific and project-relevant criteria can be nominated for supply to the project.
- The material supplier with expert knowledge of their product can economise and where appropriate, optimise the design using innovative techniques to meet the desired properties.

3. MEETING CLIENT EXPECTATIONS

To deliver a satisfactory end product to the client, it is important to understand what the client's expectations are. The more common ones for floors are listed below:

- No unforeseen shrinkage or plastic cracking, curling or drummy areas (for whatever reason).
- Reinforcement correctly located within the slab (relates to curling, cracking etc.).
- No dusting.
- No delamination problems.
- No edge fretting of joints, or failure of joint sealants. No excessive shrinkage movement.
- The floor will be flat and level.
- The floor will not be a slipping hazard when wet.
- The floor will be a non-maintenance item for some time (10 years or more) after it is handed over.

For structures in a marine environment, client expectations could be:

- Resistance to chloride attack which could initiate corrosion.
- Resistance to cracking for long term durability.

For civil structures, important serviceability drivers could be influenced by:

- Crack width control.
- Adsorption of moisture.
- Reinforcement placement.



4. POTENTIAL APPLICATIONS OF PERFORMANCE CRITERIA IN PROJECT SPECIFICATIONS

There are several different ways by which a performance specification may be used, namely:

- As a design tool.
- For pre-qualification of a contractor.
- For quality control.

The specifier and/or designer needs to be aware of the differences between each of these approaches and be clear about the use of each of them. The interaction between them should also be considered, as the assessment of the effectiveness of a particular criterion must take into account its effect on the whole design and construction process, not only the initial aspects at which it was primarily aimed.

4.1 AS A DESIGN TOOL

The designer will specify the performance criterion they desire during the design process, to achieve the required service life of the structure.

4.2 FOR PRE-QUALIFICATION

The designer specifies certain requirements that the contractor needs to satisfy before the concrete is accepted for use on the project. These requirements are defined in terms of an acceptance level. The specifier must be aware that the values nominated in this specification need to be carefully selected as small changes in definition can have an enormous effect on the desired outcome. Tender documents need to recognise the time needed to carry out the appropriate tests and allow for it in the tender period.

4.3 FOR QUALITY CONTROL

The specifier nominates the tests to be adopted for the project together with the acceptance criteria and the level of testing expected for the project. As concrete is an inherently variable product, it is very important that the criteria nominated are set and assessed on a statistical basis that balances the client's risk of accepting defective concrete, against the supplier's risk of having compliant concrete rejected.

5. DEVELOPING A PROJECT SPECIFIC PERFORMANCE SPECIFICATION

In many instances, it may be desirable to develop a performance specification which is project-specific. For example, consider a client who wants a high quality industrial floor slab suitable for high rack storage systems, and who also wants to avoid a strength-based specification as this is no guarantee of fitness for purpose. In this instance, floor flatness and abrasion resistance could be nominated, based upon values derived from an existing structure that is deemed to be suitable.

6. GUIDELINES ON MATERIAL PROPERTIES FOR CONCRETE PERFORMANCE

Concrete needs to be designed for the specific end use if a performance based specification is to be used for a particular contract or project. The mix design considerations will need to address the performance objectives for the end use. It may be necessary to make compromises to take into account potentially opposing performance objectives. For example, increasing strength through the use of higher cement content may have the potentially undesirable effect of increasing shrinkage.

Understanding what can, and cannot be achieved from a concrete, is extremely important when consideration is being given to using a particular performance requirement for a concrete mix. This section describes in outline, what can be expected from concretes specified for a particular performance criteria other than strength. The overall objective is to produce a concrete of adequate performance using local materials where possible. The important performance factors to be considered are:

- Strength and related characteristics,
- Placing and finishing characteristics,
- Shrinkage, and
- Durability, against:
 - Environment
 - Abrasion
 - Chemicals

6.1 COMPRESSIVE AND FLEXURAL STRENGTH

The standard method of specifying concrete for most structural applications is by specified compressive strength. This is not necessarily the most appropriate property to be specified. For example, the important strength parameter for trafficked ground-supported slabs is flexural tensile strength.

Flexural tensile testing of concrete is not common and fixed relationships, based on empirical data, are used to calculate flexural tensile strength (refer to Table 9.1 of *Concrete industrial ground floors - a guide to their design and construction UK Concrete Society TR 34 3rd edition*).

Any factor that increases compressive strength will increase flexural tensile strength in accordance with Table 9. Flexural tensile strength can also be further influenced by aggregate type, and changes would require test data to establish the flexural tensile strength of a proposed concrete mix.

Also refer to NZS 3101, 3104, 3109 and 3112 for guidance on strength related issues, and TR 34 for specific design of concrete pavements.

6.2 SPECIFYING FOR FLATNESS



In New Zealand we have two standards that specify concrete tolerances. The first, NZS 3109, provides floor tolerances to ensure that structural behaviour is not impaired. It does not specify tolerances for the serviceability or usefulness of a concrete floor. *NZS 3114: Specification for concrete surface finishes* specifies flatness tolerances in more detail but does not recognise the stringent flatness requirements for forklift movements in warehouses with narrow aisles and high stacker trucks (MHE's). The measurement of such floors using the current NZS 3114 - 3 m straightedge methodology is impractical for large areas and does not predict the roughness of a particular section of floor which requires measurement of frequency of irregularities.

Improved methods for specifying/measuring floor surface irregularity are used overseas, namely in the USA and in UK and Europe. The UK method is outlined in the UK Concrete Society TR 34 Section 4 which covers free movement areas and defined movement areas. Surface irregularity needs to be limited in two ways, by flatness to eliminate possible forklift bumpiness and stability, and by levelness to allow functioning of MHE's in the building as a whole. Flatness relates to variations over short distances whereas levelness relates to longer distances.

The method in TR 34 is the preferred method to be adopted for a future NZS 3114 amendment.

6.3 SHRINKAGE

Several generic types of shrinkage are of concern. They are:

- Drying shrinkage.
- Early thermal contraction.
- Cracking.
- Plastic shrinkage.

6.3.1 DRYING SHRINKAGE

All concrete shrinks as the unbound water in the concrete evaporates to the atmosphere, though the shrinkage mechanism is not fully understood. The key to minimising the drying shrinkage of concrete is to keep the water content as low as possible.

When specifying low shrinkage concrete:

- Do not specify a higher strength than necessary.
- Specify the largest appropriate aggregate volume for the mix. Large sized coarse aggregate can assist in this.
- Do not specify a high minimum cement content.
- Avoid pump mixes.
- Keep slump under 100 mm commensurate with the placing technique.
- Consider using water-reducing (superplasticising) admixtures.
- Consider using shrinkage-reducing admixtures (SRA's).

The Australian drying shrinkage test has become the default drying shrinkage test for use in New Zealand. The main ready-mix companies will have historical shrinkage test data on their main mixes.

NZS 3101 does not have any in depth coverage on concrete shrinkage. However the New Zealand Transport Agency, NZTA has an amendment to section 4 of the bridge manual on estimating creep and shrinkage which is downloadable from the NZTA website.

Refer to NZS 3112 Part 3; AS 1012 Part 13: Methods of Testing Concrete: Determination of the Drying Shrinkage of Concrete for Samples Prepared in the Field or in the Laboratory; and Properties of New Zealand Concrete Aggregates TR 11.



6.3.2 EARLY THERMAL CONTRACTION

It would appear that a common cause of cracking in ground floor slabs is early thermal contraction caused by lowering ambient temperatures during the first few days of the slabs life. Early thermal contraction is not well understood, both by designers and constructors. This is in part due to a lack of guidelines on how to identify when there is a risk of restrained thermal contraction cracking. A further in depth study is required, however in the interim it is suggested that precautions to prevent early thermal contraction cracking are taken if the slab is restrained, and the ambient temperature is likely to drop more than 13 °C over the 24 hours following finishing the slab. Insulating a slab surface with polystyrene or sand on polythene is an effective way of limiting concrete temperature fluctuations.

Christchurch has the highest incidence of thermal cracking as being further south it has the greatest drop in overnight temperature.

Refer to Project Slab: Comparison of Industrial Concrete Floor Slabs in the Auckland and Christchurch Markets.

6.3.3 CRAZING

Crazing is the result of differential shrinkage of the surface zone of a concrete slab relative to the bulk, and is a common feature of power-finished floors. The topic is discussed in more detail in Section 5.6 of TR 34. Experience suggests that despite its appearance, crazing generally has no effect on the performance of a floor surface.

6.3.4 PLASTIC SHRINKAGE

The main cause of plastic shrinkage is rapid drying of the exposed concrete surface. The drying rate is dependent on the wind speed, the air temperature, the relative humidity and the concrete temperature. If the rate of evaporation from the surface exceeds the rate at which bleed water rises to the surface, net shrinkage will occur (with the possibility of subsequent cracking). This is a phenomenon commonly associated with floor slabs and large mass raft foundations.

Modern cements bleed less than older cements because they are ground more finely and contain fine supplementary cementitious materials, and consequently plastic shrinkage cracking has become more prevalent in recent years.

Refer to TR 34 and CCANZ Guide to Concrete Construction TM 35, Chapter 12, for more details.

6.3.5 DELAMINATION

Delamination occurs under similar environmental conditions and mix characteristics to plastic shrinkage. It is caused by finishing with power trowelling too early whilst bleed water is still rising towards the surface. The bleed water is trapped under the hard surface and eventually causes the surface to blister.

Delamination has been prevalent in recent times, particularly in Christchurch. This may be because natural aggregates are prevalent in Christchurch, consequently the mix water is low resulting in concrete with a low bleed. Air entrained mixes in particular appear to result in delamination, overseas specifications recommend that power trowelled floors should not use air entrained mixes.

Refer to TR 34 and TR 09 Surface Delamination in Slab on Ground Construction: A Report Based Upon Site Experience and Observation in the Auckland Region.

6.4 ALKALI-AGGREGATE REACTION

In common with many overseas countries New Zealand does have some rock types that contain reactive acidic components that in the long term can react with the alkaline components in the rest of the concrete. The resultant reactions cause expansion and possible cracking. This phenomenon has been well researched over the years in New Zealand leading to the publishing of a set of specified guidelines to control the risk of damage from this reaction. The CCANZ publication *TR 3 - Alkali Aggregate Reaction: Minimising the Risk of Damage to Concrete*, provides guidance notes and model specification clauses. One key factor in controlling the problem has been to restrict the alkali level of concrete to 2.5 kg/m³. This restriction only applies when reactive materials are present in the aggregate. However levels of alkali above 2.5 kg/m³ are permissible by using SCM's (e.g. flyash and slag) which suppress the ASR reaction.

A recent amendment has included evaluating recycled aggregates for contribution to ASR, and a case history of ASR in precast concrete piles with concrete containing South Island quartz aggregate.

Changes to the methods of specifying concrete in NZS 3109/3104 have not changed this limiting factor but automatically give answers that the 2.5 kg/m³ limit will be observed in all normal concretes using potentially reactive materials.

Where the specifier is considering special concretes for a project, reference to TR 3 is recommended in conjunction with the other factors that may be under consideration e.g. high strength concrete, long term durability etc.

Refer to TR 3 for more detail.

6.5 ABRASION RESISTANCE

Achieving appropriate abrasion resistance and other surface characteristics requires careful control of the placing and power finishing and curing operations. Although compressive strength is also a criteria, the densification of the top 5 mm by power trowelling and subsequent curing to optimise the cement hydration is critical. Fine aggregate which will make up the fine mortar fraction must not include any soft friable materials.

Table 3.8 from NZS 3101 gives requirements for finishing process, curing and compressive strength for four abrasion classes from light industrial to very heavy duty engineering workshops.

6.6 CHEMICAL RESISTANCE

The ability of a floor to resist chemical attack depends on the quality of the surface zone, which is about 2 mm thick. Durability is enhanced by the process of densification of the surface through repeated power trowelling, thereby reducing the permeability (and abrasion resistance) of the surface.

Cement replacements, such as fly-ash, slag or micro-silica potentially reduce the calcium hydroxide content of mature concrete, are thus are less susceptible to acid attack.

In specialist flooring applications where aggressive chemical attack is likely, consideration should be given to protecting the floor with a chemically resistant sheet material or liquid applied system which protects the floor from the action of the particular aggressive agent.

According to NZS 3101, concrete is subject to attack by low pH groundwater and sulphate soils. Chapter 3 gives guidance for concrete subjected to natural aggressive soil and groundwater attack. Minimum binder contents and maximum w/c ratios are given.

For information on aggressive agents see Section 5.3 of TR 34 and Section 3.4.3 and 3.5 of NZS 3101 for more detail.

6.7 CONCRETE FOR MARINE APPLICATIONS



6.7.1 ALLOWABLE CHLORIDES

NZS 3101 Table 3.11 places limits on the amount of chloride which is acceptable in concrete. Chloride sources include sand and aggregates and admixtures. The concrete producer should be able to provide these figures.

6.7.2 CONCRETE COVER FOR DURABILITY

Much of New Zealand's infrastructure is located near the coastline and for exposed reinforced concrete structures, durability design in Chapter 4 of NZS 3101 is based on limiting the ingress of marine chlorides, and consequential corrosion of the reinforcement during the design life of the structure. Tables 3.6 and 3.7 give minimum cover requirements for design lives of 50 and 100 years respectively for five exposure classifications. The most aggressive exposure classifications C, B2, are based on chloride ingress causing corrosion of the reinforcement and the most mild exposure, A1, A2 indoors are based on carbonation.

Concretes made with blended cements (slag, flyash or silica fume) have significant potential to reduce the chloride ingress. It is recommended that such concretes be used for all new structures in the tidal and splash 'C' zone, and there is also potential for their use in the 'B2' zone. Some blended cements are more susceptible to poor curing than GP cement concretes, thus they need the requisite quality control on-site.

The NZS 3101 Durability Commentary (C3) gives details on the use of chloride based life prediction models and durability enhancement methods. Users of the models need to be aware of the assumptions which are made in each model and the sensitivity of the life prediction on those assumptions.

Durability enhancing measures covered include:

- (a) Integral Waterproofers
- (b) Corrosion Inhibitors
- (c) Corrosion Resistant Reinforcement
- (d) Controlled Permeability Formwork
- (e) GRC Permanent Formwork
- (f) Concrete Coatings and Surface Treatments

Care needs to be taken when using these durability enhancement measures. It is recommended that they be used to increase life, rather than being a trade-off for cover. The significance of a 10 mm reduction in cover as a result of workmanship error increases as the cover is reduced.

6.8 MATURITY OF CONCRETE IN COLD STORE FLOORS

Concrete floors are used in stores with temperatures as low as -40°C. It is essential that cold store slabs are allowed to mature for at least 28 days, or that other steps are taken to ensure adequate in-situ strength before the temperature is drawn down.

Concrete not subject to wetting will resist both continued exposure to temperatures below freezing and freeze-thaw cycles. However, if a floor is to be exposed to regular freeze-thaw cycles when it is wet, some enhancement of freeze-thaw resistance should be considered.

Guidance on suitable concretes for cold stores can be found in BS EN 206: 2000. Concrete. Specification, performance, production and conformity; and BS 8500: 2002. Concrete. Complementary British Standard to BS EN 206-1.

7. DEALING WITH NON-COMPLIANT WORK

The consequences of non-compliance need to be thought through and documented by the specifier. If clearly defined processes (such as remedial in Bamforth, P., et al.) are not in place there will be considerable debate as to the actual consequences of non-compliance.

At present, compressive strength may be the only performance property with testing methods and acceptance protocols sufficiently well developed for quality control. Acceptance criteria for other properties can be developed for specific projects, and compressive strength can be calibrated against other relevant properties.

8. SPECIFYING CONCRETE USING NZS 3109 AND NZS 3104

8.1 TYPES OF CONCRETE SPECIFICATION

The new standards documents nominate three types of specification methods for concrete mixes:

- Prescribed Concrete
- Normal Concrete
- Special Concrete

The choice of concrete specification is the prerogative of the design consultant. The detailed production requirements of the three concretes are contained in NZS 3104.

The terms used previously like ordinary, high and special grades have all been dispensed with. These terms broadly related to the accuracy to which concrete could be produced.

The term 'grade' has been reused to mean strength of the material in the same way that the term was used for reinforcing steel e.g. Grade 300.

8.1.1 PRESCRIBED CONCRETE

The prescribed concrete permitted by NZS 3109/3104 ranges from 17.5 MPa to 25 MPa. As such, the concrete application fits with concrete used in NZS 3604 and NZS 4229. The mix quantities are fully listed in Part 3 of NZS 3104 and this part sets out the production requirements for the concrete. This concrete is not tested for strength but by checking that the materials used are batched correctly.

Because of the limited checking requirements, the cement contents of the mixes are significantly higher than those where testing for strength is a routine requirement e.g. normal concrete. The specifier's control over these mixes is by way of checking cement content of the hardened concrete by chemical analysis, however, the accuracy of the test is low with an accuracy of $\pm 15\%$.

Typical use of prescribed concrete would be on small remote projects outside the operating areas for ready mixed concrete plants, and where concrete strength is not required over 25 MPa.

8.1.2 NORMAL CONCRETE

Specifications calling for the use of normal concrete 17.5 to 50 MPa in accordance with NZS3109/3104 should be used where the structural designer's primary concern is the compressive strength of the concrete. This is the predominant range of strengths used for most structural projects, and as such it probably represents 80% of all production.

The structural designer has the following to specify:

- (a) Concrete strength at 28 days
- (b) Maximum nominal aggregate size. The detailing of reinforcement may lead to close spacing of steel which may require a maximum aggregate size of other than 19 mm to be specified
- (c) Workability
- (d) Method of Placement
- (e) Additional requirements for Special Concrete

Based on this information the concrete producer will design, produce and take responsibility for the concrete. The quality assurance that concrete will be produced in accordance with NZS 3104 lies in requirements in NZS 3104 that obliges the concrete producer to have an independent audit of the plant's production capability and viability of production on a statistical basis.

There is also a requirement that each ready mixed concrete plant must have an assigned plant engineer who is either a chartered engineer (CP Eng) or registered engineering associate. This technical person is not necessarily based at the plant but must visit and be in regular communication with the plant manager.

The NZRMCA has set up a Plant Auditing Committee of six engineering assessors. While two assessors are from within the industry, the remaining four assessors are independent with one being the nominee of IPENZ and one being the nominee of the New Zealand Concrete Society. This group reviews various activities of the individual plants on a quarterly and annual basis. Each plant is given a full audit site inspection every two years for compliance with NZS 3104. An audit certificate is only issued for a 12 month period. The status of any plant can be checked by visiting www.rmcpplantaudit.org.nz. The operation of the Plant Audit Scheme itself is audited annually by BVQI.



8.1.3 SPECIAL CONCRETE

As the name implies this concrete will have performance requirements that may be outside the strength range 17.5 to 50 MPa or have special features not necessarily measured by compressive strength such as shrinkage, tensile strength, chloride durability etc.

Clearly a special concrete is still most likely to be a designed concrete requiring specialist skills of the concrete producer. The plant must have a current audit certificate for Normal concrete. The structural designer must now specify the special features required, together with a test method or other means that the concrete supplier can demonstrate specification compliance. The specifier also needs to get some prior assurance that these special mixes will perform at the time of the project. NZS 3109 requires the specifier to enter into dialogue with the concrete producer. Clearly if the concrete producer is able to produce records from a different project that may satisfy the specifier, then assurance may be satisfied. Dialogue between the specifier and concrete producer should involve the following:

- Producers records in producing similar compliant concrete.
- Need for test trials prior to production. Ample time must be available for these test trials prior to the commencement of production.
- Acceptable production variation in special parameter.
- Required test frequency for compression and for the special parameter initially for production and reduction in testing rate once compliance is established.

8.2 RECYCLED AGGREGATE

CCANZ have produced a Best Practice Guide on the use of recycled aggregates in new concrete. This defines three types of recycled aggregate:

- Recycled Concrete Aggregate (RCA) crushed from demolition concrete.
- Leftover Concrete Aggregate (LCA) crushed from returned concrete which is left to harden.
- Recovered concrete aggregate, aggregate from returned concrete where the fines fraction washed out through a re-claimer.

Green Star New Zealand awards points for the use of all three recycled concrete aggregates in this way, which contribute to the Green Star rating for the building as a whole.

The use of recycled aggregate in concrete can affect the concrete strength depending on the Specified Strength of the new concrete and the substitution rate of recycled aggregate. Leftover concrete provides a better performance than RCA from demolition concrete.

Refer to Best Practice Guide for the use of Recycled Aggregates in New Concrete TR 14.



REFERENCE LIST

Alkali aggregate reaction: Minimising the risk of damage to concrete: Guidance notes and model specification clauses. (Technical Report 3). (Second Edition 2012). Wellington: Cement & Concrete Association of New Zealand.

Bamforth, P., et al. (2002). Concrete durability by design: Limitations of the current prescriptive approach and alternative methods. In *New Zealand Concrete Society conference and AGM [on] enduring concrete [2002 :Wairaki] technical papers*. Auckland: New Zealand Concrete Society.

Best Practice Guide for the use of Recycled Aggregates in New Concrete. (Technical Report 14). (2013). Wellington: Cement & Concrete Association of New Zealand.

British Standards Institution. (2002). *BS 8500:2002. Concrete. Complementary British Standard to BS EN 206-1*. Berkshire: British Standards Institution.

British Standards Institution. (2000). *BS EN 206:2000. Concrete. Specification, performance, production and conformity*. Berkshire: British Standards Institution.

Concrete industrial ground floors – A guide to their design and construction. (Technical Report 34). (2003). London: Concrete Society.

Guide to Concrete Construction. (Technical Manual 35). (2010). Wellington: Cement & Concrete Association of New Zealand.

Project slab: Comparison of industrial concrete floor slabs in the Auckland and Christchurch markets. (2001). Wellington: Cement & Concrete Association of New Zealand.

Properties of New Zealand Concrete Aggregates. (Technical Report 11). (2003). Wellington: Cement & Concrete Association of New Zealand.

Standards Australia. (1992). *AS 1012.13:1992. Methods of Testing Concrete: Determination of the drying shrinkage of concrete for samples prepared in the field or in the laboratory*. Sydney, N.S.W.: Standards Australia.

Standards New Zealand. (2006). *NZS 3101:2006. Concrete structures standard*. Wellington: Standards New Zealand.

Standards New Zealand. (2003). *NZS 3104:2003. Specification for concrete production: High grade and special grade*. Wellington: Standards New Zealand.

Standards New Zealand. (1997). *NZS 3109:1997. Concrete construction*. Wellington: Standards New Zealand.

Standards New Zealand. (1986). *NZS 3112:1986. Methods of test for concrete*. Wellington: Standards New Zealand.

Standards New Zealand. (1987). *NZS 3114:1987. Specification for concrete finishes*. Wellington: Standards New Zealand.

Surface Delamination in slab on ground construction: A report based upon site experience and observation in the Auckland region. (Technical Report 09). (2002). Wellington: Cement & Concrete Association of New Zealand.

