



HARDENED CONCRETE PERFORMANCE GUIDELINES FOR CONSTRUCTION PROJECTS IN NEW ZEALAND

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Hardened concrete properties are important for ensuring structural performance and durability of infrastructure and buildings.

Designers require a range of hardened properties are achieved during construction including strength, dimensional stability and durability. This article considers the following issues that affect hardened properties of concrete:

- Measuring the strength development of concrete in the structure at early ages.
- Reliably estimating the in-situ strength of concrete from core testing.
- Controlling dimensional stability of concrete and when should drying shrinkage of concrete be specified.
- Can tensile strength be simply inferred from compressive strength and when should tensile testing be specified.

COMPRESSIVE STRENGTH DEVELOPMENT

Strength of concrete increases with curing time and this is quantified by the maturity index being the product of temperature and time. This maturity approach is used in ASTM C1074 to predict in-situ strength of concrete and has several advantages over empirical estimates and non-destructive testing such as Schmidt hammer. Figure 1 show the typical relationship between maturity index and strength.

This maturity approach has several advantages over traditional methods such as casting cylinders on site:

- Thermocouples can be cast into the concrete core that is less affected by external temperature fluctuations.
- Sensors near the surface allow wireless extraction of information to be downloaded including temperature, maturity and predicted strength.
- Correlations between maturity index and strength can

be undertaken during the pour to allow for material and mix design variations.

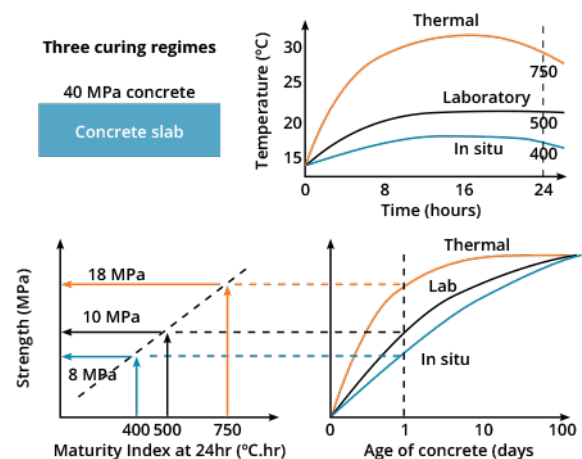


Figure 1: Maturity index approach for predicting strength of concrete

Post-tensioned industrial slabs still use traditional methods of monitoring in-situ strength (field cylinders cured next to the slab in accordance with NZS 3109). Internationally strength assessment in the field has moved to the maturity approach as per ASTM C1074, which is more efficient and reliable.

The reliability of core strength testing of concrete is often

CORE STRENGTH MEASUREMENT

compromised by the following issues:

- Sampling done widely across the structure such that each core is a snatch sample.
- Core diameters chosen of less than 100 mm due to thin slabs or limited clearances.
- Core testing done without hard plaster caps or grinding of the ends (rubber capping).

- Incorrect analysis and interpretation of core strengths of concrete.

The most significant issue is the way laboratory testing of concrete cores is being carried out in New Zealand. Rubber capping of the core ends is not in accordance with the standard and in some cases no capping of any type is used on sawn ends of cores. Cores diameters are invariably less than 100 mm diameter and this means the restrained rubber capping rig does not work as intended. Recommendations to be included in an updated version of CCANZ IB74 include the following:

- Core ends must be either ground or hard plastered to NZS 3112 tolerances.
- Restrained rubber capping system should not be used for core testing.
- Cores should be tested in the as received moisture condition.
- Mode of failure must be reported to identify unusual modes of failure.
- Any obvious voidage or lack of homogeneity must be reported.

Cores cannot be tested as if they are test cylinders since there are several key differences including diameter

not been exactly 100 mm, test samples are generally extracted from the structure at a moisture state well below saturated and compaction may be variable. Lower strength ranges are particularly vulnerable to poor end preparation and splitting induced by the neoprene capping dilating under load.

TENSILE STRENGTH

Tensile strength is sometimes specified when performance cannot be simply inferred from compressive strength due to the importance of this property in situations such as when designing unreinforced airport hard-standings. When specifying for tensile strength of concrete, the following should be considered:

- Whether tensile splitting or flexural tensile strength testing is appropriate (tests produce significantly different strengths – see Figure 2).
- What size test specimen should be used for testing (larger dimension generally give low strength and large beams are more vulnerable to handling damage).
- What level of tensile strength is required and at what age should this be achieved (tensile strength develops faster than compressive strength).

Structural specifications concerning tensile strength will often have supplementary requirements such using

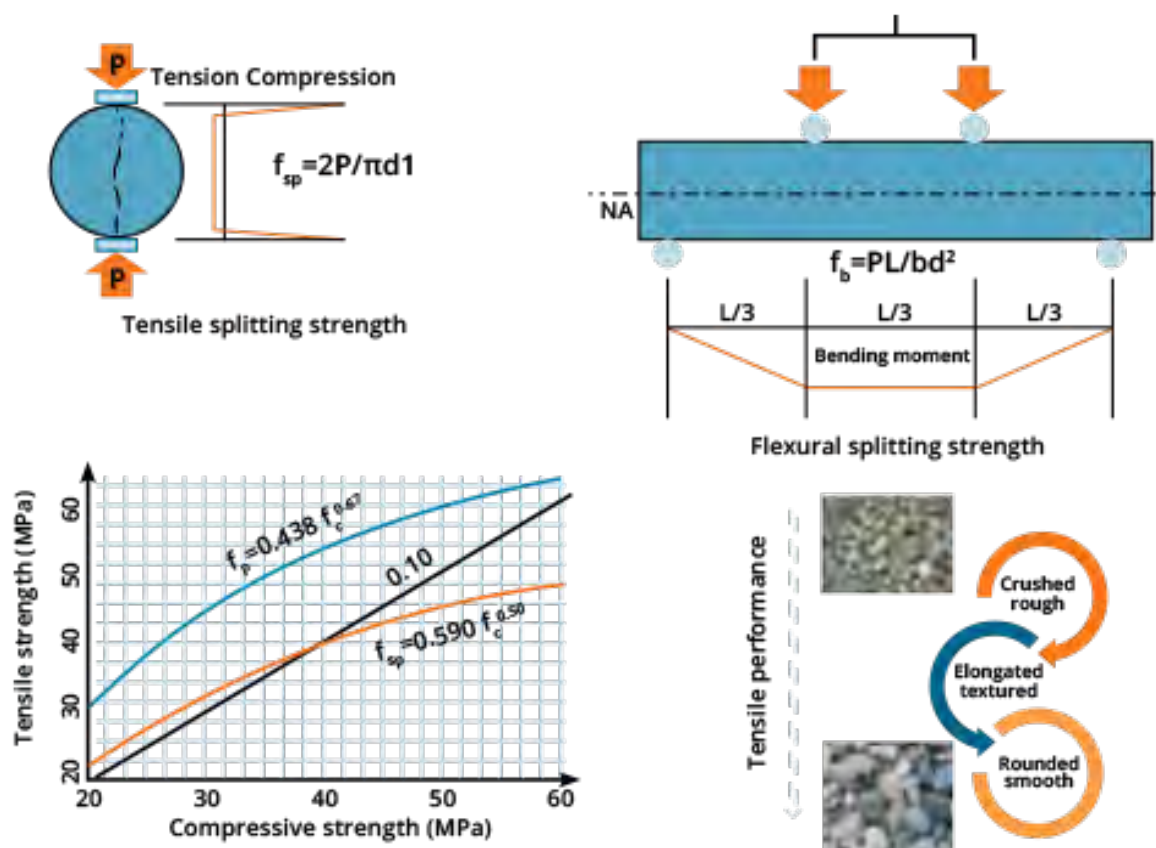


Figure 2: Tensile strength types and material influences

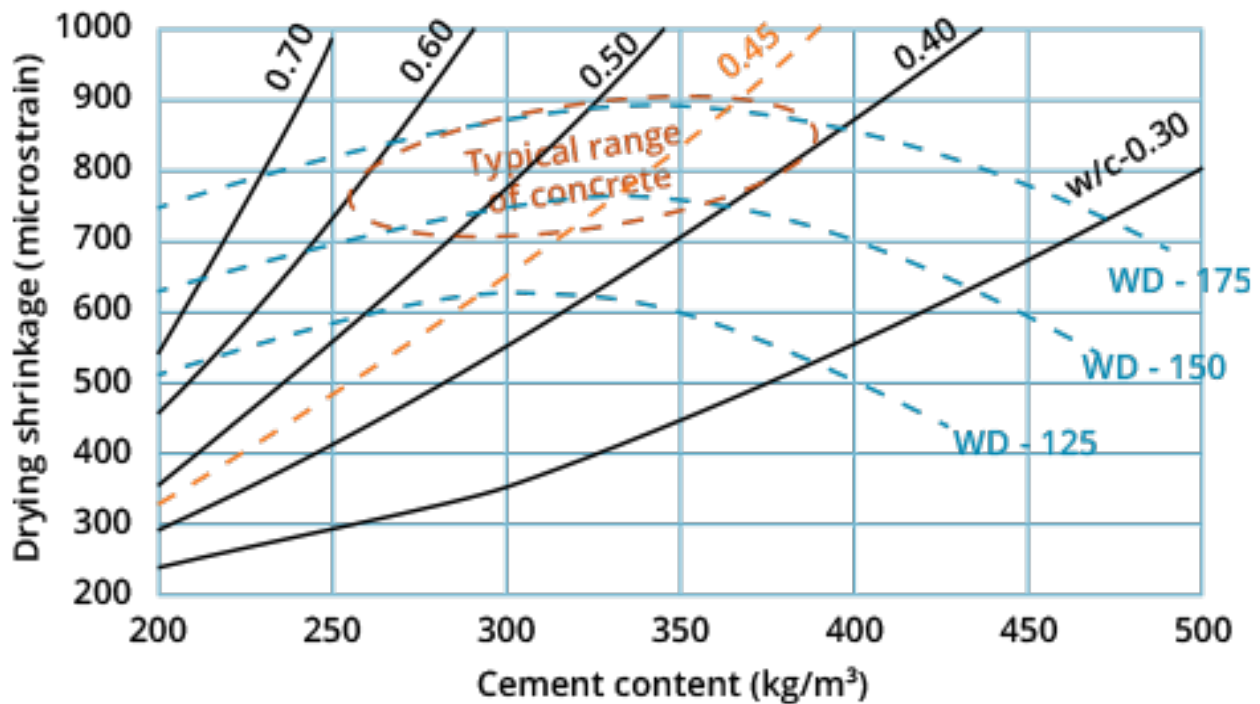


Figure 3: Typical range of drying shrinkage for laboratory testing (AS 1012.13)

crushed aggregates or limiting slump. These prescriptive requirements are generally unnecessary if the tensile strength has been explicitly specified and in some cases may adversely affect performance.

DRYING SHRINKAGE

Drying shrinkage of concrete involves numerous material, environmental and structural factors, which results in widely variable in-situ strains in concrete. Even laboratory testing of the free shrinkage of standard prisms is subject to several material factors. The main material factors affecting drying shrinkage are shown in Figure 3. Shrinkage reduces at higher water/cement ratios due to lower paste contents while very low w/c ratios appear to reduce drying shrinkage since a significant amount of autogenous shrinkage occurs before measurements start at 7 days.

The above shrinkage strains are based on an accelerated drying regime (AS 1012.13) and values need to be modified for restraint, size and environmental conditions. Shrinkage strains in concrete structures are therefore lower than laboratory shrinkage strains. Large raft

slabs are typically 1-2 m thick and only limited drying is possible from the top surface. As such typical drying shrinkage estimated for these structures may be as little as 30 percent of the laboratory shrinkage. Guidance on drying shrinkage is now given in NZS 3101 based on data from CCANZ TR11 and using AS 3600/NZ Bridge Manual provisions. This allows adjustment for local materials and structural geometry and restraint. The structural performance of concrete depends on good design being

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converted into appropriate construction on site. To achieve this goal designers must ensure that material properties are achieved in practice and this can only be done when structural specifications are practical, relevant and measurable.

This article is based on the paper "Hardened Concrete Performance Guidelines for Construction Projects in New Zealand" by Dr James Mackechnie, presented at the 2017 New Zealand Concrete Conference in Wellington.

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