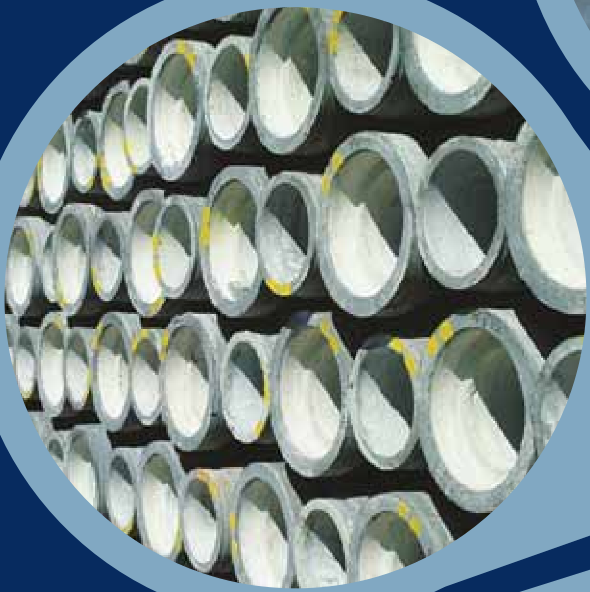
TECHNICAL BRIEF

Water Absorption in Concrete Pipes



Concrete Pipe Association of Australasia

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1 Introduction

The general quality and strength of concrete, as well as its ability to resist chemical attack, is determined to a large extent by the distribution of small and large pores in the concrete. Durability in particular depends on the resistance which this structure presents to penetration and permeation by fluids.

The permeability of high quality, dense concrete is so low (typically 10^{-13} to 10^{-14} m/sec) that it is extremely difficult to measure unless the tests are carried out at unnaturally high water pressures. As an alternative, water absorption tests are often used to provide a measure of the concrete durability.

Measurement of the water absorption value of concrete is the commonly accepted method of assessing the quality and durability of concrete pipe. A low absorption value is an indication of low permeability. In general terms low permeability concrete will be more durable.

The Australian and New Zealand Standard AS/NZA 4058 Precast Concrete Pipes (Pressure and Non-Pressure) specifies a test method for measuring water absorption and sets an upper limit of 6% for all concrete pipe.

2 Description of Absorption Test Method in AS/NZS 4058

The test piece is a core cut from the pipe, having the full thickness of the pipe wall. Shape and size are not specified exactly but the end faces (corresponding to the internal and external surfaces of the pipe) must have area between 1.0 x 10^4 mm^2 and 1.5 x 10^4 mm^2. A core 125 mm in diameter could be regarded as typical.

The test piece is dried to constant mass at 105°C (nominal). It is then immersed in water; boiled for 5 hours, cooled in water over a 2-hour period, surface dried and re-weighed.

The absorption value is the increase in mass from the initial dry condition to the final condition (surface dry after boiling and cooling), expressed as a percentage of the dry mass of concrete.

3 Factors affecting the absorption value

The principal factors which influence the result of an absorption test can be grouped under three headings:

- Material parameters
- Manufacturing process and subsequent treatment of the pipe
- Testing parameters.

3.1 Material Parameters

3.1.1 Water Content of the Mix

The quantity of mixing water directly influences the ease of compaction of the concrete and in addition has the greatest influence on the volume of pores formed in the concrete. Usually, the quantity of water added is significantly greater than that actually required to hydrate the cement.

For example, if a mix requires 20 litres of water to provide full hydration, and 30 litres of water are used to make the mix workable enough to compact, then the excess water will create 10 litres of voids in the concrete, even after the cement is fully hydrated.

3.1.2 Aggregate Characteristics

Aggregates have their own inherent water absorption (AS 2758.1 and NZS 3121) and therefore have a direct influence on the absorption of the concrete. While particularly high water absorption values for aggregates indicate poor quality, once the percentage of water absorption is below a certain level (eg 2.5% for coarse aggregate), the value ceases to be an indicator of aggregate quality, but nevertheless may have an influence on the absorption of concrete made with it.

In addition, aggregates can have an indirect effect on concrete because the shape and surface texture of aggregate influences the water demand to achieve a particular degree of workability.

3.1.3 Mix Proportions

Mixes with relatively high cement contents are workable with low water/cement ratios, which have the effect of lowering the absorption value.

Provided the concrete is close to full compaction, mix proportions together with the particle densities of the component materials determine the final density (mass per unit volume). If the concrete has a high density, a lower absorption figure will be recorded for the same volume ratio of water absorbed to size of test specimen. Thus high concrete density from any cause (including good compaction and low water/cement ratio) will tend to give a favourable water absorption value.

3.2 Process and Treatment

The absorption test is carried out on concrete taken from the product and therefore measures a property of concrete in the actual product. This is in contrast to compression strength tests, in which the test specimens are given special treatment. If the concrete is poorly compacted or cured, the absorption test will reflect the inadequate treatment given.

Specimens for water absorption tests can be taken from pipes after load testing or hydrostatic testing. However; microcracking in concrete is initiated at stress levels of approximately

30% of the ultimate strength. The absorption value of a test piece will be influenced if previous testing has caused microcracking in the area from which the specimen is taken.

3.3 Testing Parameters

3.3.1 Size and Shape of Test Specimens

The test method limits the range of dimensions for the surfaces of the test piece which were previously surfaces of the pipe wall. However, the specimen thickness is the same as the pipe wall thickness and this varies widely depending on the size of pipe.

Specimen thickness affects the absorption result in two ways:

- Increasing thickness reduces the rate of drying, and with a thick test piece the drying may be incomplete even if the piece has apparently dried to constant mass.
- During the boiling and soaking phases, water is absorbed from the surface. Water penetrates only slowly into dense concrete and, except for very thin sections, would never fully penetrate the pipe specimen during the test. Thus the absorption test for two samples equal in all respects other than thickness, for a given penetration depth, will indicate an apparently lower value of water absorption for the thicker sample.

Both these mechanisms tend to increase the absorption values obtained for thin-walled pipes and correspondingly to reduce the values for thick-walled pipes. Comparative trials have indicated an effect of 0.5% to 0.8% in the absorption value, across the range of wall thicknesses up to 150 mm.

3.3.2 Steel Reinforcement

The test measures the mass of water absorbed compared with the mass of concrete, not the mass of concrete plus steel.

At the end of the test, the specimen is broken up. Reinforcing steel is taken out and weighed. This weight is subtracted from the initial dry sample mass.

3.3.3 Soaking Time

After boiling, the specimen remains in water and absorbs water as it cools. The process is both time and temperature dependent and, even though the specimen has been boiled for 5 hours, water will continue to be absorbed at an appreciable though diminishing rate as it cools. The test specifies a two-hour cool-down period. This has brought under control a significant variable, which was not specified in the Standards which preceded AS/NZS 4058.

4 Other Related Absorption tests

4.1 Other Water Absorption Tests

Other concrete pipe Standards (BS, ASTM) specify absorption tests and corresponding acceptance limits. Results depend on details of the methods and so caution is required in comparing specified absorption limits. In particular, the British Standard method requires the test piece to be cooled in air after drying and then immersed in cool (20°C) water. There is no boiling in water and subsequent cooling while the sample remains immersed, as in the methods employed in AS/NZS 4058.

A comparison of the British and Australasian method involving two pipe sizes with tests carried out in three separate laboratories gave an average absorption 2.4% higher using the AS/NZS method, and also lower coefficients of variation.

Thus specification limits and any interpretation of absorption values must take account of the method used for the absorption test.

4.2 Related Tests

4.2.1 Sorptivity

As discussed the degradation of concrete is usually initiated by ingress of certain agents into the concrete, concrete with a low porosity is generally considered to exhibit sound durability. An accepted method of testing different to water absorption, is sorptivity measurement. This type of test is a useful measure of the durability of concrete and typical values of sorptivity are 0.09 $mm/min^{0.5}$ for concrete with water/cement ratio of 0.4, and 0.17 $mm/min^{0.5}$ at a water/cement ratio of 0.6 (Neville,1996).

Whilst most concrete technologists are familiar with the uniaxial water absorption (sorptivity) test, there is no approved method outlined in an Australian Standard or as an Australian Standard Test Method despite there being a number of versions of this test available.

In general the test requires the exposure of the circular face of a core sample or cylinder to water at ambient temperature and measuring the uptake in terms of weight and height over time. The test is generally designed for samples that have a flat surface at the face.

Cores taken from pipes generally have a curved face. This means any sorptivity test with a concrete pipe sample needs to be "adjusted" to suit. For example, samples may need to be placed in water to a depth allowing the entire curved circular face to be exposed, and absorption through the sides eliminated by applying of a water resistant coating to the exposed core sides. The water absorption test outlined in AS/NZS 4058 was devised to ensure that testing involved the full core sample to provide confidence in the impermeable matrix of the pipe concrete.