Concrete Pipe Association of Australasia Technical Paper

Setting the standard for concrete pipe

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INTRODUCTION

Australian Standards set out to define conditions in which concrete structures will provide the service life which is required of them, without undue maintenance. The Standard for concrete pipe, AS 4058 Precast concrete pipe - pressure and non-pressure, is no exception, identifying potentially harmful situations and providing limits for concentrations of aggressive agents, along with specifications for cover, to give the typical required service life of 100 years minimum. More general concrete structures codes AS 3600 and AS 5100.5 also include durability specifications and so the question must arise as to whether these are relevant to concrete pipe.

DURABILITY SPECIFICATIONS IN AS 4058

Environments seen as having the potential for reducing the service life of concrete pipe fall into two categories – those which pose a threat to the concrete, and those for which the concern is mainly the effect on the steel reinforcement. The former are identified as sulphate, acid and carbon dioxide dissolved in water. Severity of the condition depends on the mobility of water in contact with the concrete surface and the concentrations of aggressive contaminants in the water. For sulphate there is a further influence of the type of cement. Guidelines are provided for concentration limits of the aggressive agents, where covers specified elsewhere in the Standard have been adopted.

The most common marine exposure of concrete pipe occurs in underground drainage lines subject to tidal flow. Covers are specified for this environment, and also for the more severe conditions of exposure to salt spray, or prolonged wetting and drying by sea water.

An absorption limit of 6.5% applies for all situations where there is a recognised aggressive agent in the environment and the guidelines for durability are to be adopted, setting a minimum standard for the quality of the concrete. Manufacturing processes used in Australia for concrete pipe in fact produce concrete having absorption less than 6.0%, and characteristic strength well above 50MPa.

Because of the similar conditions of service, the format of durability provisions in AS 4058 has been adopted (though with some differences of detail) in AS 4139 *Fibre-reinforced concrete pipes and fittings* and AS 4198 *Precast concrete access chambers for sewerage applications*

AS 3600 AND AS 5100

The durability requirements of AS 3600 apply to plain, reinforced, and prestressed, concrete structures and members with a design life of 40 to 60 years (Clause 4.1). AS 5100 applies to bridge construction and the design life is 100 years (AS 5100.1, Clause 6.2). Construction in concrete is covered in Part 5 (AS 5100.5). Both AS 3600 and AS 5100.5 use the same formats for classifying exposure conditions and they relate these to minimum covers to reinforcement. The main difference between the two standards relates to more concrete cover under AS 5100.5, evidently to cater for the longer design life. AS 3600 came into existence in 1988, well before AS 1500.5 (2004) and durability provisions in AS 5100.5 are obviously derived from AS 3600.

For environments defined in these Standards, there are basic divisions – into above or below ground and likelihood of exposure to dissolved or airborne salt. For those environments not related to salt the descriptions refer to climate, proximity of industry, nonaggressive soil and fresh water. Aggressive soils fall into the category U, for which there is no associated specification for the quality of the concrete or the depth of cover.

ARE AS 3600 OR AS 5100 SPECIFICATIONS APPLICABLE TO CONCRETE PIPE?

Formally, the answer for concrete pipe, which complies with AS 4058, is emphatically in the negative.

The scope of AS 3600, Clause 1.1.2 reads: "It is also not intended that the requirements of this Standard should take precedence over those of other Australian Standards" and from AS 5100.1, Clause 1: "This Standard sets out the requirements for design (of bridges and other structures) except those covered specifically by other Standards."

Nonetheless, familiarity with the AS 3600/AS 5100 format can make it attractive to specifying engineers and for this reason it is worthwhile to set out the reasons from an engineering viewpoint why the durability provisions of these Standards are not appropriate for concrete pipe.

For underground environments the exposure classifications in AS 3600 and AS 5100.5 and the associated covers bear minimal relationship to any recognisable mechanisms of deterioration or actual levels of aggressive chemicals. This is in contrast to AS 4058 (Appendix E) which sets concentration limits for a range of chemical types which can attack concrete and corresponding soil conditions for pipes conforming to the standard specification. Of equal significance is the lack of correspondence in AS 5100.5 and AS 3600 between specified covers and the effect of concrete quality, as reflected in the different strength grades. There are clear examples with respect to carbonation and chloride penetration, both of which have been the subject of extensive scientific study.

Beckett and Snow[1] present relationships between rates of carbonation and water/cement ratio, which can be translated to corresponding strength grades. From these relationships, depths of carbonation for concrete exposed to the atmosphere (which is more severe than other conditions of exposure) are related to strength grade as shown in table 2:

TABLE 2. DEPTH OF CARBONATION

Compressive strength (MPa)	32	40	50	60
w/c	0.63	0.52	0.43	0.37
Carbonation depth (mm) 50 yrs	29	18	6	2
after 100 yrs	42	25	9	3

Carbonation depth for 50MPa concrete is about one third of the depth at the same age for 40MPa concrete. For a 100-year design life, with a characteristic strength at least 50MPa and any reasonable depth of cover, carbonation is not even a relevant mechanism. Nevertheless in environments where there is no other recognisable mechanism of deterioration, AS 3600 and AS 5100 allow no more than 5mm reduction in cover for 50MPa compared with 40MPa concrete, and minimum cover at least 15mm for 50MPa concrete.

Figure 1 further illustrates the effect of dense, impermeable concrete as in concrete pipe on the rate of carbonation. There is minimal carbonation after 65 years. Reinforcement located only a couple of millimetres below the surface would be fully protected from corrosion by the alkalinity of the concrete.

Typical effect with concrete of average quality – significant depth of carbonation within the service life

Concrete pipe made in the early 1920s, not installed but exposed to the weather for 65 years (wall thickness 75mm)

Figure 1. Progress of carbonation

Relationships between strength and rates of chloride penetration are illustrated in figure 2, from Baweja et al[2]. In this example, for 40 years duration to loss of passivity of the reinforcing steel, 50mm cover is required for 50MPa concrete and 90mm is required for 40MPa (ie: 40 mm more cover for the lower grade of concrete); yet AS 3600 allows a difference of only 15 mm.

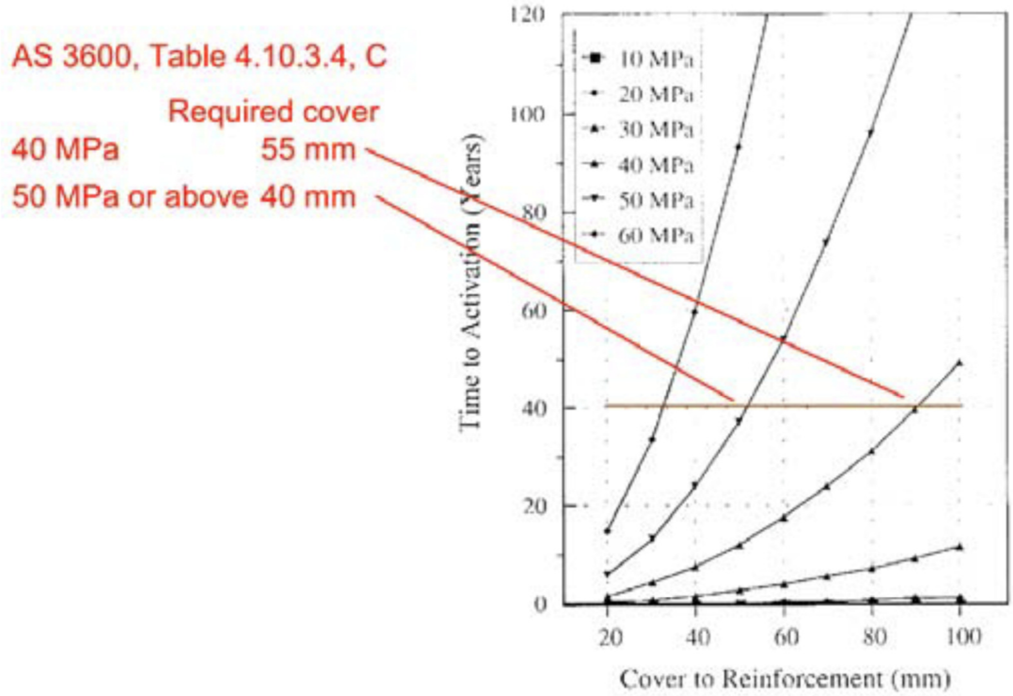

Figure 2. Time to activation from penetration of chloride

The basis of cover provisions in AS 3600 and AS 5100.5 is practical and not scientific. They cannot reasonably be applied to structures where the practical considerations envisaged, such as the quality of on-site construction work, are irrelevant. Concrete pipe is a clear example - dense concrete, small diameter reinforcing wire, accurate reinforcement placement and underground environments for which descriptions amounting to nothing more than contact or otherwise with soil or water (even if qualified, respectively as "non-aggressive" or "fresh") are meaningless.

The exposure classifications and covers in AS 3600 and AS 5100.5 have no place in the specification of concrete pipe.

REFERENCES

1. D Beckett, F Snow, Carbonation and its Influence on Durability of Reinforced Concrete Buildings, Construction Repairs & Maintenance, January 1986, pp 14-16.
2. D Baweja, H Roper, V Sirivivatnanon, Specification of Concrete for Marine Environments: A Fresh Approach, ACI Materials Journal, Vol 96, No 4, July-Aug 1999, pp 462-470; Fig 4.