Canadian Concrete Pipe & Precast Association

Build on our strength

Abrasion Resistance of Concrete Pipe

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Concrete is one of the most widely used building materials in the world, and has been around for a very long time however it continues to have an identity crisis. Many are under the impression that concrete technology has not changed much, or assume that all concretes are the same as that bag of dry concrete mix that can be purchased at a local building supply store. The reality is that with research and development spanning several centuries, concrete has continually evolved into a sophisticated construction material that can be designed to have specific properties with vast combinations of cements, aggregates, and chemical admixtures.

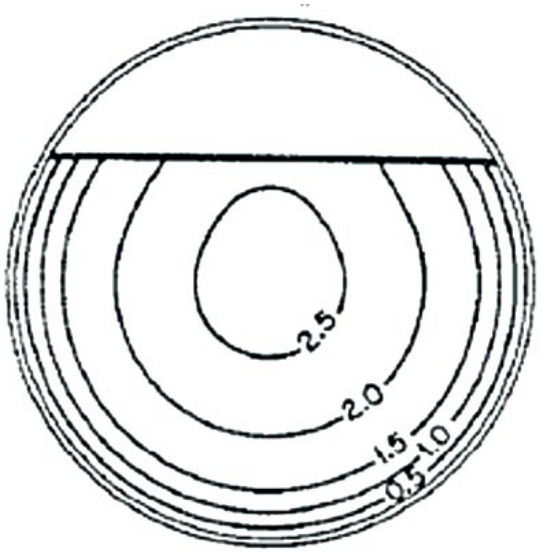
One point that illustrates this is the fact that *CSA A23.1 – Concrete Materials and Methods of Concrete Construction* lists 15 different exposure classes for concrete mix designs. They range from temperate environments, such as an interior wall of a residential building, to very severe environments, such as storm or sanitary sewer system components exposed to chlorides, sulphates, freeze-thaw cycles, acid attack, and abrasion damage from waterborne sand, gravel, and other debris.

Minimum and Maximum Velocity

Abrasion resistance has always been important to gravity pipe design engineers however it has been generally paid little attention because of the good design practices and exceptional performance of reinforced concrete pipe in Ontario. *The Ontario Ministry of Environment (MOE) – Design Guidelines for Sewage Works 2008* requires that all sewers have a minimum sewage flow velocity, when flowing full, of at least 0.6 m/s (2.0 ft/s) for self-cleansing of grit and organics. The maximum velocities in sanitary sewer systems should not be more than 3 m/s (10 ft/s), and in storm sewers should not be greater than 6 m/s (20 ft/s). Where velocities are greater than 4.6 m/s (15 ft/s), the MOE guide suggests that special provision be made to protect against pipe displacement by impact and erosion.

Flow Velocity Profile in Pipe

One fact that a design engineer should keep in mind is that fluid particles do not all travel at the same velocity within a pipe. The textbook, *Open Channel Hydraulics* by Ven Te Chow first published in 1959 illustrated this flow velocity profile inside a gravity pipe. Chow noted that the typical velocity of the fluid at the pipe wall is about ½ the cross-sectional average velocity that is determined by the Manning's equation.



Typical Curve of Equal Velocity Relative to Mean Velocity in a Pipe

Abrasion Resistant Concrete

The American Concrete Institute report – *ACI 210R-93 Erosion* of *Concrete in Hydraulic Structures* is an excellent reference that discusses the causes, control, maintenance and repair of erosion in hydraulic structures.

Another excellent reference is a 2003 research paper by Yu-Wen Liu et al entitled: *Abrasion Erosion of Concrete by Water-borne Sand*. This study investigated the effects of the constituent materials on the abrasion erosion resistance of concrete. While the findings of this study should help find viable engineering solutions for designing abrasion resistant concrete structures, it also enables us to better understand why abrasion erosion of precast concrete pipe has been generally an insignificant problem in most applications. Some of this report's findings are summarized here:

1- A reduction in the w/cm ratio increases the concrete abrasion resistance (Figure 1). Due to the dry cast manufacturing of concrete pipe, a low w/cm ratio (typically less than 0.40) must be used to produce the zero slump concrete that can survive this production process.

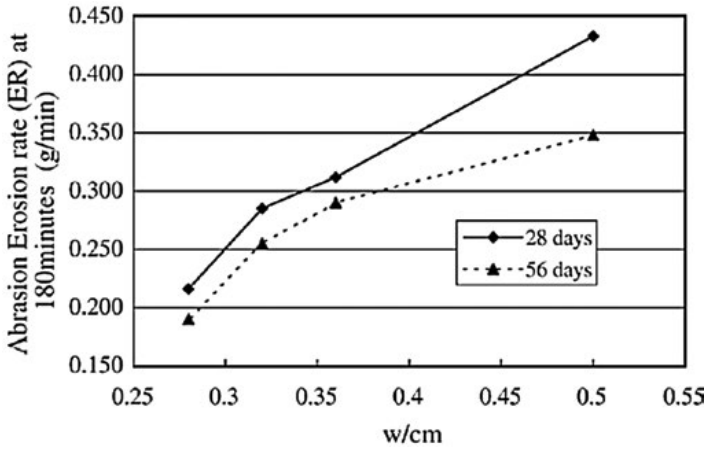


Figure 1: The relationship of w/cm and abrasion erosion rate

2- Low permeability concrete exhibits good abrasion resistance. The dry cast concrete used to produce pipe in Ontario typically contains 35% to 50% ground granulated blast-furnace slag as a supplementary cementing material. This is not only good for the environment by using a by-product of the steel industry, but it also produces a more durable, impermeable concrete that achieves less than 1,000 Coulombs in the ASTM C1202 rapid chloride ion penetration test.

3- Abrasion resistance increases as concrete strength increases (Figure 2). Again due to the dry cast manufacturing process and accelerated curing of concrete pipe, the typical 1-day compressive strength ranges between 25 to 30 MPa (3,600 to 4,400 psi). This inherently results in a 28-day compressive strength of 55 to 60 MPa (8,000 to 8,700 psi).

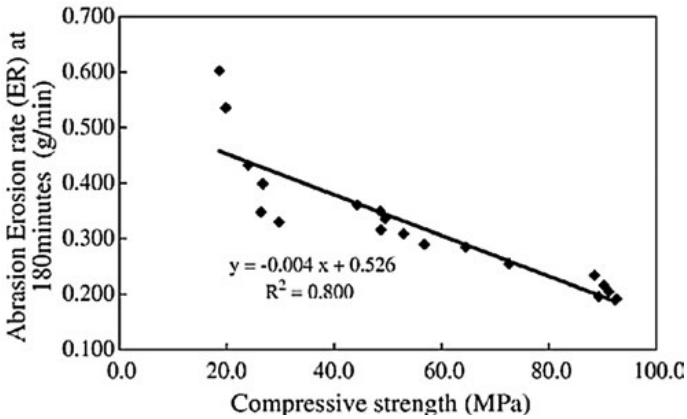


Figure 2: The relationship of compressive strength and abrasion erosion rate

Many flexible pipe advertisements promote the abrasion resistance of their products and usually draw a comparison to concrete pipe. This marketing strategy diverts attention away from the fact that certain plastics get brittle or lose strength over time, and may also deteriorate when exposed to common elements such as ultraviolet light, hydrocarbons, and temperature fluctuations. While all pipe materials may be susceptible to long-term abrasion damage, concrete offers the longest proven history and is one of the few pipe materials that can easily be repaired or rehabilitated.