Cracks & Autogenous Healing

What is an Acceptable Crack Width in Concrete Pipe?

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Through proper design and curing, concrete can be considered one of the most durable building materials in existence. Concrete structures typically have a design life of 100 years; however, countless examples of ancient concrete structures are still erect today. Concrete is inherently strong under compressive stresses but weak in tension. This is why most concrete structures have embedded reinforcement to resist these tensile forces, typically in the form of steel wire/rods. Some cracking is normal and usually accounted for in a design. This just implies that the tensile forces have exceeded the concrete's strength capacity and the force is getting transferred to the steel reinforcement.

Figure 1: The Pantheon of Rome. This ancient concrete structure was originally constructed in 126AD.

So what is an acceptable level of cracking in concrete? There's no straight forward answer as different civil engineering disciplines each have their own design criteria. Concrete sub-structures typically have more tolerance to cracking versus concrete bridges and buildings which are more exposed to weathering from the natural elements. Based on the American Association of State Highways and Transportation Officials' (AASHTO) post installation guidelines for underground concrete pipe, a key reference for many municipal specifications, the following crack criteria is used [1]:

- Longitudinal crack width < .05"
  - Considered minor and not a cause for remediation.
- Longitudinal crack width greater than .05" but less than .10"
  - *In areas where soil and runoff pH > 5.5, not a cause for remediation.*
- Longitudinal crack width > .10"
  - Remediate or replace the pipe.

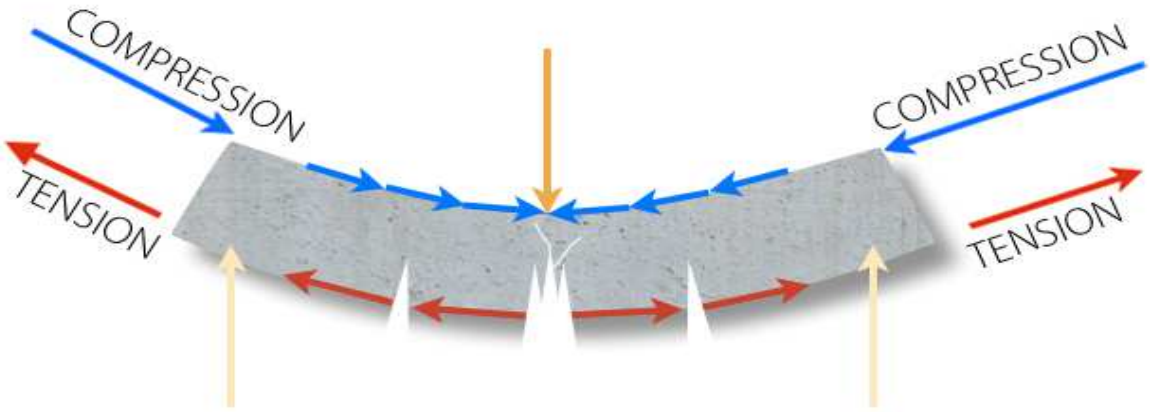

Figure 2: A simply supported concrete beam reacting to a point load.

Autogenous healing of concrete occurs when the continuity between two sides of a crack is restored without repair work. According to the Concrete Society, based in the UK, *"Autogenous healing is the natural process of crack repair that can occur in the presence of moisture and the absence of tensile stress" [2]*. The formation of calcium carbonate crystals. $CaCO_3$ is the primary cause for the self-healing of cracks.

Figure 3: Calcium carbonate crystals have completely formed over an existing crack in this concrete pipe.

Calcium carbonate crystals are formed in two phases: The first phase involves water reacting with calcium ions, Ca^{2+}, on the surface of the crack; this process occurs much more rapidly than the second phase [3]. After these surface ions are consumed, Ca^{2+} diffusion will develop due to the concentration gradient and continue to form $CaCO_3$ crystals at a slower rate. Through laboratory testing, it was found that autogenous healing is influenced by the crack width and the prevailing water pressure. Furthermore, the type of cement used and the type of water have no influence in forming $CaCO_3$. The formation of $CaCO_3$ crystals can be accelerated by:

- a rising water temperature
- a rising pH of the water
- a falling CO_2 partial pressure in the water

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