Rules of Thumb

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Getting it right from the start is the best defense for corrosion, columnist Keivan Rafie

The demand for larger and more extensive sewer tunnel systems is increasing due to population growth, insufficient capacity in existing systems, and more stringent regulations. This, in turn, is causing an increase in corrosion as longer conveyance distances result in higher concentrations of sulfides and longer retention times.

CORROSION AND CONCRETE

Concrete has long been used for sanitary sewer system infrastructure – concrete pipe for conveyances and cast-in-place concrete structures for junction chambers, manholes, sumps, treatment basins, etc.

Concrete in sewer tunnels can be subjected to different types of physical or chemical attack, including exposure to soil and groundwater sulfate, exposure to wetting-drying cycles, erosion, etc. However, hydrogen sulfide, which can lead to the formation of sulfuric acid (a sulfate), is the most common cause of degradation. The process of concrete degradation in sewers by sulfate attack can be briefly described as follows:

1) H_2S is created by decomposition of organic materials in wastewater flow
2) The H_2S is stripped/released from the wastewater flow when turbulence is encountered.
3) The H_2S settles on the damp concrete surface above the level of flow of the wastewater.
4) Deposited H_2S produces sulfur on the sewer structure or pipe surface.
5) Microbial bacteria convert the sulfur deposits to sulfuric acid, which causes the corrosion within the system.

Portland cement concrete is also susceptible to chemical attack from **acids, salts, alkalis and sulfates.** Naturally occurring sulfates of sodium, potassium, calcium, or magnesium are sometimes present in soil or groundwater.

CORROSION OF STEEL

Corrosion of steel reinforcement in concrete is a leading cause of deterioration. The two main mechanisms are carbonation and chloride ions.

Carbonation occurs when carbon dioxide penetrates the concrete and reacts with the hydroxides to form carbonates, which reduce the pH. The intrusion of chloride ions into the concrete can cause steel corrosion if oxygen and moisture are present to sustain the reaction. Growth of the corrosion in the form of rust can lead to concrete damage of cracking, delamination, and spalling.

CORROSION POTENTIAL

The rate and amount of corrosion are influenced by the soluble salt content of the soil/water, amount of moisture, conductivity of the soils/water, pH, and oxygen concentration. The wastewater flow rate is also a factor since a decrease in the flow rate increases the risk of the production of hydrogen sulfide.

The mechanism of corrosion potential around a tunnel depends on groundwater chemistry. On the outside of the tunnel, there is potential for chloride migration from the tunnel liner extrados to the tunnel liner intrados, at a rate that is proportional to the permeability of the liner materials and salt content of the groundwater.

With respect to external corrosion, coatings exist to provide barriers and protection of salt water intrusion. Systems include impregnating materials, such as polyurethane coatings, or coatings like bitumen or epoxy type products.

Other ways to reduce, the corrosion potential from the external environment is to reduce the permeability of the concrete, increase the thickness of concrete cover of the reinforcing steel, use of a sulfate-resistant admixture, and use of an alkaline aggregate.

COATINGS

Coatings applied to the entire pipe circumference are distinguished from liners in that they are brushed or sprayed on rather than inserted as a preformed material. Some coatings are applied during pipe manufacture, and others are applied in-situ after installation, typically on pipelines that have started to exhibit corrosion. When correctly applied, these coatings can be very effective, but each has potential shortcomings.

LINERS

Installation of corrosion resistant materials can generally be classified into two methods: one-pass and two-pass. The basic difference between is when the material is installed. In a one-pass system, the corrosion resistant material is applied or added to the tunnel segments during the concrete casting process. In a two-pass system, the material is installed on the face of the tunnel segments after tunnelling operations are completed.

CONCLUSION

As wastewater conveyance systems get longer and carry greater flows, they are increasingly exposed to highly corrosive environments. This worldwide problem can reduce infrastructure design life to fewer than 10 years and lead to collapse.

In most cases, a robust higher-cost liner installed during construction is more cost effective over the long-term when reduced maintenance and repairs, and greater longevity are considered.

References and additional readings:

Abbas - Structural and Durability Performance of Precast Segmental Tunnel Linings – 2014.
Carroll and Ivory - Corrosion Protected Systems for Tunnels and Underground Structures - 2010.
Talley and Wallace - Calcium Aluminate Technology and Biogenic Corrosion - 2009.

Agree or disagree?

Let us know what your experience has taught you. Or let us know what topic should be included in future *Rules of Thumb* columns. *editor@tunnelsandtunnelling.com*