A Holistic Approach to Determining Concrete Deterioration in Wastewater Structures

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Synopsis

The "durability" of concrete has increasingly become the focal point of research in the concrete community all throughout the world. How to make durable concrete, and what maintenance procedures must be implemented to extend the service life of concrete are regularly discussed at concrete related meetings, seminars, workshops, as well as major international conferences.

An urban wastewater system typically consists of a series of wastewater treatment plants, lift stations, and a network of sewer pipes. Each of these units is further subdivided into subunits, for example, a lift station, which is basically an underground cast-in-place or precast concrete structure, consists of two sections, namely a wet well and a dry well. The wet well functions as a pit in which the city's sewage enters periodically and is then pumped out when it reaches a pumpable level, whereas a series of pumps are usually housed in the dry well of a lift station.

Although the entire wastewater system is susceptible to chemical attack, characteristically sulfate attack and acid attack, the interior of a sewer pipe and lift station represents one of the most severe environments for concrete.

In order to rehabilitate concrete exposed to such a corrosive condition, or even to make a determination whether the concrete is worthy of repair, it is often necessary to carry out a systematic evaluation of the state of the concrete prior to specifying any kind of repair procedure. A holistic approach to determine the extent of concrete deterioration ill wastewater structures, particularly in lift stations and sewer pipes has been developed. This will be discussed with reference to the condition survey of the concrete recently carried out in the wet well of the largest lift station in the City of Houston, known as the 69th Street WWTP lift station. The wet well was approximately 160 ft long, 44 ft wide, and 40 ft deep with a diversion channel close to the south wall. The facility was constructed in 1981.

A detailed visual inspection of the concrete walls and ceiling was first undertaken. A black protective coating was noted on both. A multitude of blisters, pinholes (holidays) and pits were observed in the coating. Several vertical or near-vertical cracks were also identified on the walls. Interestingly, the coating on the ceiling was in a much better condition, with only minor delamination appearing at the metal beam interfaces. A large ventilation unit in the center of the ceiling was probably responsible for preserving the ceiling in such a good condition. The coating thickness ranged from 8 to l0 mil on walls and up to 35 mil on ceiling.

Cores were collected from 15 locations to represent different heights of walls, inflow and outflow conditions, cracks in walls, various degrees of coating damage, and the ceiling. The ceiling slab was composed of a cementitious composite consisting of a 1 inch layer of mortar in contact with the coating, overlain by a layer of lightweight concrete, and finally normal weight concrete at the upper exposed surface. In contrast the wall concrete was normal weight concrete all throughout its thickness.

Cores were tested in compression. The compressive strength ranged from 5,300 psi (36 MPa) to 9,000 psi (62 MPa). Over 70% cores tested greater than 6,000 psi (41 MPa). The pH was measured up to a depth of 2 inch on all the cores. The pH at the coating surface ranged from 8 to 9, and at 2 inch depth it was between 10 and 12.5.

One thin section was prepared from the exposed face to 3-inch depth of each core for petrographic analysis in order to examine the deterioration profile of concrete as a function of depth. The water-cement ratio was estimated to be in the range of 0.50 and 0.55. The concrete was air entrained, and air content was calculated to be in the range of 5 and 6%. A few microcracks were observed in the paste, but microcracks in concrete is a rule rather than an exception. Deposition of foreign mineral was not observed in air voids or in microcracks.

Petrographic analysis revealed that there has been a limited amount of deterioration of concrete immediately below the coating. The deterioration manifests in the form of partial delamination of the coating from the concrete substrate, deposition of a microscopic layer of foreign mineral at the concrete - coating interface. In a few instances the aggregate particles were found to been affected. The foreign mineral was identified as gypsum ($CaSO4.2H2O$) from X-ray diffraction analysis. This is a characteristic product of both sulfate attack and acid attack, and is known to cause volume expansion in concrete.

The depth of deterioration never exceeded 1/4 inch in any of the cores. No definite increase in the frequency of microcracks was observed in the interior of the concrete, implying that the bulk of the concrete has not been affected due to damage to the coating. The relatively high compressive strength of cores supports this observation.

The nature of coating damage suggests that attack of the concrete must have occurred through pinholes and holidays, which later grew into blisters as a result of the volume increased due to gypsum crystallization. Several of these blisters had exfoliated to expose the gypsum at the surface of the wall.

Thus, in order to rehabilitate the concrete in this wet well, it is necessary to remove the damaged coating first, followed by removal of the gypsum layer wherever was formed. Otherwise expansion at the interface is bound to recur. Removal of gypsum under these circumstances is known to be possible using hydrojetting technique. The present state of the concrete suggests that extensive repair is not required. Wherever the concrete has corroded to any appreciable depth, application of a dense patching mortar or shotcrete ought to be sufficient. The gypsum deposited in the visible cracks also need to be removed, and the vacant space in the cracks should be filled using a compatible polymeric material before applying the coating.

This case study clearly underscores the need to adopt a holistic approach to determining the condition of concrete in severe environments such as in wastewater structures before embarking on expensive and an elaborate rehabilitation procedure. A systematic evaluation of the concrete can eventually help to save substantial amount in repair costs.