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LIFE FACTOR DESIGN OF RCP SEWERS

SIGNIFICANT FACTORS

Along with the age of consumerism and increased environmental concern, the public has become aware that certain situations do not have to be tolerated. The days are over for quiet acceptance of air charged with noxious hydrogen sulfide fumes. The public now, and rightfully so, demands not only a quiet and clean environment but one which is devoid of foul smells, particularly in the vicinity of homes.

The second significant factor was the 1974 Clean Water Act Amendments. Currently, Federal law requires that each entity processing domestic sewage must enact an ordinance limiting the quantity and quality of industrial wastes which may be discharged into that system. Federal regulations require that an industrial waste monitoring system must be established by each agency to insure that the requirements of the industrial waste ordinance are being met. Penalties are levied when dischargers violate the ordinance. Violators can even be held responsible for damage to the system. This virtually elimi-

nates the old fear "we do not know what wastes will be dumped in the sewer line."

The third factor in this changing picture has been the EPA emphasis on value engineering analysis. Value engineering requirements have been spelled out in Program Guidance Memorandum No. 63 and No. 19A by the EPA. To emphasize the fact that these are mandatory requirements of the EPA Construction Grants Program, the title "Program Guidance Memorandum" has been changed to "Program Requirement Memorandum."

PGM 63 states that the voluntary value engineering program which was included in the Step II grant process in 1974 is now mandatory as of July 1, 1976 for all Step II (preparation of plans and specs) grant applications for all projects with a total estimated cost of \$10 million or greater. Value engineering analysis must be applied to all components and systems. The value engineering fee is grant eligible. Value engineering is also encouraged for projects of lesser cost.

INTRODUCTION

Several factors have significantly altered the reinforced concrete pipe sanitary sewer market. These factors brought us from the dark ages or era of fear and superstition, largely promoted by competing products, into the present situation where modern technology can be applied in the project design stage to the design of concrete pipe in a particular sulfide environment.

EPA MANUAL

Probably the single most important factor in the changing outlook for reinforced concrete sewer pipe was publication in late 1974 of the EPA Manual "Sulfide Control in Sanitary Sewerage Systems."

The major emphasis of the EPA Manual is, as the name implies, control of sulfides. The Manual includes curves which list slope-flow relationships as shown in Figure 1. These relationships are used to design sewer lines which will produce little or no sulfides. For slope-flow values which are above and to the right of the "A" curve sulfide concentrations will be negligible. Values between the "A" and "B" curves may generate moderate sulfides. Values below and to the left of the "B" curve may be rather severe sulfide generators.

Concerning the specific "A" and "B" curves, The Manual states:

While the climatic condition prevails, a system functioning with slope-flow relationships as shown by Curve "A" may be expected to produce very little sulfide, rarely more than 0.1 or 0.2 mg/1 of dissolved sulfide. The annual average dissolved sulfide concentration is expected to be only a few hundredths of a mg/1. While the climatic condition prevails, a system functioning with slope-flow relationships as shown by Curve "B" may produce dissolved sulfide at concentrations of several tenths of a mg/1.

The climatic condition referred to is defined as the six hour, high flow period of a day during a time when the temperature of the sewage is equal to that of the warmest three months of the year. This represents the worst possible sulfide condition for a sewer. The Manual makes further definite statements concerning the life expectancy of concrete sewers:

If the slope-flow relationships of sewers upstream from a given

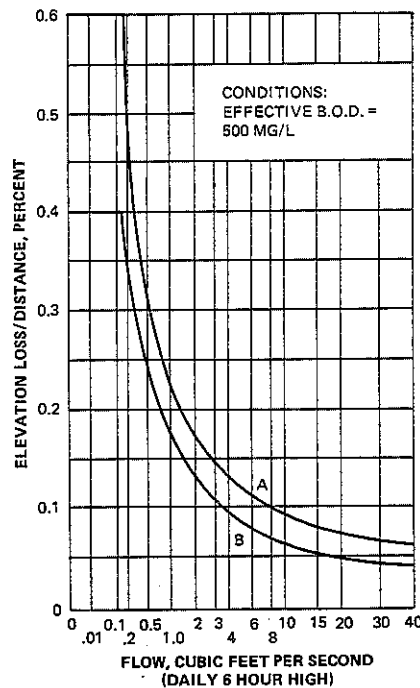


Figure 1. Flow-slope relationships as guides to sulfide forecasting.

point correspond to Curve "A" (adjusted for EBOD), and there are no force mains operating without proper sulfide control, then sulfide concentrations will be so low that the rate of corrosion of concrete pipe will be inconsequential. Small collecting sewers so designed, made of concrete pipe with granitic or other inert aggregate will have a life expectancy of 100 years or more. . . . Considering the thickness of the pipe wall in the very large pipes, a life of several centuries would be expected. Where over-all slopes are represented by Curve "B", sulfide conditions under some circumstances may be such that bare concrete pipe made with granitic aggregate will be significantly corroded. Sulfide conditions become worse at slope-flow combinations deeper in the domain below Curve "B". It may be satisfactory to use concrete pipe under these conditions if it is made with calcareous aggregate. . . .

Where slope-flow relations given by Curve "A" cannot be attained, methods have been developed to design for a particular desired life. In the past, additional concrete thickness, calcareous aggregates or combinations of the two have been used to extend the life of concrete pipe sewers in a sulfide environment. Additional cover and alkalinity requirements were based on judgment and experience. Too often, the results were an excessive amount of protection at greatly increased costs.

Until the publication of the EPA Manual, there was no rational method in existence to calculate required alkalinity and amount of additional concrete thickness. The Manual relates those factors which affect sulfide transferred to the pipe wall to corrosion rate and alkalinity in an equation which expresses average rate of penetration of the cover material in inches per year based on flow conditions, sulfide levels, pH and the alkalinity of the material as follows:

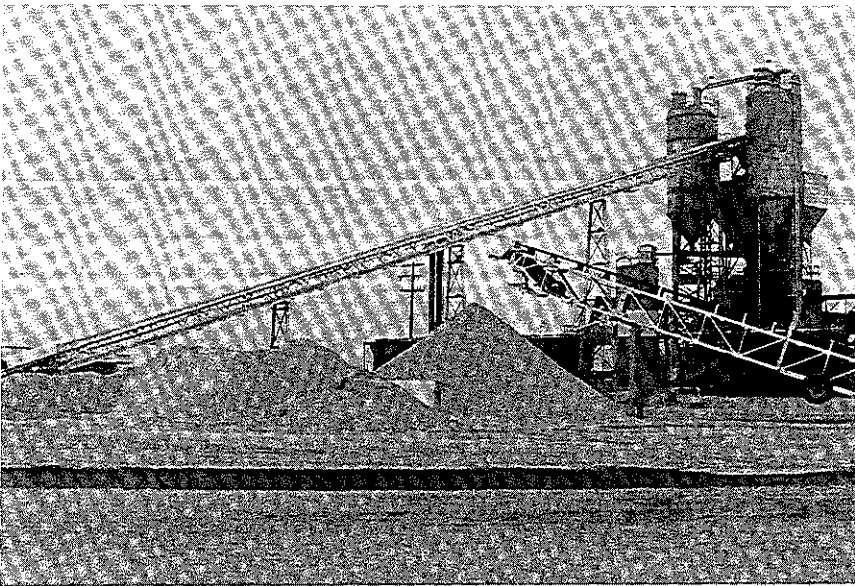
$$C = \frac{0.45 k \phi_{sw}}{A}$$

- Where C = corrosion rate, inches per year
 k < 1.0, all losses in reaction
 ϕ_{sw} = sulfide flux to pipe wall
 A = concrete alkalinity

LIFE FACTOR DESIGN

Once the projected corrosion rate for concrete pipe is determined, the expected service life can be calculated or the pipe designed for a particular service life. The latter is defined as Life Factor Design. By setting \underline{z} equal to the thickness of allowable concrete loss and \underline{L} as the required service life, then the service life is equal to \underline{z} divided by the corrosion rate, \underline{C} .

Substituting for \underline{C} in the EPA corrosion rate equation and rear-



Blend of granitic and calcareous aggregates was used at Hydro Conduit's Fresno plant to produce desired alkalinity. Photograph shows limestone sand stockpile on left, granitic rock on right. Project was Herndon Avenue Sewer, City of Fresno.

ranging terms results in the Life Factor Equation:

$$Az = 0.45 k \phi_{sw} L$$

The term Az is called the Life Factor and is the product of concrete alkalinity times the thickness of allowable concrete loss. This thickness is generally assumed as the concrete cover over the inner reinforcement cage. Concrete alkalinity is defined in terms of the amount of acid which a known weight of concrete can neutralize as compared to the acid neutralizing capability of pure calcium carbonate.

The advantage of the life factor design method is that if the life factor, Az, is specified, maximum design flexibility is possible. Basic production decisions regarding the use of partial or 100% calcareous aggregates and increasing cement factor for increased alkalinity, and varying wall and cover thickness, etc., can be made by the concrete pipe manufacturer. Each manufacturer can use the most efficient combination of the variables to suit his own manufacturing process, equipment avail-

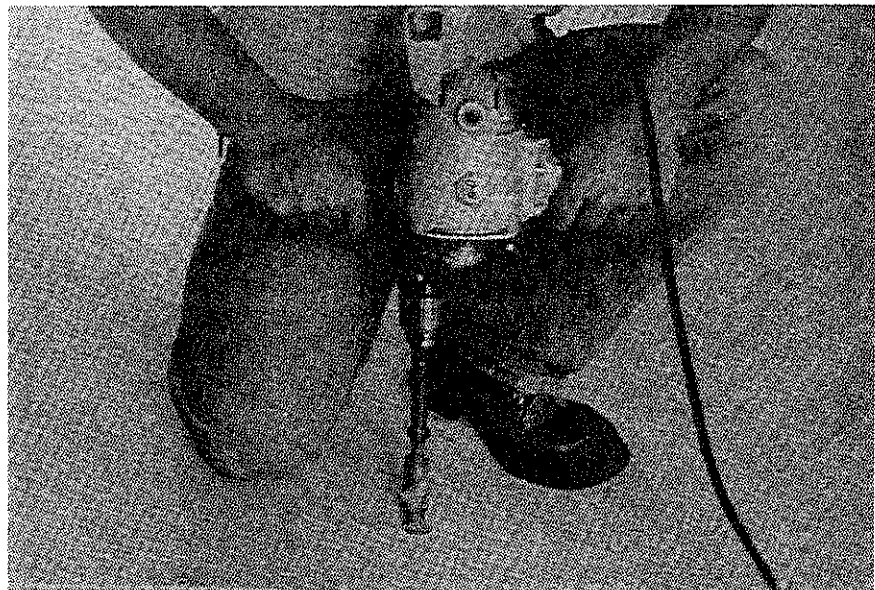
ability and aggregate sources to produce the required pipe life factor.

Quality control for the life factor method is relatively simple. The procedure consists of obtaining two one-inch drill hole samples of the cover concrete from the specimen pipe. The alkalinity test is performed on the samples and the average alkalinity used to calculate the Az factor.

LIFE FACTOR USE

The California Precast Concrete Pipe Association (CPCPA) adopted life factor design as a uniform procedure for sanitary sewer promotion. One of the major activities of CPCPA has been sulfide testing in communities where interceptor sewer designs are anticipated. Some of this work has been done by CPCPA Engineering Manager, Ernie Rogers, with the assistance of industry personnel. In other cases, local Civil Engineering schools, and, in particular, the Sanitary Engineering Departments, have been utilized to conduct these studies. Probably the

Method of obtaining sample of cover concrete for alkalinity testing.



Projects on which Az Life Factor has been specified (as of 4-29-77)

Agency	Project	Design Engineer	Remarks	Alternates
City of Fresno, CA	Herndon Int.	Braun, Pasillas & Wagner	17 miles of 39" through 84" interceptor sewer Az = 0.70 to 1.40	VCP and PVC lined RCP
Madera County, CA	Parksdale Int.	Mc Glasson & Assoc.	3 miles of 21" and 27" Az = 0.60	VCP
City of Clovis, CA	Clovis-Herndon Int.	Boyle Engineering	3½ miles of 24" through 39" Az = .92 to 1.32	VCP
Clark County San. District, NV	Twain Int.	G. C. Wallace Eng.	6 miles of 30" through 45" Az = 0.50	VCP
Clark County San. District, NV	Desert Inn Int.	G. C. Wallace Eng.	3 miles of 21" through 33" Az = 0.50	VCP
Clark County San. District, NV	Spencer Int.	Baughman-Turner Eng.	1 mile of 27" through 30" Az = 0.50	VCP
City of Dallas, TX	Pleasant Grove Int. Cont. 75-70-R	Dallas Water Utilities Dept.	1½ miles of 54" through 84" Az = 1.0	None
Mojave Water Agency, CA	Regional Int.	Brown & Caldwell	6½ miles of 27" through 42" Az = .30 to 1.20 (800' of 18" at 2.50)	VCP and PVC lined RCP

most significant and extensive of these, sponsored by CPCPA, has been the study recently completed for the City of Delano, California. This study was conducted by a Sanitary Engineering graduate student for his Master's thesis under the direction of Dr. George Tchobanoglous, Civil Engineering Department, University of California at Davis. An interesting facet of this report is that two sulfide generation prediction equations were analyzed. Excellent correlation was obtained between observed sulfide build up and that predicted by Dr. Pomeroy's sulfide prediction equation, but no correlation with the Thistlethwaite equation was found. This report includes observations of sulfides in the existing system, prediction of sulfide levels for the new sewer design and recommended life factor de-

sign for the new concrete pipe interceptors.

As of April, 1977, approximately \$8.0 million worth of concrete pipe sewer has been manufactured in California using the life factor system. A list of projects on which the life factor method has been specified shows that of a total of 48½ miles, the life factor concrete pipe was the successful alternate bid on 41½ miles.

The use of modern technology has provided engineers with a new tool to assist them in the design of sanitary sewers, a discipline of engineering long thought to be systematized.

The application of this technology in the design of sanitary sewers has benefited the taxpayers of the southwest with more economical construction of their sewer systems.

by
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