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PIPE MATERIAL EVALUATION

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CITY OF PHOENIX

TO Mr. Attebery
City Engineer

DATE November 13, 1987

FROM Mr. Blakley
Engineering Supervisor

SUBJECT PIPE EVALUATION FOR STORM DRAINS

Enclosed is the final report of the evaluation of pipe for storm drains. Included in this report are results of the field investigation performed between May and August 1987 and a list of recommendations. These recommendations are intended to ensure that hydraulic characteristics of the mainline pipe are equivalent for all pipe materials and that a service life of 70 to 100 years is achieved.

Mr. Robert Williams has reviewed this report and his comments were incorporated into the recommendations.

I would appreciate an opportunity to meet with you to discuss these recommendations.

Ross D. Blakley, Jr.

ROSS D. BLAKLEY, JR.

GB:ps/GB01

Attachment

INTRODUCTION

Beginning June 3, 1987, a storm drain inspection team assembled at designated locations. The purpose of this team was to visually inspect the structural and hydraulic integrity of storm drain pipe materials used by the City of Phoenix and obtain material samples as deemed necessary.

To date we have inspected 3 metal-lined corrugated metal pipes (CMP), Type F; 3 asphalt paved CMP's, Type D; 6 cast-in-place pipes (CIPP); 5 mortar (concrete) lined CMP, Type E; and 3 reinforced concrete pipes (RCP). These storm drains ranged in age from 1-27 years. Several of the newer installations had no outfall and have therefore not yet been put into service. Only one of the CIPP storm drains (the one at 83rd Avenue and Osborn) inspected was in service.

OBSERVATIONS

Type F (corrugated metal pipe with smooth steel interior liner)

<u>Location</u>	South of Cactus on 35th Avenue
<u>Date of Installation</u>	1981
<u>Date of Inspection</u>	June 3, 1987
<u>Diameter</u>	84-inch

Standing water up to 1.5 inches deep was present along a majority of the pipe. The asphalt coating along the invert has scoured away. Mastic at several pipe joints was peeling or missing. A curve in this section of storm drain was inspected. Excessive joint separation was observed; mastic was used to fill the gaps. Corrosion of the invert with some perforations were observed along the section of pipe inspected. Two coupons were removed; the invert coupon showed corrosion and perforations of the smooth inner liner, the outer pipe wall showed no evidence of corrosion. Slight discoloration (white-gray oxide) was observed on the springline coupon. A steel rod approximately 18-inches long was inserted through the pipe wall where the sample was taken to obtain an indication of bedding density. Resistance to rod insertion in the granular material was minimal.

<u>Location</u>	East of 51st Avenue on Van Buren
<u>Date of installation</u>	1986
<u>Date of inspection</u>	July 9, 1987
<u>Diameter</u>	96-inch

This storm drain has not yet been put in service. The asphalt coating and joints were in good condition. Standing water and sediment up to 2 inches, extending for over 100 feet, was observed in several places. This water may have resulted from a leakage test. No coupons were removed to determine whether water leaked through lock seams or to examine the quality of backfill. A slurry bedding was utilized on this job.

Type D (Asphalt paved corrugated metal pipe)

Location 35th Avenue and Roosevelt

Date of installation 1962

Date of inspection June 3, 1987

Diameter 57-inch

Nuisance water was present. Debris in pipe included trash, aggregate and sticks. Lining and joints appeared to be in good condition. Asphalt coating in the pipe appeared to "creep" causing the coating in the invert to be extra thick. A 6-inch thick layer of asphalt coating had separated from the invert, however, a coupon sample of the pipe taken at the invert showed an additional 3/4" to 1" of asphalt coating. No corrosion was evident. A coupon sample taken at the springline showed no evidence of corrosion and that a granular bedding material had been utilized. It is interesting to note that resistivity test results in this area indicate a potential for corrosion.

Location 19th Avenue and Broadway

Date of Installation 1967

Date of Inspection June 10, 1987

Diameter 57-inch

Standing water approximately 1" deep. No sediment was present. The asphalt paving was completely removed in some areas with some corrosion evident at the invert of pipe. Mastic was peeling at some joints with excessive joint separation. A coupon sample was removed at the invert at a location where the asphalt paving was intact, no corrosion was observed, the asphalt thickness was approximately 1 inch.

Location 43rd Avenue and Roosevelt

Date of installation 1977

Date of inspection August 19, 1987

Diameter 76-inch

Water was flowing 1-2 fps at a depth of 1-2 inches. No sediment or debris was present. Mastic was peeling at some joints. The asphalt coating was intact and still soft. No coupons were removed to assess corrosion of the pipe. No

sag or deflection was observed.

Cast-in-place pipe (CIPP)

Location Tatum north of Thunderbird

Date of installation Under Construction

Date of inspection June 12, 1987

Diameter 60-inch

An inflatable sausage method was used to construct this pipe. Ring cracks and some longitudinal cracking was observed. Undulations and variation in pipe diameter were visually observed. Honeycombing was observed in some areas. The smoothest sections were comparable to RCP except for undulations. While inspecting the pipe, workers were wetting and placing backfill and water was leaking into the pipe through cracks. Under full flow condition this may allow excessive water to exfiltrate and wet the supporting soil, possibly leading to additional problems with the pipe.

Location Squaw Peak Parkway, north of Osborn

Date of installation Under construction

Date of inspection June 12, 1987

Diameter 78 inch

Interior forms were used to construct this pipe. Ring and longitudinal cracking was present. However, the frequency of cracking was less than the 60" CIPP inspected on Tatum.

Misalignment of forms causes an offset of up to approximately 1/2 inch. These were finished with mortar to smooth the pipe wall. The relative roughness of the larger diameter pipe appeared to be less.

Location 56th Street, south of Justine

Date of installation under construction

Date of inspection June 12, 1987

Diameter 54-inch

Interior forms were used to construct this 54-inch CIPP. Form offset up to approximately 1/2 inch were present. Ring and longitudinal cracking were evident. Undulations and variation in pipe diameter was observed and some

areas with significant honeycombing.

Location Thomas and West Manor Drive

Date of installation 1986

Date of inspection June 25, 1987

Diameter 98 inch

Interior forms were used to construct this pipe. Form offsets up to approximately 1/2 inch were evident, cold joints were rough. Ring and some longitudinal cracking was observed. A caulk-like material was used to patch cracks and adhesion to pipe wall was not good. Scour may cause loss of caulking especially in the invert. This large diameter pipe looked relatively smoother than the small diameter C.I.P.P. and a small amount of honeycombing was observed. This storm drain did not have an outfall at the time of inspection.

Location 12th Street and Virginia

Date of installation 1986

Date of inspection June 25, 1987

Diameter 98 inch

This section of storm drain pipe is down stream (south) of the section previously discussed. Form offsets were minimal, cold joints are rough. Some ring and longitudinal cracks were present. Standing water up to 3-inches deep was present along most of this section of pipe. An excessive amount of construction debris (concrete, burlap sacks filled with soil) was left after construction.

Location 83rd Avenue and Osborn

Date of installation 1984

Date of inspection July 30, 1987

Diameter 78-inch

This CIPP was selected because of the depth of the storm drain. In this section of pipe the height of cover was approximately 15 feet. The most distinguishing feature was an almost continuous hairline crack along the soffit of the pipe. This crack may have been a result of excessive cover or

backfilling trench before adequate strength was developed. Mortar lined corrugated metal pipe was also used in this section of trench and will be discussed next.

TYPE E (coated and mortar-lined CMP)

Location 83rd Avenue and Osborn

Date of installation 1984

Date of inspection July 30, 1987

Diameter 78 inch

This pipe was placed under approximately 15-feet of cover. Measurements of the horizontal diameter (79 inches) and vertical diameter (73 inches) indicate that approximately a 7% vertical deflection occurred relative to its nominal 78-inch diameter. This pipe had an obvious elliptical shape with cracking in the soffit of the pipe. Some of the mortar appeared ready to spall, however, repeated blows with a hammer failed to do any significant damage.

Location 75th Avenue and McDowell

Date of installation 1983

Date of inspection June 18, 1987

Diameter 78 inch

Ring cracks up to 1/8 inch wide were common in the mortar lining and some longitudinal cracking was present, however, this was relatively minor. Areas of potential spalling were identified and a hammer was used to try to dislodge sections of the lining, no damage occurred. Cracks reflected through mortar used to patch cracks. A pipe inspector with the City of Phoenix noted that the condition of the pipe was the same as at the manufacturing plant and cracking in the mortar liner did not appear to be worse in the field.

Location 67th Avenue, south of Buckeye

Date of installation 1986

Date of inspection June 18, 1987

Diameter 90 inch

Ring cracks up to 1/8 inch wide were common and in some cracks the metal was exposed. One section of pipe was damaged with many hairline cracks in the invert extending from one end of the section. This damage may have occurred

in transit or in field placement of this section of pipe. The mortar liner was still intact. In this section of pipe grade control was a problem. Water up to 6 inches deep was observed. Some of the joints were separated between 1 and 2 inches. Mortar used to patch cracks and joints had cracks reflected through and some spalling was observed.

Location Thomas and West Manor Drive

Date of installation 1986

Date of inspection June 25, 1987

Diameter 96 inch

This section of pipe contained 2 curves with a radius of 45 feet. Water up to 6 inches in depth was present in the curved section. The pipe was rough at joints in the curve with excessive joint separation; a larger radius curve may reduce this problem. Ring and longitudinal cracking appeared to be normal compared with other storm drains constructed with mortar lined CMP.

Location 12th Street and Virginia

Date of installation 1986

Date of inspection June 25, 1987

Diameter 96 inch

Sections of the pipe were in the same condition as at the manufacturing plant (typical ring and longitudinal cracks), while adjacent sections were a "spider web" of patch work. These sections were most likely damaged in transit or in field placement. A plastic resin material was used to patch cracks. This material was observed to separate from the pipe wall frequently. It appears that water seeps through cracks under the patch and causes a loss of adhesion.

REINFORCED CONCRETE PIPE (RCP)

Location 19th Avenue and Hadley

Date of installation 1960

Date of inspection July 2, 1987

Diameter 72 inch

This storm drain is in excellent structural condition but the hydraulics are

not adequate. The slope goes from very steep to a negative slope. Depth of water ranged from 4" to over 2 feet with a large amount of sediment present in low velocity regions. (In the high velocity region scour of the invert was not observed). The variation in slope may have been present upon completion of the project with additional settlement occurring later. This storm drain appears to carry water year around. River algae was rooted at some pipe joints where the mastic had been scoured away.

Location Van Buren, east of 51st Avenue

Date of installation 1983

Date of inspection July 9, 1987

Diameter 36 inch

The depth of water was approximately 2 inches and extended beyond sight distance, with no flow observed. This pipe was too small to inspect for any extensive distance. The pipe appears to be in good condition, although a hairline crack was observed in the soffit. No sediment or abrasion was noted.

Location 35th Avenue and Buckeye

Date of installation 1966

Date of inspection July 30, 1987

Diameter 63 inch

Depth of water was 3-4 inches, flowing approximately 3 fps. No sediment or debris was present. Grade control on this pipe was good. This pipe was in good condition.

PRELIMINARY RECOMMENDATIONS

1. Type F

Evidence of corrosion and perforation have been discovered in corrugated metal pipe utilizing the smooth steel inner liner. The corrosion was primarily along the invert of the pipe. The lockseam holding the lighter gauge inner liner to the outer shell is not watertight and therefore not acceptable in its present form. Water was observed between the unprotected inner surfaces of the inner liner and outer shell. A moratorium pending a more satisfactory protection of the metal is recommended.

2. CIPP

- a) Increase the inside diameter to be more representative of a wall roughness closer to $n=0.017+$, see calculations in appendix.
- b) Increase wall thickness to $(1/12 \times \text{I.D.}) + 1\text{-inch}$. Structural calculation shall be used to deviate from this recommendation.
- c) Do not allow CIPP in any soil environment that does not maintain vertical walls. Soil that will not maintain a vertical wall during construction is not acceptable.
- d) No backfill of CIPP will be permitted until 3000 psi concrete strength has been verified by laboratory test.
- e) CIPP less than 36 inches will not be allowed under permanent pavement or under future or presently unpaved roadway.
- f) Wall thickness, as measured in the Field, shall be shown at the correct location on the record drawings.
- g) Cast-in-place concrete pipe should not be installed in locations where a minimum of two pipe diameters of the storm drain (up to 12' maximum) cannot be maintained between the storm drain and other existing or proposed utilities, or designated utility corridors, except that the above clearances may be reduced to one storm drain pipe diameter (up to 6' maximum) in cases where the other utility is or will be installed not less than 6 vertical feet above the top of the storm drain.
- h) Maximum height of cover shall be fifteen (15) feet.

3. **TYPE E PIPE - Coated and Concrete-Lined Pipe**

- a) All angles needed for bends and curves shall be factory manufactured.
- b) The corrugated steel pipe shall continue to be hot-dipped galvanized and asphalt coated.
- c) All corrugated steel pipe used in storm sewers shall be a minimum of 14 gauge. 12 gauge or thicker may be warranted for relatively flat slopes and bends and curves.
- d) Cement enriched (1-1/2 sack/C.Y.) slurry bedding shall be utilized for CMP. This slurry shall be placed from the bottom of the pipe to the top of the pipe. A modified trench bottom and width will be specified.
- e) The durability of the concrete lining has not been verified in this area and appears to be relatively rougher than R.C.P. An increase of 6 inches I.D. is recommended (70 to 100-year service life assumed).
- f) Continuation of the leakage test is recommended.
- g) CMP should not be allowed without a free outfall.

4. **REINFORCED CONCRETE PIPE**

- a) Slurry bedding/modified trench should be offered as an option.
- b) Continue to design for "Unrestricted Trench Condition" and 130 lb/ft³ -

140 lb/ft³ backfill density.

c) RCP shall be utilized thru all major signalized 1/2 mile and mile intersections.

Control of pipe grade, quality and durability of patching materials used at joints and connector pipe connections to the storm drain appear to be the most common problems observed among all pipes inspected.

Pipe evaluation should be conducted once every two years. This results in the suppliers/contractors delivering the best possible product.

GB:jp/sdpipe

Use Manning Eq to determine the required pipe diameter for an increase in "n" compared with reinforced concrete pipe (n = 0.012)

Assume pipe is Flowing Full (R = D/4) and constant Q & S

$$V = \frac{1.486 (D/4)^{2/3} S^{1/2}}{n}; \quad Q = VA = \frac{1.486 (D/4)^{2/3} S^{1/2}}{n} \left(\frac{\pi D^2}{4}\right)$$

$$Q = \frac{0.463 D^{8/3} S^{1/2}}{n} \quad D = \left(\frac{Qn}{0.463 S^{1/2}}\right)^{3/8}$$

$$\frac{D_2}{D_1} = \left(\frac{n_1}{n_2}\right)^{3/8} \quad D_2 = D_1 \left(\frac{n_1}{n_2}\right)^{3/8}$$

n = 0.012 D ₁	0.014		0.017		0.024	
	D ₂	Avail	D	Avail	D	Avail
15	16	18	17	18	19	21
18	19	21	21	21	23	24
24	25	27	27	27	31	33
30	32	33	34	36	39	39
36	38	39	41	42	47	48
42	44	48	48	48	54	54
48	51	54	55	60	62	66
54	57	60	62	66	70	72
60	64	66	68	72	78	78
66	70	72	75	78	86	90
72	76	78	82	84	93	96
78	83	84	89	90	101	102
84	89	90	96	96	109	114
90	95	96	103	108	117	120
96	102	102	109	114	124	126