Overview of Polymer Coatings for Corrugated Steel Pipe in New York

ROBERT M. PYSKADLO and WALLACE W. RENFREW

ABSTRACT

Polymer-coated corrugated steel culverts were first installed in New York State in late 1977 and 1978 on two sections of the Genesee Expressway in Livingston County. Since then they have also been installed at nine other test sites to study the performance of polymer pipe, paved polymer pipe, and bituminous-coated-and-paved pipe under a variety of conditions. Two types of polymer pipe--laminated and roller coated--were used in all the installations. Although the evaluation is continuing, two tentative findings are discussed: stilling basins are an effective means of preventing early loss of polymer coating, and a roller-coated pipe is performing better than a laminated pipe at an aggressive site.

Currently, all corrugated steel pipe (CSP) used by the New York State Department of Transportation (NYSDOT) is galvanized with 2 oz/ft^2 of zinc on both sides to aid in preventing corrosion. In addition, asphalt coating and invert paving are used on many installations for further prevention of corrosion and abrasion. In recent years steel companies have begun producing CSP protected with polymer coatings. The manufacturers list the following advantages of polymer coatings:

1. They eliminate the need for asphalt and heated dip tanks;
2. They can be shipped as soon as fabricated;
3. Unlike asphalt-based coatings, polymer coatings do not stick or pull away during handling;
4. Different sizes of pipe can be nested for economical trucking;
5. Polymer coatings will not readily scar or scuff, thus eliminating the need for special handlabor in patching;
6. They perform better than asphalt under freeze-thaw cycles;
7. They are noncombustible;
8. Air pollution is eliminated during production; and
9. They provide superior resistance to abrasion and corrosion.

Polymer coatings are of two types--laminated and roller coated. Polymer is applied to galvanized steel in a sheet on laminated pipe and as a liquid on roller-coated pipe. There are six suppliers of polymer-coated pipe:

1. United States Steel Corporation ("Nexon"),
2. Inland Steel Company ("Blac-Klad"),
3. Bethlehem Steel Corporation ("Beth-Cu-Loy PC"),
4. Wheeling-Pittsburgh Steel Corporation ("PlastiCote"),
5. Republic Steel Corporation ("Polycote"), and
6. National Steel Corporation ("Duracoat").

The first two supply laminated pipe; the next four supply roller-coated pipe. Inland Steel and National Steel do not supply pipe to New York.

Polymer-coated pipe is available in 10- through 18-gauge thicknesses. Although it is generally supplied with a 10-mil coating inside and 3 mils outside, other coating thicknesses are available. It is available up to 144 in. in diameter.

Three series of installations of polymer-coated pipe have been made in New York; in chronological order they were as follows:

1. Polymer coatings were first used in New York in 1977 and 1978 on two sections of the Genesee Expressway in Livingston County between Dansville and Mount Morris. Beth-Cu-Loy PC was installed in one section, and Nexon was installed in the other. Some Nexon culverts have shown early signs of abrasion, but the Beth-Cu-Loy PC culverts are performing satisfactorily (under Research Project 154-1).
2. Because of the rapid deterioration of some Nexon culverts, use of polymer culverts in New York State has been curtailed. Because performance under the severe conditions on the Genesee Expressway may not be indicative of the performance of the polymer pipe at other sites, a new study (Research Project 154-2) was initiated that is examining the performance of roller-coated and laminated polymer pipe, paved polymer pipe, and bituminous-coated-and-paved pipe under a variety of conditions. Pipes were installed at nine sites during the 1981 and 1982 construction seasons.
3. In 1981 test plates of various materials were installed inside two test culverts on the Genesee Expressway because of the severe conditions prevailing there. Each culvert contained two sets of six plates each--Nexon, Beth-Cu-Loy PC, galvanized steel, aluminized steel Type 2, Galvalume, and aluminum.

In this paper the performance to date at these three series of installations is described. Installations 1 and 3 at the same site are discussed first, the nine installations for Project 154-2 are described next, and findings to date are then summarized.

GENESEE EXPRESSWAY

In early 1977 Region 4 of NYSDOT (administered from Rochester) requested the Technical Services Division of the department to suggest possible alternatives to bituminous-coated CSP for Section 7B of the Genesee Expressway between Dansville and Mount Morris (Figure 1), then in the late stages of design. This request resulted from expected high water velocities (15 to 24 ft/sec) and abrasive conditions that could render bituminous coating ineffective. Paving the invert was considered, but that would cover the corrugations, thereby increasing the already undesirably high water velocities. Corrugated aluminum pipe and concrete pipe with energy-dis-

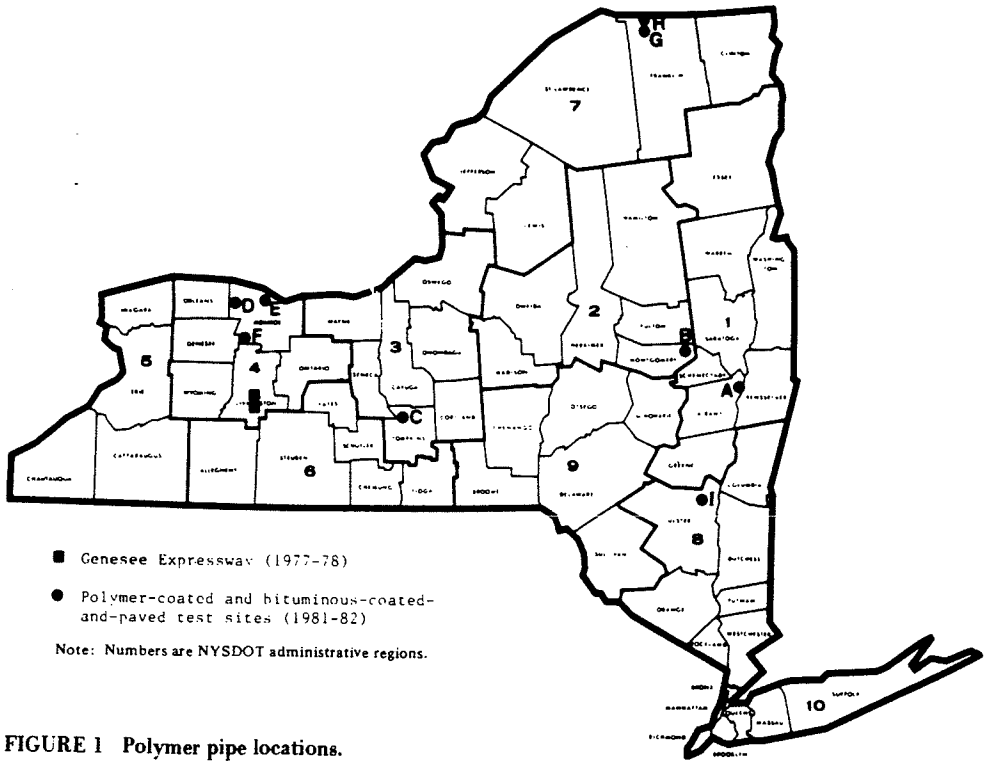

FIGURE 1 Polymer pipe locations.

sipating rings were considered but were subsequently found not to be feasible. Consequently, polymer-coated CSP was selected. The polymer coatings were 20 mils thick inside because of the expected severe conditions and 3 mils thick outside. Nexon-coated pipe was used on Section 7B and Beth-Cu-Loy PC was used on Section 7A (directly south of Section 7B).

Within a few months of installation the Nexon pipe indicated early signs of abrasion along the full length of several of the steeper-graded culverts, but the Beth-Cu-Loy PC culverts appeared to be performing satisfactorily. In a few of the Nexon culverts the coating began bubbling, and in one severe case it began to peel off in large sheets (Figure 2). Because of these problems, use of polymer coatings on culverts was suspended in New York State, and a study of the installations was initiated by the Engineering Research and Development Bureau under Research Project 154-1.

FIGURE 2 Peeling polymer coating (pipe 21).

These installations were first inspected in April 1978 while some culverts were still being installed. They have been inspected annually each fall, starting in 1978. Interim reports were published in 1979 and 1984 (1,2).

In April 1978 Engineering Research personnel first inspected several pipes in Sections 7A and 7B. Type and severity of deterioration were observed and the terrain was examined. As a result of that inspection, a tentative rating system was developed that was believed to encompass the various coating conditions. That system has since been revised slightly and is now as follows:

Rating	Description of Coating Condition
0	No abrasion of coating material
1	Isolated nicks and scratches
2	Frequent nicks and scratches with little or no bare metal
3	Frequent nicks and scratches with much exposed bare metal
4	Crests evenly abraded with coating peeling back (extent of exposed area recorded)
5	Coating peeling off in sheets with coating removed at crests of corrugations

The data in Table 1 summarize culvert conditions and the ratings received by each culvert during the first 6 years.

Section 7B (Nexon)

After initial inspections it appeared that the severity of deterioration could be related to inlet

TABLE 1 Summary of Culvert Condition

Pipe	Date Placed	Pipe Slope (%)	Inlet Slope (%)	Rating[a] 10/78	9/79	10/80	9/81	8 82	9/83
SECTION 7B									
3	8/31/77	3.9	3.3	0	0.5	0.5	0.5	0.5	0.5
4	8/31/77	3.1	3.0	0	0	0	0	0	0
5	8/21/77	4.1	9.0	0	1	1.5	3	3	3
10	8/22/77	10.8	14.2	1	2	2	2	2	2
11	9/30/77	8.2	44.0	2	2	2	2	2	2.5
13	9/13/77	10.3	–	2	5	5	5	5	5
14	9/1/77	11.1	11.0	0	0	0	1	1	1
15	4/27/78	10.3	12.6	0	1.5[b]	1.5[b]	1.5[b]	1.5[b]	1.5[b]
16	4/29/78	10.2	20.0	0	1	2	2	2	2
18	9/27/77	8.6	7.1	1	1	1	1	1	1
19	8/25/77	9.8	4.8	2.5[b]	5	5[c]	5	5	5
20	8/27/77	14.1	15.5	0	0	0	0	0	0
21	8/27/77	12.5	9.6	5[b]	5	5	5	5	5
22	8/30/77	15.9	15.2	3	3[b]	3[b]	3[b]	5	5
23	9/12/77	9.1	16.7	1	3	3	3	3	3
24	9/15/77	9.8	27.7	4[d]	4	4[e]	5[c]	5[c]	5
25	9/9/77	10.5	13.6	1	1	1	1	1	2.5
27	9/12/77	8.7	7.1	0	0	0	1	1	1
29	8/13/77	5.5	6.1	1.5	2	2	2	2	2
31	8/29/77	4.8	13.9	1.5	2	2.5	2.5	2.5	2.5
32	4/7/78	15.5	13.9	0	2	4[e]	4	5	5
36N	10/31/77	5.8	5.7	1	1	1	1	1	1
36S	10/31/77	5.8	5.7	0	0	0	0	0	0
44	10/15/77	6.7	20.0	1	1	1	1	1	1
46	10/29/77	13.6	4.4	0	0	0	0	0	0
46A	10/31/77	13.6	4.4	0	0	0	0	0	0
47	4/18/78	11.9	8.8	3	4	4[c]	4[e]	4	4
48	9/29/77	7.0	12.1	2	2	2	2	2	3
49	5/18/78	12.0	12.2	1	1.5	2	2	2	2
50	5/15/78	11.7	10.0	1	1	1	1	1	1
51	5/12/78	9.8	13.1	0	1	2	2	2	2.5
52	5/10/78	12.5	9.2	1	2	2	2.5	2.5	2.5
53	4/13/78	11.2	21.4	4[d]	4	4[c,e]	5	5	5
54	4/17/78	16.9	20.7	1	1	1	1	1	1
55	10/4/77	12.4	22.6	4[d]	4	4	4	4[e]	4
56	9/29/77	16.3	23.5	2	4	4	4	4[e]	4
57	4/21/78	12.5	26.9	0	1	1	1	1	1
58	10/27/77	12.8	18.5	1	1	1	1	1	1
59	10/21/77	12.7	16.1	4[d]	4	4	4	4	4
60	10/28/77	12.6	43.6	4[d]	4	4[e]	5	5	5
61	10/11/77	11.6	5.0	2	3	3	3	3	3
62	10/5/77	13.4	12.6	0	1	1	1	1	1
64	8/31/77	11.2	6.1	0	0	0	0	0	0
66	9/1/77	11.5	5.9	2[b]	5	5	5	5	5
68	9/2/77	10.1	11.1	4[d]	4	4	5	5	5
69	9/13/77	13.5	24.4	4[d]	4	5	5	5	5
76	8/20/77	4.4	3.8	0	0	0	0	0.5	0.5
77	8/19/77	3.3	3.8	0	0	0	0	1	1
78	8/27/77	2.5	3.7	0	0.5	0.5	0.5	0.5	0.5
80	9/15/77	7.5	–	0	0.5	0.5	0.5	0.5	0.5
80A	–	–	–	0[b]	0	0	0	0	0
81	10/6/77	2.1	–	0	0	0	0	0	0
82	8/11/77	9.7	8.3	0	0.5	0.5	0.5	0.5	1
83	8/22/77	9.3	11.8	1	1.5	2	2	2	2
84	8/30/77	7.8	20.8	1	2.5[b]	2.5[b]	2.5[b]	2.5[b]	2.5
92	10/7/77	3.0	12.3	1	1	1	1	1	1
95	10/15/77	15.5	13.2	4[d]	4	5	5	5	5
SECTION 7A									
46	10/11/77	14.0	8.9	2	2	2	2	2	2
55	11/28/77	9.8	–	2	2	2	2	2	2
56	11/22/77	11.4	9.6	2	2	2	2	2	2
67	8/18/77	4.2	15.8	1	1	1	1	1	1
90[f]	10/4/77	8.0	30.7	1	1	1	1	1	1
91	9/14/77	10.0	5.4	1	1	1	1	1	1
92	8/19/77	6.0	7.7	2	2	2	2	2	2
95	10/4/77	6.4	11.2	0	0	0	0	0	0
96	9/8/77	7.0	20.0	0.5	0.5	0.5	0.5	0.5	0.5
97	8/25/77	8.0	10.4	0.5	0.5	0.5	0.5	0.5	0.5
99[g]	10/12/77	1.5	7.4	0	0	0	0	0	0
102	10/13/77	13.9	5.6	0	0	0	0	0	0
103	10/18/77	7.0	6.4	1	1	1	1	1	1
104	10/6.77	9.0	8.3	0.5	0.5	0.5	1.5	1.5	1.5

[a] Rating key: 0 = no abrasion, 1 = isolated nicks and scratches, 2 = frequent nicks and scratches with little or no bare metal, 3 = frequent nicks and scratches with much exposed bare metal, 4 = crests evenly abraded with coating peeling back (abrasion area recorded), and 5 = coating peeling off in sheets with crests abraded.

[b] Polymer coating bubbled.

[c] Rust beginning to form under coating.

[d] Measured abrasion was 1 ft x 0.5 in. in pipe 24, 2 ft x 0.5 in. in pipe 53, 1 ft x 0.5 in. in pipe 55, 1 ft x 0.25 in. in pipe 59, 2 ft x 0.75 in. in pipe 60, 16 x 0.5 in. in pipe 68, 2 ft x 1 in. in pipe 69, and 16 x 1 in. in pipe 95.

[e] Measured abrasion was 28 x 1 in. in pipe 24, 1 ft x 1 in. in pipe 32, 1.5 ft x 0.75 in. in pipe 47, 3 ft x 2 in. in pipe 53, 1.5 ft x 1 in. in pipe 55, 1 ft x 0.5 in. in pipe 56, 1 ft x 1.5 in. in pipe 59, and 3 ft x 2 in. in pipe 60.

[f] Last 20 ft is asphalt-coated pipe.

[g] First 9 ft of inlet coated and paved (alligatored), last 5 ft at outlet coated and paved (0.5 ft gone).

slope, pipe slope, and channel-bedload material. However, after closer examination it was noted that unless there was a shale bedload, most culverts were performing satisfactorily. The data in Tables 2 and 3 list culverts that are and are not subjected to shale bedloads.

TABLE 2 1983 Ratings of Culverts With and and Without Bedload Shale

Culverts With Bedload Shale		Culverts Without Bedload Shale	
Culvert No.	Rating[a]	Culvert No.	Rating[b]
5	3	3	0.5
19	5	4	0
22	5	10	2
23	3	11	2.5
24	5	13	5[d]
25	2.5[c]	14	1
31	5	15	1.5
32	5	16	2
47	4	18	1
48	3	20	0
50A	1[e]	21	5[d]
51A	2.5[e]	27	1
52A	2.5[e]	29	2
53	5	36N	1
55	4	36S	0
56	4	44	1
57	1[c]	46	0
58	1[c]	46A	0
59	4	49	2
60	5	54	1
61	3	62	1
66	5	64	0
68	5	76	0.5
69	5	77	1
95	5	78	0.5
		80	0.5
		80A	0
		81	1
		82	0.5
		83	2
		84	5[d]
		92	1

[a]22 of 25 (88 percent) have bad ratings (greater than 2).

[b]28 of 32 (87.5 percent) have good ratings (2 or less).

[c]Much vegetation in channel, indicating low flow.

[d]Coatings delaminated or bubbled.

[e]Small drainage area between inlet and outlet of upstream pipe.

Twenty-eight of the 32 culverts (87.5 percent) that do not have shale bedloads are rated 2 or less. (Those so rated are considered to be in very good condition.) Three culverts (numbers 13, 21, and 84) have failed in a different manner. The coatings have delaminated and bubbled, presumably because of a material or manufacturing defect. The fourth culvert (number 11) is now rated 2.5. This pipe has a steep inlet slope and rip-rap. There may be shale under the rip-rap.

Twenty-two of the 25 culverts (88 percent) that have shale bedloads are rated greater than 2. Two of the three culverts that received very good ratings of 1 had much vegetation in the channel (which indicates low flow), but the other had a small drainage area between the inlet and the outlet of the upstream pipe. The three culverts with ratings of 2.5 (numbers 25, 51, and 52) are in the "gray" area between good and bad culverts and can be explained in the same way.

Section 7A (Beth-Cu-Loy PC)

Although several culverts located in this section do have shale in their streambeds, the initial alarm caused by the premature abrasion of the Nexon-coated pipes (Section 7B) caused Region 4 personnel to require stilling basins at inlets where shale was present. As noted in the data in Table 1, there has been no progressive deterioration of the Section 7A culverts. It also can be noted that there have been no problems with bubbling or delamination of the Beth-Cu-Loy PC coating. A direct comparison of the two products was not possible because of the stilling basins and because the pipes could not be swapped. (Initially it was hoped that some Nexon could be used on the Beth-Cu-Loy PC project and vice versa. This could not be done.)

Test Plates

Because of the dissimilarity of the terrain between Sections 7A and 7B and the previously mentioned stilling basins in Section 7A, it was decided that, as part of a larger study, 2- by 4-ft test plates of both polymer materials in the worst 48-in. culvert in each section would be installed. In October 1981 two sets of both polymers, three metallic coatings for steel (galvanized, Galvalume, Aluminized Type 2), and aluminum were installed. The sites chosen were known to be among the most aggressive from each section. Figure 3 shows the types of material, the order of installation, and the plate numbers. The plates were last inspected in September 1983. The following is a brief summary of the findings for the polymers (the metallic plates are not discussed in this paper):

1. Section 7B (Nexon site): Nexon plates: number 1 plate--middle 12-in. path rated 3, 6-in. path on both sides rated 2, and one lock-seam rated 4 (16- by 0.5-in. peel-back); number 2 plate--20-in.-wide

TABLE 3 Polymer-Coated and Bituminous-Coated-and-Paved Test Sites

Site[a]	NYSDOT Region	County	Location	Contract	NYSDOT Drainage No.	Diameter (in.)	Type	Date Installed
A	1	Albany	12th Avenue, Watervliet	D96755	DS9	36	Storm sewer	6/7/82
					DS11	42	Storm sewer	6/7/82
B	2	Montgomery	Rte 30, Amsterdam	D96526	DN2	36	Cross culvert	7/29/81
C	3	Tompkins	Warren Road, Ithaca	D96676	DR4	36	Cross culvert	7/9/81
D	4	Monroe	North Pond Road, Greece	D96680	D204	36	Storm sewer	5/27/81
E	4	Monroe	Redman Road, Brockport	D96679	DR36	36	Storm sewer	6/9/81
F	4	Monroe	Rte 36, Caledonia	D96505	D17	42	Storm sewer	7/6/81
G	7	Franklin	Water Street, Ft. Covington	D96565	DR22	48	Cross culvert	6/16/81
H	7	Franklin	Rte 37, Ft. Covington	D96881	DR8	42	Cross culvert	5/7/82
I	8	Ulster	Rte 375, Woodstock	D96919	DR6	42	Cross culvert	6/19/82

[a]See Figure 1.

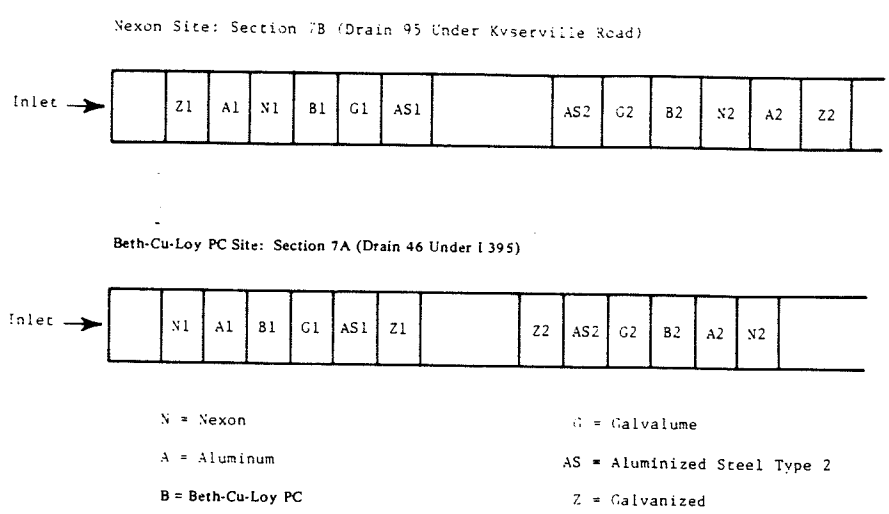

FIGURE 3 Experimental plates installed in October 1981.

path rated 3.5, two crests rated 4. Beth-Cu-Loy PC plates: number 1 plate--20 in. wide rated 2; number 2 plate--18 in. wide rated 2 with slight peel-backs (8 by 0.25 in.) on two lock-seams.

2. Section 7A (Beth-Cu-Loy PC site): Both sets of polymers rated 0.

Some observations can be made after only 2 years of exposure at these aggressive sites:

1. As expected, the 7B site is much more aggressive than the 7A site;
2. The Nexon plates are performing the same as the Beth-Cu-Loy PC plates at the 7A site, where presumably no shale is going through the pipe;
3. At the 7B site the Beth-Cu-Loy PC plates are performing better than the Nexon plates; and
4. The Beth-Cu-Loy PC plates at the 7B site are worse than any of the Beth-Cu-Loy PC pipes at the 7A site; even though the plates and the worst 7A pipe are rated 2, there are no peel-backs in the 7A pipe.

POLYMER-COATED AND BITUMINOUS-COATED-AND-PAVED TEST SITES

After two inspections (1978 and 1979) of the Genesee Expressway, it appeared that the early failures were limited to pipes with steep slopes and shale bedloads or pipes with presumed material or manufacturing defects. In addition, newly developed CSP design and service life criteria based on the results of another Engineering Research study (3) precluded the use of 14- and 16-gauge asphalt-coated-and-paved pipe in the southern half of New York State. If polymer-coated pipe ultimately proves to be superior to asphalt-coated-and-paved pipe, those gauges may again be used. Because New York State had few installations of polymer-coated pipe and none included asphalt-coated-and-paved pipe or either type of polymer-coated pipe (laminated or roller-coated) under the same conditions, it was impossible to obtain direct comparisons. Thus Research Project 154-2 (4) was initiated to compare polymer-coated and paved polymer-coated CSP with asphalt-coated-and-paved CSP, and to gather information on various site conditions and their effects on polymer coatings.

Four of the six suppliers of polymer-coated pipe are participating in this project. (Because Inland Steel and National Steel do not sell culvert in New York, they are not included.) Details of substitutions are as follows:

1. The steel companies agreed that because the three that produce roller-coated polymer pipe are supplied polymer by the same manufacturer, only one roller-coated pipe is needed in each installation. Beth-Cu-Loy PC was used. Nexon was the laminated pipe because it is the only one supplied in New York.
2. Pipes were rolled and stockpiled in a company's yard so that they would be available when needed.
3. All pipes were 14-gauge steel, thus allowing substitution for either 14- or 16-gauge pipe (10- and 12-gauge polymers were not manufactured when this project began, and 18-gauge is not used for cross culverts).
4. Three diameters were stockpiled: 36, 42, and 48 in. These are the most common diameters used for 14- and 16-gauge pipe. Most pipe larger than 48 in. is 12 gauge, and anything smaller than 36 in. is difficult to inspect.
5. Each test culvert contains one 10-ft roller-coated section, one 10-ft roller-coated and asphalt-paved section, one 10-ft laminated section, one 10-ft laminated and asphalt-paved section, and at least 20 ft of asphalt-coated-and-paved pipe.

Because of the new design criteria and the fact that new construction is currently limited in New York State, it has become increasingly difficult to find suitable test sites. To date, installations have been made at nine sites. These are shown and identified by capital letters in Figure 1 and listed in Table 3. They are being inspected each year, and none has shown signs of defects to date.

FINDINGS

Although research is continuing on polymer coatings to determine long-range performance, these tentative findings can be stated:

1. If a stream channel appears to have an excessive amount of abrasives (especially shale), use of stilling basins is an effective means of preventing early coating loss;
2. Unless the Nexon laminated-polymer pipe can be manufactured without a tendency to delaminate, it should not be used; and
3. At an aggressive site, Beth-Cu-Loy PC pipe is performing much better than Nexon.

ACKNOWLEDGMENT

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REFERENCES

1. R.M. Pyskadlo. Polymer Coatings for Corrugated Steel Pipe. Special Report 64. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, Oct. 1979.
2. R.M. Pyskadlo and W.W. Renfrew. An Overview of Polymer Coatings for Corrugated Steel Pipe in New York. Special Report 79. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, July 1984.
3. P.J. Bellair and J.P. Ewing. Metal-Loss Rates of Uncoated Steel and Aluminum Culverts in New York. Research Report 115. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, Aug. 1984. (Note: Also see paper by Bellair and Ewing elsewhere in this Record.)
4. R.M. Pyskadlo and J.P. Ewing. Performance of Polymer-Coated and Bituminous-Coated-and-Paved CSP. Study Proposal for Research Project 154-2. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, May 1980.

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Durability of Asphalt Coating and Paving on Corrugated Steel Culverts in New York

WALLACE W. RENFREW

ABSTRACT

The metal-loss rate of uncoated corrugated steel pipe in New York State has been well-defined. To complete a design procedure for coated-and-paved corrugated steel pipe, paving life also had to be defined. A method developed to determine the effectiveness of paving by measuring the longitudinal percentage of exposed metal is described in this paper; 294 coated-and-paved pipes were surveyed and measured. In New York State paving has effectively protected round pipe on the state system for 30 years and pipe-arches for at least 20 years. Beyond 30 years, paving is ineffective in protecting any corrugated steel pipe.

Corrugated steel is one of the most commonly used materials for culverts in New York State and throughout the country. There has been concern for many years about the durability of this material. New York recently completed a long-term durability study of uncoated galvanized corrugated steel pipe (1). [All corrugated steel pipe (CSP) is galvanized with a coating of zinc to improve its resistance to corrosion.] This study provided corrosion (metal-loss) rates for uncoated CSP. By using these corrosion rates, many CSPs would not last the desired design life. Thus additional protective measures are needed.

One of the most common protective measures is an asphalt coating, which is applied by dipping the pipe sections in a tank of hot asphalt. The resulting coating dries to a thickness of about 0.05 in. on both the interior and exterior of the pipe. Some states use the coating mainly as a protection for the exterior or soil side of the pipe. New York has found little soil-side corrosion in its studies. A previous New York study (2) indicated that interior asphalt coatings alone are not effective in preventing corrosion, and New York has not used them alone for the past 17 years.

Azar (3) found that coating gave an additional 8 years of service. A Kansas study by Worley (4) of 500 coated pipes revealed that inside coatings were good on only 12 percent of 3- and 4-year-old pipes and on none of the older ones. It was concluded that Kansas should discontinue the use of coatings because they are of little value. A survey of the other 49 states in the summer of 1978 (5) indicated that few states use coated pipe, and those that do use it assign only 7 to 9 additional years of life for the coating.

In addition to asphalt coating, paving of asphalt can be applied to the interior of the pipe. This is normally at least 0.125 in. thick over the crests of the corrugations, thus providing a smooth surface over the length of the pipe. It is generally placed in the lower quadrant of the pipe to protect the invert (i.e., the lowest point where water flows through the pipe).

Paving is applied to a coated pipe by partially blocking its ends and pouring asphalt in the bottom. The pipe is rotated and the process is repeated until the bottom quarter of round pipes and the