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DEPARTMENT OF TRANSPORTATION
Bureau of Materials and Physical Research

FINAL REPORT

STORM SEWER PLASTIC PIPE EVALUATION
Project IHD-18

By

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A Product Evaluation Project by
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in cooperation with
U. S. Department of Transportation
Federal Highway Administration

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16. Abstract

This report describes laboratory and field tests of Acrylonitrile-Butadiene-Styrene (ABS) composite plastic sewer pipe installed in three experimental storm sewer projects. The purpose of the study was to evaluate ABS composite sewer pipe (also known as ABS Truss Pipe) in terms of its structural performance, durability, abrasion resistance, economy and ease of installation.

Laboratory test results indicate that the structural strength of plastic pipe compares favorably with that of concrete pipe. However, physical characteristics of the plastic pipe were affected by UV when exposed outdoors for long periods of time.

After over three years of service, the average deflection for the 15-inch-diameter pipe was about 1 1/2 percent of it's internal diameter, and for the 12-inch size it was about 1.0 percent.

The cost of the Truss Pipe was competitive with other storm sewer materials normally used in Illinois.

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INTRODUCTION

Purpose

This study was undertaken in 1973 to evaluate Acrylonitrile-Butadiene-Styrene (ABS) composite plastic sewer pipe in terms of its structural performance, durability, abrasion resistance, economy, and ease of construction in three experimental plastic pipe storm sewer projects.

The ABS composite pipe used was manufactured by the Armco Steel Corporation, Springfield, Illinois under the trade-name Armco Truss Pipe. It was claimed to be competitive in cost with other pipe materials normally used for storm sewer construction in Illinois, thereby providing a healthy opportunity for competition between the manufacturers of flexible and rigid storm sewer pipes.

This report covers the laboratory test data, field test data, and conclusions derived from the study after three years of service.

Preliminary Evaluation

The Armco Truss Pipe (ASTM D 2680 Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Composite Sewer Piping) is an extruded ABS plastic pipe consisting of outer and inner walls separated and supported by webs in a truss configuration. The voids between the webs are filled with a lightweight foamed concrete to provide continuous support between outer and inner walls and to control web buckling. Essentially, Truss Pipe is a flexible pipe, the physical properties of which are described in terms of stiffness and deflection rather than in crushing strength.

The first installation of Truss Pipe in the United States was made in 1963 at Huntington, West Virginia. Since then, over 100 million feet of pipe have been installed in 49 states as gravity sanitary and storm sewers.

Truss Pipe is available in nominal diameters of 8, 10, 12 and 15 inches. It has excellent flow characteristics due to its very smooth inner surface that also tends to reduce sliming on the invert. The pipe sections are 12 1/2 feet in length, which is about three times longer than standard lengths of rigid pipe, thus several joints are eliminated. The joints are chemically welded to insure watertight joints throughout the system.

Scope

This study includes experimental projects selected in three different Highway Districts for the purpose of evaluating the performance of the ABS Truss Pipe. The projects consist of 8-, 12-, and 15-inch size Truss Pipe for a total length of about 18,600 feet.

Prior to the selection of the experimental projects, a comprehensive laboratory testing program was conducted to determine the physical properties and structural integrity of Truss Pipe as produced and after prolonged exposure to sunlight. The laboratory test results were compared to the ASTM minimum strength requirements for concrete pipe.

Deflection tests were conducted on the three experimental projects immediately after the pipes were installed, and later on a yearly basis in the designated test sections in one project.

Conclusions

Based upon laboratory test results and field data collected for three years following construction, the conclusions derived from the study are the following:

1. The ABS Truss Pipe compares favorably with the structural strength of concrete pipes normally used in storm sewer construction.

2. The physical properties of the ABS Truss Pipe were affected by exposure to the sun when the pipe was stored outdoors for long periods of time. The change seems to have been associated with the embrittlement of the ABS plastic due to UV radiation. This was accompanied by an abrupt increase in pipe stiffness from the initial minimum of 200 psi coupled with a drastic decrease of deflection with rupture values below the 7 1/2 percent specified minimum after a short period of exposure outdoor.

3. The results of the laboratory tests on specimens stored in the moist room seems to indicate that once the Truss Pipe is installed, its physical properties should remain essentially unchanged through the design life of the installation.

4. No abrasion was noted on the invert of the Truss Pipe after three years.

5. The Truss Pipe should be tested for acceptance as near as possible to the date of installation. The pipes should be re-tested if not installed within one construction season.

6. Average deflections of about 1 1/2 percent for the 15-inch size pipe and 1.0 percent for the 12-inch size were recorded in the test sections. These deflections are well below the allowable 5 percent of the pipe's internal diameter specified for the plastic pipe.

7. The Truss Pipe was competitive in cost with other storm sewer materials normally used due to its longer laying lengths, light weight, easy handling installation, and maintenance free operation.

Recommendation

Based on the satisfactory laboratory test results and the excellent performance of Truss Pipe in the field after over 3 years of service, it is recommended that the ABS Truss Pipe be approved for permissive use as an optional material in storm sewer construction.

LABORATORY TEST PROGRAM

Armco Truss Pipe was specified under ASTM D 2680, Acrylonitrile-Butadiene-Styrene (ABS) Composite Sewer Piping. This specification covers ABS composite pipe, joints, and fittings for use in gravity non-pressure sanitary and storm sewers and drainage installations.

Because of concern for both the structural and material integrity of the ABS pipe, the Central Bureau of Materials laboratory initiated in 1971 preliminary physical testing of the pipe to determine its vertical deflection, rupture, and pipe stiffness in accordance with ASTM D 2680. Also, comparison of the ABS pipe and concrete pipe was made to determine their relative ultimate load-carrying capacities.

Although ABS plastics seem to have well balanced physical characteristics, they are affected by exposure to sunlight. Additional laboratory tests were conducted in 1973 to determine the effect of exposure to sunlight on the physical properties of ABS pipe. The tests were conducted on one 12 1/2-foot section of 8-inch size pipe.

The section was sawed into 6-inch-long specimens as required by the testing procedure. Some specimens were immediately tested as control specimens and the rest were individually stored on the roof of the laboratory and tested at three-month intervals.

In 1974, another section of ABS pipe was obtained from the manufacturer's plant in Springfield to conduct more tests on specimens stored outdoors. After cutting, the specimens were tied together end to end so that only the end specimens received direct sunlight on the invert. Testing was done every three months on the pair of end specimens progressing towards the center.

An additional section of pipe was obtained later to conduct tests simulating the moist environment of the pipe in the trench. The specimens were stored in the moist room and tested about every three months to determine any change in physical properties.

LABORATORY TEST RESULTS

Preliminary physical testing of the ABS Truss Pipe was initiated in 1971 with samples of 8-, 10-, 12-, and 15-inch size pipes submitted by the Armco Steel Corporation. The samples were tested to determine physical properties in accordance with ASTM D 2680. A summary of the test results is shown in Table 1.

From Table 1, all the pipes, except one, deflected at least 7 1/2 percent without rupture; and all pipe stiffness determinations, except two, exceed the 200 psi minimum for each diameter.

In addition to the testing of the ABS pipe, a comparison was made of its strength and the ASTM specifications for concrete pipe with classifications C-14-SS, C-14-ES, C-76-II, C-76-III, C-76-IV, and C-76-V. Any discrepancy in the comparison was in the type of test performed and the unit of measurement. Since the ABS pipe was tested by the parallel plate method the results were those at rupture in pounds per lineal foot of pipe. The ASTM values of the

TABLE 1

RESULTS OF PHYSICAL TEST*
(ABS Truss Pipe)

Nominal Diameter (in.)	Load at 5% Deflection (lb./ln. ft.)	Load at Rupture (lb./ln. ft.)	Pipe Stiffness (psi, ≥ 200)	Vertical Deflection w/o Rupture (%, ≥ 7.5)
8	1400	1640	292	10.2
	1650	2480	344	12.3
	1330	2060	277	11.8
	1780	2140	371	9.2
	1740	1940	361	8.4
	1540	2160	321	9.0
Avg.	1572	2070	328	10.1
10	1260	1980	210	18.3
	1500	2480	250	10.8
	1180	2020	197**	27.6
	1700	2560	283	10.6
	1760	2700	293	10.5
	1860	2600	310	9.9
Avg.	1544	2390	257	14.6
12	2360	3140	328	11.1
	2140	2480	297	11.2
	2040	2380	283	6.3**
	2020	2880	281	11.3
	2080	2940	289	10.4
	1960	2600	272	9.8
Avg.	2100	2736	292	10.0
15	2360	3900	262	11.5
	2500	3580	278	9.7
	1780	3060	198**	11.8
	1960	3260	218	10.3
	1960	3240	218	10.3
	2020	2780	224	9.7
Avg.	2096	3303	233	10.6

*ASTM D 2680
**Out of tolerance

concrete pipe were those specified for minimum strength when tested by the 3-point bearing method in pounds per lineal foot and pounds per lineal foot per foot diameter (D-load) of pipe.

Table 2 shows the comparison of strength between the ABS pipe and concrete pipe. The data indicate that the ABS pipe compares favorably with the concrete pipes.

Results of the series of tests conducted from 1973 to 1975 on 8-inch size specimens stored outdoors are shown in Figures 1 and 2.

ASTM D 2680 specifies that the ABS composite pipe "shall deflect at least 7.5 percent without rupture of either inner or outer wall. The computed pipe stiffness at 5 percent vertical deflection shall equal or exceed 200 psi for each diamter". Figure 1 indicates that the pipe deflection at rupture was initially 12 percent. After 3 months of exposure outdoors, the deflection at rupture dropped to 6 percent, which was below the minimum requirement of 7.5 percent. At 24 months, the pipe ruptured when the deflection was only 4 percent. The loss of flexibility seems to be caused by the embrittlement of the outer surface of ABS. Figure 2 shows the rapid increase of the pipe stiffness (PS) from the initial 331 psi to 415 psi after 3 1/4 months of exposure outdoors. At 14 months of exposure, the PS value was exceptionally high at 500 psi. However, the pipe ruptured when the deflection was 3 percent, indicating that the ABS plastic was very brittle.

Another series of tests was conducted from 1974 to 1977 to verify the results of the earlier tests. This time the specimens were arranged and held together in the order they were sawed from a section of pipe. The procedure allowed each specimen to receive the same amount of UV on the outer shell while only the end specimens received UV on the invert portion of the pipe. Testing was done each time on a pair of end specimens until all succeeding specimens were tested. The results are plotted in Figures 3 and 4. Figure 3 indicates that the initial pipe deflection at rupture was 30 percent. After 3 months of exposure outdoors, the deflection at rupture dropped to about 11.0 percent, which is still above the minimum requirement of 7 1/2 percent. Thereafter, the deflection gradually decreased in value until about 24 months when it started to fall below the required 7 1/2 percent. The PS values shown in Figure 4 exceeded the required minimum of 200 psi with the data indicating an initial PS of 270 psi increasing to about 300 psi at 24 months of exposure outdoors. The results of the second series of tests were encouraging and probably are realistic as to what was happening to the pipe in the field. However, it should be recognized that the ABS plastic degrades and becomes brittle when exposed outdoors for long periods of time.

In conjunction with the study on the effects of UV on the ABS plastic, a series of tests on samples stored in the moist room was also conducted from 1974 until 1977. The test results are shown in Figures 5 and 6. From Figures 5 and 6 the initial pipe deflection at rupture was about 10 percent and the PS value was 320 psi. These values did not change significantly after 36 months of testing. The data seem to indicate that the physical properties of Truss Pipe at the time of its installation will remain unchanged or nearly so for the design life of the installation.

TABLE 2

COMPARISON OF TRUSS PIPE AND CONCRETE PIPE STRENGTHS

Nominal Diameter (inch)	ABS TRUSS PIPE TEST RESULTS (1971) Load at Rupture* (lb./lin. ft.)	C-14-SS 3 Edge Bearing (lb./lin. ft.)	C-14-ES Method (lb./lin. ft.)	CONCRETE PIPE ASTM SPECIFICATIONS Minimum Strength Requirement (1971) C-76 Class II D-Load** (lb./lin. ft./ ft. dia.)	C-76 Class III D-Load** (lb./lin. ft./ ft. dia.)	C-76 Class IV D-Load** (lb./lin. ft./ ft. dia.)	C-76 Class V D-Load** (lb./lin. ft./ ft. dia.)
8	2070	1300	2000	-	-	-	-
10	2390	1400	2000	-	-	-	-
12	2736	1500	2250	1500	2000	3000	3750
15	3303	1750	2750	1500	2000	3000	3750

*Average of 6 tests for each diameter
**D-Load to produce the ultimate load

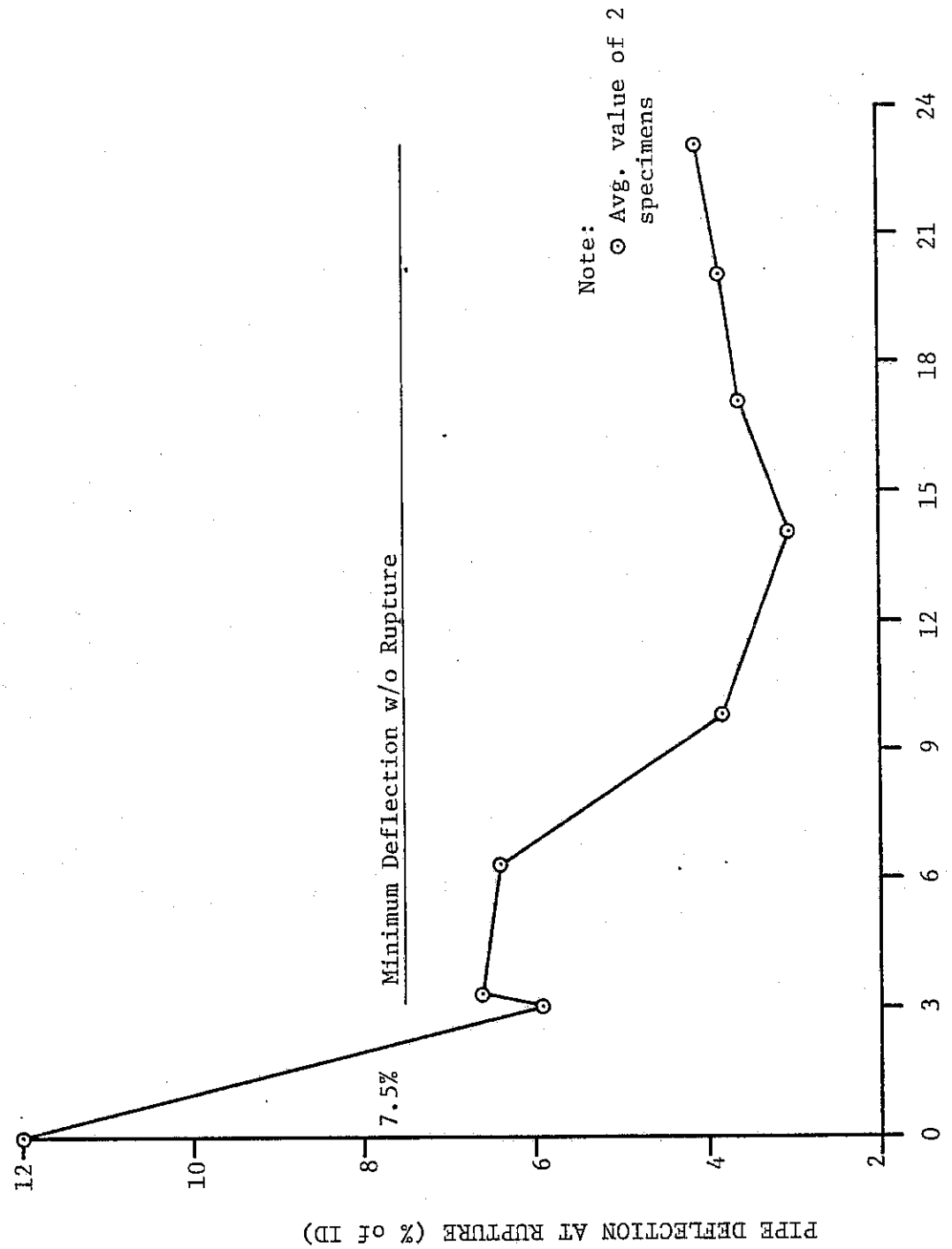

Figure 1. 8-Inch Truss Pipe Deflection-Time Relationship (1973-75 outdoors)

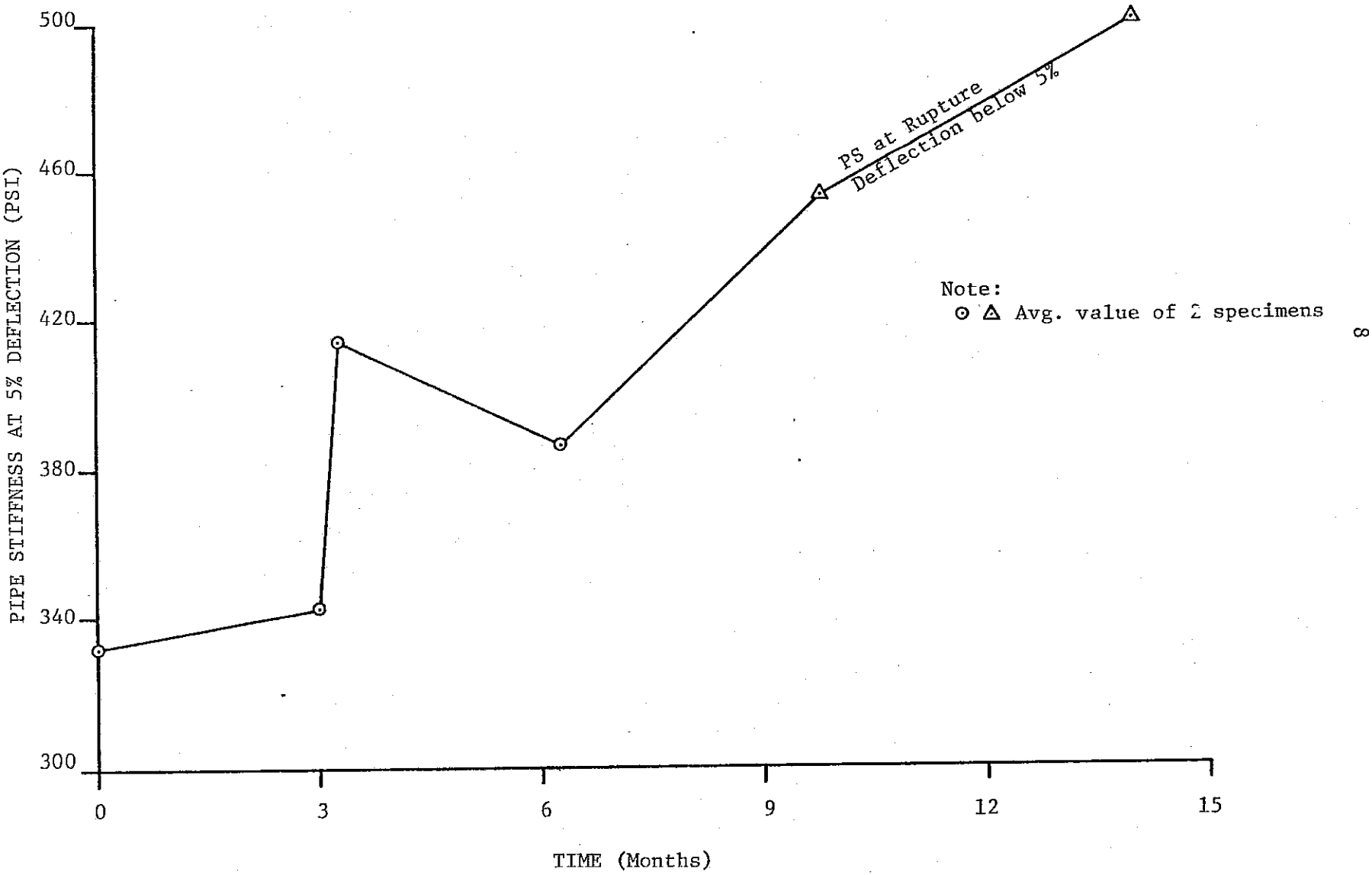

Figure 2. 8-Inch Truss Pipe Stiffness-Time Relationship (1973-75 outdoors)

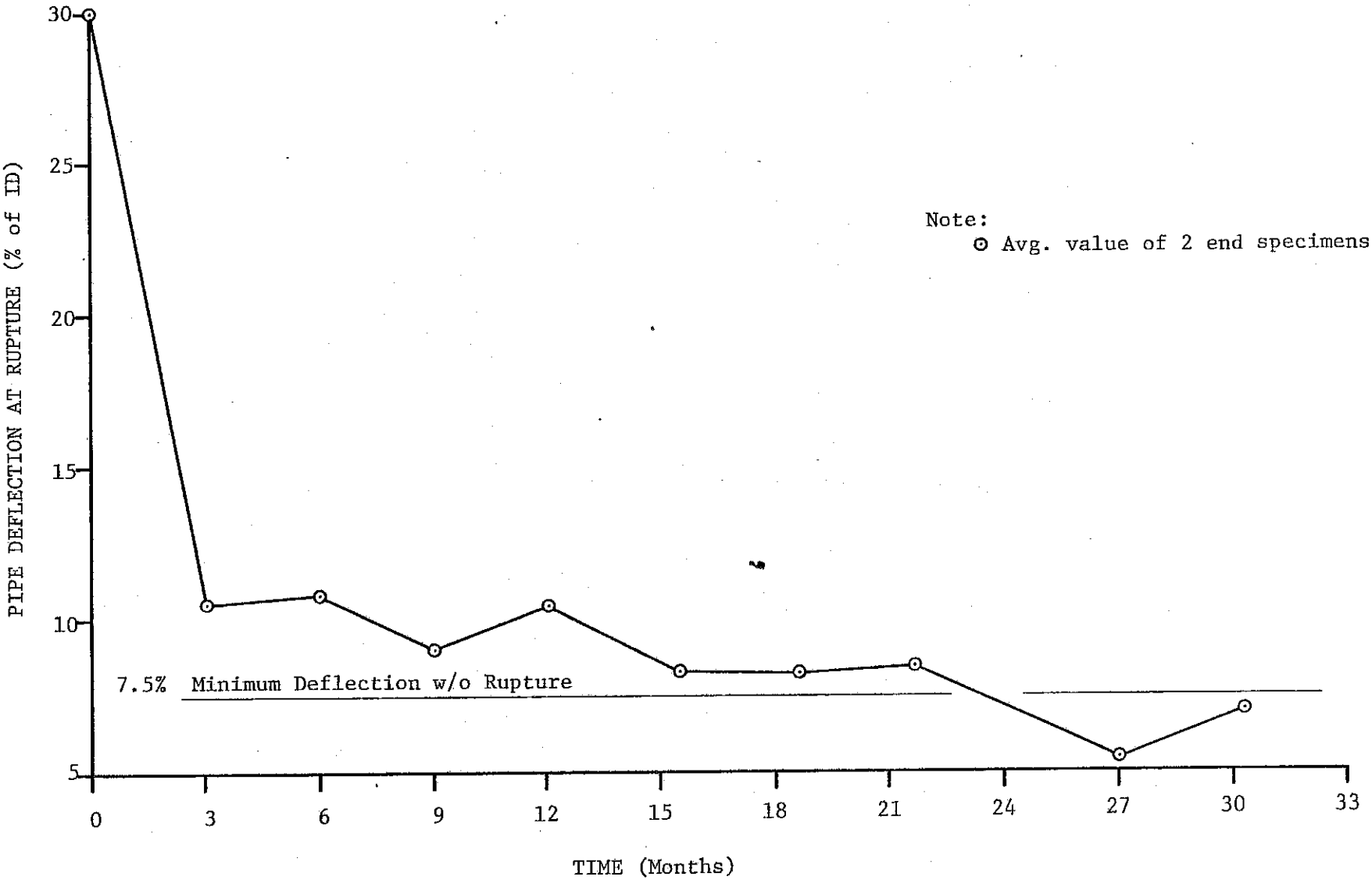

Figure 3. 8-Inch Truss Pipe Deflection-Time Relationship (1974-77 outdoors)

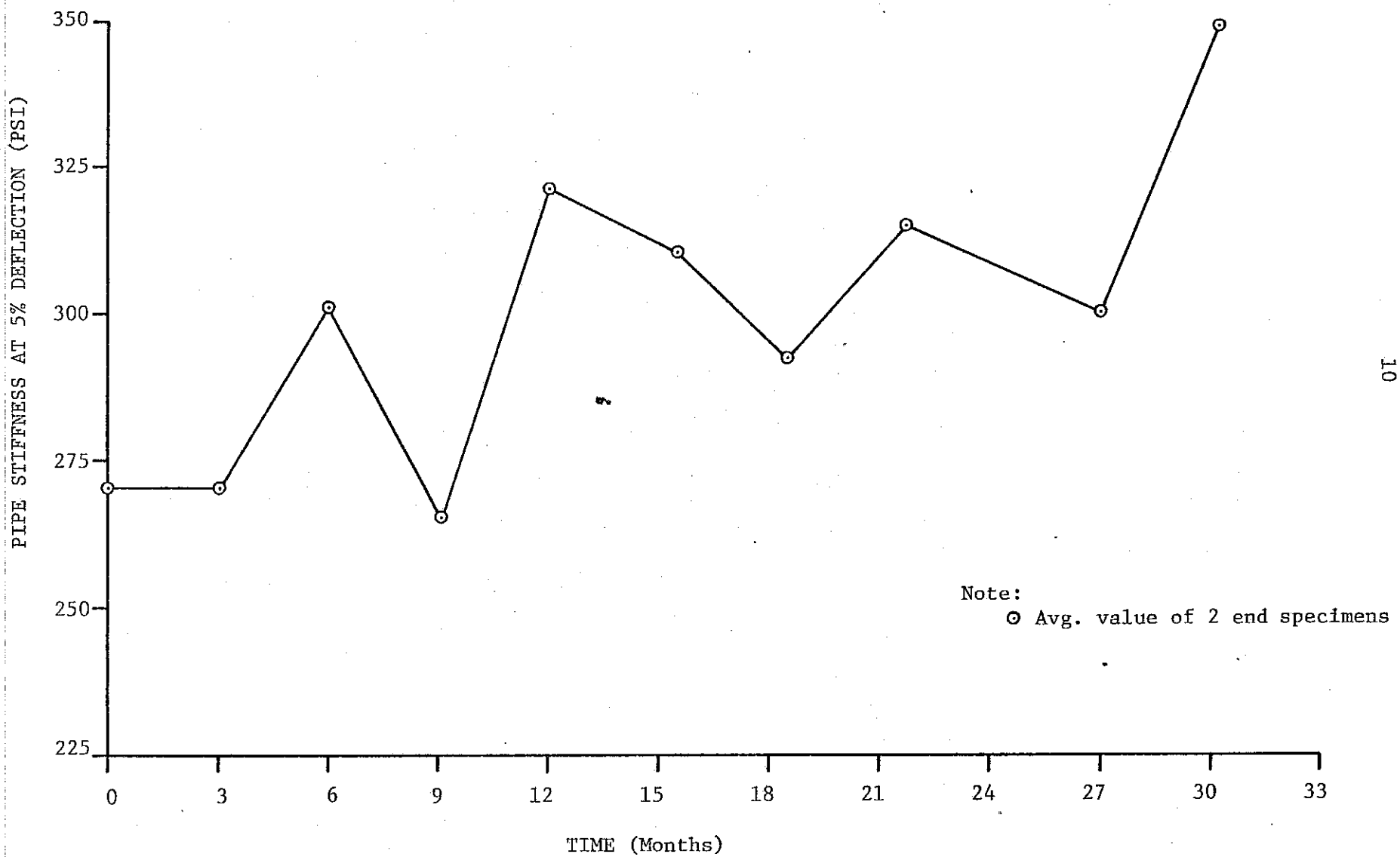

Figure 4. 8-Inch Truss Pipe Stiffness-Time Relationship (1974-77 outdoors)

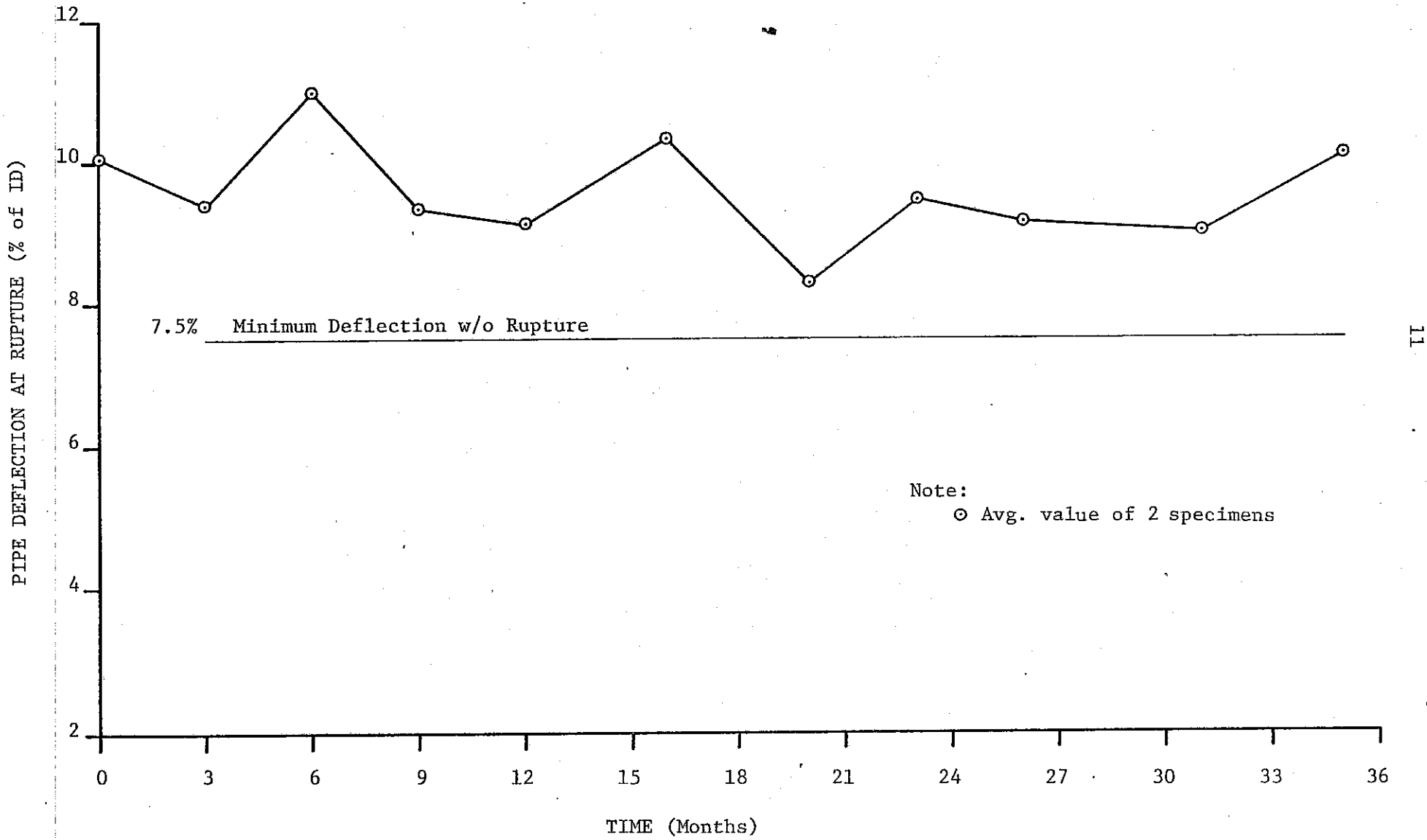

Figure 5. 8-Inch Truss Pipe Deflection-Time Relationship (1974-77 moist room)

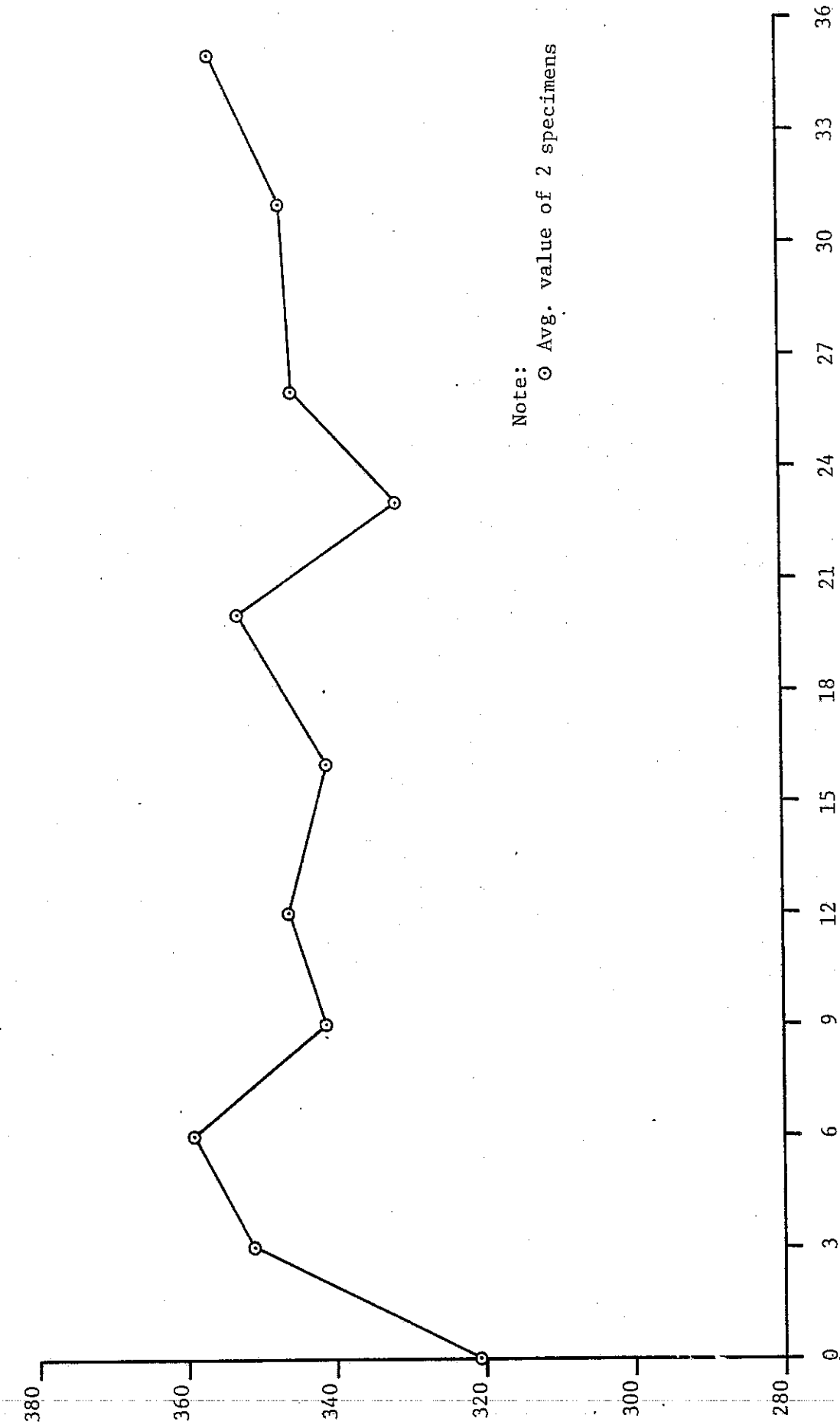

Figure 6. 8-Inch Truss Pipe Stiffness-Time Relationship (1974-77 moist room)

Based on the above, it may be necessary that testing of ABS pipe be done as near as possible to the date of installation. If the pipe is not installed within one construction season after testing, it should be sampled again and re-tested for acceptance.

FIELD TEST INSTALLATIONS

Three experimental projects were selected for the purpose of evaluating the field performance of ABS Truss Pipe. The three projects are identified as follows:

1. FA Route 119, Project T-5059(2), Section 113R-2, Champaign County. This project is located on US Route 136 (Champaign Avenue) between Murray Road and Garrad Street in Rantoul and contains approximately 6600 feet of 8-, 12-, and 15-inch size pipe.

2. FA Route 13, Project U-235(22), Section 34-1, St. Clair County. This project is located on US Route 50 between Bunkum Road and Illinois Route 159 in Fairview Heights and contains approximately 9,400 feet of 8-, 12-, and 15-inch size pipe.

3. FA Route 84, Project FU-122(19), Section 135Z-(I, W, RS-1), Fulton County. This project consists of the improvement of Locust Street, between Avenue "B" and Fifth Avenue; Fifth Avenue between Locust Street and Elm Avenue; Main Street between Ash Street and Locust Street; all in the City of Canton. This contract contains approximately 2650 feet of 12- and 15-inch size pipe.

Laying of the pipe was started in the spring of 1974 and most of it was completed by the fall of 1975. The average bid prices were $13.00 per foot for the 8-inch size; $17.00 per foot for the 12-inch; and $20.00 per foot for the 15-inch. These prices were competitive with other pipe materials normally used for storm sewer construction.

Deflection tests were conducted in about 8,670 feet of pipe or 47 percent of the total (18,600 feet) installed. The test involves the use of a deflectometer device that measures the vertical deflection of the pipe as it moves through the pipe. The deflection is detected by strain gages attached to a spring steel arm probe that contacts the inside top of the pipe to record any change in the vertical diameter.

A typical installation consists of digging a trench about 2 1/2 feet wide and the required depth by means of a mechanical backhoe. The trench bottom was prepared with a sand bedding to set the pipe to the required alignment and elevation as shown in Figure 7. The Truss Pipe was then lowered to the prepared bed, and sand backfill was dumped and compacted around the pipe to the elevation of the top of the pipe as shown in Figure 8. A primer and the ABS plastic cement were applied liberally to the outside of the spigot and inside of the coupling. The joint was then made by shoving the pipe home with a slight rotation until the coupling met the stencil marking on the pipe as shown in Figures 9 and 10. The remainder of the trench was backfilled to the natural line or finished surface. The backfill consists of the excavated material deposited in such a manner as to not damage the pipe.

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Pages 14 and 15 ----- "Colored Pictures" of Plastic Pipe

have been retained by "Doy" Mascunana.

1-10-80 - gwm

Negatives and Plates of above pictures in metal cabinet.

FIELD TEST RESULTS

Post-construction deflection tests conducted randomly in the three experimental projects indicated deflections up to a maximum value of 2 percent of the internal diameter. These deflections were within the allowable 5 percent deflection specified in the Special Provisions of the contract.

The Champaign County project was selected as the ideal test section for continued observation because of its wide range of fill heights, easy accessibility, minimum requirement for traffic protection, and clean inverts. The test sections consist of 12-inch and 15-inch ABS Truss Pipe for a total length of about 1,023 feet. The sections were tested initially in 1974 and 1975, and later in 1976 and 1977. The deflection test results shown in Table 3 indicate an average deflection of about 1 1/2 percent for the 15-inch size pipe and 1 percent for the 12-inch size.

Since all of the observed initial deflections have been well within the specification requirements, it was evident that the quality of construction conforms satisfactorily with the requirements of the Standard Specifications.

IMPLEMENTATION STATEMENT

ABS Truss Pipe is manufactured in accordance with ASTM D 2680 "Acrylonitrile-Butadiene-Styrene Composite Sewer Piping". It consists of concentric tubes or walls separated and intergrally braced across the annulus by webs in a truss configuration. The voids between the webs in the resultant annular space are filled with lightweight concrete to control web buckling. The Truss Pipe is essentially a flexible pipe, the strength properties of which are described in terms of stiffness and deflection rather than in ultimate crushing loads.

After installation, and prior to acceptance of the Truss Pipe, the vertical deflection should be checked. In any area where deflections exceed 5 percent of the internal diameter of the pipe, the trench should be re-excavated and the backfill recompacted in accordance with the Standard Specifications. If the pipe has been damaged by overdeflection, the pipe should be removed and replaced in full accordance with the Standard Specifications.

The Truss Pipe is acceptable as an optional pipe material for storm sewer construction.

TABLE 3
DEFLECTION TEST RESULTS
(Rantoul, Champaign County)

Station	to	Station	Length (Ft.)	Pipe Size	Fill Height (Ft.)	Date of Test	Avg. Deflection (%)
Lt. 2259 + 65		Lt. 2261 + 50	185	12-SST_2	5	8/27/74 8/20/76 8/2/77	0.08 0.08 0.39
Lt. 2261 + 50		Lt. 2263 + 00	150	12-SST_2	5	8/27/74 8/20/76 8/2/77	0.24 0.05 0.62
Lt. 2264 + 75		Lt. 2265 + 90	115	15-SST_2	4.5	8/27/74 8/23/76 8/2/77	1.09 1.47 1.28
Rt. 2288 + 40		Rt. 2289 + 54	110	15-SST_2	8-17	8/27/74 8/20/76 8/2/77	0.03 0.71 0.75
Rt. 2288 + 68		Lt. 2288 + 58	63	15-SST_2	4-9	11/6/74 8/23/76 8/2/77	0.10 1.11 1.15
Lt. 2288 + 58		Rt. 51 + 10	64	12-SST_2	4-6.5	11/6/74 8/23/76	0.10 0.12
Rt. 51 + 10		Rt. 51 + 80	58	12-SST_2	6-6.5	11/6/74 8/23/76 8/2/77	0.09 0.22 0.16
Rt. 2292 + 00		Rt. 2294 + 10	206	12-SST_2	3-8	10/29/75 8/20/76 8/2/77	0.70 0.25 0.70
Rt. 2288 + 68		Rt. 2289 + 44	72	15-SST_2	10-12	8/20/76 8/2/77	1.16 1.24
		Total Test Line -	1,023				