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16. ABSTRACT

Synopsis

Waterstops are cast into concrete structures across construction and expansion joints to prevent leakage of water through the joints. The material, to function properly, should flex or deform sufficiently to permit movement of the concrete due to temperature, shrinkage, and minor settlements, and be strong enough to withstand the stresses that develop from such movements without causing failure in the concrete; and under all conditions maintain a watertight seal at the joint.

For California highway work the 6" solid dumbbell type, made of GRS rubber, is normally specified and used although a variation known as the split type but otherwise the same has been used on several contracts.

However, the development of polyvinyl chloride plastic waterstops of various compositions and designs made it desirable to investigate by means of tests the suitability of these new types for use in highway structures and to compare them with the waterstops currently used.

By letter of September 22, 1955, to F.N. Hveem, Mr. A.L. Elliott of the Bridge Department requested that this department undertake such an investigation.

Accordingly, a series of comparative tests was conducted, using the 6" rubber dumbbell type of waterstop as a standard for comparison.

The procedure used and the information accumulated to date are discussed in this report.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

REPORT ON COMPARATIVE TESTS OF VARIOUS MATERIALS USED AS WATERSTOP.

57-21

November 15, 1957

State of California
Department of Public Works
Division of Highways
Materials and Research Department

November 15, 1957

Lab. Project Auth. 53-R-6061

Mr. F. W. Panhorst
Assistant State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

REPORT

ON

COMPARATIVE TESTS OF VARIOUS

MATERIALS USED AS WATERSTOP.

Study made by . . . . Structural Materials Section
Under general direction of . . . . J. L. Beaton
Work supervised by . . . . H. F. Kuhlman
Report prepared by . . . . H. F. Kuhlman, W. Faist, V. M. Sayers

Very truly yours,

F. N. Hveem
Materials and Research Engineer

cc: JWTrask
ALElliott
IOJahlstrom

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SYNOPSIS

Waterstops are cast into concrete structures across construction and expansion joints to prevent leakage of water through the joints. The material, to function properly, should flex or deform sufficiently to permit movement of the concrete due to temperature, shrinkage, and minor settlements, and be strong enough to withstand the stresses that develop from such movements without causing failure in the concrete; and under all conditions maintain a watertight seal at the joint.

For California highway work the 6" solid dumbbell type, made of GRS rubber, is normally specified and used although a variation known as the split type but otherwise the same has been used on several contracts.

However, the development of polyvinyl chloride plastic waterstops of various compositions and designs made it desirable to investigate by means of tests the suitability of these new types for use in highway structures and to compare them with the waterstops currently used.

By letter of September 22, 1955, to F. N. Hveem, Mr. A. L. Elliott of the Bridge Department requested that this department undertake such an investigation.

Accordingly, a series of comparative tests was conducted, using the 6" rubber dumbbell type of waterstop as a standard for comparison.

The procedure used and the information accumulated to date are discussed in this report.

INTRODUCTION

The first phase of the testing program involved performing the standard ASTM mechanical tests required by the current Division of Highways waterstop specifications: tensile strength, Shore durometer hardness, elongation, and oxygen aging. The results afforded a comparison of the basic mechanical properties of the materials. However, the test requirements of the current specifications were originally intended to apply to the standard 6" dumbbell waterstop, made of rubber, while the study discussed herein involved waterstops of different shapes and included polyvinyl chloride plastics as well as rubber. This opened the question of whether the ASTM tests cover durability of nonrubber compounds.

Therefore it was felt that tests which simulated conditions in the structure and reflected the probable behavior of the materials when subjected to the joint movements and stresses developed when they were in use had to be devised and performed.

Accordingly specimens of the various types of waterstop were cast in concrete blocks and tests were performed that subjected the specimens to the following types of stress:

1. Shear

2. Bending stress (beam action)

3. Pull, tending to result in the material slipping out of the joint (to evaluate bonding to the concrete)

Also, the ability to prevent leakage was tested by means of a hydrostatic test.

Detailed descriptions of the test specimens and the tests are given under "Test Specimens" and "Test Procedures".

CONCLUSIONS AND RECOMMENDATIONS

The program of comparative tests involved a comparison of shape designs as well as of materials. Certain specific types of waterstop which are either presently or potentially available in the commercial market were used for the tests. The effect of the design of each specific type, as well as of difference in mechanical properties of the materials, must be considered in evaluating the results.

Some general indications brought out by the test results are as follows:

1. This study disclosed no evidence to indicate any superiority of plastics over rubber and that there is some question whether plastics are yet equal to rubber for use as waterstop material in highway structures.

2. All the types tested indicated adequate resistance to water leakage.

3. In general, the plastic waterstops tested did not deform as readily as the rubber. Therefore, where excessive deflections (2" to 3" movement in any direction) are anticipated, then the plastic type of waterstop now available commercially should not be used.

4. The over-all behavior of plastic specimen 4C (Durajoint Type 4) in the tests indicates good resistance to water leakage, good bond to concrete, and ability to withstand small joint movements without tearing of the waterstop or damage to the concrete. On the basis of these results, further evaluation by means of a trial installation would appear to be justified.

5. If new plastic formulations with improved deformation characteristics are developed, additional tests should be performed to evaluate them.

6. The plastic types tested did not comply with the requirements of the current specifications, so the specifications would have to be modified if it were decided to permit the use of any of the plastic waterstops now available commercially.

TEST SPECIMENS

The types of waterstop tested were as follows:

No. 1: 6" GRS rubber dumbbell waterstop, split lengthwise along edge. See Figure 1. This specimen was made of GRS rubber 6" wide conforming to California Standard Specifications dated August 1954. The web was 3/8" thick, and the beads along the edges were 3/4" in diameter. One half the width was split along the center line. (The split section is claimed to simplify the installation.)

No. 2: This is similar to No. 1 except that it is solid rather than split and is the type most used in California construction. See Figure 1.

No. 3: See Figure 2 (a). This specimen was made of polyvinyl chloride. The designation is "Durajoint Standard Type 3".* The width was 4".

Nos. 4A, 4B, and 4C: See Figure 2 (b). These were similar to No. 3, except that they were "Standard Type 4"*, 6" in width. These waterstops are recommended by the manufacturer for use in temperate climates.

Nos. 5A, 5B: See Figure 2 (c). These were similar to No. 3, except that they were "Arctic Type 4"*, recommended by the manufacturer for use in cold climates.

No. 6: See Figure 3. This was a polyvinyl chloride waterstop known as "Labyrinth Type B-4"*, with 4 ribs and 6" in over-all width.

No. 7: See Figure 4. This specimen was similar to No. 6, except that it was designated as "Type B-3"*, had 3 ribs, and was 3 1/2" wide.

Standard ASTM specimens were prepared from the various types for the ASTM tests. For the other tests, full-width specimens of various lengths (as described under "Test Procedures") were used.

* Manufacturer's designations.

TEST PROCEDURES

The tests performed were as follows:

Standard ASTM Tests:

Standard ASTM tests, required by the current specifications for rubber waterstop, were performed on specimens of each type of waterstop. The test values obtained included Shore durometer hardness, tensile strength, percent elongation, and tensile strength and elongation after oxygen bomb aging.

All test specimens were cut in the direction of extrusion and from random portions of the samples.

The aging test was done in an oxygen bomb with 300 psi pressure at room temperature. The aging period varied from 5 to 46 days.

The test results are shown in Figure 16.

Vertical Shear:

Full-width specimens 12" long were cast in concrete to form a unit composed of three blocks joined together with waterstop. The test load was applied vertically to the center block. The vertical deflection was measured with reference to the two outer blocks. See Figure 5.

The results are shown in Figure 17 and Figure 18.

Tensile Stress in Bending (beam action):

A full-width specimen 12" long was cast in concrete to form a unit made up of two blocks joined together with waterstop. This unit was supported as a simple beam, and the test load was applied vertically at the center. Vertical deflection was measured at the center of the span.

Figure 6 shows a typical test assembly.

The test results are shown in Figures 19 and 20.

Bond Between Waterstop and Concrete:

A full-width specimen of waterstop 20" long was cast in concrete so as to form a unit made up of two blocks joined together with waterstop.

The direction of tensile stress was longitudinal to the axis of the waterstop (and assembled unit), so that it would tend to pull the waterstop out of the blocks.

See Figure 7 for details.

The results are shown in Figures 21 and 22.

The "deflections" are indicated by relative movement of the blocks, rather than by gage marks on the specimen, so they may include some slipping as well as elongation. The "ultimate" values indicate the point at which the load dropped off, indicating no further effective resistance to slipping. The results should be considered as being comparative only of over-all resistance to slipping.

This comparison is based on total load (applied to equivalent contact areas) required to cause free movement out of the joint.

Hydrostatic Test:

Considerable information on watertightness tests performed by other agencies was available in the following reports:

(a) Electrovert Limited.

Report of Investigation No. 56203, Hydrostatic Pressure Tests on "Durajoint" Waterstops, Ontario Research Foundation, Toronto.

(b) Laboratory Tests of Rubber Waterstops, Report No. M-76, U. S. Bureau of Reclamation.

(c) Laboratory Tests of Rubber and Metal Waterstops, Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers.

The results of the tests covered by these reports indicate that commercially available rubber and plastic waterstops have sufficient resistance to water leakage for any conditions likely to be encountered in service.

Tests of a few of the samples tended to confirm these results, so the tests described were not performed on all the samples.

For the tests that were performed, the waterstop specimen was embedded in a concrete block with a cavity in the center connected to the top and bottom by openings so that the center portion of the waterstop was free to deflect and could be subjected to hydrostatic pressure from one side.

The specimens were subjected to hydrostatic pressure equivalent to a head of 100 feet. They deflected to about two inches without rupture or leakage.

DISCUSSION

The results of the Standard ASTM mechanical tests, included in the current specifications for rubber waterstop, are shown in Figure 17.

The current Division of Highways specifications for rubber waterstop require an ultimate tensile strength of 2500 psi minimum, an elongation of 425% minimum, and a durometer hardness of 50-60.

Three plastic samples had the required tensile strength, but all the plastics tested were well below the specified minimum elongation.

The relative inability to deform indicated by these results was significant in that the shear and beam test results reflected the same characteristic.

The plastics tested also had higher durometer hardness exceeding the presently specified maximum of 60.

In the oxygen bomb test the plastic specimens tested gave results that indicated comparatively good resistance to aging.

The results of the shear test are shown in the tabulation, Figure 17, and the graph, Figure 18.

Rubber specimens 1 and 2 and plastic specimen 4C (Durajoint Type 4) deformed sufficiently to permit vertical deflections of 3 to 4 inches without tearing of the waterstop or showing distress in the concrete. The other Durajoint specimens (of varying formulations) tore or pulled out at lower deflections. There was also some concrete cracking. See Figures 11 and 12.

Durajoint specimen No. 3 and Labyrinth specimen No. 7 slipped out of the joint at relatively low deflections. This was attributed to narrow widths plus relative inability to deform.

In the case of Labyrinth specimen No. 6, the concrete failed at a deflection of 0.48" and a total indicated load of 1800 pounds.

This appears to be due to two factors:

1. The design of the waterstop was such as to produce a joint that was susceptible to shear failure of the concrete in the bond areas.

2. The comparative inability of the waterstop to deform under load intensified the effect of the above factor (No. 1).

The effect of this design factor is discussed further with reference to the beam test.

The results of the test in which the assembled unit was subjected to simple beam loading are shown in Figures 19 and 20.

This test also indicated a marked difference in deformation characteristics between the GRS rubber waterstops and the plastic waterstops. The rubber waterstops deformed readily and permitted a deflection of about 2" before slipping out of the joint. Plastic specimens 4A, 4B, 4C, and 5A permitted vertical deflections of 1" to 1.25" and then failed by tearing. The stress deflection relationships are shown graphically in Figure 20.

The photograph, Figure 9, shows a typical tearing failure. Figures 8 and 14 show the deformation of the rubber waterstops in this test.

Figures 10 and 13 show the concrete failures that occurred with the Labyrinth waterstops.

The failure of the concrete was apparently due to the design of the waterstop, which resulted in a reduction of the concrete section resisting stress at the joint, plus the strong bond and relatively slight deformation of the waterstop. It will be noted that in the case of the narrow Labyrinth waterstop the concrete failure occurred at a deflection of only 0.13" and an indicated test load of only 100 pounds. For the wider specimen the deflection was slightly over 1" at failure.

The results of the "slippage" or "bond" test are shown in Figures 21 and 22. Test specimen 4C (Durajoint Standard Type 4) withstood a total indicated stress of 1100 pounds without slipping out of the joint. Figure 15 shows this specimen in the testing machine.

The results indicated that the type of plastic waterstop represented by specimen 4C has excellent bond to the concrete.

As previously stated, reference data and partial tests indicated that <u>all</u> of the waterstops tested have sufficient resistance to water leakage for any conditions likely to occur in service. No leakage occurred with hydrostatic heads of up to 100 feet.

Several different plastic formulations were offered for test by the vendors during the course of the study. The waterstop represented by test specimen 4C (Durajoint Standard Type 4) is said by the vendor to be a stock item, representative of what will henceforth be commercially available from the manufacturer.

SUMMARY

The test results can be summarized as follows:

1. In the standard ASTM tests the plastic specimens showed lower tensile strengths and elongations than the rubber specimens, but their aging properties, as indicated by the oxygen aging test, appeared comparable to those of the rubber waterstops. The lesser ability of the plastic waterstops tested to deform under load without rupture was reflected in the results of the tests simulating job conditions as will be discussed later in this report.

2. All the waterstops tested appeared to have satisfactory resistance to water leakage under conditions comparable to those encountered in service.

3. Plastic test specimen 4C (see Figure 2) demonstrated excellent bond to concrete in comparison with the other specimens (plastic <u>and</u> rubber).

4. In the tests which involved application of shear and bending stresses at the joints, the rubber waterstop tended to deform and pull out of the joints. The plastics deformed only slightly and tended to fail by tearing. The tearing may have been due in part to the thinner sections used. In two cases in which plastics were used, the concrete failed.

   In the shear test, plastic specimen 4C pulled out of the joint at nearly the same stress at which the rubber waterstop pulled out.

As is discussed in detail under "Conclusions", the test results are indicative but not necessarily conclusive. Some inferences which can be derived from the results are:

1. The comparative suitability of the plastics for use as waterstop would depend on:

   (a) the composition and properties of the plastic waterstop used. There was considerable variation in properties among the plastics. In order to use a plastic material, it would be necessary to specify the desired physical and mechanical properties.

(b) the movements and stresses developed in the structure. If the anticipated differential movements were to be high enough to rupture the plastic or cause failure of the concrete at the joint, the rigidity of the plastic waterstops might be detrimental. (Under these circumstances, the rubber waterstop would deform and eventually pull out rather than fail.)

If the anticipated joint movements are to remain within safe limits as indicated by the test results, the sealing and bond characteristics of the plastic waterstops probably would be satisfactory, and they might even be comparable or superior to rubber in long time performance.

2. Several different plastic formulations with varying properties were offered by vendors for test during the project. It is possible that still other formulations might be developed which would embody more favorable deformation properties and retain satisfactory bond, aging, and sealing characteristics.

3. Results on some of the plastic specimens, such as No. 4C, indicate that further studies and tests would be justified -- perhaps even trial installations.

4. Additional studies would be necessary in order to determine definitely whether specification revision to permit use of one or more of the plastic types is advisable, and to develop suitable specifications to this end.

The details of the specimens and procedures and additional discussions of the results together with test data are given in other sections of this report.

APPENDIX

Figure 1 Photograph of test specimens

Figure 2 Photograph of test specimens

Figure 3 Photograph of test specimens

Figure 4 Photograph of test specimens

Figure 5 Photograph of test equipment and assembly

Figure 6 Photograph of test equipment and assembly

Figure 7 Photograph of test equipment and assembly

Figure 8 Photograph of test results

Figure 9 Photograph of test results

Figure 10 Photograph of test results

Figure 11 Photograph of test results

Figure 12 Photograph of test results

Figure 13 Photograph of test results

Figure 14 Photograph of test results

Figure 15 Photograph of test results

Figure 16 ASTM mechanical and physical test data

Figure 17 Shear test tabulation

Figure 18 Shear test graph

Figure 19 Beam test tabulation

Figure 20 Beam test graph

Figure 21 Bond test tabulation

Figure 22 Bond test graph

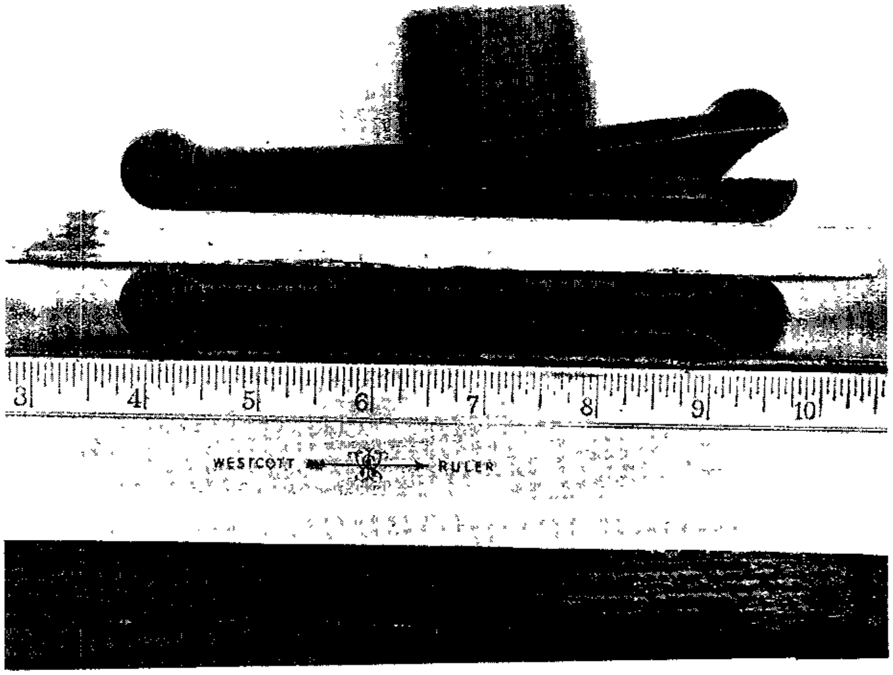


Figure 1

Rubber Waterstops, split and solid.

Top - Specimen 1

Bottom - Specimen 2

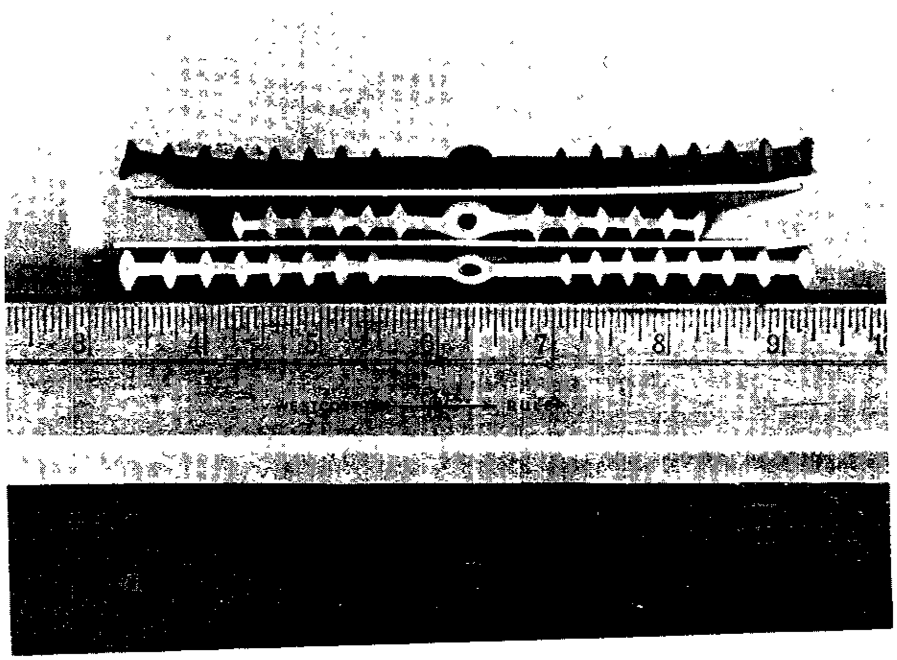


Figure 2

"Durajoint" Waterstops

(a) Middle specimen: 4" "Durajoint Standard Type 3" (Specimen 3)

(b) Bottom specimen: "Standard Type 4" 6" wide (Specimens 4A, 4B, 4C)

(c) Top specimen: "Arctic Type 4" (Specimens 5A, 5B)

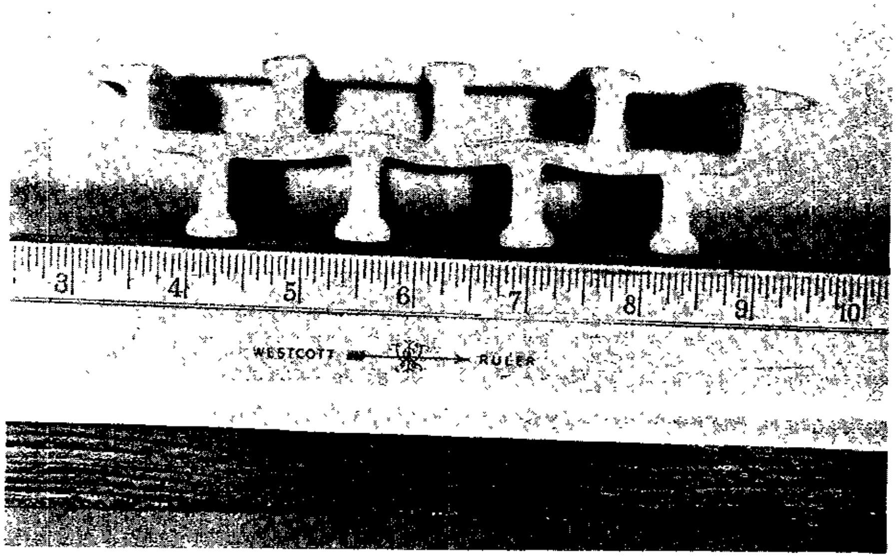


Figure 3

"Labyrinth Waterstop"
6" wide

Specimen 6

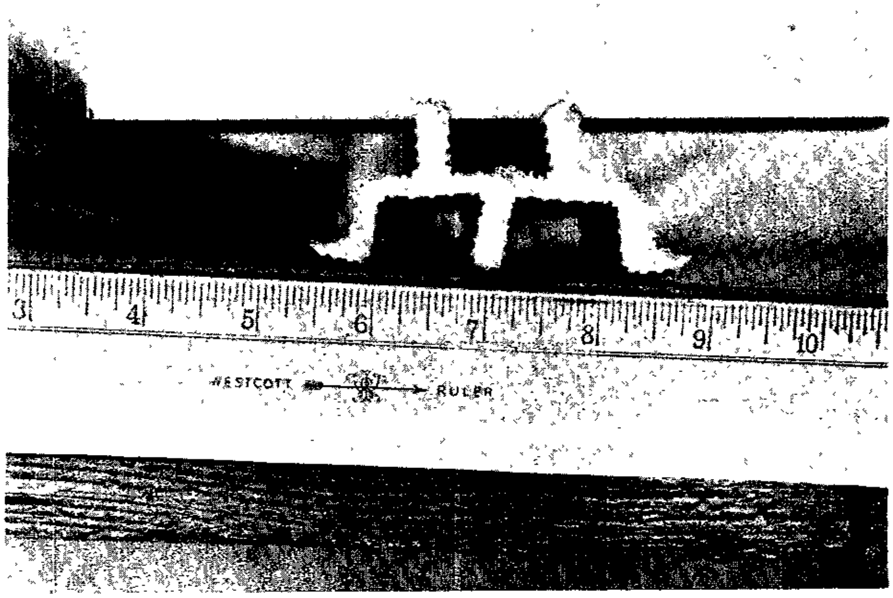


Figure 4

$3\frac{1}{2}$" Labyrinth
Waterstop

Specimen 7

Figure 5

Shear Test Assembly

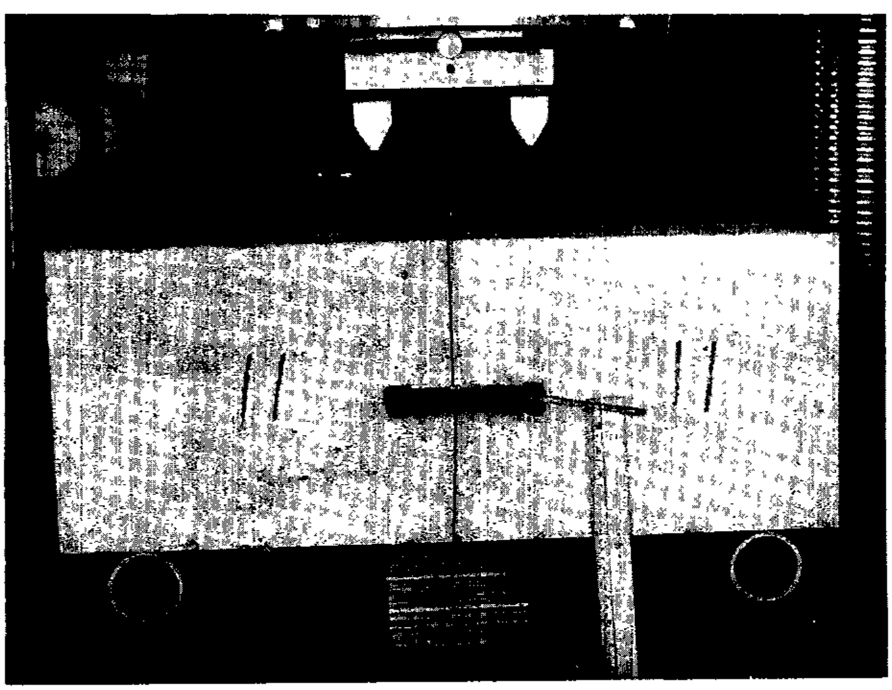


Figure 6

Bend Test Assembly

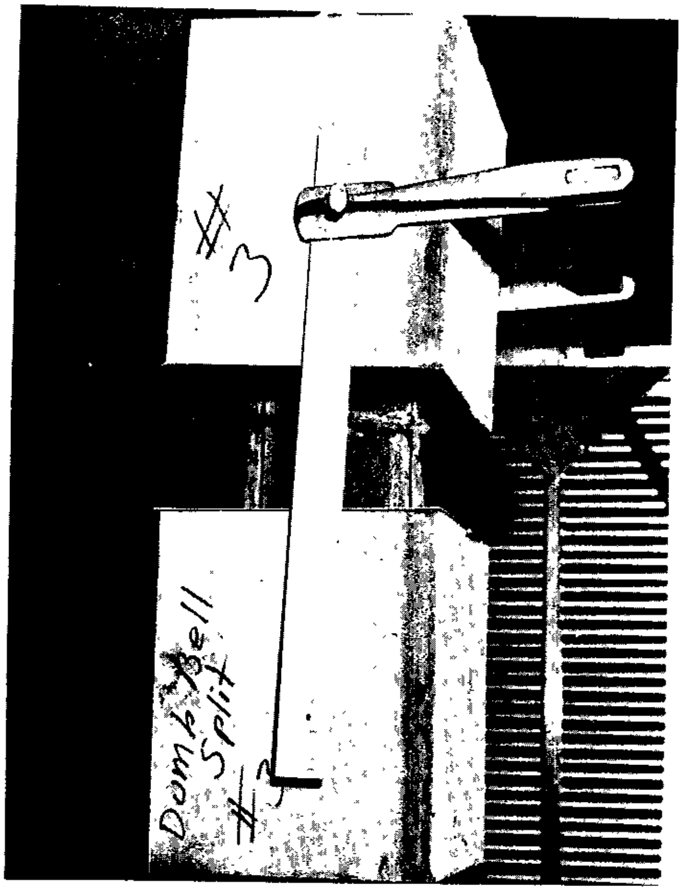


Figure 7

Pull Test Assembly

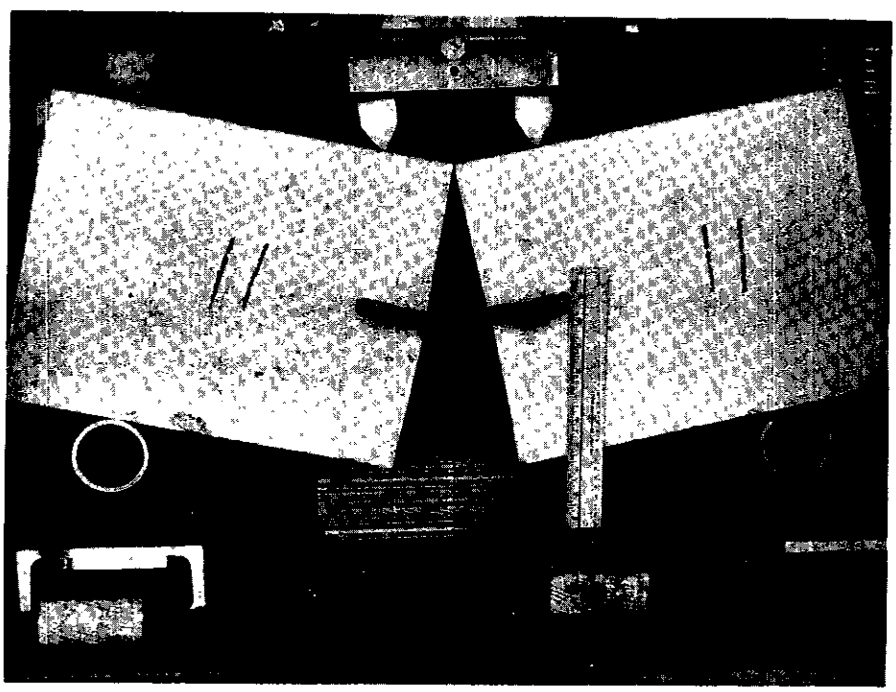


Figure 8

Test Specimen 1

Deformation of rubber waterstop in beam test.

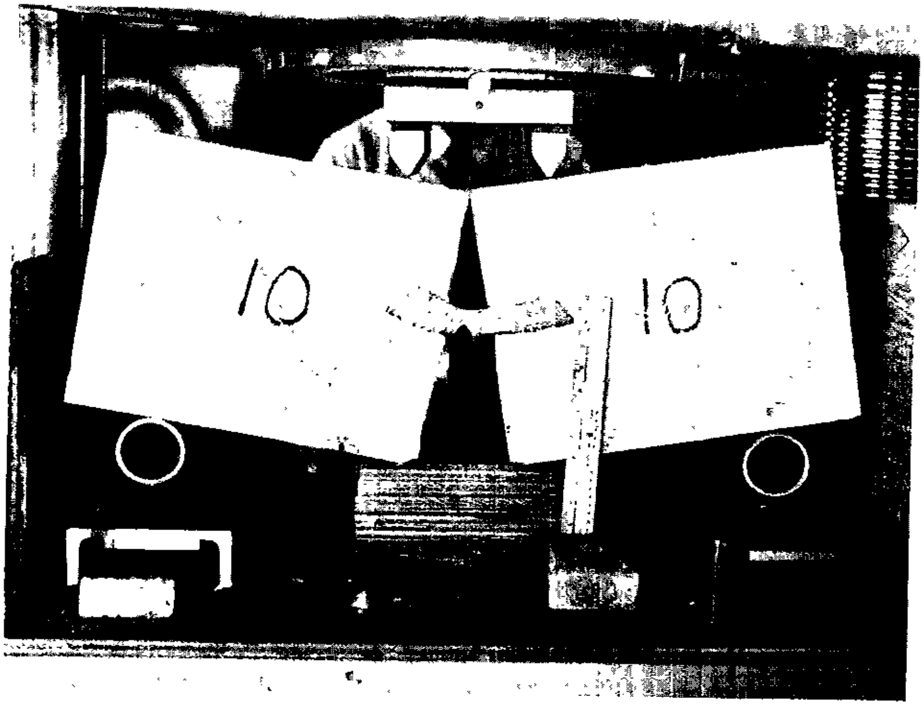


Figure 9

Test Specimen 4A

Tearing failure of plastic (Durajoint) waterstop in beam test.

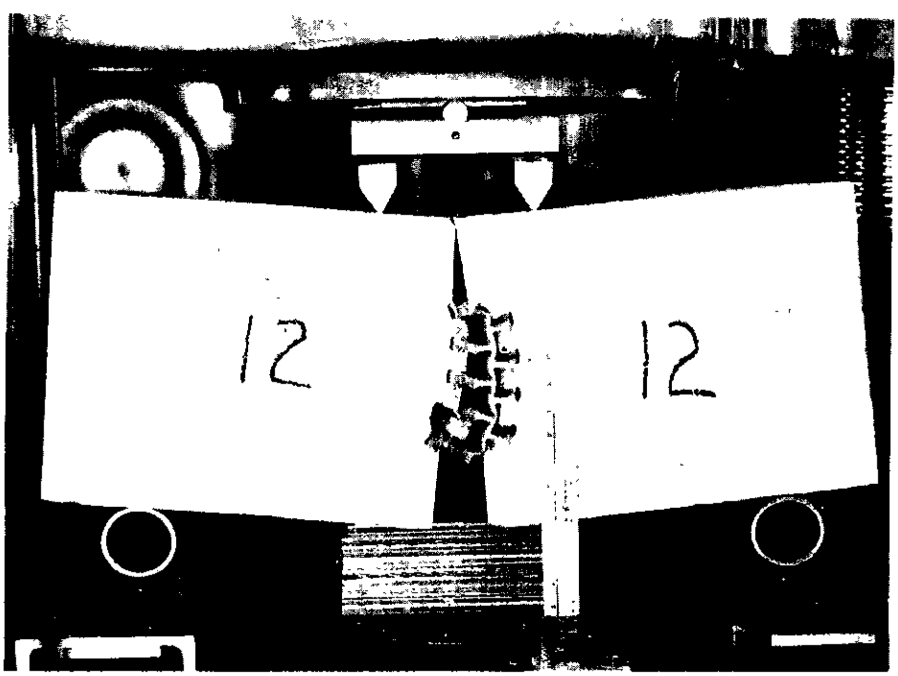


Figure 10

Test Specimen 6

Concrete failure and pull out of Labyrinth waterstop in beam test.

Figure 11

Test Specimen 4B

Tearing failure of plastic (Durajoint) waterstop in shear test.

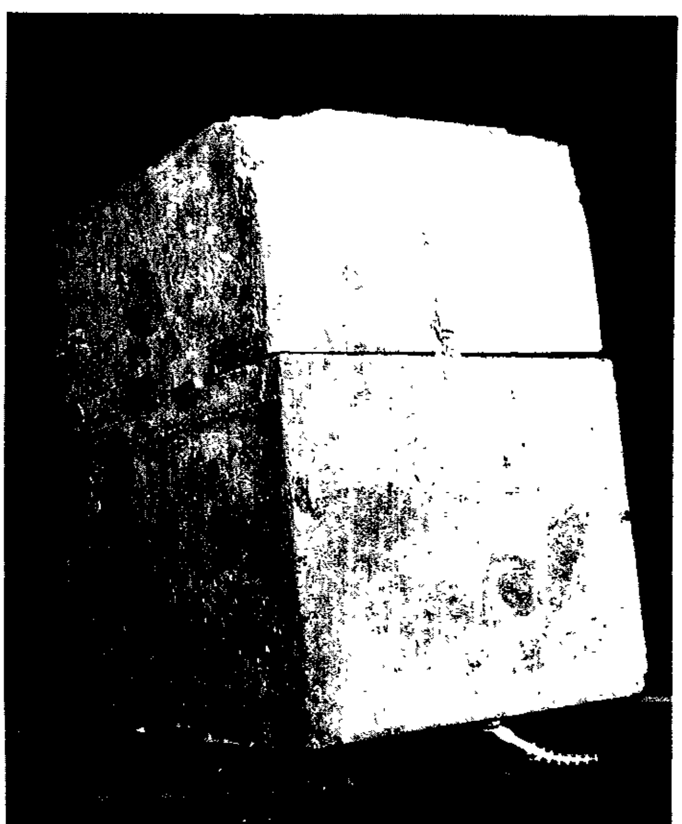


Figure 12

Test Specimen 4B

Concrete cracking which occurred during shear test of plastic (Durajoint) waterstop.

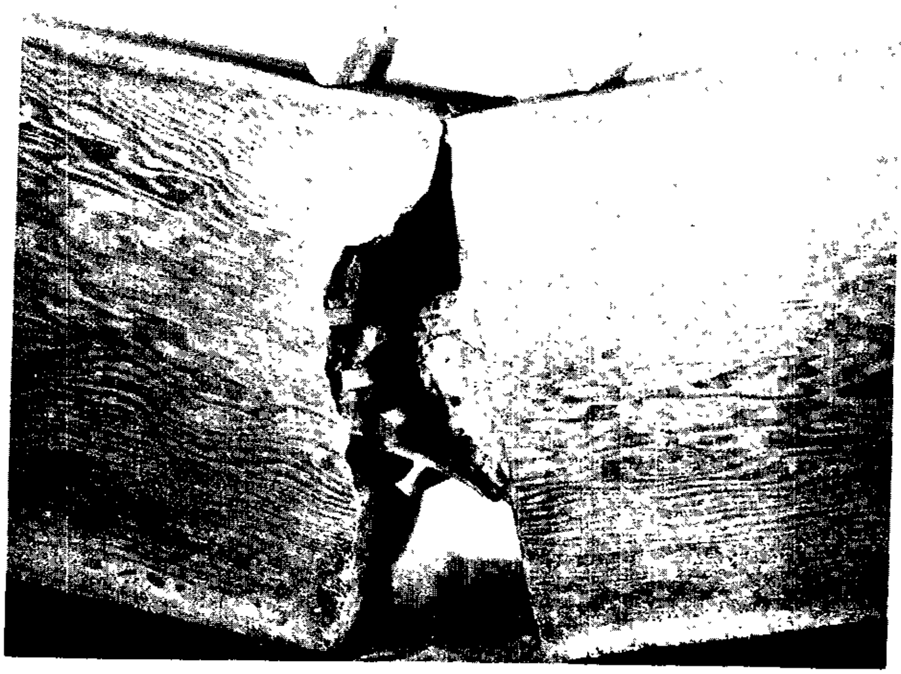


Figure 13

Test Specimen 6

Concrete failure in beam test of Labyrinth waterstop

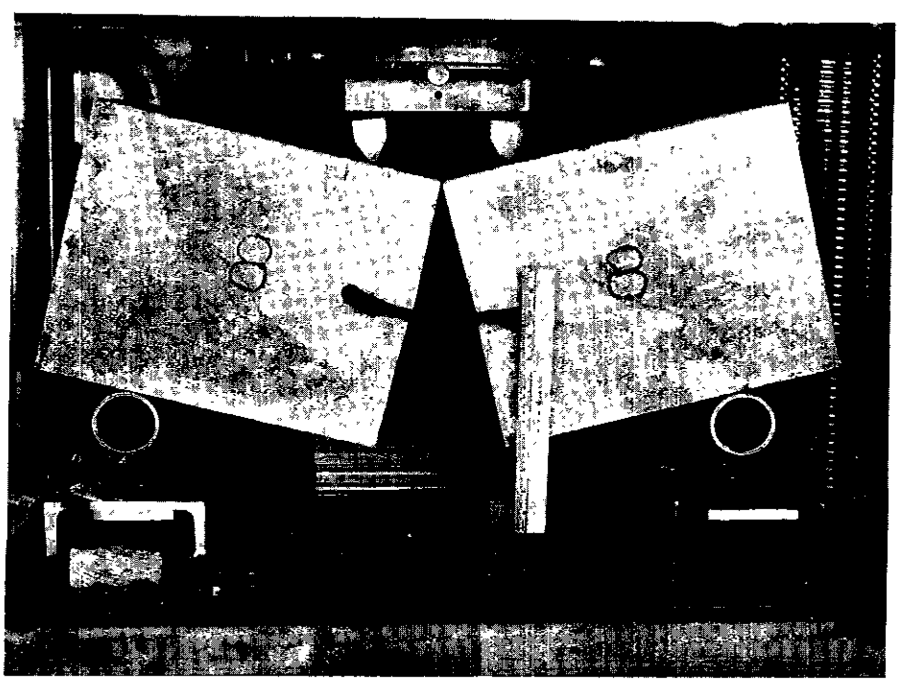


Figure 14

Test Specimen 2

Deformation of rubber waterstop in beam test.

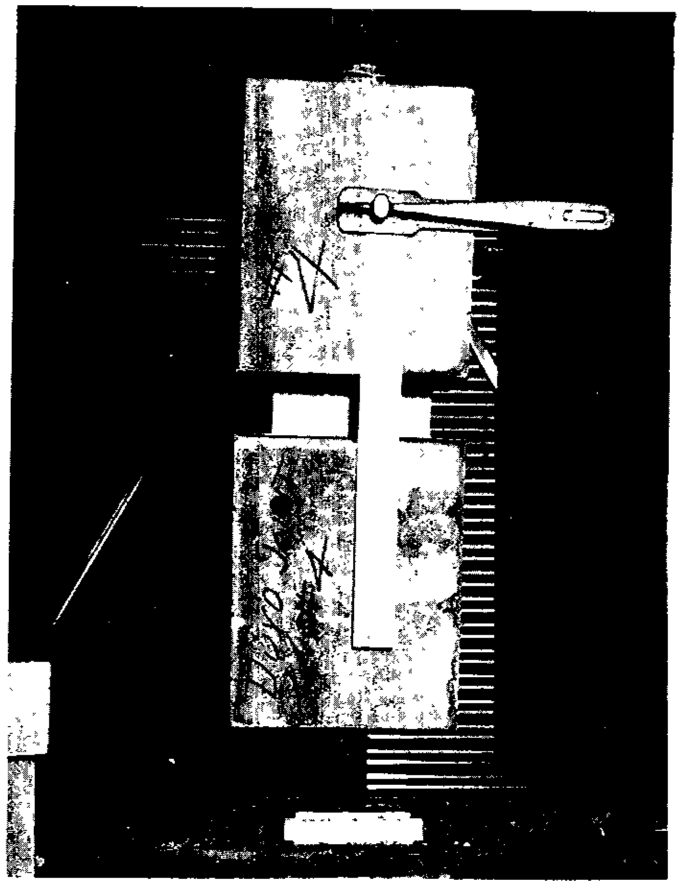


Figure 15

Test Specimen 4C

Slippage test
with
Durajoint waterstop

ASTM TEST DATA ON WATERSTOP MATERIALS

Mechanical and Physical Properties

Test Spec. No.	Type	Hardness Shore Durometer	Ultimate tensile strength and elongation: As Received		Aged in oxygen bomb: 5 days		12 days		46 days	
			psi	Elong.%	psi	Elong.%	psi	Elong.%	psi	Elong.%
1	Dumbbell "Split"	55	3220	450	3020	410	2980	400	2700	380
2	Dumbbell "Solid"	60	3180	460	3100	430	2890	400	2690	360
4A	Durajoint Type 4 (original sample)	78	2790	270	2570	240	*	*	*	*
4B	Durajoint Type 4 (second sample)	75	2870	275	2550	237	*	*	*	*
4C	Durajoint Type 4 (third sample)	68	2620	320	**	**	2475	340	2465	320
5A	Durajoint Type 4 (original sample)	68	2440	343	2580	335	2410	360	2550	355
5B	Durajoint Type 4 (second sample)	62	2135	293	**	**	2272	350	2026	290
6	Labyrinth Type B-4	63	1353	333	1450	320	1222	350	1289	340

* Tests discontinued - vendor replaced with new stock material (Specimen 4C)

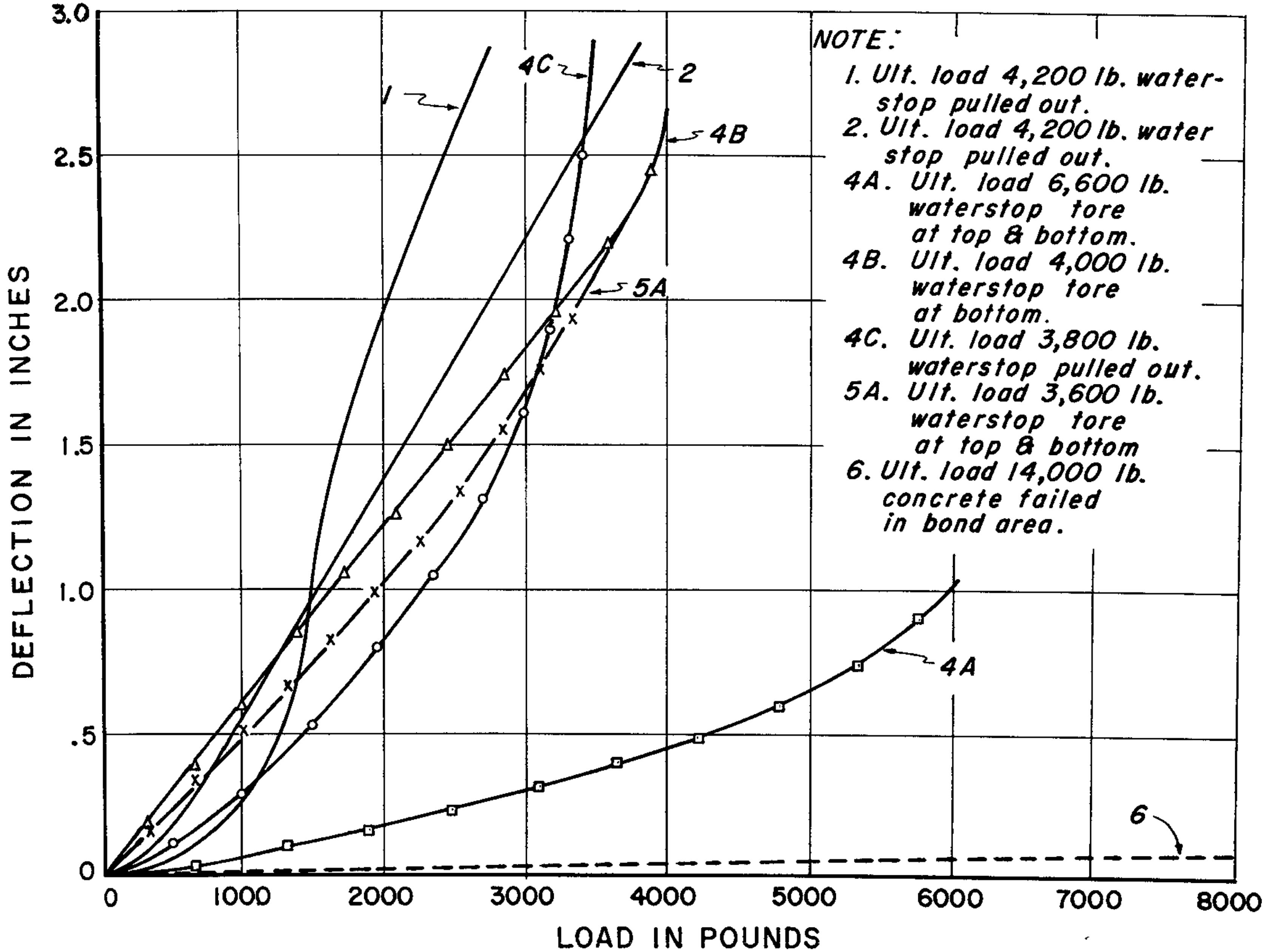
** Results not listed (erratic, possibly due to damaged samples)

TEST DATA ON WATERSTOP MATERIALS

Specimens loaded in double shear. Deflection = vertical displacement

Specimen No. (Identified in Figure 16). Deflection in inches. * Deflection at maximum load.

Load Lbs.	Dumbbell Split 1	Dumbbell Solid 2	Durajoint Type 3 3	Durajoint Type 4 4A	Durajoint Type 4 4B	Durajoint Type 4 4C	Durajoint Arctic 5A	Labyrinth B-4 6	Labyrinth B-3 7
200	0.00	0.03	0.03	0.00	0.09	0.02	0.06	0.00	0.02
400	0.00	0.10	0.13	0.00	0.21	0.08	0.15		0.02
600	0.02	0.42	0.33	0.00	0.32	0.12	0.30		0.04
800	0.45	0.52	0.42	0.00	0.45	0.21	0.40		0.05
1000	0.80	0.60	0.50	0.02	0.60	0.31	0.46		0.14
1500	1.33	1.00	0.65	0.10	0.92	0.56	0.74	0.01	0.33
2000	2.18	1.31	0.81	0.18	1.25	0.80	1.05	0.01	*0.48
3000	2.39	2.15	*0.93	0.34	1.78	1.55	1.66	0.02	
4000	*3.83	2.90		0.52	*2.70	*3.60	*2.22	0.02	
5000		*3.12		0.70				0.05	
6000				1.05				0.05	
7000				*1.36				0.07	
8000								0.08	
9000								0.09	
10000								0.11	
11000								0.11	
12000								0.12	
13000								0.12	
14000								*0.13	
	Ultimate load 4,000 lbs. Waterstop pulled out	Ultimate load 4,200 lbs. Concrete started to fail	Ultimate load 2,400 lbs. Waterstop pulled out	Ultimate load 6,600 lbs. Waterstop tore	Ultimate load 4,000 lbs. Waterstop tore	Ultimate load 3,800 lbs. Waterstop pulled out	Ultimate load 3,600 lbs. Waterstop tore	Ultimate load 14,000 lbs. Concrete failed	Ultimate load 1,800 lbs. Waterstop pulled out



WATERSTOP MATERIALS & DESIGN

Test Specimens Loaded in Shear – Load Deflection "Vertical"

Figure 19

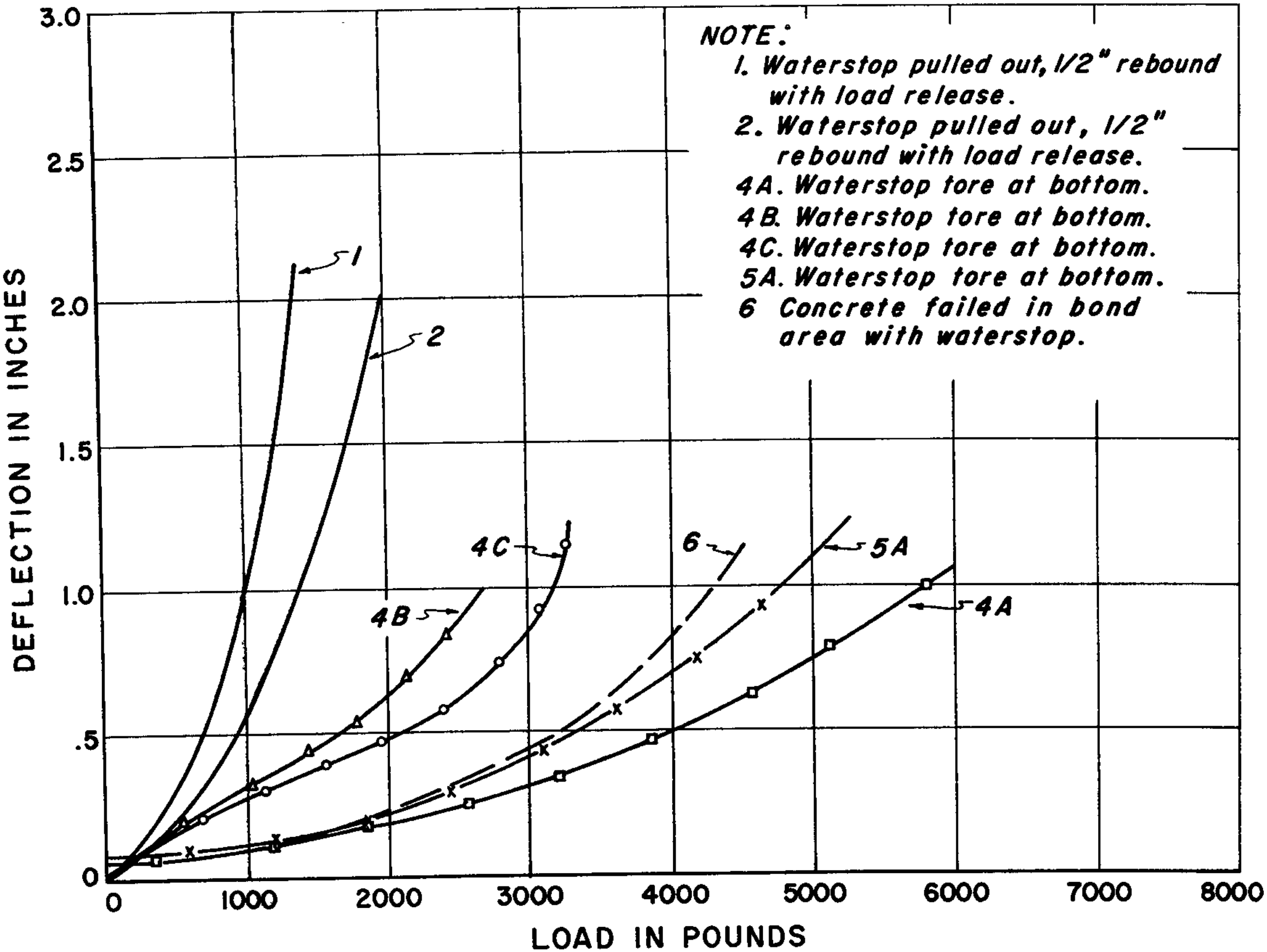
TEST DATA ON WATERSTOP MATERIALS

Test specimens loaded as a simple beam. Deflection = vertical beam deflection

Specimen No. Deflection in inches

Load Lbs.	Dumbbell Split 1	Dumbbell Solid 2	Durajoint Type 4 4A	Durajoint Type 4 4B	Durajoint Type 4 4C	Durajoint Arctic 5A	Labyrinth B-4 6	Labyrinth B-3 7
200	0.10	0.12	0.06	0.12	0.10	0.10	0.03	*0.13
400	0.20	0.15	0.06	0.15	0.15	0.10	0.06	
600	0.25	0.26	0.06	0.21	0.20	0.10	0.09	
800	0.75	0.38	0.08	0.27	0.24	0.10	0.13	
1000	1.01	0.56	0.13	0.31	0.27	0.11	0.13	
1200	1.38	0.88	0.14	0.37	0.32	0.13	0.19	
1400	*2.13	1.13	0.16	0.39	0.38	0.14	0.19	
1600		1.25	0.17	0.49	0.40	0.18	0.21	
1800		1.69	0.19	0.55	0.44	0.20	0.25	
2000		*2.00	0.19	0.62	0.48	0.22	0.25	
2500			0.25	0.90	0.62	0.27	0.31	
3000			0.31	*1.00	0.86	0.33	0.50	
3500			0.38		*1.20	0.54	0.63	
4000			0.50			0.79	0.69	
4500			0.63			0.89	*1.19	
5000			0.75			1.12		
5500			1.00			*1.25		
6000			*1.00					
	Ultimate load 1,400 lbs. Waterstop pulled out	Ultimate load 2,000 lbs. Waterstop pulled out	Ultimate load 6,000 lbs. Waterstop tore	Ultimate load 2,700 lbs. Waterstop tore	Ultimate load 3,300 lbs. Waterstop tore	Ultimate load 5,200 lbs. Waterstop tore	Ultimate load 4,500 lbs. Concrete failed	Ultimate load 100 lbs. Concrete failed

* Deflection at maximum load



WATERSTOP MATERIALS & DESIGN

Test Specimens Loaded as a Simple Beam
Load Deflection "Vertical"

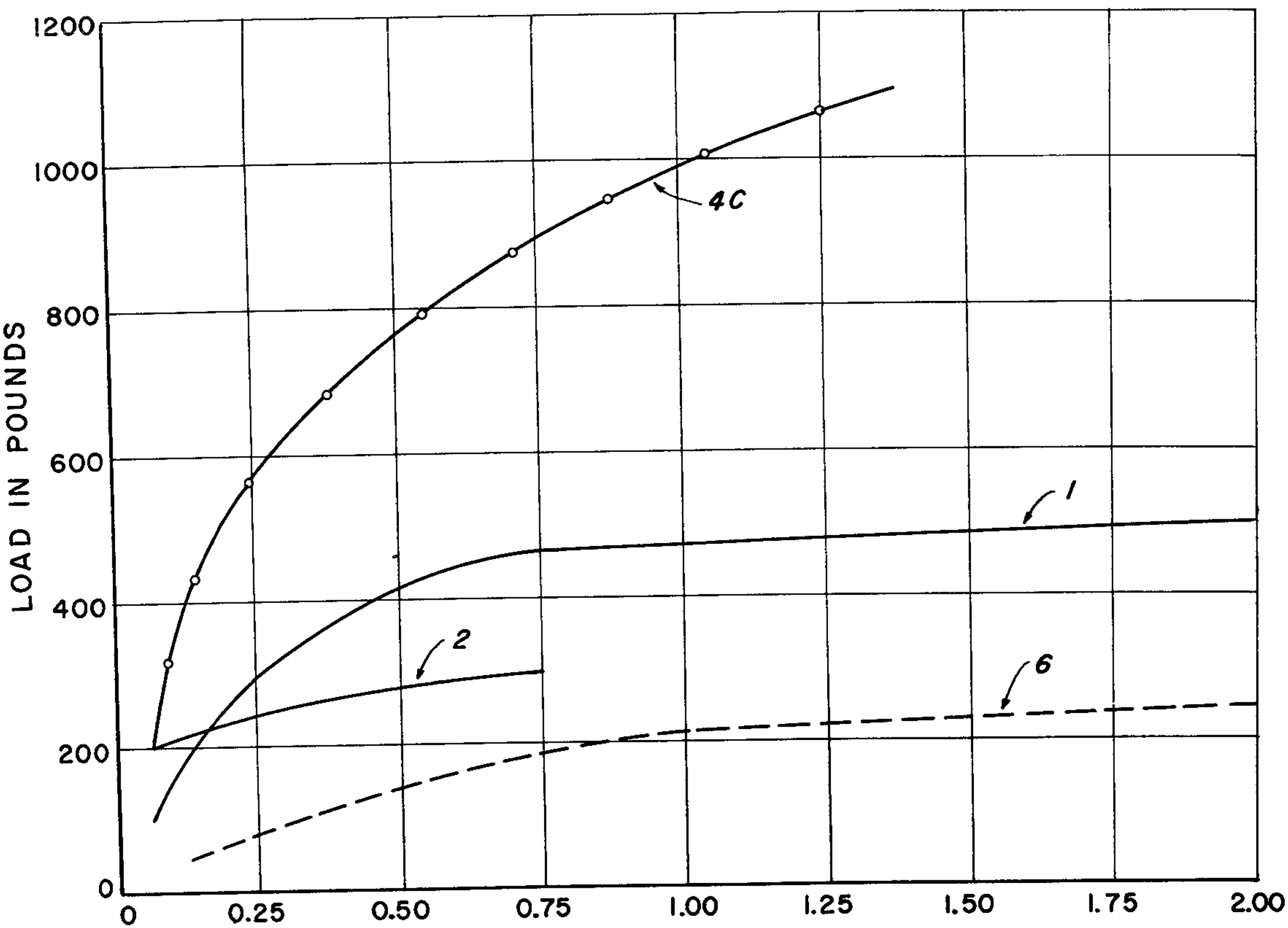
Figure 21

TEST DATA ON WATERSTOP MATERIALS

Test specimens loaded in Tension. Load deflection vertical.

Deflection in inches

Load Lbs.	Dumbbell Split 1	Dumbbell Solid 2	Durajoint Type 4 4C	Labyrinth B-4 6
50	0.03			0.13
100	0.06			0.31
150	0.09			0.69
200	0.125	0.06	0.06	0.81
250	0.26	0.25	0.10	1.25
300	0.44	0.75	0.125	
400	0.56		0.13	
500	2.00		0.19	
600			0.31	
700			0.44	
800			0.63	
900			0.88	
1000			1.13	
1100			1.38	
	Ultimate load 500 lbs.	Ultimate load 300 lbs.	Ultimate load 1100 lbs.	Ultimate load 250 lbs.



JOINT SEPARATION - IN INCHES

WATERSTOP MATERIALS & DESIGN

Bond Strength - Waterstop to Concrete

Fig. 22

AUTHOR Materials & Research Lab. Div. of Highways.

TITLE REPORT ON COMPARATIVE TESTS OF VARIOUS MATERIALS USED AS WATERSTOP.

DATE	BORROWER'S NAME	ROOM NUMBER
1-22	MBO'Hara	A406
4-3-59	R.W. Hutchinson	A334
6-28-60	G D Hood	A326
2-21-61	R.W. Hutchinson	A334