REC-ERC-84-14

SUMMARY REPORT ON PVC CONTRACTION JOINT-FORMING WATERSTOPS

January 1984
Engineering and Research Center

U. S. Department of the Interior
Bureau of Reclamation

7-2090 (4-81)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
REC-ERC-84-14		

4. TITLE AND SUBTITLE Summary Report on PVC Contraction Joint-Forming Waterstops	5. REPORT DATE January 1984 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Henry Johns	8. PERFORMING ORGANIZATION REPORT NO. REC-ERC-84-14
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bureau of Reclamation Engineering and Research Center P O Box 25007 Denver, CO 80225	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. 13. TYPE OF REPORT AND PERIOD COVERED
12. SPONSORING AGENCY NAME AND ADDRESS Same	14. SPONSORING AGENCY CODE DIBR

15. SUPPLEMENTARY NOTES

Microfiche and/or hard copy available at the Engineering and Research Center, Denver, CO

Ed:JTC

16. ABSTRACT

Cycling fatigue tests and constant-load elongation tests were conducted on eight contraction joint-forming waterstops. Conclusions are: (1) fatigue cycling of the PVC strips in the Bostik Mastic Tester does not distress the waterstop section or cause deformation of the waterstop sealing bulbs; (2) constant load elongation tests show that if the PVC strip is free to deform, it may stretch to failure, but field experience is that only in unusual circumstances do canal contraction joints open more than 3.2 mm (1/8 in); (3) even with a large, 10.2 mm (>0.4 in), and long-term (340 days) elongation of the waterstop section, deformation of the waterstop sealing bulbs will not occur in a properly designed strip; (4) the PVC (polyvinyl chloride) strips behave almost identically whether strains caused by elongation occur in only a few minutes or develop during long-term loading; and (5) the Bostik Mastic Tester can be a useful tool in a joint sealer research program.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. *DESCRIPTORS*-- /joints (connections)/ *contraction joints/ concretes/ laboratory tests/ installation/ thickness/ *canal linings/ specifications/ concrete-lined canals/ concrete construction/ *water stops/ Polyvinyl chloride/ cracks seals (stoppers)/ performance/ canal sealants/ plastics/ product evaluation/ concrete linings

b. *IDENTIFIERS*-- /*crack controls/ Pleasant Valley Canal, CA/ Central Valley Project/ San Luis Canal, CA/ Tehema-Colusa Canal, CA

c. *COSATI Field/Group* 13C *COWRR:* 1305 *SRIM:*

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161. (Microfiche or hard copy available from NTIS)	*UNCLASSIFIED*	14
	20. SECURITY CLASS (THIS PAGE) *UNCLASSIFIED*	22. PRICE

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SUMMARY REPORT ON PVC CONTRACTION JOINT-FORMING WATERSTOPS

by
Henry Johns

January 1984

Applied Sciences Branch
Division of Research and Laboratory Services
Engineering and Research Center
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

ACKNOWLEDGMENTS

This study was conducted under the supervision of J. L. Kiewit and B. V. Jones, retired Head and Head, respectively, of the Materials Science Section.

Laboratory photographs were taken by W. K. Lambert, and drawings were made by L. Kinslow, Design Support Section. W. R. Morrison, Materials Science Section, and Joe Carriero, Technical Publications Branch, prepared the report for publication.

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INTRODUCTION

The intent of this report is to summarize available information on PVC plastic contraction joint-forming waterstops for concrete canal linings. It briefly covers some of the data and conclusions presented in reports No. ChE-103[1], REC-OCE-70-35[2], and REC-ERC-72-30[3], and some previously unreported data developed from laboratory cycling fatigue tests and from continuous load deformation tests. A contraction joint-forming waterstop is often referred to as a "PVC strip" and is so described in USBR (Bureau of Reclamation) specifications; for brevity, it is used in this report.

The PVC strip consists of a plane-weakening vertical member and a miniature waterstop horizontal member. It is extruded from a plasticized polyvinyl chloride resin compound and is inserted into fresh concrete during lining placement. During drying shrinkage, the vertical member induces cracking, and the waterstop member develops a seal at the crack that is independent of sealant bond. Because it is buried in the concrete, weathering of the waterstop section is virtually eliminated once the canal is in service, and its innate inertness precludes deterioration from water contact. The PVC strip is a manufactured item receptive to high quality control standards. It can withstand high hydrostatic pressures and allows the lining and sealing of a canal in one operation.

TEST PROCEDURE

Test specimens (see fig. 1) were prepared for each of the eight shapes of PVC strip listed in tables 1 and 1A. After the concrete was cured for 14 days, the specimens were inserted into the Bostik machine and cycling was begun (see fig. 2). The waterstop portion of the PVC strip was first elongated 3.2 mm (⅛ in), then cycled in elongation and compression. A cycle consisted of increasing the elongation from 3.2 mm (⅛ in) to 4.8 mm (3/16 in), then decreasing it to 1.6 mm (1/16 in), followed by a return to 3.2 mm (⅛ in). Every 112.5 seconds the Bostik machine completed a step, which consisted of one-sixteenth of the cycle; i.e., 0.4 mm (1/64 in) of movement. This is the "stick-slip" method of operation. This method simulates the actual behavior of a structure where intermittent joint dimensional changes occur as temperature-induced stresses are relieved by the expansion or contraction of structural components. One thousand 30-minute cycles were completed on each of the eight specimens.

Following the cycling tests, the same specimens were loaded, as shown on figure 3, to ascertain the effect of a sustained long-term load on the PVC strip. The initial loading of each strip was accomplished with a 3.8-L (1-gal) paint bucket containing enough lead shot to induce a 3.2-mm (⅛-in) extension. Observations of the continuing deformation of the strip were made at frequent intervals during the earlier stages, then at more widely spaced intervals as the rate of change decreased. Testing was discontinued after 340 days of continuous loading. Physical properties of the PVC strips were determined from laboratory acceptance tests.

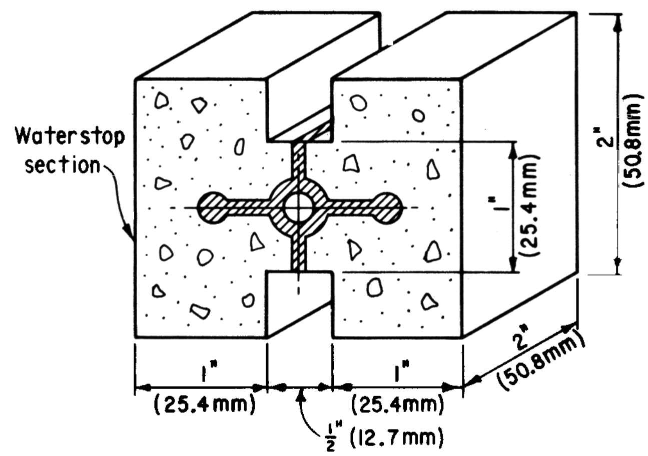


Figure 1. — Test specimen for cycling in the Bostic Mastic Tester and for the constant load elongation test. Upper and lower vertical members were trimmed to 25.4 mm (1 in).

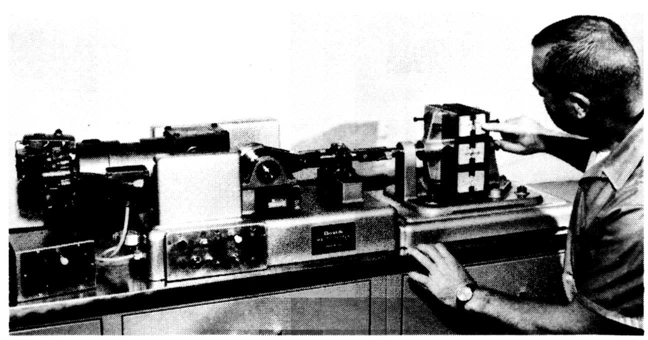


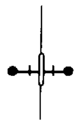
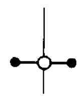
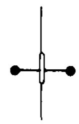
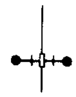
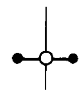
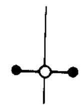
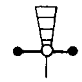
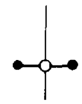
Figure 2. — Bostik Mastic Tester for cycling fatigue tests. Test specimens are installed at extreme right side of machine. Initial elongation is 3.2 mm (0.125 in); cycling is then conducted: extension to 4.8 mm (0.19 in) followed by compression to 1.6 mm (0.06 in) then return to 3.2 mm (0.125 in). This constitutes one cycle. Photo No. P801-D-80729

[1] Report No. ChE-103, *Extension Tests on PVC Contraction Joint Forming Waterstops*, September 1969.

[2] REC-OCE-70-35, *Contraction Joint Sealing Systems, San Luis Drain, Central Valley Project* — Evaluation of cores containing preformed polysulfide rubber strips, machine extruded polysulfide, rubber sealant, and polyvinyl chloride plastic contraction joint forming waterstop, August 1970.

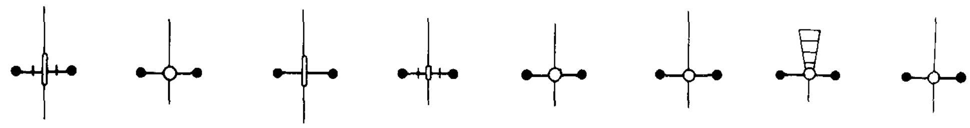
[3] REC-ERC-72-30, *PVC Contraction Joint Forming Waterstops — An evaluation of cores from the concrete lining in the Tehama-Colusa Canal, Central Valley Project*, September 1972.

Table 1. — Constant load elongation (creep) tests (SI units)

Test number	1	2	3	4	5	6	7	8
General shape								
Center bulb hole shape	Vertical oval	Round	Vertical oval	Vertical rectangle	Round	Round	Round	Round
Center bulb hole dimensions, mm	10.2x2.5	6.4*	10.2x2.5	3.8x2.0	7.6*	5.1*	5.1*	2.5*
Ribs on horizontal flange	Ribs	No ribs	No ribs	Ribs	No ribs	No ribs	No ribs	No ribs
Horizontal flange thickness, mm	3.2	2.3	3.2	3.8	3.6	2.3	2.3	2.3
Specimen length, mm	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8
Cross-sectional area, horizontal flange, mm^2	161	119	161	194	185	116	116	116
Sealing bulb height, mm	6.4	6.1	6.4	8.6	7.0	6.6	6.2	6.4
Load required for 8.5 mm extension, N	95.6	105.9	81.0	290.0	113.9	171.2	172.6	215.3
Initial stress, MPa	0.59	0.89	0.50	1.50	0.61	1.47	1.48	1.85
Deformation after indicated number of days loading, mm 1	5.08	5.08	5.08	6.35	5.33	6.48	7.62	7.62
5	5.97	5.97	6.48	10.16	6.35	9.65	9.52	9.65
7	6.48	6.48	6.86	12.19	6.73	10.80	10.16	10.54
8	6.60	6.60	7.11	12.83	6.86	10.92	10.29	10.67
11	6.73	6.73	7.11	13.59	6.98	11.05	10.29	10.92
13	6.98	6.98	7.24	14.48	7.11	11.56	10.41	11.43
14	6.98	6.98	7.37	14.48	7.11	11.56	10.67	11.43
18	7.24	7.11	7.62	14.60	7.24	11.81	10.92	11.43
27	7.37	7.62	7.75	16.76	7.62	12.19	11.30	11.68
32	7.49	8.00	8.13	18.29	8.13	12.83	11.94	12.19
39	8.13	8.26	8.64	19.30	8.64	13.59	12.32	12.95
46	8.38	8.5	8.89	Tensile failure	8.89	13.97	12.70	13.21
54	8.51	8.64	9.02		9.14	14.35	13.08	13.46
62	8.64	8.64	9.14		9.27	14.35	13.08	13.59
81	9.02	8.89	9.52		9.52	14.73	13.34	13.97
104	9.14	9.52	9.78		9.65	14.86	13.59	14.35
132	9.52	9.65	10.16		9.65	14.86	13.59	14.60
249	9.78	9.78	10.29		9.78	15.49	14.48	15.24
340	10.16	10.29	10.67		10.41	16.13	14.86	15.62

*Inside diameter of bulb.

Table 1A. Constant load elongation (creep) tests (English units)

Test number	1	2	3	4	5	6	7	8
General shape								
Center bulb hole shape	Vertical oval	Round	Vertical oval	Vertical rectangle	Round	Round	Round	Round
Center bulb hole dimensions, inches	0.4x0.1	0.25*	0.4x0.1	0.15x0.08	0.3*	0.2*	0.2*	0.1*
Ribs on horizontal flange	Ribs	No ribs	No ribs	Ribs	No ribs	No ribs	No ribs	No ribs
Horizontal flange thickness, inches	0.125	0.092	0.125	0.15	0.14	0.09	0.09	0.09
Specimen length, inches	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cross-sectional area, horizontal flange, in^2	0.250	0.184	0.250	0.300	0.287	0.180	0.180	0.180
Sealing bulb height, inches	0.250	0.242	0.250	0.339	0.277	0.260	0.246	0.250
Load required for ⅛ inch extension, pounds	21.5	23.8	18.2	65.2	25.6	38.5	38.8	48.4
Initial stress, lb/in^2	86.0	129.0	73.0	217.0	89.0	213.0	215.0	269.0
Deformation after indicated number of days loading, inches 1	0.200	0.200	0.200	0.250	0.210	0.255	0.300	0.300
5	0.235	0.235	0.255	0.400	0.250	0.380	0.375	0.380
7	0.255	0.255	0.270	0.480	0.265	0.425	0.400	0.415
8	0.260	0.260	0.280	0.505	0.270	0.430	0.405	0.420
11	0.265	0.265	0.280	0.535	0.275	0.435	0.405	0.430
13	0.275	0.275	0.285	0.570	0.280	0.455	0.410	0.450
14	0.275	0.275	0.290	0.570	0.280	0.455	0.420	0.450
18	0.285	0.280	0.300	0.575	0.285	0.465	0.430	0.450
27	0.290	0.300	0.305	0.660	0.300	0.480	0.445	0.460
32	0.295	0.315	0.320	0.720	0.320	0.505	0.470	0.480
39	0.320	0.325	0.340	0.760	0.340	0.535	0.485	0.510
46	0.330	0.335	0.350	Tensile failure	0.350	0.550	0.500	0.520
54	0.335	0.340	0.355		0.360	0.565	0.500	0.530
62	0.340	0.340	0.360		0.365	0.565	0.515	0.535
81	0.355	0.350	0.375		0.375	0.580	0.525	0.550
104	0.360	0.375	0.385		0.380	0.585	0.535	0.565
132	0.375	0.380	0.400		0.380	0.585	0.535	0.575
249	0.385	0.385	0.405		0.385	0.610	0.570	0.600
340	0.400	0.405	0.420		0.410	0.635	0.585	0.615

*Inside diameter of bulb.

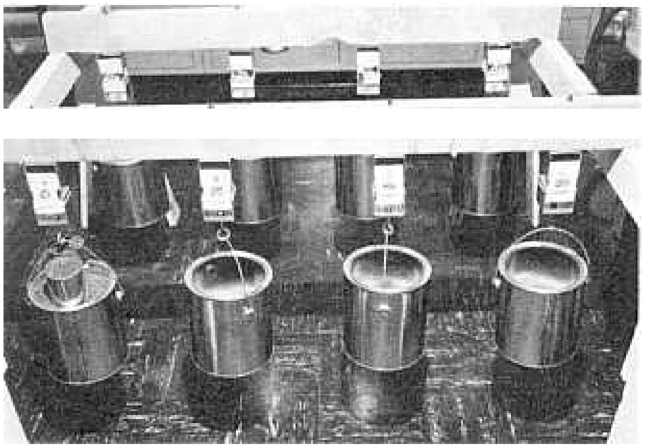


Figure 3. — Constant Load Deformation Test apparatus. Each specimen was loaded to produce a 3.2 mm (0.125 in) elongation of the plastic strip. Loading is accomplished with lead shot in 3.8 L (1 gal) paint buckets. Photo No. 801-D-80730

TEST RESULTS

Bostik Cycling Tests

No observable effect was produced in the waterstop sections of any of the PVC strips after 1,000 cycles. The testing was discontinued at that point.

Continuous Load Elongation Tests

The results of these tests are shown in table 1. Figures 4 and 5 show the test specimens after short-term and long-term loading. Figure 6 is a graph of elongation versus duration of loading.

Table 2 lists the results of the tests conducted on the PVC strips to ascertain compliance with the requirements of materials specifications. All of the PVC strips used complied with the specification.

APPLICATIONS

The contraction joint-forming waterstop, referred to in USBR specifications as the "PVC strip" has now been used for 19 years. Laboratory and field experience show that the use of the strip should be continued and encouraged. Future developments may improve the joint sealing and forming mechanisms, but the strips shown on figures 7 and 8 have been found satisfactory for both their installation and performance characteristics. The strip, as presently designed and installed, should be effective and should continue to serve well.

CONCLUSIONS

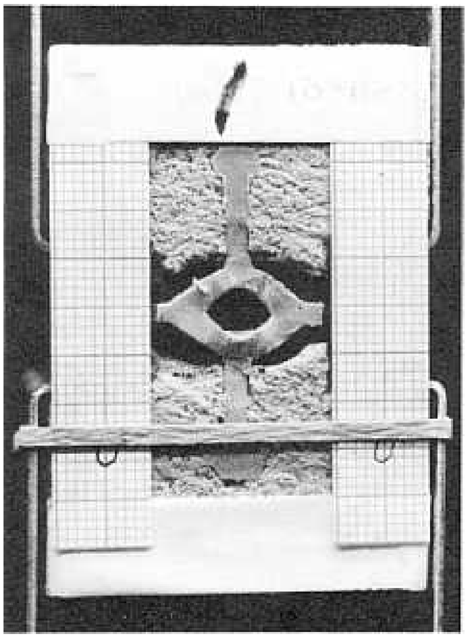
1. Fatigue cycling of the PVC strips in the Bostik Mastic Tester does not distress the waterstop section or cause deformation of the waterstop sealing bulbs.

2. Constant load tests show that if the PVC strip is subjected to unrestricted deformation, it may stretch to failure, but field experience is that only in unusual circumstances do canal contraction joints open more than 3.2 mm (1/8 in).

Table 2. — Tests for compliance with material specifications

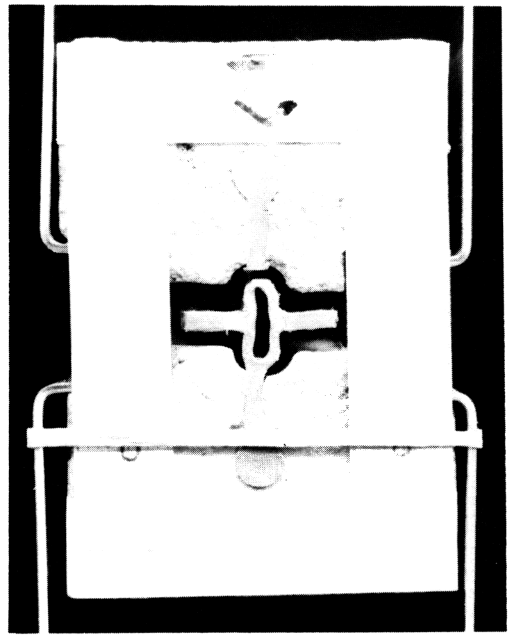
Test	Lab. No.	Project	Feature	Tensile Strength[1] MPa	Tensile Strength[1] lb/in²	Elongation[2] percent	Stiffness in Flexure[3] MPa	Stiffness in Flexure[3] lb/in²
1	17255	Central Valley	Pleasant Valley Canal	14.75	2,140	430	3.10	450
2	17143	Central Valley	Tehama-Colusa Canal, Reach 1	18.48	2,680	420	10.00	1,450
3	7255	Central Valley	Pleasant Valley Canal	14.76	2,140	430	3.10	450
4	16976	Central Valley	San Luis Canal Reach 5	16.75	2,430	340		
5	17326	Central Valley	San Luis Drain	10.62	1,540	390	—	—
6	17138	Central Valley	Tehama-Colusa Canal, Reach 1	17.03	2,470	390	8.07	1,170
7	17305	Nav. Ind. Irrig. District	Main Canal	17.58	2,550	410		
8	17339	Nav. Ind. Irrig. District	Main Canal	17.44	2,530	410		

[1] Specifications require 9.65 MPa (1,400 lb/in²) minimum.
[2] Specifications require 280 percent minimum.
[3] Specifications require 2.76 MPa (400 lb/in²) minimum.



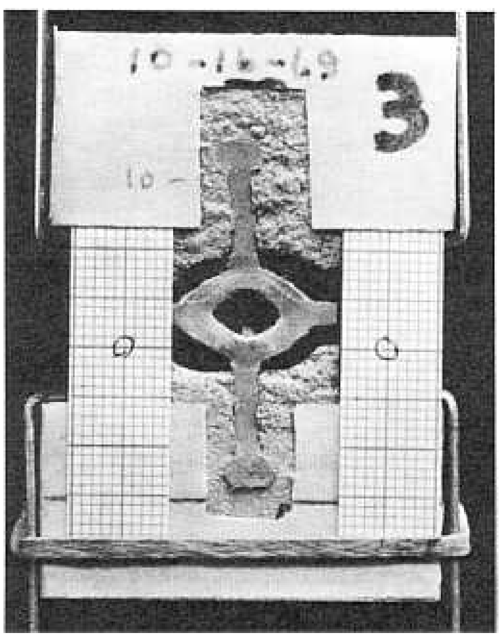
Test No. 1

Initial extension: 3.2 mm (0.125 in)
5-day elongation: 5.8 mm (0.23 in)
Load required: 95.6 N (21.5 lbf)
Stress: 0.59 MPa (86.0 lb/in²)
Photo No. 801-D-80731



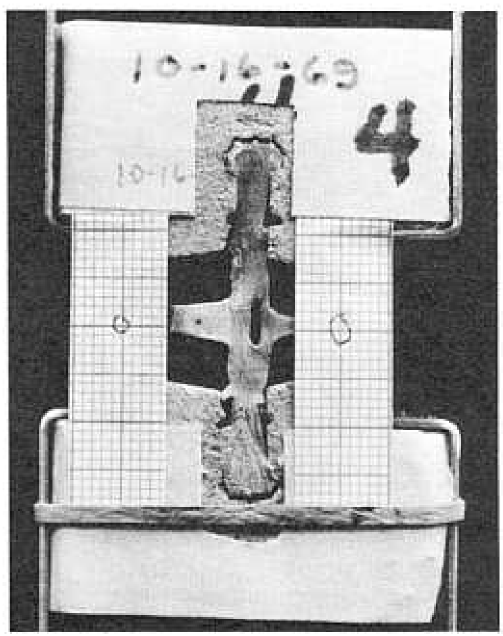
Test No. 2

Initial extension: 3.2 mm (0.125 in)
4-day elongation: 5.8 mm (0.23 in)
Load required: 105.9 N (23.8 lbf)
Stress: 0.89 MPa (129.0 lb/in²)
Photo No. 801-D-80732



Test No. 3

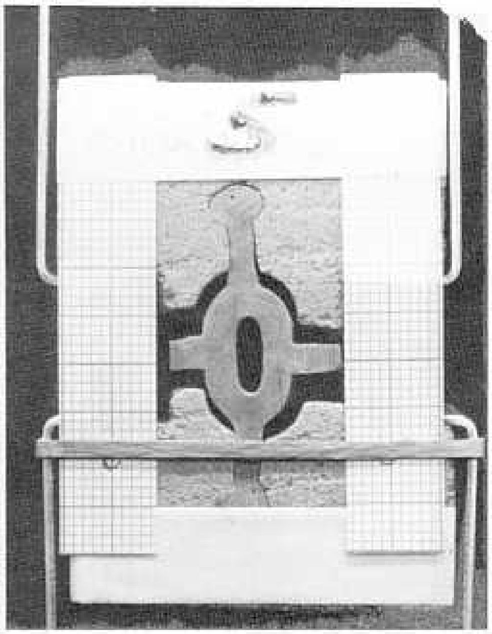
Initial extension: 3.2 mm (0.125 in)
8-day elongation: 7.1 mm (0.28 in)
Load required: 8.10 N (18.2 lbf)
Stress: 0.50 MPa (73.0 lb/in²)
Photo No. 801-D-80733



Test No. 4

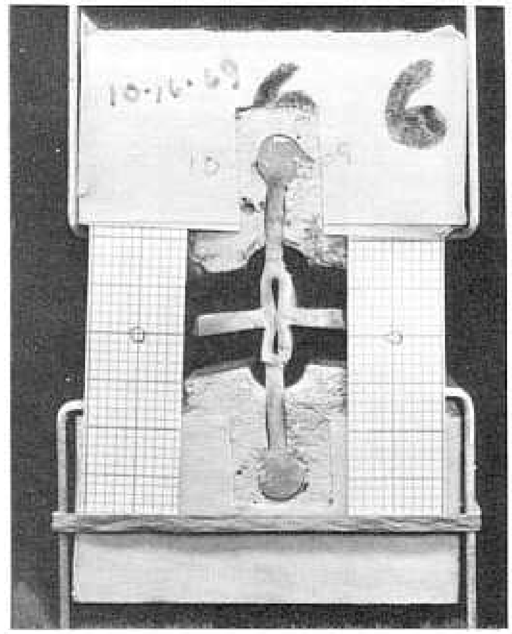
Initial extension: 3.2 mm (0.125 in)
8-day elongation: 13.2 mm (0.52 in)
Load required: 290.0 N (65.2 lbf)
Stress: 1.50 MPa (217.0 lb/in²)
Photo No. 801-D-80734

Figure 4. Constant load deformation tests; early stages of loading (sheet 1 of 2).



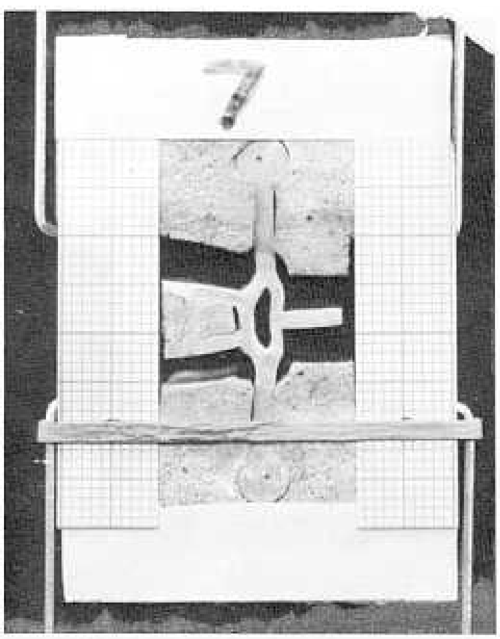
Test No. 5

Initial extension: 3.2 mm (0.125 in)
5-day elongation: 6.4 mm (0.25 in)
Load required: 113.9 N (21.5 lbf)
Stress: 0.61 MPa (89.0 lb/in²)
Photo No. 801-D-80735



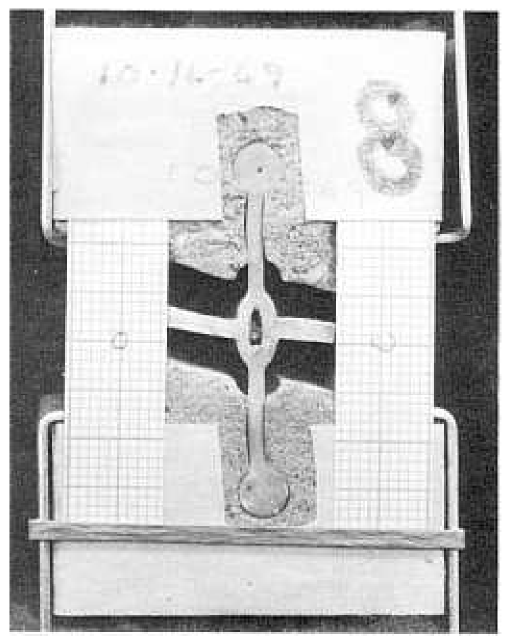
Test No. 6

Initial extension: 3.2 mm (0.125 in)
8-day elongation: 10.9 mm (0.43 in)
Load required: 171.3 N (38.5 lbf)
Stress: 1.47 MPa (213.0 lb/in²)
Photo No. 801-D-80736



Test No. 7

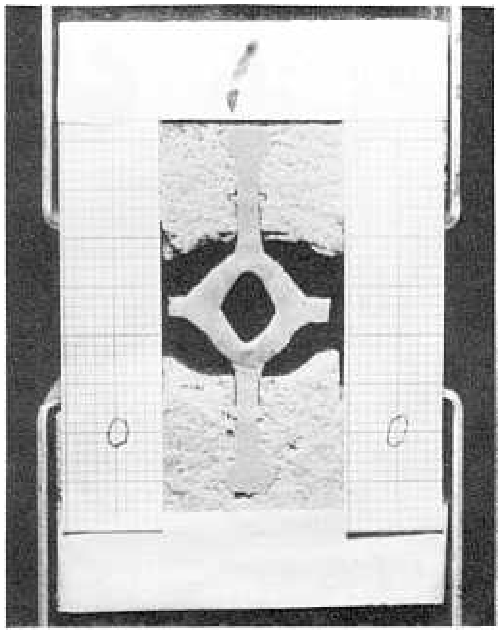
Initial extension: 3.2 mm (0.125 in)
8-day elongation: 9.5 mm (0.375 in)
Load required: 172.6 N (38.8 lbf)
Stress: 1.48 MPa (215.0 lb/in²)
Photo 801-D-80737



Test No. 8

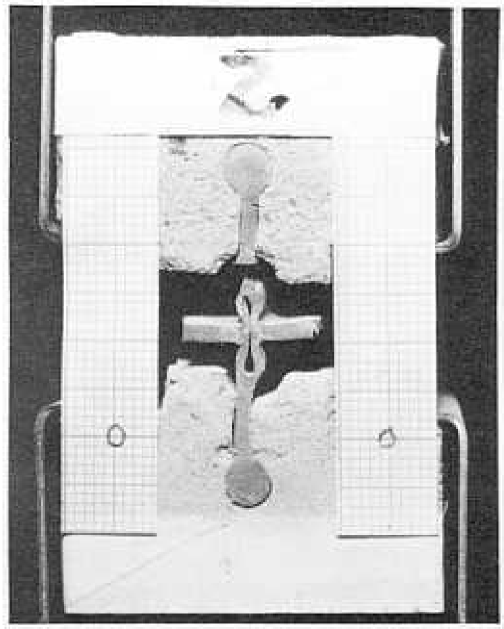
Initial extension: 3.2 mm (0.125 in)
8-day elongation: 10.7 mm (0.52 in)
Load required: 215.3 N (48.4 lbf)
Stress: 1.85 MPa (269.0 lb/in²)
Photo No. 801-D-80738

Figure 4. — Constant load deformation tests; early stages of loading (sheet 2 of 2).



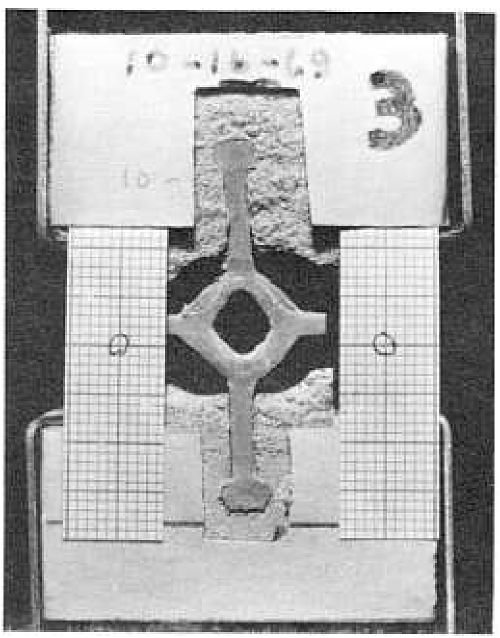
Test No. 1

340-day elongation: 10.2 mm (0.40 in)
Creep: 160%
Photo No. 801-D-80739



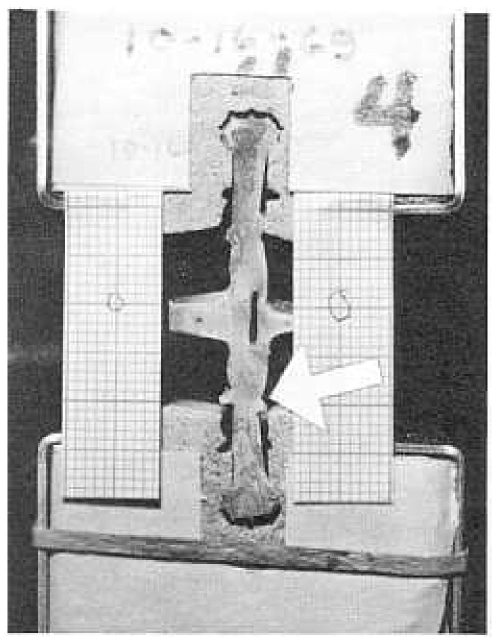
Test No. 2

340-day elongation: 10.3 mm (0.405 in)
Creep: 164%
Photo No. 801-D-80740



Test No. 3

340-day elongation: 10.7 mm (0.42 in)
Creep: 176%
Photo No. 801-D-80741

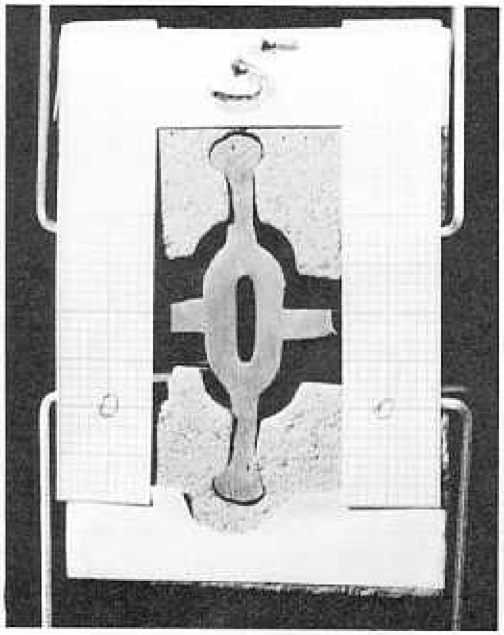


Test No. 4

39-day elongation: 19.3 mm (0.76 in)
Creep: 428%

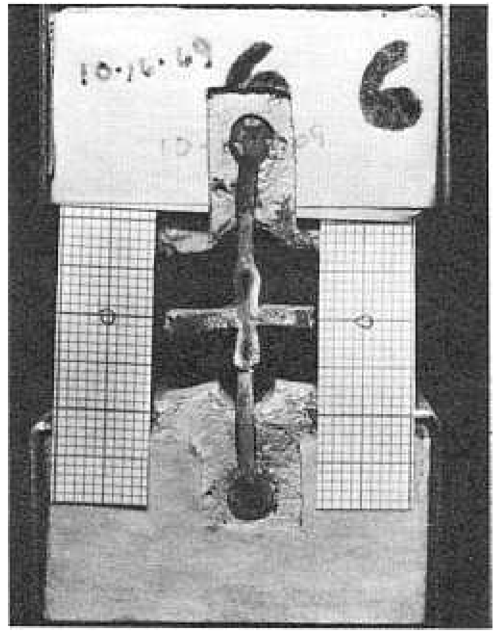
Note: Tensile failure occurred on 40th day at point indicated by arrow.
Photo No. 801-D-80742

Figure 5. — Constant load deformation tests; 340-day loading (sheet 1 of 2).



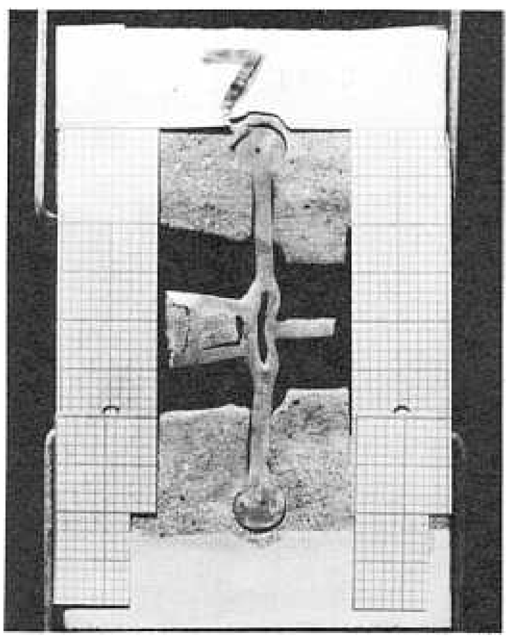
Test No. 5

340-day elongation: 10.4 mm (0.41 in)
Creep: 128%
Photo No. 801-D-80743



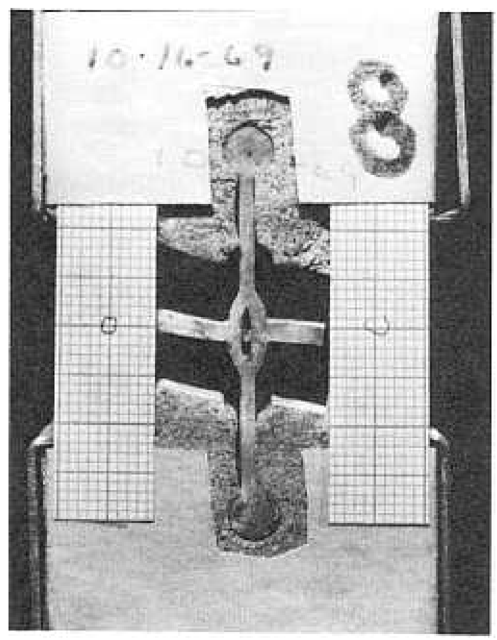
Test No. 6

340-day elongation: 16.1 mm (0.635 in)
Creep: 408%
Photo No. 801-D-80744



Test No. 7

340-day elongation: 14.9 mm (0.585 in)
Creep: 368%
Photo No. 801-D-80745



Test No. 8

340-day elongation: 15.6 mm (0.615 in)
Creep: 392%
Photo No. 801-D-80746

Figure 5. — Constant load deformation tests; 340-day loading (sheet 2 of 2).

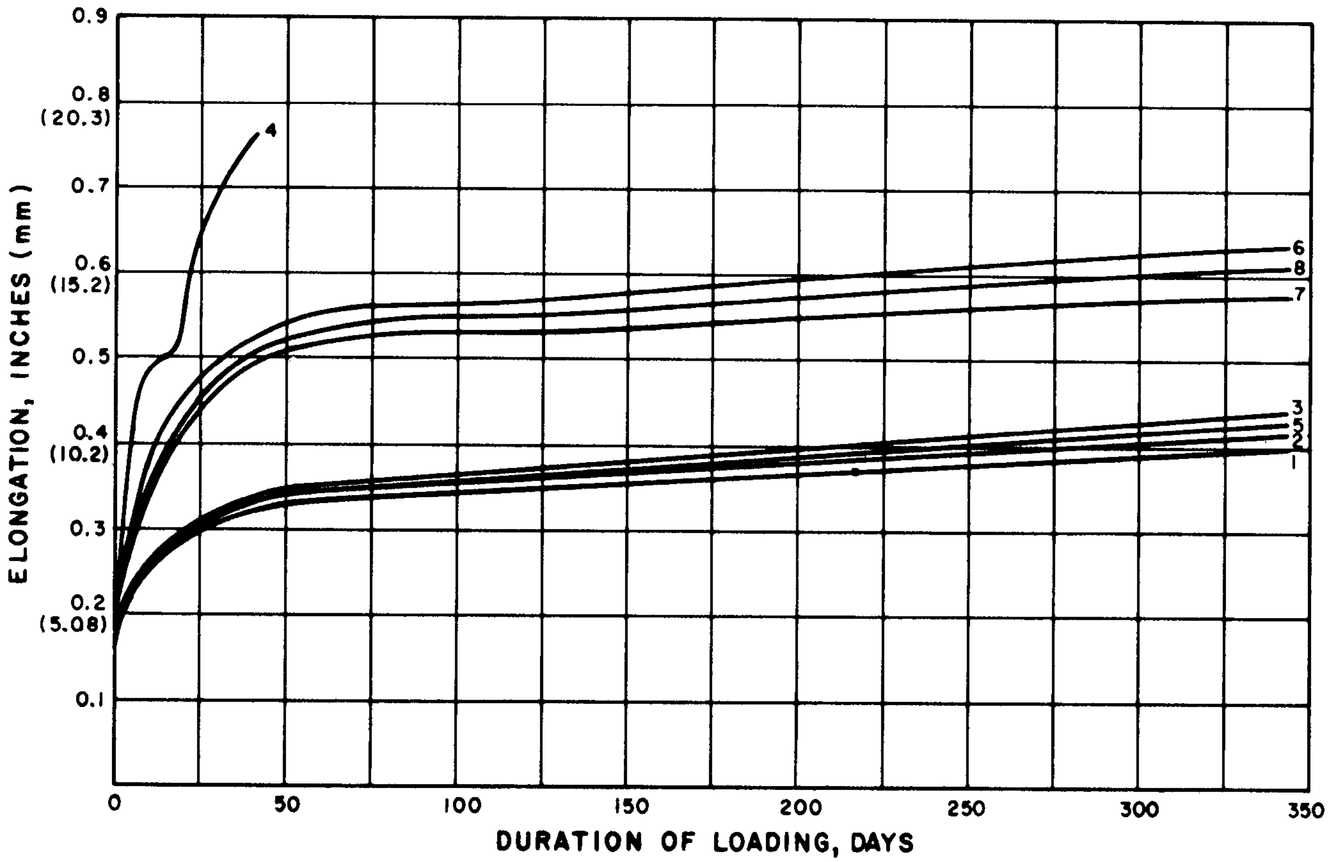


Figure 6. — Graph of elongation vs. duration of loading.

3. Even with a large, 10.2 mm (>0.4 in), and long-term (340 days) elongation of the waterstop section, deformation of the waterstop sealing bulbs will not occur in a properly designed strip.

4. The PVC strips behave almost identically whether strains caused by elongation occur in only a few minutes or develop during long-term loading.

5. The Bostik Mastic Tester can be a useful tool in a joint sealer research program.

DISCUSSION

It would be useful to examine the conclusions from the previous reports to see if they are still valid. All of these reports indicated that any of the PVC strips that could be satisfactorily placed would function properly when the joint opening is 4.2 mm (¼ in) or smaller. Listed below are the conclusions from the previous reports with comments based on the results of recent research.

Conclusion	Comment
From ChE-103	
1. All eight strips were satisfactory at joint openings of 6.4 mm (¼ in) or smaller.	1. If installation is within specified requirements, the statement is true. Joints seldom open much more than 1.6 mm (1/16 in)
2. Most strips could be elongated 50.8 mm (2 in) before failure.	2. At a 2-inch elongation, all strips would be beyond their elastic limits, and the effectiveness of the waterstop would be diminished.

Conclusion	Comment
3. Small dimensional variations do not affect strip performance significantly.	3. Particularly true of center bulb and horizontal flange dimensions. Dimensional tolerances may be more significant to field inserting equipment than to the strip performance.
4. Restraining projections on the waterstop section are useful in confining deformation to the center bulb.	4. True for the usual joint openings of less than 3.2 mm (1/8 in).
5. Sharp angles should be filleted to prevent stress concentrations.	5. True.
6. The PVC strip should restrain slab movement.	6. Theoretically true, but has not been proven in practice.
7. Elongation at constant loading and the effect of cycling fatigue should be studied.	7. Both items are covered in this report.
From REC-OCE 70-35	
1. The PVC strip was generally installed well. Orientation was excellent. Consolidation of concrete around the strip was good, and contraction crack development was generally good.	1. All of these statements were true for this contract on the San Luis Drain, Central Valley Project, Specifications No. DC-6703; but much depends on the competence of the installation crew and equipment and on the diligence of the inspection staff.
From REC-ERC-72-30	
1. Crack control was effective.	1. True in this case (Tehama Colusa Canal), but much depends on the quality of the installation.
2. Only a small percentage of the strips failed to cause a contraction crack to develop.	2. The absence of a contraction crack is often caused by unsatisfactory lining thickness control. Theoretically, a crack should develop at each weakened area.
3. Only one-fourth of the strips were placed in complete accordance with specified requirements, but the majority still should serve satisfactorily, showing that some departure from requirements can be tolerated.	3. Limits of specified requirements were not intended to be "go-no-go" figures, but it is important to have installations within requirements in all aspects to ensure proper functioning.
4. Intersections of transverse and longitudinal strips are the most difficult part of the installation and the point at which sealing is least effective.	4. A leak is built in at each intersection; but, if desirable, an injection of chemically cured sealant can ensure a tight seal at this location also.

The effectiveness of contraction joint-forming and sealing systems is always worthy of consideration and is best judged when seepage losses can be compared. Table 3 was furnished by the Los Banos Office of the Central Valley Project. Data on the San Luis Canal and on the Pleasant Valley Canal were developed by their personnel. Information on other linings was taken from *Linings for Irrigation Canals*, U.S. Department of the Interior, Bureau of Reclamation, 1963.

A direct comparison of the four sealing systems cannot be made because their water depths are different. However, it is apparent that remarkable improvement in sealing capability has been achieved where the PVC strip was used. It would

Table 3. — Data on joints and sealing systems in some concrete canal linings.

Feature	Project	Contraction joint type and sealing system	Water depth m (ft)	Lining thickness mm (in)	Seepage rate (ft³/d)[1]
West Canal	Rio Grande	Believed to be formed contraction grooves without joint sealer	Not indicated	102 (4)	0.26 to 0.83
Friant Kern Canal	Central Valley	Formed contraction grooves containing two-component asphalt mastic	5.2 (17.2)	89 (3½)	0.07
San Luis Canal, Reach 1	Central Valley	Formed contraction grooves containing one-component asphalt mastic plus sponge rod backup	9.6 (31.54)	114 (4½)	0.04
Pleasant Valley Canal, Reach 1	Central Valley	Contraction joint-forming waterstop in longitudinal and transverse directions, shape No. 1 in table 1[2]	1.7 to 2.9 (5.5 to 9.4)	76 (3)	0.008

[1] Cubic feet per square foot per 24 hours.
[2] Intersections were sealed by injecting a two-component polysulfide sealer at time of construction. About 2 in³ of sealer were used at each intersection.

be useful to have data from a canal where PVC strip intersections were not sealed, as in the Pleasant Valley Canal. The originator of the contraction joint-forming waterstop, Dr. Lee Worson, maintained that silting action would seal tiny separations at the waterstop-concrete interface, reducing exfiltration to a negligible amount. It is probably only in the tortuous passageways at intersections that silting would be less effective.

The shape of the PVC strip (fig. 7) has been changed little from that designed from recommendations made in 1971, which were, in turn, almost identical to Dr. Worson's. The main change since 1971 is shown on figure 8: alternative No. 2, having the slender vertical member, is used in the longitudinal direction of the canal only, and alternative No. 3, with the honeycomb-shaped upper vertical member is used in the transverse direction. The "flat-top" strip has been found effective in reducing spalling of the concrete in transverse joints, particularly in the Granite Reef Aqueduct in Arizona. Severe temperature changes are common in this area; apparently, the cushioning effect of the "flat-top" strip is sufficient to prevent the crushing of the upper concrete surface.

The findings of the cycling tests, covered under "Test Procedure" and "Test Results," are encouraging. Although the stresses applied in these tests were probably greater than would be encountered in a field installation and were more rapidly applied than those caused by natural conditions, no defects were detected. The results are especially encouraging because the same test specimens used in the cycling tests were later used in the constant load elongation tests.

The Bostik Mastic Tester is a valuable tool in this type of research because its stick-slip method of elongation simulates natural structural behavior.

The findings of the constant load elongation tests did not differ significantly from those of the constant deflection tests covered in report No. ChE-103. Since the compound from which the PVC strip is made is viscoelastic in behavior, it is not surprising that a load sufficient to cause a ⅛-inch elongation would cause continued elongation. Nevertheless, waterstop sections in each test behaved similarly. Figure 9 shows test specimens from both tests.

Earlier in this report statements were made on the effectiveness of the restraining projections of the waterstop section in confining deformations to the center bulb area. This effectiveness is graphically depicted on figure 10.

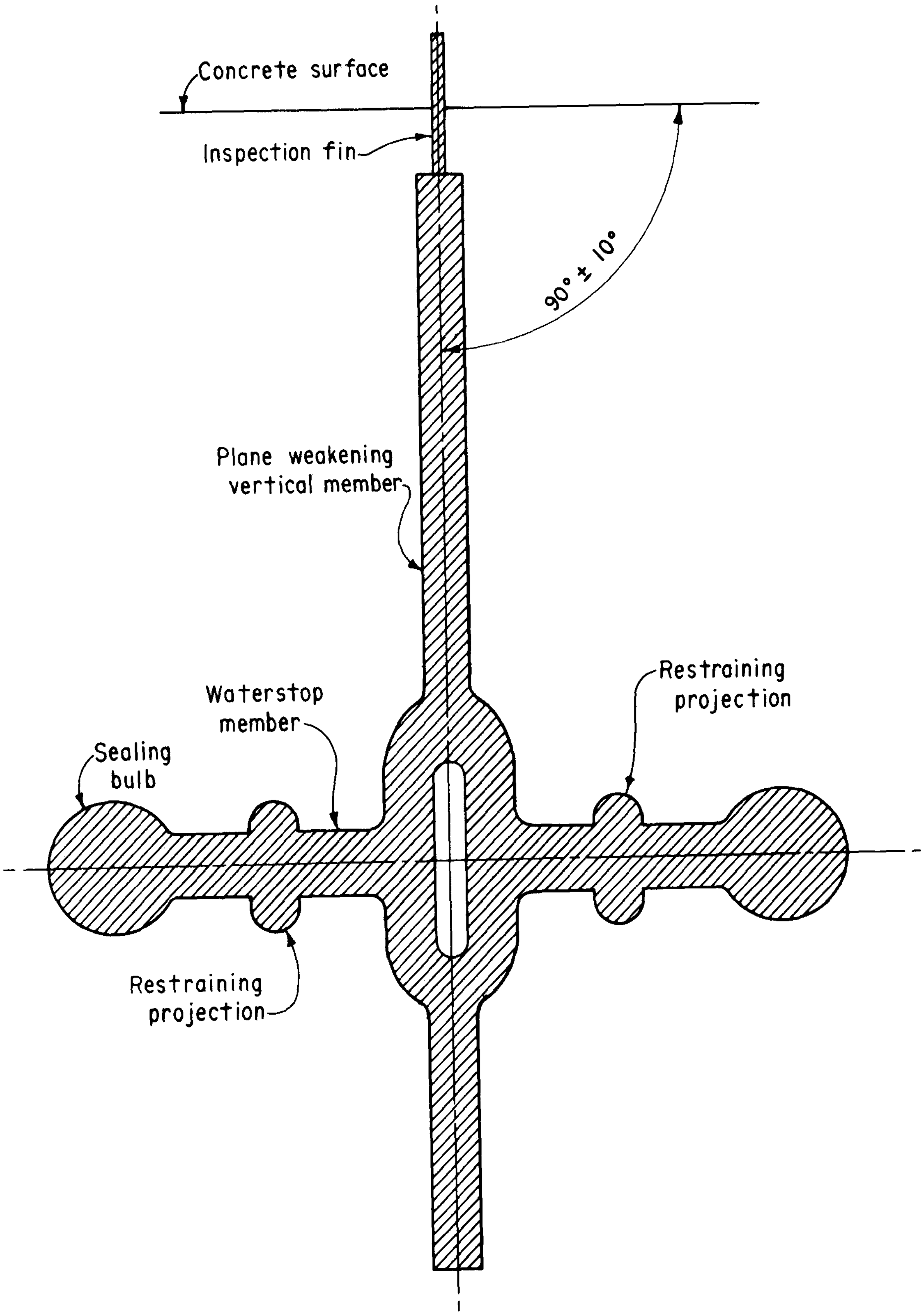


Figure 7. — Recommended shape for contraction joint-forming waterstop.

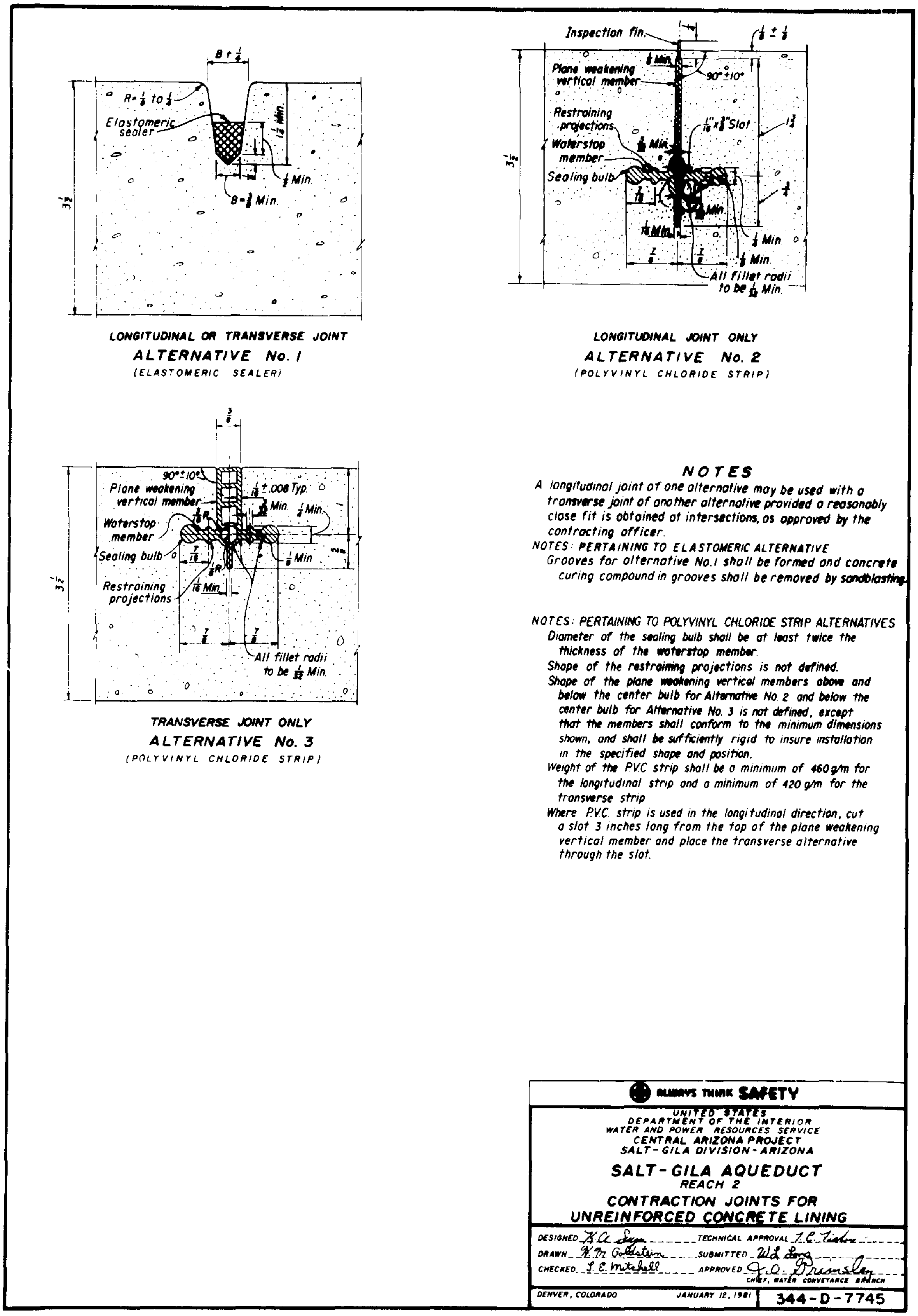
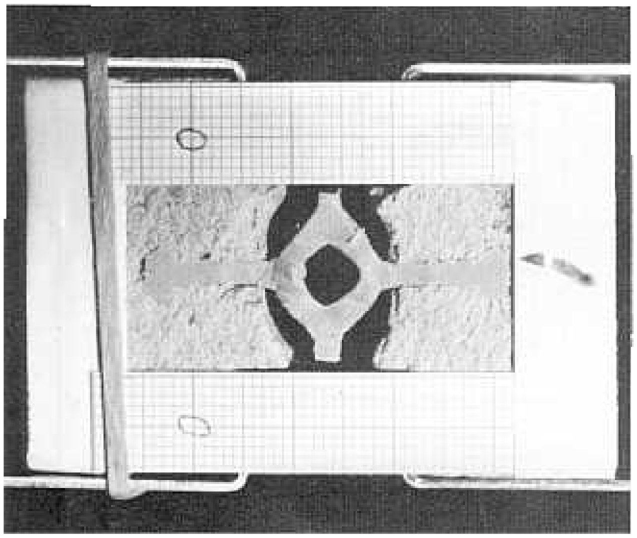
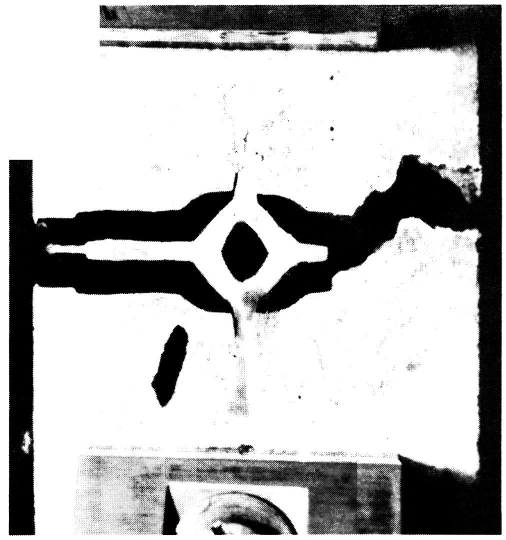


Figure 8. — Drawing 344-D-7745, contraction joints for unreinforced concrete lining.



A. Specimen stretched for 46 days using a constant load. Photo No. 801-D-80747



B. Specimen stretched in 2 minutes slightly greater amount than shown in Figure 9 Photo No. 801-D-80748

Figure 9. Similar PVC strips stretched at different rates.

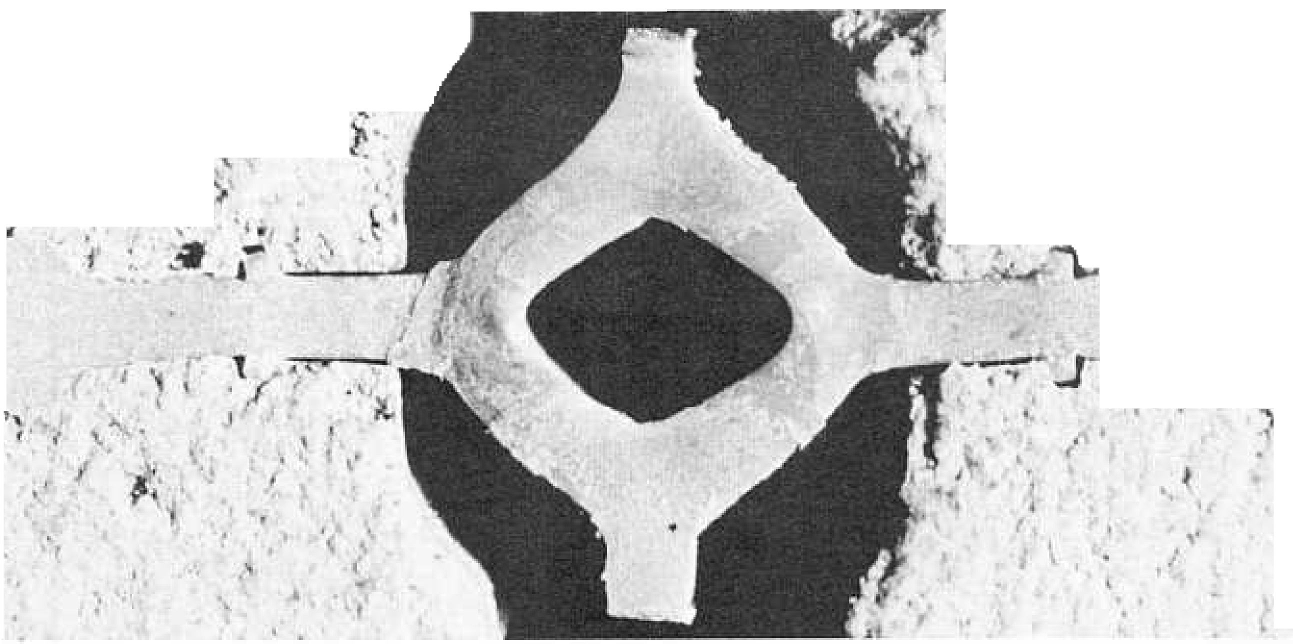


Figure 10. — Magnified view of stretched PVC strip (test specimen No. 1 shown on fig. 5). Although the waterstop section has been extended 10.2 mm (0.40 in), nearly all of the deformation is confined to the section between the restraining projections so that water sealing capability is not impaired. Photo No. 801-D-80749

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Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

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