Preformed Elastomeric Bridge Joint Sealers: Evaluation of the Material

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This paper, the second in a series, presents up-to-date knowledge on sealer material. It includes the best available tentative qualification and identification specifications, and furnishes producers and users with practical ways to develop and/or identify a reasonably adequate product. These specifications are as realistic and as closely related to field application as present-day knowledge of the subject permits. To this end, simulated service tests were given extended coverage and a section on quality control of materials was included. The correlation between the specifications and the functional applications of the product is assured by an ongoing research program.

•A PAPER on the subject of the design and construction of bridge joints sealed by preformed elastomeric sealers was presented previously (1). Since then, new knowledge of the material has been acquired and its application was further explored. A research program was developed with the following specific aims in mind:

1. To test and improve suggested methods of design and construction of bridge joint systems and to establish relationships between deck and air temperatures and joint movements; and
2. To develop realistic material specifications, closely related to the actual field applications of the products.

As a result of the research program, a sequence of four papers was planned. The first paper, on design and construction, was published earlier (1). The present paper is the second one and its subject is the material in the preformed elastomeric sealers. The third paper is intended to cover temperature and joint movements and the fourth the results and conclusions.

The first paper barely touched the subject of the sealer's material; since then, the need for more knowledge about it has become apparent. The previous paper presented to the engineer a basic understanding of the material. This one will concern itself mainly with the qualification and identification of the material. But first it is appropriate to introduce an amendment to clarify a misunderstanding.

AMENDMENT TO THE SEALER DESIGN PRACTICES

One of the criteria for a "functional" sealer, as defined in the previous paper (1), is its ability to remain functional within certain limits of the sealer's compressibility. "Efficiency coefficients" X, Y, and Z were introduced and tables were offered as guidelines for the design of sealers. Other tables showed that the sealers presently available are not meeting the requirements. In spite of this demonstration, the factor of functional limitation somehow remained concealed.

Later in this paper, the producers and users of sealers will be offered practical ways for the development and/or identification of a reasonably good product. This section

Paper sponsored by Committee on Sealants and Fillers for Joints and Cracks in Pavements and presented at the 48th Annual Meeting.

TABLE 1

GUIDE TO THE DESIGN OF SEALERS

W_n (in.)	At 100 F		Δ at Δt = 70 F	At 30 to 90 F		Δ at Δt = 90 F	At 0 F		Limits of Span
	W_{jmin}	Z		W_j (in.)	Y		W_{jmax}	X	
1½	0.875	0.58	0.00	⅞	0.58	0.00	0.875	0.58	Up to 30 ft
	0.735	0.49	0.14			0.18	1.055	0.70	
1¾	0.86	0.49	0.14	1	0.57	0.18	1.18	0.67	30 to 35 ft
	0.84	0.48	0.16			0.21	1.21	0.69	
2	0.965	0.48	0.16	1⅛	0.56	0.21	1.335	0.67	35 to 45 ft
	0.915	0.46	0.21			0.27	1.395	0.70	
2½	1.165	0.47	0.21	1⅜	0.55	0.27	1.645	0.66	45 to 50 ft
	1.145	0.46	0.23			0.30	1.675	0.67	
3	1.52	0.51	0.23	1¾	0.58	0.30	2.05	0.68	50 to 60 ft
	1.47	0.49	0.28			0.36	2.11	0.70	
4	1.97	0.49	0.28	2¼	0.56	0.36	2.61	0.65	60 to 90 ft
	1.83	0.46	0.42			0.53	2.78	0.695	
5*	2.455	0.49	0.42	2⅞	0.58	0.53	3.405	0.68	90 to 115 ft
	2.345	0.47	0.53			0.68	3.555	0.71	
6*	2.97	0.50	0.53	3½	0.58	0.68	4.18	0.70	115 to 130 ft
	2.90	0.48	0.60			0.77	4.27	0.71	

Temperature Range: 0 to 100 F
Construction Temperature: 30 to 90 F
Installation Temperature: 30 to 90 F
Degrees of Efficiency: $Z_{min} = \pm 0.50\ W_n$; $Y_{avg} = \pm 0.60\ W_n$; $X_{max} = \pm 0.70\ W_n$

NOTE: All the above temperatures are those of the concrete. Since these temperatures cannot readily be measured, the daily average temperature of the air with a tolerance of +5 to +10 F would be presently acceptable.

*Because of the lack of experience with these two largest sizes, it is preferable not to use the sealer widths W_n = 5 in. and 6 in. until further data are available.

TABLE 2

GUIDE TO THE DESIGN OF SEALERS

W_n (in.)	At 100 F		Δ at Δt = 70 F	At 30 to 90 F		Δ at Δt = 90 F	At 0 F		Limits of Span
	W_{jmin}	Z		W_j (in.)	Y		W_{jmax}	X	
1½	0.875	0.58	0.00	⅞	0.58	0.00	0.875	0.00	Up to 40 ft
	0.695	0.46	0.18			0.24	1.115	0.74	
1¾	0.945	0.54	0.18	1⅛	0.64	0.24	1.365	0.78	40 to 45 ft
	0.915	0.52	0.21			0.27	1.395	0.80	
2	1.04	0.52	0.21	1¼	0.625	0.27	1.52	0.76	45 to 55 ft
	1.00	0.50	0.25			0.33	1.58	0.79	
2½	1.25	0.50	0.25	1½	0.60	0.33	1.83	0.73	55 to 70 ft
	1.18	0.47	0.32			0.42	1.92	0.77	
3	1.555	0.52	0.32	1⅞	0.625	0.42	2.295	0.765	70 to 90 ft
	1.455	0.485	0.42			0.53	2.405	0.80	
4	2.08	0.52	0.42	2½	0.625	0.53	3.03	0.76	90 to 120 ft
	1.95	0.49	0.55			0.71	3.21	0.80	
5*	2.575	0.515	0.55	3⅛	0.625	0.71	3.835	0.77	120 to 150 ft
	2.435	0.49	0.69			0.89	4.015	0.80	
6*	3.06	0.51	0.69	3¾	0.625	0.89	4.64	0.77	150 to 180 ft
	2.92	0.49	0.83			1.07	4.82	0.80	

Temperature Range: 0 to 100 F
Construction Temperature: 30 to 90 F
Installation Temperature: 30 to 90 F
Degrees of Efficiency: $Z_{min} = \pm 0.50\ W_n$; $Y_{avg} = \pm$ 0.60 to 0.65 W_n; $X_{max} = \pm 0.80\ W_n$

NOTE: All the above temperatures are those of the concrete. Since these temperatures cannot readily be measured, the daily average temperature of the air with a tolerance of +5 to +10 F would be presently acceptable.

*Because of the lack of experience with these two largest sizes, it is preferable not to use the sealer widths W_n = 5 in. and 6 in. until further data are available.

presents an amendment to the previous paper in the form of Tables 1 and 2. The meaning of Tables 1 and 2 is illustrated by the following example:

Span	At 20 Percent Range		At 30 Percent Range		At 40 Percent Range	
	W_n	Estimated Material Price, $/ft	W_n	Estimated Material Price, $/ft	W_n	Estimated Material Price, $/ft
90 ft	5 in.	16.00	4 in.	11.00	3 in.	6.00
130 ft	Composite sealer design (larger than 6 in.)	above 27.00	5 in. or 6 in.	16.00 26.00	4 in.	11.00

The prices mentioned are only for purposes of comparison, but it is apparent that the cost of this type of sealer application is influenced considerably by the sealer's efficiency. Often the initial cost of the product is increased, but sometimes the design and installation costs also are adversely affected.

The problem of the temperature of installation is frequently raised. This is a complex question. Practically it has been answered in the previous paper in the section, "Design of Preformed Elastomeric Joint Sealer Application". We hope to substantiate this more completely in the future.

QUALIFICATION AND IDENTIFICATION OF THE MATERIAL

As already stated elsewhere, the use of elastomeric materials in the construction field is recent and unexplored. The structural designers and builders have relatively less clear understanding of elastomers than they have of the more common construction materials. On the other hand, most specialists in the field of elastomers seem to be more concerned with material properties than with the functional requirements of application. Thus, it appears that at the present time nobody seems really to know which properties best express the actual performance of the material when it is used as preformed elastomeric joint sealers.

As a result, specifications presently available have very little basis in fact, because on the one hand there is hardly any correlation between them and the actual sealer application, and on the other hand, not enough testing has been done on actual seals.

An effort was already made to improve the understanding of the material by the engineer and of the functional criteria by all concerned. Now, mainly for the benefit of the engineer, the material specifications are discussed and presented on the basis of the best information available.

DISCUSSION OF THE TENTATIVE SPECIFICATION

I have indicated that the use of the elastomeric material in the construction field is new, and that this material and its use are poorly understood. In other words, nobody seems really to know which properties best express the actual performance of the material when it is used as a preformed elastomeric joint sealer. The tentative specification, therefore, can only be intended as an interim action, after which all concerned will have an opportunity to take steps to correct, amend, or otherwise improve it.

This specification, which is reproduced in the Appendix to this paper, covers the material and its manufacture, physical requirements and test procedures, and sampling, certification, and acceptance requirements. The section on quality control of material, mainly in the form of simulated service tests, is the most notable development.

For an easier understanding of the specification, let us start with a discussion of the tests for identification and qualification requirements (Tables A1 and A2 in the Appendix) and clarify some possible misunderstandings. For simplicity of identification the tests are grouped and numbered. Their discussion was developed with the assistance of E. I. du Pont de Nemours and Company.

Group I, Tests 1 to 4

The tests of tensile strength, elongation, hardness, and permanent set at break are widely used to characterize rubber products. They give very little useful information themselves, since they only describe "original" properties measured right after vulcanization. But they do tend to establish the broad quality classification of the product.

The rubber industry uses the word "quality" in a specific context. When applied to a particular compound, quality refers to the degree to which the maximum properties available from the polymer have been developed. In most elastomers, polychloroprene included, there must be other ingredients in the compound, as already indicated, to develop optimal properties. Therefore, even the highest quality compound will not contain more than 60 to 65 percent of elastomer by weight. Since the elastomer is the most expensive major ingredient in a rubber compound, the higher the percentage of elastomer, the more expensive the compound will be.

Tensile strength and elongation—in a given hardness range—give an immediate indication of the quality level, because these properties reflect the degree to which the compound has been diluted. Permanent set indicates whether or not the compound has reached its optimum state of vulcanization and is reflected in stress relaxation or creep. The hardness test gives only an approximate value; it is therefore not an adequate measure of load-carrying capacity (stiffness). As stated before, however, the product must be further defined by other tests in order to determine its usefulness in a given service.

Group II, Tests 5 to 7

The oven aging, ozone resistance, and oil swell tests serve a twofold purpose:

1. To measure the effects of various environments on the rubber product, and
2. To identify the elastomer used.

It should be noted that the degree to which these tests measure the resistance to aging in different environments depends on how well each test is related to actual exposure. Precise correlation is difficult, if not impossible, to obtain without intensive study over long periods of time.

Oven aging is a rough indication of how well a rubber product will resist age deterioration (which includes oxidation effects), as well as other deteriorating factors such as heat.

The ozone test, on the other hand, measures resistance to a specific deteriorating influence. Many types of rubber are susceptible to severe attack from ozone. Since ozone is present in the atmosphere, resistance to ozone attack is necessary for a material to withstand prolonged weathering. While oxygen affects the entire unit of the material, ozone attacks the surface, causing cracks that open under loading, exposing it to further ozone damage and possibly rupture under stress.

Volume increase of the product in oil is not a true indication of the resistance of an elastomer to deterioration. If one were testing for deterioration, then one should determine retention of physical properties after oil aging. Although polychloroprene is a medium-swell elastomer, it retains physical properties better than the so-called low-swell elastomer. In this specification, the oil test (combined with the ozone requirement) serves mainly to help assure that the elastomer is polychloroprene.

The Group I and II properties must be viewed as a composite. No elastomer compound can be designed to have the maximum desirable levels of all properties. What is done to improve one property may hurt another. Therefore, each compound is a composite. The compound must have a balance of good levels of the properties most necessary to good service.

Group III, Tests 8 to 10

While one could not quite think of the recovery tests as simulated service tests, they bear more resemblance to service conditions than the others.

The high-temperature recovery test is an indication of how completely the seal is vulcanized. Poorly vulcanized seals would tend to take too high a set after being compressed in a highway joint. The field data available at this time are not sufficient to allow anyone to attempt to correlate a given recovery value with some specific useful life in a joint.

The low-temperature recovery tests have a different purpose. A seal will not pass these two tests unless it has been compounded to resist both crystallization and thermal stiffening. The recovery requirement at +14 F is designed to ensure that a crystallization-resistant neoprene polymer is used. The -20 F test will assure specifically that the compound has a good level of low-temperature flexibility and that the brittleness characteristics will be controlled. The plasticizers improve flexibility and depress the brittle point of materials at low temperatures. The -20 F temperature appears to be adequate for the area of the State of New Jersey.

The function of the material specification is to set practical limits on the important properties from a production standpoint, as well as to ensure the procurement of serviceable material. Irrelevant tests should be avoided.

There are also other basic rubber material tests such as tear, compression set, and low-temperature stiffening. These tests are omitted from the proposed specifications because they are irrelevant and could even be misleading for sealer service purposes.

The recovery tests are used to take the place of the low-temperature stiffening and compression set tests. The tear test, although valid, cannot be performed properly by methods presently available.

Both the recovery and compression set tests indicate the state of cure. Curing is executed on an already extruded product. A balance must be maintained between compression set and tear—an undercured material will cause excessive set, an overcured one will result in cracking. Obviously, neither is permissible.

The compression set on the preformed sealer, designed as a structural unit, is best represented by recovery tests, since the compression set test is preformed on the solid sample of material, whereas the recovery tests are conducted on a sample of a sealer unit. The sealers are specifically designed always to act as a structural unit within certain limits. Compression beyond these limits might result in failure. Therefore, a compression set test on solid material is not entirely representative and may even be misleading.

Both tear and compression set tests are generally good when run exactly as prescribed by ASTM. When performed on samples obtained from finished seals they can be clouded by error.

As indicated, the balance between the tests is essential regarding the state of cure. This is why it appears desirable in the future to include the tear test in the specifications, as soon as satisfactory methods of testing are developed.

Suggested Changes

In the foregoing I have suggested some changes from accepted practice in the physical properties and requirements to be specified and tested. These suggestions can now be reviewed.

The round-robin tests performed for ASTM Committee D-4, Subcommittee 3e, have indicated the increase as well as the loss of tensile strength after oven aging. Since the increase of tensile strength in this test indicates somewhat undercured material, it seems advisable to limit both.

A segment of the manufacturing industry claims that to ensure the adequacy of the degree of precision in the process of extrusion of sealers larger than 4 in. the "minimum tensile strength" property requirement of 1800 psi is essential. As indicated before, in a given hardness range this means dilution of the compound and lower "quality" level of the material. Because the properties that best express the actual performance of the material when used as a subject sealer are unknown, such relaxation of the subject requirement, I suppose, could be tolerated until it becomes apparent that it will not also lead to a lower quality product (a sealer). Under these circumstances any increase in hardness requirements becomes ill-advised.

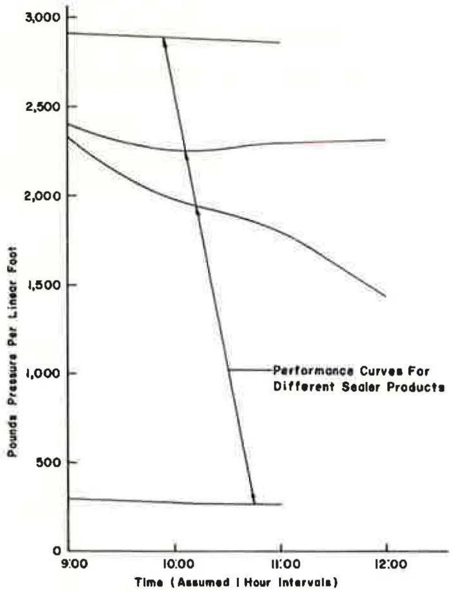

Figure 1. Pressure-decay curves (averages) for nominal sealer size $2\frac{1}{2}$ (W_n) x $2\frac{3}{4}$.

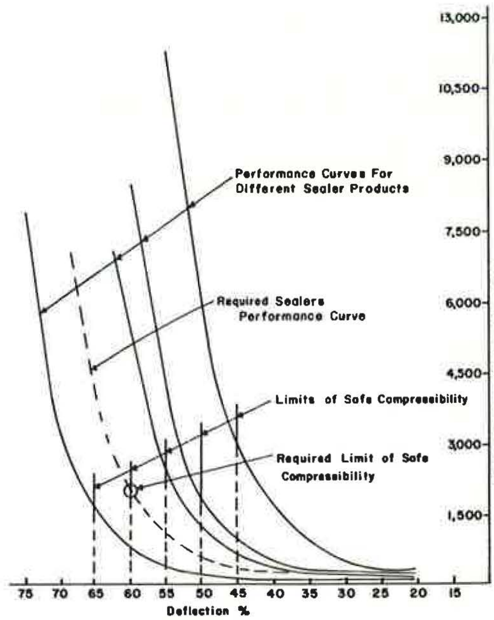

Figure 2. Pressure-deflection curves (averages) nominal sealer size $2\frac{1}{2}$ (W_n) x $2\frac{3}{4}$.

Essentially, the "Tests for Identification Requirements" in the specification (Appendix) summarize material requirements, while the "Tests for Qualification Requirements" represent simulated service tests.

With addition of pressure-deflection testing and the development of the relationship between the limit of safe compressibility and the percentage of deflection during the high-temperature recovery test, the recovery tests become definitely more meaningful because they can, and I believe they will, be accepted as simulated service tests, rather than tests of material.

The development of pressure-deflection tests as well as the limit of safe compressibility are the offshoot of a program first presented to the ASTM at its January 1968 meeting. They remain a part of the New Jersey pilot research program on this subject.

What is the "limit of safe compressibility" and what is the "pressure-deflection test"? The specifications (Appendix) explain it in paragraphs 4 and 5; Figures 1 and 2 clarify it further. The pressure-decay graph (Fig. 1) is illustrative only, since the lack of equipment capable of adequate accuracy (such as a Universal Testing Machine) does not permit the extension of this test far enough to establish sufficiently acceptable pressure-decay values of Y.

Figure 2 illustrates the limit of safe compressibility and the minimum contact pressure. The solid lines indicate the pressure-deflection values of products presently in existence; the dashed line represents the minimum required pressure-deflection values of a desirable product and this indicates the way a producer can develop such a product. In reference to the minimum contact pressure X, the same difficulty exists as in the case of Y.

Hall, Ritzi, and Brown (3) are presently improving the testing device mentioned in their article for the purpose of obtaining equipment that will permit the determination of sufficiently accurate values of X.

Some time ago I stated that in the high-temperature recovery test the percentage of deflection should be 60 percent. At present this value is Z percent and is the limit of safe compressibility. The previous statement read in substance that this is being done to facilitate the requirements of design (Z_{min} = 40 percent), installation, and material.

[Values X, Y, and Z here are "efficiency coefficients" as explained in my earlier article (1).] In the same test, the 70 hours/212 F requirement seems to eliminate more efficiently the inadequate material.

These changes, with some other minor ones, have only one purpose—to reduce the sealer service inadequacies observed in the field. The fact is that to date, in New Jersey, sealers in bridges under observation have failed in various degrees—joints are leaking. This situation necessitates tightening of the material requirements, and seeking constructive cooperation on the part of the sealer manufacturers.

The degree of failure may be argued, although it is beside the point in this discussion. At the present time the observed inefficacy cannot always be attributed directly to an inadequacy of the sealer material. But one thing has been established: almost all sealers were installed at higher than 60 percent Y compression and many relaxed in winter months to more than 80 percent X.

For the present, considering the methods of joint construction used in New Jersey, the sealers should be compressed during installation to about Y = 55 percent and should never relax to more than X = 70 percent (Table 1).

Further, as indicated in the cost analysis example, this type of material is expensive; therefore, inefficient utilization of the sealers may not justify their cost. This can very easily happen if efforts are not made to meet the suggested requirements. I believe they can be met, provided all concerned endeavor to improve quality. This type of seal should and can solve the problem of joints in a large percentage of bridges.

In reference to the "lubricant-adhesive" material, as presently used to facilitate the application of these seals, it is useful as a lubricant. But during prolonged periods of high temperature (above 90 F) it has the tendency to set rather quickly while being applied. For all practical purposes, it is admittedly an adhesive by name only, as observed in the field.

All told, expanded research on better bridge joints is a growing need. This is why New Jersey is already proceeding with the implementation of an improved program along these lines:

1. Thorough testing of all sealers to be utilized on actual construction in accordance with the accepted specifications;
2. The same kind of testing of all sealers removed from joints for reasons of failure or otherwise; and
3. Testing for the purpose of research.

The direction of this research will be toward further development of the idea of positive retention of contact pressure in conjunction with minimum compressed width and sealer recovery.

The ultimate goal of all this measuring, recording, and correlating will be to relate the material and the simulated service tests to actual field application and to the specific period of useful life in a joint.

An explanation for the deflection value Z has already been offered; the simulated service tests are presented and explained in the proposed tentative specifications in the Appendix. As to the present implementation of the research program, the material submitted for approval, while being tested officially, is being tested completely in accordance with the tentative specifications, but for research purposes only. This obviously covers the first and third points. Regretfully, point 2 cannot as yet be implemented because no "used" sealers are available.

Some data already available are very encouraging. These data allow much better judgment of the quality of the material; so much so, in fact, that I would not hesitate to pass some material that may fail numerically in some of the tests (mainly in the material part of the specifications), while on the other hand I would fail some of the material previously considered adequate. The data already indicate possible values for Y and X in the pressure-deflection tests. If nothing else, this clearly indicates the correctness of the direction in which the study is proceeding.

TABLE 3

45-DEGREE SKEW ANGLE JOINT TEST

Load	P						1.41P						P_2			P_1 $1.41P - P_2 = P_1$						P	P_2	P_1
% \ run	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	1	2	3	4	5	6	Avg.	Avg.	Avg.
20	160	150	145	156	160	156	225	211	204	220	225	220	80	70	70	145	141	134	140	155	150	154	73	144
25	200	175	177	187	190	187	282	247	250	264	268	264	82	72	70	200	175	180	182	196	194	186	74	187
30	235	220	212	225	228	222	331	310	299	317	321	313	100	87	85	231	223	214	217	234	228	223	90	224
35	268	252	250	257	260	259	378	355	352	362	367	365	160	140	135	218	215	217	202	227	230	257	145	218
40	310	287	290	305	304	305	437	405	409	430	428	430	235	200	205	202	205	204	195	226	225	300	213	209
45	400	370	370	375	382	380	564	522	522	529	539	536	380	330	335	184	192	187	149	209	201	379	348	187
50	530	520	510	500	520	505	747	733	719	705	733	712	625	---	---	122	---	---	80	---	---	514	625	101
45	295	305	310	305	320	320	416	430	437	430	451	451	210	---	---	206	---	---	220	---	---	309	210	213
40	235	235	240	240	250	252	331	331	338	338	352	355	132	147	155	199	184	183	206	205	200	242	145	196
35	192	197	200	200	211	213	271	278	282	282	298	300	85	92	95	186	186	187	197	206	205	202	91	194
30	165	170	165	170	180	180	232	240	233	240	254	254	60	60	60	172	180	173	180	194	194	171	60	182
25	145	140	140	140	150	149	205	197	197	197	211	210	55	55	55	150	142	142	142	156	155	144	55	148
20	105	110	120	115	125	124	148	155	169	162	176	175	52	55	52	96	100	117	110	121	123	116	53	111

THE SKEWED JOINT TEST

Table 3 and Figure 3 represent data on the skewed joint effect on a sealer, in this case a nominal sealer size of 2½ by 2¾ in. This test was performed experimentally for the purpose of acquiring tangible data. Basically it is a success, but the relationship of some numerical values is dubious, the reason being the test procedure.

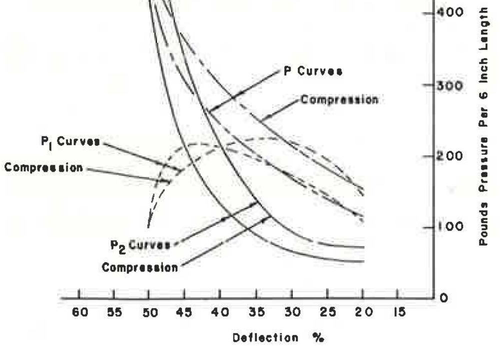

Figure 3. Pressure-deflection curves for 45-deg skew angle (averages): Graphs of forces P, P_1, P_2 for nominal sealer size $2\frac{1}{2}$ (W_n) x $2\frac{3}{4}$.

To determine the P_2 force, i.e., the force perpendicular to the width of the sealer, a usual pressure-deflection procedure was used. This force is correct when measured by itself in this manner. The skew force P was measured also in accordance with the regular pressure-deflection procedure, and by itself, is correct. The force P_1 is calculated as shown in Table 3.

The fallacy lies in the separate measuring of forces P_2 and P. I believe that if both of these forces could be measured during the skewed test, the numerical relationship of all three forces P, P_1, and P_2 would be different, although the graphs in Figure 3 would look very similar.

The value of this test is multiple. First, the basic relationship is as shown in the graph. Second, the minimum contact pressure of a sealer located in a skewed joint is larger whereas the peak of pressure is smaller than in a joint that is perpendicular to the span. Third, the force parallel to the joint is declining after a while and its peak is far below the other forces.

One very important question is not being answered and further testing is needed for that: Do we need a larger sealer for a skewed joint and, if so, at what degree of the skewed angle does the increase in size begin and, finally, what changes of sealer sizes are needed as the skew angle increases?

Sealer sizes are being enlarged presently with the skew, but it is not certain that the enlargement is necessary. It is hoped that research will find the answer to this question.

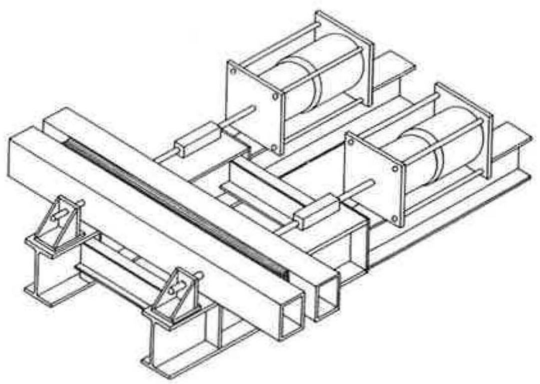

Figure 4. Schematic of model joint machine.

TESTING PROGRAM

Before going into the description of the testing phase of the research, it is important to realize the necessity of it. E. I. du Pont de Nemours and Co., among others, has amassed a considerable amount of data. In the brochure, "Elastomers Notebook" (4), for example, they discuss long-term (20 years) outdoor exposure tests of some polychloroprene compounds, but only under static service or unstressed conditions. In the application of rubber products anywhere in construction and specifically as joint sealers, the outdoor dynamic service conditions of exposure are predominant.

Outdoor weathering exposure is the condition where the similarity ends. A 50-year life span on an outdoor rack might, but also might not, represent a sealer in actual application. Therefore, the material properties and their physical requirements, if based on these tests, would not necessarily ensure quality material for use in products such as sealers, regardless of their application. Only if tested for outdoor dynamic service could such knowledge be claimed. The present program represents such a condition test for outdoor dynamic service exposure.

Methods of Procedure

Testing will be accomplished under existing field exposure conditions using "model joint" machines to simulate most of the bridge behavior patterns except for traffic. Such a machine is already developed. Its basic capability will be to compress a sealer within a range of minimum to maximum compressed widths, while being exposed to outdoor conditions and activated by environmental variations such as temperature change.

It has been recognized that adequate simulation of the outdoor exposure conditions is impossible and therefore the time period required for this test is governed by the time factor of daily (24 hours) and yearly cycles.

The principle of the model joint machine is based on the fact that some materials have an expansion coefficient many times higher than concrete, making it possible to simulate, for bridges, thermal movements of considerable magnitude, without resorting to large-size models or mechanical means of motoring.

The model joint machine is illustrated in Figure 4. In this apparatus, a sealer product is placed between a stationary and a movable jaw. The movable jaw is activated by a set of bellows. The bellows in turn are powered by a thermo-sensitive liquid. Thus, the bellows are in this case thermostatic motors and fit the purpose mostly because they will function regardless of the pressure they must overcome. In the case of minimum pressure, the internal spring with a nominal rate of 500 lb/in. will suffice. The machine will have a considerable range and the design approach was thorough.

CONCLUSIONS

In this paper a more complete attempt is made not only to describe the material but also to provide the best available tentative qualification and identification specifications (Appendix). These specifications are as realistic and as closely related to the actual field applications as combined knowledge of the subject permits. To build the bridge between these specifications and reality, the simulated service tests and a section on "quality control of material" were added.

To substantiate these specifications, to make them realistic in as complete a sense of the word as possible, the correlation between subject specifications and the functional application of the product is needed. Because I had to conclude that field data for such a correlation are neither available nor reliable, I propose the research program mentioned in this paper. The results will be presented in the final paper of this series.

REFERENCES

1. Kozlov, George S. Preformed Elastomeric Bridge Joint Sealers. Highway Research Record 200, pp. 36-52, 1967.
2. ASTM Compression-Deflection Test, Designation D 575-67, Method A. 1967 Book of ASTM Standards, Part 28.
3. Hall, F. K., Ritzi, J. H., and Brown, D. D. Study of Factors Governing Contact Pressure Generation in Neoprene Preformed Compression Seals. Highway Research Record 200, pp. 53-74, 1967.
4. E. I. du Pont de Nemours and Co. Elastomers Notebook, April 1961.

Appendix

PROPOSED TENTATIVE SPECIFICATION FOR PREFORMED ELASTOMERIC JOINT SEALERS FOR BRIDGES

1. Scope

1.1 This specification covers the material qualification and identification requirements for preformed elastomeric compression joint sealers, to be utilized in bridge construction, the base polymer being in accordance with 2.1.

2. Materials and Manufacture

2.1 Sealers shall be preformed and manufactured from vulcanized elastomeric compound, using polychloroprene as the only base polymer.

2.2 If other base polymers are shown to be suitable in this application, the requirements of this specification shall be amended by alternate requirements, which shall be developed to define adequate quality of the new composition.

3. Physical Requirements

3.1 The material shall conform to the physical properties prescribed in Tables A1 and A2.

4. Dimensions and Permissible Variations

4.1 The size, shape, and dimensional tolerances of the sealers are subject to design and/or shall be guided as outlined in paragraphs 4.1.1 and 4.1.2.

4.1.1 The accepted width and height of a sealer shall be not less than nominal; the height of a sealer can be in excess of nominal but by not more than one quarter (+1/4") of an inch.

4.1.2 The dimensional tolerances shall be determined on the basis of the limit of safe compressibility of the sealers.

4.1.3 The limit of safe compressibility of sealers is the border line between closure of essentially all of the air voids and the beginning of solids compression and is clearly defined on the pressure deflection curve by rapid and considerable increase of pressure.

4.1.4 The limit of safe compressibility of sealers shall be at not less than "Z"% deflection from sealers nominal width, where "Z" in per cent shall be the maximum deflection contemplated in the joint sealing design, and shall be specified as stipulated in the paragraph 4.1.5.

4.1.5 The value of "Z" (in per cent) shall be agreed upon between purchaser

TABLE A1

TESTS FOR IDENTIFICATION REQUIREMENTS

TEST NO.	PROPERTIES DETERMINED ON ACTUAL SEALS	[a] TEST PROCEDURE	PHYSICAL REQUIREMENTS
Group I			
1	Tensile Strength, min. psi (kg/cm^2)	D-412	[c] 2000 (141)
2	Elongation at break, min. per cent	D-412	250
3	Hardness, Type A, Durometer	[b] D-2240	55+5 -5
4	Permanent Set at Break, max. per cent	D-412	10
Group II			
5	Oven or heat aging 70 hrs./212°F	D-573	
	a. Tensile strength, change, max. %		+10 to -20
	b. Elongation, change, max. per cent		-20
	c. Hardness, Type A, points change		0 to +10
6	Ozone resistance 20% strain, 300 pphm in air, 70 hrs./104°F(40°C) (Wipe with solvent to remove surface contamination)	D-1149	No cracks
7	Oil Swell, ASTM Oil #3, 70 hrs./212°F Weight Change, max. per cent	D-471	+45

[a] These designations refer to the following methods of the American Society for Testing and Materials:

D-412, Test for Tension Testing of Vulcanized Rubber

D-395, Test for Compression Set of Vulcanized Rubber

D-573, Test for Accelerated Aging of Vulcanized Rubber by the Oven Method

D-471, Test for Change in Properties of Elastomeric Vulcanizates Resulting from Immersion in Liquids

D-1149, Test for Accelerated Ozone Cracking of Vulcanized Rubber

D-2240, Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer

D-575-67, Test for Compression-Deflection Characteristics of Vulcanized Rubber

E-4-64, Verification of Testing Machines

[b] The hardness test shall be made with the durometer in a durometer stand.

[c] For sealer sizes larger than four (4) inches in width the "Minimum Tensile Strength" of 1800 psi is required.

TABLE A2

TESTS FOR QUALIFICATION REQUIREMENTS
(simulated service tests)

Group III			
8	High Temperature Recovery 70 hrs./212° under [e]"Z"% deflection	[d] Subsection 8.1 to 8.1.1.3	85% min.[f](no cracking or sticking)
9	Low Temperature Recovery 72 hrs./+14°F under 50% deflection	[d] Subsection 8.1 to 8.1.1.3	88% min.[f](no cracking or sticking)
10	Low Temperature Recovery 22 hrs./-20°F under 50% deflection	[d] Subsection 8.1 to 8.1.1.3	83% min.[f](no cracking or sticking)
11	Pressure-deflection 20% deflection at 73°F ± 2°F	[d] Subsection 8.1.2	
	a. Min. contact pressure, psi		"X"
	b. Max. Pressure-decay, percent		"Y"
	[e]"Z"% deflection @ 73°F ± 2°F c. Max. contact pressure, psi		200

[d] The reference Subsections are those of this specification.

[e] "Z"% deflection is defined and numerically specified in Subsections 4.1.4 and 4.1.5.

[f] Cracking or splitting and/or sticking of specimen during recovery shall mean that specimen has failed the test.

and the manufacturer as stipulated in paragraph 4.1.4 and so specified in the purchaser's specification and/or drawings.

5. Quality Control of Material

5.1 The amount of Initial Contact Pressure which sealers shall be capable of exerting uniformly when compressed is stipulated in paragraphs 5.1.1, 5.1.2 and 5.1.3.

5.1.1 The minimal Initial Contact Pressure at 20% deflection for any size of bridge sealer shall be "X" pounds per square inch (lbs/in^2) on the third successive test-run or cycle, at which time the pressure-decay shall not exceed "Y" per cent (%) from the first test run. ("X & Y" values must be established by tests.) Calculate pressure-decay at 20% deflection as follows:

$$\%\ \text{Pressure-decay} = \frac{\text{Pressure at 1st test run} - \text{Pressure at 3rd test run}}{\text{Pressure at 1st test run}} \times 100$$

5.1.2 The maximum Initial Contact Pressure at "Z"% deflection for any size of bridge sealer shall not exceed 200 pounds per square inch (lbs/in^2) on the first test run or cycle.

5.1.3 The amounts of Initial Contact Pressure (lbs/in^2) are based on the actually measured length (6 in) and height (H_a) of the sealer's test sample; they shall be established on the basis of three successive test runs or cycles, performed on the Compression Testing Machine (ASTM Designation: E4). Calculate Initial Contact Pressure as follows:

$$lbs/in^2\ \text{Pressure} = \frac{\text{Total Pressure}}{\text{Actual Contact Area}} = \frac{P}{6.0 \times H_a}$$

6. Sampling

6.1 A lot shall consist of a quantity for each cross section agreed upon by the purchaser and manufacturer.

6.2 The schedule of minimum lengths of samples for testing purposes, graduated by sealer sizes, is prescribed in Table A3.

6.3 In all tests, the material to be tested shall be furnished from standard production.

6.4 The specimens shall be taken at random from each new shipment of the preformed sealer.

TABLE A3

Minimum Lengths of Samples for Testing Purposes

Properties \ Sealer size widths	6"	5"	4"	3" to 3-1/2"	2" to 2-1/2"	1-1/2" to 1-3/4"
	Lengths of samples (inches)					
Tensile Strength, Elongation, Hardness, Permanent Set	6	6	6	6	6	18
Oven Aging: Tensile Strength, Elongation, Hardness	0*	0	0	6	6	18
Ozone Resistance	0	0	0	0	6	0
Oil Swell	0	0	0	0	0	0
High Temp. Rec.	6	6	6	6	6	6
Low Temp. Rec.	6	6	6	6	6	6
Low Temp. Rec.	6	6	6	6	6	6
Pressure-deflection	6	6	6	6	6	6
Total	30	30	30	36	42	60
Reserve for duplicate testing	6	6	6	6	12	12
Min. length of sealer sample	36	36	36	42	54	72

*"0" means that for the specific test no additional sample length is required.

7. Specimen Preparation

7.1 Compliance with the requirements of this specification shall be determined by tests conducted in accordance with the methods specified, using specimens cut or buffed from the actual extruded compression joint sealers.

7.2 Specimens for the high and low-temperature recovery tests shall consist of six-inch lengths of the preformed sealers.

7.2 .1 In the high-temperature test the internal surfaces shall remain as received from production while the outside surfaces only may be dusted off with talc to prevent them from sticking to the steel compression plates.

7.2.2 For the low-temperature tests, to prevent adhesion, talcing of outside and internal surfaces is desirable.

7.3 Specimens for pressure-deflection test shall consist of six-inch lengths of preformed sealers.

7.3.1 In the pressure-deflection test, to prevent adhesion, talcing of outside and internal surfaces is desirable.

8. Methods of Testing

8.1 Perform the high and low-temperature recovery test and the pressure-deflection test, using specimens prepared in accordance with 7.2, 7.2.1, 7.2.2, 7.3 and 7.3.1 respectively. Use a new specimen for each test.

8.1.1 Deflect the specimens between parallel plates to 50 percent (%) or "Z" percent (%) of the nominal width in accordance with the schedule shown in Table A2 using the compression set clamp assembly described in ASTM D395, Method B. Each width measurement shall be taken in the center of a six-inch length using a dial caliper graduated in thousandths of an inch.
If a gauge is used, it shall have a 1/4 inch diameter foot and shall be mounted on a platform. The dial caliper, made of stainless steel hardened throughout, shall be carefully calibrated. The width measurements shall be made at both the top and bottom longitudinal edges of the specimen. For this purpose, each edge shall be placed at the center of the foot of the gauge or at the measuring tips of the caliper jaws. The position of the foot or jaw shall be carefully marked on the specimen before the first reading is made.

Prior to compression, the specimen shall be placed in such a horizontal position that the plane, through both edges of the top surface of the sealer, is perpendicular to the compression plates. As the specimen is being compressed, the top surface of the joint sealer shall fold inward toward the center of the specimen. The compressed width shall be measured on the centers of all four (4) sides of the clamp assembly, with a carefully calibrated internal-dial caliper.

8.1.1.1 Low Temperature Tests: Expose the clamp assembly with the compressed specimen in a frost-free refrigerated box for the time and at the temperature specified in Table A2. To achieve the frost-free condition, a sufficient amount of a disiccant such as calcium chloride shall be placed into the box. When the cold aging period is completed, unclamp the test specimen at the test temperature, allow it to recover for two (2) hours in a free state at the test temperature. At this point, measure the recovery width at the test temperature. The measurements shall be made at the locations at which the original widths were determined.

Calculate the recovery as in 8.1.1.3.

8.1.1.2 High Temperature Tests: Expose the clamp assembly with the compressed specimen for 70 hours in an oven maintained at 212°F± 2°F. Do not preheat the clamp assembly. When the aging period in the oven is completed, remove the clamp assembly and immediately unclamp the test specimen. Cool the test specimen at room temperature (73°F ±4°F) on a wooden surface for one hour before measuring the heat-aged recovery width; this measurement is to be made at the same location as the original width. Calculate the recovery as in 8.1.1·3.

8.1.1.3 Calculations: Calculate the recovery-expressed as a percentage of the original width and in relation to the corresponding recovered width-separately for the top and the bottom measurements. For the determination of physical requirements, use the smallest of the two recovery percentages. Calculate recovery as follows:

$$\% \text{ Recovery} = \frac{\text{Recovered Width}}{\text{Original Width}} \times 100$$

8.1.2 Pressure-Deflection. The pressure-deflection test shall be performed in accordance with the ASTM Compression-Deflection Test Designation: D-575-67, Method A. The speed that must be used in this test shall be at the rate of approximately 0.2 inch/minute. The test shall be performed in a reasonably dust-free enclosure at the constant room temperature (73°F ±4°F). The specimen shall be placed between the platens of the testing machine in the horizontal position in such a way that a plane through both edges of the top surface of the sealer shall be perpendicular to the platens, which must be larger than the specimen.

The test limits are: "from zero percent (0.0%) deflection until the limit of safe compressibility is established", as described in paragraphs 4.1.2, 4.1.3 and 4.1.4; after this the specimen shall be immediately released at the same rate. This pressure-deflection cycle or test run shall be successively repeated three times as before, and up to the limits of pressure-deflection established in the first run.

The zero percent (0.0%) deflection corresponds to a pressure of zero pounds (0.0 lbs). The pressure exerted by the sample, its deflection, and the time-schedule of test run, shall be continuously read and recorded from the beginning till the end of the test.

For the purpose of graphing the pressure-decay, the time at the beginning and the end of a cycle, and the rate of speed, shall be read and recorded.

9. Certification and Acceptance

9.1 The acceptance of the preformed elastomeric joint sealer shall be based upon one of the following procedures as specified by the purchaser:

9.1.1 A certification indicating conformance to the test requirements, including the value of "Z" (in per cent).

Each lot of the joint sealer shall be identified with the manufacturer's name or trade mark and shall be accompanied by the manufacturer's affidavit attesting his conformance with the test requirements as well as a copy of the manufacturer's test report. Each certification so furnished shall be signed by an authorized agent of the manufacturer.

9.1.2 A certification by an independent testing agency of test results indicating the material has been sampled, tested, and inspected in accordance with the provisions of the specification. Each certification so furnished shall be signed by an authorized agent of the testing agency.

9.1.3 Testing by the purchaser of any or all properties in accordance with the provisions of the specification.

9.1.4 Any alternative method agreed upon by the purchaser and manufacturer.