

MICHIGAN
STATE HIGHWAY DEPARTMENT
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ASPHALTIC OIL-LATEX
JOINT-SEALING COMPOUND
Project 58 G-4 (¹/₈)

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ASPHALTIC OIL-LATEX JOINT-SEALING COMPOUND

INTRODUCTION

The historical background of asphalt-rubber compounds for highway purposes was characterized by the development in England and the Netherlands of various mixtures of latex with bituminous substances. These mixtures retained certain properties of the parent materials, notably the elasticity of the rubber and the adhesion, cohesion and ductility of the bitumen.

While these experiments were being conducted in Europe, the design of expansion joints for concrete pavements was undergoing its initial development in this country. American highway officials, recognizing the need for an effective sealing compound for use in excluding moisture and foreign bodies from expansion joints, tried tars, pitches, asphalts and many other substances. For some time, asphalt was held to be the best material available for use as a joint-sealing compound.

Asphalt, however, had certain disadvantages, which soon became apparent. For one thing, expansion joint seals made of asphalt tended to flow at higher summer temperatures. Conversely, they became brittle in winter and lost most of their ductility, cohesion, and adhesion to concrete.

It was only natural that American highway engineers should become interested in the progress of European experimentation with rubber and asphalt mixtures in the hope of devising a joint-sealing compound of superior quality. As early as 1935, the state of California used a material consisting essentially of about 70% SC-4 asphaltic oil and 30% rubber latex as a seal on about 680 linear feet of expansion joints on the heavily traveled highway between Lebec and Grapevine in Kern County (1). These joints, spaced at 100-foot intervals, were sealed immediately after the concrete surface was completed. When inspected in 1939, after 4 years of service,

the rubber compound joints were intact and in good condition.

Stanton (2) reported early experiences (1936) of the California Division of Highways with the new material, indicating the necessity of choosing a good asphaltic oil and basing its selection on high ductility at low temperatures. Stanton pointed out the deleterious effects of moisture in securing a good bond and showed how to convert the sealing compound into a crack filler by cutting the oil with gasoline before adding the latex.

By March, 1934, Woolf and Runner (3) had set up a procedure for testing various types of "resilient expansion joint fillers" in the laboratory. Among the nine types of fillers investigated were compounds of asphalt and rubberish particles of vulcanized rubber.

Encouraged by the results in California, the neighboring state of Oregon experimented with a seal made up of 50 parts of 60% rubber latex and 70 parts of 150-200 penetration asphalt. The mixture was poured hot and the seal allowed to come within 1/4 inch of the pavement level. The hot material was covered with rubber grindings to complete the seal and filling of the joint.

Impressed by the work in California and Oregon, engineers in Massachusetts and Oklahoma began experimenting with similar compounds. A formula was developed in Oklahoma for a joint seal using the following mixture:

SC-4	5.475 parts by weight
38% Latex	2.431 " " "
Lime	0.0553 " " "
Cresol Soap Solution	0.0444 " " "
Paraffin	0.0395 " " "

The soap solution used in the formula was a proprietary material of the brand name Kremulso. Experience in Oklahoma prior to 1939 (4) indicated that good joint seals are readily obtained with the above mix if the following precautions

are taken: (1) thorough cleaning of the concrete sides of the joint; (2) accurate proportioning of materials; (3) uniformity of control of mixing, temperature, and consistency of each batch; (4) pouring of a uniform flush joint (seal); (5) delay of shouldering operations for one week after pouring of joints; and (6) the exercise of care that joints are not poured at temperatures below 40°F.

As progress in the development of bitumen-rubber materials in the United States came to the attention of highway engineers, various proprietary or commercial preparations appeared on the American market, some of which showed considerable promise, and a few of which gave good results in actual service. Nevertheless, research continued in highway departments and other laboratories (5-9) on problems associated with the development of latex-bituminous types of joint-sealing compounds having superior properties.

The Michigan State Highway Department concerned itself at an early date with these investigations, and undertook the development of a bituminous-rubber sealing compound suitable for use on expansion joints in Michigan climates (10). In December, 1936, project 36 G-4 was authorized by the Administration for the investigation and development of new joint sealers, notably types using normal latex and road oil. Whereas considerable success has attended this project during its eight-year life, the investigation is by no means closed. At the present time consideration is being given to the use of synthetic latices as substitutes for normal latex.

DEVELOPMENT OF COMPOUNDS IN MICHIGAN

Michigan investigations of joint-sealing compounds were first patterned very closely after those of California insofar as materials and properties were concerned. However, the scope of the project was soon enlarged to take into consideration many significant factors relative to the behavior of these compounds, including properties, materials, admixtures, preparation and handling of the compounds in the field.

It was early determined that a mixture of latex, lime and road oil of the SC 4 type A.A.I. (1940 designation) gave the best results. In this mix prevulcanized, specially stabilized latex of 58.8 per cent concentration of solids produced a very tough, elastic sealer, which set up rapidly. The workability of this mix was improved by adding paraffin and varying the percentage of lime. Paraffin also increased the toughness of the set mix, but it tended to lower adhesion and increase "graininess". Its use was, therefore, discontinued. Little success was obtained with powdered rubbers, probably because of their relatively larger particle size and the consequent slowness with which these materials disperse in road oil. Adhesion and ductility were gravely impaired by the addition of such inert fillers as bentonite (colloidal aluminum silicate), fine sawdust, diatomaceous silica, Fuller's earth and cotton in percentages sufficiently high to appreciably promote toughness and, therefore, were not given further consideration.

The sealing compound has been found to undergo a steady, prolonged vulcanization over a period of years, resulting in the progressive hardening observed in mixes several months after pouring. Attempts to control vulcanization by developing a vulcanizing agent of optimum activity included investigations using sulfur flowers and sulfur monochloride. Results indicated

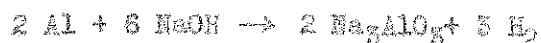
organic sulfur to be more satisfactory as a vulcanizing agent than inorganic sulfur. The problem was complicated by the necessity of maintaining suitable workability for pouring.

According to the work of H. L. Fisher (11), all vulcanizing agents are either oxidizing agents or require the presence of oxidizing agents. If this view is accepted, the presence of sulfur in the oxidizing group is not necessary, for the fundamental reaction is one of oxidation-reduction. There are many substances besides sulfur capable of giving rise to such a reaction. Several were tried out, such as piperidine pentamethylene dithiocarbamate, 50% aqueous sodium mercaptobenzothiazole, zinc oxide and casein.

In general, it was found that although the use of these vulcanizing agents produced laboratory mixes whose properties when set were highly desirable, the quantity of vulcanizing material required was so critical that a variation of about 1 percent would determine the difference between excellent workability and no workability.

The relative failure of sponge rubber to extrude under pressure, its comparative toughness when well vulcanized, and the economic feasibility of using 50% air in the mix prompted an investigation into the possibility of producing voids in the sealing compound, and of the influence of such voids upon its properties.

The method used employed the chemical reaction which occurs between sodium hydroxide and powdered aluminum, during which molecular hydrogen gas is liberated:



It was found that a mix with delayed volume expansion and satisfactory workability could be produced, but that here again the quantities of materials used were too critical for operations in the field. The properties of the

resulting compound were too susceptible to very slight alterations in the technique of manufacture.

A satisfactory joint-sealing compound was finally developed, in which prevulcanized latex was substituted for normal latex. This material adhered satisfactorily to concrete, remained ductile and displayed low susceptibility over a wide range of temperatures. It possessed satisfactory workability for pouring. Specifications for this seal are given at the end of the text.

The mixing and application of the compounded joint material in the field presented a trying problem. Various mechanical devices were tried with the object of mixing and pouring the compound in one or two operations. Any such method was found unsatisfactory, because the rate of set could not be effectively controlled. Finally, it was found that the asphaltic oil and latex could be satisfactorily combined in small batches (5 gallons) by either mixing by hand or by a small mechanical agitator. After proper blending of the materials the compound could then be readily transferred to a standard pouring pot for subsequent filling of the joint opening.

FIELD PROJECTS SEALED WITH ASPHALT-LATEX COMPOUND

By 1940, sufficient experimental work had been done by the Department to warrant the use of the asphalt-latex sealing compound on regular concrete pavement projects. The task of mixing the compound and sealing the joints became the responsibility of the contractor and his personnel. Expansion joints containing one-inch bituminous premolded fiber boards were sealed on two complete projects with asphalt-latex joint-sealing compound before the supply of rubber latex was stopped by the War Production Board. These projects include the design section of the Michigan Test Road, projects 18-20 C3 and 67-87 C4 on M-115 between US 10 and M 36 northwest of Farwell, Michigan, and the Grand Rapids-East Belt construction project F41-34 C6 on US 131 by-pass south of US 16.

Michigan Test Road

The joints on the Michigan Test Road were sealed in the summer and fall of 1940, using sealing compounds made with both normal latex and pre-vulcanized latex for comparative study. The mixing equipment and method of pouring the joints are illustrated in Figures 1A and 1B. Preparation of the joints prior to pouring was done in accordance with accepted practice for any type of joint-sealing material. In general, the operation was done in the following manner:

The asphaltic oil was heated to approximately 90°C. in tar kettle (A) Figure 1. To mix a batch of asphalt-latex material, a quantity of hot asphaltic oil was drained into mixing drum (B) and lime added and mixed into the asphaltic oil. The correct amount of latex was allowed to flow slowly from container (C) into container (B) while constantly stirring to thoroughly blend the ingredients. The finished mixture was then transferred from (B)

into pouring can for subsequent sealing of the joints as illustrated in Figure 1B.

Compounds made with both normal and prevulcanized latex have given excellent service during the first five years without any maintenance whatsoever. However, present conditions indicate that the prevulcanized latex produces a more durable compound. Figures 2A, 2B and 2C illustrate the general condition of the material in the spring of 1945. The compounds have retained their excellent bonding and plastic characteristics. It has been observed that at some points the joint seal has cracked or has lost some of its cohesive properties during the winter season although the material has remained plastic. In the summer these cracks disappear and the material appears to have considerable life. This phenomenon is more common in the compound made with normal latex and evidently this is the first stage in the ultimate failure of the joint-sealing compound. It may be possible to correct this weakness where it first appears by an application of some appropriate treatment. This is being studied.

Grand Rapids-East Belt

This project was constructed the following year, 1941, by a different contractor, but the joints were sealed in the manner described above, except that prevulcanized latex was used in preparing the seals. The general condition of the joints at the present time is illustrated in Figures 3A, 3B and 3C.

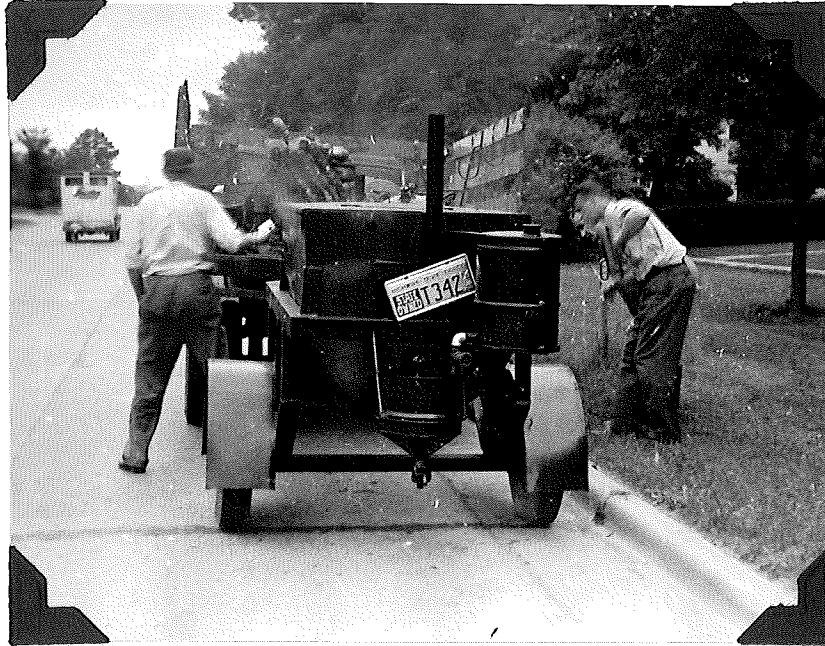
Quantity and Cost Per Joint

In the case of a normal expansion joint of 1-inch opening, the concrete slab being 22 feet wide and the depth of sealer being $\frac{3}{4}$ inch, the total volume of sealer used in each joint would be 198 cubic inches. This would be equivalent to 0.357 gallons. To allow for waste, a quantity of 1

gallon of compound per joint seems to be a reasonable amount for estimate purposes.

Based on 1940 prices of materials in large quantities (50-gallon drums for road oil, 10-gallon drums for latex and 50-pound lots for lime), a specific gravity of 0.981 for road oil, a specific gravity of 0.949 for prevulcanized latex, and a specific gravity of 0.97 for the final product, the following material costs can be stated for the oil-latex joint sealers:

- (a) Per Pound \$0.0842
- (b) Per Gallon \$0.68
- (c) Per Joint \$0.68

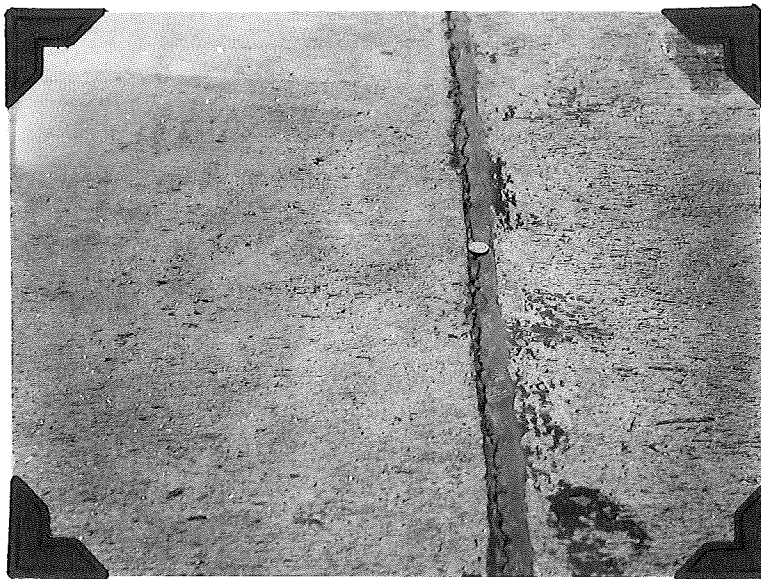


A. Equipment used in preparing Asphalt-Latex Joint Sealing Compound.

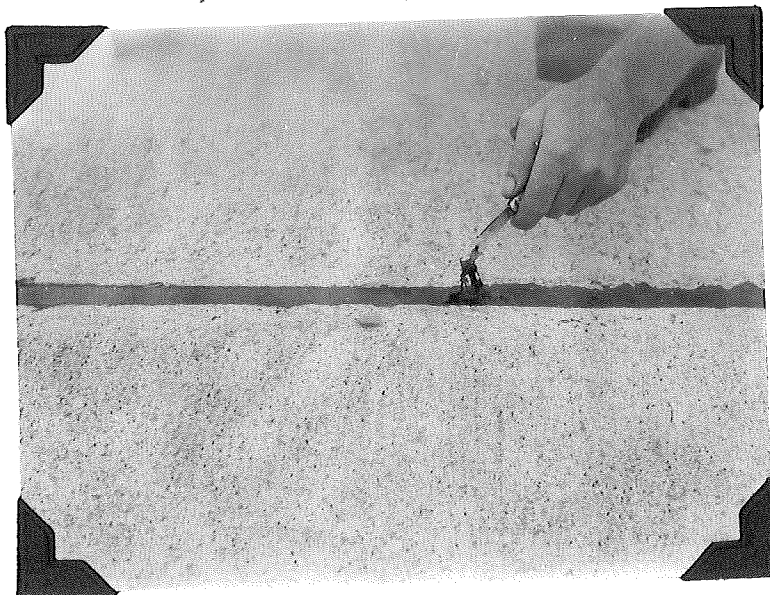
- A. Standard tar kettle
- B. 5 gal. Mixing drum
- C. 5 gal. can to hold latex



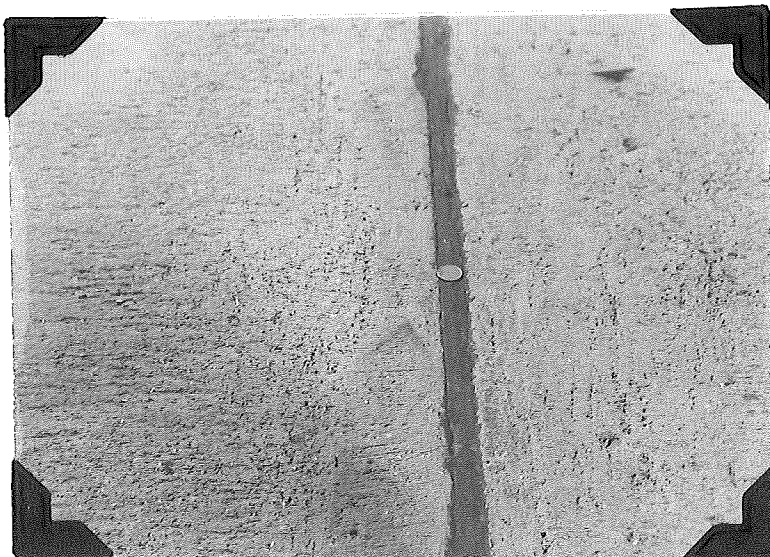
B. Pouring Asphalt-Latex Joint-Sealing Compound
(Note rubbery consistency of the material.)
Design Project - Michigan Test Road.
Photograph taken October, 1940



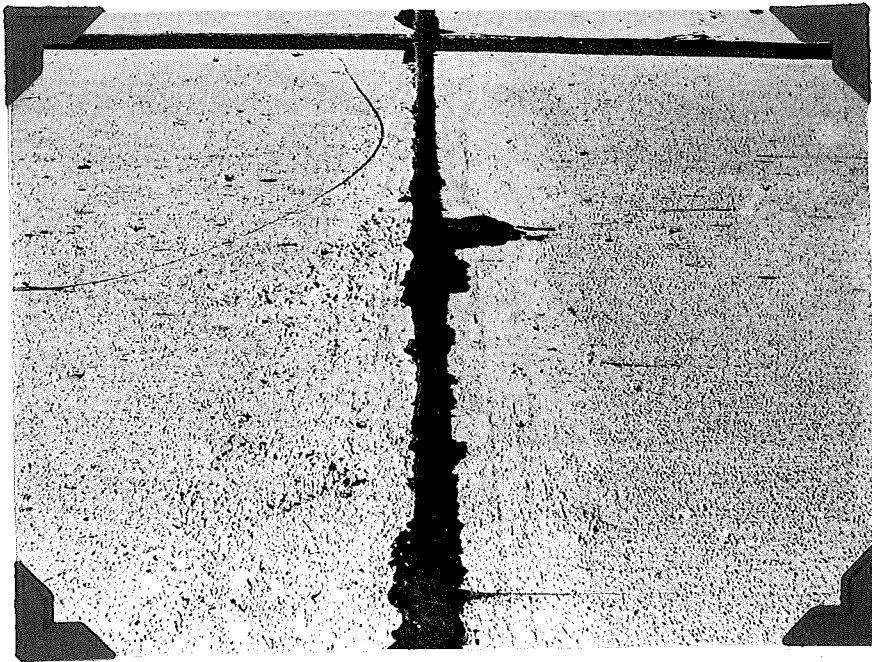
A. General view of Joint Seal containing Normal Latex after 4-1/2 years in service. Note partial failure in cohesion which appeared after 3 years in service. This phenomenon takes place in cold weather and disappears during summer months. Design Project - Michigan Test Road. Photograph taken March 21, 1945.



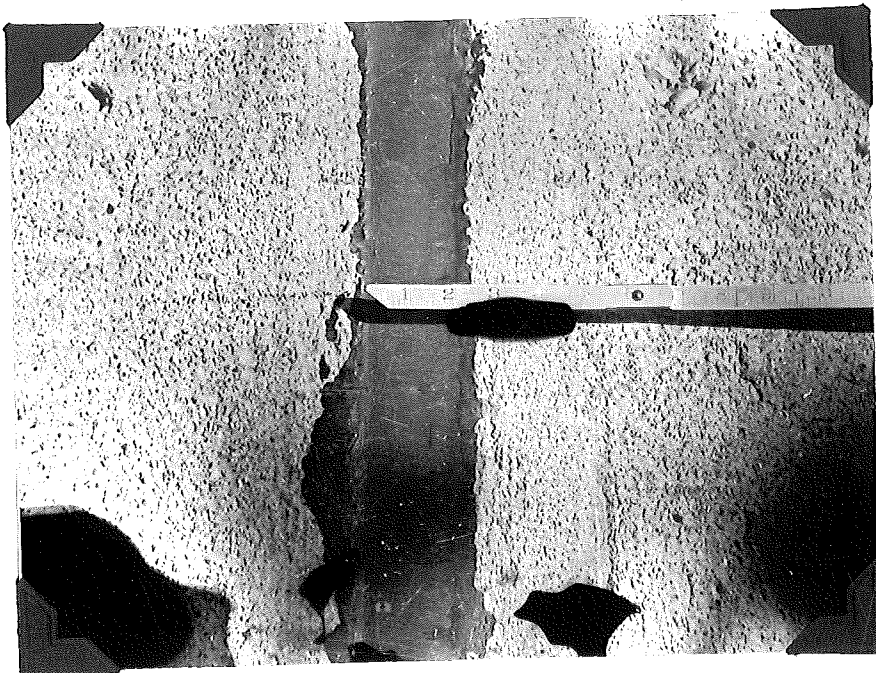
B. Close view of Joint Seal material containing Normal Latex after 4-1/2 years in service. Note consistency of material during warm weather. Design Project - Michigan Test Road. Photograph taken August 15, 1944.



C. General view of Joint Seal containing Pre-vulcanized latex. Note that this material does not fail in cohesion during cold weather and possesses better durability qualities than those of the joint seal with unvulcanized latex. Design Project - Michigan Test Road. Photograph taken March 21, 1945.



A. General View of Joint Seal Containing Pre-Vulcanized Latex. Joint sealed October, 1941. Grand Rapids-East Belt. F-41-54,06. Photograph taken October 19, 1944.



B. Close View of Joint Seal Containing Pre-vulcanized Latex. Note unusual width of joint and perfect bond of joint seal material to concrete. Same joint as illustrated in "A". Photograph taken October 19, 1944.



C. General Plasticity of the Joint Seal Material
Illustrated in "A" after 3 Years in Service.
Temperature 50°F. Photograph taken October, 19,
1944.

LABORATORY TESTS

Certain tentative laboratory tests have been developed by the Michigan State Highway Department for evaluating and comparing various properties of joint seals (10). The properties studied for which tests were devised included ductility (cohesion), adhesion and flow properties (viscosity).

Ductility and Adhesion

A standard ductility machine was employed, using specially constructed steel forms. (See Figure 4A). These forms functioned to grip regular mortar briquettes which were molded with a brass strip imbedded through their centers in such a way that they left the molds in symmetrical halves, each half presenting a working surface of one square inch cross section.

Preparation of the Briquettes. A cement mortar consisting of two parts natural sand to one part Portland cement with sufficient water for a troweling consistency is prepared. This mixture is placed in gang molds for the type used in making A.S.F.M. tensile strength briquettes. A metal brass divider is placed in the center of the mold so as to divide the briquette into two symmetrical halves of one square inch working surface area each. (See Figure 4B). Specimens not having perpendicular faces are rejected.

The briquettes are cured in the moist room for one week, then allowed to air dry before use. The faces are ground on a glass plate prior to use with Grade F Carborundum powder to remove irregularities and laitance material after which they are washed and surface dried.

Preparation of the Sealer: A mercury amalgamated brass mold consisting of two side pieces, bottom plate, and three "C" clamps is attached to opposite briquette halves so that a 1 cubic inch space between the faces

can be filled with the sealing compound to be tested. (See Figure 4B). The compound is heated to its application temperature, stirred and poured into the 1 cubic inch space a little higher than the upper surface of the briquette.

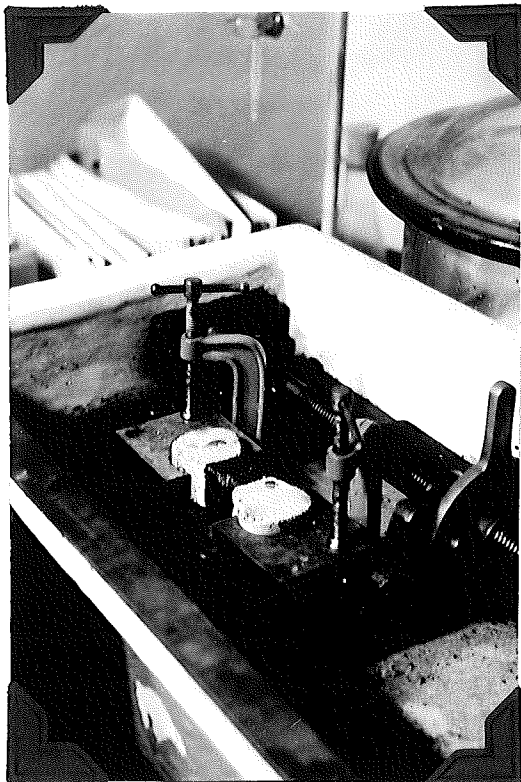
Method of Conducting the Test After the sealing compound has been poured, the specimens are allowed to stand over night and excess compound over 1 cubic inch is trimmed off with a hot knife. The clamps are removed and the side pieces and bottom plate are disassembled. The specimens are placed in a refrigerator to prevent deformation.

A standard ductility machine is adapted for operation at the rate of 1 inch per hour by use of necessary speed reductions. The glycerins bath used for low-temperature measurements is maintained at 0°F, by suitable additions of crushed dry ice and adequate stirring. Specimens are placed in the bath a half hour before testing. Figure 4A shows the specimen in place and ready to be tested.

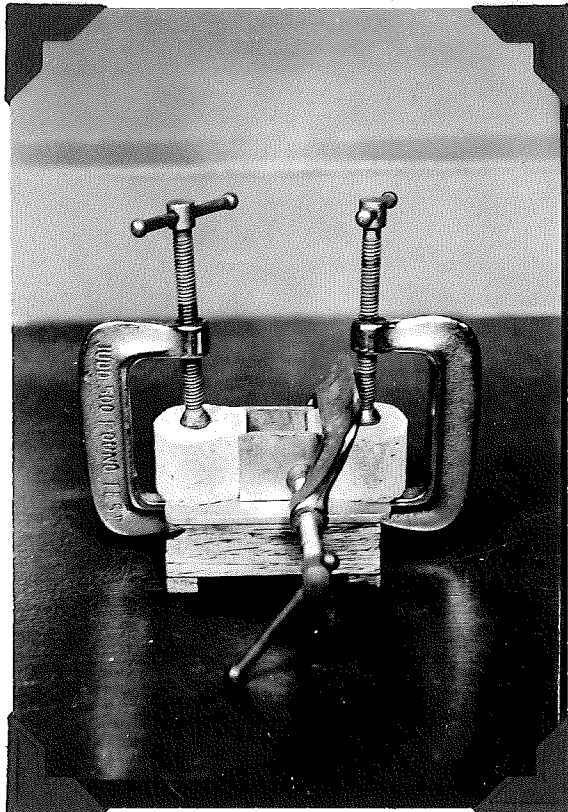
The distance the specimen can be drawn in inches before failure in bond (adhesion) or in ductility (cohesion) is recorded, and the type of failure is noted.

Viscosity

The constant temperature bath of a Kopper's viscometer was used in developing a test for the rheological properties of joint-sealing compounds, as shown in Figure 5A. Special flow cells were designed (Figure 5B) embodying the use of semi-ball ground-glass joints and clamps, which were furnished by the Scientific Glass Company. The test was based on a method proposed by Bingham and Stephens (14), making use of the formula of Pitman and Trozler (15):



A. Specimen in place ready for test.



B. Mold assembled prior to pouring in joint seal.

DUCTILITY AND ADHESION TEST

$$\eta = \frac{PR^2t}{4hL}$$

where

η = viscosity in poises

P = pressure applied in dynes per cm²

L = length of column of seal

t = time of flow

h = length of extrusion in time t

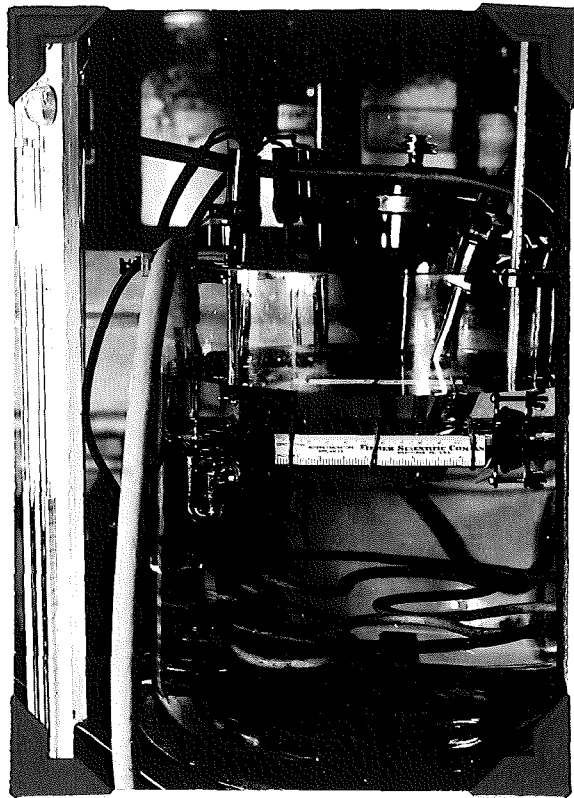
R = radius of tube in cms

Viscosities were plotted on the standard A.S.T.M. chart, on which the double log of viscosity versus the log of the absolute temperature is a straight line function. The slope of this line is called the susceptibility of the material, and represents the degree to which its viscosity is affected by temperature. This value is also referred to in the literature as viscosity index.

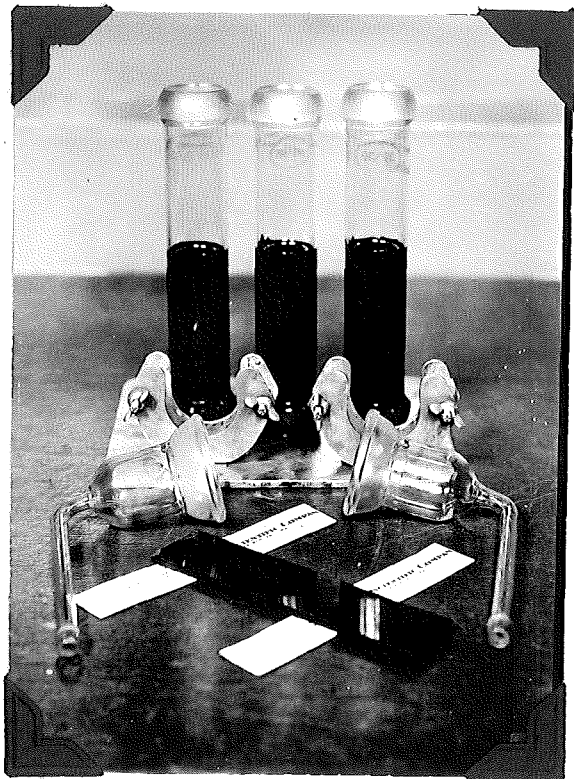
Pouring of Sealing Compound into Flow Cell. The compound is heated to application temperature, melted, mixed to homogeneity and poured into the flow cell (Figure 5B). The specimen is allowed to stand over night.

Assembly of Flow Cell. The cylinder is removed from the amalgamated plate, the unit is assembled in a horizontal position as in Figure 5C, and special clamps are placed in position to hold the glass joints in place. Millimeter scales are placed at the rear and front of the tube.

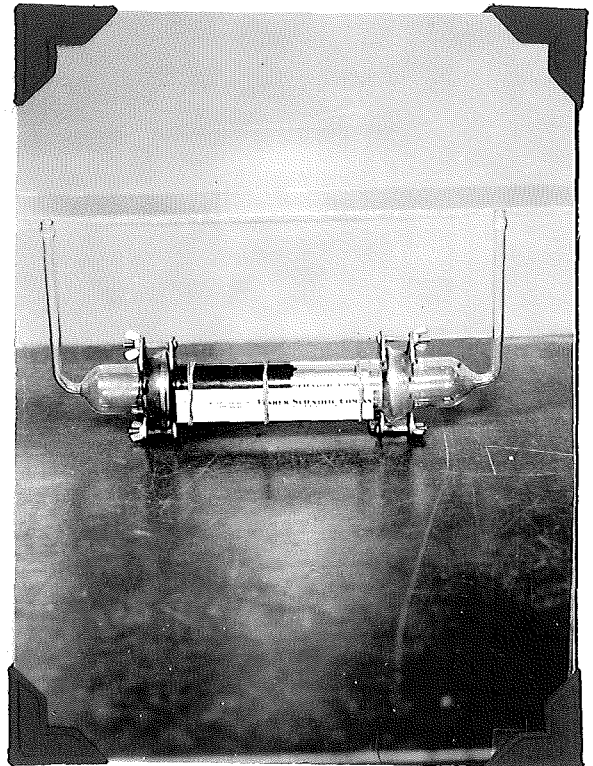
Test Procedure. The flow cell unit and scales are placed in the constant temperature bath and left for 30 minutes. The vacuum hose is attached to one end of the cell, the other end being left open to the atmosphere unless more pressure is required to obtain flow. The time of flow from the 1/2 cm. mark to the 1 cm. mark is recorded, as well as the pressure indicated on the manometer.



A. Viscometer used to Study Flow Properties of Joint Sealer.



B. Flow Cells used with Viscometer



C. Flow Cell Assembled and Ready for Determining Viscosity of Joint Seal.

Practical Application of Laboratory Tests.

The above Laboratory tests were conducted at the Michigan State Highway Department Research Laboratory on joint-sealing materials of the following types:

Types 1 and 6. Proprietary brands of asphalt-rubber joint-sealing compound of the hot-pour type.

Type 2. Standard commercial joint seal of the asphalt type.

Type 3. Experimental asphalt-rubber compound not commercially available.

Type 4. Seal made of 30% prevulcanized latex and 70% SC-6 asphaltic oil.

Type 5. Seal made of 30% normal latex and 70% SC-6 asphaltic oil.

The above seals were so made as to be free of extraneous water, coal tar and other tar products, pressure still residues, pitches, or other products of decomposition. Manufacturing specifications for types 1, 2, 3 and 6 were such as to preclude heating the bituminous materials above 700°F. or exposing them to pressures appreciably above atmospheric, and to assure that the finished product have characteristics within the following limits:

1. Specific gravity at 77°F.	1.22 to 1.30
2. Flash point, Cleveland open cup	Not less than 350°F.
3. Melting point, ring and ball	122°F. to 155°F.
4. Penetration at 77°F., 100 gms. 5 sec.	40 to 50
5. Ductility at 77°F.	Not less than 30 cm.
6. Loss at 325°F., 50 gms., 5 hrs.	Not more than 3.0%
(a) Penetration at 77°F. 100 gm., 5 sec.	Not less than 20
7. (a) Bitumen sol. in CS ₂	62 to 75%
(b) Ash on ignition	20 to 32%
(c) Difference between 100% and sum of (a) + (b)	Not less than 4%

Results of the adhesion and cohesion (ductility) studies on the above materials are shown graphically in Figure 6. All specimens were drawn in the ductility bath at a rate of 1 inch per hour. At this low rate of drawing, all specimens gave good results at room temperature, a 24 penetration asphalt failing in drawing 1/8 inch. In Figure 6, distance drawn is plotted against temperature of the bath, the lowest temperature being 0°F. At 0°F., seals No. 4 and 5 went to the limit of the test (2 inches), whereas seal No. 1 went 0.825 inches before failure and both No. 2 and No. 3 failed in adhesion and cohesion at 0.125 inches.

In carrying out adhesion and cohesion studies, it was found virtually impossible to get good adhesion to the mortar briquettes when the latter were cold and damp. This fact suggests the significance of cold, damp weather during construction and the practical importance of developing a means of eliminating or minimizing its deleterious effect on adhesion of joint-sealing materials to the slab. No such means has yet been found satisfactory other than straightforward cleaning and drying of the joint surfaces.

Flow rate properties of the five types of joint seal as measured by the apparatus described above are plotted in Figure 7.

JOINT-SEALING COMPOUNDS

ADHESION & COHESION TEST EFFECT OF TEMPERATURE

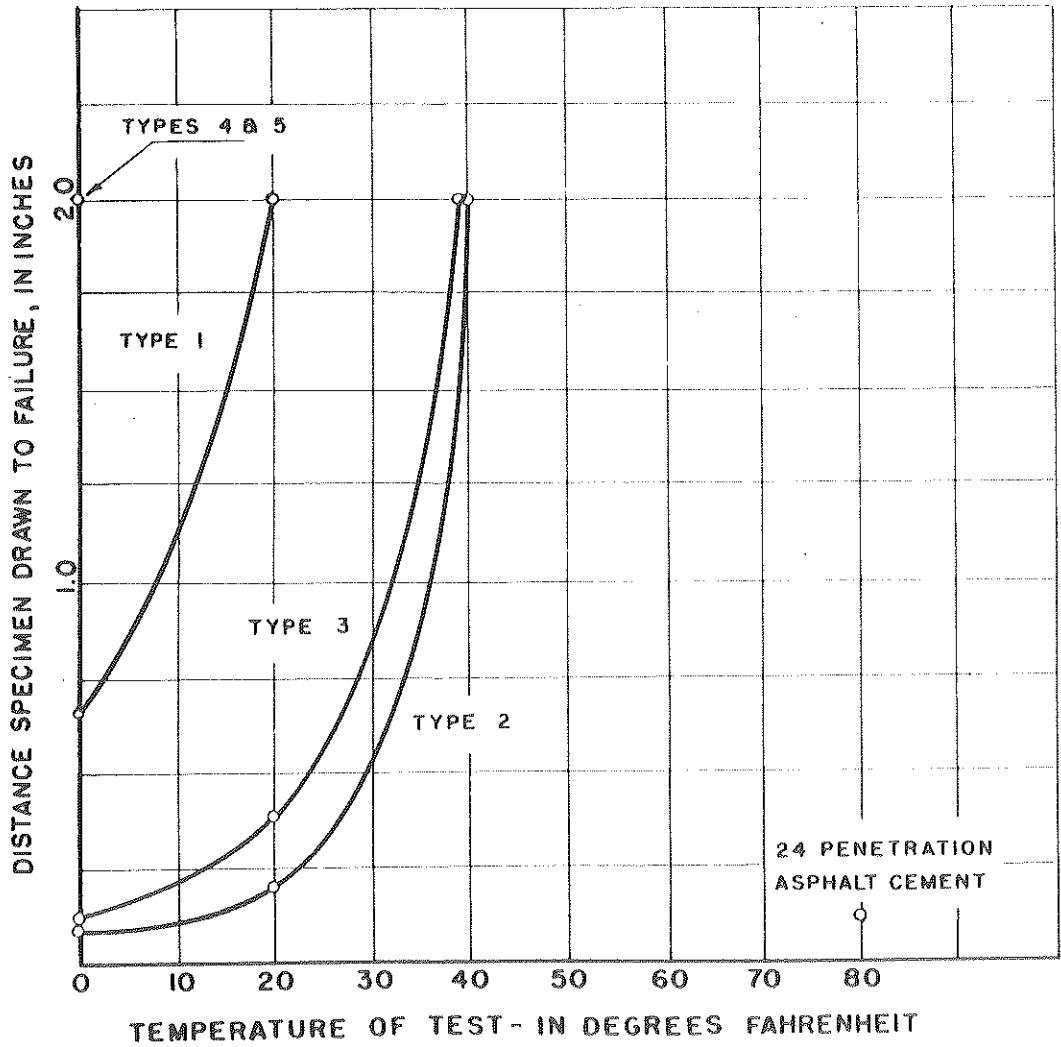


Figure 6

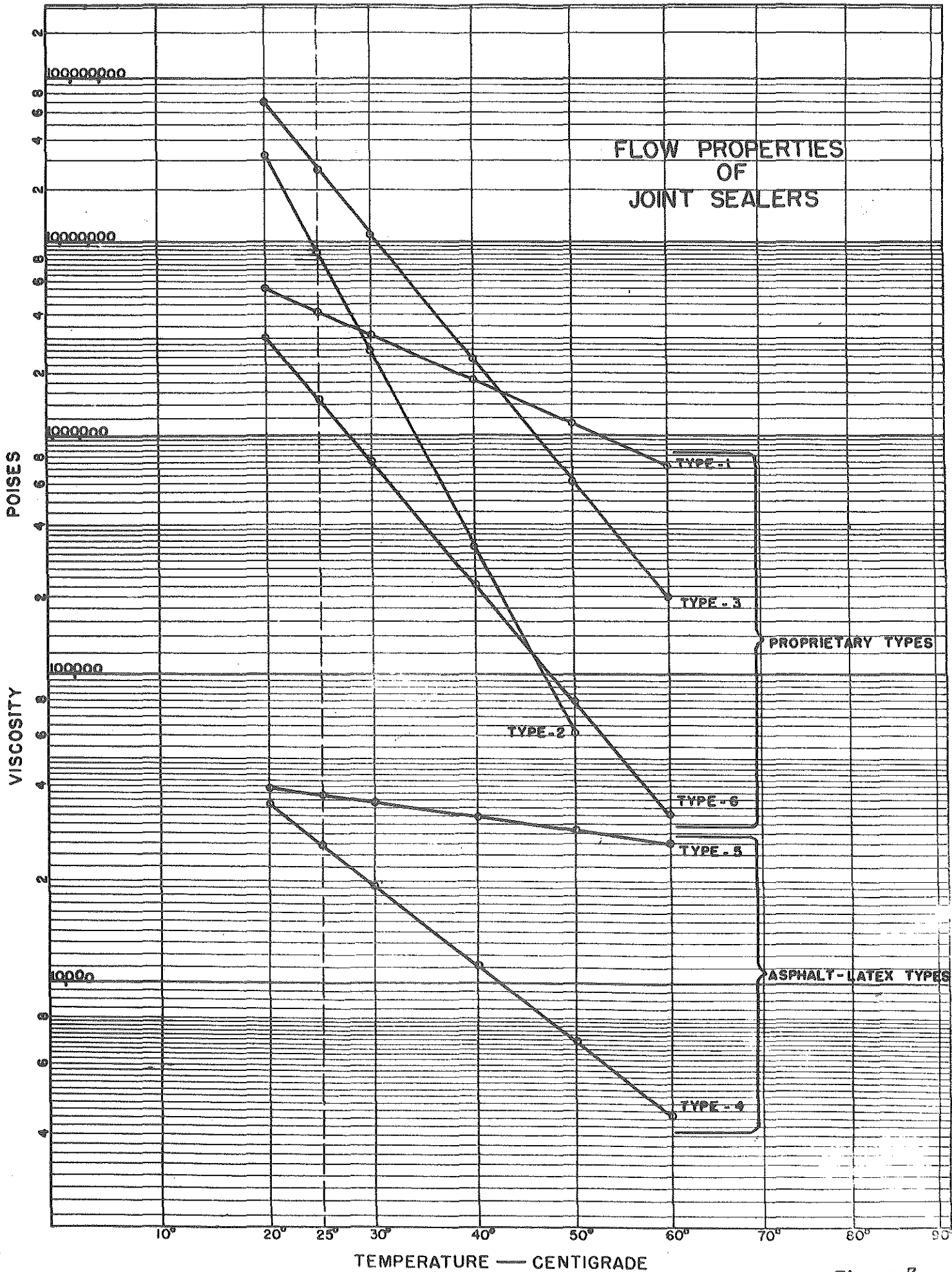


Figure 7

SEALING OF JOINTS WITH ASPHALT-LATEX COMPOUND

Experience in Michigan has shown that asphalt-latex joint-sealing compounds made and applied in accordance with the following practices are the most satisfactory.

Preparation of the Joint

As stated in the 1942 specifications of the Michigan State Highway Department, the tops of expansion joints and all edged joints must be sealed as soon as the curing agent is removed and before any traffic is permitted on the pavement. Joint openings must be thoroughly cleaned, all contact faces wire brushed, and surfaces must be dry when the seal is poured. Any membrane curing material remaining after wire brushing would be almost certain to afford a good bond for the asphalt-latex compound.

Preparation of the Asphalt-Latex Compound

A tank of at least 25 gallons capacity must be provided for heating the oil (see Figure 1A). The mixing tank should be of 5 to 10 gallons, and a stirring device must be used which will produce a homogeneous mixture of uniform consistency.

The following steps are followed in compounding:

- a. Heat oil to temperature of between 85° and 95°C.
- b. Measure correct quantity of lime.
- c. Measure correct quantity of oil.
- d. Measure correct quantity of latex.
- e. Pour correct quantity of hot oil into mixing tank.
- f. Add correct quantity of lime to oil in mixing tank.
- g. Stir lime into oil rapidly until thoroughly dispersed.

h. Continue to stir while adding approximately one-half of the correct quantity of latex to the mixing tank. Continue to stir until thoroughly blended.

i. Continue stirring while adding balance of latex until mix is homogeneous and of desirable thickness.

No more compound should be made than can be poured before it becomes too thick for handling. Stirring can be done by hand or mechanically. A 1-gallon container with a handle on one side and a spout on the other has been found suitable for pouring. In general, it may be said that 5 gallons of compound may be prepared at one time and still remain sufficiently workable for the operator to pour the entire amount. Compound or oil can be removed from equipment with kerosene or other organic solvent. Traces of latex can be flushed out with water when wet or removed by mechanical stripping when dry.

CURRENT SPECIFICATIONS FOR ASPHALT-LATEX JOINT SEAL

The following additional specifications are given by the Michigan State Highway Department:

The vulcanized latex shall be an aqueous dispersion of rubber particles in an ammoniacal solution, having a rubber solids content not less than 58 percent. It shall be kept in sealed containers to prevent evaporation of the emulsifying agent. The vulcanized latex shall be protected from temperatures less than 40°F. and greater than 100°F.

The asphaltic oil shall be homogeneous, shall not foam when heated to the required temperature and shall conform to the following requirements:

	Minimum	Maximum
Specific Gravity, 25/25 C		1.0
Water, percent by volume		0.5
Flash point, Cleveland Open Cup, deg. C	120	
Loss on Heating at 165°C., 50 g 5 hr. percent		6
Viscosity, Saybolt Furol, at 60°C	350	600
Solubility in Carbon Tetrachloride, percent	99.5	
Olefinic Spot Test	Neg.	
Residue of 100 Penetration:		
Percent Residue	70	
Ductility, 25°C., cm.	100	
Ductility, 4°C., cm.	7	
Sulfur Content, Percent	2	4

Hydrated lime shall conform to the requirements for Mason's hydrated lime in the 1942 specifications for Hydrated Lime for Structural Purposes, A.S.T.M. Designation C 6.

The proportions by weight of the mixture shall be

Lime, Ca(OH) ₂	2 parts
Vulcanized Latex	30 parts
Asphaltic Oil	70 parts

Compounds made in accordance with the above procedures have given satisfactory performance in Michigan over a period of 4 years.

ACKNOWLEDGMENTS

The writer is indebted to Messrs. George A. Mansfield and Thaddeus Wolczynski, formerly of the Michigan State Highway Research Laboratory staff, for their early researches on important fundamental and practical aspects of asphalt-latex joint-sealing compounds.

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