DEPARTMENT OF MAINTENANCE

Field Experimentation with Bituminous Undersealing Materials

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The practice of injecting hot asphalt under concrete pavements for stabilizing the slabs and controlling pumping has been used extensively in Illinois for several years. Much of the work has been in conjunction with resurfacing of old concrete pavements with bituminous-concrete resurfacing, where the underseal is used to fill voids in the subgrades and reseat unstable slabs prior to resurfacing operations.

The underseal material is a slightly modified Grade A Oil Asphalt Filler AASHO Designation: M18-42A. This material appears to have satisfactory fluidity at the time of pumping and does not bleed excessively at prevailing summer temperatures. However, there is some evidence that the material becomes brittle and cracks at low temperatures, destroying its intended function as a flexible barrier against the pumping of subgrade fines under heavy traffic.

In the experiment described, three asphaltic materials were used in conjunction with two rates of application: (1) AASHO Designation: M18-42A, with a modified minimum limit for ductility set at 3.0 cm; (2) 0-Korite, a material having relatively high ductility at low temperatures; and (3) Experimental No. 2, a material having a low-temperature ductility midway between that of M18-42A material and 0-Korite.

Test sections 4,000 ft. long were used for each material and each rate of application. Condition surveys were made during the spring prior to the underseal application and during the spring following application. The second survey indicated that the treatment materially reduced pumping. Further observations will be necessary before the performance can be established and materials and undersealing methods can be evaluated.

● THE practice of injecting hot asphalt under concrete pavements for stabilizing the slabs and controlling pumping has been used extensively in Illinois for several years. Much of the work done in recent years has been in conjunction with the resurfacing of old portland-cement-concrete pavements with bituminous concrete, where the underseal is used to fill voids in the subgrades and reseat unstable slabs prior to resurfacing operations. Over 3,900,000 gal. of asphalt were used in undersealing in 1951, approximately three quarters of which was used in connection with bituminous resurfacing. Good success has been obtained in the underseal work. However, experience has indicated that improvements in both materials and methods may be possible, and this report describes some field experimentation undertaken to provide information on materials and methods not now used in standard practice.

STANDARD PRACTICE

The asphaltic material generally used in undersealing operations in Illinois complies with the requirements for a Grade A Oil Asphalt Filler AASHO Designation: M 18-42A, except that the minimum limit for ductility at 77 F. has been set at 3.0 cm. instead of 4.0 cm. This single change was made in the interest of economy because materials meeting this reduced ductility requirement are more readily available in Illinois.

The pressure distributors which are used to pump the asphalt comply, in general, with the usual requirements for such equipment. The pumping nozzle which is inserted in the hole drilled in the pavement is connected to the distributor by a flexible hose with packed couplings. The nozzle is slightly tapered and provided with replaceable gaskets to prevent leakage around the nozzle when pumping is in progress. A metal safety shield for protecting the operator from being sprayed with hot asphalt is rigidly attached to the nozzle handle in such a manner that the shield will be parallel to and just clear of the pavement surface when the nozzle is in pumping position.

Holes for pumping are approximately 1½ in. in diameter, usually drilled in the center of each pavement lane about 15 in. from a transverse joint or crack and on the far side, when facing in the direction of traffic in that lane. Holes are not drilled more than one day in advance of pumping operations because it has been noted that open holes foster mud-pumping in rainy weather. After pumping is completed, and prior to placing the prime coat on resurfacing projects, the holes are filled flush with the top of the slab with a portland-cement grout. The grout is not always used where immediate resurfacing is not contemplated.

The asphalt is maintained at a temperature of 400 to 475 F. at the time of pumping. Just prior to pumping, water is sprayed on the pavement surface adjacent to the hole to prevent the asphalt which comes in contact with the pavement from adhering to it. The nozzle is securely held in place in the hole by the operator during pumping operations to prevent leakage. Whatever appears to be the most satisfactory pressure for doing the work is that which is maintained, usually in the neighborhood of 30 to 40 psi. The asphalt is usually pumped under the pavement until it breaks out either at the joints, through breaks in the slab, along the pavement edge or in the shoulders, or until it is the opinion of the inspector that no further pumping is necessary. If the asphaltic material extrudes before the pavement appears to be satisfactorily undersealed at the location, pumping is stopped and water sprayed on the extruding asphalt and the adjacent pavement. As soon as the extruding asphalt has chilled sufficiently to prevent further extrusion, pumping is resumed until further uncontrollable extrusion takes place, or until sufficient material to fill the voids appears to have been placed.

After pumping is stopped, the nozzle is left in place 20 to 30 sec. Immediately following the removal of the nozzle, the hole is plugged with a tapered plug of soft wood driven into the hole and left in place until the asphalt has hardened sufficiently so as not to flow out when the plug is removed. Asphalt which has accumulated on the pavement is removed to the shoulder as soon as the plug is taken out of the hole, and picked up for disposal, along with the extruded asphalt, at the end of the day's undersealing activities.

Because of the ever-present possibility of being badly burned when handling hot materials, the nozzle man and plug man usually wear goggles, or some other form of face protector, and asbestos gloves.

PURPOSE OF STUDY

The modified M 18-42A asphaltic material now generally used has been considered to have given reasonably satisfactory service; and the application procedure which has been outlined has also been considered generally satisfactory. However, evidence has been accumulating which has indicated that some improvements may be made, both in the asphaltic material and in the undersealing operation.

The oil asphalt filler which is being used appears to have satisfactory fluidity at the time of pumping and does not bleed excessively under the summer temperatures that prevail in Illinois. However, there is some evidence that the material becomes brittle and cracks at low temperatures, destroying its intended functions as a flexible barrier against the pumping of the subgrade fines under heavy traffic and as a seal against large amounts of water reaching the subgrade.

Limited experimentation with No. 0 Korite, an asphaltic material which is considerably more ductile at low temperatures than the regularly used modified M 18-42A material, had previously indicated that this may be superior to the modified M 18-42A as an underseal. However, the Standard Oil Company, which produces No. 0 Korite, in answer to a query concerning its availability, indicated that because of a limited source of required crudes it could probably not be made available in sufficient quantity for large-scale undersealing operations. This precluded further consideration of the material as an underseal. In its stead the Standard Oil Company suggested, and agreed to produce for experimental use, an untried material with ductility characteristics at low tempera-

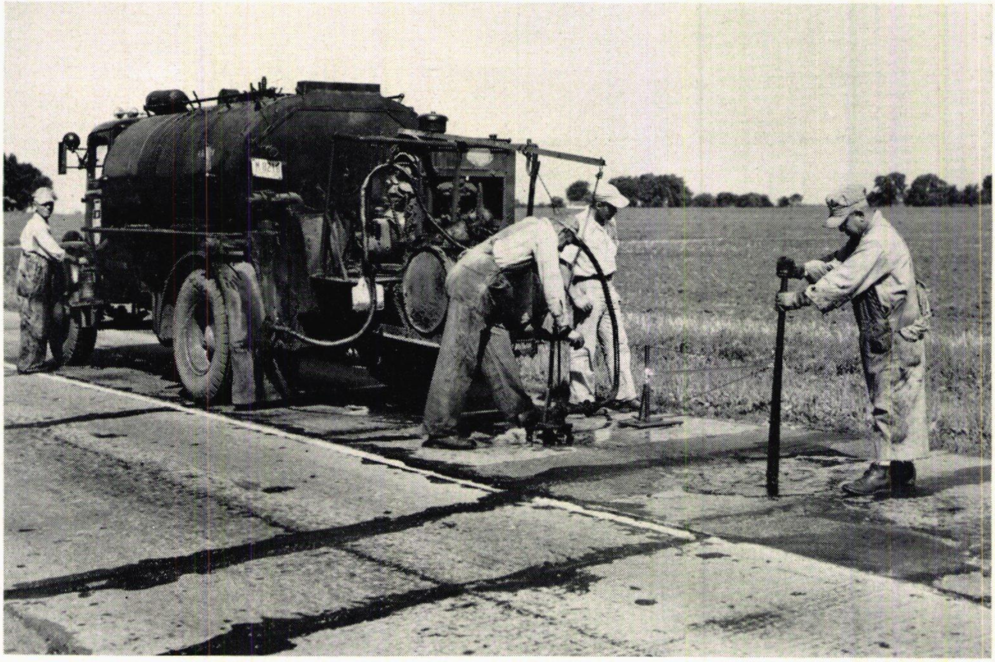

Figure 1. Type of undersealing-application equipment generally used in Illinois.

tures superior to those of the modified M 18-42A, although not equal to those of No. 0 Korite. It was indicated that the experimental material could be made available in large quantities should a market for it develop. Throughout the remainder of the report this material will be referred to as Experimental No. 2. In the experiment which will be described, test sections containing all three of the materials were installed for comparative purposes. The characteristics of the materials as determined by laboratory tests are given in Table 2. These will be discussed in detail later in the report.

In regard to the underseal operation itself, a number of measurements made with an Ames dial and lever-arm arrangement referencing movement of the pavement to the shoulder have indicated that under present methods of application the pavement is sometimes allowed to rise ½ in. before pumping is discontinued. Unless a correction is being made for faulting, this does not seem to be necessary, and some evidence has been accumulating to indicate that it may increase unnecessarily the roughness of joints and induce additional cracking of the slabs. Figure 1 shows application equipment of the type normally used in underseal operations in Illinois. In the right center of the picture is the lever-arm arrangement used to determine pavement rise. Similar equipment was used for measuring pavement movement in the study described in this report, in which definite limitations were placed on the allowable pavement rise.

The purpose of the study, then, has been twofold in nature: first, to evaluate and compare the performance as underseal agents of a number of selected asphaltic materials, and second, to determine whether a definite limitation of pavement rise during pumping operations will improve overall pavement performance and, if so, what the limitation should be.

LOCATION AND LAYOUT OF TEST SECTIONS

The project on which the three materials were used is on US 66, Sections 24-R and 25-R, Sangamon-Logan Counties, between Sherman and Lincoln. The experimental portion of the work extends from about 7½ mi. north of Sherman to 4 mi. south of grained subgrade in 1943 and 1944. It is of plain concrete, 24 ft. wide and 10 in. thick. Premolded bituminous fiber expansion joints were placed at 120-ft. intervals and intermediate contraction joints of the weakened plane type at 20-ft. intervals. Because of wartime restrictions on steel, load-transfer devices were used at only a few of the expansion joints. The remainder of the expansion joints and the contraction joints were not provided with mechanical load transfer. The

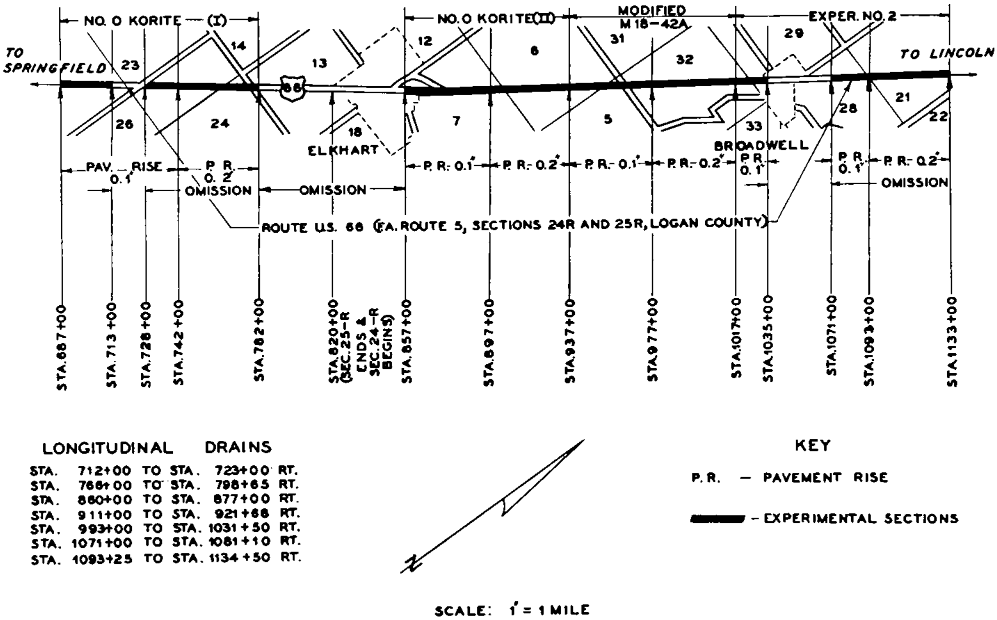

Figure 2. Location and layout of bituminous-underseal test project.

Lincoln. Figure 2 shows the location of the experimental project, together with the stationing of the test sections and of longitudinal drains installed during construction. The test sections are not continuous, because omissions were made where the pavement had been placed on granular subbase or where it had been previously undersealed or mudjacked. Of some interest is the fact that no pumping was noted in the areas where the granular subbase had been used.[1]

The pavement on which the undersealing work was done was constructed on a fine-

[1] For a discussion of granular subbase performance on US66 in Illinois, see "Performance of Concrete Pavements on Granular Subbase," Highway Research Board *Bulletin 52*, 1952.

pavement is in good structural condition with very few cracked panels, but evidence of pumping had been increasing prior to undersealing. There is also a considerable amount of light faulting at the transverse joints. A typical roadway cross section is shown in Figure 3.

Longitudinal drains are present along the east edge of the pavement throughout much of the project. The drains consist of 6-in.-diameter standard clay drain tile backfilled with porous granular material. The flowline of the tile varies in depth from 28 to 40 in. below the surface. The ditch containing the porous material is located in the shoulder either immediately adjacent to or 12 in. away from the low edge of the slab. A natural earth cover varying from 7 to 12 in. thick is placed over the granular material. The various locations of the drains with reference to the pavement edge are shown in Figure 3.

TRAFFIC

The experimental area is located on one of the highest traffic volume rural pavements in the state. The average daily traffic volume was 5,000 vehicles per day in 1950. Traffic counts made near Sherman, a town 7½ mi. south of the experimental area, showed an annual daily average of 1,640 commercial vehicles, including 1,050 tractor-semitrailer combinations and full-trailer combinations. The legal axle load limit for Illinois is 18,000 lb. for single axles and 16,000 lb. for each tandem axle.

SOILS

The test project is in a nearly level to very gently sloping area. Although the pavement between Lincoln and Sherman is in cut, in a few places, practically all of the portion included in the experiment is on fill, because granular subbase was used in the cuts and, as previously noted, all granular subbase areas were excluded when laying out the test sections.

Surface soils are dark colored, and were developed through the weathering of thick to moderately thick loess (over 100 in. thick). Subsoils are of medium texture and moderate permeability. Average test results for 15 samples taken from the subgrade immediately below the pavement are given in Table 1. From the limited data, no prediction as to

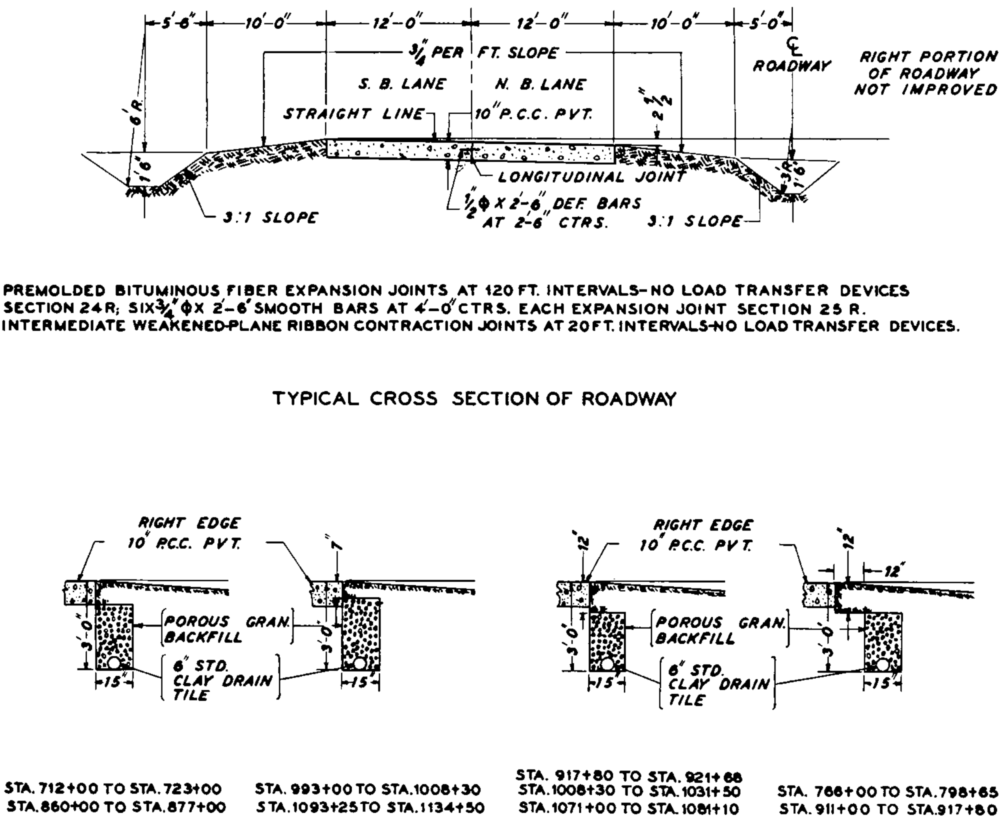

Figure 3. Typical cross section for improvement, longitudinal pipe underdrains.

the arrangement of these soils in the general profile is possible. However, the whole of the test project may be considered to be within an area of A-4, A-6, and A-7-6 soils potentially subject to pumping.

MATERIALS AND METHODS

Selection of Experimental Sections

The condition of the pavement chosen for the experimental work had been surveyed and sketched during the previous spring as part of a general performance study of US 66 between Springfield and Chicago. This work was done only a few months prior to undertaking the experimental project, and the information obtained served as a valuable aid in selecting comparable sections on which to use the three undersealing materials. Selections were based on the number of joints and cracks showing indications of pumping and, also, on the similarity of subgrade materials as indicated by available information.

Three sections, each 8,000 ft. long, were originally chosen for studying the three types of material, one of which was to be used on each section. A fourth section, also 8,000 ft. long, was later chosen for undersealing with No. 0 Korite, providing two No. 0 Korite sections differing somewhat in the extent of pumping before undersealing. The two No. 0 Korite sections will be referred to as No. 0 Korite I and No. 0 Korite II. The No. 0 Korite I section showed the greater amount of pumping prior to undersealing (see Table 4).

Each 8,000-ft. section was divided into two 4,000-ft. subsections. On one subsection, the slabs were allowed a maximum rise of 0.1 in. at the edge during pumping, and on the other a maximum rise of 0.2 in. The edge rise was determined with an Ames dial and lever-arm arrangement for referencing pavement movement to a point some distance out on the shoulder. The base of the lever-arm (see Fig. 4) was placed on the pavement near the edge, with the arm and the specially mounted Ames dial extended out over the shoulder.

TABLE 1
LABORATORY TEST RESULTS FOR SOIL SAMPLES TAKEN FROM SUBGRADE UNDERNEATH PAVEMENT

Station	Sieve Analysis Percent Passing			Liquid Limit	Plastic Limit	Plasticity Index	BPR Classification (HRB Modification)	Soil Mortar Separates, Percent			Textural Class
	No. 10	No. 40	No. 200					Sand 2.0–.05	Silt .05–.005	Clay .005	
	%	%	%					mm.	mm.	mm.	
688 + 50	100	96	81	24	19	5	A-4(8)	21	57	22	Si C L
731 + 70	100	100	98	37	25	12	A-6(9)	8	59	33	Si C
735 + 00	100	99	96	39	23	16	A-6(10)	8	53	39	Si C
750 + 50	100	99	94	30	19	11	A-6(8)	11	61	28	Si C L
750 + 95	100	95	79	24	20	4	A-4(8)	23	59	18	Si L
762 + 95	100	98	96	47	26	21	A-7-6(14)	7	53	40	Si C
763 + 44	100	99	96	43	25	18	A-7-6(12)	4	72	24	Si C L
861 + 35	100	99	99	52	26	26	A-7-6(17)	1	49	50	Clay
887 + 15	100	99	98	36	21	15	A-6(10)	2	61	37	Si C
903 + 95	100	99	98	36	23	13	A-6(9)	4	74	22	Si C L
939 + 35	100	99	98	38	21	17	A-6(11)	6	61	33	Si C
942 + 68	100	99	98	35	22	13	A-6(9)	2	66	32	Si C
995 + 95	100	99	98	40	25	15	A-6(10)	7	59	34	Si C
1094 + 10	89	87	85	38	23	15	A-6(10)	19	51	30	Si C
1130 + 40	90	87	85	44	24	20	A-7-6(13)	18	46	36	Clay

Undersealing Materials

Samples of the three types of asphaltic material were subjected to all of the commonly specified laboratory tests, and in addition, to special ductility tests made at low temperatures. Low-temperature ductility was considered to be one of the governing features in the choice of materials. The special ductility tests were made at temperatures of 20, 10, and 2 F. A tolerance limit of plus or minus 2 F. was permitted at the low temperatures.

A ductility machine equipped to pull at a speed of ¼ cm. per minute was modified for use in the low-temperature tests. Modification of the machine included the placing of a screened partition across the center of the innerbath to form two compartments, one for testing and the other to hold the cooling medium. A mixture of crushed ice and sodium chloride was used as a coolant to maintain the necessary low temperatures. The test compartment was filled with a sodium-chloride solution which was permitted to circulate through the cooling medium. To assure proper circulation of the solution, an electric stirrer was placed in the test compartment near the screened partition.

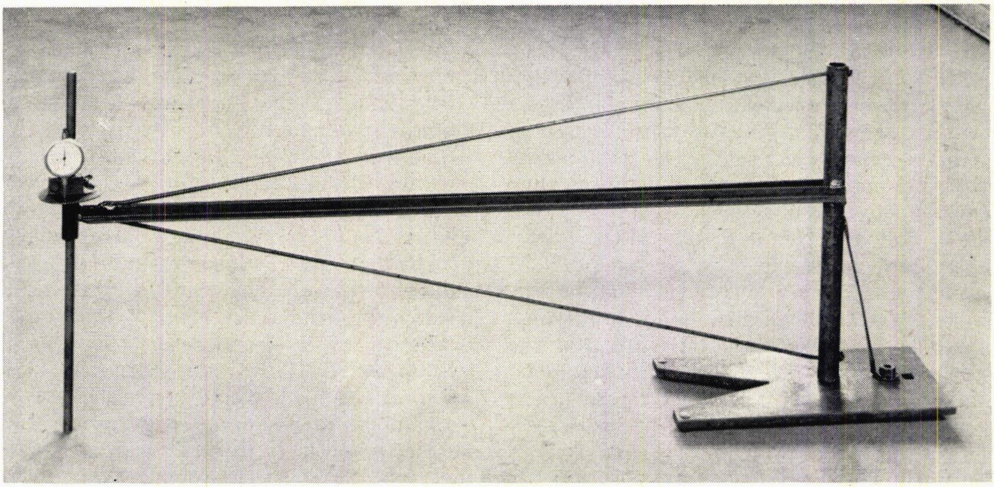

Figure 4. Ames dial and lever-arm arrangement for measuring pavement rise.

TABLE 2
LABORATORY TEST RESULTS FOR SAMPLES OF ASPHALTIC MATERIALS

Type of Material	M 18-42A Modified	M 18-42A Modified	M 18-42A Modified	No. 0 Korite	No. 0 Korite	Experimental No. 2
Flash Point (open cup) F.	510	570	455	515	500	465
Softening Point (R. & B.) F.	170	170	177	180	178	171
Penetration at 32 F., 200 g., 60 sec.	20	18	21	49	54	35
Penetration at 77 F., 100 g., 5 sec.	39	37	40	73	77	64
Penetration at 115 F., 50 g., 5 sec.	70	71	76	124	131	119
Ratio, Penetration 115 F./Penetration 32 F.	3.50	3.94	3.62	2.53	2.43	3.40
Ductility 5 cm/min. at 77 F., cm.	3.9	4.1	3.8	2.4	2.5	2.8
Ductility ¼ cm/min. at 20 F., cm.	2.2	2.2	2.2	1.85	1.87	1.95
Ductility ¼ cm/min. at 10 F., cm.	1.3[a]	1.4[a]	1.1[a]	1.85	1.80	1.60
Ductility ¼ cm/min. at 2 F., cm.	0.45[a]	—[a]	—[a]	1.75	1.70	1.22
Specific Gravity 60/60 F.	0.999	1.002	0.999	0.980	0.979	0.987
Bitumen Soluble in Carbon Disulphide %	99.80	99.77	99.88	99.81	99.82	99.84
Loss at 325 F., 5 hrs. %	0.34	0.04	0.35	0.14	0.29	0.40
Penetration at 77 F., 100 g., 5 sec.; residue from 5 hour loss	34	33	34	68	68	55
Percent of original penetration	87.17	89.19	85.00	93.15	88.31	85.94
Bend test at 0 F.[b]	Failed	Failed	Failed	OK	OK	OK

[a] The briquettes snapped or tore, and values listed should not be considered true measures of ductility.
[b] A regular ductility test specimen was prepared and after trimming, the mold was placed in the cold room at 0 F. for 12 hours. The specimen was then tested for brittleness by slowly bending the end pieces through an angle of 180 deg.

Ductility briquettes for the low-temperature tests were made in accordance with ASTM Designation D 113-44, with the following three exceptions: (1) the briquettes were trimmed at room temperature and then placed in the testing compartment of the ductility machine to cool to the required temperature; (2) the briquettes were cooled for a minimum of two hours; and (3) pulling of the briquettes was at the rate of ¼ cm. per min. The results of the special ductility tests, and of the standard tests, are given in Table 2.

An inspection of the low-temperature ductility results in Table 2 will show that for the 10 F. and 2 F. tests, only the No. 0 Korite and the Experimental No. 2 materials exhibited true ductility. In testing, the samples of these two materials coned out to a point until rupture occurred, as in a normal ductility test. The modified M 18-42A samples snapped or tore in testing, and even where measurements were made, the results should not be considered true values of ductility. A further inspection of the 10 F. and 2 F. test results will show that the Experimental No. 2 material was somewhat less ductile than the No. 0 Korite.

The susceptibility to changes in physical characteristics with changes in temperature within the normal climatic range is also of importance in selecting underseal materials. A consideration of both penetration and ductility test results given in Table 2 will show that the No. 0 Korite was the least susceptible to change, and the modified M 18-42A the most susceptible. The Experimental No. 2 will be seen to be an intermediate material in this respect. The ratios of the penetrations at 115 and 32 F. are given to aid in this comparison. The effect of changes in temperature on ductility may be easily seen.

The results of tests dealing less directly with temperature susceptibility characteristics will be seen from the table to be of about the same order for all samples.

Undersealing Procedure

The undersealing operation on this job followed, for the most part, the established practice in Illinois. The material was heated to approximately 400 F. and pumped from a 1,000-gal. distributor through the holes which were drilled at each joint and crack. Instead of permitting the underseal to be applied until blowout occurred or until, in the judgment of the engineer, sufficient material had been applied, as is normally done, Ames dials mounted as previously noted were used to indicate the vertical movement of the slab. In locations that received the minimum treatment, the material was pumped from the distributor until the dial indicated a 0.1-in. rise of the slab near the outside edge; areas of maximum treatment were pumped until the dial indicated a 0.2-in. rise of the slab. During the application it was not uncommon for blowouts (the extrusion of the undersealing compound from joints, cracks, and at the pavement edges) to occur, even though limitations were placed on the allowable amount of pavement rise. When blowouts occurred before the required pavement rise had been secured, it was necessary to stop the undersealing operation for a short time to permit the extruding material to chill sufficiently to resist further blowing out. It was usually possible to continue the undersealing operation to completion without further blowing out upon the elapse of approximately a 30-sec. cooling period. The hole through which the undersealing material was introduced was not refilled after the undersealing material had cooled. This left the holes unfilled for depths ranging from 1 to 4 in.

The distributor used for this work had no metering device for measuring the exact quantity of material pumped into each hole. The number of gallons per hole was determined by dividing the gallonage required for a number of holes by that number of holes, the result being an average value.

The experimental underseal work was carried on between July 7 and August 4, 1951. An effort was made to postpone experimental work for 48 hr. following heavy rains which were believed likely to cause sufficient water to reach the subgrade to influence results. Careful records were kept of the location on which the material from each distributor load was placed; the average gallons used per hole per distributor load; air and asphalt temperatures; blowouts of material at joints, cracks, and shoulders; and other pertinent information.

Cost records of the undersealing operation, which was accomplished by State Day Labor forces, show the in-place cost of the asphaltic materials to be 24.13 cents per gal., and the unit cost of drilling the holes to be 30.11 cents per hole. In the area where the pavement rise during pumping was limited to 0.1 in., this resulted in a cost per mile of $974 (average of 6.4 gal. per hole). Where a 0.2-in. rise was permitted, the cost was $1,538 per mi. (average 10.6 gal. per hole). The overall average cost per mi. through the test area was $1,256. These figures include all applicable overhead costs but not the cost of making and recording the experimental observations.

EXPERIMENTAL DATA

Construction Data

Following are the more important observations which were made during and immediately following pumping operations:

1. All three of the materials could be pumped with equal facility.

2. Best results were obtained in containing the materials under the pavement when the joints and cracks were surface sealed with asphalt and the eroded holes at the pavement edge filled with dirt and tamped.

3. Various positionings of the pumping holes in the 12-ft. traffic lanes resulted in the selection of a location 5 ft. from the center joint as being most effective. This location was used throughout most of the experimental portion of the project. Holes placed much closer to the pavement edge resulted in what appeared to be an unreasonably large number of blowouts of material.

4. The average gallons per hole for the three asphaltic materials and for the two

TABLE 3
FIELD APPLICATION DATA FOR THE INDIVIDUAL DISTRIBUTOR LOADS

Stations	Pavement Rise, Inches	Distance of Holes from Centerline	No. Holes Treated	Avg. Gallons Per Hole at 60 F.	No. of Blowouts
0-Korite I		*ft.*			
687 + 00- 713 + 00 NB*	0.1	6	129	4.4	13
687 + 00- 700 + 80 SB†	0.1	6	66	6.5	35
700 + 80- 713 + 00 SB	0.1	6	62	4.4	36
728 + 00- 735 + 30 NB	0.1	5	39	7.3	14
735 + 30- 742 + 00 NB	0.1	5	31	8.6	5
728 + 00- 742 + 00 SB	0.1	5	70	6.0	29
742 + 00- 750 + 75 NB	0.2	6	46	8.9	30
750 + 75- 773 + 60 NB	0.2	6	115	7.2	78
773 + 60- 782 + 00 NB	0.2	6	40	8.3	20
742 + 00- 744 + 30 SB	0.2	5	12	11.0	8
744 + 30- 762 + 50 SB	0.2	5	91	9.2	51
762 + 50- 769 + 90 SB	0.2	5	37	16.7	12
769 + 90- 782 + 00 SB	0.2	5	60	8.5	55
0-Korite II					
857 + 00- 879 + 60 NB	0.1	5	113	5.4	1
879 + 60- 897 + 00 NB	0.1	5	87	4.4	32
857 + 00- 886 + 30 SB	0.1	5	147	4.7	30
886 + 30- 897 + 00 SB	0.1	5	54	6.3	13
897 + 00- 915 + 20 NB	0.2	5 & 6	92	7.5	65
915 + 20- 936 + 40 NB	0.2	5	106	10.1	25
936 + 40- 937 + 00 NB	0.2	5	3	7.4	1
897 + 00- 907 + 70 SB	0.2	5	55	9.2	52
907 + 70- 927 + 50 SB	0.2	5	102	7.4	96
927 + 50- 937 + 00 SB	0.2	5	47	8.0	24
Modified M 18-42A					
937 + 00- 964 + 20 NB	0.1	5	136	5.6	10
964 + 20- 977 + 00 NB	0.1	5	64	6.9	10
937 + 00- 956 + 70 SB	0.1	5	100	6.0	2
956 + 70- 960 + 70 SB	0.1	5	20	8.9	2
960 + 70- 969 + 50 SB	0.1	5	44	9.0	4
969 + 50- 977 + 00 SB	0.1	5	36	11.1	8
977 + 00- 982 + 80 NB	0.2	5	31	14.8	23
982 + 80- 992 + 00 NB	0.2	5	46	17.3	45
992 + 00-1002 + 60 NB	0.2	5	53	15.9	26
1002 + 60-1017 + 00 NB	0.2	5	73	11.5	48
977 + 00- 982 + 30 SB	0.2	5	26	14.8	26
982 + 30- 996 + 50 SB	0.2	5	73	11.4	68
996 + 50-1013 + 00 SB	0.2	5	84	10.6	65
1013 + 00-1017 + 00 SB	0.2	5	22	11.1	13
Experimental No. 2					
1017 + 00-1035 + 00 NB	0.1	5	90	9.2	8
1017 + 00-1035 + 00 SB	0.1	5	91	5.9	6
1071 + 00-1081 + 50 NB	0.1	5	52	11.2	9
1081 + 50-1093 + 00 NB	0.1	5	58	7.3	3
1071 + 00-1081 + 50 SB	0.1	5	52	8.1	17
1081 + 50-1093 + 00 SB	0.1	5	58	7.3	10
1093 + 00-1100 + 50 NB	0.2	5	42	10.1	23
1100 + 50-1111 + 60 NB	0.2	5	57	12.4	40
1111 + 60-1128 + 40 NB	0.2	5	86	9.9	72
1128 + 40-1133 + 00 NB	0.2	5	23	7.7	22
1093 + 00-1099 + 30 SB	0.2	5	33	10.9	30
1099 + 30-1114 + 50 SB	0.2	5	77	11.1	73
1114 + 50-1123 + 90 SB	0.2	5	50	16.0	23
1123 + 90-1133 + 00 SB	0.2	5	46	14.5	30

* NB denotes northbound lane.
† SB denotes southbound lane.

pavement rises are as follows:

	0.1-in. Rise	0.2-in. Rise
	gal. per hole	*gal. per hole*
No. 0 Korite I	5.65	9.19
No. 0 Korite II	5.02	8.44
Modified M 18-42A	6.85	13.07
Experimental No. 2	8.02	11.90

This gives a gallonage ratio between the 0.1-in. rise and the 0.2-in. rise of 0.60 for the No. 0 Korite I, 0.59 for No. 0 Korite II, 0.52 for the modified M 18-42A, and 0.67 for the Experimental No. 2. No comparisons of asphalt gallonages may be made between sections involving different underseal materials, because it is not known whether the differences resulted from differences in void space or from differences in fluidity of the undersealing materials. Gallonage data for the individual distributor loads are given in Table 3.

5. In some instances the prescribed rise could not be obtained because of blowing out of the asphaltic material. As could be expected, blowouts were more frequent on the 0.2-in. rise sections. The percents of locations pumped which showed blowing out of material are as follows:

	0.1-in. Rise	0.2-in. Rise
	% blowouts	*% blowouts*
No. 0 Korite I	33.2	63.3
No. 0 Korite II	19.0	64.9
Modified M 18-42A	9.0	77.0
Experimental No. 2	13.2	74.0

There was a much greater tendency toward blowouts where eroded holes were found at the pavement edge. The existing data do not offer an explanation for the differences between the percent of blowouts found on the four test sections for the 0.1-in. pavement rise. However, there was a tendency, though not perfect, for the blowouts to occur most frequently on the sections having the greater number of pumping locations and shoulder holes. Blowout data for the individual distributor loads are given in Table 3.

6. Water placed on the pavement around the underseal holes prior to undersealing permitted an effective removal of the excess modified M 18-42A material which spilled onto the pavement. Water was not completely effective with the other two materials and considerable tracking resulted. A mixture of calcium chloride and water was also tried as an aid in removal, but no improvement was noted. The tracked material discolored the pavement but did not appear to greatly reduce its skid resistance, as measured by applying the brakes of an automobile traveling at a moderate speed and noting the tendency to skid. After a few weeks the discoloration became fairly well removed from the wheel paths and the No. 0 Korite and Experimental No. 2 sections presented about the same surface appearance as did the modified M 18-42A section.

Condition Survey Data

The condition survey which was conducted before beginning this underseal work consisted of sketching the entire length of pavement and marking the locations of cracks, pumping at joints and cracks, and shoulder holes. Shoulder holes are those holes found at the pavement edges in the vicinity of transverse joints and cracks, similar to those found in connection with pumping but with no sign of ejected material. The results of the original condition survey conducted during March and April 1951 are shown in Table 4 and compared with the first post-undersealing condition survey made in March and April 1952 about 9 mo. after treatment. Underseal data for the individual test sections are also summarized in this table. It will be noted from the table that all of the treated sections showed less pumping in the second survey, although no definite trends are discernible, either for the materials themselves or their amounts as measured by pavement rise. The shoulder-hole data are more erratic, showing an increase in some instances and a decrease in others.

Table 5 is included to give an indication of the overall effectiveness of the treatment. It will be noted from this table that for the entire experimental project, pumping noted during the survey 9 mo. after treatment was reduced to 30 percent of the amount of pumping found prior to treatment, and shoulder holes to 84 percent. At the time of the original survey, pumping was found at 22 percent of the joints and cracks. Shoulder holes were found at 39 percent of the joints and cracks.

The entire length of pavement included in the study contained but 17 transverse cracks at the time of the first survey. Only one additional crack was found at the time of the second survey.

length along the edge of the pavement. Most were carried about 1 ft. under the pavement, although three were extended from 18 to 30 in. underneath. Underseal material was

TABLE 4
GENERAL SUMMARY SHEET

Material Used for Undersealing	No. 0-Korite I		No. 0-Korite II		Modified AASHO M 18-42A		Experimental No. 2		Totals for Project	
Pavement Rise	0.1″	0.2″	0.1″	0.2″	0.1″	0.2″	0.1″	0.2″	0.1″	0.2″
(1) Distance, lane feet	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	32,000	32,000
(2) Number of holes treated	397	401	401	405	400	408	401	414	1,599	1,628
(3) Average gallons of underseal per hole, at 60 F.	5.6	9.1	5.0	8.4	6.9	13.0	8.0	11.7	6.4	10.6
(4) Percent of holes having blowouts during undersealing	33	63	19	65	9	77	13	76	19	70
(5) Condition Survey Data:										
March-April Survey, 1951 (Before Undersealing):										
(a) Pumping joints and cracks, number	95	91	74	87	40	101	95	123	304	402
(b) Shoulder holes, number	136	191	140	160	154	140	142	200	572	691
March-April Survey, 1952:										
(a) Pumping joints and cracks, number	35	65	7	19	23	11	24	27	89	122
(b) Shoulder holes, number	159	82	74	91	169	105	229	151	631	429
(6) Percent pumping, expressed as percentage of number of pumping locations existing before undersealing	37	71	9	22	57	11	25	22	29	30
(7) Percent shoulder holes, expressed as percentage of number of shoulder holes existing before undersealing	117	43	53	57	110	75	161	75	110	62

No excessive bleeding of any of the materials was noted during the hot weather of the past summer.

Special Excavations

During the latter part of November and early December 1952, approximately 16 mo. after treatment, 20 excavations were made at the edges of the pavement opposite undersealed locations in an effort to develop further information on the underseal performance. Of particular concern was the condition of the undersealing material at the transverse joints. Each type of material and each of the specified pavement rises were represented in the excavations. Various combinations of pumping conditions were also represented at the locations chosen for study. Fourteen excavations were made at joints where pumping was found prior to undersealing. Seven of these showed pumping after undersealing. Six excavations were made at locations where no pumping was found during the survey made prior to undersealing. Four of these showed pumping following undersealing.

Excavations were approximately 5 ft. in

TABLE 5
MARCH TO APRIL 1952 CONDITION SUMMARY BY MAJOR SECTIONS

	0-Korite I	0-Korite II	Modified M 18 42A	Experimental No. 2	Totals
Pumping					
Total pumping locations before undersealing	186	161	141	218	706
Total pumping locations March-April Survey, 1952	100	26	34	51	211
Percent pumping, expressed as percentage of number of pumping locations existing before undersealing	54	16	24	23	30
Shoulder Holes					
Total number of shoulder holes before undersealing	327	300	294	342	1,263
Total number of shoulder holes, March-April Survey, 1952	241	165	274	380	1,060
Percent shoulder holes expressed as percentage of number of shoulder holes existing before undersealing	74	55	93	111	84

found at 13 of the locations excavated; seven where a pavement rise of 0.2 in. was permitted and six where a 0.1-in. rise was permitted.

Thicknesses of the underseal layer were found to vary from ⅛ to 1 in. Underseal material was found to have reached the transverse joint at only six of the areas excavated. At five of the joints, two of which were expansion and three of which were contraction joints, the seal appeared unbroken underneath the joint. At the sixth joint a crack was found in the underseal directly under the joint, which was of the contraction type. This was at a location where No. 0 Korite was used in combination with a 0.1-in. pavement rise. No pumping has been found at the joint since undersealing, although pumping was found prior to treatment.

Pieces of No. 0 Korite and of Experimental No. 2 materials which were removed from the excavations were considerably more flexible at temperatures of 15 to 20 F. than were pieces of the modified M 18-42A material. None of the materials was found to adhere to the bottom of the pavement.

No relationships were established between pumping and any of the materials or pavement-rise limitations nor with the presence or absence of the underseal materials in the excavated areas, either under the slabs or at the joints.

Two of the excavations were carried down to the longitudinal drains that parallel the pavement at the edges through much of the test area (see Fig. 2). Pumping was found at both locations at the time the excavations were made. Although the backfill material (¾ in. to 1½ in.) was clean and the tile open, impervious, fine-grained soil appeared to separate the porous backfill from the pavement slab, and to prevent water on the subgrade from reaching the drains. One excavation was made where construction plans called for bringing the backfill material up level with the subgrade at the pavement edge, and the other where the backfill material was to be brought 3 in. above the subgrade at the pavement edge. An inspection of one of the locations several days after excavating, following a heavy rain, showed no pumping. It appears that, in excavating, a drainage channel may have been opened from the subgrade to the porous granular backfill.

Future Studies

Additional condition surveys, made as part of the general performance study of US 66 between Chicago and Springfield, will be conducted. The advance of pumping and the structural performance of the pavement will be followed closely, so any differences in service attributable to characteristics of the undersealing materials or to the amounts used as measured by pavement rise may be determined. Additional soil information will become available to aid in the evaluations as the US 66 performance study progresses. Additional excavations are also planned for the underseal test area to determine whether the bituminous materials have sufficient ductility to withstand cracking at low temperatures.