EVALUATION OF SULPHLEX AS A BINDER IN PAVEMENT RESURFACING MIXTURES

Final Report

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SUMMARY

Michigan was one of seven states whose Department of Transportation constructed experimental test sections to evaluate Sulphlex, an experimental plasticized sulfur material, developed by the Federal Highway Administration as a substitute for asphalt cement in bituminous paving mixtures. Michigan's experimental Sulphlex test section and a comparative control section of a conventional asphalt mixture were paved on M 54 at I 75 in Genesee County in July 1981.

The experimental Sulphlex binder was formulated by Southwest Research Institute, San Antonio, Texas, under a research contract with the FHWA and was mixed and shipped to the job site by Chemical Enterprises Inc. of Houston, Texas.

Mix designs for the Sulphlex paving mixture were prepared in the Testing Laboratory and checked by the FHWA laboratory in Maryland. Job control at the mixing plant included sampling the materials and measuring temperatures at various stages of mixing, in addition to checking the proportioning of materials in the batch plant. During construction, temperatures were measured throughout the paving and rolling operations while nuclear gage density tests were being made.

The experimental sections were inspected, sampled and tested at six-month intervals during the two-year evaluation period. After two years the Sulphlex section had deteriorated to such an extent that removal and replacement were recommended. The Federal Highway Administration is currently conducting further studies to increase the plasticity of Sulphlex and to determine why the material used in this study was as stiff and brittle as it was.

INTRODUCTION

The purpose of the study is to evaluate pavement resurfacing mixtures composed of mineral aggregates combined with 'Sulphlex,' a plasticized sulfur binder.

As part of its Highway Research and Development Program, the FHWA is concerned with the development of alternative paving materials to replace conventional asphalt-aggregate mixtures. Considerable research is now in progress throughout the country to determine the value of plasticized sulfur for this purpose.

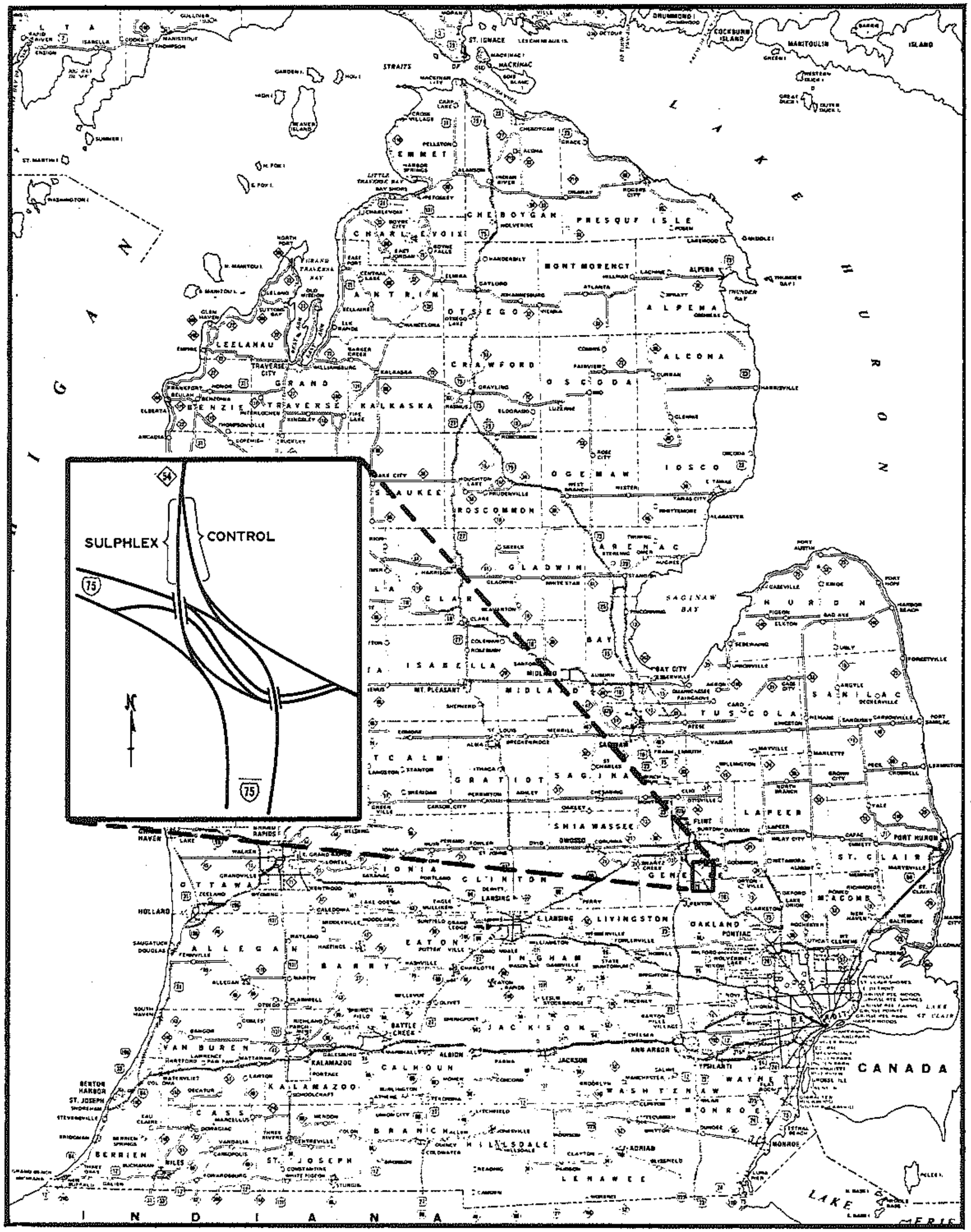
Elemental sulfur is a crystalline material at ordinary temperatures which, when mixed in molten form with an aggregate and allowed to cool, forms a sulfur concrete having compressive and flexural strengths comparable to portland cement concrete. This sulfur concrete, however, is not suitable for most engineering applications because the crystalline binder is very brittle and of low impact strength. Research effort has been expended to plasticize the sulfur in order to obtain a binder material with acceptable performance under both static and dynamic conditions of loading.

Through a contract with the FHWA, the Southwest Research Institute of San Antonio, Texas developed a plasticized sulfur containing chemical modifiers that allow polymeric sulfur (obtained by heating crystalline sulfur above 130 C) to retain its plastic qualities indefinitely, when cooled to ordinary temperatures.

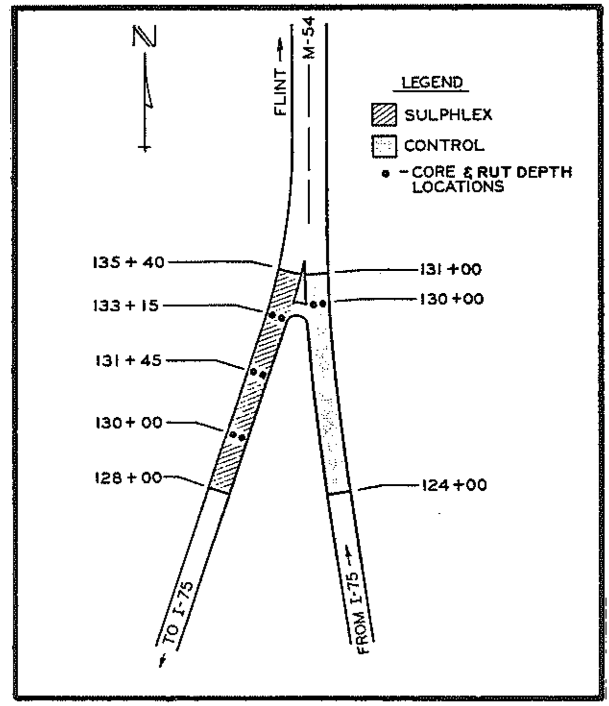
This material, designated 'Sulphlex' is covered by a patent application of the Southwest Research Institute which permits Federal, state, and municipal government agencies to use the material without payment of patent fees.

Research sponsored by the Federal Highway Administration shows that Sulphlex binder behaves much like conventional asphalt binders when used in paving mixtures (1). Properties of a Sulphlex binder were compared with those of an AC-20 asphalt cement using conventional laboratory measurements. Penetration, ductility, and softening point were comparable for the two binders. Viscosities, however, are, generally, significantly lower for Sulphlex binders at comparable temperatures.

Engineering properties of mixtures made with Sulphlex were compared in the laboratory with mixtures made with an AC-20 asphalt. Sulphlex binders were added to aggregates in the same proportions by weight as are normally used in conventional asphalt mixtures. It was found that established mix design techniques, such as the Marshall method, could be used to design Sulphlex mixtures. Typical mixture properties determined by the Southwest Research Institute are shown below.



Location map for experimental Sulphlex overlay construction.



Sulphlex and control section plan showing core sample and rut depth locations.

Figure 1. Location of Sulphlex evaluation sections.

	Sulphlex-233	AC-20
Marshall Stability, (Flow) (60 C, ASTM C 1559)	5900(20)	2000(14)
Compressive Strength, psi (ASTM C39)	2400	1300
Tensile Strength, psi (ASTM C496)	500	230
Wet-Dry Strength Ratio (ASTM D1075)	80	95
Freeze-Thaw Cycles (one cycle = 18 hr at -20 F, 8 hr at 140 F)	100	100
Specific Gravity (77 F, ASTM D71)	1.54	1.02

Unless otherwise specified, these tests were conducted on laboratory prepared and compacted mixtures at 25 C, for a 6 percent by weight binder content with a well-graded limestone aggregate. These results indicate that, at this time, only in the area of moisture susceptibility is the Sulphlex binder inferior to asphalt cement. An interesting and important point to recognize is that, while these mixture properties were measured at the same binder content by weight, the difference in binder specific gravities means that a significantly smaller volume of Sulphlex binder is being used to produce very acceptable engineering properties for these mixtures.

Field Evaluation

In November 1979, the Department agreed to participate in the field evaluation of Sulphlex, and in June 1980, entered into an agreement with the Federal Highway Administration under Basic Agreement No. DOT-FH-11-9211 (Task Order No. 5).

After preliminary laboratory studies, a test section was paved, in July 1981, with the Sulphlex mixture on M 54 and I 75 in Genesee County, along with an adjacent control section using a conventional asphalt paving mixture (Fig. 1).

The Sulphlex section was placed on the two southbound lanes and the control section on the northbound lanes as shown in Figure 1. Both sections are on similar foundations and involved the resurfacing, with the comparative mixtures, of an existing reinforced concrete pavement having a deteriorated bituminous surface.

Mix designs for the Sulphlex paving mixture were prepared in the Testing Laboratory and checked by the FHWA laboratory in Maryland. Job control at the mixing plant included sampling the materials and measuring temperatures at various stages of mixing, in addition to checking the proportioning of materials in the batch plant. During construction, temperatures were measured throughout the paving and rolling operations while nuclear gage density tests were being made. Photographs were taken during construction operations as well as throughout the performance evaluation.

Core samples were obtained after paving, so that resilient modulus, thermal contraction coefficient and tensile strength could be measured in the laboratory. Surface friction measurements, visual inspections, and photographs were made during the first few weeks following construction.

A progress report was prepared in February 1982 which described construction operations, material and mixture properties and initial performance measurements (2).

EVALUATION

Laboratory tests were performed on core samples obtained from the completed roadways to determine resilient modulus, tensile strength, and thermal contraction coefficient. Tensile strengths were also measured for both dry samples and samples that had been immersed in water. Field evaluation consisted of visual inspections and photographs, friction measurements including speed gradients, using the Department's Friction Tester (ASTM E-17 and E-274), and rut depth measurements. The field measurements were scheduled at six-month intervals.

Laboratory Test Results

Results of laboratory tests are summarized in Tables 1 and 2. Resilient modulus results, Table 1, show Sulphlex to be from 3 to 10 times stiffer than the conventional mixture. Temperature sensitivity (change in modulus caused by temperature change) of Sulphlex is about half that of the conventional mixture.

TABLE 1
RESILIENT MODULUS VALUES MEASURED
ON CORES OBTAINED FROM EXPERIMENTAL
SULPHLEX AND CONTROL SECTIONS

Loading Time, sec	Resilient Modulus, psi			Test Temperature, F
	0.5	0.1	1.0	
Sulphlex	1.5×10^6	1.1×10^6	0.5×10^6	76
	4.5×10^6	4.6×10^6	3.8×10^6	40
Control	0.2×10^6	0.1×10^6	0.05×10^6	76
	1.4×10^6	1.2×10^6	0.7×10^6	40

Thermal contraction coefficients were measured in the laboratory and resulted in values of 8.9×10^{-4} in. per degree F and 12×10^{-4} in. per degree F for the control and Sulphlex sections respectively.

Tensile strength measurements, Table 2, show Sulphlex to be both stronger and stiffer than the conventional paving mixture. Soaking of the Sulphlex samples resulted in a 40 percent loss of strength and stiffness but was not detrimental to the conventional material.

TABLE 2
TENSILE STRENGTH AND MODULUS OF ELASTICITY MEASURED ON CORES OBTAINED FROM EXPERIMENTAL SULPHLEX AND CONTROL SECTIONS

	Dry Samples		Soaked Samples	
	S_T (psi)	E (psi)	S_T (psi)	E (psi)
Sulphlex	390	128,300	244	75,900
Control	39	6,700	63	7,200

Field Evaluation Results

Average rut depth measurements for each of the three years of evaluation are presented in Table 3. The degree of rutting is not significant in either section. Rutting in the Sulphlex section is less, however, than for the control section.

TABLE 3
AVERAGE RUT DEPTH MEASUREMENTS FOR SULPHLEX AND CONTROL TEST SECTIONS
(all values in inches)

	Sulphlex				Control			
	Driving Lane		Passing Lane		Passing Lane		Driving Lane	
	OWT[1]	IWT	OWT	IWT	IWT	OWT	IWT	OWT
1981	.017	.025	.058	.033	.025	.025	.033	.016
1982	.017	.025	.058	.025	.042	.042	.050	.042
1983	.000	.025	.033	.033	.033	.042	.042	.033

[1]OWT = Outer wheel track; IWT = Inner wheel track

Although friction numbers shown in Table 4 are essentially identical for the Sulphlex and control sections, the control section values are, on the average, slightly greater.

TABLE 4
PAVEMENT FRICTION NUMBERS FOR
SULPHLEX AND CONTROL TEST SECTIONS

Lane	Test Speed MPH	Sulphlex			Control		
		1981	1982	1983	1981	1982	1983
Driving Lane	30	35	51	46	47	53	51
	40	29	46	43	33	47	46
	55	19	40	38	25	41	39
Passing Lane	30	45	58	52	48	61	52
	40	35	55	50	37	54	50
	55	25	48	45	29	47	45

Reflective cracking and associated deterioration of the Sulphlex, as illustrated in Figure 2, indicate its excessive brittleness as compared with the control material. This type of deterioration is predominate in the Sulphlex section, and has progressed to the point where large chunks (4"x4") have been thrown onto the shoulder by traffic. Deterioration as shown in Figure 2, has occurred at each transverse joint in the pavement covering an estimated 10 to 20 percent of the entire surface area of the Sulphlex test section.

CONCLUSIONS

Sulphlex mixtures can be blended and paved using conventional equipment and procedures as easily as can conventional asphaltic material. Temperatures for both Sulphlex binders and Sulphlex mixtures are lower than the temperatures normally used in conventional asphalt paving operations.

The Sulphlex binder was extremely stiff resulting in a paving mixture which was brittle and subject to rapid deterioration under traffic.

Friction levels were slightly lower, for the Sulphlex test section than for the comparative control section, the difference, however, may not be significant.

RECOMMENDATION

Reflective cracking and disintegration have progressed to the point where large pieces of Sulphlex have been loosened and extensive spot patching is required. It has, therefore, been recommended that the Sulphlex material be removed and the section be resurfaced.

References

1. Harrigan, E. T., "Technical Note, Research and Plasticized Sulfur (Sulphlex) Binders," Federal Highway Administration, August 1979.

2. DeFoe, J. H., "Evaluation of Sulphlex as a Binder in Pavement Resurfacing Mixtures," Progress Report, MDOT Research Report No. R-1189, February 1982.

Disintigration of Sulphlex over joint in underlying pavement.

Control section at reflective crack over underlying joint.

Figure 2. Condition of comparative sections at the time of final inspection, Fall 1983.