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EVALUATION OF SULPHLEX AS A BINDER IN PAVEMENT RESURFACING MIXTURES

Progress Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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EVALUATION OF SULPHLEX AS A BINDER IN PAVEMENT RESURFACING MIXTURES

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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 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 adequate compressive and flexural strengths. However, this concrete 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 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 has developed a plasticized sulfur containing a chemical modifier which allows polymeric sulfur (obtained by heating crystalline sulfur above 130 C) to retain its plastic qualities indefinitely when cooled to ordinary temperatures.

The 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. 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.

In November 1979, the Department agreed to participate in the field evaluation of Sulphlex, and in June 1980, entered an agreement with the Federal Highway Administration under Basic Agreement No. DOT-FH-11-9211 (Task Order No. 5). A 1,000-ft section of M 37 in Kent County was selected as the experimental site and laboratory mixes were designed to

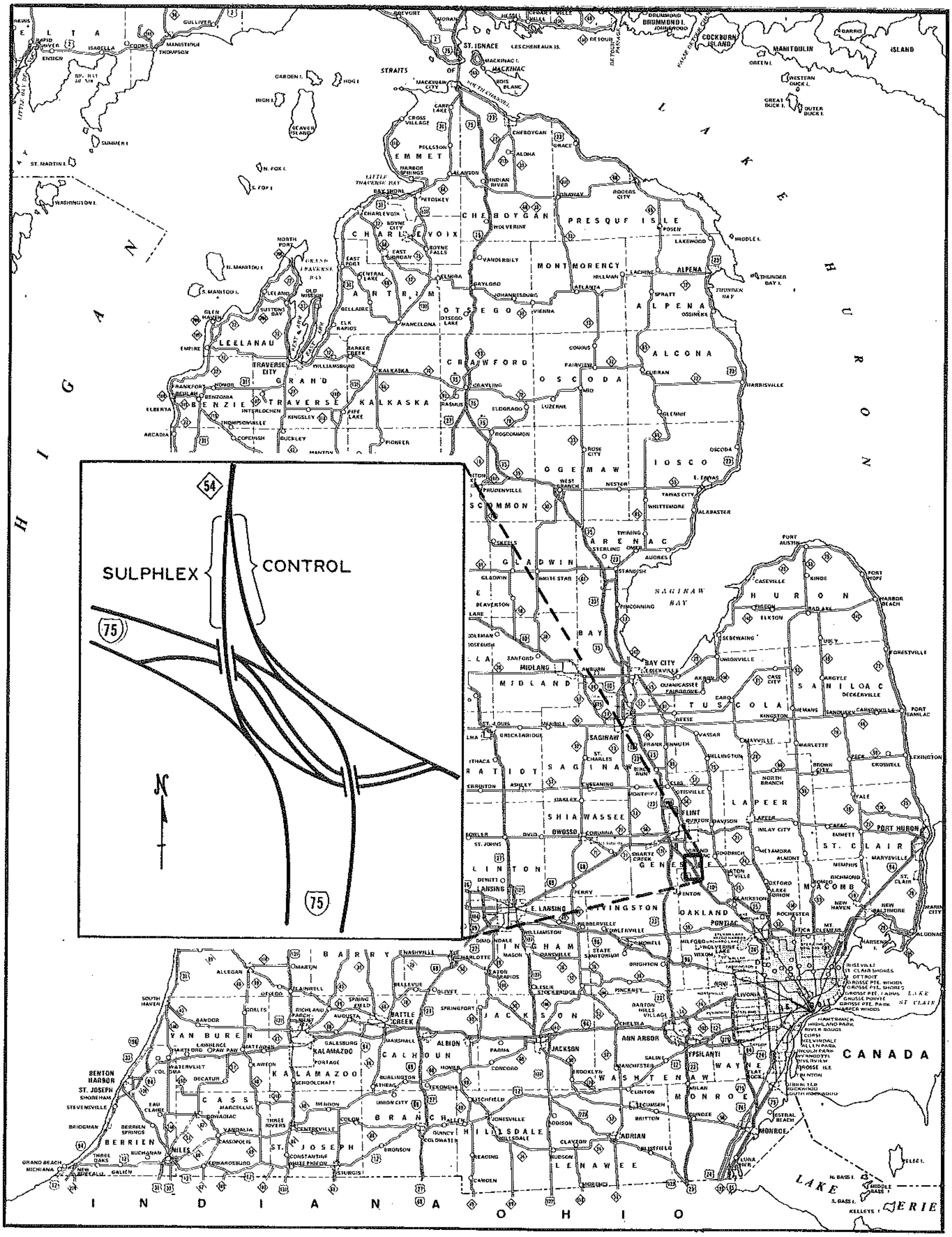


Figure 1. Location map for experimental Sulphlex overlay construction.

establish job control quantities. The Sulphlex binder could not be delivered on schedule due to production and shipping classification delays so the work was postponed and another test site had to be selected.

After a one year delay a test section was paved, in July 1981, with the Sulphlex mixture on M 54 at 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 2. Both sections are on similar foundations and involved the resurfacing, with the comparative mixtures, of an existing reinforced concrete pavement having a 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 and will continue to be taken throughout the performance evaluation.

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

Construction of the Test Section

The Sulphlex and comparative control sections were part of the resurfacing of an existing 9-in. concrete pavement supported by an 11-in. granular subbase on an embankment subgrade (Fig. 3). The Sulphlex mixture, 248 tons, was placed in a single 2-1/2-in. lift with two passes of a 12-ft paver. The control section mixture was placed in two lifts as is normally done when using 2-1/2 in. or more of conventional mixtures in Michigan. Preliminary laboratory mix design work indicated that the Sulphlex mix would be quite stiff. It was felt, therefore, that heat would be retained longer in a thicker layer and thus aid in compaction.

As part of the construction phase of this study, the FHWA requested that a briefing and field demonstration be conducted for highway engineers in FHWA Region 5 (Indiana, Illinois, Michigan, Minnesota, Ohio, and Wisconsin) as well as local paving contractors. The briefing, in which the

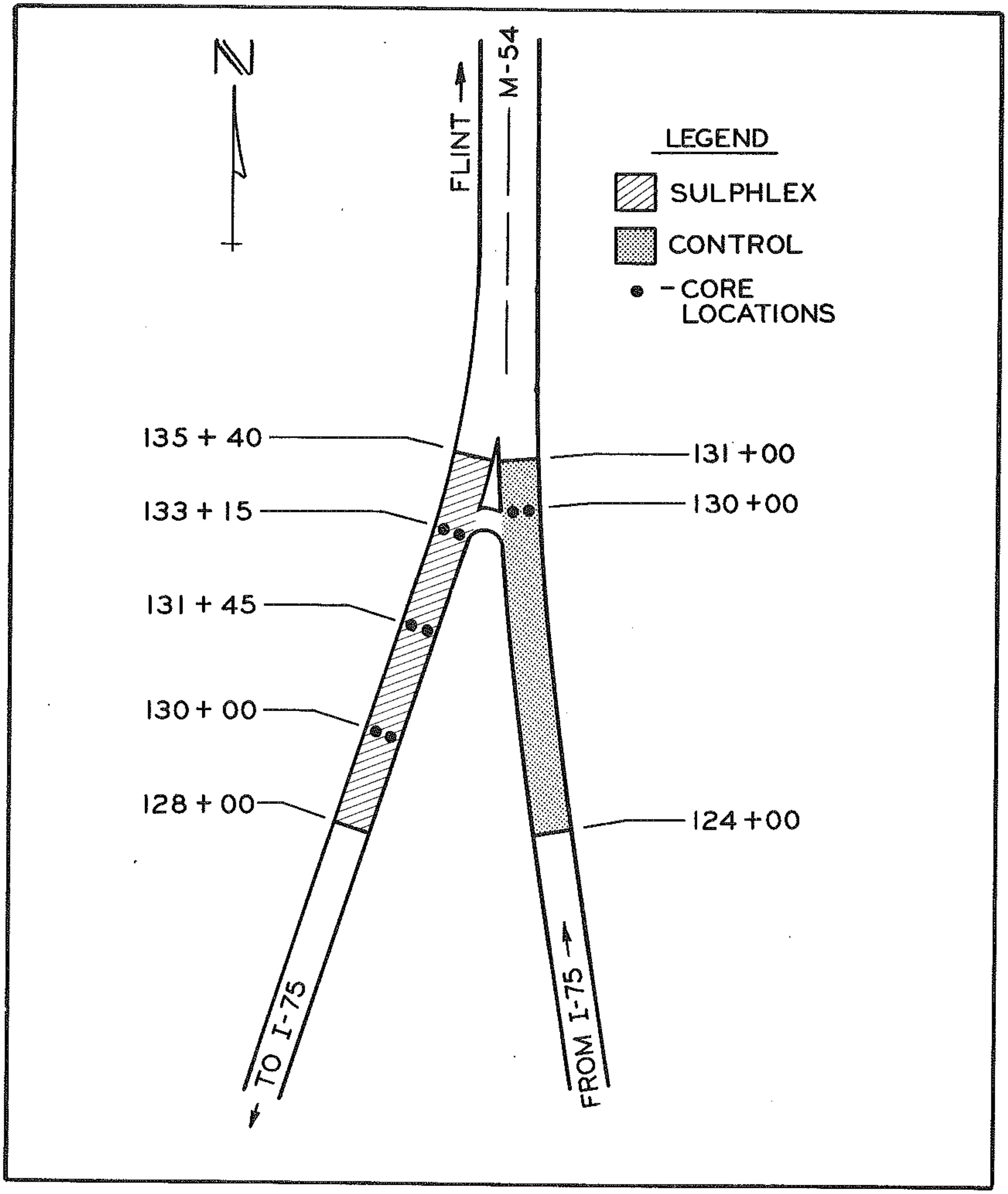


Figure 2. Sulphlex and control section plan showing core sample locations.

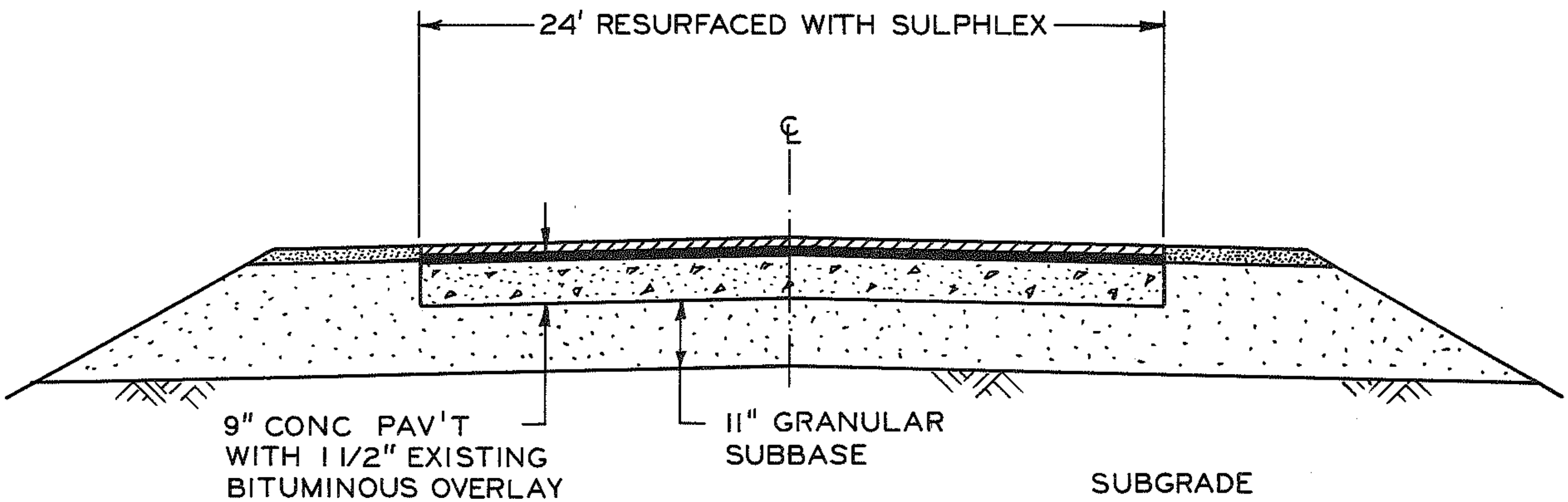


Figure 3. Cross-section of experimental Sulphlex paving, M 54, Genesee County.

development of Sulphlex was described, was held on July 29 with the paving demonstration the following morning, July 30, 1981.

Design of Sulphlex and Control Mixtures

Prior to construction, samples of aggregate, Sulphlex binder, and conventional asphalt binder were obtained for laboratory mix designs. The preconstruction mix design was performed in the Department's Testing Laboratory using the Marshall method to optimize stability, flow, air voids, and unit weight parameters.

Based on the laboratory mix design, the conventional mixture for the control section called for a Type II mix (1979 Michigan Standard Specifications) using 20AA aggregate, applied in two courses with 5.2 percent asphalt in the first course and 5.8 percent asphalt in the top course. The mix design for the Sulphlex required 8.0 percent Sulphlex binder with the same aggregate as used for the control mixture.

Table 1 summarizes the Marshall mix design values for the Sulphlex mixture along with the aggregate gradation as used in the test sections.

TABLE 1
MARSHALL MIX DESIGN VALUES AND AGGREGATE GRADATION FOR SULPHLEX TEST SECTIONS

Marshall Values

Stability	2,260 lb
Flow	14.3
Air voids	3.06 percent
Design density	153.4 pcf
Sulphlex binder	8.0 percent (by weight)

Aggregate Gradation

Sieve Size	Percent Passing
3/4 in.	100.0
1/2 in.	97.3
3/8 in.	89.5
No. 4	70.1
No. 8	52.1
No. 16	35.9
No. 30	22.3
No. 50	13.7
No. 100	7.8
No. 200	5.5

Construction Operations

Construction of the experimental section involved the conventional hot mix procedures of batch mixing, hauling, paving, and compacting. The only significant deviation from normal practice was the required temperature range. Sulfur compounds, such as Sulphlex, solidify when cooled to 246 F and emit hydrogen sulfide and sulfur dioxide gases when heated above 300 F. Also, the viscosity increases abruptly when heated above 300 F, making pumping difficult, if not impossible.

The mix was prepared (by Asphalt Products, Sterling Heights) in a batch plant using the following batch weights:

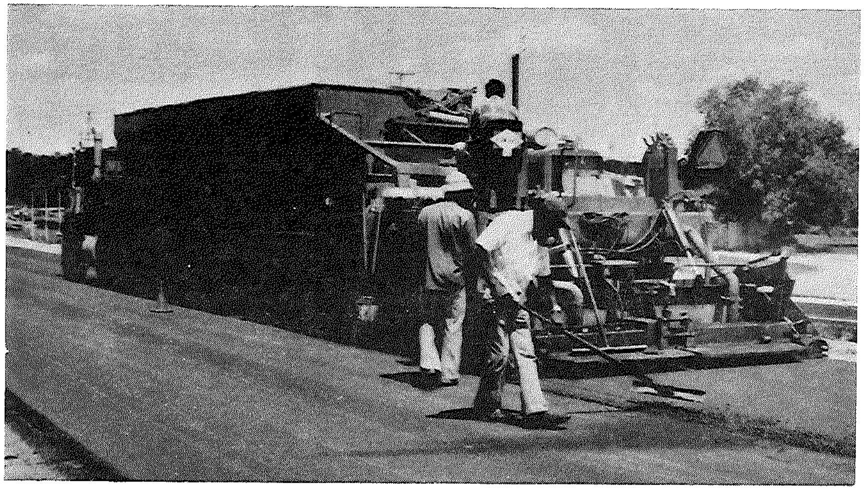
Stone	4,300 lb
Sand	4,900 lb
Sulphlex binder	800 lb (8.0 percent)

Aggregates were dry mixed for 14 seconds before adding the Sulphlex binder, followed by an additional 37 seconds of wet mixing. Aggregate temperatures ranged between 290 and 300 F in the hot bins with the Sulphlex held at 270 F in the storage tanker. These component temperatures resulted in a mixture which was 270 to 275 F when dropped from the pugmill into the hauling units.

The mix was transported approximately 40 miles to the paving site in covered and insulated trucks. The haul required about one hour. Temperature of the mix in the trucks averaged 268 F at the plant's sampling platform and 255 F when dumped into the paver. Temperatures measured throughout mixing and placing operations are summarized in Table 2.

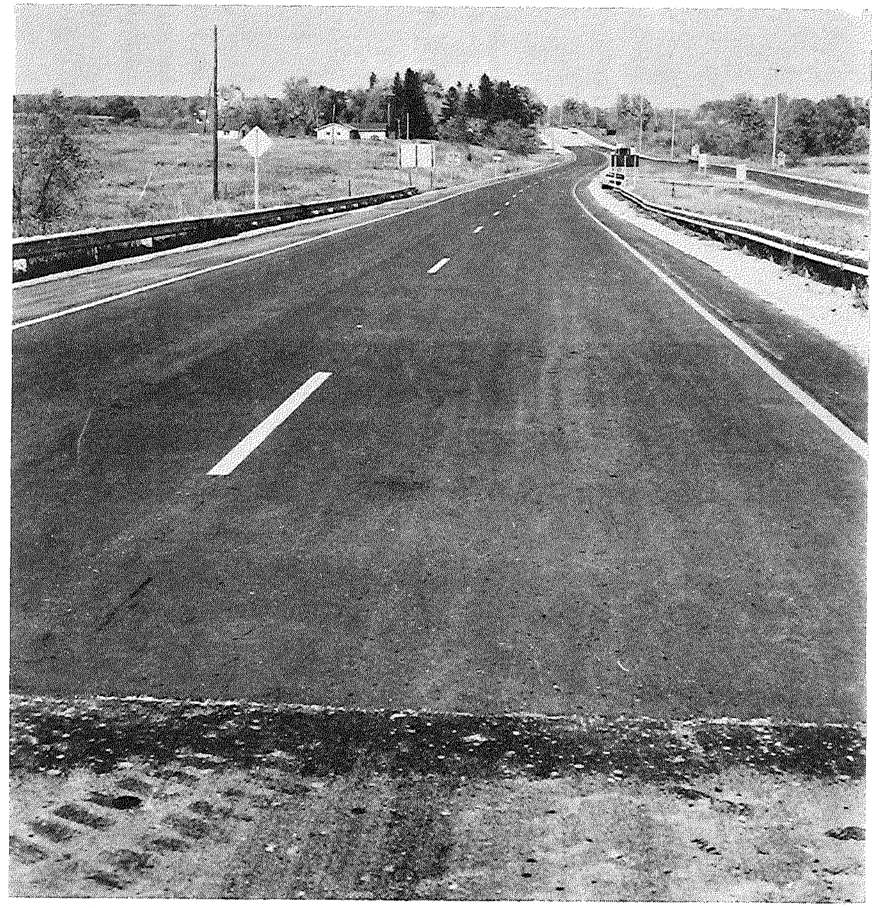
TABLE 2
TEMPERATURES OF SULPHLEX MIXTURE
DURING CONSTRUCTION OPERATIONS

Operation	Temperature, F	
	Range	Average
Truck at plant	250-275	268
Truck to paver	230-265	244 @ 1 hour after mixing
Behind paver screed	230-260	242
Start breakdown rolling	205-260	225 @ 8 min. after paver
Start finish rolling	160-185	175 @ 1/2 hour after paver
End of rolling	130-160	146



Conventional paving operation used in spreading Sulphlex overlay mixture.

Rolling and compaction testing of Sulphlex.



Completed Sulphlex test section.

Figure 4. Construction of experimental Sulphlex test section.

A conventional asphalt paver was used to spread the material. A 10-ton steel drum breakdown roller was used for initial compaction, followed by a 20-ton steel drum finish roller, operating in the vibratory mode. Two passes with each roller were used to achieve 97.2 percent of the mix design density of 153.4 pcf. Figure 4 shows the conventional paving and rolling operations involved in constructing the Sulphlex test section as well as a view of the section as completed.

Material Characteristics

Core samples obtained from the test and control sections were tested in the laboratory for resilient modulus and thermal contraction coefficient. Modulus values show Sulphlex to be approximately 10 times stiffer than the conventional mixture (Table 3), and the temperature sensitivity (change in modulus caused by temperature change) of Sulphlex is about twice that of the conventional mixture.

Thermal contraction coefficients of 8.9×10^{-4} per degree F and 1.2×10^{-5} per degree F were obtained for the control and Sulphlex core samples, respectively.

Penetration and viscosity measurements were made on Sulphlex binder sampled from the supply line at the batch plant. Penetrations were measured at 4 C (200 gm, 60 sec) and at 25 C (100 gm, 5 sec); absolute viscosity at 60 C and kinematic viscosity at 135 C were also determined in the laboratory. Results are shown in Table 4 along with measured values of the asphalt cement used for the control section.

Sulfur Compound Emissions

Emissions of sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) can be present in annoying and possibly toxic concentrations when sulfur compounds are heated. Previous Sulphlex experiments have been monitored and only low levels of these emissions were detected. During the preliminary mix design phase of this study, measurements were made of hydrogen sulfide and sulfur dioxide concentrations in air from an oven in which a quantity of Sulphlex paving mix was heated at 280 to 290 F. No hydrogen sulfide was detected. When no air flowed through the oven, sulfur dioxide was measured at 6 to 10 ppm. When compressed air was used to ventilate the oven, sulfur dioxide concentration was 5 ppm. These measurements were expected to establish the worst condition data resulting from handling Sulphlex as a paving material.

TABLE 3
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

TABLE 4
PENETRATION-VISCOSITY VALUES FOR SULPHLEX AND ASPHALT CEMENT BINDERS SAMPLED AT THE PLANT

	Temperature, C	Sulphlex	Asphalt
Penetration (dmm)	4	18	--
Penetration (dmm)	25	70	91
Viscosity, absolute (poises)	60	2340	1530
Viscosity, kinematic (centistokes)	135	542	363

Sulfur dioxide results were:

280 F	—	2 ppm
300 F	—	6 ppm

The threshold limit value of sulfur dioxide recommended by the American Conference of Government Industrial Hygenists is 5 ppm. Sulfur dioxide is irritating to the eyes, nose, throat and lungs in concentrations greater than 6 to 20 ppm. Hydrogen sulfide concentrations less than 10 ppm reportedly cause no appreciable discomfort, with concentrations of from 50 to 150 ppm causing slight irritations after several hours exposure.

Performance Evaluation

Evaluation of the performance of the Sulphlex will consist of friction testing, rutting measurements, crack surveys, visual inspections, and photographs all made periodically for the next two years.

Initial friction tests, visual inspections, and rutting measurements were made during the first few weeks after paving.

The stiff, brittle nature of Sulphlex is illustrated by the reflective cracking in Figure 5. After three months, chunks of Sulphlex material have broken from the edges of the cracks in many places. In general, the Sulphlex pavement is showing signs of early deterioration in the vicinity of the transverse cracks which reflect through the surfacing at the joints. Currently, the control section has only a limited amount of hairline reflective cracking which is typical of bituminous overlays.

Wet sliding friction measurements, made one month after paving, show the Sulphlex area to have lower friction numbers than those obtained on the control section of conventional asphalt surfacing (Fig. 6).

Conclusions

Sulphlex mixtures can be blended and paved using conventional equipment and procedures as easily as can conventional asphalt material. Temperatures for Sulphlex are lower throughout the construction process than for conventional asphalt. The Sulphlex blend (233A) used on this project yielded a stiff, brittle mixture which seems to be more susceptible to reflective cracking than conventional bituminous mixtures.

Performance of the test section is to be evaluated for several years in terms of cracking, rutting, pavement friction resistance, and changes in material characteristics.

Three weeks after paving.

Ten weeks after paving.

Figure 5. Typical reflective cracks in Sulphlex overlay three weeks and ten weeks after construction.

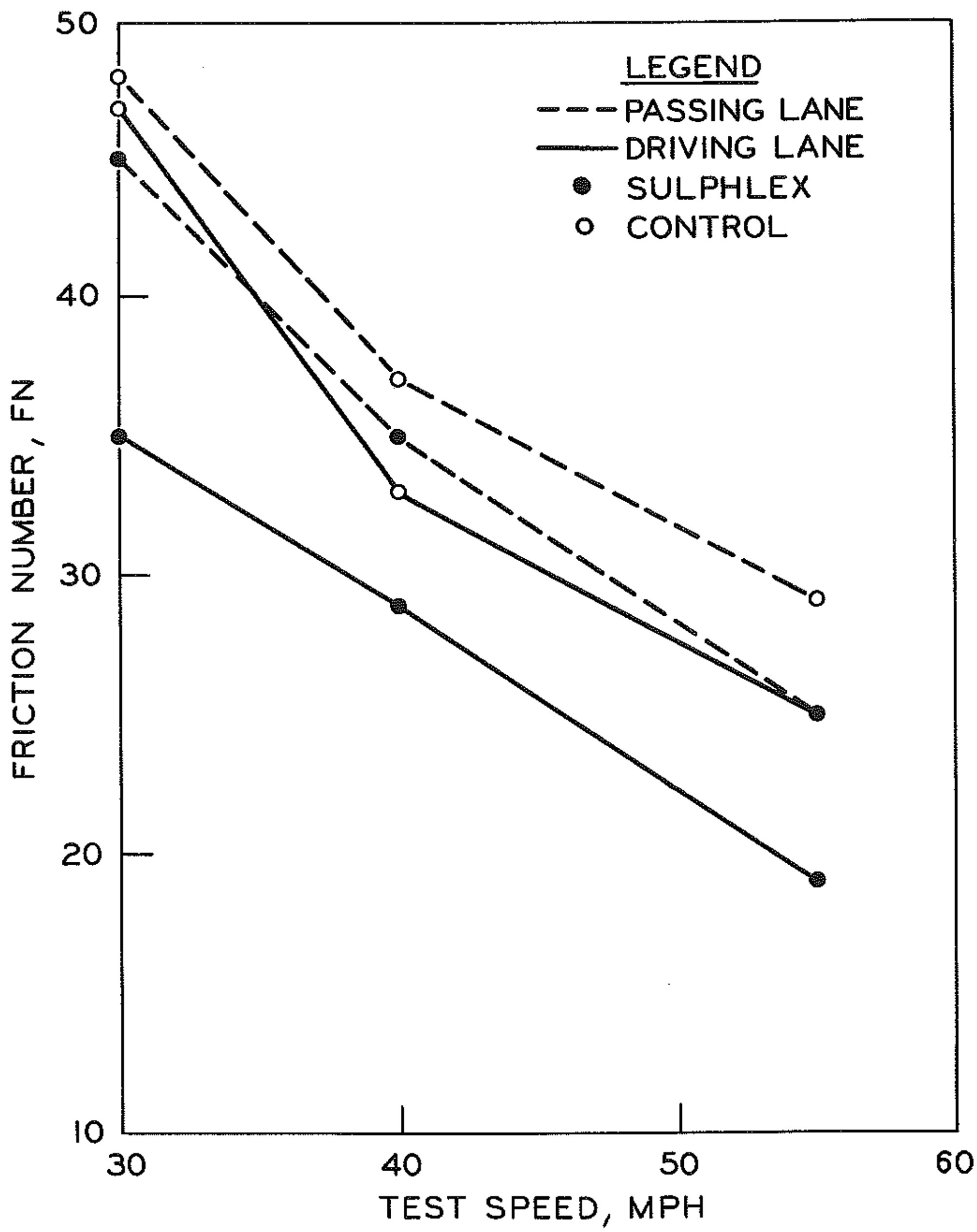


Figure 6. Friction number and speed relationship for Sulphlex and conventional, control overlays measured one month after paving.