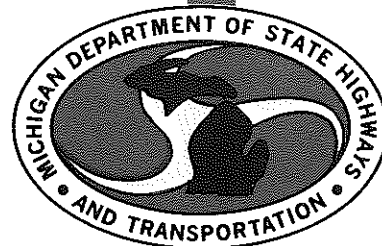


EVALUATION OF SULFUR-ASPHALT BINDER FOR  
BITUMINOUS RESURFACING MIXTURES

Progress Report



**TESTING AND RESEARCH DIVISION  
RESEARCH LABORATORY SECTION**

EVALUATION OF SULFUR-ASPHALT BINDER FOR  
BITUMINOUS RESURFACING MIXTURES

Progress Report

J. H. DeFoe

Research Laboratory Section  
Testing and Research Division  
Research Project 74 D-29  
Research Report No. R-1078

Michigan State Highway Commission  
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,  
Vice-Chairman; Hannes Meyers, Jr., Weston E. Vivian  
John P. Woodford, Director  
Lansing, January 1978

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This research project was initiated in 1974, at the request of the Engineer of Testing and Research, for the purpose of evaluating sulfur-asphalt binders as used in bituminous paving mixtures, and is being conducted in cooperation with Gulf Oil of Canada, Ltd. For this operation molten sulfur is blended with hot asphalt cement in specific and carefully controlled proportions, to form a sulfur-asphalt binder which is then mixed with aggregate, sand, and mineral filler in the usual manner to form a sulfur-asphalt paving mixture.

Benefits to be expected from the use of sulfur have been reported elsewhere (1, 2, 3) and include:

- 1) Use of less asphalt than is normally required for comparable conventional mixes (as much as 50 percent by weight of asphalt cement may be replaced by sulfur),
- 2) Lower mixing and placing temperatures can be used, due to improved viscosity-temperature characteristics,
- 3) Longer fatigue life compared with conventional mixes, because of improved viscosity-temperature characteristics,
- 4) Reduced rutting might be expected because of improved viscosity characteristics.

Four one-quarter mile experimental sulfur-asphalt test sections were constructed as part of a resurfacing project (Control Section 26011, Job No. 11032A) on M 18 in Gladwin County (Fig. 1). In addition to the four sulfur-asphalt test sections, two adjacent sections using conventional mixes, located on either end of the test sections, were included as control sections in this study.

The four test sections consist of mixes made with two different ratios of sulfur-to-asphalt binder. Two test sections were made with each sulfur-to-asphalt ratio at two different percentages of binder as shown in Table 1 and in Figure 2.

The experimental sections were paved in accordance with the 1976 Department Specifications for Bituminous Concrete Pavement (4.12) involving a leveling course (25A) and a Type C wearing course. Asphalt cement, 85 to 150 penetration, was used to make the sulfur-asphalt binder. Materials and experimental features unique to the project were covered in a Special Provision for Sulphur-Bituminous Concrete Pavement which was included in the project proposal, and is contained as an Appendix to this report.

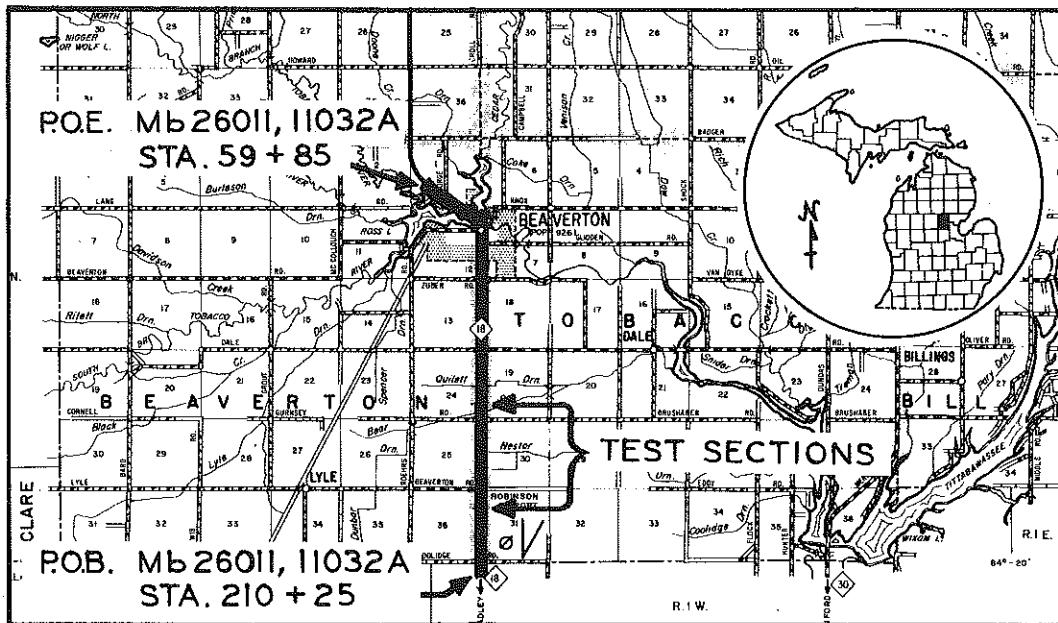


Figure 1. Location of experimental sulfur-asphalt test sections on M 18 in Gladwin County.

TABLE 1  
COMPOSITION OF SULFUR-ASPHALT MIXTURES AS  
PROPOSED FOR THE FOUR TEST SECTIONS

Test Section	Sulfur-to-Asphalt Ratio in Binder, percent by weight	Sulfur-Asphalt Binder in Mixture, percent	
		Leveling Course	Wearing Course
1	30:70	5	5.5
2	30:70	5.5	6
3	50:50	5	5.5
4	50:50	5.5	6

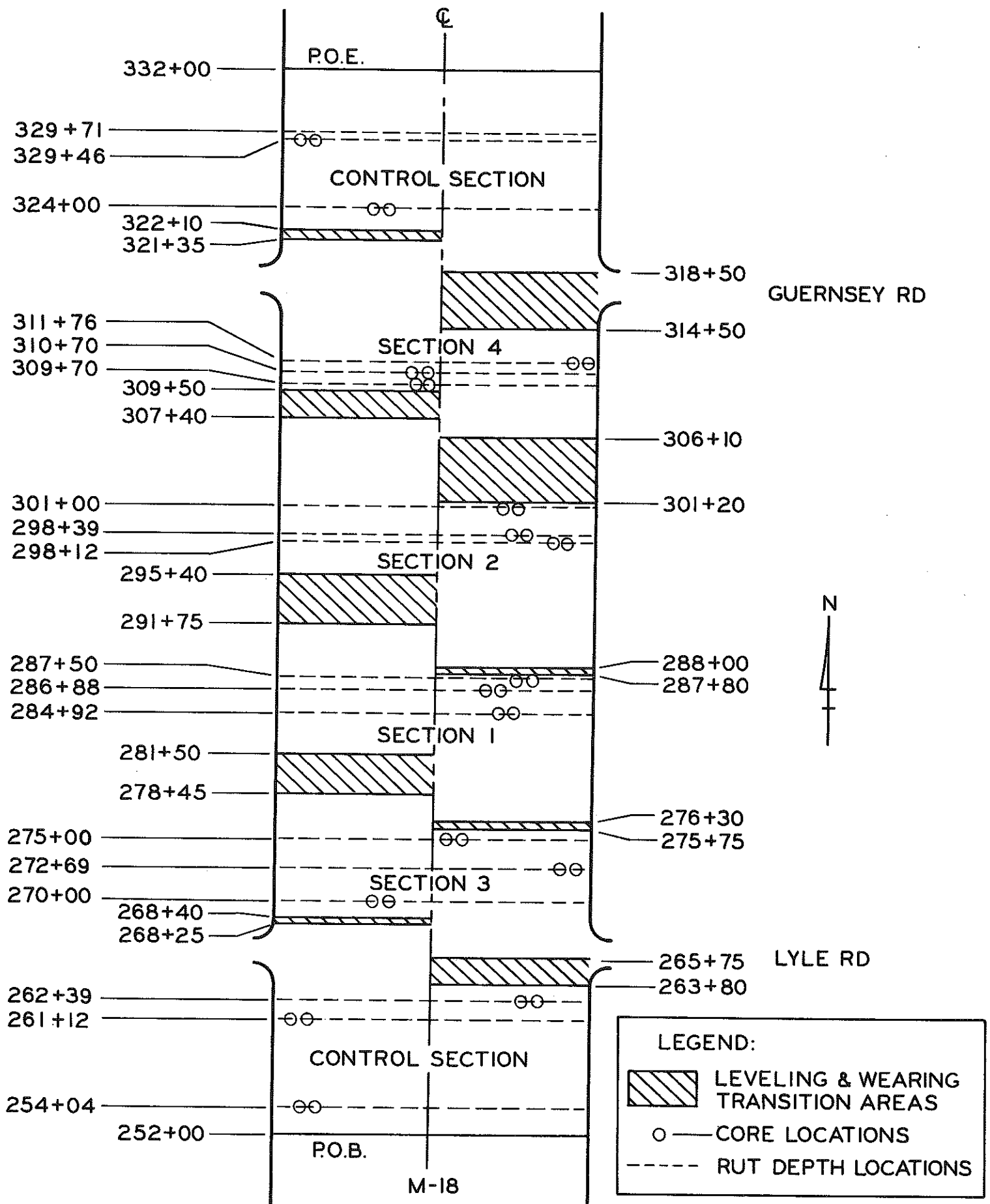


Figure 2. Experimental sulfur-asphalt test sections.

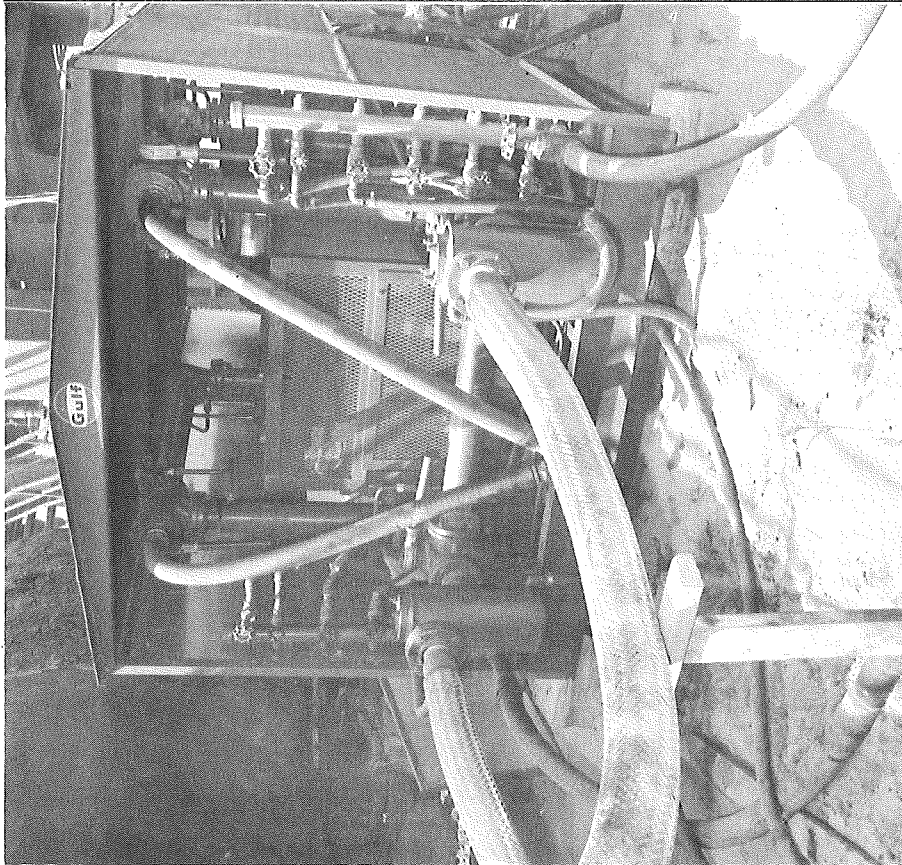
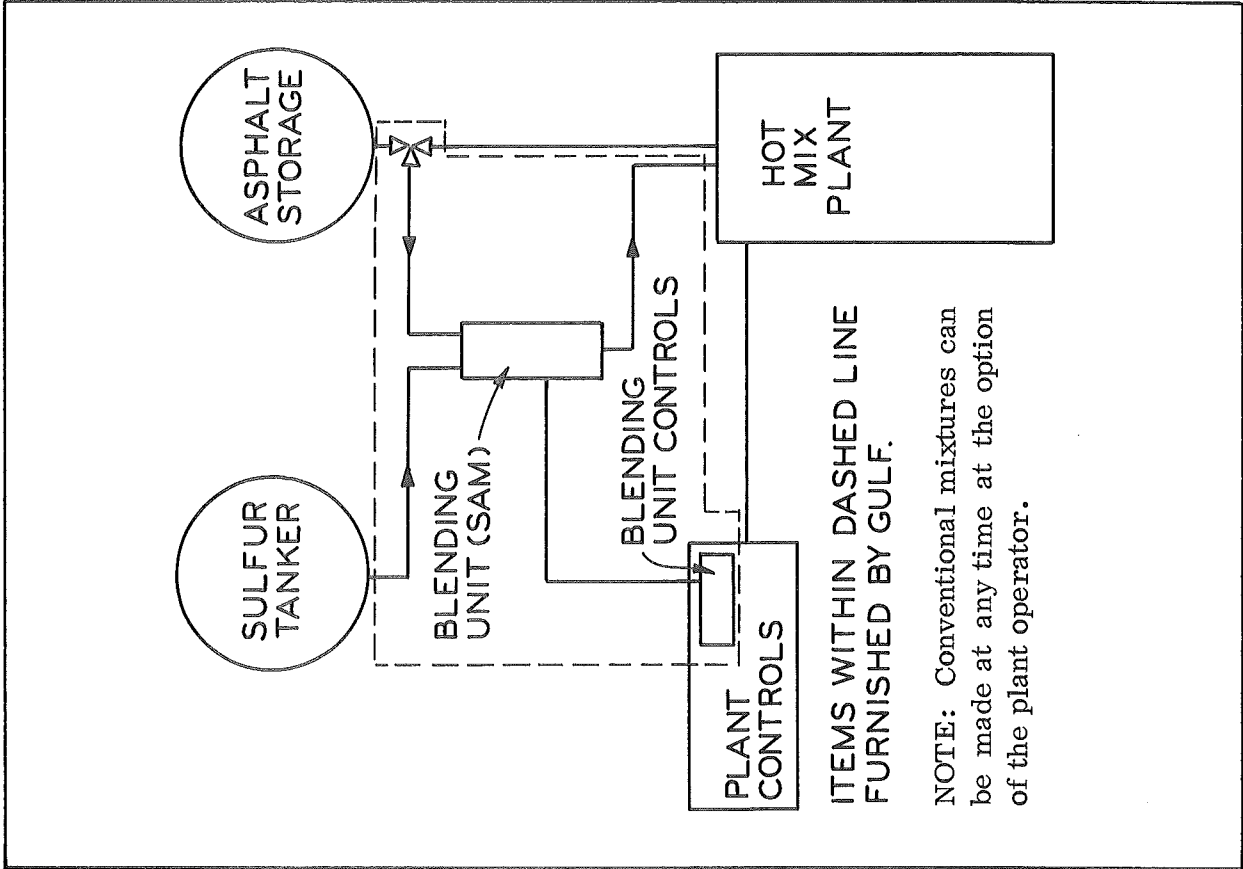


Figure 3. Sulfur-asphalt blending unit, SAM, connected to the hot sulfur and asphalt supply tanks.

Figure 4. Schematic diagram of plant set-up to make sulfur-asphalt paving mixtures.



Prior to construction, crack surveys and rut depth measurements were made on the four test sections and on the two control sections. These measurements form the basis for future performance evaluation. Locations of rut depth measurements are shown in Figure 2 along with points where cores were taken from the experimental and control mixtures. Construction with the experimental sulfur-asphalt mixtures involved preliminary mix design, plant set-up, plant sampling, transportation of the mix, and paving. Several weeks before the job was to start, samples of aggregate and asphalt were sent to the Gulf Laboratory and to the Department's Testing Laboratory for mix design testing.

A conventional stationary batch plant, owned by the contractor and located in Midland, produced the mixtures. A special set-up by Gulf, prior to mixing the sulfur-asphalt material, required connection of a specially designed sulfur-asphalt blending module (SAM) between the regular asphalt storage tank and the plant with a control unit in the plant operations trailer (Fig. 3). The schematic diagram, Figure 4, shows the extra units involved; all of which were supplied, connected, and operated by Gulf personnel.

During production, samples of the sulfur-asphalt binder were obtained and analyzed for proportion of sulfur. Mixtures were also sampled from the trucks before leaving the plant, tested for binder level, and then formed into specimens for later laboratory testing of physical properties. The material was transported to the job site, about 25 miles, with each truck hauling approximately 40 tons. Paving consisted of two courses, leveling and wearing, meeting requirements for Bituminous Concrete Pavement, Section 4.12 of MDSHT Standard Specifications for Highway Construction. Finished appearance of the sulfur-asphalt overlay is shown in Figure 5.

Except for the addition of sulfur, the project involved standard construction methods. The presence of sulfur in the mix was accompanied by a strong and distinct odor. Previous studies by Gulf have shown sulfur emissions to be well within current clean air standards, provided the temperature of the sulfur does not exceed 300 F throughout the process. The formation of hydrogen sulfide is prevented when temperatures remain below 300 F. To provide further assurance regarding personnel and environmental health conditions, Gulf maintained a mobile laboratory on the job to measure levels of hydrogen sulfide ( $H_2S$ ), sulfur dioxide ( $SO_2$ ), elemental sulfur, hydrocarbons, and particulates (Fig. 6). Portable monitors were also used to measure sulfur emission levels on the paver, especially at the operators station (Fig. 7).



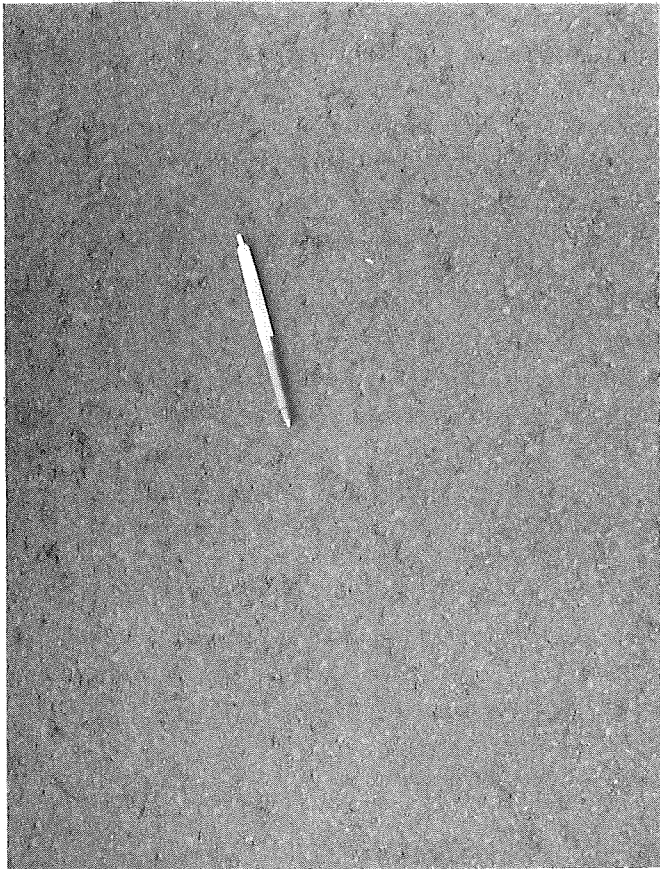


Figure 5. Finished sulfur-asphalt wearing course, sulfur-asphalt ratio 50/50.

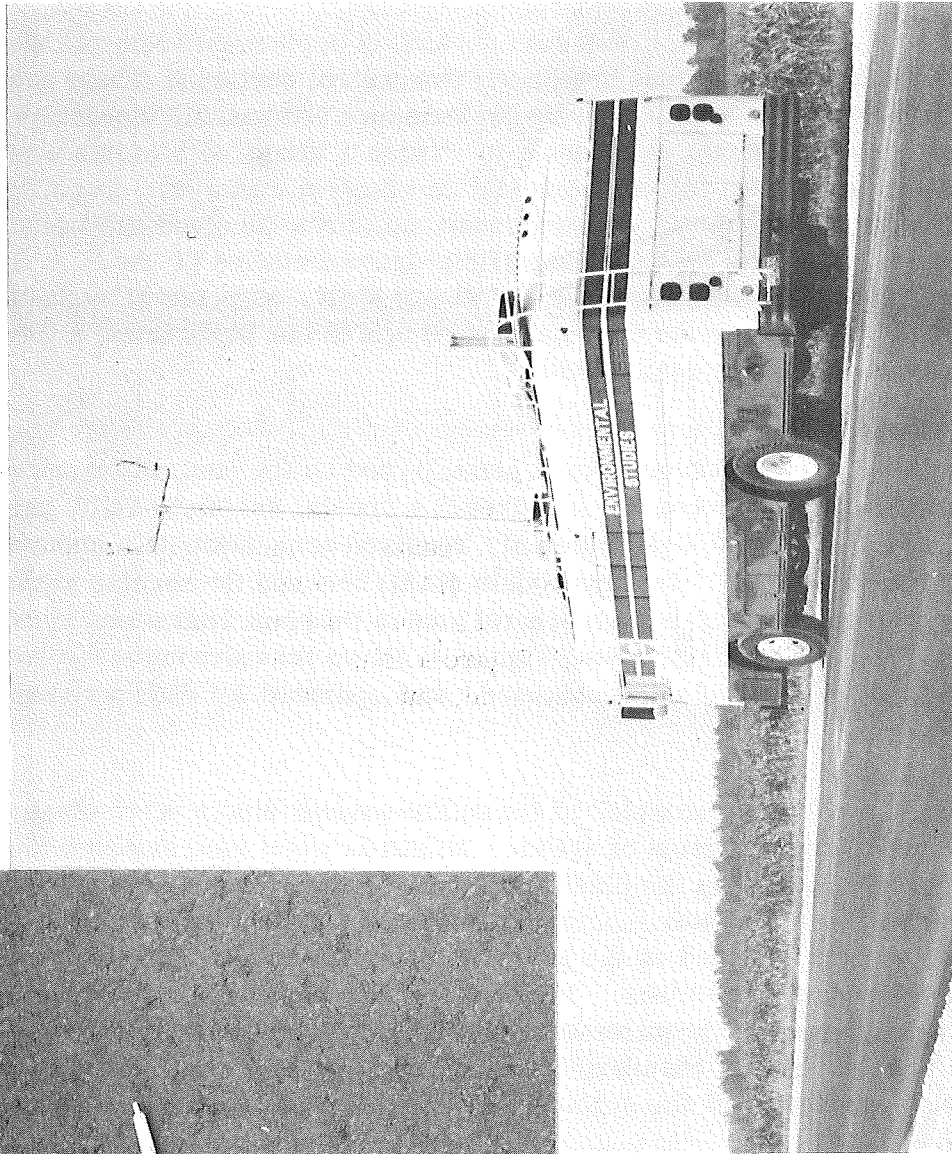


Figure 6. Mobile environmental laboratory at the paving site.



Figure 7. Paver operator with monitor to measure sulfur emissions.

Construction of the test sections was completed in two days and required 1,765 tons of the sulfur-asphalt mixtures, containing approximately 18 tons of sulfur. Unit prices for the sulfur-asphalt wearing and leveling courses were \$17.69/ton and \$17.33/ton, respectively. Unit prices for a ton of conventional mix used on the remainder of the project, were \$19.45 for wearing and \$18.19 for leveling courses.

### Evaluation

No significant problems were encountered in the construction of the test sections. Some difficulty was experienced, however, in controlling the length of the test sections to within 100 or 200 ft of the specified length. This was due to the shortness of the sections and the hauling distances from the plant. All material for a particular section had been produced and was on the way to the job site before a check on the yield and necessary adjustments could be made.

Laboratory tests will be made on cores taken from the overlay to determine density, resilient modulus, and binder content. Field performance measurements such as rut depth and crack surveys will be made periodically during the next five years to complete the evaluation.

### Recommendations

Even though the performance of this experimental paving remains to be evaluated, the successful completion of construction opens the way for further work which seems to be needed regarding sulfur-asphalt mixtures. Maximum benefit to be gained from the addition of sulfur to asphalt, in regard to temperature and fatigue characteristics, should be investigated. Specific recommendations include:

- 1) Laboratory studies should be conducted to measure structural and fatigue characteristics of sulfur-asphalt mixtures made with various Michigan mix designs at low temperatures, i.e., 0 F.

- 2) Additional field test sections should be constructed using softer (higher penetration in the 200 to 300 penetration range) asphalts. Such asphalts should be more flexible at winter temperatures with the sulfur addition providing adequate stiffness during hot weather to prevent rutting and shoving.

3) Performance of sulfur-asphalt mixtures as a flexible pavement overlay should be evaluated. The project described in this report (M 18) represents an overlay over a rigid pavement.

4) Field test sections should be at least one mile in length to allow for mix adjustments and transition between sections.

#### REFERENCES

1. Saylals, D., Gallaway, B. M., and Noel, J. S., "Evaluation of a Sulphur-Asphalt Emulsion Binder System for Road Building Purposes," Texas Transportation Institute, Texas A&M University, Prepared for the Societe Nationale des Petroles d'Aquitaine and the Sulphur Institute, January 1976.
2. "The Gulf Canada Sulfur-Asphalt Process," Interim Status Report, Gulf Oil, Canada, Ltd., 1976.
3. Deme, J., "Processing of Sand-Asphalt-Sulphur Mixes," Association of Asphalt Paving Technologists, Proceedings V. 43, 1974.

**APPENDIX**

MICHIGAN  
DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION  
SPECIAL PROVISION  
FOR  
SULPHUR-BITUMINOUS CONCRETE PAVEMENT

a. Description. - This work shall consist of furnishing, preparing, and placing a bituminous bond coat and a sulphur-bituminous mixture on a prepared base in accordance with the requirements specified under Bituminous Concrete pavement, 4.12, and Bituminous Mixtures -- Plant Mixed, 7.10, of the 1976 Standard Specifications, and as specified herein. The various sulphur-bituminous mixtures shall be placed at the locations designated on the plans or in the proposal.

b. Materials:

1. Aggregates. - The aggregates used in the mixture shall be Coarse Aggregate 25A and Fine Aggregate 3CS.
2. Bituminous Material. - The bituminous material for the mixture shall be Asphalt Cement, penetration grade 85-100.
3. Sulphur. - The sulphur compounds to be blended with the bituminous material shall be elemental sulphur in the free state, conforming to the following requirements:

<u>Characteristic</u>	<u>Value</u>
Purity, % dry basis	97.5 min
Moisture, %	1.0 max
Ash, %	1.0 max
Carbon Content, %	1.0 max
Acidity (as H <sub>2</sub> SO <sub>4</sub> ), %	0.05 max

Elemental sulphur will be accepted based upon certification from the supplier.

The sulphur shall be delivered in molten form to the job site in an insulated truck transport. The transport shall have internal coils so that hot oil or steam can be circulated to maintain the proper temperature of the sulphur at the job site.

c. Composition of Sulphur-Bituminous Concrete Mixture. - The mixture shall be proportioned in accordance with Section 7.10 of the 1976 Standard Specifications, except that the specified sulphur compound shall be blended with the bituminous material as follows:

Location	% S/B	Sulphur-Bituminous, % of Mixture	
		Leveling Course	Wearing Course
Test Strip 1	30/70	4.5-5.5	5.0-6.0
Test Strip 2	30/70	5.0-6.0	5.5-6.5
Test Strip 3	50/50	4.5-5.5	5.0-6.0
Test Strip 4	50/50	5.0-6.0	5.5-6.5

d. Sulphur Blending Equipment. - A portable sulphur module shall be used for mixing the sulphur and the bituminous material. The sulphur module shall have 2 pumps for feeding continuous streams of molten sulphur and bituminous material and a mixer with a 25 hp motor for mixing the sulphur with the bituminous material. The module shall have thermostatically controlled electric heating elements capable of regulating the temperature of the sulphur and the bituminous material within the required range.

e. Preparation and Mixing. - The bituminous material shall be pumped from the bituminous storage tank to the sulphur module. The sulphur shall be fed in molten form from an insulated truck transport to the sulphur module for blending with the bituminous material. The sulphur-bituminous blend shall be pumped to the bituminous weigh hopper of batch plants or to the metering pump of continuous plants.

The temperature of the sulphur-bituminous mixture shall be maintained within the temperature range of 240 to 290 F at the temperature designated by the Engineer. Aggregates shall be delivered to the pug mill at temperatures not to exceed 300° F.

f. Method of Measurement. - Sulphur-Bituminous Wearing Course, Type C and Sulphur-Bituminous Leveling Course, 25A will be measured by weight in tons. When blast furnace slag is used in the sulphur-bituminous mixture, the pay weight in tons will be determined by dividing the actual tons measured by a factor of 0.95.

g. Basis of Payment. - The completed work as measured for SULPHUR-BITUMINOUS CONCRETE PAVEMENT will be paid for at the contract unit prices for the following contract items (pay items).

<u>Pay Item</u>	<u>Pay Unit</u>
Sulphur-Bituminous Wearing Course, Type C - - - - -	Ton
Sulphur-Bituminous Leveling Course, 25A - - - - -	Ton

Bituminous bond coat will not be paid for separately.

Notice. - Gulf Oil Canada Limited developed the sulphur-bituminous mixtures used on this project and they are participating with the Department on the test road portion of the project.

Gulf Oil Canada, at no cost to the Contractor, has agreed to:

1. Supply the sulphur-bituminous blending equipment and to hook it up to the bituminous plant.
2. Provide operators for the blending equipment.
3. Provide technical assistance during production of the sulphur-bituminous mixtures.
4. Provide electrical power for the sulphur-bituminous blending equipment.
5. Provide for heating the sulphur in the transport truck at the job site.