Abridgment

Sulfur-Asphalt Mixtures as Soil Stabilizers

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In recent years, there have been several investigations of methods for reducing the amount of asphalt in bituminous mixtures by the substitution of sulfur for part of the asphalt. The use of sulfur in sand-asphalt pavements appears to be potentially valuable (1). Shell Canada, Ltd., has developed a material known as Thermopave, in which elemental sulfur is used in hot asphalt mixes (2), and sand-sulfur-asphalt mixtures made with inexpensive, poorly graded sands are reported to perform as well as or better than conventional asphalt cements made with dense-graded aggregates (3). Sulfur can be effectively used as a binder and reduce the asphalt content by 30 percent by weight (4). The addition of sulfur seems to result in lower viscosity, improved workability, and a wider permissible range of mixing and placing temperatures (4). Flexible pavements made with poorly graded beach sand and sulfur-asphalt mixtures can have properties superior to those of pavements made with dense-graded sands (5). Compared with asphalt concrete, thinner pavements are permitted for sulfur-asphalt-sand mixtures having a sulfur content of 13.5 percent by weight of the asphalt (5). The addition of sulfur to produce sulfur-bitumen emulsions tends to result in decreased viscosity, increased specific weight, and lower temperature sensitivity of the emulsion (6). There is a good possibility that river sands, dune sands, silty soils, and some types of clayey soils could be stabilized by using bituminous materials (7).

This paper reports the results of an investigation of the prospects of using sulfur-asphalt mixtures to stabilize typical Iraqi soils with locally available types of asphalts.

MATERIALS

The properties of the materials used are given below.

Soils: The gradations and properties of the four Iraqi soils used in this investigation are shown in Figure 1.

Asphalts: Two types of asphalt were used: a grade 85-100 asphalt cement and a grade MC-30 cutback asphalt, both produced at the Dora refinery in Baghdad.

Sulfur: The sulfur used was a natural sulfur of 99.9 percent purity by weight from Mishraq, Iraq.

SPECIMEN PREPARATION AND TESTS

The binder materials made with asphalt cement were prepared by separately heating the asphalt and the correct amount of sulfur to the required temperature and then mixing them thoroughly. Temperatures used were 130°C, 150°C, and 170°C (266°F, 302°F, and 338°F). Those made with cutback asphalt were prepared by heating the cutback in a closed container to 130°C and then adding the sulfur, also heated to 130°C, and mixing thoroughly. Both types of materials were allowed to cool to room temperature.

Hot mixtures: The mixtures made with soils 1 and 2 were prepared by separately heating the soil and the binder to the required temperature and then mixing them thoroughly. Each mixture was compacted by 25 standard hammer blows and static compaction at 26.7 kN (6000 lbf) for 2 min at a loading rate of 2.54 cm/min (1 in/min) to give specimens 5.1 cm (2 in) in diameter by 5.1 cm in height (ASTM D 915).

Cold mixtures: To prepare the mixtures made with soils 3 and 4, water was added to the soil and mixed in by using a mechanical mixer and then the amount of asphalt or cold asphalt-sulfur binder required to bring the fluid content to the optimum water content for modified Hubbard field compaction was added. The materials were mixed again and compacted according to the modified Hubbard field method to produce the specimens.

Curing conditions: The compacted specimens were cured in an aerated room for the required period of time.

Compressive strength tests: The compressive strengths of the specimens were determined by using a strain-controlled compression machine. The rate of loading was 0.15 cm/min (0.06 in/min). The samples were stored in a temperature-controlled oven for 2 h at the required test temperature before testing. The results reported are the average value of triplicate tests.

RESULTS

Soils 1 and 2

The amount of sulfur asphalt used was that equivalent to the amount of asphalt that produced the maximum compressive strength, i.e., 6 and 8 percent by weight for soils 1 and 2, respectively. The following results (8) were observed (see Figures 2 and 3):

1. For the binders mixed at 130°C, the addition of sulfur decreased the strength of both soils. This reduction in strength appears to be due to the reduction in net asphalt content; the strength of a sulfur-asphalt specimen was equal to that of an asphalt-only specimen having the same net asphalt content (8). Thus, at this temperature, sulfur seems to act as mineral filler.
2. For a given sulfur content, the strengths of the specimens prepared at higher mixing temperatures were higher.
3. At a mixing temperature of 170°C, where sulfur becomes very reactive, the addition of it markedly increases the strength of soil-asphalt specimens. The maximum strength was that for specimens prepared by substitution of 10 percent by weight of the asphalt cement by sulfur.
4. At a mixing temperature of 170°C, the evolution of H_2S and SO_3 gases, due to the chemical processes of dehydrogenation and polymerization, could become a major problem in the field.
5. The addition of sulfur slightly improved the temperature susceptibility of the mixture. This was particularly true at higher mixing temperatures as indicated by the slope of the strength versus temperature lines shown in Figure 3.
6. The addition of sulfur made the mixtures easier to compact and to work with (i.e., the workability of the mixture was improved).

Soils 3 and 4

For these two soils, substitution of part of the cutback asphalt by sulfur was useful. The following results were observed (Figures 2 and 3):

1. As the amount of sulfur substituted for asphalt

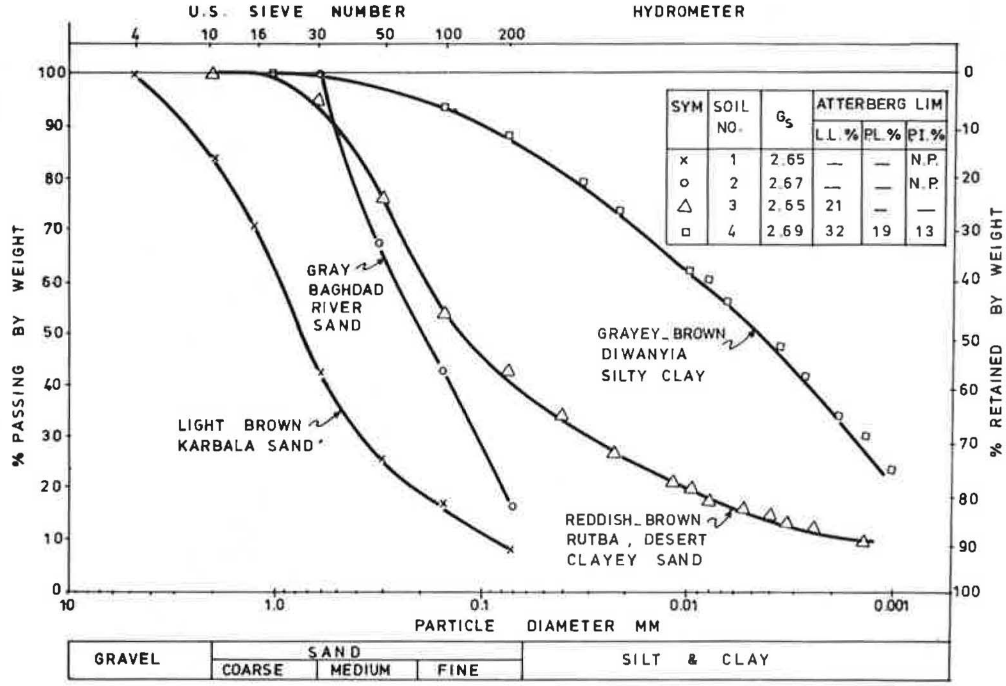


Figure 1. Gradations and properties of soils used.

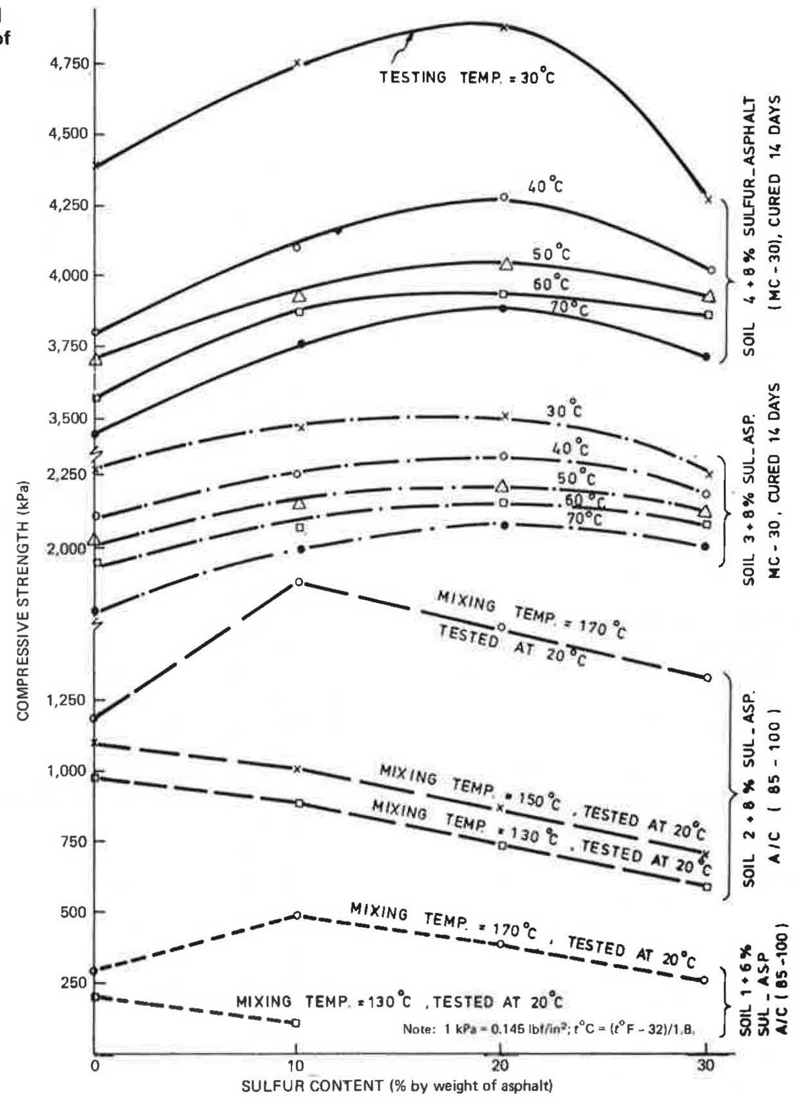
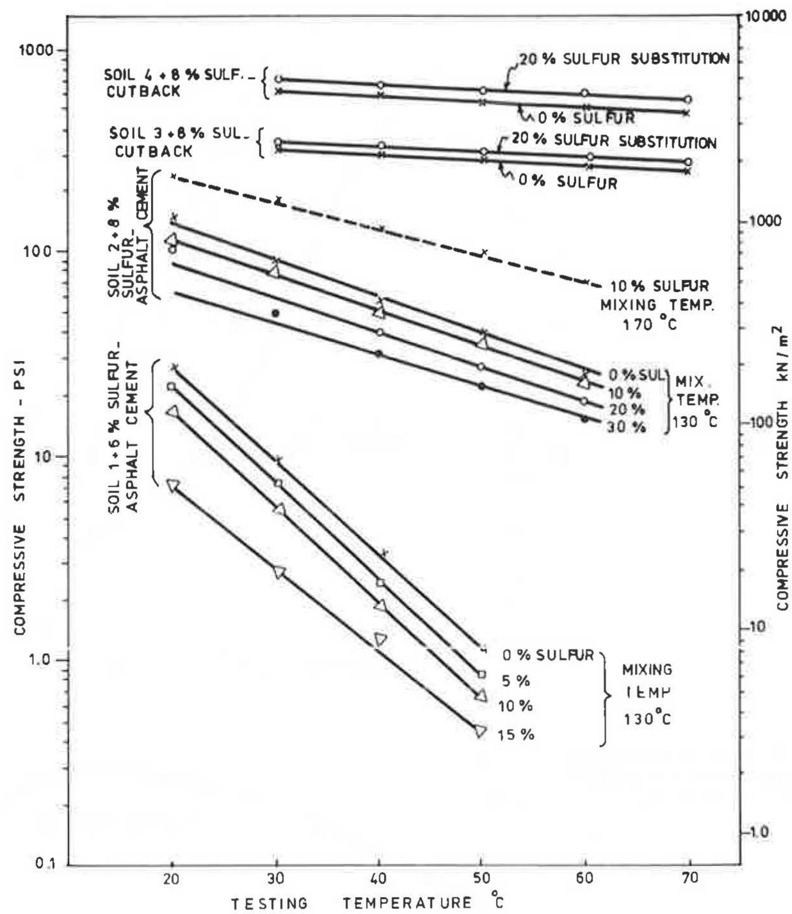


Figure 2. Effect of mixing and test temperatures on strength of sulfur-asphalt mixtures.

Figure 3. Effect of amount of sulfur substitution and mixing temperature on temperature susceptibility of sulfur-asphalt mixtures.



increased, the compressive strength increased to a maximum at 20 percent sulfur by weight of asphalt and then decreased. At all test temperatures, the mixtures in which sulfur had been substituted for part of the asphalt were stronger than the corresponding mixtures without sulfur.

2. The addition of sulfur to cutback asphalt at a mixing temperature of 130°C had no marked effects on the temperature susceptibility of the mixtures.

3. The addition of sulfur made the mixtures easier to compact.

CONCLUSIONS

The following conclusions may be drawn.

1. Sulfur as an additive to cutback asphalt can be used to stabilize clayey sands and silty clays. The addition of sulfur could save up to 20 percent by weight of the asphalt.

2. When sulfur is added to asphalt cement, the mixing temperature influences the strength and temperature susceptibility of the mixtures produced. Better specimens are produced at higher mixing temperatures.

3. The addition of sulfur makes soil-asphalt mixtures easier to compact.

4. At a mixing temperature of 170°C, the evolution of H_2S and SO_3 gases could become a major problem.

REFERENCES

1. R. M. Jimeson, L. W. Richardson, and T. S. Needols. Fossil Fuels and their Environmental Impact. Paper presented at Symposium on Energy and Environmental Quality, Illinois Institute of Technology, Chicago, IL, May 1974.
2. I. Deme. Basic Properties of Sand-Asphalt-Sulfur Mixes. Paper presented at 7th International Road Federation Meeting, Munich, Federal Republic of Germany, Oct. 1973.
3. B. M. Gallaway, D. Saylak, and H. Ahmad. Beneficial Use of Sulfur in Sulfur-Asphalt Pavements. Paper presented at American Chemical Society Meeting, Los Angeles, CA, April 3, 1974.
4. D. Saylak, B. M. Gallaway, and J. S. Noel. Evaluation of a Sulfur-Asphalt Emulsion Binder System for Road Building Purposes. Societe Nationale des Petroles d'Aquitaine, Paris, France, and Sulphur Institute, Washington, DC, Jan. 1976.
5. D. Saylak, B. M. Gallaway, J. A. Epps, and H. Ahmad. Sulfur-Asphalt Mixtures Using Poorly Graded Sands. Journal of the Transportation Engineering Division, Proc., ASCE, Vol. 101, No. TE1, Feb. 1975, pp. 97-113.
6. Societe Nationale des Petroles d'Aquitaine. Properties of Sulphur Bitumen Binders. Paper presented at 7th International Road Federation Meeting, Munich, Federal Republic of Germany, Oct. 1973.
7. N. M. El-Rawi. Prospects of Using Asphalt to Stabilize Iraqi Soils. Al-Muhandis, Baghdad, Iraq, Vol. 15, No. 3, Dec. 1971.
8. H. I. Al-Saleem. Use of Sulfur in Soil Bitumen Mixtures. College of Engineering, Univ. of Baghdad, Iraq, M. Sc. thesis, April 1976.

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