An Investigation on Sand Asphalt Sulfur Mixes by using Polymer Modified Binder

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Abstract

To meet the targets of the road development plan of India (1981-2001), about 1 million kilometers of new roads are required to be constructed by the year 2001. To achieve this target, a huge quantity of road aggregates, among other things, are required. Although there is scarcity of coarse aggregates in many areas, sand is available in plenty almost everywhere in India. Keeping in view the deficiencies of the engineering properties of Sand Asphalt paving mixes, a Sand- Asphalt- Sulfur (S-A-S or SAS) mix is likely to satisfy both the criteria of performance and availability of aggregates. Therefore it was decided to carry out the present investigation on SAS mixes using poorly graded medium fine river sand obtained from a nearby river.

One of the drawbacks of the SAS mixes is their high air voids content. An effort has been made in this investigation to bring down the voids by replacing a part of the sand by flyash filler, the resulting mix being named as Sand- Asphalt- Flyash- Sulfur (SAFAS) mix. It is expected that the fine particles of the flyash filler will go into the voids to some extent. Possibility of that will improve the strength properties too.

In some of the earlier investigations, the effect of varying contents of sulfur and asphalt on the engineering properties of SAS mixes has been studied. However, in doing so, the effect that the varying aggregate contents on the properties of the mixes has been overlooked. This aspect has been taken care of in the present investigation, in that, while varying the asphalt and sulfur contents, the aggregate content has been kept fixed at a particular proportion.

In the absence of any specifications regarding the optimum compactive efforts required for SAS mixes, which is less than that for asphalt mixes, it was decided to investigate on the optimum levels of compaction required for SAS and SAFAS mixes.

Briefly, the study attempts to cover the following aspects.

Effect of varying compactive efforts on Marshall Properties of SAS and SAFAS mixes and selection of an optimum level of compaction, Effect of varying all the constituents namely Sand Asphalt Flyash and Sulfur on Marshall proportion, Indirect tension test, Modulus of resilience, Repeated load indirect tensile test.

Keywords— Modified binder, Flyash, Sulfur, Performance, Marshall properties, Indirect tension test, Modulus of resilience.

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1. Introduction:

The primary objective of a highway Engineer is to provide a pavement surface for safe, comfortable and economical transportation. The achievement of these goals depends upon various factors. The relative importance of these factors varies according to the situations. In India, the need of the day is to construct a large network of roads at economical costs. This makes the role of materials which mainly contributes to the cost of road constructions, highly important in our country.

In India, majority of surfaced roads are bituminous pavements because of high initial cost of concrete pavements. The two main components of bituminous pavements are bitumen and aggregates. Hence properties of these two go a long way in ensuring the design life of a pavement.

2. Methodology / Work Plan

- Selection of different proportions of sand asphalt sulfur flyash.
- Casting the Marshall specimens with different no. of blows.
- Finding the optimum no. of blows from previous step.
- Casting the Marshall specimens with 9 different contents of sand asphalt sulfur flyash for Marshall testing, indirect tension test etc...
- Finding the S.A.FA.S contents at which the Marshall criteria are satisfied.
- Conducting the Repeated load indirect tension test on the sample at binder contents at which the Marshall criteria are satisfied.

Table 1: Characteristics of Materials used

.Material (1)	*Parameter measured (2)*	*Source (3)*	*Value (4)*
Asphalt (PMB70)	Penetration (25^{0}C, 5s, 100g) Softening point (ring and ball method) Ductility (27^{0}C, 5cm/min.) Specific gravity (27^{0}C) Flash point (Cleveland open cup method)	I.O.C. Haldia	50 61^{0}C 75cm 1.05 336^{0}C
Sand	Specific gravity	River Kansai	2.634
Flyash	Specific gravity	Kolaghat thermal power station.	2.36
Sulfur	Specific gravity	Local market	2.07

3. Effect of Compactive effort

An SAS mix of the composition 85-5-10, that is,85% sand , 5% asphalt, 10% sulfur and an SAFAS mix of 80-5-5-10 composition, that is 80% sand , 5% asphalt, 5% flyash and 10% sulfur were selected for this study.

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Marshall Samples have been prepared by giving different number of blows of Marshall Hammer. The Marshall properties of these samples have been determined and evaluated. Considering all factors, a compactive effort of 25 blows on each face is considered most suitable. This compactive effort has been used in this investigation.

Table 2: Results of Stability Test

No.of Blows	*Stability (KN)*	
	S.A.S	*S.A.FA.S*
75	7.37	7.83
50	10.03	10.34
30	12.15	15.56
20	9.72	11.00
10	7.711	8.62
5	6.11	8.09

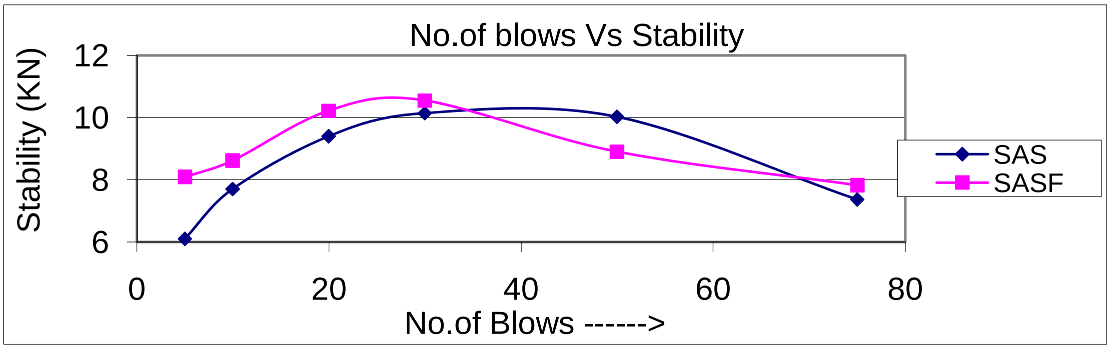

Fig 1: Graph showing the variation of Stability with no. of blows for SAS and SASF

4. Marshall Test

About 1050 g of sand of different gradation, and also flyash in case of SAFAS mixes were heated to about 145^0C. Required quantity of asphalt was heated to about 135^0C and was mixed thoroughly with the heated aggregate. Mixing time varied from 30 seconds to 1minute, depending on the constituents. In the meantime, sulfur was heated to 140^0C and mixed thoroughly with the hot sand asphalt mix in a second mixing cycle. The time of mixing was about 30 seconds. The mix was then poured into moulds heated to 135^0C and compacted by giving 25 blows of Marshall hammer on each face. This level of compaction was fixed on the basis of a series of test on Marshall Samples cast with varying number of blows.

Table 3: Variation of Stability for SFAAS and SAS

S.FA.A.S	*Stability(KN)*	*S.A.S*	*Stability(KN)*
75-5-5-15	23.44	80-5-15	16.56
73-7-6.5-13.5	17.64	80-6.5-13.5	11.22
70-10-8-12	13.12	80-8-12	8.62
77-5-4-14	25.71	82-4-14	23.64
75-7-6-12	18.33	82-6-12	14.85
72-10-8-10	13.50	82-8-10	9.17
80-5-3-12	21.52	85-3-12	18.07
78-7-5-10	14.82	85-5-10	17.72
75-10-8-7	9.94	85-8-7	6.93

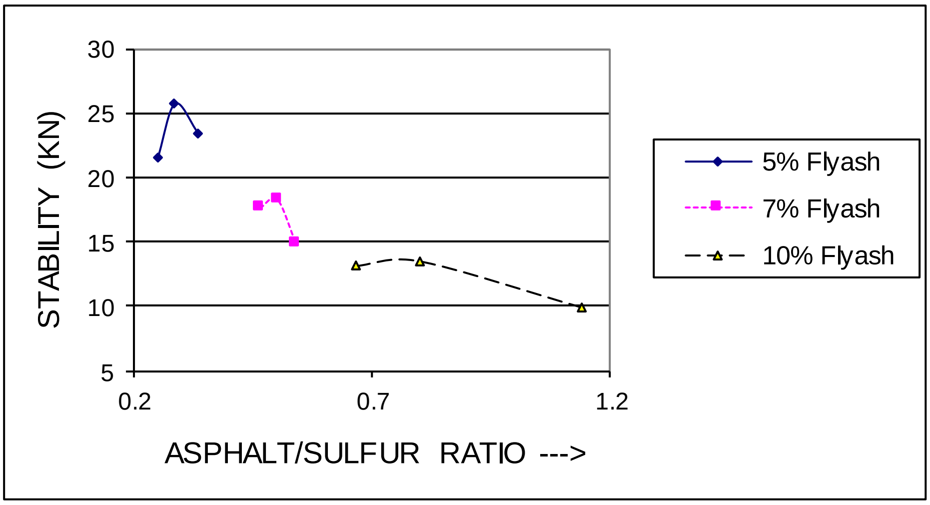

Fig 2: Graph showing the variation of Stability with A/Sulphur ratio

5. Static Indirect Tensile Test

Split cylinder test was carried out on Marshall Samples. The load was applied along the diametrically opposite lines through two 1.25 cm wide mild steel loading strips. The temperature of test was 25^{0}C.

Table 4 Variation of ITS for SAS and SFAAS

S.A.S	*I.T.S value in MPa*			*S.FA.A.S*	*I.T.S value in MPa*		
	40⁰ C	*25⁰ C*	*5⁰ C*		*40⁰ C*	*25⁰ C*	*5⁰ C*
80-5-15	0.54	1.26	2.34	75-5-5-15	0.61	1.35	2.83
80-6.5-13.5	0.51	1.11	2.20	73-7-6.5-13.5	0.56	1.26	2.68
80-8-12	0.45	0.90	2.09	70-10-8-12	0.43	0.96	2.11
82-4-14	0.74	1.29	2.60	77-5-4-14	0.75	1.63	3.42
82-6-12	0.63	1.16	2.37	75-7-6-12	0.66	1.44	3.06
82-8-10	0.48	0.93	2.10	72-10-8-10	0.49	1.08	2.23
85-3-12	0.81	1.10	2.68	80-5-3-12	0.85	1.87	3.93
85-5-10	0.66	1.30	2.40	78-7-5-10	0.84	1.72	3.62
85-8-7	0.53	1.12	2.29	75-10-8-7	0.62	1.36	2.91

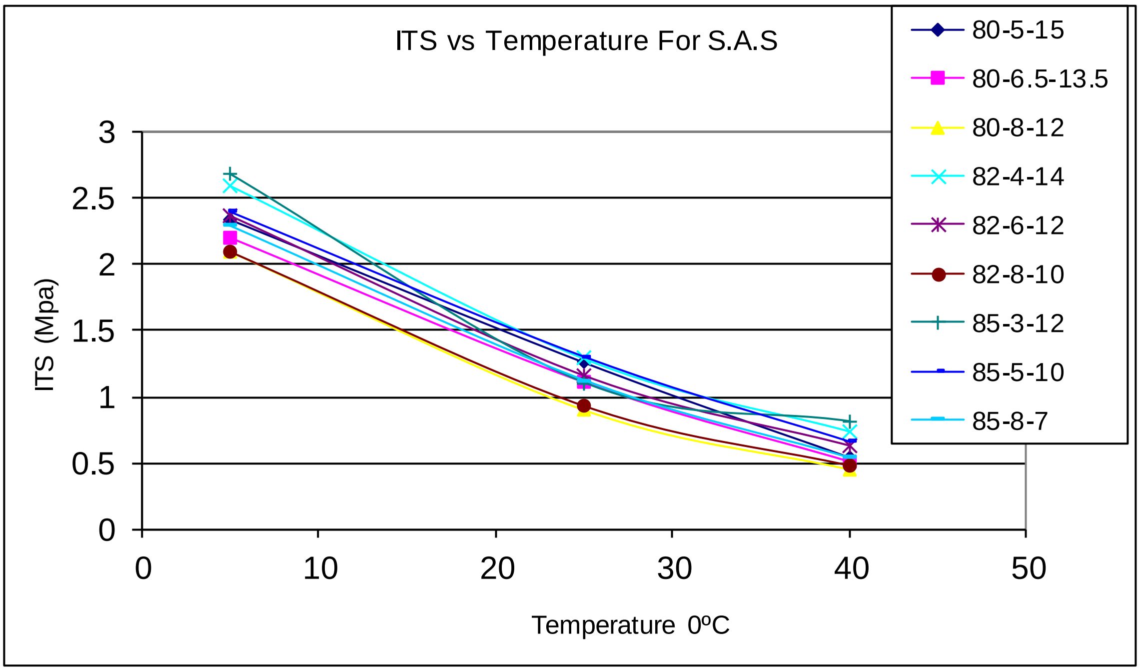

Fig 3: Graph showing the variation of ITS with Temperature for SAS

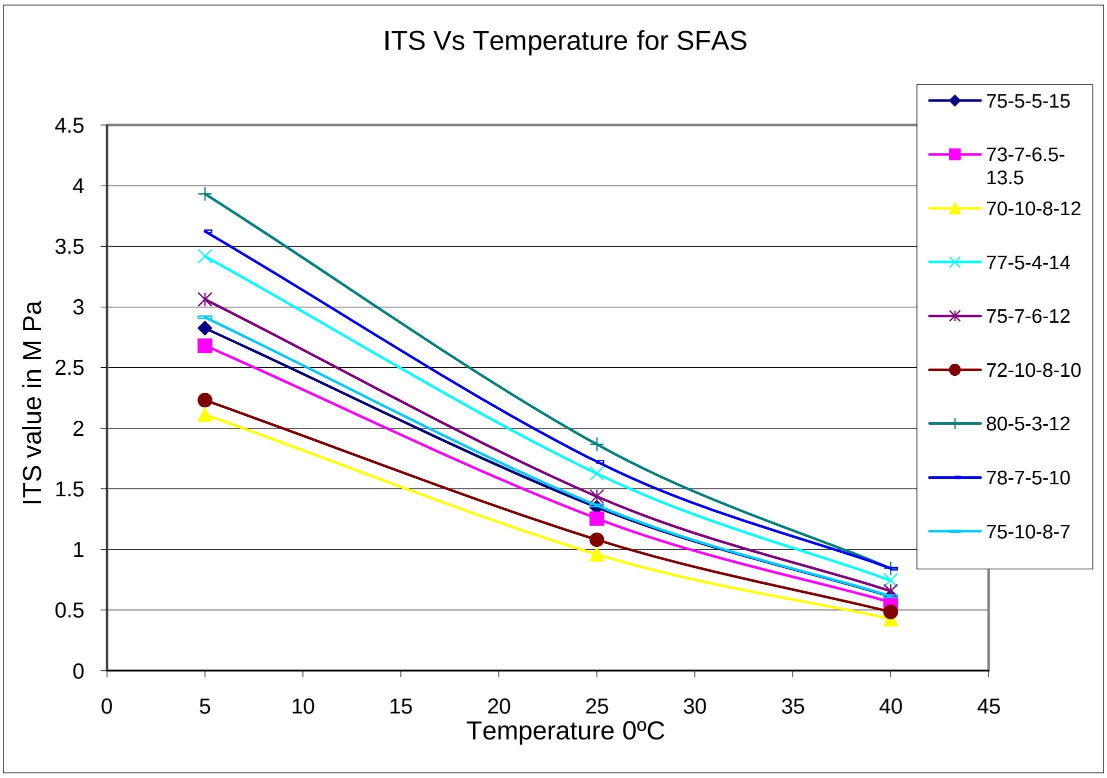

Fig 4: Graph showing the variation of ITS with Temperature for SAS S.A.S.FA

6. Fatigue Characteristics of Mixes

Fatigue characteristics of the mixes were evaluated by conducting repeated indirect tensile tests on the mixes at 5^0, 25^0 and 40^0C temperatures. The test method was selected because of its simplicity and the ease with which the samples for the test can be prepared. A number of investigators in the past (Mohammad and Paul 1993; Salter and Rafati-Afshar 1987; Kennedy 1978; Kennedy 1977) employed this test for evaluating the fatigue performance of asphalt mixes.

An equipment fabricated (Palit et al 2001c) in the Transportation Engineering Laboratory of Indian Institute of Technology, Kharagpur was used for conducting repeated indirect tensile tests. Haversine pulsating load was applied diametrically to the Marshall specimens through the piston of a double acting cylinder, which was controlled by a solenoid valve. Different operations of the test were controlled with the help of the data acquisition system and personal computer. A loading period of 0.1 second and a rest period of 0.9 second were applied during the test. Horizontal and vertical deformations of the specimen were recorded. The tests were conducted under constant load condition. Load applications were continued till a visible crack was formed in the specimen. This condition was considered to be due to the fatigue failure of the specimen. A number of tests were conducted at 5^0C, 25^0C, and 40^0C to determine the resilient modulus and Poisson ratio values of the mixes.

Table 5: Variation of M.R for SAS and SFAAS for various proportions

S.A.S	*M.R Mpa*			*S.FA.A.S*	*M.R MPa*		
	5ºC	*25ºC*	*40ºC*		*5ºC*	*25ºC*	*40ºC*
80-5-15	3306.62	2114.55	330.94	75-5-5-15	4762.87	2782.50	473.64
80-6.5-13.5	2205.00	1354.88	310.48	73-7-6.5-13.5	3567.91	1868.79	397.34
80-8-12	1603.20	1171.02	194.06	70-10-8-12	3017.11	1643.41	275.71
82-4-14	3693.02	2272.82	347.66	77-5-4-14	4927.44	2677.68	582.42
82-6-12	2582.64	1649.71	343.13	75-7-6-12	3973.76	2013.12	441.70
82-8-10	1695.47	1046.63	217.25	72-10-8-10	3243.15	1706.24	330.60
85-3-12	2535.47	1274.54	314.56	80-5-3-12	5799.76	3205.20	611.98
85-5-10	1809.04	1071.79	276.53	78-7-5-10	4010.41	2120.04	378.07
85-8-7	1713.34	833.24	259.32	75-10-8-7	2811.23	1132.38	321.50

7. Conclusions

7.1 General

The following conclusions are drawn from this investigation on Sand-Asphalt-Sulfur (S-A-S) and Sand-Asphalt-Sulfur-Flyash (S-A-S-FA) mixes.

7.2 Effect of Compactive Effort on Marshall Properties

Marshall Properties of both S-A-S and S-A-S-FA mixes are improved with increasing compactive effort, but only up to an optimum level of compaction. Considering all aspects, 25 blows of Marshall Hammer on each face of the Marshall sample are considered to be the optimum level of compactive effort.

7.3 Effect of Varying Contents of the Constituent Materials of S-A-S and S-A-S-FA Mixes on Marshall Properties:

1. *Effect of Asphalt –Sulfur ratio*
   a) Stability values decrease with increasing Asphalt-Sulfur ratio
   b) Very high stability values can be achieved by using low Asphalt-Sulfur ratios. The maximum values of stability achieved are 23.64KN for S-A-S mixes at an Asphalt-Sulfur ratio of 0.286 (Sulfur content of 14% and Asphalt content of 4% by weight of mix) and 25.71 KN for S-A-S-FA mixes at an Asphalt- Sulfur ratio of 0.286 (Sulfur content of 14% and Asphalt content of 4% by weight of mix). The stability values are, in general, more than those obtained with asphalt concrete mixes.
   c) Bulk density values attain a peak value at a particular value of Asphalt-Sulfur ratio. The optimum Asphalt-Sulfur ratio is higher in the case of 82% (sand + flyash) mixes than in the case of 80% and 85% series.
   d) Air voids, at first reduced to a minimum value and then increase again with further increase in Asphalt-Sulfur ratio.
   e) Flow values increase with increasing Asphalt-Sulfur ratio.
2. *Effect of varying Flyash content on Marshall properties*
   a) Stability values decrease with increasing flyash content from 5% to 10%, but there is significant increase in the stability values of the mix at 5% flyash content compared to the control mix.
   b) Bulk density increased significantly upon addition of Flyash.
   c) Air voids decreased with addition of Flyash.
3. *Comparison of Marshall properties of mixes having different Sand + Flyash contents*
   a) In general, the 82% sand + Flyash content series produced mixes with higher stability values, compared to 80% and 85% series.
   b) Flow values of 80% and 82% (Sand + flyash) content mixes are very close, while those for 85% mixes are significantly high.
4. *General conclusions on Marshall properties*
   a) All the mixes have stability values higher than 3.4KN which is the minimum value suggested by Asphalt Institute, U.S.A., for asphalt concrete mixes for heavy traffic condition.

b) Though the air void contents in both SAS and SAFAS mixes are high compared to asphalt concrete mixes, all the mixes are regarded suitable for use as a base course material.

c) Considering all factors, it is concluded that 82% (Sand + Flyash) series produced the best mixes, because these mixes have maximum stability and minimum air void contents.

7.4 Effect of Flyash on Fatigue Life Of Sand Asphalt Mixes

The fatigue life of Sand asphalt sulfur mix at mix 4% binder content is 64000 load repetitions in indirect tension mode, whereas sand asphalt sulfur flyash mix at 3% binder content has not failed even after 67000 load repetitions.

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