Alkylbenzene Sulphonate as Additive in Asphalt Paving Mixtures

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Abstract

Engineering properties, including Marshall stability, indirect tensile strength, and tensile stiffness modulus have been carried out on alkylbenzene Sulphonate-modified asphalt paving mixtures. In this study, four percent of alkylbenzene sulphonate by weight of asphalt were used at optimum asphalt content which was obtained by Marshall method.

The result indicated that 2% of alkylbenzene sulphonate is effective in improving the indirect tensile strength properties, while other percents slightly improved these properties. Results also indicated that the addition of alkylbenzene sulphonate to asphalt reduced the fluidity temperature of asphalt by 8% at 2% of alkylbenzene sulphonate, this phenomenon is more economical in the asphalt plant and not consuming time for heating of asphalt in storage tank.

الخلاصة

الخصائص الهندسية المتضمنة كلا من ثباتية المارشال ، مقاومة الشد غير المباشر ومعامل صلابة الشد ،تم دراستها على الخلطات الإسفلتية المطورة بمادة (ABS).في هذه الدراسة استخدمت مادة (ABS) بأربعة نسب وزنية من الإسفلت في تحضير الخلطات الإسفلتية عند النسبة القصوى المستحصلة من طريقة المارشال.

أوضحت الدراسة بأن النسبة 2% من مادة (ABS) فعالة في تحسين خصائص مقاومة الشد للخلطات الإسفلتية ، بينما هنالك تحسين طفيف عند اضافة النسب الأخرى من هذه المادة.كما أوضحت النتائج بأن النسبة المذكورة أنفا من مادة (ABS)تقلل من درجات الحرارة اللازمة لتسخين الإسفلت وجعله سائلا بنسبة 8% ،لذا فأن مثل هذه الظاهرة ستوفر مردودات اقتصادية من حيث تقليلها للوقت اللازم لعملية تسخين الإسفلت في معامل تحضير خلطات الاكساء الإسفلتية.

Introduction

For many decades the tensile strength of asphaltic concrete has been recognized as a major contribute to its performance problems. Bituminous pavements are subjected to a variety of loading conditions that result in internal tensile stresses and consequently, may induce cracking. The capacity to resist cracking is requisite to pavement durability and longevity.An often encountered source of cracking that could be prevented or at least controlled by an increase in tensile strength is the reflection of cracks from under laying pavement layers.

Investigations into the reinforcement of bituminous mixtures to improve tensile properties have been performed utilizing homogeneously dispersed fibers. Pyrolisis polymers and carbon black within the mixtures.

The primary objective of this study was to determine whether alkylbenzene sulphonate (ABS) improve the Marshall and indirect tensile strength properties of asphaltic

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concrete, when it is added as a percentage of asphalt cement binder.

Background

Some laboratory studies have been performed on the reinforcement of the surface or binder course of pavements. Reed et al. [1] tried to study the polyester fibers in asphalt paving mixtures, they found that the fibers will often reduce the dry indirect tensile strength of the control mixture by (3-15%), while the addition of polyester fibers resulted in a decreased susceptibility to moisture damage.

Al-Hadidy A.I. [2] studied the pyrolisis low-density polyethylene in asphaltic concrete mixtures, he concluded that the inclusion of polyethylene within asphalt mixtures improved the adhesion between asphalt and aggregate (i.e. reducing the asphaltic concrete mixtures to moisture damage).

Asal F.N.[3] studied the effect of polyvinyl chloride (PVC) on the indirect tensile strength .She concluded that the addition of (1.25%) of (PVC) increase the indirect tensile strength by (38%) which improve the resistance of asphalt paving mixture to cracking.

Abbas T.M.[4] studied the reinforcement of carbon black (CB) microfiller and its effect on low temperature cracking in asphalt paving mixtures .he found that the addition of (12%CB) to asphalt cement are not adversely affected.

Materials

Alkylbenzene Sulphonate

The alkylbenzene sulphonate (ABS) was brought from Al-Kornesh market in Mosul city. The price of this material was 400 ID/kg. The results of the physical and chemical properties of (ABS) are shown in Table (1).

Asphalt Cement

The asphalt cement used was (40-50) penetration grade taken from Baiji refinery (200Km–north of Baghdad). This asphalt is usually considered the type, which have been used widely in the highway construction projects in Nineva Government. The results of the physical properties of the used asphalt are shown in Table (2). The result indicated that this asphalt complies with ASTM[5] and SCRB[6] specifications for penetration graded asphalt cement.

Aggregates

In addition to asphalt binder and ABS additive used in the testing program, Al-Kazer aggregate was utilized in the preperation of asphaltic concrete specimens. Table (3) show the results of the physical properties of this aggregate, while Table (4) show the gradation limits of the aggregate used in the mix design according to the ASTM[5] specification (D-3515) for dense graded mix.

Filler

Portland cement was used as a filler in mix design and it's brought from Senjar cement factory. The results of the physical and chemical properties are listed in Table (5a&b) respectively.

Test Program

Two types of tests were carried out to evaluate the mixes, Marshall test at 60°C ASTM D-1559, and indirect tensile strength at 25°C ASTM D-4123.

Marshall Mix Design

All specimens were prepared according to the Marshall method of mix design, using 75 blows SCRB (6) of the automatic Marshall compactor on each side. Table (6) shows the results of Marshall mix design for the control mix (having 0% ABS additive). The optimum asphalt content was determined as the numerical average of the values of asphalt content corresponding to the maximum stability, maximum density and 4% air voids, without violating the minimum void content requirements.

Preparation of Marshall and Indirect Tensile Strength Specimens of Modified Mixtures

An optimum asphalt content of (5%) as found from Marshall control mix design (by wt.of total aggregate and filler)was used in preparing all other ABS modified mixes to maintain consistency through the research.

Then the following steps were performed for the formulation of compacted specimens:

1. The combined aggregate and filler were heated to (160°C) in controlled electric oven.
2. The modified binder with ABS was heated to (140°C) in an electric control oven.
3. The combination was mixed by mechanical mixing at temperature of (140±5°C) for 1.5 min.
4. The specimens formulated were then compacted using electric Marshall apparatus specified by the Asphalt Institute Method [8].

Indirect Tensile Strength Test

A three of Marshall specimens at optimum asphalt content (O.A.C.) for each percent of ABS were prepared according to ASTM [5] D –1559 but the curing of specimens before testing was done according to ASTM[5] D-4123.

The specimens were then tested after immersed in water at 25°C for 2hrs under a rate of loading of (3.8 mm/min) as recommended by Lottman[9,10],then the indirect tensile strength(St), tensile stiffness modulus (TSM), and horizontal deformation (Δ) were calculated using the equations mentioned by Lottman[9,10], and as illustrated below:

$$St = \frac{S_{10}}{10000} x \frac{P_{max}}{L}$$

where:

St = tensile strength (psi).

S10 = maximum tensile strength (psi) produces in (4-in.) diameter solid cylinder by a load (10000 pound per thickness of 1 in.) obtained by calculating:

S10 = 1591 + 437a – 1889a2 + 2854a3 – 2474a4 + 885 a5

in which:

a = amount of core or specimen flattening in inch under Pmax. (0 < a < 1 in.)

Pmax = maximum compressive load on core specimen in lb, and

L = thickness of core specimen in inches.

While:

TSM =[Pmax *(v+0.2734)/L*Δ]

Where:

TSM =tensile stiffness modulus in (psi).

Pmax = load at failure in (lb).

L = sample thickness in inches.

Δ = total horizontal deformation of sample in inches, which is read from a dial gauge under P_{max} and as shown in plate 1.

v = poison's ratio assumed between (0.35-0.45) for asphaltic concrete mixtures.

Test Results and Discussion

Marshall Stability

The relationships between Marshall properties and ABS contents were plotted at optimum asphalt content as shown in bar chart in Figure(1).

Figure (1a&b) represents the effect of ABS content on Marshall stability and flow. This figure shows that as ABS content increase the stability decrease up to (1%) thereafter its increase but remain less than that of original mix, while the flow increase due to the decrease in viscosity of binder which decrease the stiffness and though decrease the stability.

Figure (1c&d) indicates that the unit weight decrease as ABS content decrease up to (1%) after this certain point its increase but remain less than that of control mix, while the air voids increase due to the lower specific gravity of the resultant binder.

Figure (1e&f) shows the relationships between V.M.A.and V.F.B. versus the percent of ABS, it can be seen that the V.M.A. increase slightly with the increase in ABS content, while V.F.B. decrease with increasing in ABS content. The percent V.M.A. & V.F.B. meet the specification limit of SCRB [6] it well be mentioned here that air voids, VMA&VFB for control and modified mixes were calculated using the equations mentioned in superpave series No. 2(SP-2) [11].

Indirect Tensile Strength

Figure (2) indicates the relationships between indirect tensile strength properties and ABS contents. It can be seen that both the tensile strength (St) and tensile stiffness modulus (TSM) increases by 9% & 41% respectively at 2%ABS, while the horizontal deformation (Δ) decrease by 24% at this content of ABS.

Conclusions and Recommendations

A review of the Marshall and indirect tensile strength mixes design result indicated the following:

1. Marshal laboratory testing indicates that stability determined at 60 °C varied from 1633 kg to 1383.5 kg for 2% ABS content, but it remain greater than the minimum range of SCRB specification (710 kg).
2. There was a slight improvement in the retention of asphalt coating (i.e. reducing bleeding phenomenon) when ABS/Asphalt binder is used due to the adhesiveness of ABS material especially at 2% ABS.
3. The stiffness and horizontal deformation determined from the indirect tensile strength test indicated that these mixtures resist the pavement deformation forces, rutting and shoving, therefore it should be used at busy intersection or truck stops and parking lots where standing loads which cause extended periods of such deformation.
4. The addition of ABS to asphalt reduced the fluidity temperature of asphalt by 8% at 2% of ABS content, this phenomenon is more economical in the mixing plant.
5. The modification binder with ABS should be agaited before mixing with aggregate and filler in the mixing plant.

References

1. Reed B. Freeman, James L. Burati. JR. Serin N. Amirkhanin, William C. Brides JR., **"Polyester Fibers in Asphalt Paving Mixtures"** AAPT, Vol.58, pp.387-409. (1989).
2. Al-Hadidy A.I., **"Influence of Sulfur and Polyethylene Wastes on Characteristics of Asphalt Paving Materials"**. MSc.Thesis, College of Engineering., University of Al-Mustansirya. (2001).
3. Asal F.N.,**"Some Investigation Into The Properties of polymer Modified Asphalt Cement"**, MSc. Thesis, College of Engineering, University of Baghdad, (1999).
4. Abbas T.M.,**"Influence of Carbon Black Reinforcement on Performance of Paving Materials"**, MSc. Thesis College of Engineering, University of Baghda, (1999).
5. **ASTM Standard** Specification (1988). Section 4,Vol.04-03.
6. State Cooperation For Roads and Bridges (SCRB)(2003) **"Hot Mix Asphaltic Concrete Pavements"** Iraqi Standard Specifications, Ministry of Housing and Construction. Department of Design and Study, Section R9.
7. R. Norris Shreve **"Chemical Process Industries"**, Third Edition, (1967).
8. Asphalt Institute (1984) **"Mix Design Method For Asphalt Concrete and Other Hot Mix Types"**. MS-2.
9. Lottman R. and Dennis L.G. **"Pressure Induced Stripping in Asphaltic Concrete"**. TRB 340, pp.13-25, (1970).
10. Lottman R., **"Predicting Moisture Damage to Asphaltic Concrete"** NCHRP, Report No.192, (1978).
11. SHRP Asphalt Research (2002) **"Superior Performing Asphalt Pavements, Mix Design, Manual,** Series No.2 (SP-2).
12. Neville, A.M. and Brooks, J.J., "Concrete Technology", 2nd ed., First published, London, (1986).
13. Neville, A.M., **"Properties of Concrete"**, 2nd ed., Pitman Publishing Ltd, London, (1977).

Table (1) Physical and chemical properties of "ABS"

Property	Test result	Unit
Color	White	----
Chemical unit[7]		----

Table (2) Physical properties of asphalt cement

property	ASTM designation No.	Test condition & units	result	SCRB Limits	ASTM limits
Penetration	D-5	25°C, 100 gm, 5sec.	42	40-50	40-50
Softening point	D-36	Ring & ball	54	51-62	50-58
Ductility	D-113	(25°C, 5cm/min.	150+	>100	>100
Sp.gr.	D-70	(25°C/25°C)	1.053	----	1.01-1.06
Absolute viscosity	----	Poise	5×10^6	----	----
Flash point	D-92	Cleveland Open Cup, °C	263	>232	>240
Loss on heat	D-1754	5hrs, 163°C, %	0.25	0.75	0.2max.
asphaltene	D-2006	%	32.65	----	----

Table (3) Results Quality tests on aggregates

Property	ASTM designation No.	Coarse agg.	Fine agg.	ASTM limits
L.A. abrasion	D-131	18-10	----	40 max.
Bulk sp.gr.	D-127	2.704	2.675	----
Apparent sp.gr.	D-128	2.744	2.696	----
Apparent sp.gr. filler	D-128	----	3.15	----
% water absorption	----	0.503	2.354	4.0 max.

Table (4) Gradation of aggregates.

Sieve size		% passing (wearing coarse) ASTM D3515[5]	Job mix formula
inch	mm		
1/2	12.5	100	100
3/8	9.5	90-100	95
No.4	4.75	55-85	70
No.8	2.36	32-67	49.5
No.50	0.30	7-23	15
No.200	0.075	2-10	6

Table (5a) physical properties of filler (cement)

Property	Results	Unit	Specification limits[12, 13]
Specific surface by (Blaine)	2830	Cm^3/gm	2250
sp.gr.	3.15	----	-
Fines residue on sieve No.170	8%	----	10% max.

Table (5b) Chemical properties of filler (cement)

Oxidation	% of concentration	Specification limits[12, 13]
Alumina Al_2O_3	6.18	3-8
Silica, Sio_2	22.23	17-25
Ferric Oxide, Fe_2O_3	3.27	0.5-6
Lime, CaO	61.3	60-67
Sulfuric anhydride, SO_3	2.13	1-3
Magnesia, MgO	3.9	0.1-4
K_2O	0.16	-

Table (6) Marshall result of control mixture (0% ABS)

Asphalt content	Unit weight kg/m^3	Stability kg	Flow mm	Rigidity ratio kg/mm	% air voids	% V.M.A.	% V.F.B
4.0	2380	1338	1.8	743	8.1	15.46	47.6
4.5	2389	1511	2.13	709	6.6	15.55	57.6
5.0	2425	1633	2.29	713.1	4.18	14.68	71.53
5.5	2412	1510	3.25	465	3.63	15.55	76.66
6.0	2394	1369	3.51	390	3.23	16.57	80.5

Table (7) Marshall result of (ABS/A) mixtures

ABS %	Unit weight kg/m^3	Stability kg	Flow mm	Rigidity ratio kg/mm	% air voids	% V.M.A.	% V.F.B.
0	2425	1633	2.29	713.1	4.18	14.68	71.53
1	2295	1350	3.23	418	5.72	15.25	62.49
2	2307	1383.5	3.9	354.8	5.51	14.8	62.77
3	2310	1383.5	3.92	353	5.49	14.69	62.63
4	2316	1387.2	4.32	321.2	5.01	14.47	65.38

Table (8) indirect tensile strength results of (ABS/A) mixtures at 25°C immersed in water for 2hrs.

% ABS	Tensile strength, St kg/cm^2	Tensile stiffness modulus, TSM, kg/cm^2	Horizontal deformation, Δ mm
0	13.233	160.6	8.19
1	12.434	136.5	9.03
2	14.414	226	6.21
3	13.285	167	7.9
4	12.445	140.2	8.83

Dial gauge for reading load

Dial gauge for reading Δ

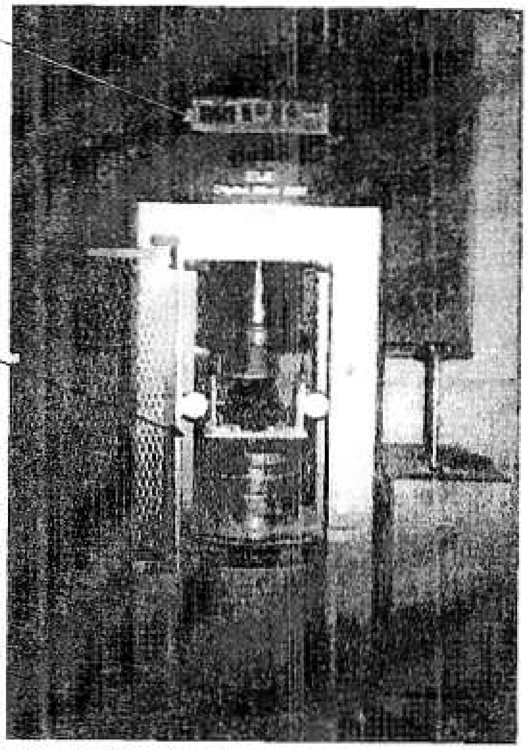
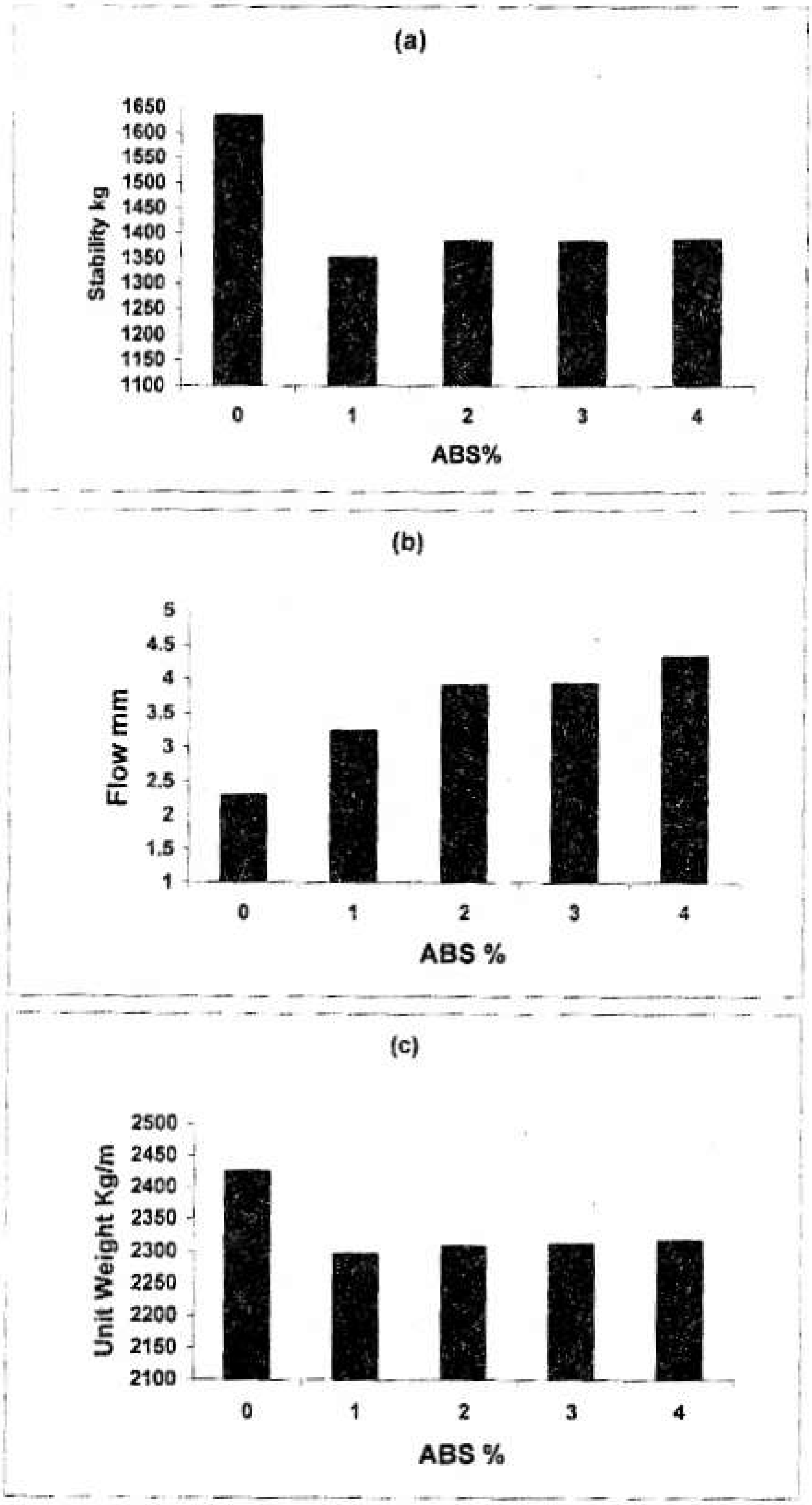


Plate 1: Indirect tensile strength testing machine.


(a)
Stability kg
1650
1600
1550
1500
1450
1400
1350
1300
1250
1200
1150
1100
0
1
2
3
4
ABS%
(b)
Flow mm
5
4.5
4
3.5
3
2.5
2
1.5
1
0
1
2
3
4
ABS %
(c)
Unit Weight Kg/m
2500
2450
2400
2350
2300
2250
2200
2150
2100
0
1
2
3
4
ABS %

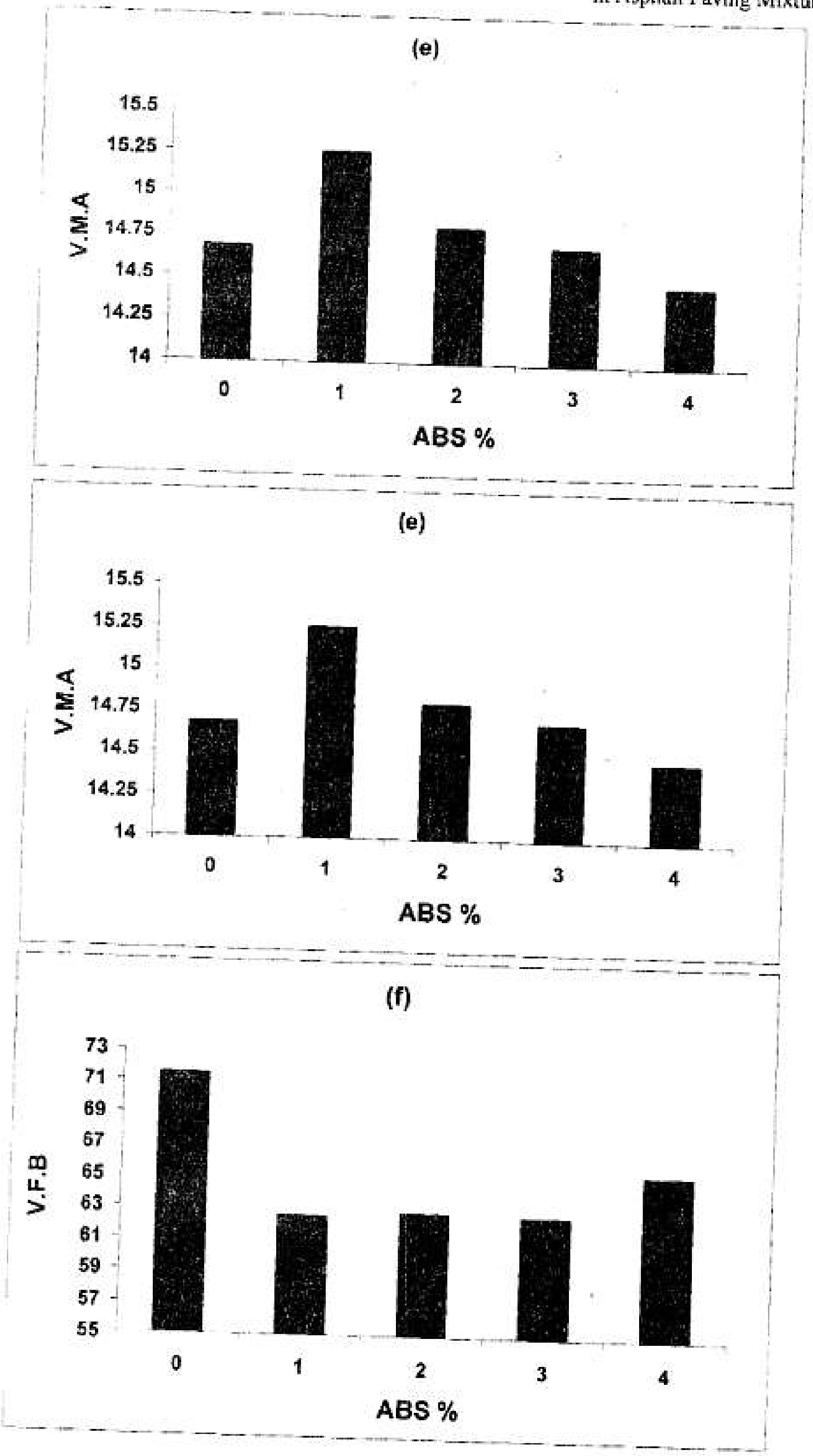


Figure (1)
Effect of ABS on Marshall Properties of Asphalt Concrete Mixture

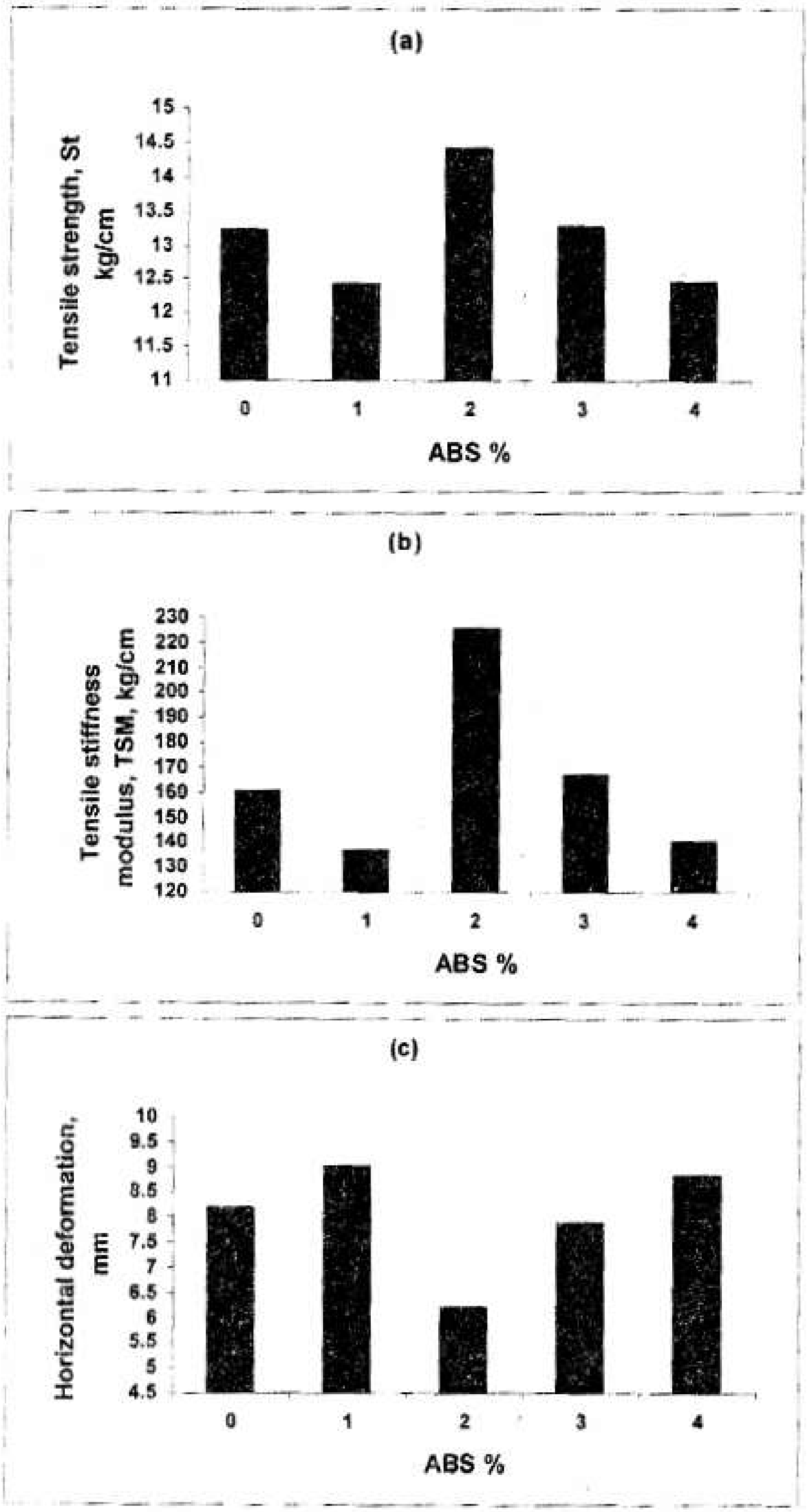


Figure (2)
Effect of ABS on Indirect Tensile Strength Properties of Asphalt Concrete Mixture