STRIPPING

A LABORATORY STUDY

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ABSTRACT

Stripping of the asphalt binder from the aggregate in hot mix is a problem which is universal in occurrence throughout the country. The problem of stripping is an expensive proposition as the repairs can cost the road owner hundreds of thousands of dollars. A laboratory study was initiated to investigate the effects that various asphalt cement sources and antistripping agents have on the stripping resistance of a particular hot mix material.

This paper describes the test method and the materials used, the results obtained from the study and the conclusions drawn. The majority of the work done involved three asphalt cement sources and three commercially available liquid antistripping agents. Also described is the small amount of work done on other asphalt cements and antistripping agents.

The data obtained clearly shows that the asphalt cement source, the antistripping agent and the aggregate type can play a major role in the ability of the hot mix to resist stripping. The study shows that each aggregate, asphalt cement type and antistripping agent must be evaluated fully before using in actual production.

RÉSUMÉ

L'existence du problème du décapage du lien de l'asphalte de l'agrégat dans un mélange chaud a été souvent constatée dans tout le pays. Ce problème du décapage peut devenir une affaire coûteuse pour le propriétaire des routes car les réparations des chaussées pourraIent lui coûter plusieurs centaines de milliers de dollars. On a entrepris des essais de laboratoire afin d'étudier les effets de diverses sources d'approvisionnement de ciment d'asphalte et d'agents chimiques antidécapants sur la résistance au décapage d'un matériau bien défini pour un mélange chaud.

Le présent rapport décrit les méthodes d'essai et les matériaux utilisés, ainsi que les résultats obtenus de cette étude et les conclusions auxquelles nous sommes arrivés. La plus grande partie du travail a été faite sur trois sortes de sources de ciment d'asphalte et sur trois agents chimiques antidécapants liquides disponibles sur le marché. Plusiers autres ciments d'asphalte étudés, peu numbreuses, qui ont été réalisées par le passé sur d'autres ciments d'asphalte et sur d'autres agents chimiques antidécapants ont été incluses dans ce report.

Les données obtenues montrent clairement que la source de ciment d'asphalte, l'agent chimique antidécapant ainsi que le genre d'agrégat utilisés ont une influence primordiale sur la capacité de résistance au décapage d'un mélange chaud. L'étude démontre que chaque agrégat, chaque type de ciment d'asphalte et chaque agent chimique antidécapant doivent être évalués à fond avant qu'ils ne soient utilisés dans la production en cours.

INTRODUCTION

Over the last few years the problem of hot mix stripping and ravelling have been on the increase and has been well documented (1-4). The ravelling problem has been around for awhile, but not in as severe a condition as now. With the increased stripping concerns and the potential repair costs in the hundreds of thousands of dollars, a laboratory study was initiated to investigate the stripping phenomenon.

This paper describes the test methods used, the materials used and the test results obtained from the study and the conclusions drawn. The study was designed to show clearly that the asphalt cement source, the antistripping agent and the aggregate type play a major role in the overall performance of the hot mix.

STRIPPING

The general definition of stripping is the separation of the asphalt cement from the aggregate primarily due to the action of water or water vapour. The stripping can be enhanced by the aggregate texture, the asphalt cement source as well as the grade of asphalt cement used.

Water-induced damage of asphalt mixtures have produced severe distress, reduced performance, and increased maintenance for pavements Canada-wide. Moisture-induced damage produces several forms of distress including ravelling, shoving and eventually complete failure.

The stripping process can be attributed to many different variables. The major variables are aggregate source, asphalt cement, antistripping agent and the actual aggregate job mix formula.

AGGREGATE SOURCE

The amount of stripping which will occur with an aggregate source varies for that source. This variation can be due to

- the length of time since crushing
- location of material in pit or quarry
- or combinations of the above

It is possible to have an aggregate source be acceptable without the need of an antistripping agent as long as the aggregate, after crushing, has been allowed to sit in the stockpile for a minimum of six months. There are also aggregates which do not strip (or strip less) depending on what area of the quarry or pit the material is located.

AGGREGATE MIX BLEND

The actual blend of the various aggregates can have an effect on the stripping properties of the mix. The variation of the fine aggregate can change the total surface area thus altering the film thickness of the asphalt binder. This change in film thickness can affect the resistance of the mix to stripping action. For this study the aggregates used in the designs were all sampled at the same time and the samples to be tested were made up of the same blend of aggregates. This would eliminate any effect of the job mix formula and the aggregates on the results of the stripping study.

ASPHALT CEMENT

Research (6) has shown that the asphalt cement source itself can have a tremendous effect on how the asphalt aggregate blend will react under stripping conditions. Each source of asphalt cement has its own unique chemical makeup. Because each asphalt cement is different chemically, how it reacts with the aggregate will be different. The reactions occurring between the aggregate and the asphalt cements could allow the mix to be designed without the need of an adhesion agent.

Work done by McAsphalt a number of years ago on one aggregate blend using four different sources of 85/100 penetration asphalt cement gave tensile strength ratio values from 55 to 68%. Based on these values one could state that only the asphalt source giving the best result should be used with that particular aggregate unless an antistripping agent was added.

In today's market a refinery is continually changing crude sources and blends. For this reason the asphalt cement being produced at the refinery could change throughout the season and with this change its effectiveness as an antistripping agent will change.

ANTISTRIPPING AGENTS

There are approximately 100 to 120 different chemical antistripping agents approved for use. These surfactants are proprietary chemicals and their exact composition is not known. The chemical antistripping agents are soluble in the asphalt cement and are designed to travel to the aggregate surface where they are adsorbed onto the aggregate surface, thus making the aggregate surface more compatible with asphalt cement. The agents must also improve the bond at the asphalt aggregate interface.

The problem with chemical antistripping agents is that results vary with aggregate source, aggregate blend, asphalt cement source and asphalt grade. With this kind of variability the research into which chemical agent to use and what dosage level is needed to give the best results becomes a long and drawn out affair. One can not just say that this particular agent will work at this concentration level. The laboratory tests have to be done to determine the agent to be used and the concentration level required.

MIX DESIGN

The Marshall method of design was used to obtain the laboratory data on the mixes. The designs were carried out using the latest Asphalt Institute (AI MS-2) test methods. There were two different mixes used in the study with both designs conforming to a HL3 type meeting Ontario's OPSS Form 1150. The following design criteria was used for both mixes:

Traffic Volume	>	5000 vehicles/day
Marshall Stability		8900 N min
Air Voids %		3 - 5
VMA %		15.0 min

The aggregates used to design the two mixes were known to be susceptable to moisture damage. Mix designs were obtained on the two aggregate sources with Mix #1 using 85/100 penetration asphalt cement and Mix #2 using 150/200 penetration grade asphalt cement. The mix designs developed in the laboratory for this study are as shown in Table 1. Mix #1 was used to study the effects of polymer-modified asphalt cement to improve the resistance to stripping (Part 1). Mix #2 was used to study the influence of asphalt source and liquid antistripping agent on resistance to stripping (Part 2). These designs were maintained throughout the study to eliminate the influence that any changes in the job mix formula and the aggregates could have on the results of the stripping study.

Table 1

Designs used for Study

Mix #	1	2
Sieve	% Passing	
16.0 mm	100.0	100.0
13.2 mm	87.4	99.9
9.5 mm	69.3	92.6
4.75 mm	58.5	66.0
2.36 mm	49.7	46.5
1.18 mm	34.6	31.8
600 μm	23.7	18.3
300 μm	14.8	10.3
150 μm	7.8	6.8
75 μm	3.9	5.2
% AC	5.5	6.2
Bulk Relative Density	2.358	2.297
Maximum Relative Density	2.459	2.399
% Air Voids	4.10	4.25
% VMA	16.5	15.4
Marshall Stability	9986	11525
Flow Index	10.1	12.3
Tensile Strength Ratio	32.3	16.0

STRIPPING PROCEDURE

Once the designs were developed the actual stripping study was started. The stripping procedure used for this study was a method developed by Tunnicliff and Root (5,6), which had been modified from the procedure developed by Lottman (7).

The test method compares the ratio of the tensile strength of an unsoaked sample and the tensile strength of a moisture conditioned sample of the same mix having the same air voids (7.0 ± 1.0). This air voids value is considered to be the typical value that is present in most roadways shortly after initial construction. A tensile strength ratio (TSR) of 70.0% or greater is considered to be adequate to provide resistance to stripping.

The compacted briquettes are divided into two groups by the average air voids. One group is the control section while the other is subjected to a partial vacuum immersion for one hour and then immersed in a water bath at 60°C for 24 hours. At the end of the 24 hour conditioning the briquettes are stabilized in a water bath at 25°C for one hour and then the saturation and swell percentages are determined. After this process the control and conditioned briquettes are tested for tensile strength at 25°C. The ratio of the moisture conditioned to control tensile strength is then determined.

Using this method the aggregates, asphalt cements and additives can be evaluated and the proper combination can be obtained to give the best design. Table 1 shows that both mixes had very low tensile strength ratios (32.3 for Mix #1 and 16.0 for Mix #2). These low tensile strength ratios certainly confirm what has been happening in the field when these aggregates have been used.

PART ONE

This section of the study involved a limited investigation into the effect that polymer modification of the asphalt cement would have on the stripping resistance of the hot mix. There have been many papers written regarding the improved adhesive properties with the addition of modifiers to the asphalt cement (8,9). With this in mind a small study was initiated to study this phenomenon. Although the laboratory study was limited in scope, the information gained has been very helpful in day to day operations.

Table 1 (Mix #1) shows the test data obtained on the hot mix design used in the polymer study. This particular aggregate was known to have a stripping problem. It was decided to look at a number of different SBS Block copolymers as well as two different latex type polymers and another chemical additive in an attempt to improve the adhesive properties of the asphalt cement.

Initial tests were carried out using 150/200 penetration asphalt cement and three different SBS block copolymers in different concentrations. The results obtained are shown in Table 2. There was an improvement in the TSR values but a difference in results with different polymers. These differences could be due to their particular chemical makeup and their reaction with the asphalt cement and the aggregate.

Table 2
Effect of SBS Type Polymers on Tensile Strength Ratio (TSR) Values

Concentration	SBS Type Copolymer			
%	Type 1*	Type 2*	Type 3*	Blend 1&2*
0.0 1.0 2.0	32.3 37 46	32.3 45 63	32.3 43 60	32.3 64

** Type 1 = Kraton 1101; Type 2 = Kraton 1107;*
Type 3 = Kraton 1118;
Blend 1&2 = 1% each Kraton 1101 and 1107

The second set of stripping tests were run using two different latex polymers (chloroprene type) which were flashed into the same source of 150/200 penetration asphalt cement as used with the SBS polymers. The quantity of latex added to the asphalt cement was varied and normal stripping tests were performed using these various concentrations. The data obtained (Table 3) shows much better TSR values with product "A" than those obtained by material "B". The two latex products, although both chloroprene types, contain different functional groups.

Table 3
Effect of Latex Type Polymers on Tensile Strength Ratio (TSR) Values

Concentration	Latex Type Polymer	
%	Type A*	Type B*
0.0	32.3	32.3
1.0	99	62
1.5	100	
2.0	100	63
2.5	100	
3.0		65
4.0	97	

* *Type A = Neoprene Latex 115; Type B = Neoprene Latex 671A*

It would appear that this difference in functional groups resulted in much improved adhesive properties to the asphalt cement at lower concentration levels when product "A" is used, compared with material "B".

Based on the test results obtained using both the SBS and the latex products, it was decided to add another chemical, which would react with the polymer and aid in obtaining better adhesive properties. The Type 1 SBS polymer was chosen as the candidate to which the new chemical would be added to determine if this in fact would occur.

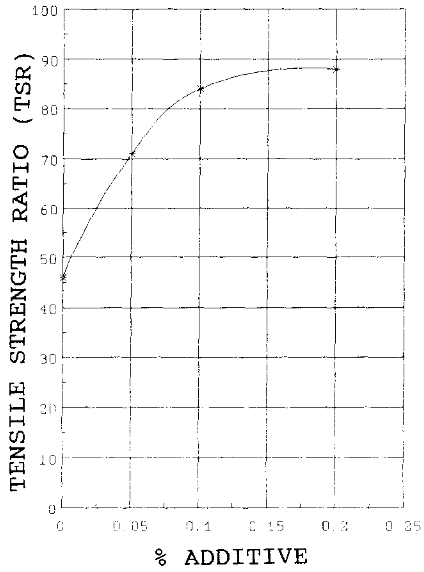
Table 4
Effect of Chemical "M" in Polymer-Modified Asphalt on the Tensile Strength Ratio (TSR) Values

"M" Concentration %	TSR
0.0	46
0.05	71
0.10	84
0.20	88

An initial set of tests were conducted whereby chemical "M" was added in various concentration levels to the same 150/200 penetration asphalt cement containing 2.0% of the Type 1 SBS copolymer used earlier in the study. The results (Table 4) obtained indicate that the samples containing the added chemical resulted in the highest improvement. Figure 1 shows this improvement graphically.

Figure 1

Effect of Chemical "M" in Polymer-Modified Asphalt on the Tensile Strength Ratio (TSR) Values

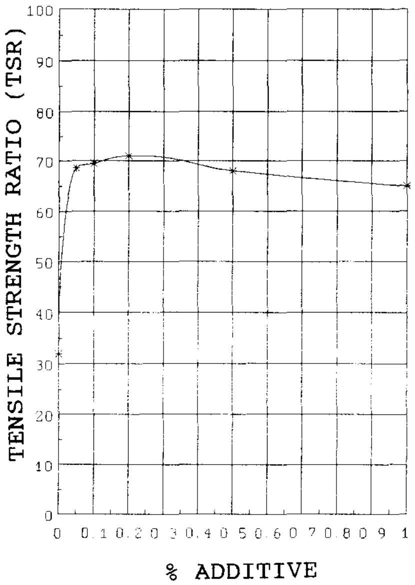


Since the addition of Chemical "M" gave improved TSR values, it was decided to examine Chemical "M" by itself as an antistripping agent. A set of six different trials were instituted using various concentration levels of Chemical "M" added to the stock 150/200 asphalt cement (Table 5). As suspected Chemical "M" appears to behave like an antistripping agent and improves the overall adhesion of the asphalt to the aggregate (Figure 2).

Table 5
Effect of Chemical "M" on the Tensile Strength Ratio (TSR) of a Mix using 150/200 Asphalt Cement

Concentration %	TSR
0.0	32
0.05	68
0.10	69
0.20	71
0.50	68
1.00	65

Figure 2
Effect of Chemical "M" on the Tensile Strength Ratio (TSR)
of a Mix using 150/200 Asphalt



The improvements in adhesion however, are greater when Chemical "M" is used in combination with the polymer. It is interesting to note that the concentrations of Chemical "M" are typically 10 times lower than the quantity normally used by regular antistripping agents. Further work is needed to determine the true effectiveness of Chemical "M".

PART TWO

This section of the study involved the analysis of liquid antistripping agents and their effectiveness in improving the stripping resistance of Mix #2. The laboratory study concentrated on three commercially available antistripping agents which have given good results in the past on other hot mix pavement projects known to have had stripping problems. Table 6 lists the three adhesion agents and their basic chemical makeup.

Table 6
List of Chemical Antistripping Agents

Additive	Chemical Type
A - Exxon ACRA 500	Amine Based
B - AKZO 91-S	Ethoxylated Amine
C - Westvaco PC-814	Polyalkylene Amine Blend

The laboratory test procedure used for this part of the study was as follows:

- Various concentration levels of each antistripping agent were used (0.0, 0.5, 0.75, 1.0, 1.25)

- The adhesion agents were used in asphalt cements from three different sources (150/200 Penetration grade)
- The stripping procedure was done on each asphalt blend and the results recorded.

Each source of asphalt cement has a unique chemical structure. Because each asphalt cement is chemically different, the reaction with the aggregate will be different. The reactions occuring between aggregate and the asphalt cements could allow the mix to be used with or without the need of an adhesion agent. Table 7 shows the influence of asphalt cement on the tensile strength ratio without any antistripping agent being employed. It is observed that with each asphalt source, a different result occurs when used with an aggregate from a particular source. If aggregate from another source was used a different set of results could be achieved.

The results indicate that Asphalt "I" (150/200) is the most susceptable to stripping of the five asphalt cements used. Asphalt "U" (85/100) is the least susceptable but is still well below the required level of 70% retained strength.

Table 7
Influence of Asphalt Cement Source on Tensile Strength Ratio (TSR) Value

Asphalt Cement Source*	TSR Value
Asphalt E (150/200)	28.7
Asphalt I (150/200)	15.7
Asphalt U (150/200)	35.8
Asphalt U (85/100)	43.0
Asphalt H (150/200)	35.4

** E = Esso; I = Irving; U = Ultramar; H = Husky*

It was also observed that higher values were obtained with the harder based asphalt (85/100) than with the softer grades. The reason this occurs is that it is more difficult for the water action to break the bond of the more viscous asphalt cement (harder asphalt) from the aggregate.

For discussion purposes the test data have been grouped into two sections:

A/ A comparison of each additive to the three asphalt cement sources.
B/ A comparison of each asphalt cement to the three anti stripping additives.

SECTION A

ADDITIVE "A" (Exxon ACRA 500)

When the data collected on the influence of Additive "A" versus the three asphalt cements (Table 8) is plotted as shown in Figure 3 it would appear that Asphalt "U" works the best of the three asphalts. Asphalts "E" and "I" give very similar results. The plots on Figure 3 show that the maximum TSR value obtained is only 62% which is below the minimum allowable TSR value of 70%. Based on the limited data, Additive "A" would not be suitable for use as an antistripping agent with this particular mix and asphalt cements.

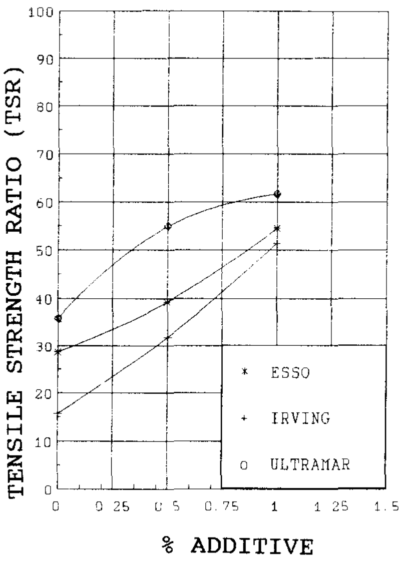
Table 8

Influence of Additive "A" (Exxon ACRA 500) on the Tensile Strength Ratio of Several Asphalt Cements

Concentration	Tensile Strength Ratio		
%	Asphalt "E"	Asphalt "I"	Asphalt "U"
0.0	28.7	15.7	35.8
0.5	39.2	31.8	54.8
0.75		44.5	
1.0	54.5	51.4	61.7

Figure 3

Influence of Additive "A" on the Tensile Strength Ratio (TSR) of Several Asphalt Cements



ADDITIVE "B" (AKZO 91-S)

Table 9 lists the test results on the effectiveness of Additive "B" when used with the three asphalt cements. Based on the data obtained, Additive "B" has no effect on Asphalt "U" while Asphalts "E" and "I" appear to react in a similar manner. The data is more easily interpreted as seen in Figure 4.

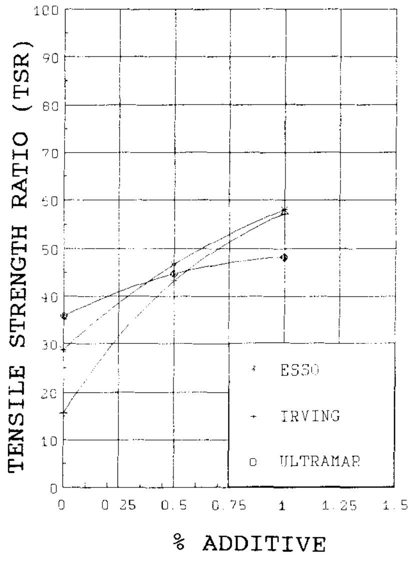
Table 9
Effect of Additive "B" (AKZO 91-S) on the Tensile Strength Ratio of Several Asphalt Cements

Concentration	Tensile Strength Ratio		
%	Asphalt "E"	Asphalt "I"	Asphalt "U"
0.0	28.7	15.7	35.8
0.5	46.7	43.2	44.7
0.75			
1.0	58.0	57.2	48.2

If the results for Asphalt "I" and "E" were extrapolated out to 1.5% additive the resultant TSR values would still be below the minimum 70% TSR required. Based on these test results the Additive "B" would not be suitable for use as an adhesion agent for this particular mix using the three 150/200 penetration grade asphalt cements used in this study.

Figure 4

Effect of Additive "B" (AKZO 91-S) on the Tensile Strength Ratio of Several Asphalt Cements



ADDITIVE "C" (Westvaco PC-814)

Table 10 gives the test data obtained on the three asphalt cements using Additive "C". The first observation with these test results compared to the results of Additives "A" and "B" are the much higher TSR values that have been achieved by all three asphalt cements. Figure 5 shows the test data graphically. Both Asphalt "E" and "I" meet the minimum requirement of 70% at the 1.0% dosage level while Asphalt "U" is borderline on meeting the minimum TSR level.

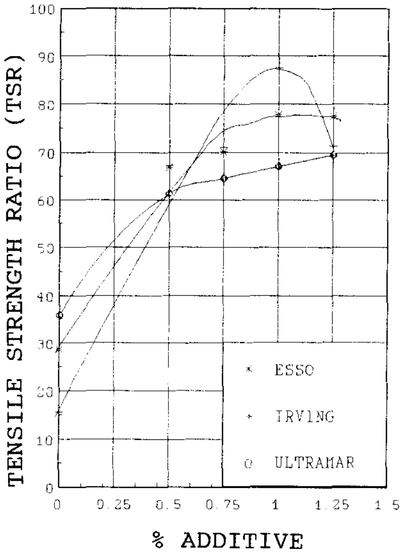
Table 10

Influence of Additive "C" (Westvaco PC-814) on the Tensile Strength Ratio of Several Asphalt Cements

Concentration	Tensile Strength Ratio		
%	Asphalt "E"	Asphalt "I"	Asphalt "U"
0.0	28.7	15.7	35.8
0.5	66.7	67.3	61.3
0.75	70.1	71.0	64.6
1.0	77.8	87.5	67.1
1.25	77.6	71.4	69.6

Figure 5

Influence of Additive "C" (Westvaco PC-814) on the Tensile Strength Ratio of Several Asphalt Cements



The test data indicate that the chemical structure of the additive as well as the chemical properties in the various asphalt cements determine the effectiveness of the additive-asphalt cement blend in preventing the asphalt cement from the stripping off the aggregate. The chemical charges in the additives, their strength, and how they react with the aggregate charges as well as the asphalt cement become the key elements in promoting adhesion. As can be seen, by comparing the three additives to each asphalt cement, the effectiveness of Additive "C" becomes more evident.

SECTION B

ASPHALT "E"

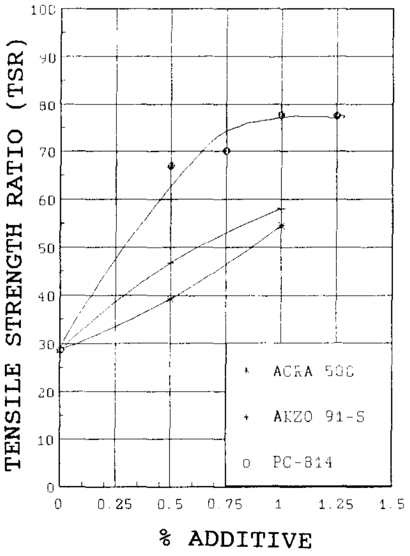
The effectiveness of Additive "C" over both "A" and "B" when incorporated into Asphalt "E" becomes very evident when looking at the data of Table 11 and the plot of the additives versus Asphalt "E" as shown in Figure 6.

The results show that Additive "C" in a concentration level of only 0.5%, gives TSR values greater than 10% higher than both Additives "A" and "B" in concentration levels of 1.0%. It would appear that the 1.0% level of Additive "C" gives the best result for stripping resistance. Any higher amount would be wasteful. The chemical makeup of Additive "C" is best suited to Asphalt "E" which was used in this study.

Table 11
Effect of Additives "A, B, C" on the Tensile Strength Ratio of Asphalt "E"

Concentration	Tensile Strength Ratio		
%	A-ACRA 500	B-AKZO 91-S	C - PC-814
0.0	28.7	28.7	28.7
0.5	39.2	46.7	66.9
0.75			70.1
1.0	54.5	58.0	77.8
1.25			77.6

Figure 6
Effect of Antistripping Additives on the Tensile Strength Ratio of Asphalt "E"



ASPHALT "I"

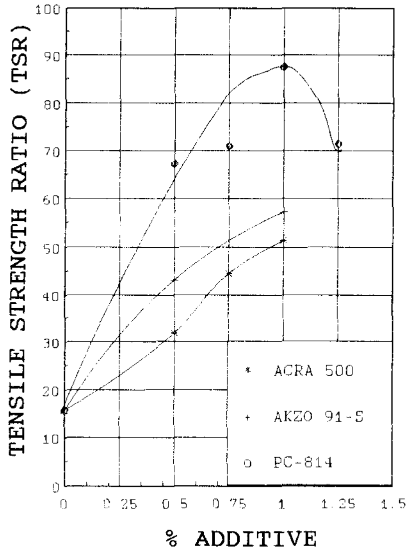
The combination of Asphalt "I" and Additive "C" has the greatest increase in TSR values of all the additive-asphalt blends tested. Table 12 and Figure 7 show this tremendous improvement. The TSR values for Additives "A" and "B" with Asphalt "E" show some increase but not sufficient to meet the minimum TSR value of 70%. The values for Additive "C" are almost twice the strength of the TSR values obtained for both Additive "A" and "B".

The most significent difference that this additive-asphalt blend has over the other two asphalts is that there appears to be a dosage range (0.9-1.1%) where the best results occur. The other two asphalts seem to peak and stay at that level of TSR value even with increased dosage levels. The results obtained for Additive "C" show that there is an optimum amount of additive needed and that using a higher concentration level can actually decrease the effectiveness of the antistripping agent.

Table 12
Influence of Antistripping Additives on the Tensile Strength Ratio of Asphalt "I"

Concentration	Tensile Strength Ratio		
%	A-ACRA 500	B-AKZO 91-S	C - PC814
0.0	15.7	15.7	15.7
0.5	31.8	43.2	67.3
0.75	44,5		71.0
1.0	51.4	57.2	87.5
1.25			71.4

Figure 7
Influence of Antistripping Additives on the Tensile Strength Ratio of Asphalt "I"



If an excess of additive is added the TSR value could actually drop below the minimum value required to prevent or delay stripping.

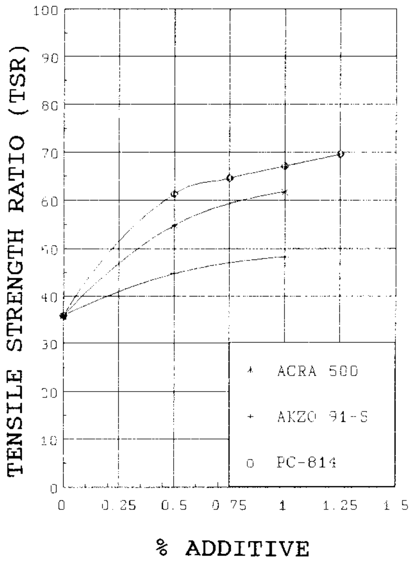
ASPHALT "U"

Asphalt "U" gives the lowest results for tensile strength for all three additives. As Table 13 and Figure 8 show Additive "B" has little or no effect on the improvement of stripping resistance. Additive "A" offers some needed protection but not sufficient to meet the minimum TSR requirements. Additive "C" shows improvement but appears to level off at the 0.75% concentration level. No real increase in TSR strength above that level is observed. All three additives fail to meet the minimum TSR values required (70%) which has been accepted as the value needed to provide adequate protection against stripping of the asphalt cement from the aggregate. The possibility exists that using a different

Table 13
Effect of Antistripping Additives on the Tensile Strength Ratios of Asphalt "U"

Concentration	Tensile Strength Ratio		
%	A-ACRA 500	B-AKZO 91-S	C - PC-814
0.0	35.8	35.8	35.8
0.5	54.8	44.7	61.3
0.75			64.6
1.0	61.7	48.2	67.1
1.25			69.6

Figure 8
Effect of Antistripping Additives on the Tensile Strength Ratios of Asphalt "U"



aggregate would give improved antistripping properties. The use of a different asphalt cement source has been proven with the results of Asphalt "E" and "I" discussed earlier.

EFFECT OF ADDITIVE "C" (Westvaco PC-814) ON ASPHALT CEMENT PROPERTIES

The three asphalt cements used in this section of the study were subjected to the standard asphalt tests that are performed for specification compliance. The three asphalts were also tested with 1.0% of Additive "C" added. Tables 14, 15 and 16 contain the test results obtained on the original asphalts as well as the three asphalt cements containing 1.0% Additive "C".

All three asphalt cements exhibit the same change in their original properties after the additive is added. The addition of the less viscous adhesion agent lowers the kinematic viscosity of the asphalt blend as well as dropping the flash point. The ductility of the three materials (both before and after the TFOT test) does not appear to be affected by the addition of the liquid antistripping agent. The solubility of the additive-asphalt blend in trichloroethylene also shows no significant change.

Table 14

Asphalt "E"
Physical Properties

Tests	Virgin	1.0% Additive "C"*
Penetration @ 25°C 100g 5 sec	160	149
Kinematic Viscosity @ 135°C mm^2/sec	225	208
Flash Point COC °C	291	279
Ductility @ 25°C 5 cm/min	100+	100+
Solubility %	99.98	99.97
Thin Film Oven Test 50 ml, 5 hr. 163°C		
% Loss by wt.	0.45	0.76
% Retained Penetration 100g, 5 sec, 25°C	61.5	60.8
Ductility of Residue 5 cm/min 25°C	100+	100+

* Additive C - Westvaco PC-814

The most interesting change is the lowering of the penetration by 6 to 10%. The addition of the antistripping agent changes the chemical structure of the asphalt cement which results in a reduced penetration value. It would appear that chemicals in the liquid antistrip agent are creating a hardening effect in the asphalt cement and causing the overall penetration of the blend to decrease somewhat. This drop in penetration could result in the asphalt cement failing to comply with the specification requirements for penetration. Typically 150/200 penetration asphalt cement produced in the refinery has a penetration value of approximately 165. The test results obtained in this study show a significant drop in the penetration of the asphalt cement and the designers should be well aware of this possibility. As well different liquid antistripping additives will react differently which could cause a quite substantial variation in the penetration.

Table 15

Asphalt "I"
Physical Properties

Tests	Virgin	1.0% Additive "C"*
Penetration @ 25°C 100g 5 sec	163	153
Kinematic Viscosity @ 135°C mm²/sec	267	243
Flash Point COC °C	300	291
Ductility @ 25°C 5 cm/min	100+	100+
Solubility %	99.95	99.95
Thin Film Oven Test 50 ml, 5 hr. 163°C		
% Loss by wt.	0.199	0.504
% Retained Penetration 100g, 5 sec, 25°C	57.1	64.1
Ductility of Residue 5 cm/min 25°C	100+	100+

* Additive C - Westvaco PC-814

Another interesting feature which is observed in the test results is the improvement in the retained penetration of the residue after the thin film oven test (TFOT). In both Asphalts "I" and "U" the % retained penetration of the residue was higher on the treated material than on the virgin asphalt cement even though the amount of weight loss on the TFOT test for the treated materials were substantially higher. The results obtained on the Asphalt "E" material do not reveal this change in the % retained penetration.

It would appear that the chemical reaction which occurs between the additive and the asphalt cement creates this change in properties. Maintaining the asphalt-additive blend at the high temperature needed for the TFOT (163°C) most likely causes the reaction to occur. Based on the test results of the three asphalts, the effect of the antistripping additive appears to

Table 16

Asphalt "U"
Physical Properties

Tests	Virgin	1.0% Additive "C"*
Penetration @ 25°C 100g 5 sec	149	139
Kinematic Viscosity @ 135°C mm²/sec	229	219
Flash Point COC °C	315	289
Ductility @ 25°C 5 cm/min	100+	100+
Solubility %	99.99	99.97
Thin Film Oven Test 50 ml, 5 hr. 163°C		
% Loss by wt.	0.096	0.435
% Retained Penetration 100g, 5 sec, 25°C	55.1	61.2
Ductility of Residue 5 cm/min 25°C	100+	100+

* Additive C - Westvaco PC-814

be asphalt sensitive and only extensive testing of the asphalt blends will ensure that all the physical properties required in the asphalt specification are achieved.

FUTURE RESEARCH

The laboratory study was only a small step in understanding the problem of stripping of the asphalt cement from the aggregate. This limited study has given us a basic understanding about stripping and in addition it shows that this phenomenon is very complex. Many factors could affect the overall performance of asphalt pavements in general and in particular those pavements which are susceptable to moisture-induced damage which results in stripping.

The study has shown that extensive research is required to provide the proper protection against stripping. With the many different factors influencing the outcome, engineers and designers must be well aware of these effects and should familiarize themselves with the methods that will assist in the prevention of serious pavement deterioration which is caused by moisture infiltration into the pavement.

Research is required into improving the capability of polymers to aid in the improvement of stripping resistance. Research is also required into developing liquid antistripping agents which are not only effective but also not harmful to the properties of the asphalt cement.

CONCLUSIONS

1. The aggregate blends without antistripping additives used in this study have serious stripping problems.

2. The addition of polymers to asphalt cement improves the resistance to stripping. The type and concentration level of polymer affects the level of improvement.

3. The addition of small amounts of various chemicals will provide improved stripping resistance. The combination of polymers and other chemicals can provide greater protection than polymers only.

4. Asphalt cements of the same penetration grade but from different sources give varying degrees of antistripping aid. Asphalt cements from the same source provide different levels of stripping resistance depending on their penetration grade. The softer grades of asphalt cement will give lower TSR values and less resistance to stripping.

5. Chemical antistripping agents react differently with different asphalt cements when the same concentration levels are used. Each liquid antistripping agent must be analysed individually to determine its suitability for a particular aggregate mix.

6. The liquid antistripping Additive "C" (Westvaco PC-814) provides the best stripping protection with all three asphalt cements. In this particular study only Additive "C" met the minimum TSR requirement of 70% with all three asphalt cements.

7. Asphalt "I" has the greatest improvement in tensile strength ratio (TSR) with all three liquid antistripping agents.

8. The addition of the liquid antistripping agents can affect the properties of the asphalt cement. The designer must analyse the additive-asphalt blend selected to ensure that all physical properties required by the asphalt cement specification are met.

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