# Effect of Antistrip Additives on the Properties of Polymer-Modified Asphalt Binders and Mixtures

MOON C. WON AND MICHAEL K. HO

The effect of liquid antistrip additives on the properties of polymer-modified asphalt binders and mixtures as related to rutting and moisture damage was investigated. The use of polymer-modified asphalts has increased in recent years because of their ability to resist rutting at high temperatures and improve fatigue resistance at low temperatures. In the Houston area liquid antistrip additives are used for almost all the mixtures to mitigate moisture damage. Liquid antistrip additives have been shown to soften certain asphalts. Whether liquid antistrip additives soften polymer-modified asphalts, thus degrading the rut resistant capability of polymer-modified asphalt, has become a concern to highway engineers. Asphalt binder properties known to have a bearing on rutting were evaluated on polymer-modified asphalts with three commercial liquid antistrip additives. Moisture damage of the mixture was evaluated using the conditioned-unconditioned indirect tensile test. In general, the liquid antistrip additives reduced the viscosity and softening point of polymer-modified asphalts, especially at high dosage. This will make polymer-modified asphalt binders more rut susceptible. For polymer-modified asphalt mixtures, increasing the dosage of liquid antistrip additives did not improve resistance to moisture susceptibility. On the basis of the investigation, lower dosages of liquid antistrip additives are recommended for polymer-modified asphalts than would be required for straight asphalts.

Moisture damage of asphalt concrete pavement has been a serious problem throughout the country. Extensive research has been conducted to identify its mechanisms and to develop methodologies for evaluating moisture susceptibility of mixtures. In 1985 Hazlett (*1*), after evaluating a number of moisture damage testing procedures for their effectiveness, selected the Lottman test and modified it for Texas Department of Transportation's (TxDOT's) use. The test uses the tensile strength ratio (TSR) of conditioned to unconditioned specimens as an indicator of the mixture's resistance to moisture damage. In TxDOT's Houston district the test is routinely conducted to ensure that the mixtures are not moisture susceptible.

Figure 1 shows TSR distributions of 103 surface mixtures evaluated in 1992 at the district laboratory. Ratios of 1 or more were obtained for more than 20 percent of the mixtures tested. Given the level of damage induced in the conditioned specimens, it is not expected that conditioned strengths are greater than unconditioned in more than 20 percent of the mixtures. There are several probable reasons for conditioned strengths being greater than unconditioned. One may be the softening of asphalt by liquid antistrip additives even though it is not known whether the asphalt softening has a more significant effect on the tensile strengths of unconditioned specimens than on those of the conditioned. Anderson et al. (*2*) found that the addition of liquid antistrip additives softened certain asphalts. They attributed this to the reactions between polar components in liquid antistrip additives and functional groups in asphalts.

In addition to moisture damage, rutting has been a major distress in the Houston area because of high temperatures, heavy traffic, and increasing tire pressures. Although such variables as proper gradation and binder content have a more significant effect on rutting, binder properties also affect a mixture's resistance to rutting. This is manifested by the creep test results, which increase rapidly with temperature. King et al. (*3*) found that for straight soft asphalts a relatively small amount of polymer can reduce rut depths significantly. The Houston district has increased the use of polymer-modified asphalts in recent years because of their ability to resist rutting. Liquid antistrip additives are used for almost all mixtures in the Houston area to meet the required minimum TSR value of 0.7. However, whether they soften the polymer-modified asphalts as they do the straight asphalts has become a concern to highway engineers. Figure 2 shows the unconditioned tensile strengths of the polymer-modified asphalt mixtures with and without liquid antistrip additives. The polymer used was ethylene-vinyl-acetate at 3.5 percent, and the base asphalt was AC-10. The mixtures were obtained from a drum mix plant where the contractor produced both mixtures to determine whether liquid antistrip additives were needed to meet the minimum TSR requirement. In Figure 2 hollow dots represent tensile strengths of asphalt concrete mixtures without antistrip additives. Solid dots represent those with antistrip additives. The figure indicates that adding liquid antistrip additive resulted in the decrease of tensile strength by more than 30 percent. The decrease appears to be due solely to the use of 1.0 percent liquid antistrip additive since all the other variables such as aggregates, gradation, and asphalt content were kept the same.

## OBJECTIVES

The objectives of the study are (*a*) to investigate the effect of liquid antistrip additives on the properties of polymer-modified asphalt binders as related to rutting and (*b*) to evaluate the effectiveness of liquid antistrip additives mixed with polymer-modified asphalts on the resistance of asphalt mixtures to moisture damage.

## TEST PROGRAM

Asphalt binder properties were evaluated to investigate the effect of liquid antistrip additives. The properties include viscosities,

Texas Department of Transportation, P.O. Box 1386, Houston, Tex. 77251-1386.

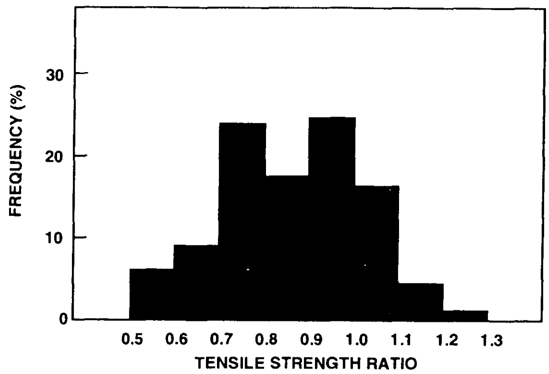


**FIGURE 1 Distribution of tensile strength ratios.**

**TABLE 1 Aggregate Gradations Selected for Study**

| sieve size | gradation | master grading |
|---|---|---|
| 1/2 " | 100 | 100 |
| 3/8 " | 94.4 | 85-100 |
| No. 4 | 65.4 | 50-70 |
| No. 10 | 39.2 | 32-42 |
| No. 40 | 25.0 | 11-26 |
| No. 80 | 9.8 | 4-14 |
| No. 200 | 3.0 | 1-6 |

softening points, ductility, and flash point. Moisture damages of asphalt mixtures were evaluated by measuring indirect tensile strengths of conditioned and unconditioned specimens.

## Materials

- Two grades of straight asphalts, AC-10 and AC-20, and their modified asphalts by styrene-butadiene-styrene (SBS) polymers, AC-30P and AC-45P, all meeting TxDOT specifications, were obtained from KOCH Materials, Baytown, Texas. AC-30P is a blend of AC-10 with 3 percent SBS, and AC-45P is a blend of AC-20 with 3 percent SBS.
- Sandstone, limestone, limestone screenings, and field sand were obtained and combined to produce mixes that met the TxDOT specification requirements for the surface courses.
- Four antistrip additives were selected: hydrated lime and three proprietary liquid antistrip additives. Liquid I is amine based with a recommended dosage of 0.25 to 1.0 percent, and the specific gravity ranges from 0.94 to 0.97. Liquid II is a highly concentrated reacted polyamine with significantly increased molecular weight. Its specific gravity is 1.04 at 25°C, and it is much stickier than Liquids I and III at room temperature. It is a low-odor product, and the recommended dosage ranges from 0.5 to 1.0 percent. Liquid III is amine based with a recommended dosage of 0.5 to 1.0 percent with an approximate specific gravity of 1.04 at room temperature. The liquid antistrip additives were blended with asphalt cement by pouring metered amounts into heated asphalt.

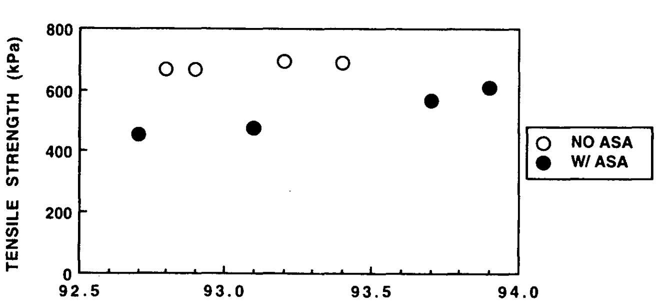


**FIGURE 2 Effect of antistrip additives on unconditioned strength of polymer-modified asphalt mixtures.**

## Mixture Design

The job mix formula was developed following the procedures in Construction Bulletin C-14 of TxDOT. The aggregate gradation of the mixture is given in Table 1. The master gradation is for fine surface course, designated as Type D surface in Item 340 of TxDOT *Standard Specifications* (*4*). The optimum asphalt content was 5.0 percent.

## Test Procedures

A partial list of binder tests conducted on polymer-modified asphalts and test methods followed is as follows: absolute viscosity at 60°C, ASTM D2171; kinematic viscosity at 135°C, ASTM D2170; penetration at 25°C, ASTM D5; softening point, Tex-505-C; ductility, Tex-503-C.

Moisture susceptibility of the mixtures was evaluated according to TxDOT Procedure (*5*) Tex-531-C test method. The mixing of aggregates with asphalt binders was done using a mechanical mixer following TxDOT Procedure Tex-205-F. Specimens 10.16 cm in diameter and 5.08 cm high were molded in a motorized gyratory-shear molding press. The number of gyrations applied was determined by trial and error so that the air voids in the specimens were within 6 to 8 percent. Eight specimens were prepared for each testing. The specimens were divided into two groups of four specimens in such a way that the average void content in each group was approximately the same. One group of specimens was stored in a desiccator (unconditioned), and the other group underwent a conditioning process that induced moisture damage (conditioned). The conditioning process consisted of saturating the voids with water and freezing and thawing of the specimens as follows. The specimens were placed in a vacuum chamber filled with enough distilled water to submerge them. Vacuum was applied at the appropriate level and duration to fill the voids in the specimens with water at 60 to 80 percent. These four specimens were then placed in a freezer at −17.8°C for a minimum of 15 hr. They were removed from the freezer and placed in a 60°C water bath for 24 hr. The conditioned and unconditioned specimens were placed in a 25°C water bath for 3 to 4 hr and tested for indirect tensile strength at a 5.08 cm/min deformation rate until sample failure occurred.

**TABLE 2 Factorial Experiment**

| Dosage | ASA / SBS / Asp Grad / Cond | Unconditioned | | | | Conditioned | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Asp Grad | 10 | | 20 | | 10 | | 20 | |
| | SBS | no | yes | no | yes | no | yes | no | yes |
| 0 | none | | | | | | | | |
| 0.5 | I | | | | | | | | |
| | II | | | | | | | | |
| | III | | | | | | | | |
| | L | | | | | | | | |
| 1.0 | I | | | | | | | | |
| | II | | | | | | | | |
| | III | | | | | | | | |
| | L | | | | | | | | |

Cond – Conditioning
Asp Grad – Asphalt Grade
SBS – Styrene Butadiene Styrene
ASA – Antistrip Additives
L – Lime

## Factorial Experiment

For polymer-modified asphalt binders three liquid antistrip additives were added to each binder at two concentrations (0.5 and 1.0 percent by asphalt weight), resulting in 12 combinations. In addition, the tests were conducted on polymer-modified and straight asphalt binders without liquid additives as control.

For evaluation of moisture susceptibility, a factorial experiment was set up to investigate the significance of variables. Table 2 gives the experimental design for this study. It is a balanced design, and each cell represents a specific combination of treatments. Since eight specimens are required for each cell, a total of 288 specimens were made.

## DISCUSSION OF TEST RESULTS

### Effect of Antistrip Additives on Asphalt Binder Properties

Measurements of polymer-modified asphalt binder properties as affected by liquid antistrip additives are given in Table 3. Blending straight asphalts with 3 percent SBS changes certain physical characteristics of the binders significantly. Changes include increases in absolute and kinematic viscosity, ring and ball softening points, and ductility. Polymer modification increased absolute viscosity of AC-10 asphalt by 400 percent, whereas a slightly smaller increase (360 percent) is observed for AC-20 asphalt. The same trend is observed for kinematic viscosity, with less magnitude. The softening point also increased by 12.2°C (AC-10) and by 8.8°C (AC-20). However, these data are merely for reference, since the purpose of the study is to determine the effect of the liquid antistrip additives on the characteristics of polymer-modified binders and mixtures, not the effect of polymer modification of straight asphalt.

Figure 3 shows the changes in absolute viscosity at 60°C due to liquid antistrip additives.

Results for AC-30P asphalts include the following:

1. At 0.5 percent liquid dosage the viscosity increased, whereas the viscosity decreased for all liquids at 1.0 percent.
2. The effect on viscosity is antistrip additive specific. Liquid I has the most pronounced effect, and Liquid III exhibits least effect; Liquid I at 0.5 percent increased viscosity by 20 percent whereas at 1.0 percent it decreased by 34 percent. The decrease at 1.0 percent is so great that it barely meets the minimum viscosity required for AC-30P by TxDOT specification.
3. For liquids with significant effect (I and II) the effect is highly sensitive to their dosage. Liquid III is least sensitive to dosage.

The following were observed for AC-45P asphalts:

1. Viscosity decreased at both dosages for all liquids. Decreases are more pronounced at 1.0 percent except for Liquid III.

**TABLE 3 Test Results for Polymer-Modified Asphalt Binder Properties as Affected by Liquid Antistrip Additives**

| Grade | Liquid ASA | | Viscosity 60 C,Poises | Viscosity 135 C,cSt | Penetration, 25 C | Softening Point, C | Flash Point, C | Ductility at 4 C | Polymer Con., % | Specific Grav., 25C |
|---|---|---|---|---|---|---|---|---|---|---|
| AC-10 | none | | 1175 | 366 | 100 | 47.2 | 315+ | 13 | none | 1.027 |
| AC-20 | none | | 2296 | 510 | 70 | 50.6 | 315+ | 6 | none | 1.030 |
| AC-30P | none | | 4674 | 932 | 84 | 59.4 | 315.6 | 37 | 3.06 | 1.024 |
| | 0.5 % | I | 5635 | 890 | 83 | 59.4 | 307.2 | 33 | 2.96 | 1.024 |
| | | II | 5025 | 871 | 85 | 54.4 | 298.9 | 41 | 3.10 | 1.023 |
| | | III | 4574 | 880 | 82 | 54.4 | 296.1 | 45 | 3.20 | 1.022 |
| | 1.0 % | I | 3081 | 818 | 83 | 52.8 | 287.8 | 54 | 3.10 | 1.024 |
| | | II | 3570 | 836 | 82 | 53.9 | 298.9 | 44 | 3.10 | 1.026 |
| | | III | 3828 | 912 | 89 | 54.4 | 293.3 | 47 | 3.10 | 1.023 |
| AC-45P | none | | 8289 | 1080 | 69 | 59.4 | 307.2 | 33 | 3.10 | 1.023 |
| | 0.5 % | I | 6511 | 1025 | 73 | 58.9 | 304.4 | 39 | 3.07 | 1.025 |
| | | II | 7494 | 1024 | 75 | 60.0 | 296.1 | 46 | 3.29 | 1.026 |
| | | III | 5516 | 995 | 76 | 58.9 | 298.9 | 45 | 3.25 | 1.024 |
| | 1.0 % | I | 5120 | 1079 | 75 | 60.0 | 285.0 | 40 | 3.31 | 1.024 |
| | | II | 6878 | 922 | 70 | 57.8 | 285.0 | 41 | 3.30 | 1.024 |
| | | III | 5653 | 963 | 76 | 57.2 | 287.8 | 29 | 3.10 | 1.025 |

2. As in AC-30P, the effect on viscosity is antistrip additive specific. At 1.0 percent dosage the largest decrease is obtained with Liquid I, followed by Liquids III and II. A similar trend is observed at 0.5 percent.

The changes in softening points due to liquid antistrip additives are shown in Figure 4. The decreases on AC-30P are significant, ranging from 5°C to 6.6°C, except for Liquid I at 0.5 percent. This amount of decrease is much more than the values reported by Anderson et al. (*2*) on straight asphalts. The decreases on AC-45P are not significant.

King et al. (*3*) investigated the influence of asphalt grade and polymer concentration on the resistance of polymer-modified asphalt mixtures to rutting using the French rutting simulator. They found that for polymer-modified soft asphalts a good correlation was obtained between rut depths and such variables as absolute viscosity and softening point. Figures 3 and 4 indicate that a 1.0 percent liquid dosage will reduce the resistance of AC-30P mixtures to rutting.

### Effect of Antistrip Additives on Moisture Damage

An analysis of variance algorithm was applied to the moisture susceptibility test results. The variables investigated, which included asphalt grade, the use of polymer, antistrip additive type, and its dosage, were all significant except for antistrip additive type. The coefficient of variation of four strength values for each combination of treatments, which corresponds to each cell in Ta-

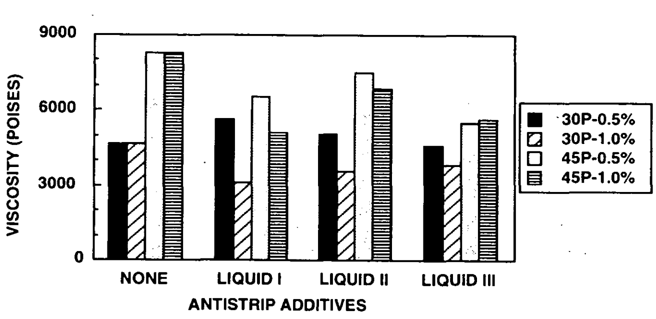


**FIGURE 3 Effect of liquid antistrip additives on absolute viscosity.**

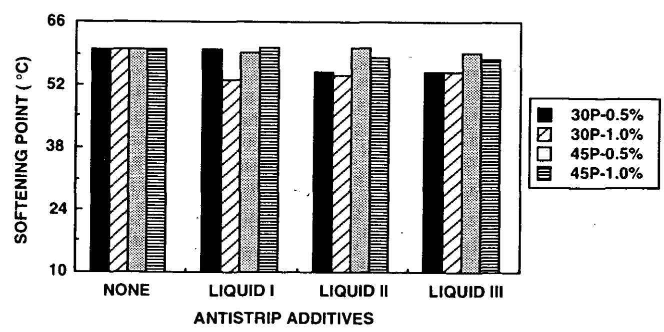


**FIGURE 4 Effect of liquid antistrip additives on softening point.**

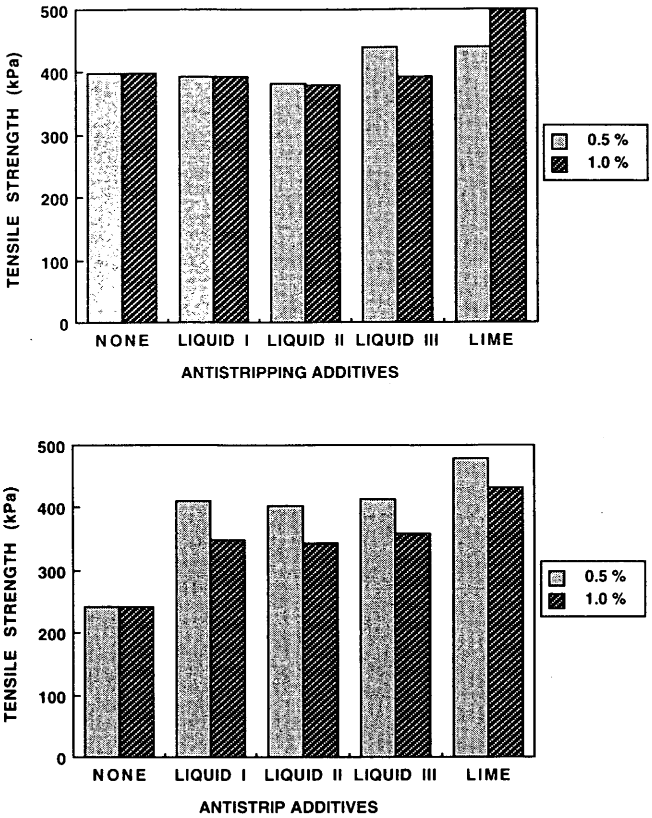


**FIGURE 5** Indirect tensile strengths of AC-10 mixtures: unconditioned (*top*) and conditioned (*bottom*).

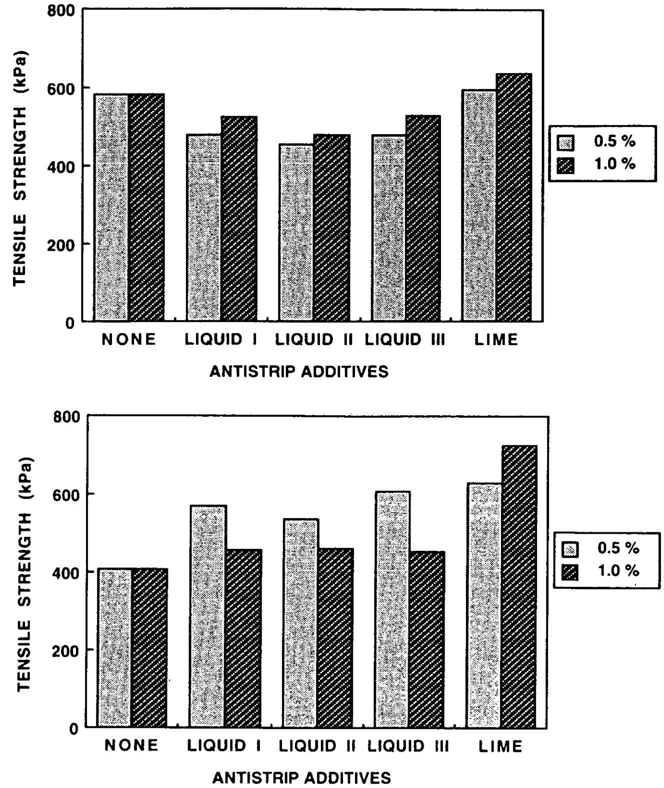


**FIGURE 7** Indirect tensile strengths of AC-30P mixtures: unconditioned (*top*) and conditioned (*bottom*).

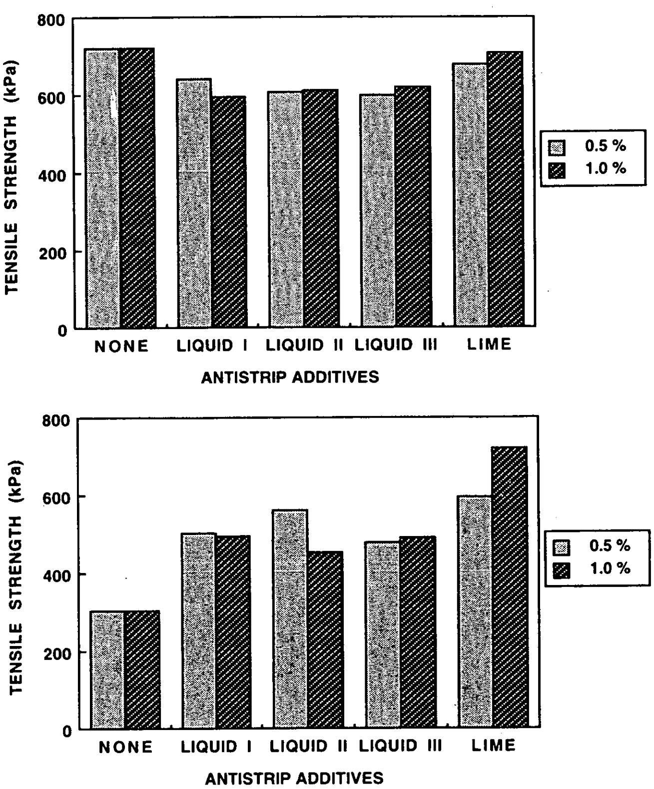


**FIGURE 6** Indirect tensile strengths of AC-20 mixtures: unconditioned (*top*) and conditioned (*bottom*).

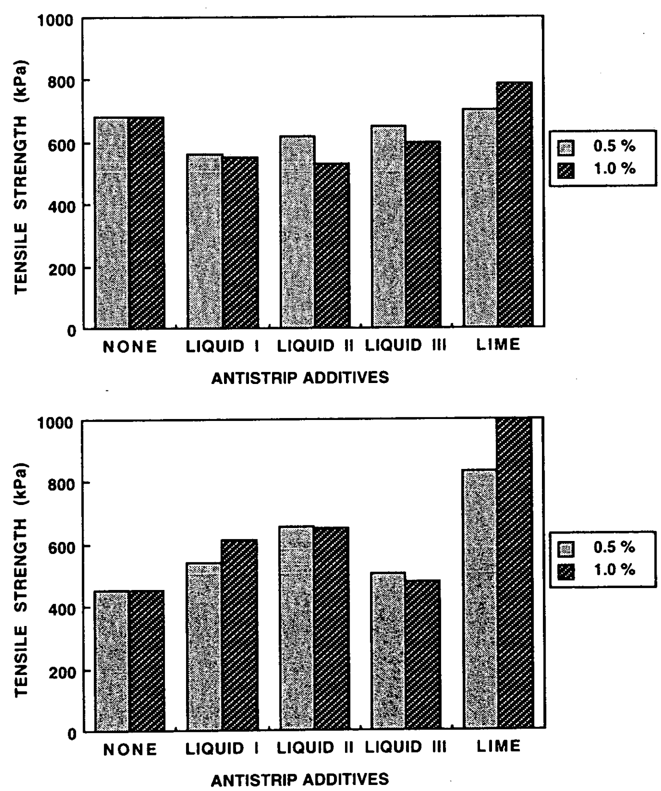


**FIGURE 8** Indirect tensile strengths of AC-45P mixtures: unconditioned (*top*) and conditioned (*bottom*).

ble 2, ranged from 1.01 to 9.9 percent; the average was 3.8 percent. Moisture susceptibility test results are summarized as follows:

- AC-10 mixtures: The strengths of unconditioned and conditioned specimens are shown in Figure 5. Whereas antistrip additives do not have a significant effect on unconditioned strengths, with the exception of lime, they improve conditioned strengths over control. The three liquids have almost identical effects on conditioned strengths. At 0.5 percent dosage the increase over control is approximately 70 percent with liquid additives and 100 percent with lime. Note that the strengths at 1.0 percent dosage are lower than those at 0.5 percent. Anderson et al. (*2*) found that each asphalt has a certain demand for the antistrip additive. On the other hand, Dybalski (*6*) states that excessive dosage of liquid antistrip additives can create a mechanically weak, water-susceptible, shear plane. It appears that the particular AC-10 asphalt binder used in this study has little demand for the liquid antistrip additives. Lime improves both conditioned and unconditioned strengths more than liquids.
- AC-20 mixtures: Figure 6 (*top*) shows a decrease in unconditioned strengths due to additives. The three liquids reduce the strengths by approximately 20 percent over the control. This can be an indication of asphalt softening by liquid additives. Lime also decreased the strengths, but by a small proportion. The improved strengths of specimens conditioned by antistrip additives are shown in Figure 6 (*bottom*). At both dosages all the liquids improve in strength by the same amount except for Liquid II at 0.5 percent. As far as conditioned strengths are concerned, lime is more efficient than the three liquids included in this study.
- AC-30P mixtures: Figure 7 (*top*) shows the effect of additives on unconditioned strengths. Strength reduction by almost identical amounts is produced by three liquids at 0.5 percent dosage. At 1.0 percent dosage the strengths are higher than those at 0.5 percent but still lower than control. Lime enhances unconditioned strengths at both dosages. The improved conditioned strengths over control are shown in Figure 7 (*bottom*). At 1.0 percent the increase is small and almost the same for the three liquids, whereas at 0.5 percent the increase is significant. From this figure it appears that the AC-30P asphalt binders have little demand for antistrip additives. Note that the same observation was made for AC-10 mixtures.
- AC-45P mixtures: A decrease in unconditioned strengths as affected by liquid antistrip additives is shown in Figure 8 (*top*). The effect is more pronounced at 1.0 percent for Liquids II and III. In the case of Liquid I the decrease is not affected by dosage. As with AC-30P mixtures, lime increases strength over control. Conditioned strengths are shown in Figure 8 (*bottom*). Whereas Liquids I and II increase conditioned strength moderately, the increase for Liquid III at both dosages is insignificant. Lime improves conditioned strengths significantly, especially at 1.0 percent dosage.

Tensile strength ratios of all the mixtures investigated in this study are summarized in Figure 9. Polymer-modification itself increases TSR values over straight asphalts. For AC-10 asphalt binders, polymerization made the mixtures exceed the required TSR ratio of 0.7. For AC-20 asphalt binders, polymerization increased TSR values by more than 60 percent. Figure 9 also shows that the effectiveness of additives in mitigating moisture damage is specific to asphalt grade and dosage.

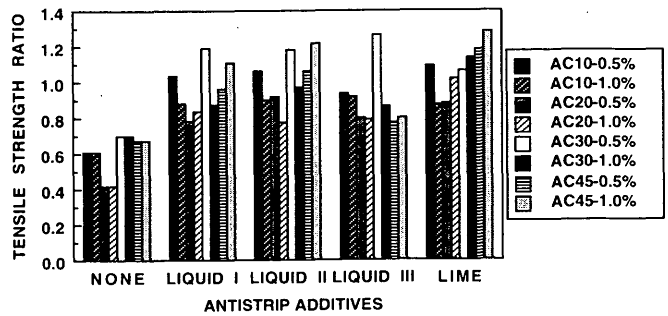


**FIGURE 9 Effect of antistrip additives on TSRs.**

## CONCLUSIONS

A limited study has been conducted to determine the effect of liquid antistrip additives on polymer-modified asphalt binder properties. The effectiveness of antistrip additives on the moisture damage of straight and polymer-modified asphalt mixtures was also investigated. On the basis of the data presented, the following conclusions can be drawn:

1. Liquid antistrip additives affect the viscosity and softening point of polymer-modified asphalts. Adding 1.0 percent of all three liquid antistrip additives included in this study significantly reduced viscosity. Softening point was also decreased with the addition of liquid antistrip additives. The effect is more pronounced for AC-30P than for AC-45P. It may be inferred that the effectiveness of polymer modification of soft straight asphalts on the rut resistance decreases by the addition of 1.0 percent of liquid antistrip additives.
2. In almost every case, liquid antistrip additives reduced unconditioned tensile strength of the polymer-modified asphalt concrete mixtures while increasing conditioned tensile strength. This resulted in tensile strength ratios of some mixtures greater than 1.0.
3. Polymerization of asphalt alone improves the TSR by increasing conditioned strength more than unconditioned strength over control. Lower dosages of liquid antistrip additives than would be required for straight asphalts are recommended for polymer-modified asphalts.
4. Lime is effective in preserving unconditioned and conditioned tensile strengths of the mixtures.

## ACKNOWLEDGMENT

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