The bond between two layers of hot mix asphalt (HMA) is critical to good pavement performance. Poor bond is typically associated with slippage failures, which often occur at locations where traffic accelerates, decelerates or turns. Other problems, such as poor compaction, premature fatigue, top down cracking and surface layer delamination, may also be attributed to insufficient bond between the layers of HMA.

A number of researchers and highway agencies around the world have worked on developing tests for measuring the bond strength between pavement layers. The most common approach has been to employ a shear load at the interface of the layers in core specimens. In 2003, the Florida Department of Transportation concluded a study in which they developed a shear-type bond test and used the method to evaluate tack coat application rates, surface textures and the effect of rain on the tack coat. They now use this method as a forensic tool to evaluate the bond of HMA layers when concerns arise about tack coat applications.

Over the past two years, the National Center for Asphalt Technology (NCAT) has worked on a bond strength project for the Alabama Department of Transportation. The first part of the project was aimed at establishing a simple bond strength test procedure and evaluating the tack coat specifications used by the department. A laboratory experiment was conducted to evaluate the effects of procedural and materials factors on the bond strength between pavement layers. The procedural factors included in the study were test temperature and normal pressure.
Bond Strength

Continued from Page 1

applied to the specimens during the shear test. Materials factors evaluated were three different tack coat materials, three application rates and two mixture gradations providing different surface textures at the interface. The various levels for each of these factors are shown in Table 1.

Analysis of the results found that all of the main factors affected bond strength. Testing temperature had the most significant impact on bond strength. At the higher test temperature, bond strengths decreased significantly due to reduced stiffness of the tack coat materials. On average, bond strengths were 2.3 times greater at 50°F (10°C) compared to 77°F (25°C), and the bond strengths at 140°F (60°C) were about one sixth of the bond strength at 77°F (25°C).

The normal pressure applied during the test affected bond strengths differently for high, intermediate and low temperatures. At the highest test temperature, normal pressure was the most significant factor affecting bond strength. At 140°F (60°C), bond strengths were affected more by interface friction than by the tack coat materials and application rates, and friction is dependent on normal load and surface texture. At 77°F (25°C) and 50°F (10°C), bond strengths were generally insensitive to normal pressure.

The results also showed that the lowest application rates generally provided high bond strengths for the samples with low surface texture. However, for the higher textured mixture, bond strengths were affected little by variations in application rates. The paving grade binder tack coat yielded higher bond strengths than the two emulsions, especially for the fine-graded mixture tested at the highest temperature.

The simple test procedure using 77°F (25°C), no normal load and a loading rate of 2 inches/minute (50mm/min) was selected as an effective and practical method for evaluating the bond strength between pavement layers. The bond test at 140°F (60°C) also has merit since this is a more critical condition at which slippage is more likely to occur. At this temperature, the use of a 10 psi (69 kPa) normal pressure appears to show the influence of friction at the interface of pavement layers. However, at 140°F (60°C) bond strengths are low and, with the observed testing variability, it would be more difficult to establish criteria to discern between acceptable and unacceptable results.

In the second part of the study, test sections with different tack coat application rates were set up on seven paving projects. For each test section, the actual application rates were measured and cores were taken to measure the bond strength. On a few projects, the measured tack coat application rates were significantly lower than the range targeted for the project. This indicates that the distributor trucks on these projects were not properly calibrated to apply the tack coat at the target rate. A key finding of the field study was that the bond strength between pavement layers is significantly enhanced for milled surfaces, which create good interlock at the interface.

The bond strength procedure has also been used in the forensic evaluation of several pavements. Several slippage failures on taxiways at the Orlando International Airport were investigated. The slippage failures were all in areas where large aircraft were turning and braking at high speeds and generally occurred at longitudinal joints. Tests on cores near the distresses showed that the bond strength at the joints averaged about 50% of that from cores taken from the interior of the mat. Bond strength tests have also been conducted on projects where questions were raised about the quality of the tack coat. A common observation on cores with low bond strength is contamination of the interface with dirt.

A number of other studies are underway to further examine tack coats and bond strength procedures. NCHRP Project 9-40 was initiated this year to determine optimum application methods, asphalt binder materials, equipment types and calibration procedures for various uses of tack coats. The lead research agency is the Louisiana Transportation Research Center. This study is scheduled for completion in January 2008. A worldwide interlaboratory study on interlayer bonding has also been initiated by the Réunion Internationale des Laboratoires d’Essais et de Recherches sur les Matériaux et les Constructions (RILEM). This round-robin study will enable comparison of different methods for measuring bond strength. Another study by the Washington State Department of Transportation and Washington State University is underway to evaluate test sections constructed with two asphalt emulsion tack coats at two application rates on milled and unmilled HMA surfaces. Other factors being evaluated are surface cleanliness and cure time. Various tests are being used to evaluate the effectiveness of the tack coats.

The advancements made with measuring the bond strength between pavement layers should have numerous benefits. Pavement engineers will be able to better evaluate pavement problems and develop improved specifications and construction methods for tack coats to assure good bond between pavement layers and better pavement performance.

| Table 1. Factors and Levels Used in the Laboratory Experiment |
| Factor | Levels |
| Mix Type (Texture) | 19.0 mm NMAS coarse graded, 4.75 mm NMAS fine graded |
| Tack Material | CRS-2, CSS-1, PG 64-22 |
| Application Rate | 0.02, 0.05, 0.08 gal/yd² (based on residual asphalt) |
| Normal Pressure | 0, 10, 20 psi (0, 69 and 138 kPa) |
| Temperature | 50, 77, 140°F (10, 25, 60°C) |
After its initial construction in 2000 and the application of over 10,000 equivalent single axle loadings (ESALS), the NCAT Pavement Test Track was reconstructed in 2003. A structural study was included in the 2003 reconstruction. Trafficking for the second cycle of the Track has now been completed, and plans are being refined for the third cycle of testing.

Trucking operations for the 2003 Track were completed on December 17, 2005. A total of 10,012,718 ESALs were safely applied to the 22 sections placed in 2003, which means that 20,012,850 total ESALs were applied to the other 23 sections that were placed in 2000 (having been subjected to two cycles of traffic). Over 1.73 million miles were driven in the Track's second research cycle in order to compress a mix design lifetime of truck traffic into two years.

Preventive and corrective maintenance is currently being performed on the fleet in order to prepare for the next cycle of traffic, which is scheduled to begin in September of 2006.

A final set of transverse profiles was measured at three stratified random test locations per section after the completion of truck traffic. Data from this effort were used to compute average rut depths for all 45 test sections. Rutting ranged from a low of 1 mm to a high of 7 mm, with an overall average of 3.3 mm. Roughness for all the experimental sections (both old and new) averaged 71 inches per mile (1120 mm/km).

Of the eight sections built with thinner pavement structures, which were designed to fail before the completion of truck traffic, only the thinnest (5-inch) sections had to be replaced. One other 7-inch section had extensive cracking, three 7-inch sections had some cracking, and two 9-inch sections had no cracking.

Based on both surface performance and subsurface pavement response measurements, it was possible to successfully calibrate mechanistic-empirical analysis methods and performance models.

A detailed forensic study to quantify the final condition of the experimental sections will be completed before the Track is rebuilt in the summer of 2006. Multiple trenches have been cut in the structural experiment in order to investigate the nature and cause of distresses. Both of the 9-inch structural sections and three of the 7-inch structural sections will be subjected to more truck traffic in order to reach failure.

A proposal for the third cycle of testing has been advertised on the Transportation Pooled Fund Program website located at http://www.pooledfund.org. This study is available to view under “Proposed Studies,” solicitation number 1032.

Planning is underway to rebuild the facility in 2006. The experiment (shown in Figure 1) will again consist of traffic continuation on some existing sections, new mix performance and structural performance options for pooled fund participants. The structural experiment will include a mix of existing and new sections.

Several innovative technologies will be employed during Track reconstruction, such as the twin layer paver shown in Figure 2.

In support of the overall transportation research focus at the Track, an off-road test facility was recently completed and will be used to research all-terrain vehicles in both military and civilian applications.
Calendar of Events

2006

June 19-23  Petersen Asphalt Research Conference and Pavement Performance Prediction Symposium
Laramie, WY
Website: http://www.petersenasphaltconference.org/

June 20-29  NCAT Professor Training Course
Auburn, AL
Contact: Ray Brown, (334) 844-6228 or brownel@eng.auburn.edu

August 12-17  10th International Conference on Asphalt Pavements (ISAP)
Hilton Quebec
Quebec, Canada
Website: http://www.icap2006.fsg.ulaval.ca

September 13-15  International Conference on Perpetual Pavement
Hilton Columbus at Easton Hotel
Columbus, OH
Website: http://webce.ent.ohiou.edu/orite/icpp/icpp.html

October 25-31  AASHTO Annual Meeting
Portland, Oregon
Website: www.transportation.org/aashto/calendar.nsf

November 14-16  SEAUPG Annual Meeting
Wilmington, NC
Contact: Jill Baumgardner at (610) 206-5330
Website: www.seaupg.org

2007

January 21-25  Transportation Research Board 86th Annual Meeting
Washington, DC
Contact: TRB (202) 334-2934 Fax: (202) 334-2003
Website: http://trb.org/news

March 12-14  Association of Asphalt Paving Technologists 82nd Annual Meeting
San Antonio, TX
Website: www.asphalttechnology.org

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