Help from the poor

Subpar aggregate gives INDOT valuable RAP insight

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Highway agencies in today's economy are facing an ongoing need to search for ways to reduce construction costs.

At the same time, public demand for environmental sustainability continues to increase, so many states are exploring options for reducing the barriers to the use of sustainable, economical paving materials. The Indiana Department of Transportation (INDOT) has recently implemented specification changes aimed at increasing the appropriate use of reclaimed asphalt pavement (RAP) and locally available aggregates with these goals in mind, while also ensuring no loss of quality. These changes were based in part on the results of two research projects sponsored by INDOT and conducted by the North Central Superpave Center at Purdue University.

Wanting the maximum

It is well known that RAP has been used successfully in a variety of asphalt mixtures for decades. RAP represents a sustainable source of aggregates and asphalt binder that can be reused in new asphalt mixtures to reduce the demand for new materials, shrink the amount of RAP stockpiled or landfilled and to decrease costs. Today's economic and environmental climates, however, are spurring demand to use greater quantities of RAP.

Like many other states, Indiana has historically limited or banned the use of RAP in asphalt-pavement surfaces because of uncertainties about the aggregate and binder properties in the RAP. INDOT questioned whether it would be possible to use RAP, with unknown aggregate properties, in surface mixes without compromising friction. Most natural aggregates in Indiana are carbonates, some of which are susceptible to polishing under traffic. There also was a concern about the possibility of substantial amounts of aged RAP binder increasing the occurrence of surface cracking.

To investigate the possibility of easing the restrictions on the use of RAP in asphalt surfaces, INDOT sponsored research to explore the effects of RAP with poor or unknown aggregate qualities in order to establish maximum allowable RAP contents that would provide friction levels comparable to the existing allowable aggregates and blends. The effects of RAP on thermal cracking also were investigated at the potential allowable RAP contents.

The first step in the research was to produce a RAP material in the laboratory that incorporated aggregates of known, poor frictional properties. This was intended to be a worst-case situation. After much searching, a suitable aggregate source was identified, and RAP was produced by laboratory mixing and aging.

The second step was to establish an evaluation procedure to investigate the effects of increasing RAP contents on mixture frictional properties. After reviewing existing laboratory test methods, the research team adopted a technique to evaluate the surface properties of lab-fabricated slabs of asphalt mix and to simulate the polishing action of traffic. The surface textures of slabs were assessed using a laser-based device called a circular track meter (CTM) and the frictional properties were measured with a dynamic friction tester (DFT). The polishing effects of traffic were simulated by a three-wheeled circular track polishing machine (CTPM). The CTM, DFT and CTPM all operate on the same footprint.

Next, asphalt mixtures with 15%, 25% and 40% of this lab-fabricated RAP were produced. The mixes were compacted into 20-in. by 20-in. slabs. The slabs were subjected to more than 165,000 wheel passes in the polishing device, with periodic measurements of the changes in texture and friction.

These results suggested that up to 25-40% RAP with unknown aggregate properties could possibly be used, when blended with higher-quality virgin aggregates, without significant loss of friction. These threshold limits were further evaluated by testing slabs made with field-sampled RAP materials from across the state to ensure that the lab-produced RAP was truly a worst case. In addition, low-temperature cracking tests were performed on mixtures at the potential RAP threshold limits to ensure that the increased RAP content would not lead to more surface cracking. Testing the actual RAP sources confirmed the findings from testing the lab-fabricated RAP.

Although Indiana did not typically allow the use of RAP in surfaces mixtures, there were a few existing experimental or low-volume roadways where RAP had been allowed. Field friction testing also was conducted on these existing roadways to explore their frictional performance. The field results showed acceptable performance after three to five years of low-volume traffic at RAP contents of 15-25% and after more than 10 years of interstate traffic with 15% RAP. These field results increased the confidence to increase the allowable RAP content somewhat.

Ultimately, the research showed that the addition of high quantities of poor-quality RAP materials did impact the frictional properties and cracking resistance of the mixtures, but that lower amounts of RAP had minimal effect. The frictional properties of mixtures with the worst-case RAP were acceptable at over 25%.

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Similarly, low-temperature indirect tensile testing showed an increased susceptibility to thermal cracking as the RAP content increased, but the change in critical cracking temperature was relatively small at the 25% RAP level. At 40% RAP, without a change in the virgin binder grade, the critical cracking temperature was about 6°C warmer than the control mixture. This finding supported the need for a binder grade change for RAP contents approaching 40%, as indicated in other research.

During the time this research was under way, INDOT also was considering changing its basis for calculating RAP content from a percentage by weight of mix to the percent of virgin binder replaced by reclaimed binder. The impetus for this change was the increasing use of fractionated fine RAP, which has higher binder contents than typical RAP, and the use of reclaimed asphalt shingles. Specifying the maximum binder replacement allows INDOT

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to control the amount of oxidized binder in new mixtures to help control cracking.

Based on the research and the change to binder replacement, INDOT increased the allowable RAP content in surface mixtures. For traffic volumes of up to 3 million equivalent single-axle loads (ESALs) over a 20-year design life, the allowable RAP content was increased from 25% by weight of mix to 40% binder replacement; reclaimed shingles may provide up to 25% of the total binder in these mixes. INDOT had previously not allowed the use of RAP in surfaces with design traffic levels greater than 3 million ESALs. Based on this and other research, the current specifications allow up to 15% binder replacement for design traffic volumes more than 3 million ESALs; shingles are not allowed in these mixtures.

Piles for progress

Another important component of Indiana's evaluation of RAP for surface mixtures was developing a thorough understanding of the properties of RAP materials in the state. INDOT accomplished this by sampling and testing more than 30 existing RAP stockpiles around the state. The RAP binder from these samples was extracted, recovered and graded according to the conventional PG grading tests. The overall average binder grade was determined to be PG 90-11 with standard deviations of 5° on the high-temperature grade and 3° on the low-temperature grade.

This data also was used to explore potential differences in RAP properties in the northern and southern parts of the state, which could have been caused by differences in virgin binders used in the past or differences in aging because of the climate. The conclusion reached is that there is no significant difference in the RAP properties in different parts of the state.

INDOT also determined the average continuous grades of virgin binder grades used in the state. With the average RAP and virgin binder grades, they investigated the maximum RAP binder contents that could be blended with the virgin binder to yield the design binder grade. This internal analysis and the sponsored research ultimately led to the revised specifications now in use. Under these specifications, up to 25% binder replacement is allowed with no change in the virgin binder grade; between 25% and 40% binder replacement is permitted if the virgin binder grade is reduced one increment on both the high- and low-temperature grades.

Working with the locals

Another approach to reducing construction costs is to maximize the use of locally available materials, specifically limestone aggregates. INDOT specifications already allowed widespread use of local aggregates in deeper courses of hot-mix asphalt (HMA) pavements, but surface mixes (especially for high-volume traffic) typically required high-friction aggregates such as steel slag, blast-furnace slag or sandstone. These types of aggregates are not readily available in all parts of the state, requiring long haul distances from limited sources in Indiana or even out of state. These premium aggregates are more expensive plus have the additional cost of transportation; using more locally available materials would reduce, but not eliminate, these costs.

The main concern with using local materials is pavement friction, similar to the concerns about using RAP in surface mixes. So, INDOT sponsored a research project to investigate the feasibility of using greater quantities of local, less-polish-resistant aggregates in asphalt surfaces. The evaluation procedure established in the RAP study was used to explore the effects of increasing the amount of limestone coarse and fine aggregates in surface mixes.

Samples of blends of various quantities of polish-susceptible aggregates with high-friction aggregates were prepared, polished to simulate the action of traffic and tested in the laboratory for their frictional properties. The variables considered include mix type (HMA and SMA), coarse-aggregate type (two polish-susceptible aggregates blended with steel-furnace slag, blast-furnace slag and sandstone), polish-susceptible aggregate content and amount of limestone fine aggregate (in HMA).

Based on the results, allowable thresholds of 20% limestone coarse aggregate and 20% limestone fine aggregate were recommended for high-volume surface mixes when blended with high-quality friction aggregates such as steel slag, air-cooled blast-furnace slag or sandstone.

The laboratory evaluation procedure has now been implemented as a standard Indiana test method. Contractors and material suppliers who want to offer a new aggregate source to INDOT for consideration as a polish-resistant aggregate (PRA) may have the source tested and compared with a known high-friction aggregate. If the new source compares favorably with the known aggregate, a field trial can be placed to test the source under real-world conditions. The field friction of the test section is monitored for two years. If the results are acceptable, the source is categorized as a PRA. PRAs may be used for traffic volumes up to 10 million ESALs as the sole coarse aggregate and may be used for higher volumes when blended with slag or sandstone.

Win-win situation

INDOT's research and implementation efforts have resulted in several approaches to controlling the costs of asphalt surfaces while preserving the pavement quality and using more sustainable construction practices. Their efforts will continue to explore other options to meet their goals of providing safe, economical and high-performing pavements. **R&B**

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