Subgrades sustaining high impact loads from trains need to be considered when specifiers and engineers conduct life cycle cost analyses. When you do a life-cycle cost analysis for future construction, you make some assumptions on how things are going to perform,” he said. “What I learned from this study and from reviews of several other area examples is that those assumptions do not match up with historical costs and performance of these pavements.”

**Do Your Own Comparison**

Specifiers and engineers need to conduct their own studies and reviews of pavement performance and expenditures in their own states, said Cross.

“This was a study in Kansas. Here is what I would tell other engineers in other states. Go back and do the study in your own state. Take a look at your materials, climate, and traffic. Then, take an objective look at those factors,” he said. “When you do your life-cycle cost analysis, you need to have some defendable, objective criteria to use,” said Cross. “And it needs to be based on how pavements have performed in the past—not preconceived notions.”

To download a copy of the report discussed in this article, go to the Asphalt Pavement Alliance website and follow the links: www.asphaltalliance.com > Life Cycle Costs > Kansas Cost Study.

**The Asphalt Pavement Alliance is an industry coalition of the National Asphalt Pavement Association, State Asphalt Pavement Associations, and the Asphalt Institute.**

Although maintenance costs have increased dramatically for today’s freight railroads, typical track roadbed construction and maintenance technologies have changed little over the past 100 years. Thousands of miles of roadbeds are in need of strengthening or rebuilding.

New technology is needed to provide stronger and longer-lasting structures to carry the higher speeds and heavier axle loading with a minimum of maintenance expense. Conventional ballast systems may no longer be feasible on some trackbeds with weak or unstable subgrades. For these conditions, hot mix asphalt (HMA) underlayment of trackbeds is a practical and effective answer. Conventional ballast systems need to be considered when specifiers and engineers conduct life cycle cost analyses.” When you do a life-cycle cost analysis for future construction, you make some assumptions on how things are going to perform,” he said. “What I learned from this study and from reviews of several other area examples is that those assumptions do not match up with historical costs and performance of these pavements.”

**Assumptions Not Valid**

Although most people view concrete as the stronger paving material, the study did not back up those stereotypes, commented Cross.

“Some people might assume that a concrete pavement is going to be maintenance free for a long portion of its life. That did not turn out to be true,” he said. “Or they might think a concrete pavement is going to have an incredibly long service life. This may not be true. It certainly was not the case in Kansas.”

According to the study, the average time until the first minor maintenance treatment for a PCC pavement was nine years. Of the PCC pavements studied in Kansas, 55 percent had a service life of less than 30 years and 63 percent of the PCC pavements had a service life of less than 35 years.

The HMA pavements studied received periodic planned overlays and maintenance work for about 30 years after construction. This maintenance consisted of HMA overlays, seals, and cold milling. After about 33 years, rehabilitation was done on HMA pavements where thermal cracking had occurred. During maintenance and rehabilitation treatments on the HMA pavements, total expenditures were much higher and the repairs more difficult on the PCC pavements. According to Cross, one major reason that HMA was more affordable was because most HMA pavement can be recycled back into new paving material.

Cross said the results of this study need to be considered when specifiers and engineers conduct life cycle cost analyses. “When you do a life-cycle cost analysis for future construction, you make some assumptions on how things are going to perform,” he said. “What I learned from this study and from reviews of several other area examples is that those assumptions do not match up with historical costs and performance of these pavements.”
Underlayment Mix Design

When HMA is used as trackbed underlayment, the composition is significantly different from that used in conventional railroad applications. The composition provides the best performance for trackbed underlayment is a low-modulus mix made by specifying the local dense-graded highway mix containing a maximum aggregate size between 1.0 and 1.5 inches.

Underlayment Solve Railroad Maintenance Issues

The asphalt binder content is increased approximately 0.5 percent above optimum highway applications. This creates the low modulus mix that can be easily compacted to a density of less than 5 percent in-place air voids and voids filled with asphalt greater than 78 percent. Used as a conventional roadway application, this mix would probably flush and rut. But this relatively soft, flexible material is just the right mix for railroad trackbeds. The increased percentage of asphalt binder in the mix increases its durability and prevents raveling and cracking.

Research Efforts

A substantial amount of private research has been done over the last twenty years by railroad researchers, the asphalt industry and university professors. Two of the experts, Dr. Jerry Rose, University of Kentucky, and Jay Hensley, retired Chief Engineer of the Asphalt Institute, have concluded that HMA underlayment provides specific benefits that maximize the operational efficiency of the railroad tracks. Some of these benefits are:

- It creates an impermeable layer that diverts water from infiltrating the ballast, which prevents fluctuation in subgrade moisture content and, consequently, variation in subgrade strength.
- It enhances load distribution and reduces the compressive live loads applied to the subgrade.
- It increases the modulus of the ballast and sub-ballast layers.

Research by the Transportation Technology Center, Inc. (TTCI) in Pueblo, Colorado, has substantiated much of the work done by railroad researchers. TTCI is a subsidiary of the Association of American Railroads. A pit approximately 700 feet long, 12 feet wide and 5 feet deep was excavated in the subgrade beneath a section of existing track. The intent of the experiment was to model the effect of a low modulus subgrade on track modulus and geometry.

130 Million Gross Tons of Traffic

Between 1991 and 1996, this section of track was subjected to approximately 130 million gross tons of traffic (39-ton axle load rail cars). During the initial phase of testing the conventional cross section, correction of track geometry was required at intervals of 10 to 30 million gross tons. Near the conclusion of these phases, however, correction of the track geometry was required after 1 to 2 million gross tons until a general shear failure of the subgrade occurred. Between 1996 and the summer of 1999, the track cross section was modified to consist of approximately 6 inches of sub-ballast, 16 inches of fabric-reinforced sub-ballast, and 8 inches of ballast supporting concrete ties and rail. After the application of more than 180 million gross tons of traffic, the reinforced sub-ballast was still well within deflection tolerances permitted for the composite material and did not require any reestablishment of track geometry.

HMA Underlayment Test

During the summer of 1999, the fabric-reinforced material was removed and the track cross section was modified to accommodate two different thicknesses of HMA underlayment. One 350-foot segment consisted of 6 inches of sub-ballast, 4 inches of compacted HMA underlayment, and 12 inches of ballast supporting concrete ties and rail. The second 350-foot segment consisted of 6 inches of sub-ballast, 8 inches of compacted HMA underlayment and 8 inches of ballast supporting the concrete ties and rail. The track was loaded with the 39-ton axle-load cars. After 240 million gross tons of traffic, the two HMA sections showed less degradation than the all ballast sections. Moisture contents for the sub-ballast under the HMA underlayment were also reduced.

Conclusion

Although not yet widely used in the railroad industry, the cost effectiveness and superior performance of HMA underlayment for trackbeds is getting the attention of railroad maintenance engineers and, as a result of the TTCI tests, the American Railroad Maintenance Association (AREMA) has recently begun the process of developing guidelines for the use of HMA underlayment. For more on HMA underlayment for trackbeds, read Hot Mix Asphalt for Quality Railroad Transit Trackbeds, IS-137, which is available from the Asphalt Institute. Tom Deddens is the Asphalt Institute’s Field Engineer for Arkansas, Illinois, Kansas, Missouri, and Nebraska.
and a significant interruption of traffic. The BNSF is currently in the process of double-tracking most of its high-speed, transcontinental track located in northern Oklahoma, the Texas panhandle, New Mexico and Arizona. HMA underlayment is included in the design section of a number of the new track sidings along this route.

HMA Underlayment in Tunnels

The Cincinnati Southern Express (CSX) has made significant use of asphalt underlayment for the support of expensive track structures, such as track switches, track crossings and roadway crossings. CSX also pioneered the use of HMA underlayment on the floor of tunnels with approximately 12 inches of ballast supporting wooden or concrete ties. The HMA underlayment acts to reduce some of the vibration that develops between the massive locomotive and the hard rock tunnel floor.

Underlayment Mix Design

When HMA is used as trackbed underlayment, the composition is significantly different from that used in conventional roadway applications. The composition that provides the best performance for trackbed underlayment is a low modulus mix made by specifying the local dense-graded highway mix containing a maximum aggregate size between 1.0 and 1.5 inches. The asphalt binder content is increased approximately 0.5 percent above optimum highway applications. This creates the low modulus mix that can be easily compacted to a density of less than 5 percent in-place air voids and voids filled with asphalt greater than 78 percent. Used as a conventional roadway application, this mix would probably flush and rut. But this relatively soft, flexible material is just the right mix for railroad trackbeds. The increased percentage of asphalt binder in the mix increases its durability and prevents raveling and cracking.

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- It creates an impermeable layer that diverts water from infiltrating the ballast, which prevents fluctuation in subgrade moisture content and, consequently, variation in subgrade strength.
- It enhances load distribution and reduces the compactive live loads applied to the subgrade.
- It increases the modulus of the ballast and sub-ballast layers. Impregnation of the sharp ballast into the flexible surface of the HMA underlayment provides a high level of confinement for the ballast, which, in turn, develops high shear resistance and uniform distribution of applied live loads.
- It separates the subgrade from sub-ballast and ballast layers.
- It prevents contamination or fouling of the ballast by the subgrade and significantly reduces stress distribution on the upper layers of ballast.

TTCI Research

During the last ten years, full-scale testing by the Transportation Technology Center, Inc. (TTCI) in Pueblo, Colorado, has substantiated much of the work done by railroad researchers. TTCI is a subsidiary of the Association of American Railroads, the Federal Railroad Administration, the railroad industry and various suppliers. In 1991, TTTI set up an experiment on the High Tonnage Loop (HTL) of the Facility for Accelerated Testing (FAST) track. A pit approximately 700 feet long, 12 feet wide and 5 feet deep was excavated in the subgrade beneath a section of existing track. The intent of the experiment was to model the effect of a low modulus subgrade on track modulus and geometry.

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