

# Long-Term Assessment of Asphalt Trackbed Component Materials' Properties and Performance

by

Jerry G. Rose, PE  
Professor of Civil Engineering  
161 OH Raymond Bldg  
University of Kentucky  
Lexington, KY 40506-0281  
859/257-4278, jrose@engr.uky.edu

and

Henry M. Lees, Jr., PE  
Sr. Engineer-Track & Structures  
BNSF Railway Company  
920 SE Quincy Street  
Topeka, KS 66612-1116  
785/435-6459, henry.lees@bnsf.com

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## **ABSTRACT**

The uses of Hot Mix Asphalt as subballast layers within railroad track structures for new trackbed construction and trackbed maintenance applications have grown steadily in the United States during the past 25 years. The asphalt layer (termed underlayment) is used in lieu of an all-granular subballast layer. This paper documents the results of a characterization and evaluation study to ascertain the effects of long-term exposure in various trackbed environments on the material properties of the trackbed materials – asphalt and underlying (roadbed) subgrade. The primary purpose of the testing program was to determine if any weathering or physical/chemical deterioration of the materials were occurring that could adversely affect long-term performance of the trackbeds. Six asphalt trackbeds, ranging in age from 12 to 25 years; on heavy traffic revenue lines in three states were recently core drilled. Test data on the trackbed materials were compared to data obtained previously. The expected benefits and trackbed life projections are discussed relative to current basic design and construction practices.

Keywords: hot-mix asphalt, railway trackbeds, trackbed performance, subgrades, subballast

## INTRODUCTION

From its beginnings in 1830, the railroads have been a primary mode of freight transport in this country. Its dominance is becoming significant in recent years as train speeds, gross ton-miles, and axle loads have increased. The latest Association of American Railroads statistics (1) indicate that in 2005 an all-time record 1.7 trillion ton-miles of freight was carried over the nation's nearly 141,000-mile (227,000 km) railroad network. The average freight car weight has increased to 129 tons (117 metric tons) with most new cars having gross weights of 143 tons (130 metric tons). The importance of developing and specifying premium track structures and components to adequately carry the increased tonnage is a current reality of the industry. Failure of the track structure and components results in difficulty maintaining track geometric features necessary for efficient and safe train operations. Maintenance costs and track outages increase due to frequent maintenance and renewal cycles.

The inability of the track structure to adequately carry the imposed loadings can be categorized into two primary failure types. The first one is failure of the **subgrade** when the pressure transmitted to the subgrade is higher than the inherent bearing capacity of the particular subgrade. The subgrade soil's ability to accommodate loading pressures is a function of its shear strength, cohesion, plasticity, density, and moisture content. A well-compacted subgrade soil that is confined and maintained reasonably dry will normally perform adequately for an indefinite period of time. A possible exception is a highly compressible soil such as peat. Subgrade failures adversely affect track geometry and are normally difficult and expensive to correct.

The second type of trackbed failure occurs when one or more of the **trackbed structural components** fail to perform satisfactorily for a reasonable period of time. This is commonly manifested by the subballast, and particularly the ballast, becoming clogged (fouled) with excessive quantities of fine size material. This lowers the shear strength of the ballast and bearing capacity of the subballast. Fouling is normally due to degradation of the ballast, infiltration of subgrade soil particles, extraneous droppings from hopper cars, or an accumulation of wind-blown fine particles. Track geometry is adversely affected to varying degrees. It is difficult to rectify track geometry in fouled ballast with typical trackbed maintenance surfacing equipment.

Periodic replacement of the track components (rails, ties, fasteners, and special trackworks) cannot be avoided (2). It is desirable to increase the service life of the components. The adequacy of the trackbed structural components supporting the track can have a significant effect on the life of the track components by reducing impact stresses and minimizing deflections of the track.

The solution for minimizing **subgrade** failures involves a combination of reducing the pressure on the top of the subgrade, improving drainage (effectively improving the properties of the subgrade), adding thickness to the trackbed structural components, or utilizing higher quality/load bearing trackbed components. The solution for minimizing **structural component** failure is designing and selecting reasonable fasteners and track components so that an optimum track structural support stiffness will be achieved. In order to design optimum track structural support stiffness, it is necessary to determine the applied pressures at different levels in the track support structure and select a combination of materials and thicknesses to withstand the applied pressures.

## **ASPHALT TRACKBEDS**

The most common trackbed is composed of all-granular materials consisting of layers of ballast and subballast over a prepared subgrade, as noted in Figure 1a. During the past twenty-five years, the use of Hot Mix Asphalt as a subballast layer within the track structure has steadily increased until it is becoming standard practice in many areas of the United States. The asphalt-bound impermeable layer, typically 5 to 6 in. (125 to 150 mm) thick, provides a “hardpan” to protect the underlying roadbed and to support the overlying ballast and track. Various tests and performance evaluations have shown numerous advantages over traditional all-granular (ballast) trackbeds, particularly on heavy tonnage lines traversing areas of marginal geotechnical engineering characteristics (3, 4, 5).

The most common asphalt trackbed, termed asphalt underlayment as depicted in Figure 1b, incorporates the layer of asphalt in lieu of the granular subballast. Ballast is used above the asphalt layer in a similar manner as conventional all-granular trackbeds. The ballast provides a protective cover for the asphalt by blocking the sunlight, protecting the surface from air and water, and maintaining a relatively constant temperature and environment. The ballast provides a means to adjust the track geometry, when necessary, with typical maintenance equipment and procedures.

Recent studies involve instrumenting asphalt trackbeds with earth pressure cells and displacement transducers to measure pressure levels and distributions within the track structure and rail deflections under moving trains. These tests, conducted in real time domain train operations with 286,000 lb (130 metric ton) cars, confirm the positive

attributes of the asphalt layer (6, 7). Peak dynamic pressures range from 13 to 17 psi (90 to 120 kPa) on top of the asphalt layer. These are further reduced to 7 to 8 psi (50 to 55 kPa) under the asphalt layer at the subgrade interface. Dynamic track deflections average 0.25 in. (6.4 mm) for wood tie track and 0.05 in. (1.3 mm) for concrete tie track. These are considered optimum for quality trackbeds. Dynamic track modulus values consistently average 2,900 lb/in/in (20 MPa) for wood tie track and 7,200 lb/in/in (50 MPa) for concrete tie track, also considered optimum stiffness levels.

### **BASIC ASPHALT TRACKBED DESIGN AND CONSTRUCTION PRACTICES**

The asphalt mix is similar to that used for highway applications, but can be slightly modified for optimum performance in the trackbed environment. It is placed as a layer or mat of specified thickness and the common term is “underlayment” since the layer is placed under the ballast and above the subgrade or old roadbed. It basically serves as a subballast. A lesser used technique, known as “full-depth or overlayment” is applicable for special situations and involves placing the track directly on the asphalt layer with no ballast between the ties or slab and the asphalt. This technique is primarily used in Europe and Japan (8, 9, 10).

The most common asphalt mix is produced as a hot mix asphalt, thus the acronym – HMA. Cold mix asphalt mixtures and in-place stabilization of roadbeds with liquid asphalts have been used sparingly. Normally the asphalt mix is produced in a local mixing plant, at a temperature around 275°F (135°C), hauled to the site in dump trucks, spread to the desired thickness, and compacted while being maintained at an elevated temperature.

The asphalt underlayment system is equally applicable for heavy tonnage freight lines, high-speed passenger lines, commuter and transit lines, freight and intermodal yards, ballast loadout facilities, and practically all types of special trackworks including crossing diamonds, turnouts, tunnel floors, bridge approaches, and highway crossings. The majority of the asphalt trackbed applications are on existing lines. The applications number in the thousands and most have been used on in-service lines in conjunction with rehabilitation or renewal of special trackworks, particularly when existing subgrade support and drainage conditions are inferior. Current installation practices, which require removal of the track, are not applicable for long sections of in-service lines since the time required to remove and replace the track is not commensurate with typical work windows. Studies are underway to develop equipment to place asphalt under a raised track on in-service lines without removing the track.

New construction, particularly double-tracking and yard installations, account for the largest projects. At these selected locations, conventional trackbed designs were considered to be inadequate or uneconomical to provide the required level of long-term performance because of inherent poor qualities of the roadbed support materials and drainage conditions. The roadbed/subgrade is readily available for regular highway paving practices prior to track placement (11, 12).

Recommended asphalt mixture specifications and trackbed section designs have evolved over the years. Following is a summary of prevailing practices. Detailed information is available elsewhere (5, 13).

Normally a local dense-graded asphalt highway base mix is specified, slightly modified with an additional 0.5% asphalt (binder) cement content. The ideal design air

void content for the compacted asphalt layer is 2 to 3%. Typical asphalt layer width is 12 ft (3.7 m) and thickness ranges from 5 to 6 in. (125 to 150 mm). Ballast thickness above the asphalt is from 8 to 12 in. (200 to 300 mm).

The roadbed should be reasonably well-compacted, well-drained, and capable of accommodating the hauling and spreading equipment without excessive rutting or deformation. A slight crown or side slope is desirable. The need to purposefully improve sub-surface drainage, or improve support with additional granular material prior to placing the asphalt, will depend on an analysis of the conditions at the specific site.

### **ASPHALT TRACKBED MATERIALS TESTS AND EVALUATIONS**

Eight asphalt trackbeds, located in five different states, ranging from 12 to 29 years old and having various asphalt thicknesses and trackbed support materials, were selected for materials characterization studies. Pertinent classification and descriptive data for the projects are presented in Table 1. Samples were obtained during summer 2007. Previous characterization studies, primarily conducted in 1998 (14, 15), were available for selected projects and are included herein for comparison purposes.

Samples normally were taken at three randomly selected locations at each project. Samples were removed from the field side crib area (Figure 2). The following sequence was followed at each location:

- Remove and sample ballast from crib area down to top of asphalt layer
- Measure ballast thickness and observe condition
- Obtain 6 in. (150 mm) diameter core sample with core drill

- Protect samples from core drilling water so as to not contaminate the underlying roadbed
- Measure asphalt core thickness, observe condition, and place in sealed plastic bag
- Auger out roadbed samples, note distance below asphalt, separate if layered conditions existed, place in sealed plastic bags
- Repeat drilling sequence, normally three cores were taken at each location
- Fill core holes with cold mix patch and replace ballast

### **Geotechnical Tests and Evaluations**

The following geotechnical laboratory tests and evaluations using standard ASTM procedures were conducted on the subgrade/roadbed samples:

- Moisture Content; in-situ condition – as sampled
- Grain Size Analysis; sieve and hydrometer
- Atterberg Limits; liquid limit, plastic limit, plasticity index
- Soil Classification Determinations; unified system
- Standard Proctor Moisture-Density
- California Bearing Ratio; unsoaked and soaked

The samples were recorded by depth below the asphalt and placed in separate containers when differences in size, color, texture, or moisture content were observed. The sealed containers were transported to the geotechnical laboratory at the Kentucky Transportation Cabinet for subsequent tests.

Table 2 contains the geotechnical evaluations for the subgrade/roadbed samples. Data from the 1998 sampling is included for comparison with the recent 2007 data. Subgrade samples were obtained from four projects. The subballast and subgrade were sampled separately at the Hoover site. This was the only project where granular subballast was used below the asphalt. The Quinlan site had two distinctly different subgrades due to differing topography. Thus, six different samples were analyzed for the four projects.

The initial testing phase involved in-situ moisture content tests, grain-size analysis, and Atterberg limits tests followed by soil classifications by the Unified procedure. Based on the classifications, similar materials from a site were combined to accumulate samples of sufficient size for the subsequent standard Proctor moisture-density test to determine optimum moisture content for maximum dry density and for the California bearing ratio (CBR) test.

#### *In-Situ Moisture Contents*

There was significant interest in determining the existing moisture contents of the subgrade materials directly under the asphalt layer and subsequently comparing these with previous measurements with the optimum moisture contents for the respective materials. Every effort was made to remove core drilling water to protect subgrade samples. No significant water penetrated the soil (particularly clay) subgrades. No sample appeared to be overly wet or wet of optimum based on initial observations.

In-situ moisture contents are provided in Table 2 for both the 1998 and 2007 sampling operations. The values varied relative to the type of subgrade soil, but were

very site specific comparable with values obtained during the 1998 sampling. These data are shown in Figure 3. There was an average net decrease of 0.1% change in moisture contents over the span of nine years.

Two of the projects had in-situ moisture tests taken during similar coring operations on several previous occasions, dating to the early 1980s. This data is presented in Figure 4. The Oklahoma City trackbed has a highly plastic clay under the asphalt. The range in moisture values is minimal. The Conway trackbed has the existing old roadbed under the asphalt that is highly variable mixture of large-size ballast, small-size ballast, cinder, coal, soil, etc. The significance of the data is that the average moisture contents of the materials underlying the asphalt have remained essentially unchanged at each respective site over the years from the time the asphalt was placed. Previous concerns about pore water pressure, and its effects on lowering subgrade soil strengths, are not founded.

#### *Unified Soil Classifications*

The soil classifications, based on grain size analyses and Atterberg limits tests, are provided in Table 2. The test projects were selected to include a wide variety of subgrade materials, ranging from reasonably high plastic clays to more silty/sandy materials having little or no plasticity. As expected, little difference in soil classifications was noticed at individual sites for the samples taken in 1998 and 2007.

### *Standard Proctor Moisture-Density*

The standard Proctor moisture-density test was conducted to determine the optimum moisture content for achieving maximum density. The minus 0.50 in. (12.5 mm) size material was removed. The optimum moisture content data is included in Table 2.

Figure 5 shows the change in optimum moisture contents for the six samples between 1998 and 2007 sampling. The changes were typically less than 1 percent, indicating similar materials.

Figure 6 is a graphical comparison of the measured in-situ moisture contents and the Proctor optimum moisture values. The linearity of the relationship is shown in Figure 7. Note that the  $R^2$  value is in excess of 0.9 indicating very good correlation. The in-situ moisture contents were very close to optimum values. These findings indicate that the subgrade materials under the asphalt layer can be considered, for design purposes, to have a prevailing moisture contents very near optimum for maximum compactability and strength.

In addition, strength or bearing capacity values used in design calculations should be reflective of optimum moisture content values. It is common practice, when designing conventional all-granular trackbeds, to assume the subgrade is in a soaked condition, which for most soils is a weaker condition than when the soil is at optimum moisture.

### *California Bearing Ratio*

California Bearing Ratio (CBR) specimens were prepared at moisture contents determined from previous Proctor tests to be optimum for maximum density. Specimens

were tested immediately in the unsoaked condition. Companion specimens were soaked in water for 96 hours prior to testing. Tests were conducted at 0.1 in. (2.5 mm) penetration.

The CBR data is presented in Table 2. The values were typical for the types of materials tested. For example, the highest CBR value was in the 50 range, which was a select river gravel used as a subballast (locally known as “Tex-Flex” base), for the Hoover project. A select crushed stone product is considered to have a CBR value of 100. The other subgrade materials have CBR values significantly lower, as expected, even for the unsoaked condition.

A comparison of unsoaked and soaked CBR test values is presented graphically in Figure 8. CBR values were significantly lower for the soaked samples, particularly those containing clay size material, which had values in the low single digits. Test results for the 1998 and 2007 sampling were reasonably close considering that materials sufficient for only one unsoaked and one soaked specimen per site were available for tests. Likely the 1998 and 2007 test comparisons would have been less variable had additional tests been conducted to obtain averages based on several replicable tests.

As noted previously, the in-situ moisture contents for individual samples were very close to the those determined from the Proctor test to be near optimum. This relationship is shown graphically in Figure 7. Since the unsoaked CBR values are derived from tests on samples at optimum moisture contents, and the test results from samples under asphalt trackbeds were determined to be at or very near optimum moisture contents, it is obvious that the unsoaked CBR bearing capacity values are

appropriate to use for structural design calculations. The soaked (lower) CBR values result in a conservative overdesign. The preceding statements are not necessarily applicable to the open all-granular trackbeds, which are prone to variable moisture contents depending on the amount of rainfall and surface drainage conditions, and corresponding variations in support strength. The subgrade/roadbed materials underlying the asphalt layers were at moisture contents near optimum, and based on long-term monitoring at two sites, maintain optimum moisture conditions for indefinite periods.

### **Asphalt Mixture and Core Tests and Analysis**

The following laboratory tests were conducted on the asphalt mixtures and cores at the National Center for Asphalt Technology (NCAT) at Auburn University:

- Density and Voids Analysis
- Asphalt (binder) Content
- Extracted Aggregate Gradation
- Resilient Modulus @ 5°C (41°F) and 25°C (77°F) @ 1 loading cycle per second
- Dynamic Modulus @ 5°C (41°F) and 25°C (77°F) @ 1 hertz load frequency
- Recovered Asphalt Binder Properties
  - Penetration @ 25°C (77°F)
  - Absolute Viscosity @ 60°C (140°F)
  - Kinematic Viscosity @ 135°C (275°F)
  - Dynamic Shear Rheometer @ 25°C (77°F)

Figure 9 depicts typical asphalt cores as obtained from the trackbeds. Table 3 contains results for the Mix Extraction Tests and Core Analysis. Table 4 contains test results on the Recovered Asphalt Binders. The most recent test results are listed in the far right columns. This represents 2007 data for six of the projects. The significance of the prior tests is so that the changes in the properties and weathering characteristics of the asphalt layers can be evaluated over a period of time.

#### *Mix Extraction Tests and Core Analysis*

The extraction test results (Table 3) are indicative of dense-graded base mixes with 1.0 in. (25 mm) maximum size aggregate and about 6 percent passing the No. 200 sieve. These are basically in conformance with guidelines previously described (5, 15). Asphalt binder contents vary somewhat, ranging from 4.5 to 7.0 percent. No particular changes are evident in aggregate gradations or asphalt binder contents over the period of years.

Tests on the asphalt cores included density and voids analyses and dynamic and resilient modulus tests. The air voids were typically higher than desirable for five of the sites ranging from 5 to 9 percent. The air voids were purposefully maintained at 2 to 3 percent range at three of the sites. This range is considered to be optimum to resist premature oxidation of the binder. Average air voids for each site were less than the 8% maximum normally believed to represent the upper limit to provide an impermeable layer.

The industry standard dynamic and resilient modulus tests were used to measure the modulus of elasticity of the asphalt cores. In both tests, repeated loads were applied

to a cylindrical specimen and the displacements were measured. The values, reported in Table 3, were measured under uniaxial compression loading for the dynamic modulus and under indirect tensile loading for the resilient modulus. Tests were conducted at two standard temperatures which represent the nominal lowest, 5°C (41°F) and highest, 25°C (77°F), temperature asphalt experiences in the insulated trackbed environment. Recent tests were limited to resilient modulus since it is now considered as more representative of the actual stiffness of the asphalt core.

Values were typically several orders of magnitude higher at the lower temperature, which is normal for a viscoelastic, thermoplastic material – and is characteristic of the asphalt binder in the mix. At lower temperatures, the asphalt becomes stiffer, as reflected in higher modulus (or stiffness) values. At higher temperatures, the asphalt becomes less stiff. Obviously, for asphalt highway environments, where the asphalt is exposed to greater temperature extremes, the stiffness differences from winter to summer are significantly greater than those existing in the insulated trackbed environment.

Figure 10 is a plot of Resilient Modulus versus Age of the asphalt mixes. The circled symbols represent data for cores (obtained from the trackbed in 1998) that cured the final nine years in the laboratory environment. They are plotted directly above the railroad cured data for similar ages. Note that the modulus values for the cores cured the last nine years in the laboratory were higher than the cores in the railroad environment.

The measured modulus values are reasonably consistent for the various sites. There is no particular trend or changes in modulus as a function of time. The mixes vary

in asphalt contents, densities, aggregate gradations, and binder properties from site-to-site, which can be expected to produce variations in modulus values. However, these variations are minimal. The significant factor is that the values are reasonably typical for new, unweathered mixes not exemplifying fatigue and cracking – thus low values, or exemplifying hardening/weathering of the binder – thus high values. The values are basically intermediate in magnitude, even after many years of loading and weathering in the trackbed. The asphalt appears to be undergoing little, if any, weathering or deterioration in the trackbed environment.

#### *Recovered Asphalt Binder Tests*

Test results for Penetration, Absolute and Kinematic Viscosities, and Dynamic Shear Rheometer on the recovered asphalt binders are contained in Table 4. Plots of Penetration and Absolute Viscosity versus Age of the Asphalt Underlayments are contained in Figures 11<sub>a</sub> and 11<sub>b</sub>. The data points circled at the ends of the trend lines represent the 2007 values. The preceding data points are nine years prior, or 1998 values.

Penetration values will tend to decrease and viscosity values will tend to increase with time due to expected oxidizing and hardening of the asphalt binders. There is indication of this phenomenon when comparing the 1998 and 2007 test values.

However, the Abson method (ASTM D1856) was used for the 1998 and prior asphalt recoveries; whereas, the Rotary Evaporator method (ASTM D5404) was used for the 2007 recoveries. The Rotovapor method is considered more effective at removing the solvent. Therefore, the 2007 penetration values would be expected to be lower and the

2007 absolute viscosity values would be expected to be higher than their respective 1998 values. These trends are evident from Figures 12<sub>a</sub> and 12<sub>b</sub> respectively.

It is likely that the original asphalt binders were PAC 60-70 penetration or AC-20 viscosity graded. The effects of short-term aging (elevated temperatures) during the pavement construction process and long-term aging for several years will reduce the binder penetration to the 25 to 40 range and the absolute viscosity at 60°C (140°F) will be maintained to less than 15,000 poises (17). These samples meet these criteria, indicating minimal oxidation and weathering.

The Dynamic Shear Rheometer (DSR) procedure for evaluating asphalt binders was developed in the mid-1990s. Fortunately this test was conducted in 1998 on samples from 5 of the 6 sites and this data is compared to the 2007 data in Figure 13. The standard for performance grade asphalt binders, after short- and long-term aging, is that the DSR at 25°C (77°F) should be less than 5,000 kPa. Note in Figure 13 that all of the samples are well below 5,000 kPa, another indication that the asphalt binders in the trackbed cores are not oxidizing and hardening excessively (17).

### *Discussion*

It is not surprising that the asphalt binder in the trackbed cores are not oxidizing and hardening to the extent normally observed for asphalt highway pavements. This is largely due to two factors. The surface of the asphalt is typically submerged 20 in. (500 mm) from the surface (atmosphere) by the ballast/tie cribs and the depth of ballast below the ties. The lack of sunlight and reduced oxygen largely negates normal weathering which occurs in highway pavements exposed to sunlight.

Secondly, the range in temperature extremes which the HMA mat undergoes from summer to winter is significantly less in the insulated trackbed environment than for exposed highway pavements. This information was developed initially during 1982 and 1995 tests in Kentucky from buried thermistors, and reported previously (14) and reproduced in Table 5. Additional tests during 2000 at the AAR Pueblo test site confirmed the previous tests (6).

## **SUMMARY AND CONCLUSIONS**

The primary purpose of this investigation was to determine, based on test results, current materials properties of the asphalt and underlying materials in order to assess if any weathering or deterioration of the materials was occurring in the trackbed environment which could adversely affect long-term performance.

Material characterization evaluations were conducted on asphalt cores and subgrade/roadbed samples from eight asphalt trackbeds. The trackbeds were from 12 to 29 years old when tested and were distributed over five states. The inherent conditions varied significantly from site-to-site. These included asphalt thickness and composition, ballast thickness, trackbed support, and traffic. Previous characterization evaluations were available for the projects and the results were included for comparisons with recent evaluations.

The significant finding relative to the materials (old roadbed/subgrade) directly under the asphalt layer, is that the in-situ moisture contents are very close to laboratory determined optimum values for maximum density of the respective materials. The asphalt layer is not performing as a membrane to collect and trap moisture, thus

weakening support. Actually, since the in-situ moisture contents are at or near optimum for maximum density, the strengths and load carrying capacities of the underlying materials are also at or near optimum. Furthermore, average moisture contents remain essentially unchanged, at or near optimum, for the two projects from which previous data was available. For design purposes, it is reasonable to base strength or bearing capacity values at optimum conditions (moisture content and density) for the material under the asphalt layer. Using strength or bearing capacity values determined for the soaked condition, common for highway designs, is inappropriate for asphalt trackbed designs. The unsoaked, optimum moisture content condition is consistent with in-service trackbed conditions.

An equally significant finding, relative to the asphalt cores characterizations, is that the asphalt binders and asphalt mixes do not exhibit any indication of excessive hardening (brittleness), weathering, or deterioration even after many years in the trackbed environment. This is considered to be primarily due to the insulative effects of the overlying ballast which protects the asphalt from excessive temperature extremes and oxidation and hardening of the asphalt binder. These factors will contribute to a long fatigue life for the asphalt layer. There is no indication that the asphalt layers are experiencing any loss of fatigue life based on resilient modulus test on the extracted cores.

The typical failure modes experienced by asphalt highway pavements are 1) rutting at high temperatures, 2) cracking and fatigue at low temperatures, 3) stripping/raveling under the suction of high tire pressures on wet pavements, and 4) progressive fatigue cracking due to inadequate subgrade support, generally augmented

by high moisture and improper drainage. These conditions do not exist in asphalt railroad trackbeds. For example, the temperatures are not sufficiently high to promote rutting. Conversely, the temperatures are not sufficiently low to promote low temperature cracking and decreased fatigue life, nor does the asphalt binder weather or harden excessively in the insulated trackbed environment which would have further negative influence on cracking and fatigue life. Obviously the tendency to strip/ravel is essentially eliminated in the trackbed environment since there is no rubber suction action. Also, the moisture contents of the underlying subgrade/roadbed support materials are maintained at or near optimum for maximum density and support strength.

In addition, peak dynamic vertical pressures on top of the asphalt layer are typically less than 20 psi (138 kPa) under 286,000 lb (130 metric ton) locomotives and heavily loaded cars. (16) This is only two to three times larger than the pressure exerted by an average-size person standing on an asphalt pavement, and much less than pressures exerted by heavily loaded highway trucks, which can be in excess of 100 psi (690 kPa). These peak dynamic pressures are further reduced to less than 10 psi (69 kPa) under the asphalt layer at the subgrade interface (6).

Based on the findings and analyses of the research reported herein, asphalt underlayments installed in conformance with the basic design and construction practices also reported herein, should have an extremely long service life as a premium subballast to properly support railroad tracks. There is no indication of any deterioration or cracks of the asphalt after many years of heavy traffic under widely varying conditions.

Ancillary benefits of a long-lasting premium subballast support material for railroad tracks include the following: increased strength, decreased abrasion, and increased life of the ballast; decreased wear and improved fatigue life of the ties, rail, and premium-cost track components such as special trackworks; a consistent level of track stiffness (modulus) designed for optimum levels; reduced maintenance activities and associated track closures; and improved adherence to track geometric parameters. All of these benefits impact favorably on achieving efficient operation of the rail transportation system.

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