Proceedings of the 2014 Joint Rail Conference
JRC2014
April 2-4, 2014, Colorado Springs, CO, USA

JRC 2014-3761

REHABILITATION, ASSESSMENT AND MANAGEMENT PRACTICES TO ENSURE LONG-LIFE, HIGH PERFORMANCE HIGHWAY-RAILWAY AT-GRADE CROSSINGS

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ABSTRACT
Rehabilitating and/or replacement of highway-railway at-grade crossings frequently accounts for major track maintenance expenses for the U.S. highway governmental agencies and the railroad industry. Substantial numbers of crossings deteriorate at a more rapid rate than the abutting trackbed and pavement. This is largely due to the structural implications of the combined highway and railway loadings within the jointly used crossing area and difficultly in maintaining adequate drainage within the immediate crossing area.

A highway-railway at-grade crossing is designed to fulfill its primary purpose of providing a smooth surface for the safe passage of rubber-tired vehicles across the railroad. The jointly used area represents a significantly expensive unit cost of the highway and railway line. Ideally a highway crossing will maintain a smooth surface and stable trackbed for a long period of time. This reduces costly and frequent disruptions to highway and railway traffic when the track needs adjusting or the surface needs replacing due to rideability concerns. Technology is available for “fast-tracking” the renewal of highway crossings within one day (if desired) using a panel system with specifically designed layered support and premium materials. The procedure involves complete removal of the old crossing panel and trackbed materials. The replacement consists of an asphalt underlayment layer, a pre-compacted ballast layer, a new track panel, and a new crossing surface. The composition of the asphalt layer is similar to that used for highways. It replaces all, or a portion of, the typical granular subballast layer.

A cooperative effort between the local highway agency and the railway company will ideally reduce costs, improve the quality of the finished product, and reduce outage of the highway and railroad during the rehabilitation process. A major objective is to minimize disruption to both highway and railway traffic during the renewal process in addition to improving the performance and extending the life of the crossing. Typical schedules are for the railroad to be out-of- service for a maximum of four hours and for the highway to be closed only eight to twelve hours, when length of closure is an issue of importance.

Numerous long-term tests and performance evaluations of heavy trafficked railway and highway crossings are presented herein. Pressure cells have been imbedded within the trackbed to document pressure levels within the layered portion of the crossing structure due to loadings from trains and highway vehicles. In addition, long-term settlement measurements and assessments for several crossings are documented. The measurements indicate significantly reduced long-term settlements of crossings incorporating the rapid-renewal, layered system, while maintaining acceptable smoothness levels. In addition, standard practices and specifications are presented for several highway agencies and railway companies using this technology for their crossing renewal programs. These long-term performance evaluations indicate this practice ensures long-life, economical, smooth crossings for improved safety and operating performances. The application of this technology continues to increase and it is considered a standard practice in many areas of the country.

A crossing management technique (model decision-making process) is described for assessing the optimum engineering solutions to restore desired smoothness, minimize subsequent settlement, and ensure acceptable long-term performances for highway-railway at-grade crossings. These are site-specific and based on historical performance, the present observed

performance and condition, and measurable parameters for the particular crossing.

The model decision-making process includes three options, depending on the source(s) of the crossing roughness. The process can involve merely making improvements to the quality of the pavement approaches. Another scenario can be to replace only the deteriorated crossing surface. The most involved solution is the complete renewal of the crossing surface, track panel, and underlying support to rectify a chronic problem that may be inhibiting the crossing from achieving optimum performance.

INTRODUCTION

The U. S. railroad system consists of over 750 railroads running on 140,000 miles of track. Every day trains travel across more than 212,000 highway-railway at-grade crossings, 136,000 (or 2/3) of which are public crossings. On the average there is one public crossing for every mile of track and one private crossing for every two miles of track. There are an additional 38,000 locations where railroad tracks and roadways cross at different levels as grade separated crossings, the ideal situation.

At-grade highway-railway crossings represent significantly expensive special portions of highway roadways and railway lines. The crossing surface and trackbed (rail, ties, and ballast/subballast) replace the highway pavement structure within the jointly used crossing area. The typical cost of open track, from the top of subgrade, is about $100 per track-foot. However, the additional cost within the crossing can add as much as $100 to $500 per track-foot, depending on the type of crossing surface utilized and the extent of the trackbed support and drainage improvements required during the renewal/rehabilitation process.

Crossings are likely to deteriorate at a faster rate and require reconstruction at more frequent intervals than the pavement (or railroad) adjacent to the crossing. This is primarily dependent on the amount and type of highway traffic and the relative quality of the trackbed support. In addition, crossings often provide a low ride quality, due to settlement soon after installation or reconstruction, and the driving public must tolerate this annoyance until the crossing is renewed.

Structurally, railways and highways are typically designed very differently for the common areas at crossings. The all-granular railroad roadbed and track system is designed to be flexible, deflecting as much as 0.25 in. (6.5 mm) under normal railroad traffic. This support is normally carried through the crossing. The highway pavement structure is designed to be essentially rigid, deflecting a minuscule amount even under heavy trucks. The crossing (track) support is basically the track structure composed of granular (crushed aggregate or ballast) that may provide a lower level of load-carrying capacity as that of the highway approaches. Thus the crossing area deflects excessively with subsequent permanent settlement. This results in rapid abrasion and wear of the crossing surface and support materials and the surface often fails prematurely due to deterioration and settlement of the crossing.

It is important that crossing structures provide adequate structural integrity to support the imposed loadings. Typical crossing designs only provide for the crossing surface to be placed beside the rails and above the ties. Only unbound granular materials and possibly a geosynthetic are placed under the ties. The open granular trackbed permits surface water entering along the rail and the joints within the surface to penetrate and subsequently saturate the underlying subgrade/roadbed, thus lowering the structural integrity of the structure support. Groundwater, if present due to inadequate drainage, can further lower the structural integrity of the trackbed support layer.

Crossing structures having inadequate structural support deflect excessively under combined highway/ railroad loadings, which increase effective impact stresses and fatigue on the crossing components. The surface deteriorates prematurely. Permanent settlement occurs within the crossing area imparting additional impact stresses and fatigue from both highway and railroad loadings.

Periodically, the trackbed on both sides of the crossing may be raised with additional ballast prior to normal surfacing of the track to restore the desired geometric features. The crossing can therefore become a permanent low spot in the railroad profile if the track profile is not equally raised through the crossing, which further increases impact stresses from the railroad loadings. In addition, the low spot collects water, and the impaired drainage can further weaken the underlying structure.

When the roughness and deterioration of the crossing adversely affects the safety and reasonable traffic operations across the crossing, the crossing must be removed and replaced at high cost and inconvenience to the traveling public and railroad operations. Typically, the crossing is replaced using similar materials and techniques, thus assuring a similar series of events.

THE IDEAL CROSSING RENEWAL PROCESS

The goals for the ideal highway/rail crossing renewal process are to (Rose, Swiderski, and Anderson, 2009):

- Provide a quality, safe, cost effective highway/rail crossing that will remain stable, smooth, and serviceable for both highway and rail traffic for a minimum of 15 years with minimal annual cost (minimizing costly disruptions for track and crossing maintenance),

- Accomplish the complete renewal (trackbed and crossing surface) in a minimum of time, when required, without significant disruption to rail and highway traffic, when necessary this can be a maximum four-hour train curfew and 8 to 12-hour highway closure, and

• Utilize a cooperative, cost-sharing approach, involving both the railroad (and its contractor, if applicable) and the local governmental/highway agency, to provide an economical, quality product.

The importance of a planning meeting well in advance of the anticipated date for the renewal cannot be overemphasized. The railroad company and governmental/highway agency must address three primary issues (Rose, 2009 (1F)):

• Select Date – This can have a major effect on minimizing disruption and inconveniences to rail and highway traffic. Site specific factors must be considered depending on the prevailing rail and highway traffic.

• Assign Responsibilities – These can be shared between the railroad company and governmental/highway agency to maximize the inherent expertise and economies of the two entities. The railroad company will normally be responsible for the work activities within the track area. The governmental/highway agency may participate with the traffic control and asphalt paving. These are activities frequently provided in concert with their typical highway maintenance responsibilities.

• Share Cost – This may be predetermined as policies vary significantly due to specific governmental statutes and railroad company policies. However, a major objective is to extend available funds by assigning activities to the entity that can provide a quality product at the lowest cost. Normally, activities within the railroad right-of-way must be conducted by, or under supervision of, the railroad company. These primarily include removal and installation of track and crossing materials. The local highway/governmental agency may handle traffic control on the highway, provide public announcements, and perform some or all of the asphalt paving.

TYPICAL ALL-GRANUALAR RENEWAL/REHAB-ALITATION PROCESS

Historically the most common track (sub-structural) support for highway-railway crossings consists of unbound granular materials as depicted in Figure 1a. The upper portion is typically composed of open-graded, free-draining ballast size particles, generally sized from 3 in. (75 mm) to about 0.25 in. (6.5 mm). A granular layer, composed of finer sized particles, or subballast, is below the ballast. The voids in the ballast layer can potentially provide a path for water to seep through and permeate the underlying subballast and possibly the subgrade. This can decrease the structural integrity of the support. The inherent lack of support for the highway vehicles in the track crossing area can result in excessive deflections of the crossing. The excessive deflections, combined with the lessening of the support strength due to the high moisture contents of the support materials, ultimately result in permanent settlement of the crossing. This adversely affects the highway and railroad profiles in the immediate crossing area.

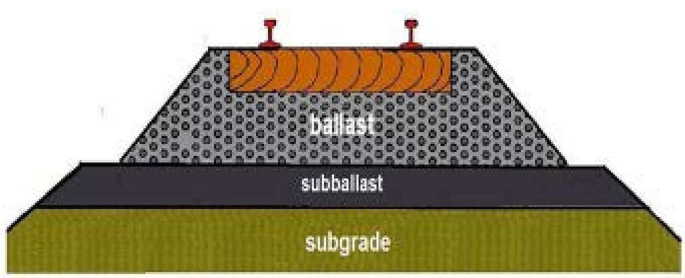

Figure 1a. Typical All-Granular Trackbed.

The typical crossing renewed with conventional granular materials often isn't structurally adequate to withstand the combined highway/railroad loadings. A high-quality substructure (or base) is needed below the trackbed to provide similar load carrying, confining, and waterproofing qualities to the common crossing area – as typically exists in the abutting pavement sections.

ASPHALT UNDERLAYMENT RENEWAL/ REHABILITATION PROCESS

The use of a layer of hot mix asphalt within the track substructure -- in-lieu-of, or in-addition- to conventional granular subballast -- is becoming widely utilized to provide ideal properties to the crossing (Rose, 2011). Perhaps thousands of crossings have been rehabilitated or initially constructed using this procedure. The basic process involves removing the old crossing surface and track panel followed by excavating the underlayment mixture of ballast, subballast, and subgrade to the required depth. These are replaced with a compacted layer of hot mix asphalt (termed asphalt underlayment), a compacted layer of ballast, a new track panel, and a new crossing surface, as depicted in Figure 1b.

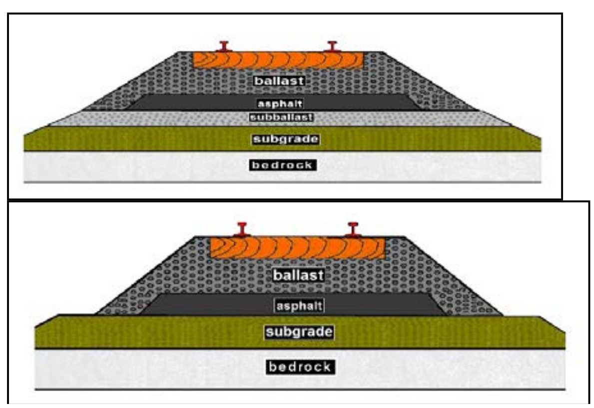

Figure 1b. Typical Asphalt Underlayment (top) and Combination (bottom) Trackbeds.

The addition of the layer of asphalt provides the ideal sub-structural support system for a highway-railway crossing, these being:

- Produces adequate strength to resist the combined highway and rail loadings thus minimizing stresses on the underlying subgrade,

- Minimizes vertical deflections and permanent deformations of the crossings due to highway and rail loadings so that the wear and deteriorations of the crossing components will be minimized, and

- Serves to waterproof the underlying subgrade so that its load carrying capability will not be sacrificed even when placed on marginal quality subgrades.

An additional benefit is that the inclusion of a layer of asphalt is amenable to the "fast tracking" process when desirable. This insinuates that the track can be back in service within four hours and the highway back in service within 8 to 12 hours depending on the extent of the approach installations. The enhanced support provided by the asphalt layer in combination with immediate compaction of the ballast precludes the need to facilitate compaction with train traffic over a period of days. Thus, renewing a crossing can be accomplished in a single day with minimal closing of the crossing and attendant benefits to the traveling public (Rose, 2012).

For a light traffic rail line or a multiple track line, closures may not impact train operations significantly. However, on single-track rail lines with heavy train traffic, the amount of time needed to accomplish the work can dictate if and when rehabilitation work will be scheduled. Also, closing the crossing to vehicular traffic for only one day minimizes disruption to the traveling public. Overall, this method provides a quality, smooth crossing in a minimal amount of time. Figure 2a shows a CSX crossing on WV Route 2 at Ashton, WV placed in 2002 and still in perfect condition requiring no maintenance during the 11 intervening years. Figure 2b shows a CSX rubber seal/asphalt crossing on US 60 west of Owensboro in Western KY, also placed in 2002 that was still in perfect condition after 11 years, although it was recently removed in conjunction with a T&S program. Figure 2c shows a completed section of a 3226-ft (983-m) long crossing on NS in West Brownsville, PA. NS is renewing this crossing in four sections over a four-year period to rectify a previous chronic maintenance expense due to having to renew portions of the crossing at frequent intervals. The final 20 percent (654 ft (200 m)) of the crossing will be renewed during a maintenance blitz on this line in 2014. This crossing, on the heavy tonnage coal-hauling line along Main Street, will have asphalt underlayment support and a concrete surface along the entire distance.

Figure 2a. CSX Crossing on WV Route 2 at Ashton, WV, Perfect Condition after 11 years.

Figure 2b. CSX Crossing on US 60 West of Owensboro, KY, Perfect Condition after 10 years but Slated for Replacement, Note Saw Cuts.

Figure 2c. NS Crossing in West Brownsville, PA, the 3226-ft (983-m) long Crossing is being Replaced in Segments over four years.

TYPICAL ASPHALT TRACKBED DESIGNS

The typical dimensions for the asphalt layer are approximately 12 ft. (3.7 m) wide and approximately 5 to 6 in. (125 to 150 mm) thick. For poor trackbed support conditions and high impact areas, an 8-in. (200-mm) thickness is commonly used. Thickness of the overlying ballast ranges from 8 to 12 in. (200 to 300 mm). Thickness of a granular subballast layer, if utilized, is usually 6 to 8 in. (150 to 200 mm) thick. The length of the asphalt layer will normally extend for a specified distance beyond the immediate crossing area. This distance is based on prevailing conditions at the specific site and the time available to perform the work. A distance of 10 ft. (3 m) or more is desirable.

The asphalt mixture specification is normally the prevailing dense-graded highway base mix in the area having a maximum aggregate size of ¾ to 1½ in. (25 to 38 mm). The asphalt binder content can be increased by 0.5% above that considered optimum for highway applications resulting in a low to medium modulus (plastic) mix, having design air voids of 1 to 3%. This mix is easier to densify to less than 5% in-place air voids and therefore facilitates adequate strength and an impermeable mat. Rutting of the plastic mix is not a concern in the trackbed since the pressures are applied through the ballast over a wide area. Bleeding and flushing are also of little concern since the wheels do not come in direct contact with the asphalt layer and the temperature extremes are minimized in the insulated trackbed environment.

TYPICAL TRACKBED INSTALLATION PRACTICES

The equipment required for installing the asphalt layer varies depending on the size of the installation. For two-lane maintenance/rehabilitation projects, the asphalt is normally back-dumped on grade and spread with a trackhoe, small dozer, bobcat, etc. already on site, prior to compacting with a conventional vibratory roller. This process requires that the old track panel be removed. Based on relative cost analyses for numerous installations, the cost to place the asphalt is minimal, slightly more than placing conventional granular subballast. The cost of the asphalt material delivered to the job site adds a small percentage, about 5%, to the total track removal and replacement costs since it replaces a portion, or all, of the granular subballast. The majority of the costs involve equipment, labor, and track materials. The added time to the track outage to place asphalt is insignificant, provided the track is to be removed and the underlying ballast/subballast replaced with new ballast.

For larger open-track projects, mainly new construction with a prepared subgrade, the asphalt can be placed with conventional asphalt laydown (paving) equipment and compacted with large vibratory rollers. The procedure is similar to highway construction. The cost of the asphalt may be comparable to the cost of granular subballast if quality granular subballast has to be transported long distances due to insufficient quality or quantity in the immediate area. Normally, asphalt is compatible with a wide variety of aggregates. The asphalt can be placed with highway paving equipment as rapidly as highway paving with much less hand-work and concerns of smoothness.

PERFORMANCE MEASURES

Vertical pressures have been measured on crossing surfaces and at various locations on the asphalt layer within the crossing track structure. In addition, long-term settlement measurements and assessments have been evaluated. These are described as follows:

Crossing Trackbed Pressure Tests

Geokon Model 3500-2 earth pressure cells have been used to measure pressures on top of the asphalt layer. These were strategically positioned during the renewal of crossings prior to placement of the ballast. Detailed descriptions for this testing program is provided elsewhere (Rose and Tucker, 2002) (Rose, et al., 2009 (2F)). The pressure distribution within the trackbed is extremely variable. Peak dynamic pressures for rail and highway traffic develop directly below the rail/tie interface.

Figure 3 contains a sample plot of a loaded coal train. The axle loads range from 33 to 36 tons (30 to 32 metric tons) and train speed was about 40 mph. Note that cell 820, located beneath the rail/tie interface, recorded the maximum dynamic pressure on top of the asphalt of about 15 psi (103 kPa) for the locomotives and initial two loaded hopper cars.

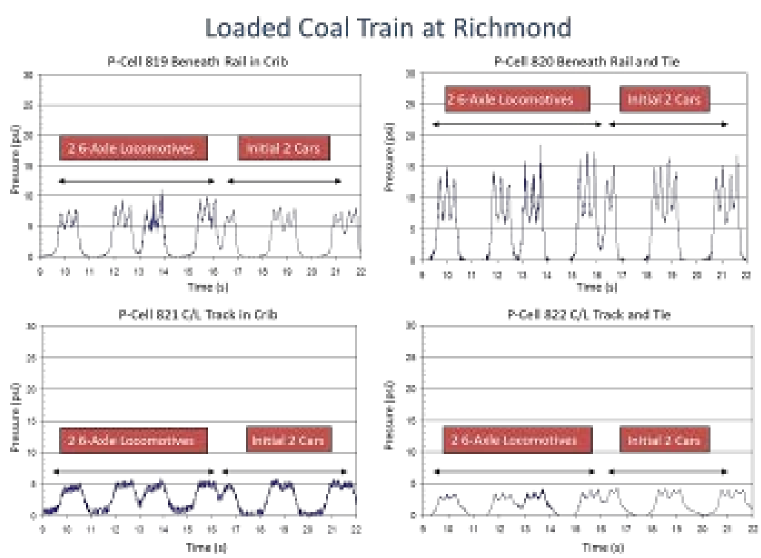

Figure 3. Typical Pressure on Asphalt in Trackbed for Loaded Coal Train.

Figure 4 contains a sample plot of a loaded 80,000-lb (36 metric ton) gross weight concrete truck. The truck wheels traversed the cell directly below the rail/tie interface. The maximum dynamic pressure on top of the asphalt layer is about 5 psi (35 kPa). Pressures for passenger cars and small trucks are typically 0.5 psi (3 kPa) and lower.

Crossing Surface Pressure Tests

Thin matrix-based pressure sensitive ink sensors, manufactured by Tekscan, Inc., have been used to measure surface contact pressures between rubber-tired highway vehicles and crossing surfaces. Detailed descriptions for this testing program are provided elsewhere (Rose, et al., 2009 (2F)). The recorded pressures are very close to the actual tire inflation pressures.

Figure 5 shows the testing procedure and data for a typical 22-wheel, 150,000-lb (68 metric ton) gross weight loaded coal truck. The green areas indicate higher pressure intensities than the blue areas. The white areas are indicative of the tread which does not contact the pavement. Note that the calculated static contact pressure was 135 psi (930 kPa). The measured tire inflation pressure was 138 psi (950 kPa), very close to the Tekscan measurement calculated pressure. This is typical of maximum contact pressures experienced by crossing surfaces.

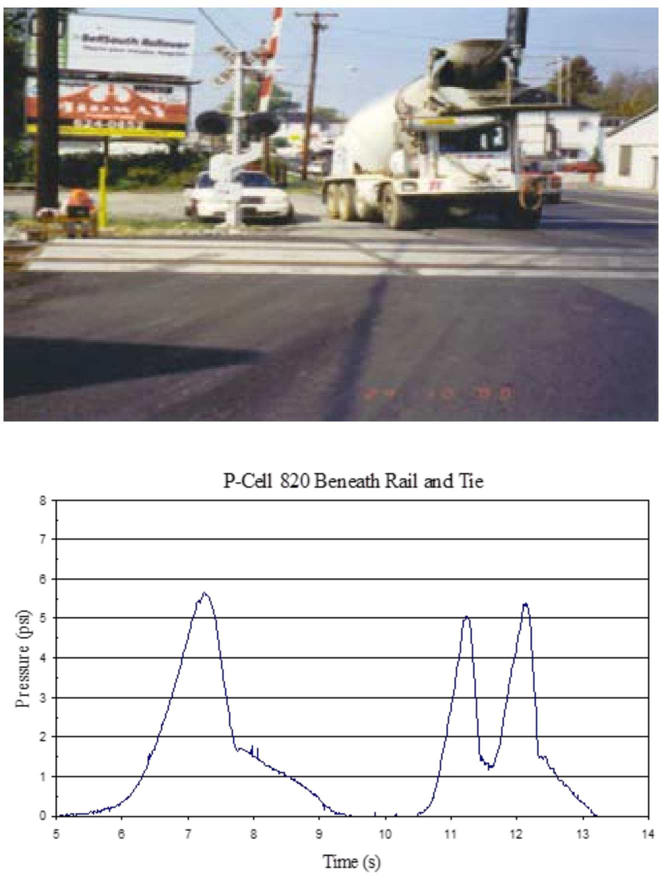

Figure 4. Typical Pressure on Asphalt Layer in Trackbed for 80,000-lb (36,300 kg) Concrete Truck, Front Tire (left) and Rear Tires (right).

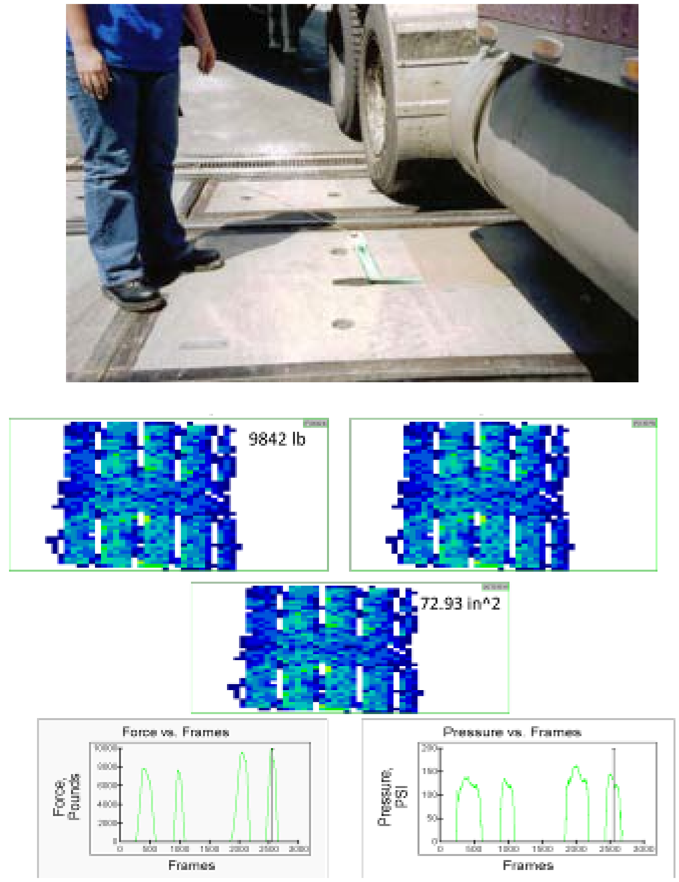

Figure 5. Imprint of Tractor Rear Tire of Loaded Coal Truck on Concrete Crossing.

Long-Term Crossing Settlements

Top-of-Rail elevation profiles were established immediately after rehabilitation of a variety of crossings for the purpose of monitoring long-term settlements. Measurements were established at 10-ft (0.3 m) intervals on both rails throughout the crossing and for approximately 80 ft. (24 m) on both approaches. Repeat profile measurements were taken periodically for three years or longer to assess the rate of total settlements. Detailed descriptions of the measurement techniques and analyses of the data are contained elsewhere (Rose, Swiderski and Anderson, 2009) (Rose, et al., 2009 (3F)).

Figure 6 depicts typical top-of-rail settlement measurements for a representative crossing containing enhanced support consisting of a layer of asphalt. The "heavier" line portion of each profile represents the portion of the highway crossing containing the layer of asphalt. The "lighter" line portions represent the all-granular trackbed approaches. The settlement data and top-of-rail profiles for the asphalt/rubber seal US 60 crossing in Western Kentucky were taken periodically for 54 month period after installation. The train traffic is moderate; the highway traffic is high-speed and high-volume. The crossing area settlement of 0.45 in. (11.4 mm) is 48% of the 0.93 in. (23.6 mm) all-granular track approach settlement. It is obvious that the settlements over the structural enhancement layers in the crossing areas were significantly less than those over the all-granular approaches.

The numerous crossings underlain with asphalt settled 41% of the amount for the all-granular trackbed crossings concurrently evaluated (Rose, Swiderski and Anderson, 2009). In addition, the crossing areas underlain with asphalt settled 44% of that of the abutting all-granular track approaches. The statistical t-test validated the significance of the findings. Settlements of the track approaches to the all-granular crossings were statistically similar to the settlements of the all-granular crossing areas.

The 36-month settlements for the asphalt underlayment crossings, averaged 0.57 in. (14 mm). All of these have heavy highway traffic. The majority of the settlement occurred within the initial 24 months. For comparison, the average settlement for the all-granular crossings, all having minimal highway traffic, for a similar time period, was 1.29 in. (33 mm). All of the asphalt underlayment crossings remain very smooth and serviceable.

EXTENT OF UTILIZATION OF ASPHALT UNDERLAYMENT CROSSINGS

Essentially all of the large Class I railroad companies are selectively using asphalt underlayments for crossings based on engineering analyses of the benefits and logistics for the particular crossing site. Many Shortline railroad companies are involved as well. Numerous Public Agencies are participating with railroad companies in specifying and funding application of this technology. These include – Caltrain, Metrolink, Iowa DOT, MDOT, WVDOT, Tri-Met/WES, KYDOT, Hillsborough Co. FL, IDOT, INDOT, and others. Literally hundreds, perhaps thousands, of crossings in the U.S. have asphalt underlayments. It is becoming a standard practice for several railroads and public agencies for specific conditions and situations. Descriptions of several representative programs follow.

Caltrain

During the past 15 years this 55-mile (88-km) long regional rail link along the San Francisco Peninsula has rehabilitated over 59 street and pedestrian crossings with asphalt underlayment. The high-traffic line caries predominately commuter trains and a limited number of UP freight trains. In addition, numerous crossovers, turnouts, stations, bridge approaches and tunnel approaches and inverts have been underlain with asphalt.

Following is the standard drawing (Figure 7) and excerpts relating to asphalt underlayment (Caltrain designates as HMAC) from Chapter 2 of their Engineering Standards. Note that the HMAC layer is designated as having a minimum thickness of 8 in. (200 mm) and extending a minimum of 10 ft. (3 m) beyond the end of the crossing surface.

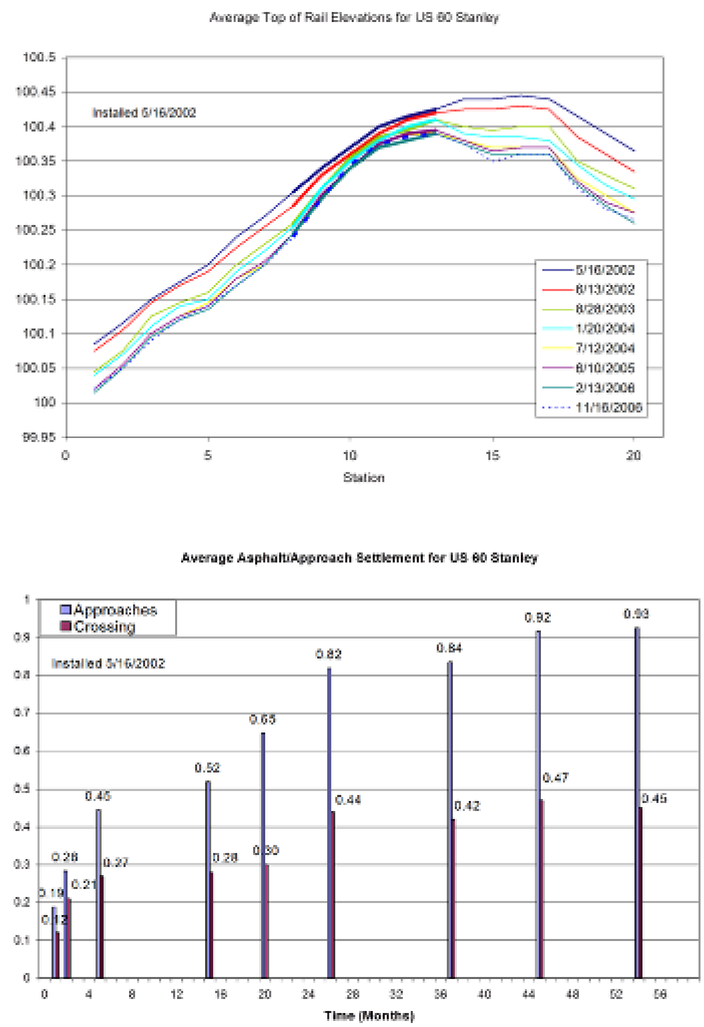

Figure 6. Top-of-Rail Settlement Data for US 60 Stanley Crossing with Underlayment.

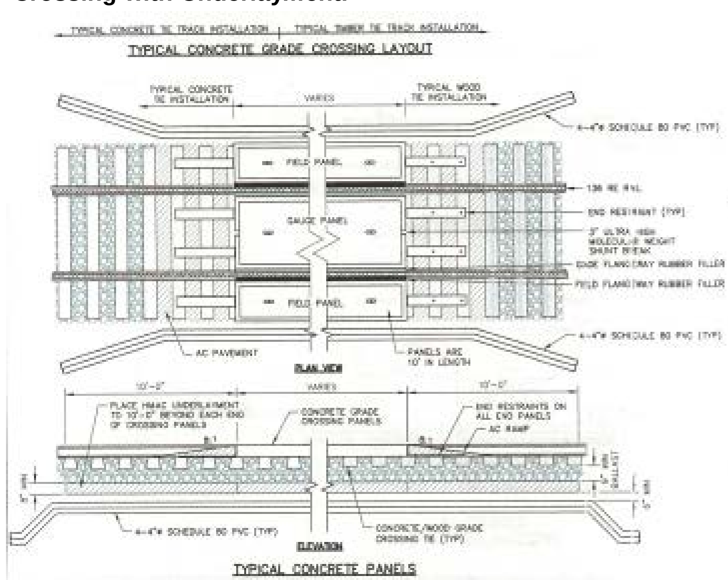

Figure 7. Standard Design for Caltrain's Highway Crossings Containing 8-in. (200-mm) minimum Thickness of Asphalt over 6-in. (150-mm) minimum Thickness of Granular Subballast.

Trackbed Preparation --- Construct the trackbed, including aggregate base and HMAC underlayment in accordance with Caltrain Standard Drawings and the Contract Drawings.

Materials --- The material for HMAC and AC pavements shall conform to the provisions of Caltrain Standard Specifications, Section 39-2, “Materials”.

HMAC pavement for track underlay: Type A with 3/4 in. (19 mm) maximum, coarse aggregate gradation.

Spreading --- Spread HMAC underlay by either a mechanical spreader or a grader. Maximum length of asphalt mixture placed by an approved mechanical spreader in a continuous strip shall not exceed 800 ft (245 m). Lay adjacent strips subject to the above limitations immediately after the previous strip is placed until the full pavement width has been achieved. Track underlay may be placed in one lift.

Rolling --- For track underlay mixture, when spread by hand, not in excess of 400 yd2 (335 m2) per hour, per roller.

For track underlay, when spread by machine, not in excess of 600 yd2 (500 m2) per hour, per roller.

West Virginia Department of Transportation

The West Virginia DOT began utilizing asphalt underlayments during the rehabilitation of crossings in 2000. Since 2000, an average of seven to eight crossings are normally underlain with asphalt each year, most of which have been on heavy tonnage, high traffic, crossings. Fourteen crossings will be underlain with asphalt in 2013. It is estimated that over 125 crossings have asphalt underlayment, the oldest having been in service for 13 years. Normal practice is to use a high-type surface material, commonly concrete precast panels, and improved support and drainage, achieved with a 6- in. (150-mm) thick asphalt underlayment. This practice is considered as a betterment program to upgrade crossings for improved performance and increased service life. On crossing rehabilitation projects, WVDOT pays for crossing materials differential, asphalt underlayment, traffic control, drainage pipe, and tie differential. Since the program began, no crossings have failed due to lack of substructure support or excessive settlement, as they have all remained smooth and serviceable. When WVDOT funds are used for crossing rehabilitation projects, the use of asphalt underlayment is considered as a standard practice. Figure 8 shows a recently completed crossing on US 50 in Bridgeport, WV.

Iowa Department of Transportation

The Iowa DOT has been using asphalt underlayment during the rehabilitation of highway/rail crossings since 2000. The service lives for the asphalt underlayment crossings have increased significantly. Railroad production track work can normally skip the crossings since only minor settlement and normal weathering of the crossing material are observed. A 6-in (150-mm) thickness of underlayment is used. It is estimated that 80 to 90 crossings out of a total of 167 crossings on the Iowa DOT primary system contain asphalt underlayments and it is considered standard practice when Iowa DOT funds are utilized to upgrade crossings. No crossing failures have been attributed to lack of structural support when specified Iowa DOT practices are followed. A few precast concrete panels have cracked under particular impact loadings and needed replacement, but no settlement issues were involved.

Figure 8. Recently Completed 144-ft (44-m) long Crossing on US 50 on CSX Line in Bridgeport, WV.

Illinois Commerce Commission and Illinois Department of Transportation

In the state of Illinois, the Illinois CC oversees and manages the majority of grade crossing renewal projects throughout the state, which amounts to over 7,000 crossings. The ICC began installing asphalt underlayment under crossings in 2010. Since then, 92 crossings have been underlain with asphalt. An additional 36 asphalt crossings are presently targeted for renewal with asphalt underlayment. The crossings that contain asphalt underlayment have performed without failure since asphalt installation. The Illinois DOT oversees about 750 crossings. Asphalt underlayment is being used on many of the renewal/rehabilitation projects.

Genessee & Wyoming-TriMet WES

The Genessee and Wyoming (G&W) Shortline Railroad began using asphalt underlayment on its Portland and Western (P&W) Railroad line in the state of Oregon about six years ago. P&W rehabilitates 12 to 15 crossings per year with asphalt underlayments. The TRIMET Westside Express Service (WES) commuter line, which stretches from Beaverton to Wilsonville in the Portland Metropolitan Area, utilized asphalt underlayment on 18 public crossings rehabilitated on the old Oregon Electric Line during the re-construction of the line for commuter service. These crossings have performed perfectly since the asphalt underlayment has been installed, having avoided problems with mud and requiring no additional surfacing or maintenance. Figure 9 is a view of the installation of the SW Durham Road crossing on the WES commuter line.

Figure 9. WES Commuter Line Crossing (SW Durham Road) on Portland & Western RR near Portland, OR, one of 13 Crossings Underlain with Asphalt.

Metrolink

Metrolink, the large commuter rail system in the Los Angeles area of Southern California, has used asphalt underlayment for several years during the new construction and renewal of numerous highway crossings, bridge and tunnel approaches, turnouts and crossovers, and yard tracks. It is considered as a standard practice for all of highway-railroad crossings along the system. Metrolink specifies that a 6-in. (150-mm) thick HMAC underlayment be used in place of portions of the subballast and ballast beneath the track. It is estimated that since 2007, Metrolink has installed 60 to 70 highway crossings with asphalt underlayments and Metrolink continues to install asphalt underlayments under all new crossings and rehabilitated crossings. The performance has been excellent with minimal settlement and long-term smooth crossings. Standard practices are similar to those used by Caltrain, described previously. Figure 10 shows a recently completed Metrolink Osborne Street Crossing on the Antelope Valley Line in the Sun Valley Area of Los Angeles.

Transkentucky Transportation Railroad

Transkentucky Transportation, a 50-mile (80-km) long Shortline Railroad in northeastern Kentucky, has been using asphalt underlayment on several portions of its rail network since 1987. An accounting in 1997 indicated that for that 20-year period, asphalt underlayment was placed beneath the track in one the track in one tunnel, seven open track sites, 26 highway crossings, seven turnouts, five bridge approaches, and two shop tracks.

Figure 10. Recently Completed Metrolink Osborne Street Crossing on the Antelope Valley Line in the Sun Valley Area of Los Angles.

The highway crossings and other applications remain serviceable today; some have been in over 20 years. It has not been necessary for TTI to renew or rehabilitate any of these crossings, with the exception of renewing the crossing surfaces on a select few of them where the asphalt or timber portions had deteriorated due to weathering.

CONSIDERATIONS FOR ASSESSING CROSSING REHABILITATION TECHNIQUES

There are three basic categories of activities to be considered when assessing the optimum engineering solutions to restore desired smoothness and ensure subsequent acceptable long-term performance for rail/highway at-grade crossings. These are site-specific and based on the present observed performance and condition of the particular crossing. The costs of the rehabilitation techniques, ultimately borne by the railroad company and/or public agency, can vary significantly depending on the solution selected based on the engineering assessment.

In addition, during the rehabilitation process, there is an inconvenience factor affecting the traveling public, so it is desirable to minimize the length of time the crossing is closed and the frequency of closures, so that highway traffic is impacted a minimal amount. Train traffic is similarly impacted until the affected track is suitable to resume operations. The three broad categories of improvement considerations are shown in Figure 11 and each one is unique in the extent and type of the rehabilitation process.

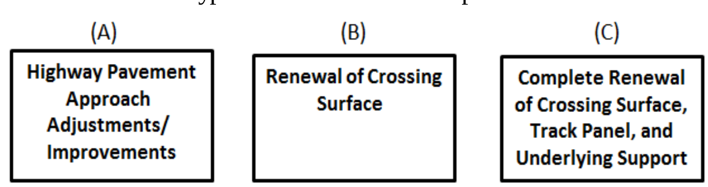

Figure 11. Categories of Improvement

A. Highway Pavement Approach Adjustments /Improvements

It is often that the highway approaches to the crossing are the primary, and maybe the only contributing factor to the roughness and less than desirable performance of the crossing. The solution can vary from quite simple if the only problem is rough pavement surfaces on the approaches to extremely involved if there is a vertical geometrical incompatibility of the highway approaches. The primary considerations are illustrated in Figure 12.

Short Distance Repaving of the Pavement Approaches

The most economical and least involved solution is to merely correct the roughness of the pavement surface approaches for a short distance, possibly 6 to 12 ft. (1.8 to 3.6 m) from the crossing. Normally the pavement surface will have rippled, rutted, worn, or cracked such that the rideability is compromised. This solution impacts railroad operations a very minimal amount.

It may be possible to resurface the approaches with a thin lift of asphalt if the pavement structure is satisfactory structurally. However, unless the pavement approaches have settled significantly, the addition of a layer of asphalt will result in the crossing being “in a hole” so that the rideability may be even less desirable. In most cases it is desirable to remove a portion of the pavement by milling off one or two inches of surface and resurfacing the pavement to match the crossing surface. The other consideration is to remove most, if not all, of the pavement and replace with a thicker lift of new paving material to match the crossing surface.

Either milling or excavating will be desirable if the existing condition of the approaches is considered to be unsatisfactory for placing a thin surface layer. This solution assumes that the track panel and crossing surface are satisfactory and at the proper elevation. This is primarily a judgment decision and assumes there is no particular reason or advantage to renew the crossing.

Adjusting the Pavement Approach Geometry

The other solution is to adjust the vertical geometry of the pavement or track when there is an incompatibility with the geometric vertical gradients at the crossing.

Raising the Grade of the Pavement Approaches. At certain crossings, particularly if the railroad is higher than the highway, this can be accomplished by raising the grade of the highway on one or both sides of the track to remove the short crest (or hump) at the crossing. The vertical grades on the approaches must be transitioned for a reasonable distance beyond the crossing, generally for at least 20 feet depending on the site conditions, and meet the existing pavement at the selected distance from the crossing.

Generally, this will involve using thicker lifts of paving material near the crossing and gradually thinning the lift thickness to transition to the existing pavement. Adjustments may be necessary to restore abutting highway intersections and drainage inlets. This is particularly the case in urban areas. At many crossings this solution can be very expensive and not desirable. Also, it is less likely to be feasible for sag highway crossings and where the highway is on a continuous grade. It is generally only a consideration for vertical crests in the highway profile.

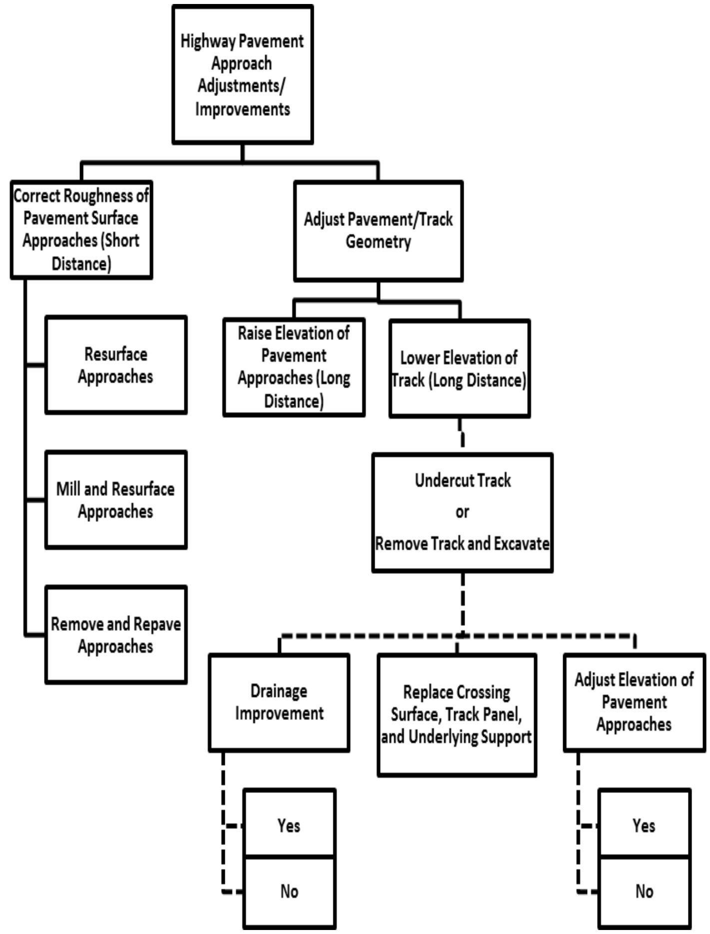

Figure 12. Approach Adjustment Decision Tree

Lowering the Elevation of the Track. The other consideration actually involves lowering the elevation of the track within the vicinity of the crossing to effectively lower the amount of elevation difference between the railroad and highway. This is applicable for sites where the railroad elevation is considerably higher than the highway so that the highway has a decided “hump” in the profile. This solution is extremely expensive and involves considerable impact on railroad operations.

One consideration is to use a typical “track undercutter” to remove a specific thickness of granular material within the trackbed, thus lowering the elevation of the track to more nearly match the elevation of the pavement. The amount of the lowering might be anywhere from one to four feet. This requires extremely long distances along the track to transition to the existing grade beyond the crossing so that a decided sag or dip doesn’t develop in the track profile. This may also impact other track features within the affected area, such as turnouts, etc. that will require re-positioning. Also, the integrity of the trackbed support may be compromised.

An alternate procedure that may be considered where there is space along the track, is to merely drag off the track sections temporarily in order to excavate the desired thickness with conventional excavating equipment and re-install the track, essentially achieving the same result as undercutting.

Track lowering is rarely selected as a means to more nearly match railroad and highway elevations to enhance the rideability and safety of the crossing by removing a portion of the "hump" at crest crossings. This arduous procedure is further complicated by the fact that the pavement approaches will need to be re-constructed to match the lowered track and a new crossing surface must be installed. The benefits to costs analyses for this solution are rarely favorable, and it is considered not feasible economically.

B. Renewal of Crossing Surface

It is also possible that the only contributing factor to the roughness of a crossing is the deteriorated condition of the crossing surface material. No adjustments to railroad or highway profiles are needed. There is little, if any, settlement so the only activity actually required is to replace the crossing surface. However, normally the highway approaches will be impacted for a short distance beyond the crossing and will have to be repaved. In addition, the track may need to be surfaced, quite often to raise the elevation slightly, particularly if the approaches have settled. If the track is raised, this will require a lift of asphalt of sufficient thickness on the highway approaches to be satisfactorily placed and adjusted to the height of the installed crossing surface. Otherwise, the approaches will likely require milling or removal, likely at an increased price, if the crossing is installed at precisely the same elevation. The primary activities are illustrated in Figure 13.

The procedure assumes the track panel can be left in place with only a portion, if any, of the ties renewed. The rail is considered satisfactory. After the old crossing surface is removed, the selections of the particular ties to be replaced are made and either the wood or concrete replacement ties are installed. If it is desirable to surface and/or raise the track, the necessary quantity of ballast is distributed and the track in the crossing area and on the track approaches is surfaced.

The next activity is to determine if the drainage in the immediate area needs to be improved. After that is accomplished, the new surface material is placed. The choice of the crossing surface material will have significant influences on the cost and the time required to complete the project.

The least expensive crossing material requiring a minimum time to install is an all-width hot-mix asphalt pavement surface. This can be normally spread along with the pavement approaches to minimize the total time requirements. The flangeway can be easily formed, while the asphalt is still hot, with a hi-rail vehicle or locomotive. This type of surface is rarely used except for light roadway traffic.

Rubber seal/asphalt and timber/asphalt are commonly used economical surfaces. The rubber seal strips or timber beams are positioned and attached along each side of the two rails. The asphalt is placed in the center of the track and on the field sides in the crossing area. If the pavement approaches require

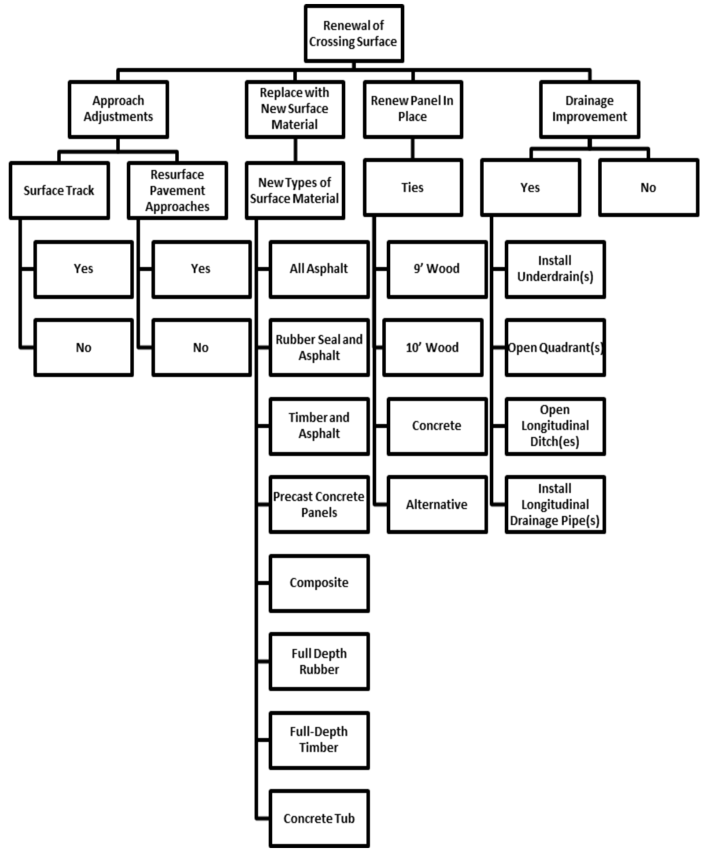

Figure 13. Surface Renewal Decision Tree

paving, this can be easily accomplished in concert with the paving in the immediate crossing area. This type of surface, compared to all-asphalt, is slightly more expensive and requires slightly more time to install.

The other four types of crossing surfaces routinely installed– precast concrete, composite, rubber, and timber – normally full-depth, are considered "premium" surfaces. They are significantly more expensive than the all-asphalt, rubber seal/asphalt, and timber/asphalt and require more time to install. These surfaces are considered to have a longer life if properly designed and installed.

The final activity is to resurface the pavement approaches, if necessary, to match the elevation of the crossing surface.

It is assumed that sound engineering judgment is utilized in determining if the crossing can be renewed in place without removing the support material below the ties. There should be no indication of trackbed pumping, excessive settlement, or excessive deterioration of the crossing and approaches. If so then the complete removal and replacement of the crossing surface, track panel, and underlying support should be the choice of the type of rehabilitation technique.

C. Complete Renewal of Crossing Surface, Track Panel, and Underlying Support

It is common for crossings to exhibit significant settlement as a result of the pumping of fines from the trackbed which creates uneven, rough crossings for highway vehicles. Also, the track may settle substantially enough to adversely affect train operations. The lack of proper drainage within the immediate area can be an additional aspect contributing to the failure of the trackbed support. Often the underlying support has insufficient load carrying capacity further extenuated by the ballast being contaminated with fines.

The series of decisions is depicted in Figure 14. It is necessary to completely remove the crossing surface, track panel, and underlying support and replace with new materials possessing increased and adequate load-carrying properties. Also, the adequacy of the drainage should be addressed and appropriate improvements selected. The pavement approaches will normally need to be evaluated and typically raised to match the elevation of the adjusted top-of-rail elevations of the track. The track approaches will be adjusted vertically, normally raised slightly, as the crossing area is surfaced prior to placing the new crossing surface.

The length of the tack panel is selected so that it extends a specified distance along the track beyond the immediate common crossing area. This distance may be a minimum of ten feet, perhaps much longer. The rail size and type of ties are selected for the new track panel relative to the traffic levels.

The two major decisions are the selections of the *proper track support materials* and the *type of crossing surface*. Assuming the existing support system is composed of all-granular materials, which have not performed satisfactorily, an improved support system is often considered. This is commonly a layer of asphalt below the ballast, with or without a layer of granular subballast below the asphalt, for added protection for the subgrade. As discussed previously, this is a standard practice for an ever increasing number of railroad companies and governmental agencies Normally, this will involve a depth of excavation of 30 to 36 in. (760 to 910 mm) below the final top-of-rail elevation.

An alternate selection is to place a layer of geofabric in combination with a layer of granular subballast to improve load-carrying capacity of the trackbed. The added cost to include a layer of asphalt or geofabric is minimal relative to the overall cost to completely rebuild the crossing. An additive cost of 5% or less is common, particularly if a more expensive premium surface is selected.

As the previous section indicates, the choice of the new surface material highly impacts the overall cost and time of the rehabilitation process. It is typically assumed that the premium crossing materials will last for a longer period of time and consequently perform better during the life of the crossing. This is not always the case as the quality of the support, as discussed previously, has significant effect on the relative performance of the crossing surface. The premium crossing materials can actually compensate for poor quality support as some amount of bridging effect, or increase in bending strength, is provided by the panels and the connections with the ties. However, this compensation is achieved at a significant increase in cost. Most often improving trackbed support is more economical.

The standard crossings materials quite commonly perform equally as well for as long of a period of time as the premium crossing materials, provided the standard crossing materials are properly supported structurally. This commonly requires a structural layer to add strength, waterproofing, and confinement to enhance the structural adequacy of the crossing support.

DISCUSSION AND COMMENTS

The goals for the ideal highway-railway crossing renewal process have been described. These include:

- Providing a quality, cost-effective rail/highway crossing that will remain smooth and serviceable for both highway and rail traffic for a minimum of 15 years with minimum annual cost,

- Accomplishing the complete renewal (trackbed and crossing surface) in a minimum of time when required without significant disruption to rail and highway traffic (maximum 4- hour train curfew and 8 to 12-hour highway closure), and

- Utilizing a cooperative approach involving both the railroad (and its contractor, if applicable) and the local governmental/highway agency.

Typically the local highway agency is better equipped and experienced to provide certain activities more economically than the railroads. These include – asphalt paving (underlayment, trenches, and approaches), preparation (milling if necessary) of the highway approaches, traffic control, and advising the public of road closures and detours. Normally the railroad company, or its contractor, performs all activities directly related to the trackbed and crossing surface installation.

The crossing management techniques described herein (involving model decision-making processes) have included procedures for assessing the optimum engineering solutions to restore desired smoothness, minimize subsequent settlement, and ensure acceptable long-term performances for highway-railway at- grade crossings. The models are diagramed in flow charts for easy adaptation to a systematic assessment and management practice. Due consideration is given to documenting the volumes of highway and rail traffic in selecting the most economical rehabilitation technique. Clear benefits of using improved structural support, when constructing new crossings and rehabilitating existing crossings, have been highlighted.

The utilization of a layer of asphalt (underlayment) during the trackbed renewal process provides quality structural support so that ballast can be immediately compacted, the track can be positioned, and the crossing-surface applied within a minimum amount of time. Crossings have remained very smooth and serviceable under heavy tonnage rail and highway traffic during the evaluation periods. These observations are consistent with documented performances of numerous crossings over the past 20 years containing asphalt underlayment.

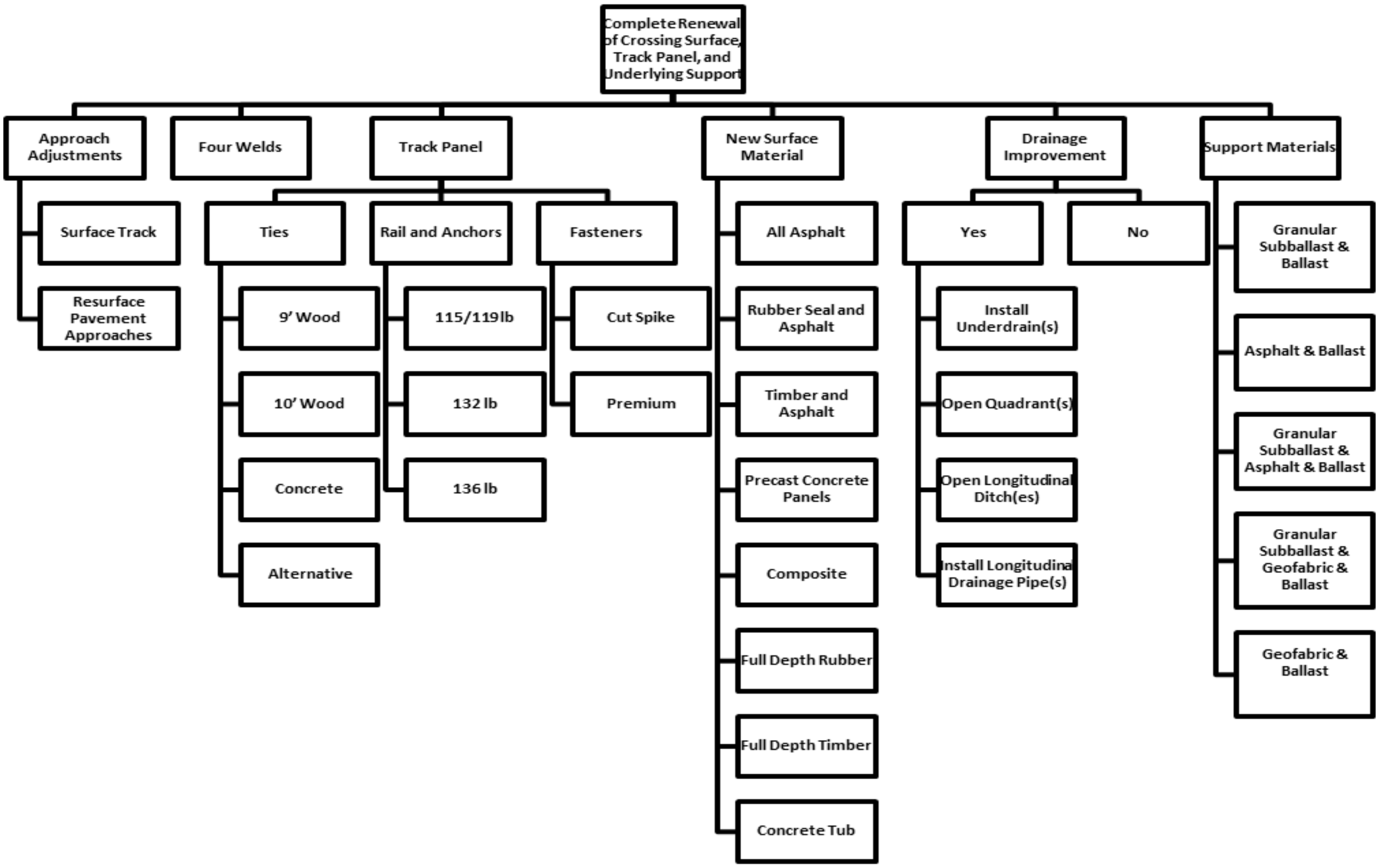

Figure 14. Complete Renewal Decision Tree

Peak Dynamic Pressures at the top of asphalt layer (below ballast) typically range from 13 to 17 psi (90 to 120 kPa) under the rail/tie intersection for highway crossings under 286,000 lb (130 metric ton) railway loadings. Transmitted pressures are considerably lower in magnitude within the crib area or center of track.

Peak Dynamic Pressures at the top of asphalt layer (below ballast) typically range from 4 to 6 psi (28 to 41 kPa) under the rail/tie intersection for highway crossings under heavily loaded highway trucks and less than 1 psi (7 kPa) for passenger cars. The instrumented crossings remain very smooth, minimizing impact forces.

Static Surface Pressures at the tire/pavement interface on highway/railway crossings for highway vehicles are very close to the respective tire inflation pressures. These range from 135 psi (930 kPa) for heavily loaded trucks to around 75 psi (515 kPa) for utility trucks.

The single-day (fast-track) crossing renewal process is feasible when enhanced structural support is provided. It permits immediate consolidation and compaction of the ballast and track minimizing subsequent significant settlement of the crossing. There is no need for train traffic to consolidate the ballast over a period of days, with attendant closure of the crossing to highway traffic.

ACKNOWLEDGEMENTS

Several graduate students over the past several years have been involved with the development of the rail/highway crossing program. Those involved include – Daniel Durret, Lindsay Walker, Jason Stith, Mary Swiderski, Thomas Witt, Aaron Renfro, Justin Anderson, Timothy Guenther, and Brett Malloy. The Kentucky Transportation Cabinet, CSX Transportation and Norfolk Southern have been the primary sponsors of the research.

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