D R A F T

Proceedings of the ASME/ASCE/IEEE 2011 Joint Rail Conference
JRC2011
March 16-18, 2011 Pueblo, Colorado, USA

JRC 2011-56015

REHABILITATION TECHNIQUES TO IMPROVE LONG-TERM PERFORMANCES OF HIGHWAY-RAILWAY AT-GRADE CROSSINGS

Jerry G. Rose
University of Kentucky
Lexington, KY, USA

ABSTRACT

The primary purpose of the highway-railway at-grade crossing is to provide a smooth surface for the safe passage of rubber-tired vehicles across the railroad. The crossing support and surface in the jointly used area represent a significantly expensive unit cost of the highway and railway line. The ideal highway crossing will maintain a smooth surface and stable trackbed for a long period of time. This will reduce costly, frequent disruptions to highway and railway traffic (to adjust the track or renew the surface due to rideability concerns), while concurrently providing improved operating performance and long life. Technology is available for rapidly renewing highway crossings within one day 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 -- and replacing them with an asphalt underlayment layer, a pre-compacted ballast layer, a new track panel, and a new crossing surface. A cooperative effort between the local highway agency and the railway company will reduce costs, improve the quality of the finished product, and reduce outage of the highway and railroad. A major objective is to minimize disruption to both highway and railway traffic during the renewal process in addition to extending the life of the crossing. Suggested procedures, based on experiences for several installations, are presented. Typical schedules are for the railroad to be to be out-of-service for a maximum of four hours and for the highway to be closed only eight to twelve hours.

Results are presented for crossings instrumented with pressure cells to document Pressure levels within the layered portion of the crossing structure. 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. These long-term performance evaluations indicate this practice ensures long-life, economical, smooth crossings for improved safety and operating performances for both highway agencies and railway companies.

INTRODUCTION

At-grade highway-railway crossings represent significantly expensive special portions of highways and railway lines. The crossing surface and trackbed (rail, ties, and ballast/subballast) replace the highway pavement structure within the jointly used crossing area. 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. 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.

It is paramount 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 potentially saturate the underlying subgrade/roadbed, thus lowering the structural integrity of the structure. Groundwater, if present due to inadequate drainage, can further lower the structural integrity of the trackbed support layer.

Crossing structures having inadequate structural support provide excessive deflections 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 become a permanent low spot in the railroad profile, which further increases impact stresses from the railroad loadings. In addition, the low spot serves to collect 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 tremendous 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 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.

Replacing and rehabilitating highway-railway at-grade crossings represent major track maintenance expenses for the U.S. highway governmental agencies and railroad industry. Substantial numbers of crossings deteriorate at a more rapid rate than the abutting trackbed due to excessive loadings from heavy truck traffic and difficulty with maintaining adequate drainage within the immediate crossing area. Others require replacing during scheduled system track maintenance activities such as tie and rail renewals and surfacing operations. At many crossings the disturbed track does not provide adequate support. The replacement crossings soon settle and become rough for vehicular and even train traffic.

The ideal highway crossing system is one that will maintain a smooth surface and stable highway/trackbed for a long period of time reducing costly and inconvenient disruptions to highway and rail traffic. It will not require frequent rehabilitation and ideally, will not have to be renewed (replaced), but merely skipped, during major scheduled track maintenance activities.

DISCUSSION

Railways and highways are typically designed structurally very differently for the common areas at crossings. The all-granular railroad roadbed and track system is designed to be flexible, deflecting about 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 different 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 fails prematurely due to deterioration and settlement of the crossing.

The most common track (sub-structural) support for highway-railway crossings consists of unbound granular materials as depicted in Figure 1. 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.

The use of a layer of hot mix asphalt within the track substructure, in lieu of conventional granular subballast, is becoming widely utilized to provide ideal properties to the crossing (Rose & Tucker, 2002) (Rose, 2009 (1F)). Literally 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 underlying 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. Figure 1 contains a typical view of an asphalt underlayment trackbed.

The ideal sub-structural support system for a highway-railway crossing:

- Provides 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 for marginal quality subgrades.

Long-term consolidation or settlement of the crossing should be minimal providing for a smoother crossing with enhanced rideability characteristics for a longer period of time. The crossing will not have to be rehabilitated as frequently with attendant disruptions and expenses to the railroad company, governmental agency, and traveling public.

CONSENSUS GOALS FOR 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 without significant disruption to rail and highway traffic (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. High volume rail lines having regularly scheduled trains must be reviewed to minimize the adverse effects of track closures. Certain times on certain days may have lighter volumes and the railroad can adjust schedules slightly. The highway volume and type of traffic coupled with the availability of alternate routes and detours will be important concerns. Site specific factors must be considered.
- 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 primary areas of responsibilities and the suggested responsibility party are:
  - Highway Closure and Traffic Control
    - Local highway/governmental agency
  - Public Announcements and Notification
    - Local highway/governmental agency
  - Obtain Railroad Curfew
    - Railroad company
  - Temporary Crossing Construction and Removal
    - Railroad company (or supervise)
  - Removal and Replacement of the Track and Crossing Surface
    - Railroad company (or its contractor)
  - Pave Asphalt Trenches and Approaches
    - Local highway/governmental agency (or supervise)
- 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. Typical shared costs are:
  - Removal and Installation of Track and Crossing Materials
    - Railroad company (may be reimbursed)
  - Traffic Control, Public Announcements, and Asphalt Paving
    - Local highway/governmental agency

TYPICAL FAST-TRACK INSTALLATION PROCESS

When replacing an existing crossing with an asphalt underlayment, the typical two-lane highway, single-track railroad crossing will be closed for four to five hours for train traffic and 8 to 12 hours for highway traffic. It is recommended that the following activities be conducted prior to rehabilitation (Rose, et al., 2009):

- Notify the public and develop a plan for traffic diversion and detours,
- Obtain adequate outage (window of time),
- Cut rail and use joint bars to keep rail in service until work begins – optional,
- Saw pavement approaches 7 ft (2.1 m) from both sides of rail to allow adequate room for excavation, and
- Store materials on-site, except for asphalt, in order to work as efficiently as possible.

Once the preparation has been completed, the process of installing the new underlayment can begin on the selected date. The following listing is the sequential activities:

- Remove the old crossing surface and excavate the trackbed to a depth of approximately 29 in. (750 mm).
- Compact subgrade with a vibratory roller, if necessary.
- Dump and spread the asphalt. The width of the asphalt mat should extend 1.5 to 2 ft (0.45 to 0.60 m) beyond the ends of the ties. Generally a 12-ft (3.6 m) mat width is used. A minimum length of 25 to 100 ft (7.6 to 30.5 m) is recommended beyond the ends of the crossing to provide a transition zone. The asphalt mat is typically 6 in. (150 mm) thick.
- Compact the asphalt. A compaction level of 95% is preferred using a steel wheeled, vibratory type standard roller. It is also beneficial to leave a side slope allowing for drainage along the asphalt.
- Dump and spread the ballast. A thickness of 8 to 12 in. (200 to 300 mm) of ballast should be on top of the asphalt after compaction.
- Compact the ballast to stabilize the trackbed and minimize subsequent settlement.
- Position the prefabricated track panel on the compacted ballast.
- Join the new rail to the existing rail either with joint bars (welds made later) or welds.
- Add the cribbing ballast and additional ballast to fill in the cribs and allow for a track raise and adjustment.
- Surface, tamp, and broom the immediate crossing area.
- Install the crossing surface including the trenches along the track.
- Pave the highway approaches.

Normally these activities will be shared between the local highway agency and the railroad company. Planning should begin several weeks in advance of the actual work.

Table 1 contains a sequential listing of activities for a typical renewal of a highway/rail crossing. The times are indicative for a typical two-lane highway crossing having a replacement track panel ranging from 75 to 100 ft (24 to 30 m) long and a crossing surface ranging from 40 to 70 ft (12 to 22 m) long. Normally, the railroad will be open to traffic within 3 to 4 hours after trackwork begins. The highway is typically opened to traffic within 6 to 12 hours after closure depending on the extent of the paving required for the approaches.

As noted in Table 1, the basic processes involve removing the existing crossing surface and track panel, excavating the contaminated trackbed material for a selected distance below top-of-rail, and replacing with a compacted layer of hot mix asphalt, a compacted layer of ballast, a new track panel, adding cribbing ballast, surfacing, and raising (if desired) the track, placing the crossing surface and paving the trenches and highway approaches. Figure 2 depicts the various operations.

The equipment utilized will vary depending on the length of the crossing, availability, and site conditions. A hydraulic excavator (trackhoe) is extremely versatile and can assist with practically all phases of project activities. An additional trackhoe or crane is desirable for longer crossings. A backhoe or two is necessary to assist the trackhoe and provide loading capability. Removal of the old crossing and trackbed spoils can be accomplished simultaneously provided that a loader and trucks are available. A steel wheel roller is necessary to compact the subgrade, asphalt, and ballast. After the asphalt underlayment is compacted, the ballast can be dumped immediately on the hot compacted mat.

In order to accomplish a crossing renewal of this magnitude within the limited time frame, it is imperative that the activities be sequentially planned so that there is no wasted time. Many activities can proceed simultaneously. In addition, it is important to have the proper equipment adequately sized to provide the production rates necessary to complete the work in the allotted time. Most of the labor is involved with assembling the track and crossing surface.

Various types of crossing surfaces have been installed. These include: full-width pre-cast concrete, partial-width pre-cast concrete, full-depth rubber, rubber seal and asphalt, rubber header and asphalt, full-width asphalt, full-width timber and experimental composite surfaces. The relative ease of the installation of the surface impact the project time schedule.

INSTALLATION TIME

One of the most attractive characteristics of using an asphalt underlayment with this method of crossing rehabilitation is that the entire crossing replacement can be accomplished in one day with typical closures of 3 to 4 hours for the railroad and 6 to 12 hours for the highway. 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 for only one day minimizes disruption to the traveling public. Overall, this method provides a quality, smooth crossing in a minimal amount of time.

COST AND ECONOMICS

Cost is another major factor in determining the extent of the work to be performed. Asphalt underlayments have been extensively used in crossings since the early 1980s. Hundreds of these supporting mats have been placed in service over the past 25 plus years. Many of these crossings are heavy-duty crossings that are still in service or maybe only surfaced through once in order to change out the crossing surface. A service life of this magnitude for crossings is very desirable. If the benefits are such, it may be justification for the extra expense of a layered installation system utilizing asphalt underlayment when renewing a crossing.

Furthermore, the extra costs of the asphalt underlayment are typically not very significant. The cost of obtaining and placing the asphalt underlayment will vary at each jobsite. Factors that affect the cost are:

- Separate placement crew and paving machine will increase costs compared to merely back dumping the mix, spreading it, and compacting it with on-site equipment,
- Prevailing cost of asphalt mix in the local area,
- Length (time) of haul to site,
- Size (tonnage) of the project,
- Availability and cooperation of local contractors, and
- Ease of delivery access and construction maneuverability.

Typically, the in-place cost of an asphalt underlayment that is back-dumped will range from $20 to $30 per track foot ($66 to $98 per track meter). Crossing track panel lengths range from 60 to 100 feet (18 to 30 m) for a two-lane highway, so the total cost for the in-place asphalt underlayment range from $1,200 to $3,000. The extra cost for the asphalt is further reduced from this figure when the cost of the sub-ballast or geotextile fabric (if considered) that it replaces is factored in. The total rehabilitation costs for a major crossing typically ranges from $20,000 to $40,000. The total net increase in cost of the renewal process using asphalt underlayment is approximately 5% to 10%, which is minimal compared to the benefits that it provides.

A practice to reduce cost to the railroad company while still obtaining a quality rehabilitated crossing with an asphalt underlayment and panelized system is to share the renewal costs among two or more parties. The local highway/governmental agency is better positioned and experienced to provide certain activities more economically than is the railroad company. These activities include asphalt paving, traffic control, and public announcements. Kentucky has been one of the initial states involved in utilizing a cooperative approach. In many of the crossing renewal projects, the state or county highway department has been willing to offset some of the expense to the railroad company by providing the activities listed above, and paying for items such as the asphalt and/or surface materials. By sharing the cost of the renewal projects, the funds for renewal projects are extended. Extended funds mean that more crossings can be renewed by the railroad company for a fixed budget making for a smoother drive over more railroad crossings.

PERFORMANCE MEASURES

Typical pressures have been measured within the track structure on asphalt underlayment layers due to highway vehicles and railroad locomotives and cars and on crossing surfaces due to highway vehicles. In addition, long-term settlement measurements and assessments have been evaluated.

Crossing Trackbed Pressure Tests

Geokon Model 3500-2 earth pressure cells and Snap-Master data acquisition system 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 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 is 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.

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 and 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)). Discussions for two representative projects follow.

Figure 6 depicts typical top-of-rail settlements for a representative crossing having conventional all-granular support. The “heavier” line portion of each profile represents the highway crossing. It is obvious that the settlements over the four-year period through the crossing and on the rail approaches were similar in magnitude. This particular highway crossing had very light highway traffic and moderately heavy rail traffic.

Figure 7 depicts typical top-of-rail settlements for a representative crossing containing enhanced support consisting of a layer of asphalt. The “heavier” line portion of each profile represents the highway crossing area containing the layer of asphalt. The “lighter” line portions represent the all-granular trackbed approaches. It is obvious that the settlements over the structural enhancement layer in the crossing area were significantly less than those over the all-granular approaches. This particular crossing had extremely heavy highway traffic and heavy rail traffic.

The crossings underlain with asphalt settled 41% of the amount for the all-granular trackbed crossings. 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 finds. 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, all having heavy highway traffic, averaged 0.57 in. (14 mm). 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 asphalt underlayment crossings remain very smooth and serviceable.

The renewal process was “fast tracked” insinuating that the track was back in service in four hours and the highway back in service in 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 precluded 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.

The advantages of installing asphalt underlayments during crossing renewals seem clear. The crossings perform well while providing smooth crossings for extended periods of time. Minimizing frequent replacements results in cost savings to the railroads and associated governmental agencies while reducing costly disruptions to rail and highway traffic.

CONCLUDING COMMENTS

The goals for the ideal highway-railway crossing renewal process are to:

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

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 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. The asphalt underlayment layer appears to provide adequate support for maintaining a smooth and level crossing surface.

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 were 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 coal trucks to around 75 psi (515 kPa) for utility trucks.

The advantage of enhanced structural support, provided by asphalt underlayment, was clearly demonstrated to minimize long-term settlement within the jointly used highway/rail crossing area. Top-Of-Rail elevation changes (settlements) throughout the highway crossings and rail approaches were monitored for extended time intervals at 20 sites using conventional differential leveling techniques.

The 16 crossing areas underlain with asphalt carry considerably heavier highway traffic and truck loadings than the four all-granular supported crossings. Long-term settlements, within the jointly used crossing areas, for the 16 crossings underlain with asphalt settled 41% of the amount for the four all-granular supported trackbed crossings. The significant difference was validated by the t-test.

In addition, the 16 crossing areas underlain with asphalt settled 44% of the abutting all-granular supported track approaches; this was also significantly different. As expected, settlements for the 20 all-granular track approaches to the crossings were statistically similar to each other and to the settlements of the four all-granular crossing areas.

All crossings underlain with asphalt remained smooth and serviceable during the 3 to 4 years of monitoring. Most of the settlement occurs within the initial 2 to 3 years. Several of the heavy highway traffic crossings have been “skipped over” during subsequent tie-changeout programmed maintenance activities, with attendant minimization of traffic disruptions and crossing replacement costs.

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 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 and Timothy Guenther.

REFERENCES

Rose, J.G. (2009). “Highway-Railway At-Grade Crossing Structures: Optimum Design/Installation Practices and Management Program – An Overview,” KTC-09-04/FR 136-04-1F, Kentucky Transportation Center Research Report, May, 39 pages.

Rose, J.G., Durrett, D.M., Walker, L.A., and J.C. Stith. (2009). “Highway-Railway At-Grade Crossings: Trackbed and Surface Pressure Measurements and Assessments,” KTC-09-05/FR 136-04-2F, Kentucky Transportation Center Research Report, May, 41 pages.

Rose, J.G., Swiderski, M.G., and J.S. Anderson. (2009). "Long-Term Performances of Rail/Highway At-Grade Crossings Containing Enhanced Trackbed Support," TRB Annual Meeting Compendium of Papers DVD, Washington, DC, January, 36 pages.

Rose, J.G., Swiderski, M.G., Anderson, J.S., and L.A. Walker. (2009)."Highway-Railway At-Grade Crossings: Long-Term Settlement Measurements and Assessments," KTC-09-06/FR 136-04-3F, Kentucky Transportation Center Research Report, May, 30 pages.

Rose, J.G. and P.M. Tucker. (2002)."Quick-Fix, Fast-Track Road Crossing Renewals Using Panelized Asphalt Underlayment System," American Railway Engineering and Maintenance Association 2002 Annual Conference PROCEEDINGS, Washington, DC, September, 19 pages.

TABLE 1. Sequential Listing of Activities for a Fast-Track Highway/Rail Crossing Renewal

Time (hours)	Activities
↑ 2.0 – 2.5 ↓	Remove existing crossing surface and track panel (panel will be longer than crossing surface) Excavate trackbed material to approximately 29 in. (750 mm) below top-of-rail Evaluate subgrade support, determine action– No additional activity needed, subgrade is firm and compact Compact subgrade to densify it Add ballast and compact subgrade if subgrade is soft
↑ 1.0 – 1.5 ↓	Dump, spread, and compact 6 to 8 in. (150 to 200 mm) of asphalt underlayment Dump, spread, and compact 8 to 10 in. (200 to 250 mm) of ballast to grade Position new track panel on compacted ballast and bolt or weld joints
	Railroad Open (If desirable, depending on traffic)
↑ 1.0 – 2.0 ↓	Add cribbing ballast, tamp, raise (if desired), and surface track
↑ 2.0 – 3.0 ↓	Place crossing surface Pave asphalt trenches along both sides of track
	Highway Open (pave highway approaches the following day if required)
↑ 0.0 – 3.0 ↓	Pave asphalt highway approaches the same day (optional)
	Highway Open (no further paving required)
6.0 – 12.0	

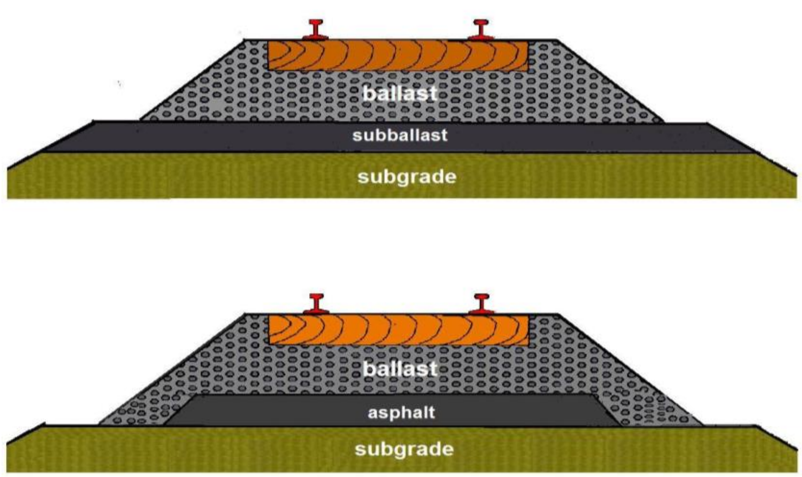


Figure 1. Cross-Sectional Views of All-Granular and Asphalt Underlayment Trackbeds.

Lifting out old Panel

Excavation

Compacting roadbed

Compacting placement of asphalt

Compacting asphalt

Compacting ballast

Positioning wood tie panel

Dumping cribbing rock

Surfacing track

Placing concrete surface

Figure 2. Typical Fast-Track Renewal Operations

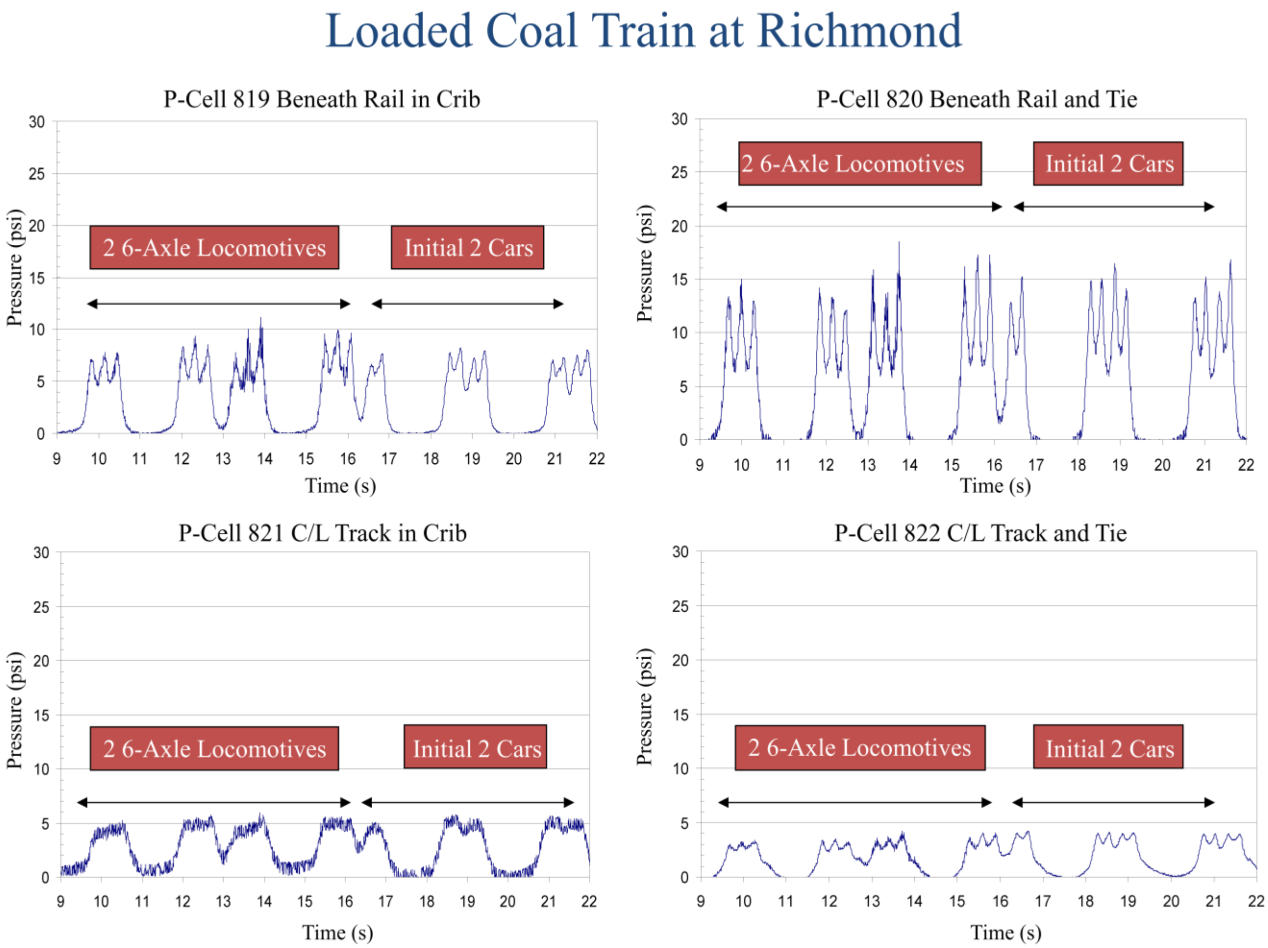


Figure 3. Typical Pressures on Asphalt in Trackbed for Loaded Coal Train

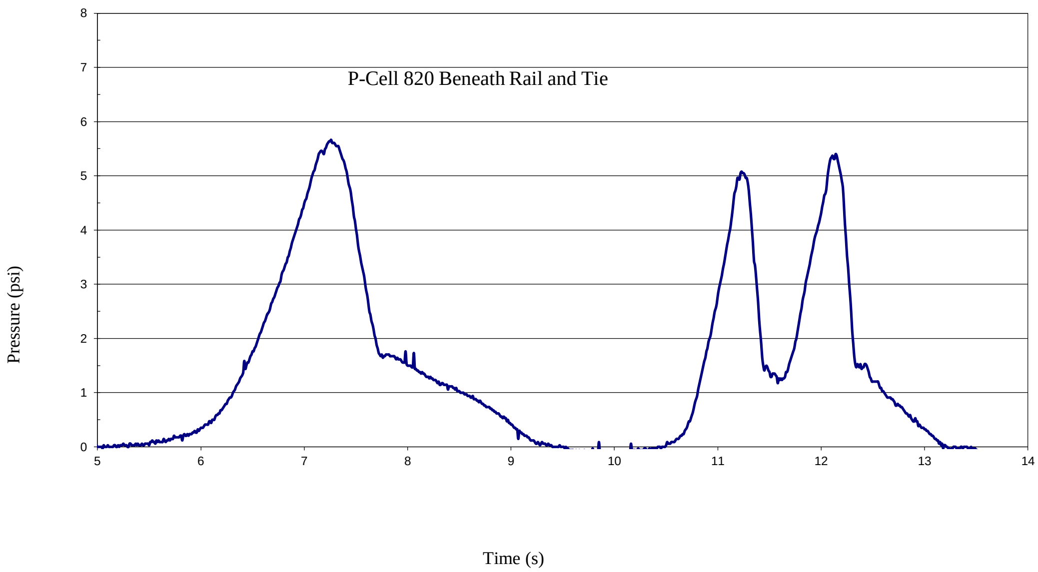


Figure 4. Typical Pressures on Asphalt in Trackbed for Loaded Concrete Truck

Rear Tires of Tractor of a Loaded Coal Truck on Concrete Crossing of Kentucky Coal Terminal

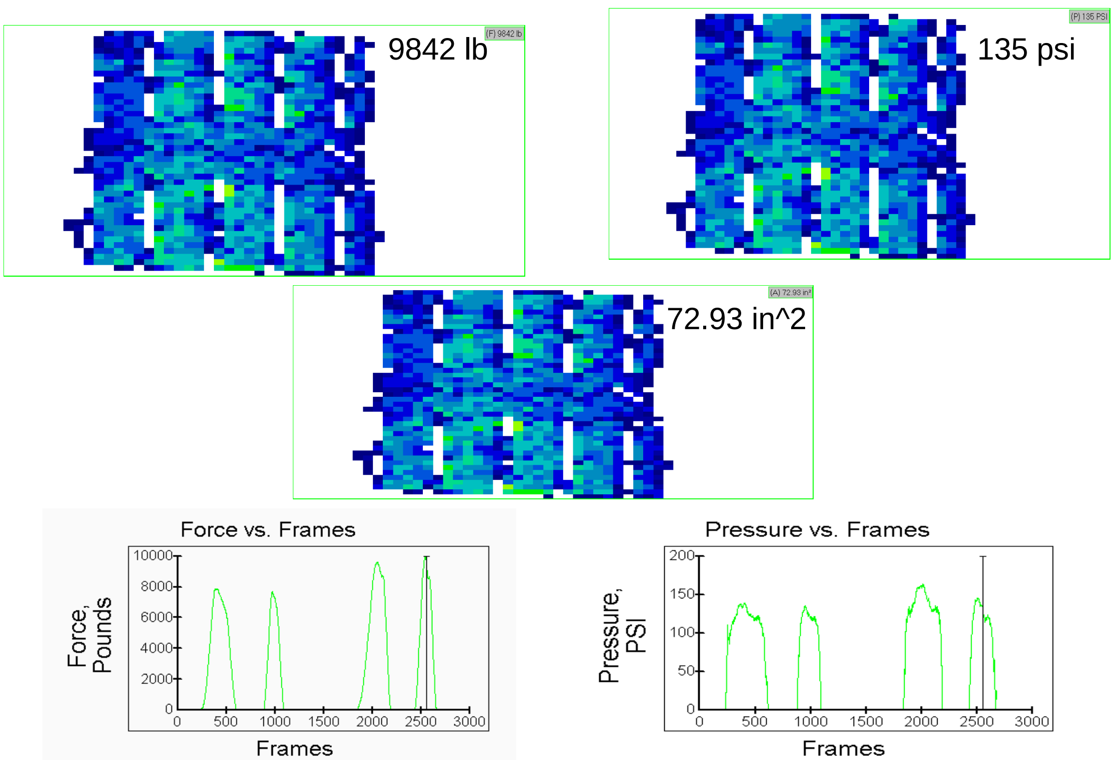
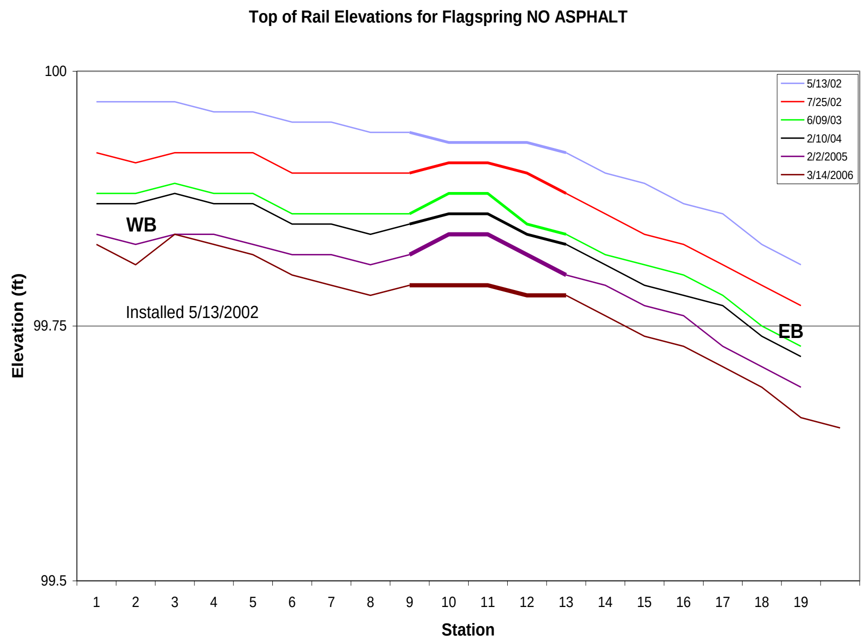


Figure 5. Imprint of Tractor Rear Tire of Loaded Coal Truck on Concrete Crossing



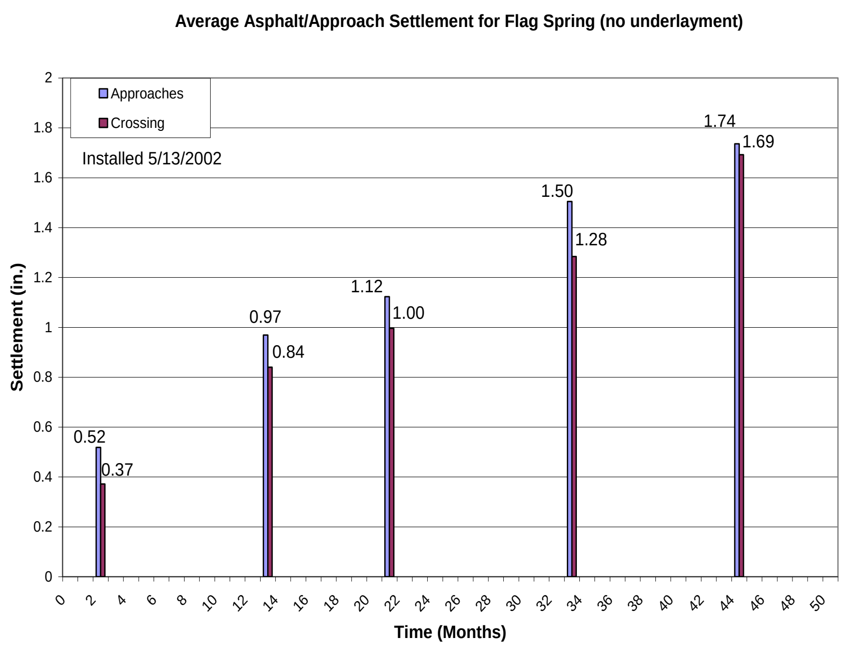
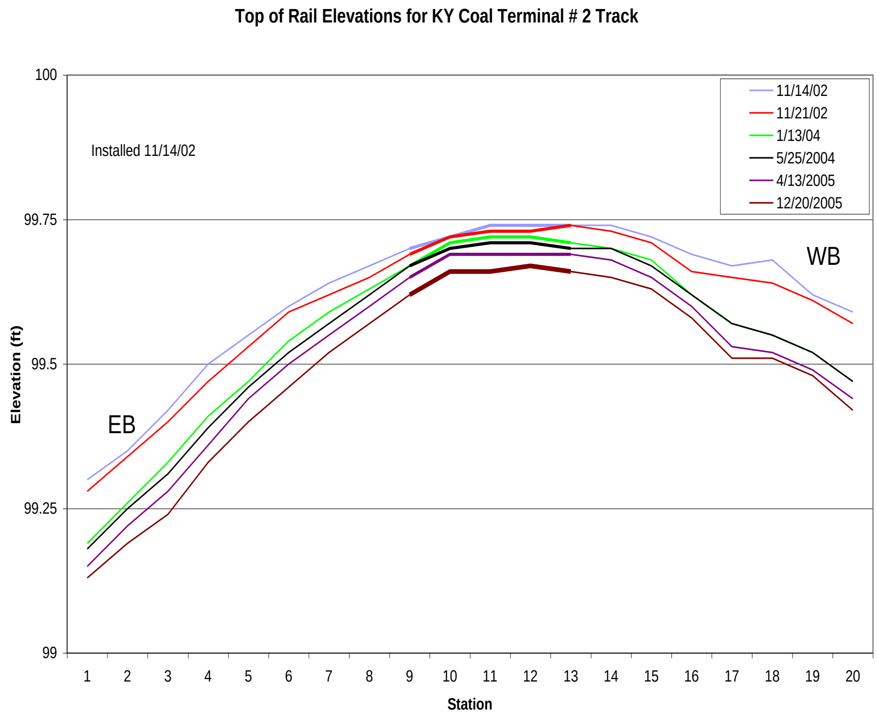


Figure 6. Representative Cincinnati Subdivision Top-Of-Rail Settlement Data for Flag Spring Crossing without Underlayment



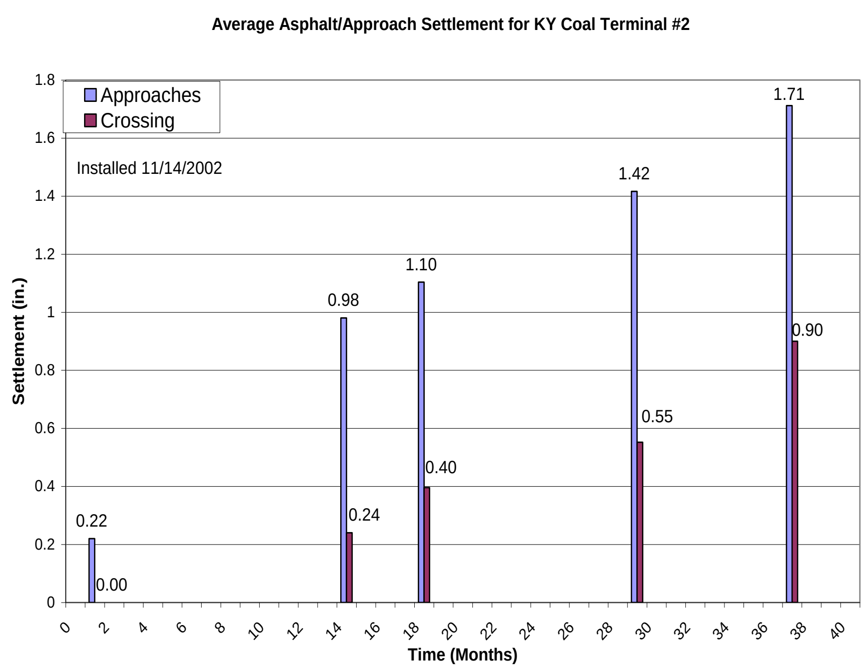


Figure 7. Representative Big Sandy Subdivision Top-Of-Rail Settlement Data for KY Coal Terminal Crossing with Underlayment