U.S. Department of Transportation

Federal Railroad Administration

STUDY OF BRIDGE APPROACH AND TRACK TRANSITION DEGRADATION:
Factors and Mitigation

Office of Research and Development
Washington, D.C. 20590

DOT/FRA/ORD-

October 2003
Draft Report

This document is available to the U.S. public through the National Technical Information Service Springfield, Virginia 22161

REPORT DOCUMENTATION PAGE	Form approved *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0702-0288), Washington, D.C. 20503

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 2003	

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Study of Bridge Approach and Track Transition Degradation: Factors and Mitigation	FRA Contract DTFR53-01-H-00305 FRA Grant 4
6. AUTHOR(S)	
Lamont Smith, Brian Doe, Dingqing Li, Duane Otter and Shakoor Uppal	

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBERS
Transportation Technology Center, Inc. P.O. Box 11130 Pueblo, CO 81001	

9. SPONSORING/MONITORING AGENGY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
U.S. Department of Transportation Federal Railroad Administration Office of Research and Development, MS 20 1120 Vermont Avenue, NW Washington, DC 20590	

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
This document is available through National Technical Information Service, Springfield, VA 22161	

13. ABSTRACT

Efforts have been made to reduce or eliminate track geometry degradation at bridge approaches and special trackwork zones for more than a century. This is a common problem that has been reported by railroads in North America, Europe, Asia, South America, and Australia. The objective of this report is to determine the entire range of variables that can contribute to these degradation problems and to examine the effectiveness of the many types of mitigation methods. This report summarizes the study of actors and mitigation methods as related to bridge approach and track transition degradation. The study was conducted based on a literature review, interviews with field personnel, and field investigations and tests.The studies performed resulted in a vast array of characteristics to consider when analyzing the reasons for track degradation at these locations. The array of potential remediation methods is nearly as broad and diverse.The findings show that the geotechnical aspects of the track geometry degradation problem are every bit as important as the consideration of the vertical stiffness transition between the approach and bridge span. By taking into consideration the importance of geotechnical characteristics, such as consolidation factors, compaction, moisture content control, erosion, vegetation control, ballast quality, and quality of backfill material and construction the railroad industry should be able to gain better control of this problem. This would result in monetary savings in track repair labor and speed or other operating restrictions.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Bridge approach, track transition, geometry degradation, factors and causes, mitigation	30
	16. PRICE CODE

17. SECURITY CLASSIFICATION	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rec. 2-89)
Prescribed by ANSI/NISO Std. 239.18
298-102

EXECUTIVE SUMMARY

Bridge approaches and other track transitions such as special track work, road crossings, and slab track to ballasted track are common locations of accelerated geometry degradation. Accelerated track geometry degradation in these localized locations can lead to increased costs due to maintenance, train delays, or slow orders. Other negative impacts include increased wear on bridge components, track components, and vehicles, as well as decreased ride quality for sensitive freight and passengers.

To assist the U.S. railroad industry in its efforts to improve operating efficiency and safety, the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) sponsored research, conducted by the Transportation Technology Center, Inc. (TTCI), to investigate the causes of track geometry degradation at bridge approaches, other track transitions, and to identify and evaluate appropriate mitigation remedies.

The early phase of this research included a literature survey, interviews with railroad maintenance personnel, field inspections, and field tests. This document presents a summary of the results and findings from the early phase of the project.

A thorough and structured strategy is essential to appropriately address and mitigate these transition problems. The first step evaluates the magnitude of the problem, specifically the frequency, severity, and cost. Second, the mechanism of the problem must be determined. In particular the different modes, causes, and factors should be understood. The third step is to identify and evaluate potential design and/or remediation techniques that can improve the situation. The final task is to implement the appropriate techniques and to monitor the effectiveness of the solution.

Transition Problems

The following is a list of problems associated with track transitions:

- Increased maintenance time and cost due to surface and alignment problems, pumping ballast, swinging or hanging ties, more rapid ballast degradation, rail battering, fatigue and corrugation, wood tie plate cutting, and concrete tie cracking.
- Increased dynamic loads increase stresses on bridge and track components
- Incurred wear on vehicles
- Slow-order or speed restriction
- Poor ride quality

Causes of Degradation

Change in track stiffness: At track transitions, (e.g., at bridge approaches), the stiffness change is often rapid and large. The track stiffness change from bridge to approach can be very high, approximately by a factor of 2, and some bridges have track modulus above 10,000 lb/in/in, which is also considered too high, being a possible cause of poor vehicle/track dynamic interaction.

Obviously, a significant change in track stiffness leads to uneven track deflections under moving traffic loading that can cause larger dynamic wheel/rail forces. Increased forces cause uneven settlement, which leads to even higher forces.

Other major causes and factors include:

- Larger settlement of ballast section: The ballast section or approach site inherently settles more because of larger (deeper) sections of materials with plastic deformation behavior, thus producing uneven profile or differential settlement that leads to adverse wheel/rail dynamic interaction. This settlement is generally the direct result of movement and/or mechanical breakdown of the ballast
- Poor materials, inadequate compaction, and consolidation of fill and embankment: These are often associated with the problems of newly constructed bridge approaches.
- Poor drainage and fouled ballast always accelerate track geometry degradation.
- Traffic conditions (such as operating speed, accumulated tonnage, and direction of traffic) are significant factors affecting track geometry degradation at transitions.
- Bridge (track) type, end connections, and presence of joints are also factors affecting transition performance.

Common Practices of Mitigation

Based on the survey and interviews, the main design principles of the mitigation methods for the problems at transitions can be summarized as follows:

- Accommodate the difference in track stiffness
- Reduce crushing and movement in the ballast section
- Accommodate consolidation differences in approach vs. bridge for both ballast and foundation layer
- Accommodate the rotation (i.e., abutment movement due to out of plane bending on girder or beam spans) and movement of track and bridge components due to strain under loads at transition zones.

In reality, these principles were not always followed. Many types of transition designs have been developed with varying degrees of success, depending on the problems specific to each transition situation, and whether all the above principles have been considered. The following is a summary of the practices developed by various railroads in many different countries for improving track transition performance, categorized by their intended mitigation:

- Reduce stiffness on the bridge side: Techniques have included use of softer pad under rail, elastic pads under ties, and ballast mats. In addition to reducing the stiffness, these pads or mats act as mechanical filters to attenuate high frequency impact loads. Use of wood ties instead of concrete ties on concrete bridges can also reduce stiffness on the bridge side.
- Gradual stiffening of the approach or ballast side: A number of techniques have been used for this purpose, including use of an approach slab (e.g., AREMA recommends a 20-foot sleeper slab from the end of slab track or bridge abutment). Tapered or stepped longitudinal slabs are variations of this approach slab technique. Extra wide ties, varying tie spacing, and varying tie length have also been used to help produce a gradual stiffness transition. In addition, hot-mix-asphalt underlayment, geocell reinforcement, and soil cement have been used to stiffen approach track foundation.
- Reduce deformation on the approach or ballast side: Techniques have included use of two additional rails connected to the ties between running rails over transitions to help spread wheel loads, thus reducing deformation on the approach side. Design lift ballast tamping has also been used to compensate for larger deformations of ballast sections.
- Prevent ballast particle movement: Use of side retaining walls has been the main method to prevent ballast particle movement. In addition, use of asphalt on top of the approach slab and even glued ballast has been mentioned to lock-in ballast particles.
- Better track foundation, fill, and embankment design and construction: Proper drainage and adequate compaction of fill and embankment materials are critical to prevent deformation and settlement. When removal is difficult, stabilization of poor subgrade materials is often necessary, using conventional soil stabilization techniques, such as a stone column and deep soil mix.

(blank page)

Table of Contents

List of Figures

1.0 BACKGROUND

Bridge approaches and other track transition zones such as special track work, road crossings, and track structure transitions are common locations of accelerated track geometry degradation. These localized zones can result in increased costs due to maintenance, track delays, or slow orders. Other negative impacts include increased wear and tear on bridge components, track, and vehicles, as well as decreased ride quality for sensitive freight or passengers.

There are various opinions on the causes of track geometry degradation at track transitions, such as at bridge approaches. For this reason, there are many mitigation methods used to improve vehicle/track performance in the transition areas. The opinions and documented test results have shown a wide range of performance for transitions from minimal to intractable maintenance problems that affect allowable train speeds. In other words, the railroad industry's experience to date suggests that the understanding of the degradation mechanisms at track transitions is certainly incomplete.

Ideally, bridge approaches should provide a smooth and durable transition between a bridge and relatively softer track, thus minimizing the impact generated and the resulting maintenance issues.

Moreover, they should be free draining, well compacted, adequately sloped, with crushed rock backfill behind, on sides and, if necessary, in front of an abutment placed over a good subgrade. This backfill behind the abutment should provide a full ballast section that should extend the full length of the bridge approach and provide stable embankment slopes. However, these conditions only rarely exist in the field and thus various means are used to cope with the issues of better dispersion of load, proper soil drainage and for reasonable containment of the ballast section.* The choice of the measure(s) used often depends on the conditions of a given site. However, keep in mind that the roadbed widths of many older bridges are not wide enough for the presently specified heavy axle load requirements. The bridge approach embankments also were built with local materials and so in many instances they are not adequate for today's loading nor are they adequately side sloped for stability due to persistent track raises over the years.

1.1 Objectives

This research, carried out by Transportation Technology Center, Inc. (TTCI) and sponsored by the Federal Railroad Administration (FRA) and Association of American Railroads (AAR), has the following main objectives:

- Identify degradation modes and causes of performance problems at track transitions
- Identify and evaluate mitigation methods to track geometry degradation at track transitions

*These means have varying degrees of success, but some of them are futile efforts because they do not touch upon the real cause of the problem.

1.2 Approach

The study identifies failure modes at bridges and determines factors contributing to failures through a combination of literature reviews, interviews with railroad-industry bridge-maintenance engineers, and test observations. This approach provides a thorough basis for future research in this area. The literature review includes several sources from the highway field, which offer valuable insight to the problem from a different perspective. Likewise, the interviews with industry personnel offer the real world perspective from those who deal with the problems in the field. The limited test information available to date indicates that this is an area deserving of further research.

2.0 LITERATURE REVIEW — DETERMINING THE MECHANISMS

In order to fully understand the track geometry degradation problem and competently evaluate potential solutions, it is necessary to understand the various mechanisms involved. In the past, most papers written on this subject have focused on the difference in track stiffness across the transition zone. A more synergistic approach is more likely to lead to greater understanding of the problem and a better selection of solutions.

The causes and factors of track geometry degradation across transition zones are separated as follows. They are describe thoroughly in subsections 2.1 through 2.8:

- Changes in track stiffness across the transition zone
- Differential track settlement
- Quality of fill and embankment material
- Quality of drainage
- Quality of ballast material
- Abutment type, bridge end connection, bridge joint
- Overall quality of construction
- Traffic considerations (weight, speed, direction, etc.)

2.1 Changes in Track Stiffness Across the Transition Zone

As a wheel moves along a section of track that has an approximately constant stiffness, the track deflects an approximately constant amount beneath the weight of the wheel. Consider the wheel moving over a section of track with a changing stiffness. The amount of deflection of the track beneath the wheel will change as well. If this change in stiffness occurs rapidly (depending upon the relationship between the rate of change of the stiffness and the speed of the wheel), the rapid deflection will result in increased track load due to impact effects.

The increased track load at these locations causes several problems. Differential settlement can occur in the foundation material due to the difference in load from one area to the next. Uneven ballast wear and degradation can occur near the track surface due to the increased loads. Both of these effects can add to the problem by increasing the difference in the amount of track deflection, and therefore increasing the impact loads. Other negative results of this process include greater wear and tear on track, bridge, and vehicle components, as well as potential ride quality issues concerning sensitive freight or passengers.

The concept of differential stiffness in bridge approaches and other transition zones is not new. Many papers, reports, and studies have discussed these phenomena as related to rail traffic.[1,2,3] However, this concept is not as prevalent in the reports involving highway traffic.

This may be due to the lighter weight of the vehicles and because the wheels of automobiles do not act as an unsprung mass.

A TTCI internal study confirms that differential stiffness by itself only contributes a small amount to dynamic wheel loads.[4] Track geometry perturbations can produce much greater dynamic wheel loads.

2.2 Differential Track Settlement

Differential settlement of the foundation material is a considerable concern, particularly at bridge approaches. This occurs when the consolidation characteristics of an area changes or when the load changes. Consider a bridge that is supported by piers or abutments that rest on the bedrock and an approach zone that is built upon fill material that consolidates and settles easily. As a train approaches, the approach zone will settle a small amount. However, as the train passes over the bridge, the piers or abutments will not settle because they are sitting on bedrock. Over time, the dead weight of the track and ballast and the weight from the traffic will cause this approach zone to settle a significant amount and cause rough sections at the ends of the bridge. The rough sections will result in higher impact loads and cause more settling. This phenomenon can also occur at other kinds of transition zones in the track that might result in high impact loads, such as at turnouts, grade crossings, and concrete tie-wood tie interfaces.

All of these areas are more susceptible to differential settlement if the foundation material is primarily clays or silts, or of high organic material content. This is due to their consolidation characteristics. In particular, some clays such as bentonite can behave quite poorly when the water content is altered. In general, sands (or other cohesionless materials) mixed with some fines can be adequately compacted into a suitable foundation.

2.3 Quality of Fill and Embankment Material

Often when a bridge is being built, or when an embankment or backfill area is being repaired, the material used is gathered from near the bridge or from another readily available source. If the material is poor quality, the effects on the bridge can also be poor, and unless remedial action is taken, the approach geometry will degrade.

Some of these problems include differential settlement, erosion problems, destruction due to vegetation, and destruction due to reactions between items in fill material and the materials that compose the track or bridge. These problems will generally result in a lack of support beneath the approach zone and will lead to poor track profile through the zone. Once a void forms beneath the approach track erosion will be difficult to control.

Some attributes that are unfavorable in fill material include:

- Excessive clays or silts that are prone to large consolidation settlement
- Excessive organic material that can decay and leave potential erosion problems
- Excessive vegetation at the surface that can cause destruction to the ballast and subgrade

2.4 Quality of Drainage

The adequate provision of drainage was considered to be of importance in many of the highway bridge reports. However, it was practically unmentioned in the rail bridge reports.[1,2,3]

Poor drainage can result in erosion problems and can have adverse effects on the strength and consolidation characteristics of the material beneath the track. Voids beneath the approach zone can become larger due to erosion from water running through and carrying away the material. Scouring of the embankment and material around the abutment can occur if the material is not protected by more resistant surface material. If the drainage is inadequate, the change in water content of the foundation material may result in strength and settlement issues.

Vegetation problems can also be amplified in areas of excess water. Damage to the surface material, and possibly the foundation material, can occur when roots grow and/or die and decompose. These locations can also be a starting point for erosion problems.

2.5 Quality of Ballast Material

Another area of potential problems that lead to track geometry degradation is the ballast section. One of the first things to consider is that the depth of the ballast is sufficient and that the ballast material is composed of the appropriate material. If the ballast is of poor quality and breaks or wears down rapidly, it will eventually cause a sag in the track. This can also occur if the ballast lacks sufficient angularity to lock together. If the ballast is too rounded, it will migrate from beneath the track. A phenomenon known as ballast memory occurs when the ballast repeatedly returns very quickly to its displaced location after tamping and surfacing. These situations can lead to a loss of track support and will cause increased vertical deflection when the train loads the track. When this occurs, it causes the impact loads to increase, further adding to the problem by wearing the ballast faster, causing increased differential settlement. This can result in excessive track maintenance and poor ride quality.

Depth of ballast on bridge decks can also be an issue. Most railroads recommend at least 8 inches of ballast beneath timber ties. Several railroads either prohibit the use of concrete ties, or discourage their use on bridge decks. Where allowed, railroads typically recommend at least 12 inches of ballast beneath concrete ties. For some railroads, the use of concrete ties on a bridge deck depends on whether the deck floor is constructed of steel, timber, or concrete. Inadequate ballast depth on the bridge deck can lead to excessive ballast degradation, tie deterioration, and the associated track surface problems.

2.6 Abutment Type, Bridge End Connection, Bridge Joint

Abutments, bearings, and end connections or joints are areas that must be examined for possible contributions to the bridge approach problem. These areas are critical because they are interface areas between the structure and the earth and, as such, are susceptible to differing track stiffness, longitudinal displacements, and differential settlements.

The design and geometry of the abutment is one of the most critical factors in approach degradation.[5] Degradation of track geometry is most likely to occur if the abutment is built on piles.[6] Some types of abutments, such as closed abutments and pedestal (spill-through) abutments, are prone to problems because it is extremely difficult to adequately compact the closely surrounding material. This material is then very prone to consolidation and will settle more than the outlying material. The attributes of the bearing are important as well. The bearing must be able to accommodate thermal stresses, but must be stable as well.[7]

Another key component in this area is the bridge joint or end connection. Integral end bents generally perform well, but care must be exercised to ensure that thermal stresses do not result in longitudinal deformations that cause voids behind the abutment. Problems that can arise at the joint include increased impact loads due to rough joint and erosion due to water infiltrating the joint.

2.7 Overall Quality of Construction

As with any construction project, poor craftsmanship and quality control can lead to problems. In particular, tolerances must be kept in check and shortcuts must be avoided. An example is compacting the backfill in fewer (thicker) lifts than recommended. This is almost guaranteed to result in increased consolidation settlement in the future.

2.8 Traffic Considerations (weight, speed, direction)

Traffic characteristics are worth considering as a potential factor in the geometry degradation problem. Some of these characteristics include axle load, vehicle suspension quality, truck spacing, speed, direction, and braking or throttling.

In general, heavier axle loads will result in larger differential settlement and greater forces on the bridge and track members. This is intuitive, as the consolidation level is greatly dependent upon the load applied.

Vehicle suspension quality can have a substantial effect on the track loads. Vehicles with better vertical suspension characteristics can better attenuate track profile deviations with higher frequency content. This will allow the wheel to make the transition from the bridge approach to the bridge surface more smoothly and will lead to decreased impact loads. The decreased impact loads will help minimize ballast wear, foundation settlement, and wear and tear on bridge and track components.

Speed is a very important factor in determining the impact loads that will occur at transition zones. In general, increased speeds will result in increased dynamic vertical wheel loads. It is also important to be aware of track geometry conditions that might induce resonant modes of vehicle movement. A common example of this is carbody rocking at speeds of 15 to 25 mph due to the length of rail sections being approximately equivalent to the modal wavelength of the railcar. In some cases, the dynamic wheel loads produced by these movements can be quite large and have a negative impact on the track geometry.

Direction of traffic should also be considered when analyzing the mechanisms of track geometry degradation. One of these considerations is determining if the approach zone degradation is occurring because of the wheel coming off of the bridge and onto the softer approach, or if the wheel is coming from the soft approach and ramming the stiff bridge section, or possibly both. Some bridges may incur loaded traffic in one direction and empties in the other, or single direction traffic only. These factors should be taken into consideration when analyzing the geometry degradation problem.

Another aspect of the traffic conditions to keep in mind is the typical train handling on the bridge. Longitudinal forces produced by locomotives in throttle, or by the entire train in braking can be quite large. If the abutment is weak, the small amount of strain in the longitudinal direction of the track can cause a small gap between the abutment and the fill material.[5] This small gap can then be exposed to erosion problems. Also, it is important to remember that the forces created by train traffic are three-dimensional. The bridge and the approach system need to be able to restrain lateral and longitudinal forces as well as vertical forces. The often neglected lateral and longitudinal forces can cause ballast migration, uneven consolidation, and a host of other problems.

3.0 LITERATURE REVIEW – IDENTIFYING AND EVALUATING POTENTIAL SOLUTIONS

After the modes of failure, and their causes and factors have been determined, potential mitigation methods can be determined and analyzed. If possible, several alternative solutions should be examined for each mode or cause of failure. When the list of potential solutions is complete, a matrix can be devised to rank the solutions based on criteria such as cost, difficulty of implementation, effectiveness, and maintenance issues.

3.1 Accommodate the Changes in Stiffness

Accommodating the change in stiffness across the transition zone was the primary objective in nearly all of the literature concerning transition problems on railway track. There are essentially two aspects of this objective. The first method is to reduce the stiffness on the bridge side through the use of tie plate pads and/or tie mats. The second idea is to gradually increase the stiffness of the approach zone such that the gradient of the stiffness difference is fairly small. This can be accomplished by the use of approach slabs, tapered sub slab beneath the ballast, ties of gradually increasing length, and geocell, HMA, or other stiff material below the ballast.

3.1.1 Reduce Stiffness on Bridge Side

The method of reducing stiffness on the bridge side has been examined by railroads from all over the world. These methods could also be used on other track transition zones, such as special track work, grade crossings, and tunnels. The theory behind this method is that by reducing the stiffness of the bridge, the difference between the loaded deflection of the approach and the loaded deflection of the track on the bridge can be reduced. By minimizing this difference, it is assumed that the magnitude of the impact load will be reduced as well, due to the decrease in vertical wheel acceleration. This would lead to reduced approach settlement, and reduced wear and tear on vehicle, track, and bridge. It is recommended that the track modulus be less than 10,000 lb/in/in to keep dynamic loads below the allowable ballast pressure levels.[8]

3.1.1.1 Tie plate pads

The use of tie pads started in the late 1800's. Since WWII, they have been used throughout the world as a method of preserving concrete ties.[2] The tie pad acts as a mechanical filter to attenuate the higher frequency impact loads and is often used in transition zones to decrease the stiffness of the bridge to approximate the stiffness of the surrounding track. The stiffness value of the pads can be optimized by measuring the rail deflection under a known load at the bridge structure and at the bridge approach. Pad stiffness can be calculated after calculating the difference in deflection. In some climates it may be necessary to gather this stiffness data at several times of year, depending upon temperature and the amount of moisture that enters the soil. By using all of this data, it may be possible to optimize the pad stiffness by modeling the transition zone and using the various stiffnesses calculated throughout the year. However, in most of these climate critical cases it may be more efficient to examine methods of remediating the soil in the transition zone to create ground conditions that are not as sensitive to the climate conditions.

There are several advantages gained by using tie pads. For example, one report states that a crew of four men installed pads on a 50-tie open deck bridge in a few hours without the use of sophisticated equipment.[2] Also, the pads only need to be placed beneath the stiff structure. This becomes a great advantage when trains are operating at high speeds because attempting to gradually stiffen the approach zone would require a very long zone. Also, the tie pads do not require any specialized maintenance procedures or equipment.

3.1.1.2 Tie mats

Another potential aid in reducing approach geometry degradation is the use of mats beneath the ties. This method was developed in the early 1970's in an effort to increase the train speeds to 250 km/h (155 mph) on the Shinkansen network in Japan.[9] Rubber mats were placed beneath the ties to reduce the dynamic loads and to prevent the destruction of the ballast. The ballast mats were produced by melting used automobile tires and adjusting voids to manipulate the spring constant. Extensive testing was performed, and it was concluded that the mats were very effective in reducing ballast wear. Germany also experimented with mats during the late 1970's.[9]

3.1.2 Gradual Stiffening of Approach Zone

One of the most common methods of attempting to control the geometry degradation of bridge approaches is to gradually stiffen the approach zone. This can be done in a number of different ways, and the costs of the different methods can vary substantially. Some of the methods are to build approach slabs, gradually increasing the length of the ties, placing a layer of HMA or geocell or other similar material above the subgrade, or using extra rails between or outside of the running rails.

3.1.2.1 Approach slabs

Approach slabs are commonly used on railway (and highway) bridges. They are generally built as a cantilever with the fixed end supported by the rigid bridge structure. The free end then extends away from the bridge and is supported by the subgrade. The ballast is then placed on top of the slab. In general, the slabs are tapered such that the thickness of the slab decreases as it extends further from the bridge. This decrease in thickness essentially alters the stiffness of the track. These slabs are generally made of concrete and the slope of the transition can be designed to account for the speed of the traffic. This can become a substantial project on bridges with very high-speed traffic.

3.1.2.2 Gradual increase in tie length in approach zone

A very common method of gradually increasing the track stiffness in the approach area is to gradually lengthen the cross ties on the track. The increased length of the tie spreads the load over an increased surface area onto the ballast. This results in a decrease in vertical track displacement during track loading. By gradually lengthening the ties, the difference in settlement between the bridge track and the approach track is incurred more slowly. This results in a decrease in impact load as well as a decrease in ballast wear and consolidation settlement.

3.1.2.3 Geocell, HMA, Cement Stabilized Backfill

Other developed methods of smoothing the stiffness include the use of geocell, hot mix asphalt, and cement stabilized backfill.[10] These can be laid in varying thickness between the subgrade and ballast to gradually increase the stiffness of the track modulus.

3.1.2.4 Installation of two rails between two running rails

A method of increasing the track stiffness on the approach side that is found occasionally in Europe is to install a pair of rails between the two actual running rails, and sometimes another pair located on the field side of the running rails. This method was developed by the German Federal Railways for the ICE high-speed lines.[9] The length of this transition zone could be adjusted to account for the train speed at the location.

3.2 Optimizing Abutment Type and Ensuring High Quality Construction

In most cases, the abutment is built on piles that extend through the subgrade to the bedrock below. This is generally the best arrangement if the approach zone is expected to consolidate and settle a reasonable amount. However, in areas where the presence of very thick layers of clays or organic material will produce very large settlements, it might be a better option to look at other abutment configurations. Abutments supported on shallow footings within the embankment will generally settle with the embankment and result in less differential settlement than abutments supported on piles.[7]

Another aspect of abutments is the difficulty of compacting the soil near the abutment to an adequate density. This area may need to be constructed in smaller lifts and compacted with more versatile equipment. An increasingly common practice in the highway industry is to use a very wet concrete mix as a flowing fill material for areas around abutments, where it is difficult to place and compact fill.

3.3 Reduce Ballast Wear and Movement

Another aspect of the bridge approach issue that should be examined concerns the amount of movement that is taking place in the ballast. Ballast plays an important role in absorbing some of the dynamic load and spreading the load to the subgrade over an increased area. One cost of this benefit is that the ballast wears in proportion to the energy absorbed, not transmitted.[11] It is therefore best to optimize the energy absorption without having the ballast migrate. Once the ballast has begun to migrate a significant distance, the long-term battle with ballast memory problems has begun. When the ballast is tamped and the track is restored to correct geometry, the ballast will immediately begin moving to its prior displaced location. This movement of ballast will then lead to a lack of track support, which will result in track pumping. The track movement will then cause more ballast migration and more ballast wear.

3.3.1 Side Retaining Walls

Side retaining walls are used to control the lateral displacement of the ballast. This in turn helps control the vertical displacement of the ballast, as it is unable to push the underlying ballast to the side and occupy the new location. Side retaining walls can be used to regulate the ballast near the bridge approaches that might otherwise be dispersed by foot traffic.

3.3.2 Glued Ballast

Another possible method of restricting the ballast movement is by using a bonding agent to glue the particles together. This might reduce the amount of deflection beneath the ties and prevent track pumping. However, possible drawbacks such as increased dynamic loads at the subgrade and complications in maintaining the ballast would need further consideration.

3.3.3 Specify Ballast Characteristics

One of the logistically easier methods of optimizing ballast performance is to specify the ballast material to be used. Ballast material should exhibit hardness and toughness, and should be angular in shape. The angularity, combined with the roughness of the surface texture, ensures adequate interlocking of the ballast particles. Fine grained, extrusive, mafic traprock, such as basalt or andesite, is preferable. Granite has adequate hardness, but is brittle and tends to fracture across or through grains. Only blasted, crushed, quarried rock with a minimum particle index of 15 (as determined by ASTM D 3398) should be used. It is recommended that an AREMA type 3 or 4A gradation be specified, and that the ballast be a minimum of 18 inches deep.[8]

3.4 Consolidation in Subgrade

It is generally assumed that the soil beneath the track will consolidate to some extent, and it is important to accommodate this settlement. In some cases, a very large surcharge load may be placed over the track subgrade prior to the construction of the track. This load will remain in place for some time and pre-consolidate the material below. During the design of the bridge approach, consideration must be given towards limiting the amount of future consolidation that will take place. A few of the options that are available for minimizing the settlement are ensuring adequate drainage, specifying and confirming the characteristics of the fill and embankment materials, removing poor material and replacing with better material, and/or stabilizing poor material.

3.4.1 Adequate Drainage

One of the many important considerations in preventing excess settlement in the subgrade material involves ensuring adequate drainage. This is particularly true in areas that have a high quantity of clay. Fluctuations in the amount of water in the subgrade can result in shrinking and heaving of clay soils. Also, excess water will promote the growth of unwanted vegetation. This vegetation can damage the foundation material due to the growth of roots. Another unwanted feature of inadequate drainage is the potential for extra erosion due to water scouring and possibly freeze-thaw cycles.

3.4.2 Specify and Confirm Characteristics of Fill and Embankment Materials

Perhaps the most critical action that can be made during the construction of a bridge approach is the specification of appropriate fill and embankment material. Many times, this material is gathered from a nearby area, regardless of the characteristics of the material. Constructing the embankment and backfill with poor material, such as fat clays or material with high organic content, will most likely result in approach problems for the life of the bridge. The two most commonly reported causes of approach roughness on highway bridges were compression of fill material and settlement of the natural soil under the embankment.[6] Rock, gravel, and sandy material are generally preferred for fill and embankments because they have very little long-term settlement. If these materials are combined with a small amount of fines and properly compacted, very little post-construction settlement will occur.

3.4.3 Removal or Stabilization of Poor Materials

In areas with very poor subgrade material, it may be necessary to remove the material and replace it with select fill; or in some cases, it might be possible to stabilize the approach using some of the methods outlined below.

3.4.3.1 Piles and/or other columns

One of the more common methods of stabilizing the subgrade soil is to use piles of some kind. These piles can include concrete piles, stone columns, sand columns, lime columns, timber columns, and others. The piles are used to support the track above and transfer the load to the subgrade. This load is usually transferred via the skin friction of the pile, although the bearing surface at the bottom of the pile can carry some of the load as well. If this bearing surface is on firm material, it can carry a substantial amount of the load. As the pile is carrying the load, and has low consolidation properties, the amount of time dependent deflection is much smaller than that of the soft subgrade material.

Piles can be very effective in limiting the settlement at approaches. They can also be driven to various depths to gradually decrease the amount of settlement through the length of the approach and smooth the transition from the open track to the bridge.

3.4.3.2 Deep soil mixing

Deep soil mixing is a method that is somewhat similar in theory to driving piles. Instead of driving piles, blades are inserted into the ground and rotated to mix up the soil. These blades are pushed into the ground to an appropriated depth, and while the mixing is taking place concrete (powder or slurry) is added. After the soil and concrete are thoroughly mixed, the concrete is allowed to cure. The result is a concrete/soil column that is strong and relatively incompressible. One potential concern is that the concrete must be well mixed until the column is fairly homogeneous. If the column is heterogeneous, failure may occur at a zone of low strength.[12]

4.0 LITERATURE REVIEW – IMPLEMENTING AND MONITORING APPROPRIATE METHODS

After the possible approach geometry degradation mechanisms and possible solutions have been identified and evaluated, decisions about the implementation and monitoring of the methods can be made. One aspect of the entire evaluation process that was missing from the literature was provided by the field interviews. Knowing the history of the bridge, including construction details and geotechnical issues is very important to understanding the fundamental causes behind the geometry degradation, as well as which avenues of remediation are most likely to be successful or unsuccessful (examples are in the interview notes in the appendix). When the history of each of these examples is given, the reason or cause of the degradation is quickly apparent to the experienced reader. Consider Case 1a: Former AT&SF line from Cleburne to Cresson, Texas. The reader, after knowing the history of the track realizes that the new soil under the short trestle approach is going to consolidate much more than the material adjacent to it.

Choosing methods of prevention or mitigation of geometry degradation is not a simple task. Every bridge will have unique considerations and will respond differently to the use of the available techniques. The first decision to make is whether the bridge has significant approach problems and whether these problems could warrant the use of any of these techniques. This will require some sort of cost benefit analysis to determine if the reduced maintenance costs will be worth the investment into degradation prevention.

In some cases, it might be a better economic choice to simply deal with the problem as it arises and forego the initial expense. Other cases might prove to be more economically efficient to perform a large amount of prevention or remediation work that will minimize future maintenance costs.

If you decide that some sort of approach geometry degradation prevention or mitigation will be performed, the next decision is which method(s) should be pursued. It is important at this point to realize which techniques will or will not be effective in preserving the track geometry. The effectiveness of the techniques will be fairly dependent on the mechanism(s) responsible for the geometry degradation. For example, if poor quality ballast is leading to ballast destruction resulting in the track sinking, installing a concrete approach slab beneath the ballast might not be the best choice. In some cases, a relatively inexpensive solution, such as gradually lengthening the ties in the approach zone, may be the most cost effective method. Other cases may warrant solutions that have significant costs.

After the appropriate prevention or remediation techniques have been chosen, it is important to closely monitor the implementation of the technique. The effectiveness of many of these methods can be significantly reduced by poor quality of construction. It is also a good idea to honestly evaluate whether the proposed methods can be performed in-house, or whether they need to be constructed by outside agencies. In either case, closely monitoring and documenting the process will help ensure that an adequate job is done. Also, the approach zones should be monitored afterward to determine the effectiveness of the solution.

5.0 SURVEY OF RAILROAD INDUSTRY FIELD PERSONNEL

A number of railroad employees were interviewed regarding their experience with bridge approaches in revenue service. The interviews included employees at many different levels, from inspectors and field supervisors to top-level engineers. The interviews are summarized below. Notes from individual interviews are attached as an appendix.

The recurring theme of the interviews with railroad personnel was that not one method worked one hundred percent. The chosen method merely slowed the geometry degradation. Managers in every territory had their own idea on how to control the approach geometry problem. But nearly everyone interviewed believes it is a soil problem. Each manager has tried different methods but none has been one hundred percent effective. Therefore, bridge location should be analyzed as to what procedure to use.

Below are some of the methods used:

1. Raise track at bridge approach by adding ballast. This sometimes requires raising back wall and wing walls or installing pre-cast ballast retaining sections.
2. Widen ballast section behind the back wall and install longer (transition) ties.
3. Provide weep holes in the abutment stem and wing walls.
4. Remove part of impervious fill material from behind the abutment and replace with free draining crushed rock.
5. Install concrete slab immediately behind the abutment under the track or install a pad of hot mix asphalt.
6. Replace fill behind the abutment with lightweight lean concrete.
7. Stabilize bridge approach by driving timber piles.
8. Stabilize bridge approach by auguring holes and filling with lime slurry.
9. Pump lime slurry or jelly into the embankment.
10. Stabilize bridge approach by auguring holes and filling with compacted crushed rock.
11. Stabilize bridge approach by vibratory compactor.
12. Stabilize bridge abutment by building a toe or cut-off wall.
13. Stabilize bridge abutment by anchoring its footing or anchoring its stem.
14. Import selected back fill.
15. Use rip-rap that is placed on the corners of the embankments to hold the fill in place.

Various railroads use some of these measures. Important steps to remember are to provide proper dispersion of load all the way from ballast section down to the subgrade level, provide adequate drainage so the soil does not weaken due to increased moisture content, and provide stable slopes so slides or drawdowns do not occur.

6.0 FIELD TESTS AND MEASUREMENTS

Union Pacific (UP) added a second track to its Cedar River bridge in Iowa (Figure 1). As part of the project, new longer end spans were added to the original bridge on the north side (Figure 2), and all new spans were added for the second track on the south side. During the course of construction, stone columns were added to the approaches for both tracks at each end of the bridge. A shoo-fly track arrangement was used to keep one track open at all times during the construction.

This installation provides the opportunity to monitor the long-term performance of stone columns as approach reinforcement for both new embankment (south track) and existing embankment (north track) that has been consolidated by years of traffic.

Figures 3 through 9 show the installation process. Pier locations were marked. An auger was used to make a hole about 30 inches in diameter and 7 feet deep. Holes were filled with 6-inch layers of Class-A road stone. Each layer of stone was tamped. The stone columns were centered 5 feet apart laterally, beneath each rail. They were spaced at 6 feet longitudinally. A total of 10 or 11 were used on each approach, covering a distance of 60 to 66 feet from the bridge back wall.

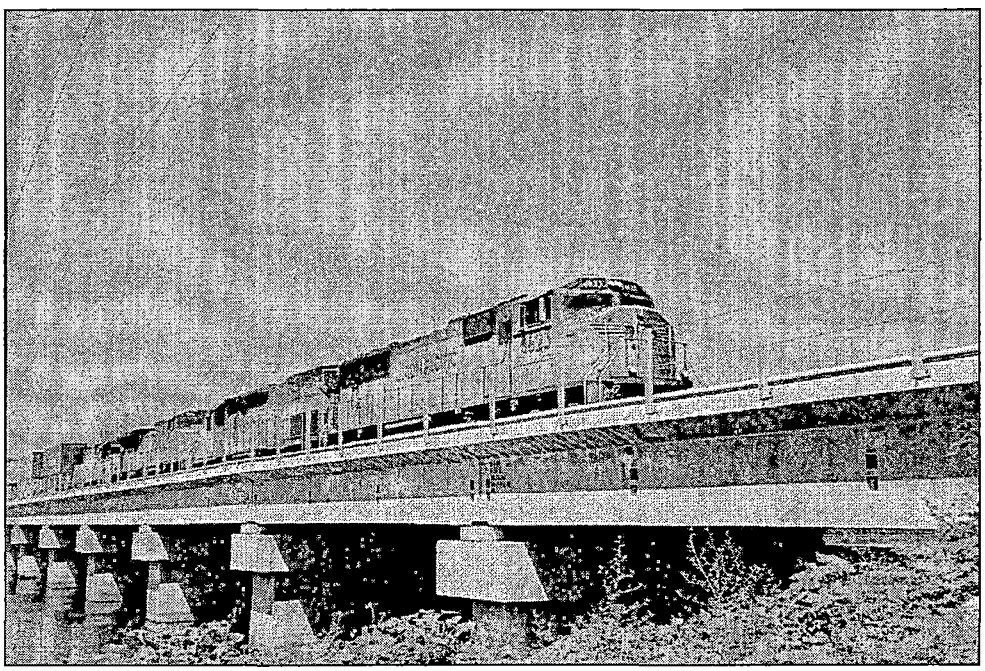


Figure 1. New Bridge for Second Main Track over Cedar River

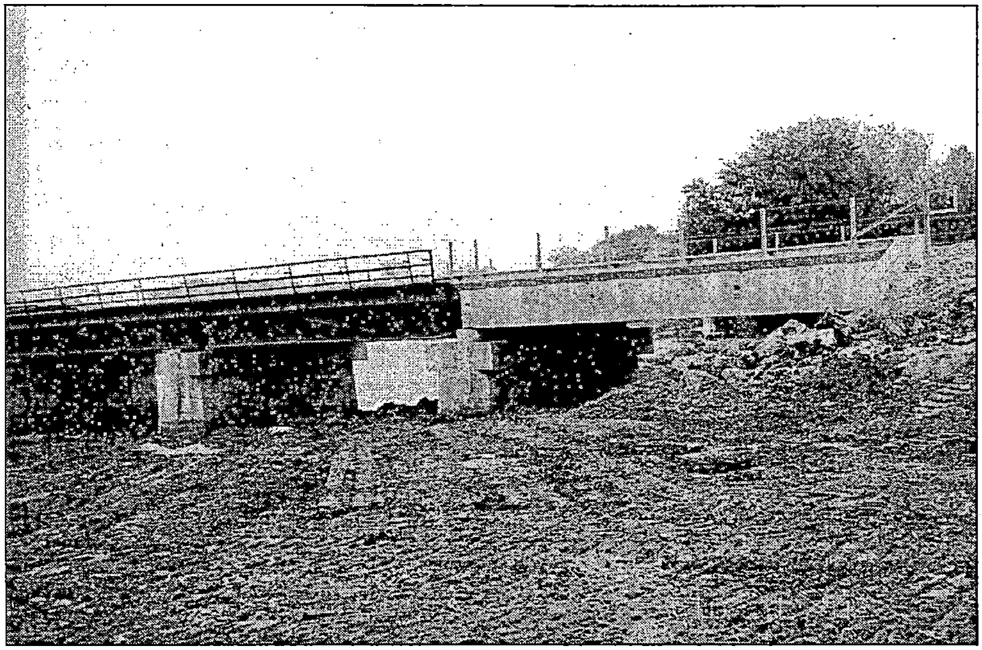


Figure 2. New End Span on North Track Bridge

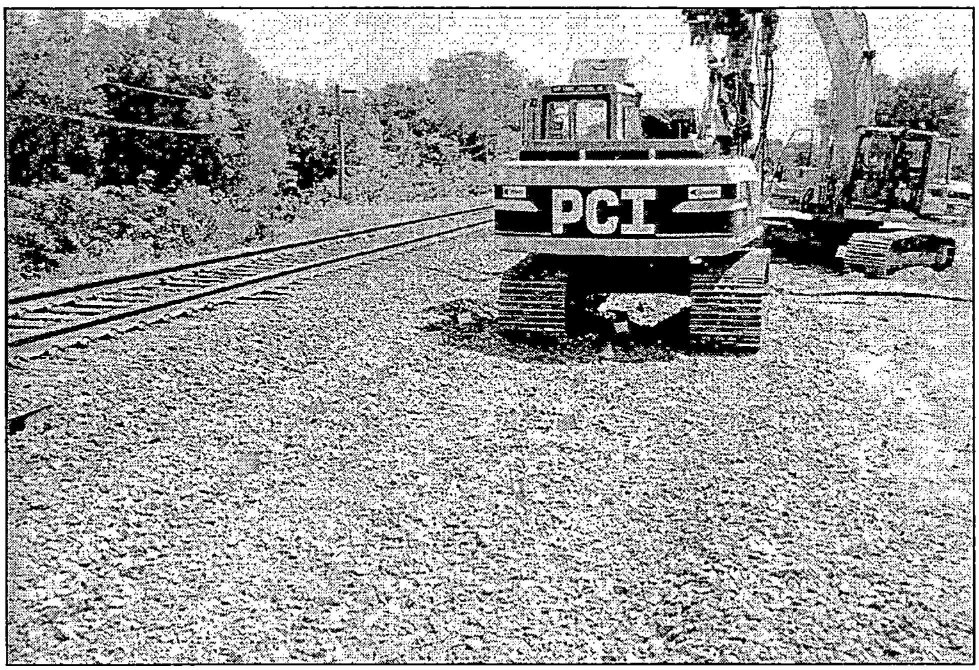


Figure 3. Locations Marked for Stone Columns

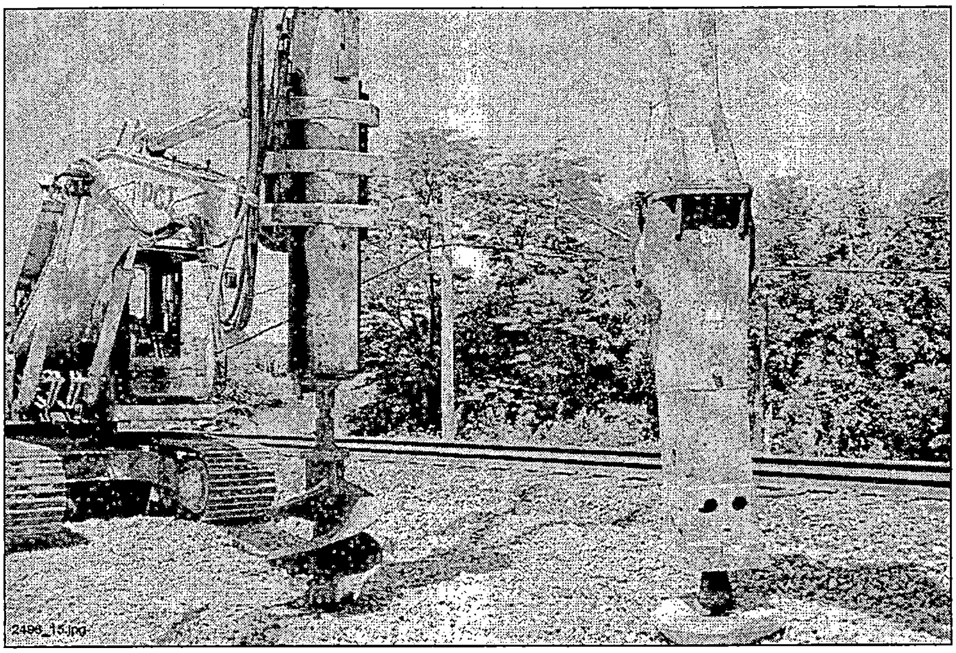


Figure 4. Auger and Tamper Used for Stone Columns

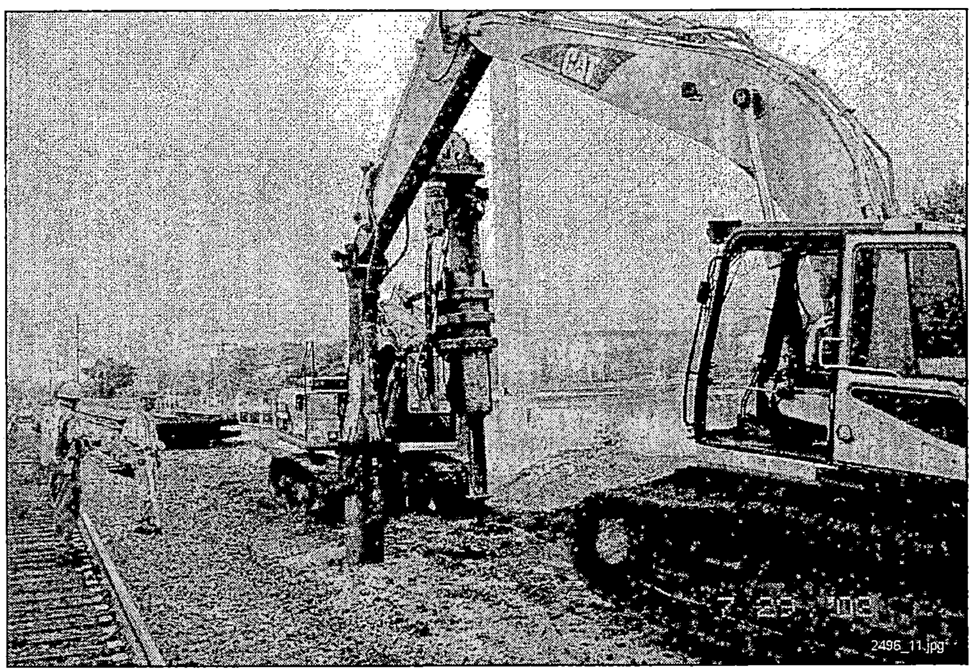


Figure 5. Installing Stone Columns

Figure 6. Holes for Stone Columns

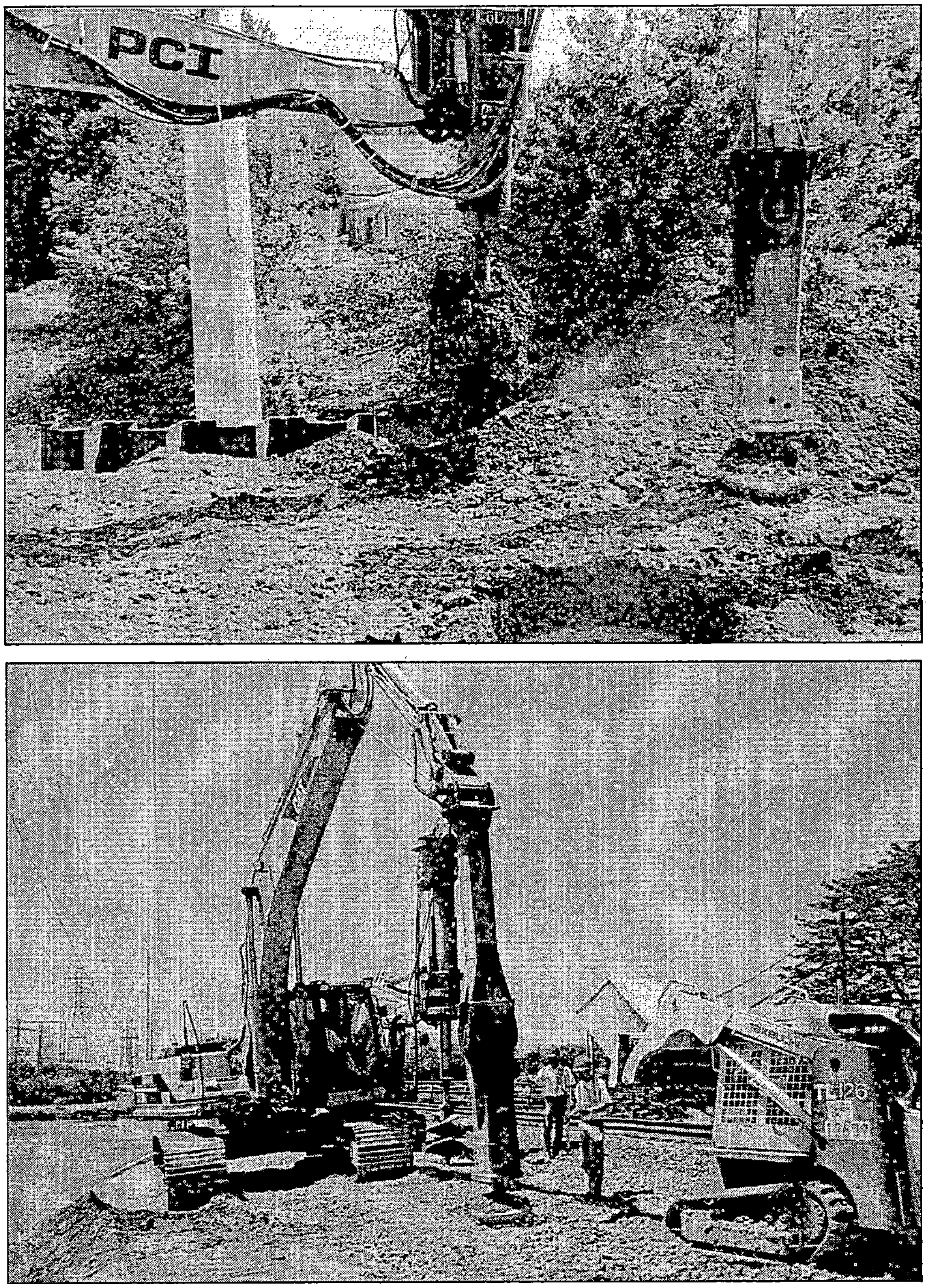
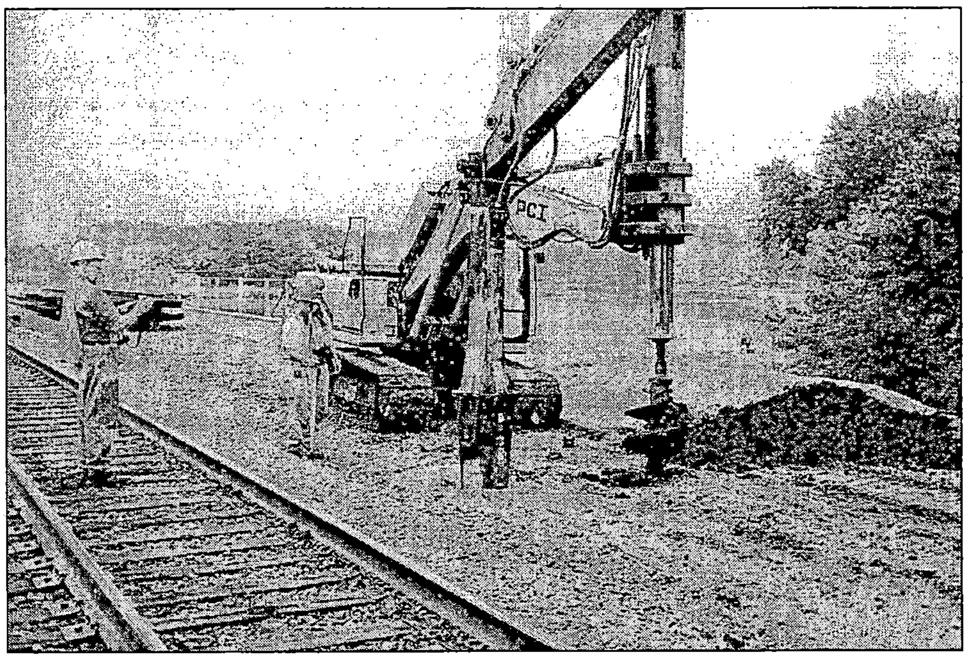


Figure 7. Installing Stone Columns



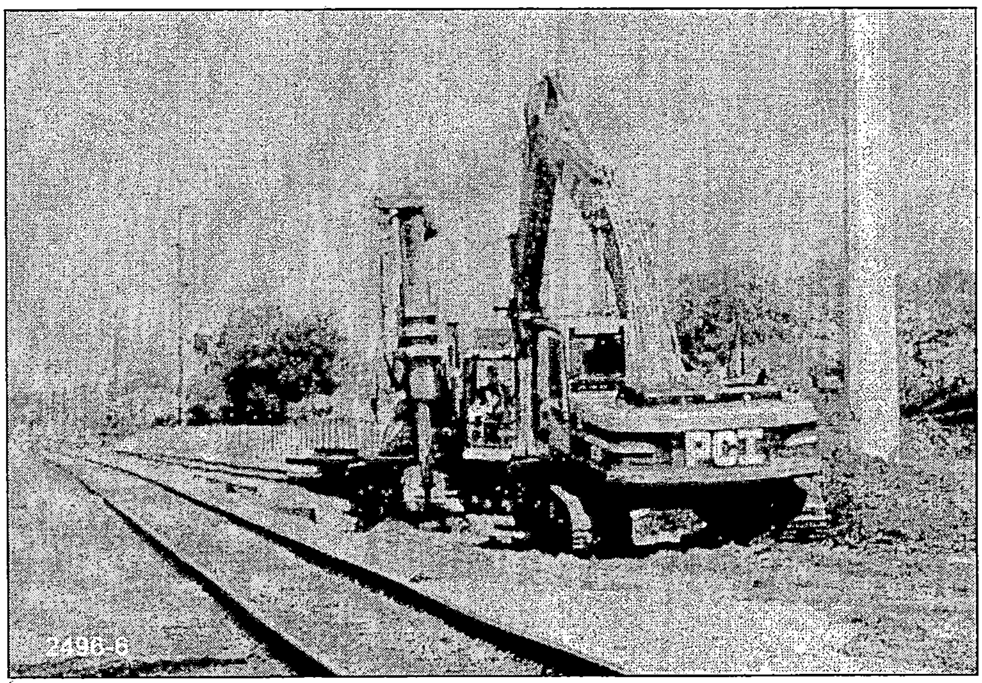


Figure 8. Installing Stone Columns
(Note Low Approach on Original Main Track)

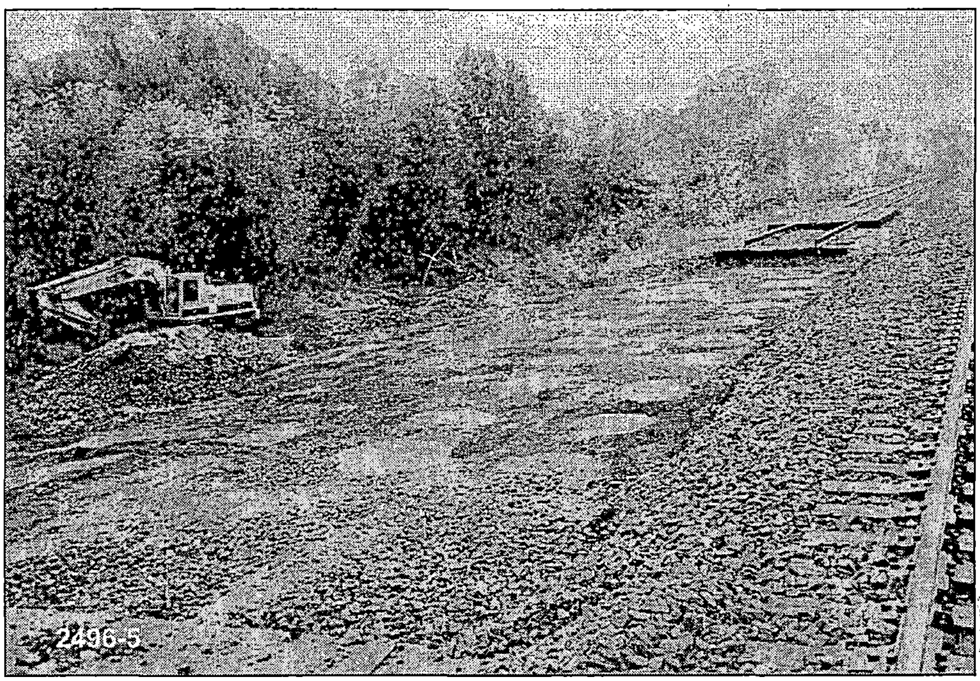


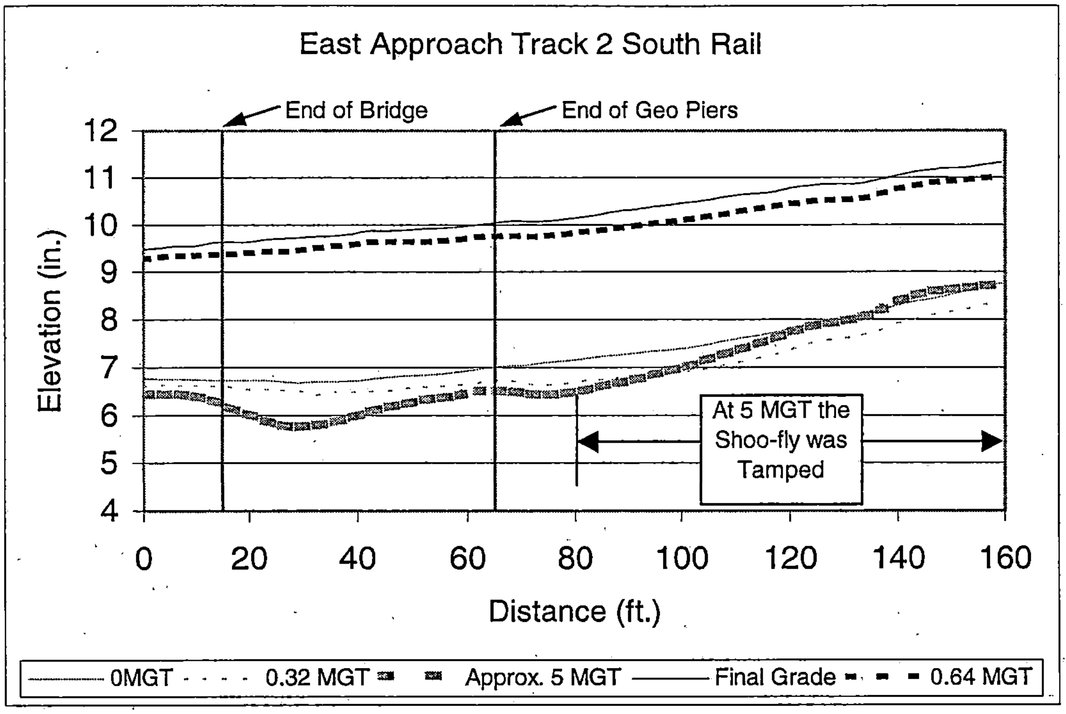
Figure 9. Completed Stone Column Installation

The stone columns provide increased strength, better drainage, and increased stiffness on the approaches.

Figure 10 shows the settlement and tamping history for the initial installation on both tracks of the east approach. Note that there was some differential settlement under the first 50 trains or so, and more during the first 5 MGT on the south track. The 3-inch lift to final grade removed the initial dips in the track. Subsequent settlement was uniform for the first 100 trains or so.

Long-term performance evaluation is ongoing. At this writing, no tamping or maintenance has been needed on any of the approaches. Estimated tonnage since installation is 30 MGT on the south track (new construction) and 57 MGT on the north track (original alignment with consolidated approaches). Historically, this area has had some track geometry problems. However, according to employees in charge of this territory, lately the problems have not been considered abnormal.

Related field measurements can be found in references 10 and 13 of this report.



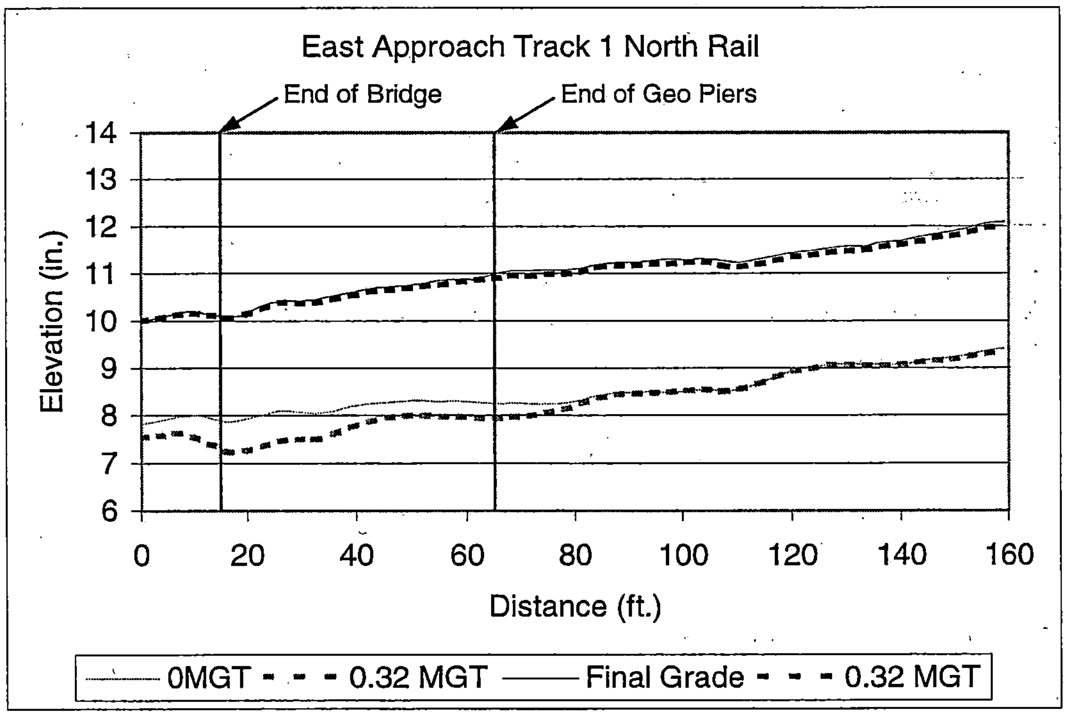


Figure 10. Settlement and Tamping of East Approach Tracks

7.0 SUMMARY AND CONCLUSIONS

In this study, causes of track geometry degradation at bridge approaches, as well as potential remedies for this degradation, were examined. These causes and remedies were determined through a literature survey, a survey of maintenance personnel, and field tests and inspections. Numerous reports on bridge approach geometry problems (highway and railway) and reports from field personnel demonstrate that geometry degradation is a problem that ranges in severity from non-existent to chronic. Also, the fact that several of the reports in the literature survey were produced in countries around the globe, or gave detailed information about occurrences in other countries, gives evidence of the wide spread nature of the problem. The negative effects of this degradation include increased costs due to wear and tear on track, bridge, and cars, as well as track delays and slow orders. Furthermore, excessive track geometry problems can lead to damage of sensitive freight and annoyance to passengers.

The railroad industry has generally considered this problem to be a function of the difference in vertical track stiffness between the approach zone and the bridge. The information gathered in this study shows that this is not always the case. This study included findings from several reports concerning approach geometry degradation on highway bridges. These findings generally pointed towards geotechnical issues, primarily consolidation and erosion, as being the primary contributors to the problem, as opposed to stiffness considerations. Also, a more complete list of alternatives can be formulated and evaluated. A brief list of the potential sources for bridge approach geometry degradation is as follows:

- Changes in vertical track stiffness across the transition zone
- Non uniform rates of consolidation and ballast movement/destruction
- Quality of fill and embankment material
- Quality of drainage
- Quality of ballast
- Abutment type, bridge end connections, bridge joints
- Quality of construction
- Traffic considerations; e.g., axle weights, suspension quality, tonnage, speed, direction, and throttle/braking

Using the knowledge of the various factors that are involved in geometry degradation, a more complete list of potential solutions was constructed. These included techniques used in China, Japan, Germany, England, France, Sweden, and the United States, as outlined below:

Addressing the change in stiffness between approach and bridge:

- Reducing stiffness on bridge
  - Tie plate pads
  - Tie mats
- Gradually increasing stiffness of approach zone
  - Approach slabs
  - Gradual increase in tie length across approach zone
  - Geocell, HMA, etc.
  - Installation of extra rails between and outside of running rails

Optimizing abutment type and ensuring quality construction

Reducing ballast wear and movement

- Side retaining walls or ballast cribs
- Glued ballast
- Specify ballast characteristics

Accommodate consolidation in subgrade

- Ensure adequate drainage
- Specify and confirm characteristics of fill and embankment
- Remove or stabilize poor materials
  - Piles or other columns
  - Deep soil mixing

After these techniques were described, a brief overview was given of the process of determining which method(s) was most appropriate and economically feasible. The importance of cost benefit analysis of the methods was stated. Close monitoring and documenting during the implementation of the methods were recommended, as well as monitoring the area afterwards to determine the effectiveness of the work.

REFERENCES

1. Frohling, R.D., H. Sheffel, and W. Ebersohn, "The Vertical Dynamic response of a Rail Vehicle Caused by Track Stiffness Variations Along the Track."
2. Kerr, A. D. and L. A. Bathurst, "Pads Ease Track Transitions," *Railway Track & Structures*, August 2000.
3. Lopez-Pita, A. "The Importance of the Vertical Stiffness of the Track on High Speed Line," Transportation Research Board 81st Annual meeting, Session 216 — Design and Construction of Nonconventional Track. January 2002.
4. Singh, Satya P., Effect of Track Stiffness-Transition Between Approach & Bridge, and Perturbation-Generated Impact Loads in this Region, TTCI Internal Report, June 2003.
5. Smekal, A., "Transition Structures of Railway Bridges," World Congress on Railway Research, Firenze, 16-19 November 1997.
6. Briaud, J.-L., S. M. Maher, and R. W. James, "Settlement of Bridge Approaches (The Bump at the End of the Bridge)." National Cooperative Highway Research Program Synthesis 234, 1997.
7. Wahls, Harvey E., "Design and Construction of Bridge Approaches," NCHRP, Synthesis of Highway Practice 159, *Transportation Research Board*, July 1990.
8. Redden, John W. P., Hanson-Wilson Inc., Ernest T. Selig Inc., Zarembski, Allen M. "Stiff Track Modulus Considerations." *Railway Track & Structures*, February 2002.
9. Kerr, A. D. and B. E. Moroney, "Track Transition Problems and Remedies," Bulletin 742, American Railway Engineering Association.
10. David D. Davis, Ruben D. Pena, Brian E. Doe, Comparison of Three Methods for Strengthening Bridge Approaches in Revenue Service, Association of American Railroads, Transportation Technology Center, Inc. *Technology Digest* TD 01-022, October 2001.
11. Moehren, H. H. "Paving Alternatives to Ballasted Track – Track Quality Improvements to Support High Speed Rail." Bulletin 762 – AREA.
12. Lin, Kai Qiu and Ing Hieng Wong, "Use of Deep Cement Mixing to Reduce Settlement at Bridge Supports," *Journal of Geotechnical and Geoenvironmental Engineering*. April 1999.
13. Dingqing Li, Randy Thompson, Previn Marquez, and Bill GeMeiner (UP), Vertical Track Stiffness Tests of Revenue Service Bridges and Approaches, AAR/TTCI *Technology Digest* TD 03-013, June 2003.
14. Phillips, A.B, Phillips, Tony, White, J., "Track Formation Behaviour in Arid Climates," Conference on Railway Engineering, Wollongong, November 1-13, 2001.
15. Hunt, Hugh M., "Track Settlement Adjacent to Bridge Abutments," Vehicle-Infrastructure Interaction IV, San Diego, June 2-7, 1996.

16. Shanafelt, George O. "Bridge Designs to Reduce and Facilitate Maintenance and Repair," National Cooperative Highway Research Program Synthesis of Highway Practice, December 1995.

17. Hoppe, Edward J., "The Use, Design, and Construction of Bridge Approach Slabs," *Routes & Roads*, N0 312, pp. 24-33, October 2001.

18. Zarembski, Allan M., "Track Modulus and Degradation," *Railway Track & Structures*,. pp. 7,8, August 1994.

19. Mitchell, Ben. "Treating Transition Zones on the NEC," *Railway Track & Structures*,. p. 16, February 1995.

20. Sharpe, P., Armitage, R.J., Heggie, W.G., Rogers, A. "Innovative Design of Transition Zones," *Railway Engineering 2002, 5th International Conference and Exhibition*, London, UK, 3-4 July 2002.

Appendix
Interview Notes
Railroad Bridge Personnel

1. William G. Byers, General Director – Structures Construction, BNSF

Case Studies – AT&SF Bridges in Dallas / Ft. Worth, Texas Area

a. Former AT&SF line from Cleburne to Cresson, Texas

Geology is shallow rock, covered with highly organic black soils and active clay known as montmorillonite. This soil undergoes a large volume change with change in water content.

The line was constructed about 1887. For years, the railroad had troubles maintaining surface on the line. Eventually after years of track raises and soil consolidation, the line became stable.

In the early 1990's, the Santa Fe replaced a long trestle with a shorter one. The area that was under the long trestle — but not the short trestle — was filled with native subgrade soil. This fill was on top of unconsolidated soil, as the older long trestle had been carrying the loads over this area in the past.

The new fill over the unconsolidated soil (where the old trestle had been) had significant settlement when placed back in service. Settlement was so great that it caused a train derailment within months of placing the new trestle in service. This line had very low annual tonnage.

The line is no longer operated by the BNSF.

b. Former AT&SF line from Zacha Jct. to Dalton, Texas

The line was built around 1955. On this construction project, montmorillonite clay was used as a fill for embankments. The line had general embankment settlement problems. The problem was not specific to bridge approaches. But it was worse at bridge approaches because of the differential settlement. The bridges, built on piles, did not settle.

In an attempt to stabilize the embankments, timber piles were driven vertically. This technique did not work in the long term. The piles leaned outwards from the track over time.

During the 1970's and 1980's, the Santa Fe rebuilt the embankments using a mixture of lime and soil, to make them more stable. The calcium in the lime replaced sodium in the soil to reduce the reactivity and swelling of the soil. This solution seemed to be successful on this line.

The line is no longer operated by the BNSF.

c. Other former AT&SF lines

On some other former AT&SF lines, ballast pockets were a problem. The AT&SF had good success by grouting them with cement and/or fly ash. This is an older method. Nowadays, lime stabilization is sometimes used for this problem too. But it is not always an appropriate solution.

The best advice is to determine the true source of the problem, and address that. If the problem is poor embankment, fix the embankment. If the problem is the soil beneath the embankment, then fixing the embankment is not going to solve the problem and could end up being a wasted effort.

2. Don Lewis, Manager –Bridges & Structures, CN/IC

Case Study – IC in Mississippi

Several soil studies were made on the Illinois Central in the late 1970's in conjunction with the 4R act. Studies were on stabilizing track in areas of expansive clay. Lime stabilization was used. This work was not directly related to bridge approaches. Rather, it was a general track stability problem that was being addressed. The problem and solution sound very similar to the Santa Fe problems in the Dallas Texas area.

Unable to locate any references reporting this work.

3. Mike Horst, BNSF, Supervisor of Structures, La Junta, CO

With new construction on an existing line, they excavate as little as possible to avoid disturbing existing fill. The area behind the end cap is dug down to approximately 3 feet so the welder can gain access to the bottom of the cap and the piling to be welded. Stringers are then stacked behind the cap to prevent the fill material pushing out from under the cap, the piling under the cap and the back wall. Screenings are used to promote the drainage of moisture away from the embankment through the weep holes in the back wall. Back east, Venset is used to help consolidate the backfill and promote good compaction. This material is mixed with water and is sprayed on the backfill material and a vibrating foot is used for compaction. The cost of the Venset is $750 for a 50-gallon drum.

4. Nelson Bynum, BNSF, Supervisor of Structures, Temple, TX

They have tried 10-foot transition ties on the approaches to stop the degradation of the approaches. On another bridge, grouting of the approaches was used, but it was just done. and they don't know what the performance of the technique is yet. With new construction, dig as small a hole as possible into the existing embankment. Use a mixture of cement and backfill material to within 5 feet of the rail. Use pea rock sometimes instead of the slurry mixture.

The open deck bridges are continuously low.

No one method can stop the degradation but can slow it down.

5. Ed Ferguson, BNSF, Manager of Structures, Denver, CO

They have tried 10-foot approach ties. They have used flowable cement fill-slurry. Another approach was to extend the wing wall sections to stop the movement of the fill out and away from the embankment. Drain tubes were installed behind the back wall to keep moisture from accumulating in the fill behind the back wall. One more method was to put back different fill material instead of the excavated material.

Mr. Ferguson believes it is more of a 'soils' problem.

6. Dale McFarland, BNSF, Supervisor of Structures, Amarillo, TX

For renewals, they would ideally use select backfill. Sometimes they form up a 19-foot-wide, 18-inch-thick, and 4-feet-long pad and then fill with slurry. The most successful procedure seems to be digging 28-inches deeper than the cap and bolting two rows of 8" X 14" bridge stringers to the new piling. Then backfill with select soil and tamp in 6-inch lifts with a tamper mounted to the backhoe. They have backfilled with screenings mixed with the local fill. This procedure just slows the degradation down but does not stop it.

In Texas they have been backfilling with material called Caliche with some moisture added and tamped every 6 inches of lift. They have had good results using the Caliche. The area rainfall is about 13-inches a year.

All of these fixes just slow the degradation down but does not stop it.

They have problems with the approaches of every open deck bridge approach between Texline and Amarillo, Texas.

Regular maintenance of the bridge approaches is limited to putting slow orders on the affected approaches and wait for the Surfacing Gang to tamp them up when they tamp the rest of the track in the area.

7. Bruce Polnicki, BNSF, Supervisor of Structures, Denver, CO

The crews install wing walls on either side of the embankment. They sometimes use timber ties to create the wing wall. Another type of wing wall used is 89# H-pile for the uprights and 8" x 16" stringers behind the pilings. Rip-rap is placed on the corners of the embankment. Ten-foot transition ties are used as the standard on the approaches to the bridges. If water is collecting behind the back wall they dig out behind the back wall and replace the material with ballast.

8. Joe Venturi, BNSF, Bridge Inspector, La Junta, CO

On the Boise City Sub, the track itself appears to be settling and not the bridge approaches alone.