

“DEVELOPMENTS IN TRACK SUBSTRUCTURE ASSESSMENT AND REMEDIES”

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Summary

Investigative techniques performed on Association of American Railroads (AAR) member roads and 15 years of track substructure research have resulted in an assessment program that will help users determine causes of substructure problems and provide the best remedial action. By applying the assessment methods, member railroads can obtain lower track life cycle costs by eliminating attempts at ineffective remedies.

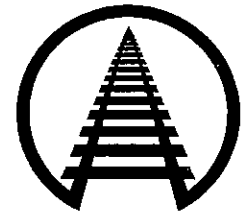
Track engineers often have been discouraged by slow investigation techniques and the uncertainty of knowing what to look for when trying to determine the cause of poor substructure performance. As a result, the AAR and the University of Massachusetts have collaborated to develop tools and methods that quickly and efficiently identify substructure problems. The findings from this work may then be used in the newly developed expert systems decision analysis to determine the best maintenance procedure.

During these investigations, the AAR's cone penetrometer test was particularly helpful in providing data for the assessment program to select the best method to resolve conditions that cause certain substructure problems like subgrade squeeze, ballast pockets, and embankment/foundation failure.

The effectiveness of certain maintenance measures was also evaluated in the investigations.

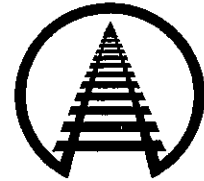
Suggested Distribution:

- Maintenance Planning
- Track Maintenance
- R&D/Test Dept.
- Maintenance of Way



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the soil may still be high, the absence of free standing water on its surface should make the soil capable of supporting the track structure.

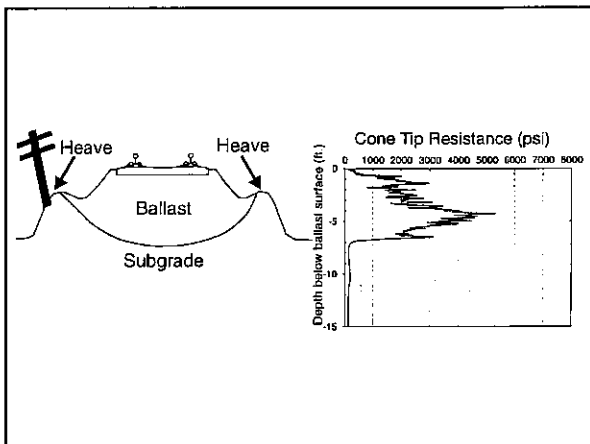


Exhibit 2. Ballast Pockets

As a third example, another railroad had experienced instability under several bridges where track was lowered by undercutting to allow for traffic with increased overhead clearance requirements (Exhibit 3). The lowering of the track, relative to the adjacent tracks, led to a poor drainage situation where water could not readily escape.

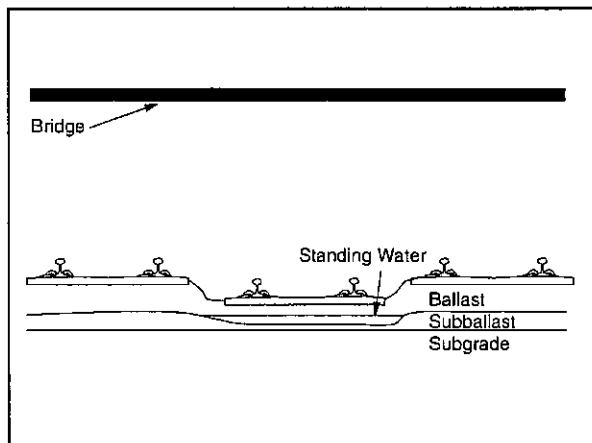


Exhibit 3. Instability under Bridge

The remedy for such a condition is a combination of improved drainage for the lowered track, and a somewhat increased amount of granular material over the subgrade as determined by an analysis using the CPT data. If the increased amount of ballast exceeds the clearance requirements, then further undercutting is required.

INVESTIGATION OF EFFECTIVENESS OF CERTAIN REMEDIAL TECHNIQUES

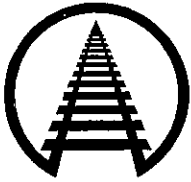
Lime Slurry Pressure Injection (LSPI)

One key finding from this substructure work on several railroads was an evaluation of certain remedial techniques. LSPI is often attempted where weak subgrade conditions are thought to exist. However, little or no preliminary investigation is typically performed to determine if the conditions are conducive to this type of remedy (i.e. is the soil type reactive to lime; is there likely to be a sufficient network of fissures which will accept the lime?). Therefore the perceived effectiveness is often based on past experience.

Based on a thorough, but limited number of investigations, where LSPI was used, it appears that very little or no mixing of the lime with the soil took place. The lime typically appeared to come back up the hole made by the injector tube where it then fouled the ballast section. If the track actually had been stabilized following the LSPI, it was more than likely due to other work performed along with the injection such as improving the drainage, or perhaps seasonal decrease in subgrade moisture.

It is not assumed that LSPI has no beneficial effect. Rather, it is argued that at least a cursory review of the nature of the problem and the soil condition and type should be performed to make sure the track time and expense of attempting to stabilize with LSPI is justified.

Such studies may determine that, rather than improving soil properties directly, there is some inadvertent benefit associated with LSPI. If it is found, for example, that the benefit is derived from the injected material pushing out excess



INTRODUCTION AND CONCLUSIONS

The symptoms of a variety of substructure problems often appear similar at the track surface (e.g. pumping at the ballast surface, rough track geometry). Track engineers have often been discouraged from trying to determine the cause of poor track substructure performance due to its relative inaccessibility and slow investigation techniques.

Investigative tools and methods to determine the nature of track substructure problems and to recommend the best remedial action have been developed as part of a cooperative program by the Association of American Railroads and the University of Massachusetts. The findings are based on field measurements on member roads. The substructure assessment program quickly and efficiently identifies and offers solutions to substructure problems.

An expert systems "best practices" approach also has been developed as part of the assessment program and provides recommended remedies based on the observed track conditions. Member roads can benefit with lower track life cycle costs by applying these tools and methods.

APPLICATION OF ASSESSMENT PROGRAM

Insufficient Granular Layer Thickness

Oftentimes the prescribed remedy for soft subgrade is simply to place a certain amount of added ballast to reduce the subgrade stresses to an acceptable level as determined by a granular design method (see the case in Exhibit 1).

The cone penetrometer test (CPT) is suited to evaluate soft subgrade problems. The instrumented cone determines subgrade stiffness and strength and the depth of the stress-reducing granular layer overlying it. This data can be used in the granular depth design model, another part of the program, to determine if the current ballast/subballast thickness is adequate for the subgrade strength and the current or anticipated loading. For an under-designed situation, the amount of required added granular material can be determined using the model.

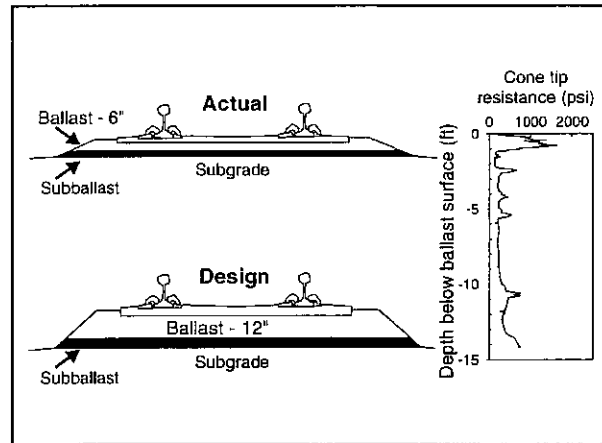
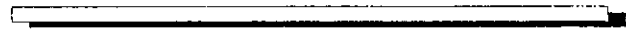


Exhibit 1. Ballast Added to Reduce Subgrade Stresses

Ballast Pockets

In another case, a very soft and deep soil deposit was found to have allowed the formation of 5- to 7-foot-deep "ballast pockets." The soil displacement was evidenced by tilting of telephone poles and bulging of the soil as shown in Exhibit 2. Simply adding more ballast in this situation will not stop the excessive deformation but will only add to the ballast pocket. The ballast merely rides along with the over stressed subgrade as it is pushed out and up along the track side. Because water may not easily escape this "bathtub" profile, the surface of the soil is often saturated and is unable to support the imposed load, regardless of the amount of ballast over it. Therefore the granular depth design method will not apply in this case.

Instead, the recommended remedy was to provide drainage at the low-elevation point within the ballast pocket as determined by the probes of the CPT. Based on visual observation of the substructure layers, as revealed by cross trenching, the ballast was relatively free of fines and free draining throughout the ballast pocket. Therefore, a drain pipe or "edge drain" installed at the bottom of the ballast should remove most of the free standing water which finds its way to this location. An undercutter is then recommended to remove the ballast down to about 12 inches below tie. A layer of subballast then may be installed which will help divert water from above to the side ditches. Although the moisture content within



water from within the track, or from sealing off the subgrade, then a better, more efficient and economical method to accomplish this should be pursued.

Hot Mix Asphalt (HMA) Underlayment

Another stabilization technique of interest was HMA under the ballast. With this technique, a layer of asphalt is placed above weaker underlying layers in an attempt to stabilize the track. HMA was originally introduced as a means to provide increased vertical track stability in areas of turnouts, road crossings, and diamonds. Its use is expanding to applications in track over weak subgrades, which may extend for many miles. It is in this latter capacity that it has been studied and compared with track which was rebuilt with conventional construction of ballast and subballast.

Although a layer of stiff compacted asphalt is substantially better at decreasing the stresses passed on to the lower softer layers compared to an equal thickness of ballast/subballast, AAR analysis indicated the life cycle cost is much greater for track constructed with asphalt (AAR research report R-892). While the added cost of using HMA in a crossing or other short track section may be small, the cost difference between these construction methods become quite large for longer sections of track.

OTHER APPROACHES

There are other methods or products which hold promise. For example, a geosynthetic material known as geoweb may be effective in lowering the stress passed onto the subgrade. The geoweb has openings which may be filled with ballast or subballast. When the geoweb layer deforms under load, it may act as a stiff composite layer which reduces the stresses passed along to the lower layers. A test to study this is planned at the AAR Transportation Technology Center (TTC).

Another material that may help soft subgrade is reinforced sand (this too will be tested at TTC). This sand has geosynthetic fibers mixed in which act to reinforce the sand and increase its stiffness, decreasing the stresses in the subgrade.

EXPERT SYSTEMS APPROACH

The findings from these and other investigations into track geotechnology over the past 15 years are being placed into a "best practices" expert systems approach to substructure problem solving. This effort encompasses the experience of practitioners, researchers, and academics involved in various aspects of track substructure.

The expert systems program asks a series of questions about the track condition by following certain guidelines to diagnose a substructure problem. The evaluation first asks questions regarding the drainage conditions because, assuming this is a contributing factor, remedies aimed at improving drainage typically have the most benefit. The program then attempts to determine if the instability is driven by deficiencies in the ballast, subballast, and subgrade condition and strength. Improving the strength and stiffness of these layers is highly beneficial where this is lacking. Further questions are asked to highlight or eliminate various potential causes. The program will only recommend a more elaborate or time consuming remedy over a simpler, less costly method, if it has a high level of confidence that the problem cannot be addressed by routine and readily available maintenance, such as tamping.

With sufficient information, the program specifies which technique(s) is most effective under the given circumstances. If there is more than one recommended remedy, the model determines the most economical choice considering the available equipment, labor, and train operating characteristics of a railroad.

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