Acela Express on the Northeast Corridor.

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Railroads and Research

Sharing Track

Gaining Track Support to Improve Track Safety, Efficiency, and the Competitiveness of the Rail Industry

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Railway track innovations historically have focused on track structure support. Although track structure is simple, improving the performance and interaction of the components under passing trains is a challenge.

From development of new rail sections to improving the tie and fastening systems, technological advances have made rail competitive as a transportation mode. Advances in track support and measurement systems are ensuring a more efficient and safe performance from the track structure. Structural measures evaluate the geometric smoothness and condition of track and provide the data for assessing track performance.

The efficiency of track structure increases with structural reliability brought about by improved components and by diagnostic tools that can identify zones of increased failure risk. These tools, along with methods to improve track stability, are critical to the competiveness of the U.S. rail industry.

Track diagnostic tools provide assessments of the most common failure modes. Each tool has developed from an accident that exposed a particular vulnerability of the track structure, indicated in the statistics of the Federal Railroad Administration's (FRA's) Railway Accident–Incident Reporting System.

Track components have been hardened and strengthened to improve durability and performance, but increases in train loads and speeds, coupled with recent extreme weather events, have necessitated constant vigilance for track safety. Reducing the stresses by ensuring proper performance of the track structure is a key endeavor. Track structure diagnostic tools can ensure that the track structure is working to reduce the stress on individual components and can help avoid the stresses associated with the deterioration of local track support.

Safe, Efficient Infrastructure

Safety and efficiency are often competing goals—safety requires good track performance, but efficiency requires low-cost track maintenance and construction. The two goals must be addressed together successfully and positively to ensure industry competitiveness. The rail industry has accomplished this—rail is the leading transportation mode in terms of safety and efficiency.

The industry has developed and implemented technologies for safe operations, but at low initial cost in response to pressure from competitors and investors. Figure 1 (below) illustrates safety trends. Periodically the industry has applied a long-term perspective to the goal of keeping costs low and has built infrastructure that will last, realizing that the cost of replacement would be prohibitive.

The service life of railway track varies; many lines have served for more than 100 years. The service life of track components, however, generally extends into tens of years. An increase in component life, therefore, will yield an economic benefit.

An economic analysis of the life cycle of track infrastructure should consider a period of more than the typical 20 years and take into account the variability of service life among components. This type of analysis places a premium on maintenance throughout the service life. The economic goal should be a predictable track life cycle in which no single component fails or compromises the integrity of the whole.

Photo: Metropolitan Transportation Authority

Workers from New York's Metropolitan Transportation Authority repair damage to Metro-North's Hudson Line after Superstorm Sandy in 2012. Extreme weather and increases in train loads and speeds require constant attention to track safety.

Performance Characteristics

One of the challenges facing the industry is the initial capital investment, which involves justifying the increased initial costs to reduce life-cycle costs. Therefore a premium, next-generation track structure is likeliest in a passenger corridor with strong ridership and a tight operating schedule (*1*). Except in California, most planned U.S. passenger projects will be incremental—new service will be established,

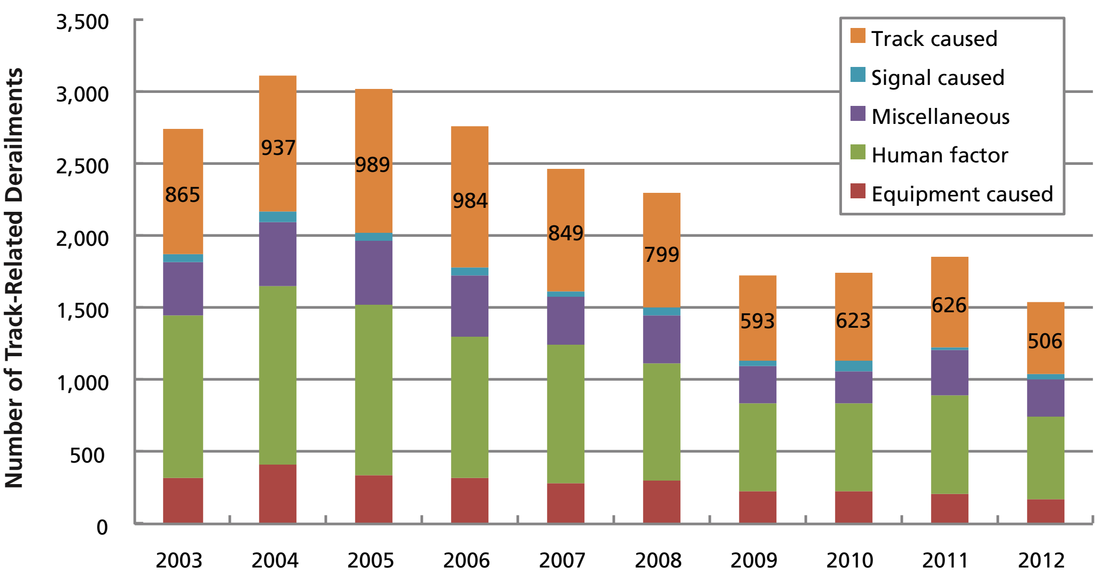

FIGURE 1 Track safety trends for the past 10 years show decreases in track-related derailments, which nevertheless constitute 32 percent of rail accidents.

Transition from slab track to ballasted track at demonstration test, Transportation Technology Center, Inc.

and existing service will be improved, while major infrastructure additions are undertaken.

Premium track designs—for example, direct fixation concrete slab track instead of ballast (see photograph, above)—may be used in critical locations, such as urban corridors, for which the primary concern is service reliability, as in large portions of the Japanese high-speed rail network. France's high-speed rail network, in contrast, has relied on ballasted track (2),which is common on corridors with speeds and traffic volumes similar to those of the emerging and high-speed corridors in the United States.

Required performance characteristics for high-performance ballasted track are as follows:

1. Premium track components;
2. Good track support;
3. Open, maintainable track structure;
4. Realignment, repair, and maintenance flexibility; and
5. Surveys of the track location.

High-speed rail in France—a system that shares features with high-speed rail in the United States—uses high-performance ballasted track.

PHOTO: RAIL EUROPE

Track constructed with these characteristics must be monitored periodically to assess condition, to plan maintenance, and to evaluate safety. The inspections should apply measures of track structural condition to identify any variations from the design at an early stage, ensuring the effectiveness of repairs in achieving the desired long-term performance.

Structural Assessment

A structural assessment measures engineering properties or physical characteristics to assess the stability and durability of the track. Track geometry inspections, in contrast, focus on smoothness for ride quality and on vehicle derailment risk. A trend of deterioration in track geometry may indicate compromised structural integrity, but additional, appropriate data are needed to diagnose the cause or to evaluate track load capacity or expected service life. A structural assessment of track applies parameters directly linked to failure mechanisms; it detects emerging structural problems, evaluates stability and durability, and enables timely repairs.

TABLE 1 Track Structural Parameters and Failure Mechanisms

Parameter	Failure Mechanism
Lateral track strength	Track buckle
Rail neutral temperature	Rail pull-apart, track buckle
Gage restraint	Wide gage, wheel drop, rail rollover
Ballast condition	Track instability, geometry fault
Track deflection	Track load capacity, settlement

The parameters for track structural assessment are linked to specific failure mechanisms and the associated failure risks, as shown in Table 1 (above). A derailment caused by track buckle or misalignment will damage cars, equipment, and track extensively, but a wide-gage track geometry—when rails are spread wider apart, so that the wheelsets drop between the rails—may be less destructive and may cause less potential harm. The failure mechanisms listed in the table either have a high likelihood of occurrence—such as wide gage—or have the potential to be particularly destructive—such as track buckle—and sometimes both.

Lateral Track Support

Lateral track strength is the resistance of track to lateral movement. Passing traffic or built-up stress in the rail generates lateral loads, which tend to deform the track. Lateral track strength measurement

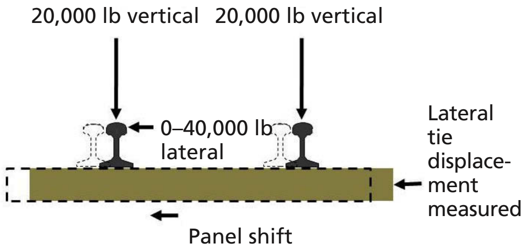

FIGURE 2 Lateral track strength measurement.

addresses tie displacement under a lateral force applied by a constant vertical load, as illustrated in Figure 2 (above). Lateral resistance can be evaluated with stationary tests or with moving loads, such as the Association of American Railroads' track loading vehicle (TLV) (*2, 3*).

Lateral track strength decreases substantially after tamping—a maintenance activity that raises the ballast layer to correct the track profile; tamping presents a particular risk to lateral track deformation until the track is stabilized, as illustrated in Figure 3 (below) (*2*).

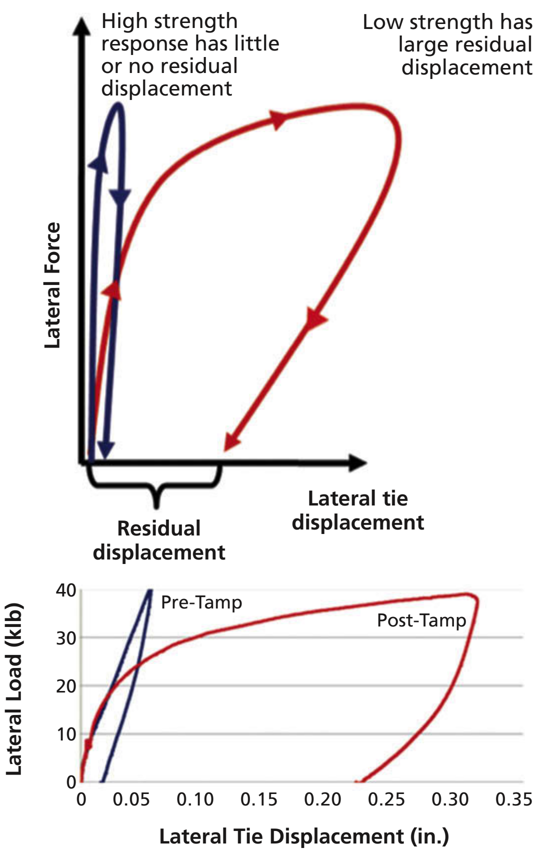

FIGURE 3 Lateral track strength data recorded by a track-loading vehicle before and after track tamping.

Association of American Railroads' track-loading vehicle.

Longitudinal Stability

Longitudinal rail movement changes both the rail stress condition and the temperature, increasing the risk that the track will buckle (*3*) or pull apart. The track lateral resistance must be high enough to avoid buckling; again, tamping may present a risk of buckling until the track is stabilized.

New rail stress measures are in development to address the effect of rail movement through the fastener, as well as to evaluate the track position, both of which are challenging tasks. Various rail compression or tension measurements have emerged and have been used in assessing rail stress, including the Vortok Verse and a noncontact, ultrasonic device pioneered by the University of California, San Diego, under the sponsorship of FRA.

Gage Widening

Track gage strength is measured by applying a lateral load to both rails under a constant vertical load and then measuring the deflection. The strength is assessed based on the difference in track gage before and at the load application; the difference is known

Testing of University of California–San Diego's rail neutral temperature measurement device on continuous welded rail with concrete ties at Transportation Technology Center, Inc. Note the strain gauge on each side for validation and comparison.

FRA DOTX-218 gage restraint measurement system with University of Nebraska–Lincoln's track deflection system.

as delta gage. Rail-bound vehicles that operate only on track and high-rail vehicles that can operate on road and track have been developed to measure gage strength (*4*); examples include the TLV, the FRA DOTX-218 gage restraint measurement system, and the Holland Track Star.

Ballast Condition

Ballast is the track's foundation, and the ballast condition affects long-term performance of the track; any settlement-related degradation of performance will cause stress on track components and rolling stock. As track degrades, ballast wear under load or from contamination with material blown in or spilled from passing trains can cause ballast fouling, which can increase the rate of deterioration (*5*).

Track inspections can detect ballast fouling with ground-penetrating radar (GPR), a nondestructive technology that pulses electromagnetic energy into the ground to develop an image of the subsurface (*6, 7*), as shown in Figure 4 (below, left). Although the measurement of fouling has been a challenge with GPR, methods have developed to analyze the difference in signal response between clean ballast and highly fouled ballast and to correlate the result with accepted measures of fouling condition (*8, 9*). GPR also may assist in measuring the layer thickness, profile, moisture content, and drainage of track substructure and may detect buried objects.

Track Deflection

Track support is critical to track performance. The best measure of track support is the vertical track stiffness, analyzed with the track vertical load-deflection curve slope (*9*), as illustrated in Figure 5 (right). Most important are the slope associated with the seating deflection, which indicates gaps of slack between track components, and the slope associated with the contact deflection, which indicates the load-deflection response of the track when all elements are engaged. The contact deflection is associated with variations in subgrade stiffness, track superstructure, and the shallow substructure.

Challenges to measuring the full load-deflection curve have led to the development of a system by the University of Nebraska–Lincoln to survey the track for locations of excessive track deflection (*10*). A beam mounted to the side frame of a truck measures the relative position of the wheel–rail contact and a reference point on the rail 4 feet away. A high reading indicates a large deflection, which implies track support problems.

Measuring deflection will become increasingly important for maintenance planning, because excessive deflection increases stress in the rail, decreasing service life (*11*, *12*). Comprehensive testing of the curve slope and of the measuring system developed by the University of Nebraska–Lincoln has shown that deflection measurements complement other track measurements.

High Expectations

The rail industry anticipates growth in intermodal traffic, both domestic and international, as public entities and trucking companies turn to the railroads to help solve problems of highway congestion, escalating fuel prices, and driver shortages. Challenges include issues associated with an aging infrastructure and an aging workforce, along with a constant pressure to maintain leadership in terms of safety and efficiency. The pressure to do more with fewer resources and less staff has never been greater.

Track structural assessment and inspection tools present unique opportunities to respond to these challenges. By providing timely and accurate safety inspections, by guiding maintenance, and by ensuring efficient use of resources, these technologies can advance the efficiency and safety goals of the industry. In addition, these technologies can assist in evaluating compliance with construction specifications, so that new rail infrastructure can offer higher levels of quality and uniformity.

The vibrant history of railway track research and development has introduced many technologies that have spurred further understanding of track behavior and quality. Industry has applied these advances to the training of inspectors and workmen in the finer points of track behavior and inspection.

These efforts have produced high expectations

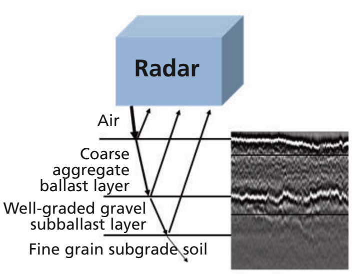

FIGURE 4 Ground-penetrating radar signal generation in response to track substructure boundaries.

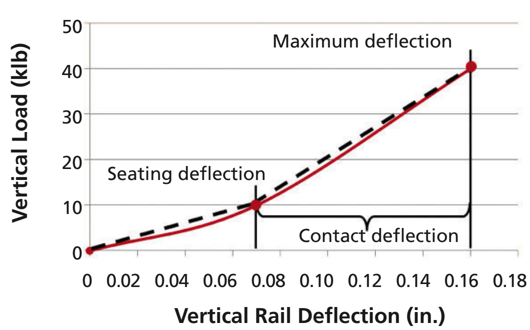

FIGURE 5 Track vertical load-deflection curve slope.

State-of-the-art track assessment vehicles near Cheyenne, Wyoming: Union Pacific EC-4 evaluation car and FRA DOTX-218 gage restraint measurement system in consist with University of Nebraska–Lincoln track deflection system.

for industry safety and efficiency. Continuing this trend will require research targeted at persistent and unrelenting safety risks. Building higher-quality infrastructure and using structural inspection tools to monitor deterioration will ensure that the industry can meet the ever-increasing safety and cost efficiency expectations of modern railway track.

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IDEA Programs Seek Proposals for Railroad Safety

The Transportation Research Board (TRB) is accepting proposals for projects to develop and test innovative methods to improve railroad safety or performance through the Safety Innovations Deserving Exploratory Analysis (IDEA) Program. Proposals should seek to develop or test promising but unproved innovations to advance railroad practice and can be applicable to any type of railroad, including high-speed rail, intercity passenger rail, or freight railroads.

Proposals are due September 16, 2013. The Federal Railroad Administration (FRA) funds the Safety IDEA program, which is managed by TRB.

For instructions on preparing and submitting IDEA proposals, see the IDEA Program Announcement on the IDEA website, www.TRB.org/IDEA. Proposals are eligible for up to $100,000 in IDEA funds. Address questions to Jon Williams, jwilliams@nas.edu, 202-334-3245.

PHOTO: IDEA

Installation of an IDEA project at the Transportation Technology Center, Inc., to detect railroad car truck hunting, or swaying.