U.S. Department
of Transportation

Federal Railroad Administration

REPORT TO COMMITTEES OF THE CONGRESS

BRIDGE DISPLACEMENT DETECTION SYSTEMS

Office of Safety **October 1999**

Executive Summary

The overall risk of damage to rail bridges is small in relation to other risks in railroad operations and is diffused over a large number of bridges. FRA has documented bridge ownership over navigable waterways, so that immediate notification can be made to the owners in the case of impacts by vessels. Where risk is known to be significantly above average due to heavy river traffic, the U.S. Coast Guard is working with bridge owners to implement protective countermeasures. Movable bridges are attended by railroad personnel, who are equipped to notify trains through use of signal systems, radios, or both, should the bridge be compromised.

Thousands of additional railroad bridges remain subject to a very small, but real risk of damage due to forces such as fires, flash floods, impacts associated with roadway underpasses, and similar hazards. Where costs were not excessive, railroads have responded to site-specific needs by installing hazard detection systems. However, extensive use of such systems is limited by their inherent costs, including the repeated disruptions associated with false warnings. Because the cost of providing power and interface with signal and communications systems constitutes the largest part of the cost associated with these systems, and because several detectors may be required on a single bridge to address the particular safety concern(s), future reductions in the cost of electronic systems are not likely to entirely eliminate the barriers to more extensive use of these systems.

However, innovative uses of technology, integrated into more capable train control systems, can result in selective enhancements to hazard detection on railroad bridges. FRA will seek opportunities to encourage implementation of these enhancements.

Introduction

Section 207 of the Federal Railroad Safety Authorization Act of 1994 requires that: "... the Secretary of Transportation shall transmit to the Committee on Commerce, Science and Transportation of the Senate and the Committee on Energy and Commerce of the House of Representatives[1] a report concerning any action that has been taken by the Secretary on railroad bridge displacement detection systems" (49 U.S.C. § 20145). This is the requested report. It covers the period 1994 to the present.

The lead role in producing this report to Congress was assigned to the Federal Railroad Administration (FRA). FRA immediately arranged for a survey of railroad bridge safety and an assessment of possible methods to detect damage to railroad bridges following impact by non-railroad vehicles, automotive, marine or airborne. Entitled "Overview of Railroad Bridges and Assessment of Methods to Monitor Railroad Bridge Integrity," this technical study was completed in 1994. The technical report, which has previously been published and provided to committee staff, is attached for ready reference. The findings of this investigation are presented in summary form here, and subsequent developments are described.

Displacement and Other Threats to Bridge Safety

The problem of bridge displacement was injected into the public debate largely as a result of the derailment of Amtrak's train, the Sunset Limited, near Mobile, Alabama on September 22, 1993. The derailment was caused by the lateral displacement of the track structure on a CSX Transportation bridge over Big Bayou Canot. One span of the bridge had been knocked out of proper alignment by the impact of a barge tow operating in heavy fog in an area not normally employed for commercial navigation. The derailment resulted in 47 fatalities, including 5 crewmembers and 42 passengers, most from drowning. It was the worst train accident in Amtrak's history.

Some bridges are also vulnerable to damage from motor vehicles. The most notable recent accident from this cause occurred in Sheperdsville, Kentucky on November 19, 1991, when a truck hauling solid waste struck a small beam span bridge over a local road, displacing the bridge and its track and consequently derailing a freight train. The derailed train continued onto a large through-truss bridge over the Salt River and knocked down two of the three spans of that bridge. Several cars of hazardous materials went into the river and the area was evacuated for several days during restoration operations.

Natural forces can also threaten bridge integrity. For instance, Amtrak's Southwest Chief derailed on the Burlington Northern Santa Fe Railway near Kingman, Arizona on August 9, 1997

[1]The Committee on Transportation and Infrastructure subsequently succeeded to jurisdiction over railroad safety matters.

on that railroad). A flash flood resulting from a large summer storm had washed away the ground under the bridge's supporting structure. Ten Amtrak employees and 173 passengers were injured.

These events, although extraordinary in relation to normal operational hazards experienced on America's railroads, called attention to the problem of damage to bridges caused by factors outside of the railroads' control. In order to obtain adequate perspective and evaluate the benefits that might be realized from use of a variety of damage detection technologies, FRA elected to review a variety of hazards and countermeasures related to externally-caused damage, including fire, flood, ice, and earthquakes, as well as other damage incurred due to impacts by other transportation vehicles. Concerns include general weakening of bridge structure and damage to, or undermining of, structural supports, in addition to lateral displacement.

Clearly, detecting damage once it is done is not the ideal approach to prevention of catastrophic events, particularly since such events could never be wholly excluded by detection technology. The Department of Transportation also promotes safe marine and highway operations, reducing the likelihood that impacts with bridges will occur. FRA's Track Safety Standards also require special inspections following serious storms and other natural events that might threaten the track structure (49 CFR §213.239).

By virtue of their design and placement on navigable waters, movable railroad bridges are perhaps most vulnerable to damage. These bridges are generally monitored by a bridge attendant who is equipped to communicate with trains by VHF radio. These bridges have generally have been protected to the extent possible by fenders, and other measures. This report does not address the issue of special track work required for proper functioning of movable bridges.[2] FRA has addressed this issue through a separate inspection program for these bridges and through new inspection requirements contained in recent revisions to the Track Safety Standards (63 FR 33992, 34012, 34041; June 22, 1998).

Results of the Technical Study

The bridge integrity technical study was completed and a final report issued in June 1994. The report covers several areas including evaluation of the risks or hazards faced by railroad bridges and the technologies available to monitor bridge condition and alignment. It discusses operational issues related to bridge integrity monitors, and predicts costs to install monitors on three hypothetical bridges typical of those found on most railroads.

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[2]A derailment of an Amtrak passenger train at the far end of a movable bridge over the Hacksensack River near Secausus, New Jersey, on November 23, 1996, was caused by a break in a specially-configured rail ("miter rail") at the junction of the movable span and the fixed span. A switch circuit controller designed to detect the position of the miter rail failed to function as intended due the break in the miter rail itself. The bridge structure itself was unimpaired.

The report notes that the FRA bridge survey revealed a population of approximately 100,900 railroad bridges of all types with an average length of 120 feet. The actual number of railroad accidents attributed to bridge misalignment or failure was found to be very small, on the order of two per year, or 1/1000th of the total railroad accidents. This low failure rate was attributed to the periodic inspection programs used by the railroads and to the conservative design standards and construction practices commonly used for railroad bridges.

In the study, generic railroad bridge accident model was developed including an initiating cause, the effects of the initiating cause on the bridge, the failure progression, and the final failure mode of the bridge. Initiating causes included those from natural and operational reasons. These causes were examined for associated physical conditions that might lend themselves to detection. These conditions include acoustic emission, light emission, temperature change, vibration, impact, movement, stress, change of shape, lack of continuity, and intrusion of objects.

A total of eighteen different technologies were compared for their advantages, disadvantages, cost, performance in detecting the effects, and likelihood of false alarms. The study concluded that track circuits used for control of railroad signal systems provide little probability of detecting bridge misalignments or damage short of collapse on bridges carrying continuous welded rail.

The key to obtaining real benefits from bridge integrity monitor systems is providing a warning to train crews. The most likely method of warning crews is through an interface to the wayside signal system, if the bridge is in signaled territory. This interface however, introduces additional requirements on the bridge monitor system so that the integrity of the wayside signal system is not degraded by the interface. If bridge monitors are interfaced with the wayside signal system, failures of the bridge monitor system will cause the signal system to display the most restrictive aspect. The necessity to stop trains and inspect both the bridge and the bridge monitor system before proceeding may cause large cost and operational impacts to the railroad if there are a large number of false alarms. Therefore, the bridge monitor system must be extremely reliable and able to discriminate between real hazards and false alarms to a very high degree.

The base cost to install bridge integrity monitors on one bridge was estimated to range between $24,000 and $40,000. This cost includes the basic items needed at every installation, including a commercial or remote electric power supply, connections to the signal system, and housing for the basic apparatus. In addition, costs that vary with the length of the bridge, particularly the application of instrumentation to the bridge itself, were estimated at approximately $9.00 per foot of bridge length.

The life cycle costs over an estimated 25-year useful life of the monitoring system were estimated at $40,000 to $54,000 base cost per bridge, plus approximately $18.00 per foot of bridge length. Applying these costs over the U.S. railroad bridge population provides as estimated life cycle cost to install and maintain these monitors ranging between $4.7 billion and $5.8 billion.

The report concludes that, even if all railroad bridges could be ranked by vulnerability and the top ten percent selected for installation of monitoring systems, the estimated life cycle cost of $469-$580 million for those bridges would be several times the projected accident cost of $14.7 million over the same 25-year period.

Nevertheless, the bridge integrity technical report describes a range of new technologies that may offer some promise for improved detection systems in the future. To the extent these systems can be engineered to be reliable and inexpensive, they may warrant more extensive use, particularly if concerns regarding provision of power and communication of alarms are addressed.

Hazard detectors of all kinds, including bridge integrity systems, may be rendered somewhat more effective if tied into a Positive Train Control (PTC) system that is designed to provide priority to emergency messages and that provides a communication path for periodic health monitoring for the device (potentially holding down inspection and maintenance costs). However, the relative effectiveness of hazard detection in the context of PTC will be determined in part by "message latency" – the amount of delay that occurs as data is processed through data links to the computer on-board the locomotive. Further, deployment of PTC will not solve the inherent problem that hazard detection systems are costly. A recent report of the Railroad Safety Advisory Committee estimated 20-year costs for a high-end PTC system, applied to the lines of the major railroads and enhanced with a significant array of hazard detection appliances, at $7.8 billion. Safety benefits for the same period were estimated at approximately $844 million, representing the prevention of a significant number of train collisions, derailments, and other accidents, including events for which prevention is questionable. (***Implementation of Positive Train Control*** (September 8, 1999). Like the results of the 1994 technical report, this finding emphasizes the need to employ a balanced approach to bridge integrity, including sound design, protection of piers and other exposed members, and use of all available means to report known damage promptly, as well as selective use of technology to detect and signal damage when it occurs.

Other Approaches to Risk Mitigation

Detecting all bridge impacts that could threaten structural integrity would require instrumenting a large number of bridges, inspecting and maintaining a whole new class of infrastructure, and dealing with significant numbers of false alarms even with use of the best available technology. At the same time, detection of threats to bridge integrity could not result in completely effective prevention measures, since a train approaching a bridge at the time the damage occurred could not stop short in many cases, even with the most timely information. Further, detection of bridge damage quite obviously does not prevent it. With the best damage detection systems, there would still be significant economic cost from halting of rail operations (and perhaps marine or highway operations) while repairs are made to the structure. As a result, a large part of the effort historically devoted to this area of risk has focused on measures to prevent bridge impacts and to prevent bridge impacts from damaging bridge structures.

In September 1994, the National Transportation Safety Board (NTSB) sent four bridge-related recommendations to the Secretary of Transportation, two of which concerned this issue of vulnerability of railroad bridges to impacts or, put another way, the assignment of risk of impact to specific structures. In condensed form these were:

- To convene an intermodal task force to develop a standard methodology for determining the vulnerability of the nation's highway and railroad bridges to collisions from marine vessels, to formulate a ranking system for identifying bridges at greatest risk and to provide guidance on the effectiveness and appropriateness of protective measures.

- Use the methodology developed by the intermodal task force to carry out a national risk assessment program for the nation's railroad . . . bridges

In connection with the first recommendation, it should be noted that since 1982, when FRA started to accumulate relevant data, and 1998 there were six train accidents attributable to impact-misaligned railroad bridges: five were caused by motor vehicles and one by a marine vessel.

The intermodal task force was formed and adopted a risk assessment methodology responsive to the NTSB's recommendations. Each mode proceeded on its individual assignments and, in March 1995, then Secretary of Transportation Federico Peña provided a detailed report to the NTSB regarding the risk assessment methodology. The risk assessment methodology adopted is basically described in the National Research Council's report entitled ***Ship Collisions With Bridges*** and in publication of the American Association of State Highway and Transportation Officials entitled ***Guide Specification and Commentary for Vessel Collision Design of Highway Bridges*** (February 1991).

The risk assessment methodology resulting from the intermodal task force's work specifically applies to bridge projects at the planning and design stages, so that vulnerability to vessel collision can be reduced and minimized before the bridge project advances to the construction stage. This consideration is generally a bridge owner's responsibility that occurs prior to a Coast Guard bridge construction permit approval action is taken. At the time of Coast Guard review and coordination, the Coast Guard conducts further risk assessment through the bridge permit process. This process includes consideration of the potential impact that location and design will have on the safety of both land and marine traffic. Pier locations are evaluated with respect to the navigation channel through the bridge, adequacy of the proposed horizontal and vertical clearances to allow transit of existing and potential marine vessels, and the need for pier protection fendering and navigational lighting systems and other markings, clearances, and gauges.

Basic factors considered in the assessments for proposed and existing bridges include the vessel, the waterway, and vessel-waterway interaction as well as the bridge itself. Some of the specific factors considered are the size, speed, loading and type of vessel; waterway and navigable channel geometry; water depths; environmental conditions; and bridge geometry and structural response.

Improvements have been made as a result of the assessments that have been conducted by the Coast Guard. For example, after the Amtrak accident in Mobile, Alabama, the Coast Guard completed a three-year national bridge survey of 10,000 existing highway and railroad bridges which were potentially vulnerable to damage by commercial vessel traffic. This vulnerability risk assessment focused upon the need for new or enhanced pier protection fendering and lighting systems. Out of the 121 bridges found to be potentially vulnerable, 83 have been upgraded with new or enhanced fendering and lighting systems to date. Owners of the remaining 38 structures are currently planning and budgeting projects to complete similar upgrades.

Railroad bridge owners currently have available the needed guidance for the performance of risk assessments, found in the recommended practices included in Chapter 8 of the ***Manual for Railway Engineering*** of the American Railway Engineering and Maintenance Association. This information has been used by the railroad industry for at least 10 years for developing and designing protection for railroad bridges over navigable waterways.

FRA has also compiled a list of railroad bridges over navigable waterways of the United States. This list includes the identification of the individual bridge, the owner and operator of the track on the bridge, and the location of the bridge in relation to waterway mileage, railroad mileage, and geographic coordinates. The list for each state is being made available to emergency response agencies in that state, and to the Coast Guard operational components that are concerned with marine safety and response to marine incidents.

On October 27, 1998, Chairman Jim Hall of the NTSB wrote the Secretary classifying the Board's recommendations "Closed–Acceptable Alternative Action."

Future Directions

Given the large number of railroad bridges, the conduct of over 600 million train miles of transportation service each year, and the very small number of incidents that occur involving rail bridges, the risk that external factors will compromise the integrity of the average railroad bridge is very low. The bridges most at risk for damage generally require special attention to prevent damage, normally through clear marking of the bridges and the use of fenders, rip-rap, or other protective structures to prevent serious damage. Current efforts by the U.S. Coast Guard and the railroads to address high risk locations should be handled to completion, and FRA will work with the Coast Guard to periodically update bridge ownership information–both to facilitate preventive action and emergency notification.

Attention to railroad structures over highway bridges is also warranted. This issue is difficult, because most roadways under railroad bridges that involve low clearances are on State, county and local roads. In some cases, rail structures were built before current clearance standards were established. In other cases, roadway authorities have reduced clearances by increasing pavement thickness. Determining which of the several thousand roadways that pass under railroad bridges currently present special risk is difficult, at best. Highway authorities can work to ensure that clearances are appropriate, checking for adequacy whenever road work is performed and verifying posted information. State and local authorities responsible for regulating motor vehicles should work to ensure that vehicles with tall loads are routed around vulnerable rail overpasses.

Only in very limited circumstances have railroads found it useful to install damage detection devices on, or proximate to, bridges. Examples include high-water detectors, fire detection systems, and a very small number of bridge alignment systems. To be effective, some of these systems must be installed on each span of a multiple-span bridge and may be subject to damage by birds, other small animals and vandals. Given the cost of providing power to operate detection devices, interfacing those devices with signal systems and other means of communication, conducting inspection and maintenance, and responding to false activations, making this option attractive in the future will be difficult. Nevertheless, FRA will seek opportunities to integrate demonstration of appropriate hazard detection technology into future rail projects involving Federal participation. In addition, as this report was prepared FRA had participated in ongoing, open solicitations under the Transportation Research Board "IDEA" program (Innovations Deserving Exploratory Analysis) and FRA's Next Generation Hight-Speed Rail Broad Agency Announcement. These solicitations actively seek and can fund new sensor technologies with potential applications related to railroad bridge integrity.