TECHNOLOGY DIGEST

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Longitudinal Forces in Bridges Due to Revenue Service Traffic

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Summary

Results from a recently completed revenue service assessment of longitudinal loading on a 324-foot-long multi-span bridge by Transportation Technology Center, Inc. are being used to update guidelines for design and rating of bridges in accordance to new equipment in use on today's railroads.

The purpose of studying this Burlington Northern Santa Fe Railroad (BNSF) bridge was to determine the statistical distribution of longitudinal forces due to locomotive tractive effort in revenue service. Locomotive tractive effort data was collected from more than 300 revenue service trains from both the BNSF and the Union Pacific (UP) Railroads over a period of eight months. Additional bridge measurements were taken under 40 trains from both BNSF and UP. Locomotive tractive effort records were also downloaded from revenue service trains over the entire subdivision that included the bridge.

The findings of this investigation are summarized as:

- Coal trains generally applied the highest longitudinal forces, and 70 to 80 percent of the applied tractive effort from head-end locomotives typically went into the bridge.
- The amount of longitudinal force applied to the bridge depends on the number and type of locomotives, their configuration, and their location in the train.
- The highest longitudinal forces applied to the bridge by revenue service trains were similar to those applied by test trains in previous tests.
- The amount of longitudinal force likely to be experienced by a bridge depends on the location of the bridge, and the amount of tractive effort typically applied at that location.
- The use of distributed power could help to minimize longitudinal forces applied to longer bridges.

The results of this study are being used to update guidelines for design and rating of bridges, so that they are appropriate for the new equipment in use on today's railroads. These results are important to railroads in understanding the influences on longitudinal forces that result from train make up, train loads, and bridge location that will allow further refinement in the method to assess bridge capacity.

This study was conducted as part of the Association of American Railroads bridge life extension program. Previous related studies have covered the effects of track construction, rail anchoring, and deck configurations.[1,2,3,4]

Suggested Distribution:
☐ Maintenance of Way
☐ Planning & Analysis
☐ Track Maintenance
☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
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INTRODUCTION AND CONCLUSIONS

The new generation of locomotives, both AC and DC, can produce considerably more tractive effort than older locomotives and thus can subject bridges to higher longitudinal forces. These higher longitudinal forces need to be considered when evaluating bridges and may require selective strengthening of bridges that are weak to resist such forces. Tests sponsored by AAR on four different bridges from 1996 through 1998 indicated these forces to be several times higher than the AREA guidelines that were used from 1969 to 1996, which subsequently were revised accordingly. All previous tests were performed using a designated test train for a limited period of time.[1,2,3,4] The tests reported here studied the effects of many revenue service trains over a period of eight months on a multi-span bridge. The findings from this investigation are summarized as:

- Coal trains generally applied the highest longitudinal forces, and 70 to 80 percent of the applied tractive effort from head-end locomotives typically went into the bridge.
- The amount of longitudinal force applied to the bridge depends on the number and type of locomotives, their configuration, and their location in train.
- The amount of longitudinal force likely to be experienced by a bridge depends on location of the bridge, and the amount of tractive effort typically applied at the location.
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- The use of distributed power could help to minimize longitudinal forces applied to longer bridges.

The results of this study are being used to update guidelines for design and rating of bridges, so that they are appropriate for the new equipment in use on today's railroads. These results are important to railroads in understanding the influences on longitudinal forces that result from train make up, train loads, and bridge location that will allow further refinement in the method to assess bridge capacity.

FIELD TEST PROGRAM

Tests were conducted on a 324-foot-long ballast deck bridge on the Burlington Northern Santa Fe line near Larkspur, Colorado, as Exhibit 1 shows. The test program included measurement of longitudinal forces on both running rails and guard rails at each end of each steel span, at both interfaces between steel and timber approach spans, at each end of the bridge, and at 100 feet from the ends of the bridge on each approach. Longitudinal ballast pressure was also measured at the ends of the bridge to determine how much longitudinal force was carried off the bridge through the ballast.

Exhibit 1. UP Coal Train Crossing BNSF Test Bridge

Measurements were carried out in phases at different intervals from May to December 1999. Each phase consisted of recording longitudinal forces over two to four days, while normal traffic crossed the bridge. Tractive effort values were recorded from cab displays (AC locomotives) or calculated from speed and throttle setting (DC locomotives) as appropriate.

TEST RESULTS

Exhibit 2 shows longitudinal forces in bridge spans versus total tractive effort generated by locomotives at the head end of trains. Coal trains generally applied the highest longitudinal forces, and typically 70 to 80 percent of the tractive effort from head-end locomotives went into the bridge. The longitudinal ballast pressure measurements confirmed earlier test and theoretical results that the ballast transmits longitudinal force to the bridge through shear with negligible axial force carried off the ends of the bridge.

Exhibit 3 gives the statistics for the locomotive tractive efforts applied by BNSF and UP trains with locomotives in conventional and in distributed power configurations while crossing the bridge. The maximum values are 309 kips for locomotives at the head end of coal trains in conventional power mode, and 324 kips for locomotives at the rear end of coal trains in distributed power mode. In Exhibit 3, the statistics for the rear end of distributed power trains include tractive effort applied by pusher locomotives coupled to the rear end distributed power locomotive(s).

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads

Exhibit 4 shows the statistics for locomotive tractive effort applied by BNSF trains over segments of lines between Big Lift and Palmer Lake, Colorado (30 miles), and between Denver, Colorado and Texline, Texas (350 miles). Note that the maximum tractive effort recorded was 435 kips from a coal train in conventional power mode with three locomotives at the head end. In Exhibit 4, the statistics for the rear end of distributed power trains do not include the tractive efforts applied by the manned pusher locomotives that are typically used between Big Lift and Palmer Lake.

Exhibit 5 shows the tractive efforts for the head end locomotives of both conventional and distributed power trains. Notice the difference in the applied tractive effort between conventional and distributed power modes, due primarily to the difference in the number of locomotives coupled together. Also note that the amount of tractive effort applied at a particular location can be quite different from that applied a few miles away.

Exhibit 6 shows a cumulative distribution plot of the applied locomotive tractive effort for the same territory, giving the percentage of the line over which the train was applying a given amount of tractive effort. Again, the difference between the applied tractive efforts of the conventional and distributed power trains is due primarily to the difference in the number of locomotives at the head end. For bridges that are shorter than two locomotives, the difference has little effect. For bridges longer than two locomotives, this results in a significantly higher amount of applied tractive effort. The use of distributed power could help to minimize longitudinal forces applied to longer bridges.

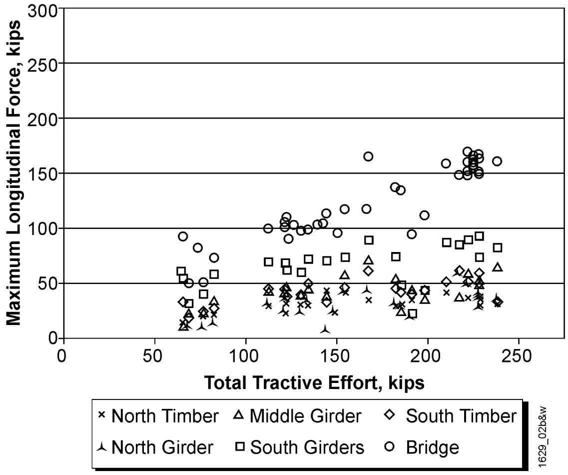

Exhibit 2. Maximum Longitudinal Force in Bridge Spans from Head End Locomotives

Exhibit 3. Tractive Effort Applied to Bridge by Locomotives

Applied Tractive Effort Statistics			
Train Type	Number of trains	Tractive Effort (kips) Avg.	Max
From BNSF Trains Crossing the Bridge			
Coal – Conventional Power – Head End	86	228	309
Coal – Conventional Power - Pushers	66	154	267
Coal – Distributed Power – Head End	46	153	186
Coal – Distributed Power – Rear End	42	252	324
Grain – Conventional Power – Head End	12	200	270
Other – Conventional Power – Head End	55	145	227
Misc. Pushers – Rear End	85	135	209
From UP Trains Crossing the Bridge			
Coal – Distributed Power – Head End	39	130	237
Coal – Distributed Power – Mid Train	31	111	200
Coal – Distributed Power – Rear End	33	134	222
Other – Conventional Power – Head End	35	89	254

Exhibit 4. Locomotive Tractive Effort Statistics for Territory Including Test Bridge

Tractive Effort Statistics from BNSF Trains		
Train Type	Maximum. Tractive Effort (kips)	Minimum. Dynamic Braking (kips)
Big Lift, Colorado to Palmer Lake, Colorado (30 Miles)		
Coal – Conventional Power – Head End (3 Locomotives)	345	-
Coal – Distributed Power – Head End (2 Locomotives)	250	-
Coal – Distributed Power – Rear End (1 Locomotive)	105	-
Denver, Colorado to Texline, Texas (350 Miles)		
Coal – Conventional Power – Head End (3 Locomotives)	435	240
Coal – Distributed Power – Head End (2 Locomotives)	280	160
Coal – Distributed Power – Rear End (1 Locomotive)	139	80

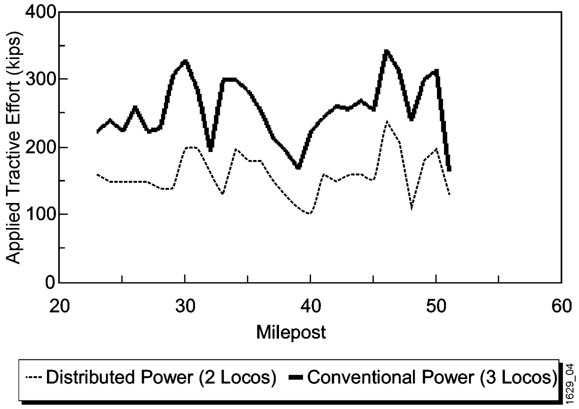

Exhibit 5. Locomotive Tractive Effort on 30-Miles of Line

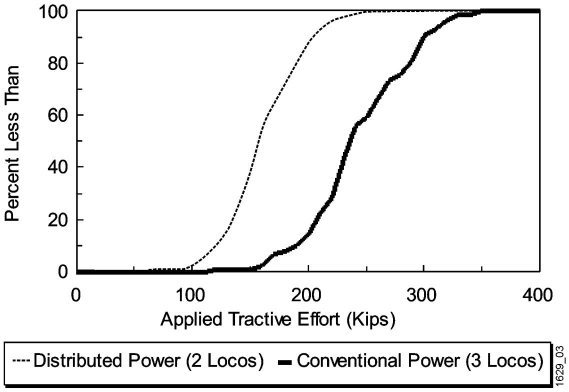

Exhibit 6. Distribution of Locomotive Tractive Effort on 30-Miles of Line

BRIDGE DESCRIPTION

The ballast deck bridge consists of three 80-foot steel deck plate girder (DPG) spans, with two timber approach spans on the north end and four timber approach spans on the south end. The grade over the bridge is 1.31 percent, with southbound traffic pulling upgrade. The alignment is on a 2.5-degree curve with inside guardrails over the entire length of the bridge.

TRAFFIC

The traffic over the bridge consisted of coal, grain, and mixed freight from both BNSF and UP. The bridge is on the southbound track. Except for rare occurrences, all traffic is in the southbound direction. The typical BNSF traffic included about 10 daily loaded coal trains, typically consisting of three SD70 MAC locomotives, two SD40-2 DC pushers and 115 to 119 cars (about 16,000 tons) each. BNSF traffic also included two daily mixed-freight trains, with various DC locomotives, and occasional loaded grain trains, consisting of three C44-9 DC locomotives, two SD40-2 DC pushers and 100-105 cars each. The typical UP traffic included a daily mixed-freight train and about two daily loaded coal trains consisting of AC4400 and SD9043MAC locomotives and 105 to 115 cars (13,000 to 15,000 tons) each. The configuration of the locomotives in UP coal trains was distributed power with one or two locomotives each at the head end, mid-train, and rear end of the train.

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