TECHOLOGY DIGEST

Timely Technology Transfer

"A SURVEY OF CROSSING DIAMOND PRACTICES"

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Summary

A recent Association of American Railroads' survey of crossing diamonds on U.S. and Canadian freight railroads showed that the most likely modes of failure in crossing diamonds are cracked frog, loss of vertical alignment and stability (ie. pumping frog), and failed substructure. It also showed that the average life of a crossing diamond is quite short. For high-angle diamonds in heavy tonnage track which survive 150 to 200 million gross tons (MGT), design type, tonnage, speed, crossing angle and maintenance are the key variables.

The survey also gathered basic information on crossing diamonds, such as, an inventory of diamond types, sizes, and locations, and data on their life and failure modes. The AAR Special Trackwork Research Program will use this information to develop and refine its crossing diamond research program.

The key to extending crossing diamond life is maintaining drainage and surface and utilizing premium frog materials. Running surface maintenance practices (ie. grinding and weld repair) also must be upgraded. Inadequate repairs will lead to cracking in the frog castings.

There are approximately 4700 crossing diamonds in use on North American railroads. The diamonds are not evenly distributed and tend to congregate around major terminals. Class 1 railroads have an average of 0.018 diamonds per track mile. A sample of terminal railroads shows that they have 0.125 diamonds per track mile. Thus, the number of diamonds a car may see is quite route specific.

Crossing diamond design has remained largely unchanged for many years. There is little published information available on crossing diamond design or analytical modeling. A comprehensive study of vehicle-track interaction at crossing diamonds is needed to improve the design.

Suggested Distribution:
- ☐ Motive Power
- ☐ Research and Development
- ☐ Planning and Analysis
- ☐ Maintenance of Way

Association of American Railroads
Research and Test Department

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INTRODUCTION /CONCLUSIONS

A recent Association of American Railroads' (AAR) survey of crossing diamonds on U.S. and Canadian freight railroads showed that the most likely modes of failure in crossing diamonds are cracked frog, pumping frog, and failed substructure. It also showed that the average life of a crossing diamond is quite short. For high angle diamonds in heavy tonnage track which survive 150 to 200 million gross tons (MGT), design type, tonnage, speed, crossing angle and maintenance are the key variables.

Crossing diamonds are the most expensive track features to maintain, largely due to the high impact loads resulting from flangeway gaps. The per-foot maintenance cost of a diamond is about 100 times that of ordinary track. Each year, an estimated $22.8 million is spent replacing and maintaining nearly 4700 crossing diamonds used on North American railroads.

The diamond provides a useful function by allowing two tracks to cross at grade. Often, alternatives to crossing diamonds, such as track realignments or grade separations, are not easily accomplished.

Crossing diamonds affect service reliability and line capacity. High angle crossing diamonds have very short lives (e.g. 100 to 200 MGT) relative to conventional track (600 to 2,000 MGT) or even mainline turnout frogs (200 to 300 MGT). In addition, frequent crossing diamond maintenance operations require permanent or temporary slow orders, which cause disruptions to train service.

Crossing diamonds also frequently cause traffic bottlenecks on high tonnage lines. These delay costs can easily exceed the actual diamond maintenance costs, which is the justification for building a grade separation to eliminate the crossing diamond in many locations.

The following conclusions were drawn from the survey data:

- There are approximately 4700 crossing diamonds on U.S. and Canadian railroads.
- Diamonds are concentrated around major terminals. (Terminal railroads have 0.125 diamonds per mile of track; whereas, Class I railroads have 0.018 diamonds per mile.)
- Diamonds are not limited to low-speed, low-tonnage track. There are a considerable number of diamonds in mainline track. (Class I railroads reported that 69 percent of diamonds they maintain are in mainline track.)
- The average life of a crossing diamond is dependent on many factors, including: operations (e.g. tonnage on each track, train speed and wheel load), design (e.g. angle, type of frog and frog material, track alignment) and maintenance. Average life for the most severe situations, such as a high-angle crossing of two Class 5 mainlines with heavy axle load (HAL) traffic, is as low as 150 to 250 MGT.
- There are two types of diamond failure modes: substructure failures and running surface failures. Substructure failures include loss of surface due to poor drainage, subgrade overstress and ballast breakdown. Running surface failures involve metal flow deformation and failed/cracked weld repairs.
- Diamond design has not changed appreciably in many years. As average axle loads increase over time, diamond components are made larger. However, no comprehensive analysis of crossing diamond forces has been conducted. A review of crossing diamond design from a vehicle dynamics point of view is needed.

CROSSING DIAMOND POPULATION

Crossing diamonds on fourteen railroads, including 10 Class 1 railroads and 3 terminal railroads, were surveyed for data. Using this sample as a basis, informed estimates for the rest of the railroads were made. Exhibit 1 lists the population for each railroad by track category. The majority of crossings are in "mainline" track.

CROSSING DIAMOND FAILURE MODES

The railroads surveyed listed the types of failures which typically occur in crossing diamonds. The list (Exhibit 2) is ranked by probability of occurrence on a scale of 1 to 10 (with 10 being most likely). It is quite illuminating that many of the failure modes are ranked highly, which suggests there is no single dominant failure mode and that there are many variables involved in the performance of special trackwork components. The list can be separated into two categories of failure modes: support related and running surface related.

The impact loading imposed on high-angle diamonds caused by wheels that "jump" flangeway gaps is quite severe. Recent measurements from the Transportation Technology Center (TTC) and revenue service trains show that these wheel loads can have magnitudes two to three times the static wheel load. These impact loads manifest themselves in the two areas listed above. Crossing diamonds with good support fail by surface or casting deterioration. Those with inadequate support fail first in the ballast and subgrade areas.

Grinding and weld repair are frequent maintenance activities for crossing diamonds. Metal flow is ground frequently to maintain flangeway clearances and running surface profiles. Failure to grind in a timely manner often requires weld repair of cracked material. Because manganese steel is difficult to weld and weld survivability under impact loads is low, weld repairs are often short-lived.

Crossing diamonds are unique because they can support three different tonnage rates: one for each track and a third for intersecting section. Thus, wear, settlement, and deterioration rates can be quite different in a very small segment of track. Trying to balance the maintenance performed with the maintenance requirements is difficult. That is the reason that maintenance policy/level is a key variable in diamond performance.

The plate work and heavy castings in diamonds tend to make them stiffer than conventional track. Yet, there is very little transition between diamonds and conventional track. Like other fixed objects in track, the diamond has abrupt changes in stiffness that cause surface and alignment problems. Recent efforts have focused on stiffening subgrade with hot mix asphalt and providing better drainage systems under diamonds.

RESEARCH NEEDS

The crossing diamond, with its different traffic rates and extensive plate work, has unique surfacing problems and requirements. Because of its short length, it is an ideal candidate for processes like stone injection or design lift tamping. These techniques offer the ability to surface a hard-to-reach area. Also, the surfacing applied will last much longer than conventional tamping. Since diamonds are critical traffic "bottlenecks," reducing track maintenance time has significant economic benefits.

Better inspection methods and techniques are urgently needed. When and where to make weld repairs to the frog have a profound effect on overall crossing life. Yet, there are almost no guidelines for inspecting and selecting welding areas. Similarly, fasteners are inspected by looking for loose pieces. This reactive approach is undesirable because damage to the crossing diamond can occur before the loose bolts are found. Bolts should be checked for proper torque with calibrated equipment. Fasteners and bolts need to be re-designed for size, location, and maintenance reduction.

Repair welding training should be improved. Better guidelines on inspection and welding procedures are needed. Minimizing heat input to avoid embrittlement is the key to a long-lived repair. A weld consumable that offers a longer life at a lower overall cost must be selected or developed.

Design should focus on smoothing the vertical and lateral changes in stiffness. Current crossing diamond designs are quite stiff compared to conventional track; there is little transition between the two.

Effort should be made to develop designs which eliminate the unsupported flangeway gap and its associated impact loads. The life of these designs under HAL traffic is unacceptably short. A comprehensive crossing diamond analysis and design model are needed to perform this work.

Note: Contact David Davis at (719) 584-0574 or Peter Rogers at (719) 584-0757 if you have any questions or comments about this document.

Exhibit 1. Crossing Diamond Population

RR	Mainline Single	Mainline Multiple	Branch Line	Yard	Total
AT&SF*	61	26	20	11	118
BN*	117	7	6	32	162
CN	176	33	71	0	280
CP	76	52	93	0	221
CR	12	124	240	42	418
CSX	384	210	235	13	842
IC	14	49	9	55	127
NS	62	123	52	46	283
SP	78	4	6	0	88
UP	435	65	0	0	500
EJ&E	4	13	1	31	49
IHB	1	32	5	4	42
HB	5	20	0	4	29
Total	1425	758	738	238	3159
%	45.11	23.99	23.36	7.53	100.00

** BN and ATSF were separate railroads at the time of this survey.*

Exhibit 2. Crossing Diamond Failure Mode Ranking (1 to 10 scale)

Failure Mode	Failure Type	Average	Low	High
Support Related	Frog Pumps	7.2	4	10
	Poor Drainage	7.0	0	10
	Poor Ballast	6.9	0	10
	Poor Timber	5.6	0	8
Running Surface Related	Fastener Failure	4.8	0	9
	Cracked Frog	8.3	7	10
	Metal Flow	6.3	2	9
	Poor Profile	5.5	0	9

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON, D.C.,20001