Field Instrumentation of Concrete Crossties and Fastening Systems

FRA Tie and Fastener BAA Industry Partners Meeting
Tampa, FL
25 October 2012
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Outline

• Background on Field Research
• Field Instrumentation Strategy
• July Testing at TTC
• Experimental Results
• Preliminary Findings
• Future Work
FRA Tie and Fastener Project Structure

**Inputs**
- Comprehensive Literature Review
- Loading Regime (Input) Study
- Rail Seat Load Calculation Methodologies
- Involvement of Industry Experts

**Outputs/Deliverables**
- Data Collection
- Groundwork for Mechanistic Design
- International Survey Report
- Load Path Map
- Parametric Analysis
- State of Practice Report
- Validated Tie and Fastening System Model
- Improved Recommended Practices

**Process Flow**
- **Comprehensive Literature Review**
- **Loading Regime (Input) Study**
- **Rail Seat Load Calculation Methodologies**
- **Involvement of Industry Experts**
- **Modeling**
- **Laboratory Study**
- **Field Study**
- **Outputs/Deliverables**

The diagram illustrates the flow of information and outputs from inputs, highlighting the iterative process from comprehensive literature review to field study, with intermediate modeling and laboratory study stages.
Goals of Field Instrumentation

- Lay groundwork for mechanistic design of concrete crossties and fasteners
- Map stresses through the fastening system
- Develop an understanding into probabilistic loading conditions
- Provide insight for future field testing

(AREMA 2010)
Loading Demands
AREMA Chapter 30 Section 4.1.2.3, 4.1.3, 4.4.1

• **Existing Content:**
  – Load factors for tie spacing (4.1.2.3)
  – Discussion of lateral stability (4.1.3)
  – Design flexural values from tie spacing, tonnage, and speed (4.4.1)

• **Proposed Improvements:**
  – Verify or modify load factors in representing field conditions
  – Quantify the demands for lateral stability and lateral resistance

• **Methodology:**
  – Conduct parametric analysis of loading conditions in the field
  – Test multiple behaviors of lateral stability: displacement, clamping force, insulator compression, etc.
  – Coordination with finite element model to provide agreement

• **Timeline**
  – Present updates to Subcommittee 4 (C-30 Spring 2013)
  – Submit ballot proposal to Subcommittee 4 (C-30 Fall 2013)
4.1.3 LATERAL LOADS (1992)

a. The lateral loads generated by moving railway equipment are applied by wheel treads and flanges to the rails, which in turn must be held in place by fastenings, ties and ballast.

b. Lateral stiffness of rail distributes lateral loads to fasteners and their ties. Structural strength of fastenings and ties hold the rail to gage. The mass of ties, friction between the ties and ballast, lateral bearing area of ties (end surface), and the mass of ballast all act to restrain lateral tie movement.

c. Lateral track stability can, therefore, be increased by decreasing tie spacing of ties of similar dimensions, increasing tie mass, increasing end bearing area of ties per unit length of track, and by increasing frictional resistance between ties and ballast. Structural strength of fastenings must be commensurate with the lateral load individual ties restrain, which in turn is determined by lateral rail stiffness and tie spacing.

d. The magnitude of lateral loads which must be restrained depends not only upon the dimensions, configuration, weight, speed and tracking characteristics of the equipment, but also upon the geometric characteristics of the track structure.
Areas of Investigation

**Rail**
- Stresses at rail seat
- Strains in the web
- Displacements of web/base

**Fasteners/Insulator**
- Strain of fasteners
- Stresses on insulator

**Concrete Crossties**
- Moments along crosstie
  - Midspan
  - Rail Seat
- Stresses at rail seat
- Vertical displacements of crosstie
Field Instrumentation Strategy

- **Full Instrumentation**
  - Vertical & lateral loads
  - Embedment and external strains of tie
  - Clip, insulator, and rail base strains
  - Displacements on rail and crosstie

- **Partial Instrumentation**
  - Vertical strain gauges on rail
Field Instrumentation Locations

- TTCI (Pueblo, CO)
- High Tonnage Loop (HTL)
  - Curve (~5°)
  - Safelok I Fasteners
Field Instrumentation Locations

- TTCI (Pueblo, CO)
- Railroad Test Track (RTT)
  - Tangent
  - Safelok I Fasteners
Loading Environment

- **Track Loading Vehicle (TLV)**
  - Static
  - Dynamic
    - Track modulus

- **Freight Consist**
  - 6-axle locomotive (393k)
  - Instrumented car
  - Nine cars
    - 263, 286, 315 GRL Cars

- **Passenger Consist**
  - 4-axle locomotive (255k)
  - Nine coaches
    - 87 GRL
Fully Instrumented Ties
Instrumented Low Rail
Field-side Instrumentation

- Vertical Tie Displacement
- Clip Strain
- Base Displacement
- Vertical Web Strain
Gauge-side Instrumentation

Lateral Rail Displacement
Data Acquisition System
Vertical Displacements of the Ties (HTL)
Vertical Tie Displacements (HTL)

Location of 40k Vertical Load
Vertical Tie Displacements (HTL)

Location of 40k Vertical Load

Displacement (in)

C

E

G

High Rail

Low Rail
Vertical Tie Displacements (HTL)

Location of 40k Vertical Load

Displacement (in)

C  D  E  F  G

0.00  0.02  0.04  0.06  0.08  0.10  0.12  0.14  0.16

High Rail  Low Rail

C  E  G
Vertical Tie Displacements (HTL)

Location of 40k Vertical Load

Displacement (in)

C

D

E

F

G

High Rail

Low Rail
Vertical Tie Displacements (HTL)
Lateral loads Acting on Crib F (HTL)

- Freight train: 10 cars
- Leading axles
- Curve track (5°)
- Locomotive: 390k
- Freight cars: 260-315k
Freight train:
- 10 cars
- Leading axles
- Curve track (5°)

**HIGH RAIL**

**LOW RAIL**

- Locomotive: 390k
- Freight cars: 260-315k
Passenger train:
- 10 cars
- Leading Axles
- Curve track (5°)

- Omitting locomotive
- Passenger coaches: 85k
Preliminary Findings

• Global tie displacements provide an understanding of load distribution and substructure stiffness, and should be expanded in future field testing

• Increasing train speeds generate higher lateral forces on the high rail

• Preliminary comparison of some axles with the finite element model shows correlation with rail strains

• Results for strains at all instrumentation locations appear relatively similar on the tangent track with more variability in the curve track

• Highest loads were imparted by the locomotives and leading axles on railcar trucks
Future Work

• Continued **data analysis** to understand the governing mechanics of the system

• Continued **comparison and validation** of the finite element model

• Improvements on an **instrumented insulator** to provide post compression and lateral load

• Preparation for **instrumentation trip** (Spring 2013)
  – Focus on displacement measurements

• Small-scale, evaluative tests on Class I Railroads
Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

• Funding for this research has been provided by the Federal Railroad Administration (FRA)
• Industry Partnership and support has been provided by
  – Union Pacific Railroad
  – BNSF Railway
  – National Railway Passenger Corporation (Amtrak)
  – Amsted RPS / Amsted Rail, Inc.
  – GIC Ingeniería y Construcción
  – Hanson Professional Services, Inc.
  – CXT Concrete Ties, Inc., LB Foster Company
    • Vince Peterson, Pelle Duong, George Righter
• Monticello Railway Museum (Tim Crouch)
• Transportation Technology Center, Inc.
  – Dave Davis, Ken Laine, Dingqing Li, Steve Luna
• For assistance in instrumentation preparation:
  – Harold Harrison, Jacob Henschen, Thomas Frankie
Questions?

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Appendix
Vertical Displacements of Tie C (HTL)

Location of 40k Vertical Load

Displacement [in]

-0.15
-0.12
-0.09
-0.06
-0.03
0

High Rail
Low Rail
Vertical Displacements of Tie E (HTL)
Vertical Displacements of Tie G (HTL)

Location of 40k Vertical Load

C  D  E  F  G

C  D  E  F  G

Displacement [in]

High Rail  Low Rail
Insulator Post Compressive Strains
Passenger Train over Curve (45mph)

Strain [in/in]

Time [sec]

FIELD SIDE
GAUGE SIDE
Transverse Strains at Rail Base
Passenger Train over Curve (45mph)

*All transverse gages are on the FIELDSIDE
Lateral Load Measurements of Two Adjacent Cribs Passenger Train over Curve (45mph)
Vertical Load Measurements of Two Adjacent Crib Passengers Train over Curve (45mph)
- Field-side strains on Top Graph
- Gauge-side strains on Bottom Graph
- ALL strains on ONE railseat on the LOW RAIL
Displacement Data from Rail Seat Passenger Train over Curve (45mph)

Output Voltage [V]

Time [sec]

HIGH RAIL
LOW RAIL
Displacement Data from Tie Passenger Train over Curve (45mph)