Turnout Design: Wheel/Rail Contact, Kinematic Geometry and Maintenance

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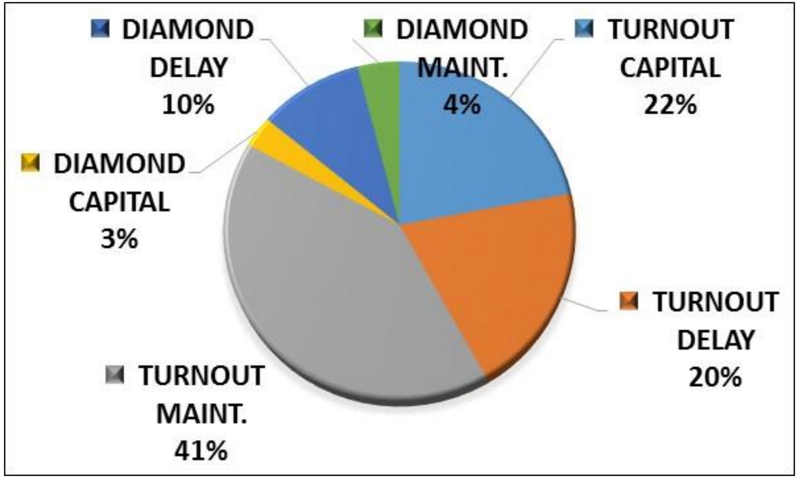
Presentation Outline

- **Progress on performance metrics**
  - Safety, Reliability, Efficiency, Capacity
- **Technical progress**
  - Alignment Design
  - Running Surface Profiles
  - Transitions
  - Maintenance
- **Future work**

High Performance Special Trackwork

- **Problem definition:**
  - Special trackwork costs more than $1B/year
  - Maintenance and train delay more than half of total costs
  - Dynamic load-sensitive components
  - Frog & switch point lives increasing
    - Still less than half of that of surrounding rail
  - Fatigue failures still significant
  - Running surface profile maintenance increasing

Distribution of Special Trackwork Costs



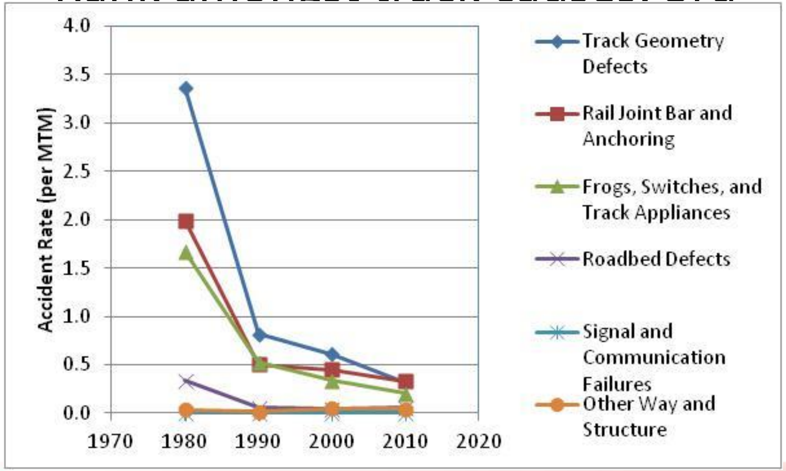
Source: TTCI analysis of R-1 data

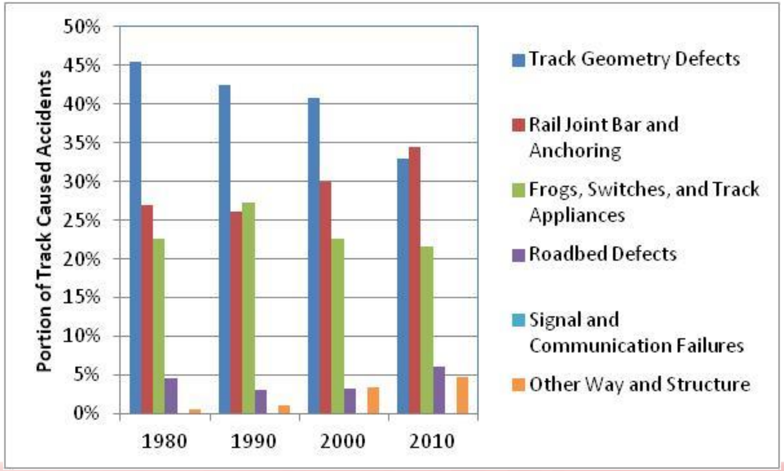
HAL Key Track Technology Enablers

- **HAL special trackwork performance (1980 – 2010)**
- **Improved service lives (from AAR Project audit)**
  - Turnout life: 500 MGT – 2,000 MGT
  - Frog Life: 100 MGT – 500 MGT
  - Diamond Life: 10 MGT – 100 MGT
- **Reduced accident rates (TTCI analysis of FRA safety database)**
  - Rate reduction: 88% Reduction since 1980
  - Rank amongst track causes: 3rd – 3rd
- **Reduced turnout maintenance (FAST experience)**
  - Labor hours per MGT:
    - 2.07 hrs/MGT 1980s
    - 0.58 hrs/MGT – today
    - 77% reduction

HAL Key Track Technology Enablers

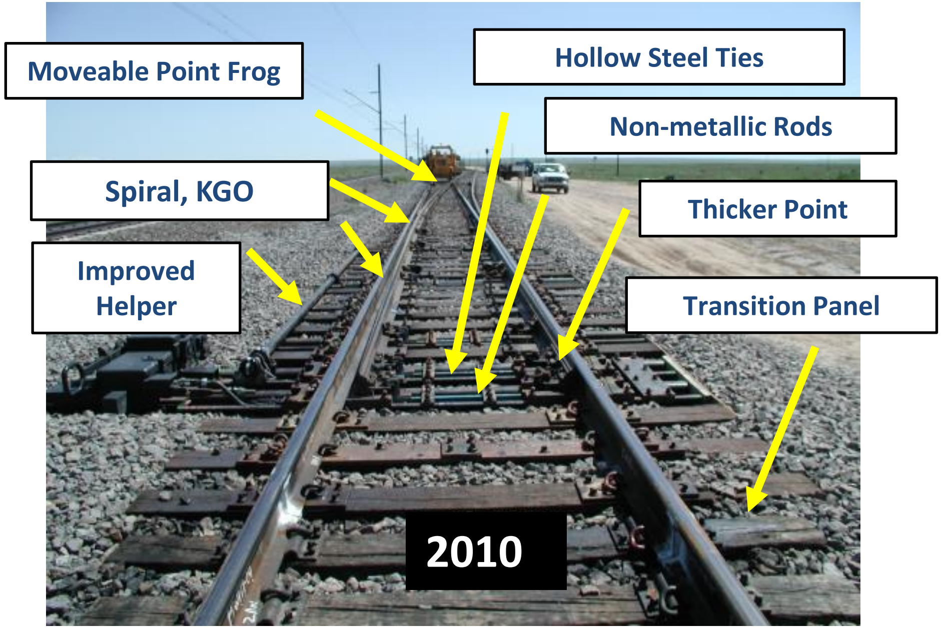
- **HAL special trackwork performance (1980 – 2010)**
- **Reduced accident rates (TTCI analysis of FRA safety database – Class 1 railroads)**
  - Rate reduction: 88% reduction since 1980
  - Rank amongst track causes: 3rd – 3rd





HAL Key Track Technology Enablers

- **Subtle, but significant changes.**

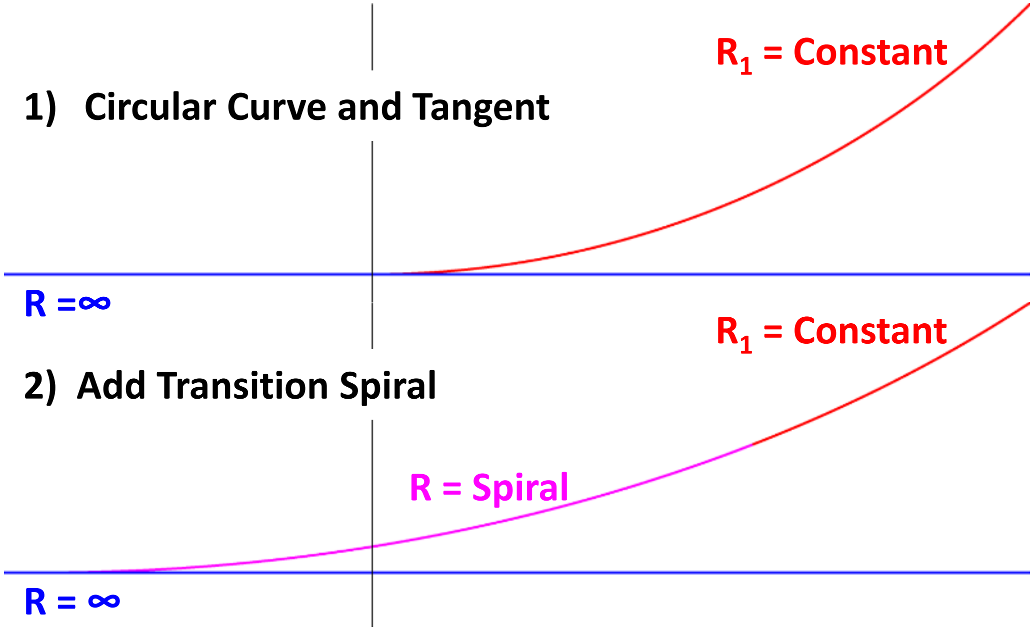


Improved Special Trackwork

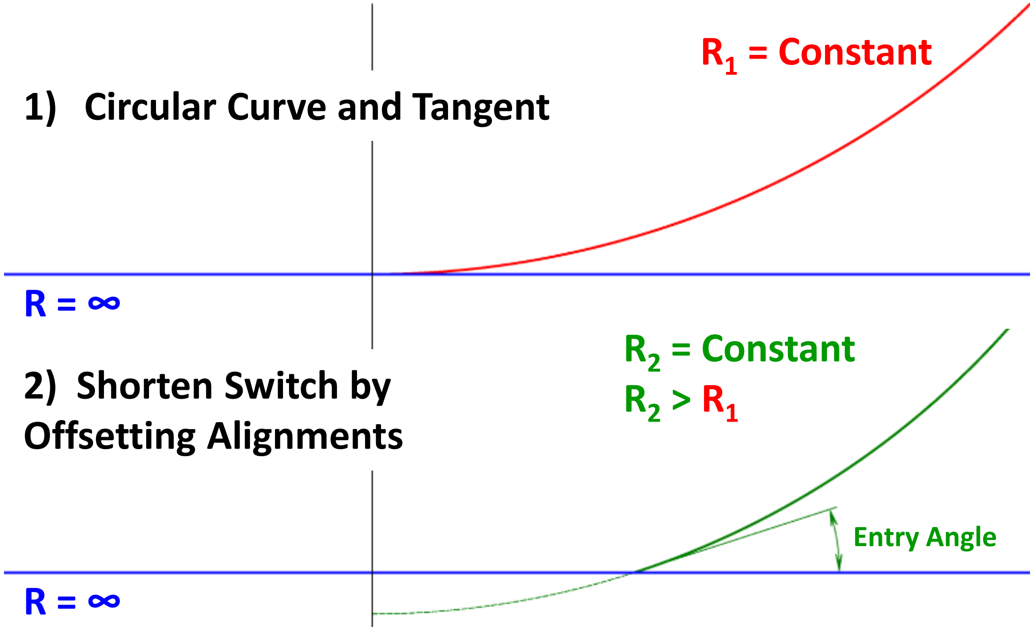
- **Areas of Improvement**
  - Alignment Design*
    - – Compromise between dynamic performance and service life
  - Running Surface Profile Design*
    - – Make profiles near conformal
  - Transitions
    - – Track structure change effects can be minimized*
  - Maintenance
    - – Accessibility to minimize track time

*We have the design tools to make significant improvements

Track Layout "101"

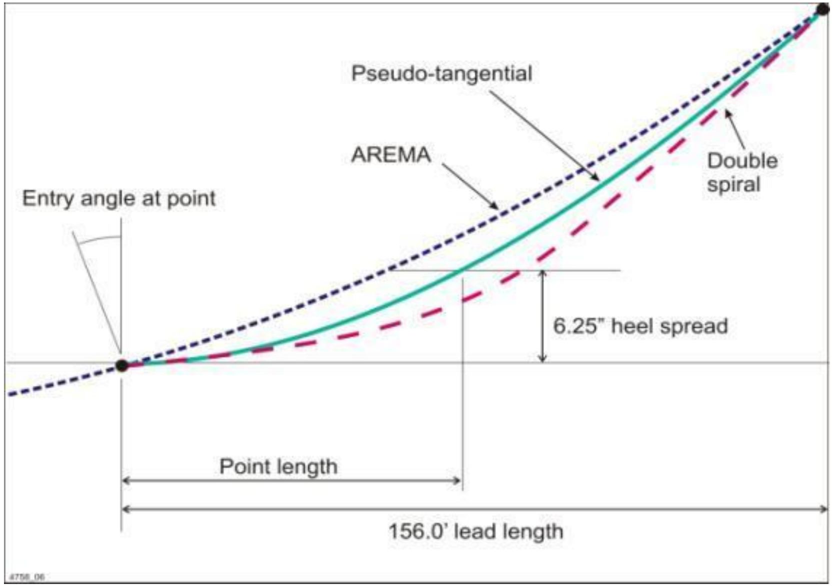


Turnout Layout "101"



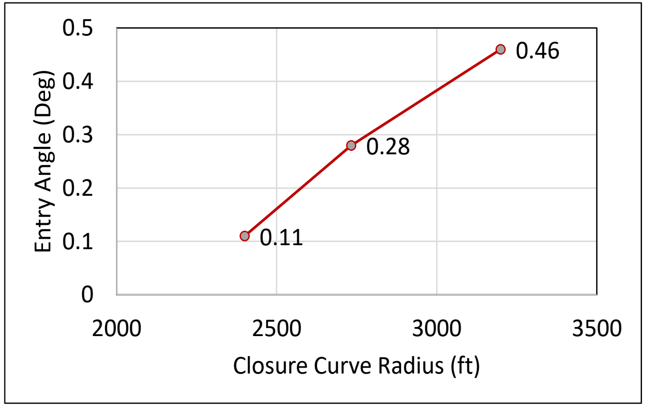
Alignment Design: Smoothing Alignments

- **Under current allowable speed rule:**
  - Maximize closure curve radius
    - – High entry angle and forces near point of switch
- **Proposed:**
  - Balance entry and curving forces
    - – Pseudo-tangential
    - – Double spiral
    - – Add elevation to compensate for smal radius curve
  - Modify cant deficiency rule



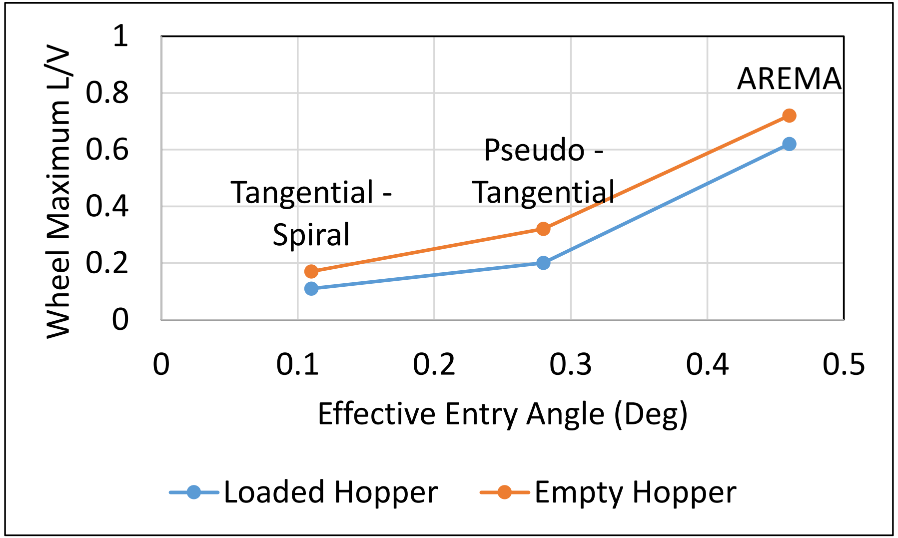
Turnout Geometry Design: North American Benchmarking

- **Comparison of #20 turnout alignments for predicted dynamic loads — study assumed a fixed turnout length 47.5 m (156 ft.)**
  - AREMA style (non-tangential) alignment
    - Large entry angle, circular curves
  - Pseudo-tangential (low entry angle) alignment
    - Straight cut, circular curves
  - Tangential – spiral alignment
    - Spiral to spiral
  - Entry angle – closure curve radius trade-off



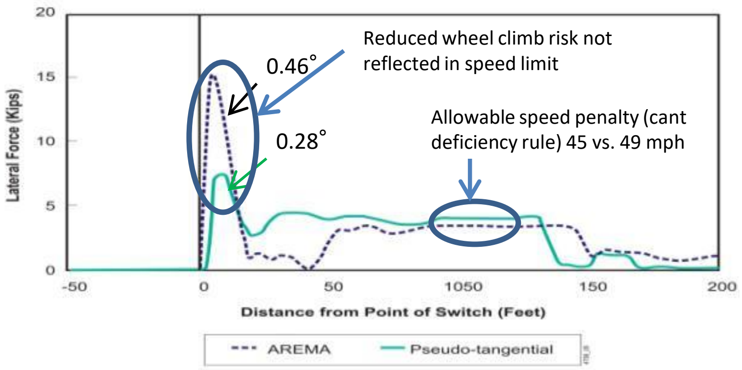
Turnout Geometry Design: North American Benchmarking

- **Comparison of #20 turnout alignments for predicted dynamic loads — study assumed a fixed turnout length 47.5 m (156 ft.)**
  - AREMA style alignment
  - Pseudo - tangential (low entry angle) alignment
  - Tangential – spiral alignment
    - Predicted dynamic performance (NUCARS®)



Optimized Turnout Alignment – Findings

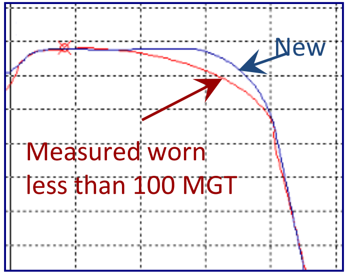
- **Minimize maximum lateral forces and life cycle costs**
  - Entry angle: significant effect
    - Pseudo-tangential alignments will provide significant benefit without lengthening switch
- **Diverging alignment: spirals important for reducing accelerations**
- **Super elevation: minimal effect on net lateral forces. Will raise allowable speed under current rule by ~5-10 mph**
- **Running surface profiles: Smooth transitions are critical**

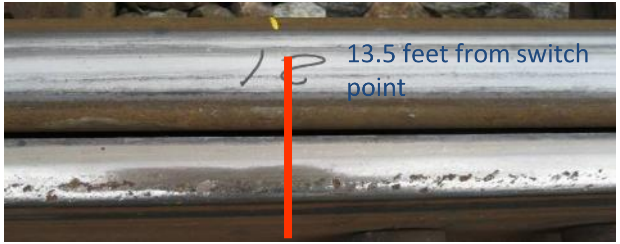


Switch Point Profile Design and Testing

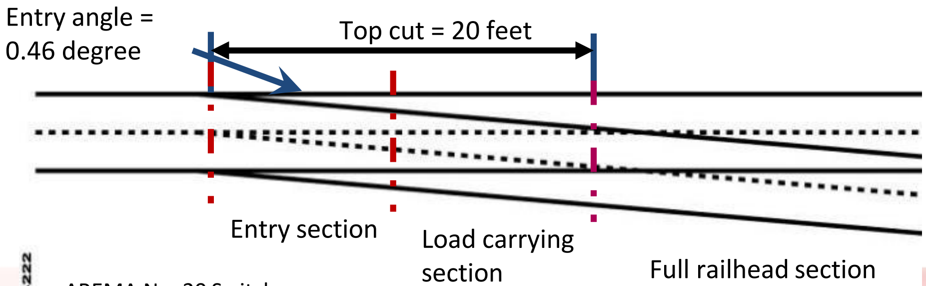
♦ Findings

- Point profiles play significant role in formation of rolling contact fatigue (RCF)
- Point wear concentrated at the gage corner
- Severe RCF defects generally first formed within the top cut section at gage corner
- Switch points show greater RCF than the matching stock rails





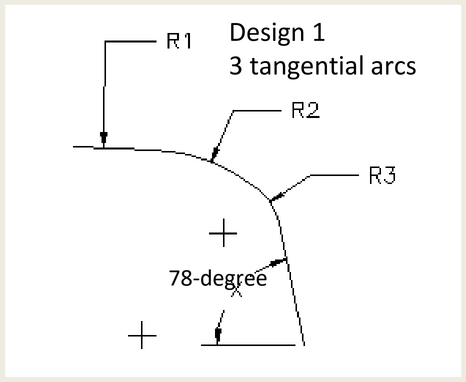
Less than 100 MGT

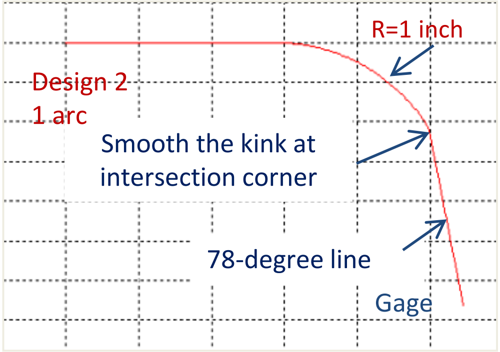


AREMA No. 20 Switch

New Switch Point Profile Design and Testing

- **Tests**
  - Two switch point profiles redesigned to improve contact conditions with anticipated reduced
    - Surface damage
    - Wear
    - Plastic flow at rail gage
  - TTCI, railroads, and one supplier to build and test prototype switch point rail profile designs
    - Prototype and base to be located on same line to assure similar traffic environments for comparison





Simplify the machining process
Utilize an existing tool

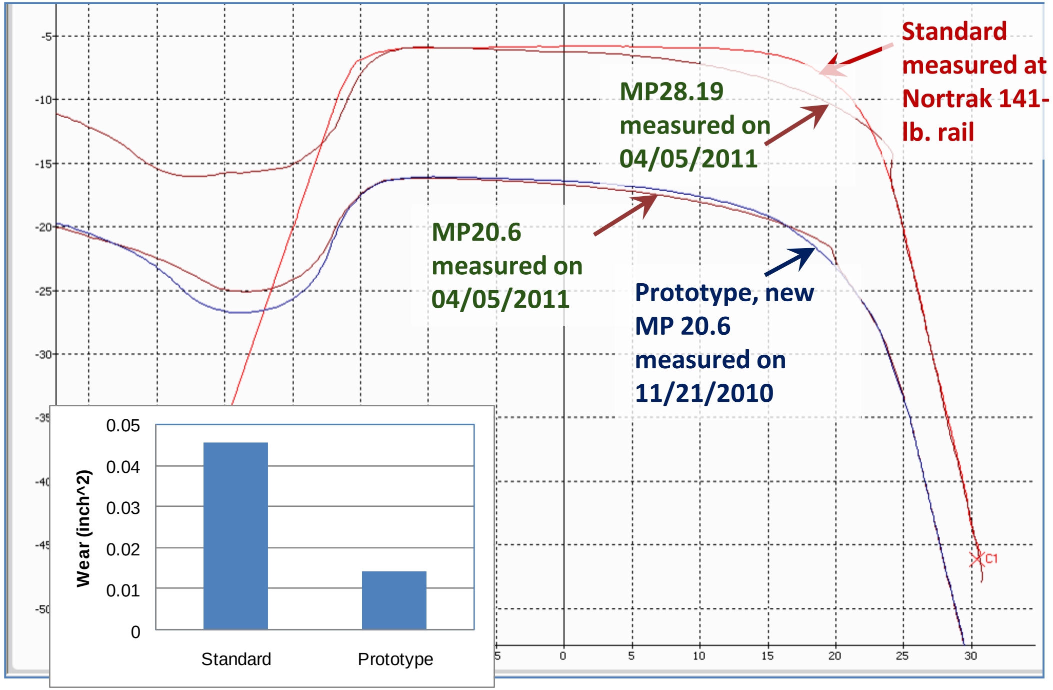
Prototype Switch Points in Revenue Service

BNSF – Marceline, MO

Union Pacific – Bonner Springs, KS

Comparison of New and Worn Switch Point Rail Profile

Straight points @ 13 feet from p.o.s.



New Switch Point Profile Design and Testing

Key Findings: Initial performance of Prototype Switch Point Profiles looks promising

Standard Straight Point

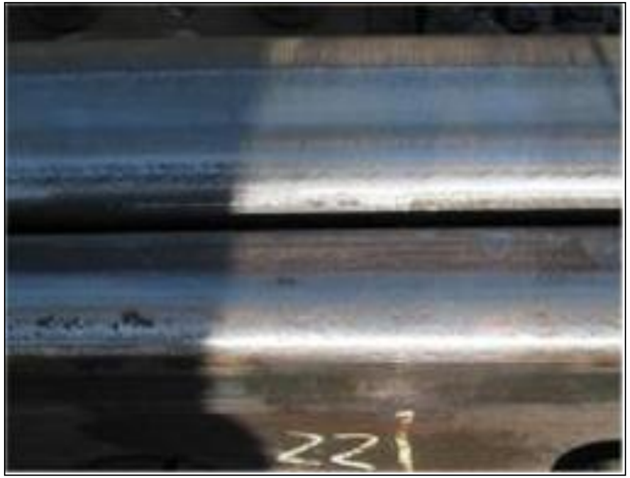
Prototype Straight Point

Contact on gage corner

Contact centered

Running Surface Appearance Standard and Prototype

Straight, @ 14 and 15 ft from p.o.s.



Standard point – RCF present

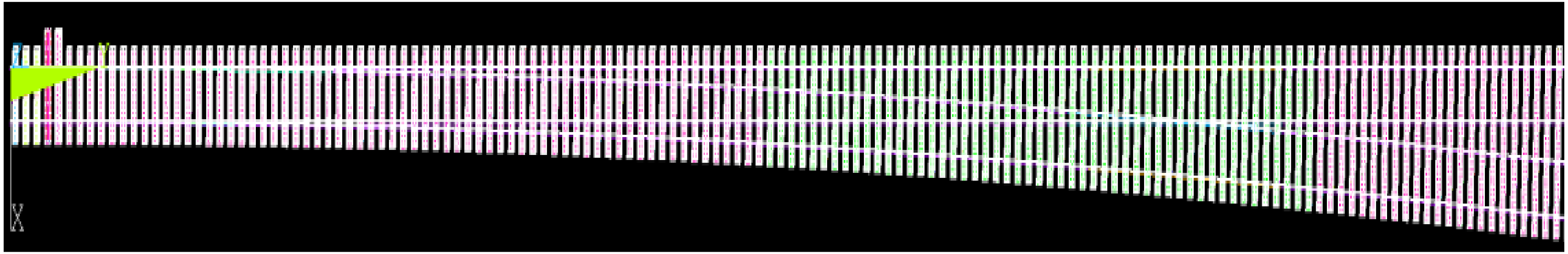
Prototype point – no RCF

New Switch Point Profile Design and Testing

- **Conclusions**
  - Simplified profile working as intended
    - Care should be taken to orient 1 inch radius to match canted rail
    - Significant reduction in wear (>50%)
    - Less RCF forming
  - Prototypes closer to design performing better
  - Study whether 3 radius design is feasible
    - 3 radius design was adopted by most railroads

Optimize Vertical Turnout Stiffness

- **Objectives: Test prototype turnout foundations to reduce stiffness changes, dynamic loads and settlement**
  - Proof of concept test
    - Timber ties and under-tie pads
  - FAST test began 2013:
    - Canadian Pacific RR #20 Turnout with Pads 1 and 2



Pad 1 to match open track

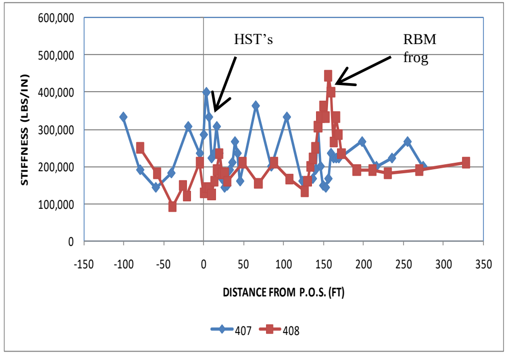
Pad 2 also adds damping

Turnout Foundation Test

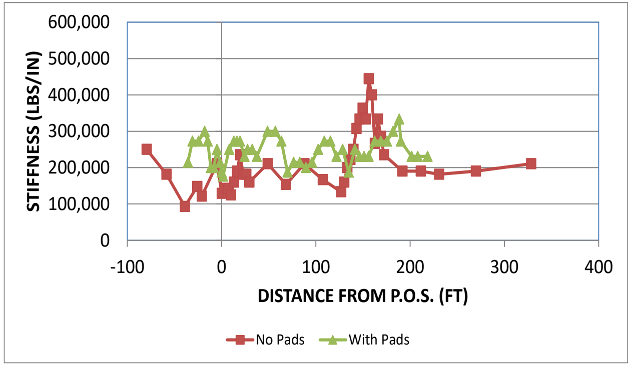
Description of Test

- ♦ **Vertical stiffness variations due to longer ties, platework and extra rails in turnouts**
- ♦ **Under-tie pads installed in turnout**
    - Uniform stiffness 200,000 – 250,000 lbs./in.

#20 Turnout With Under-tie Pads



#20 Turnouts Stiffness measured at FAST HTL – No pads

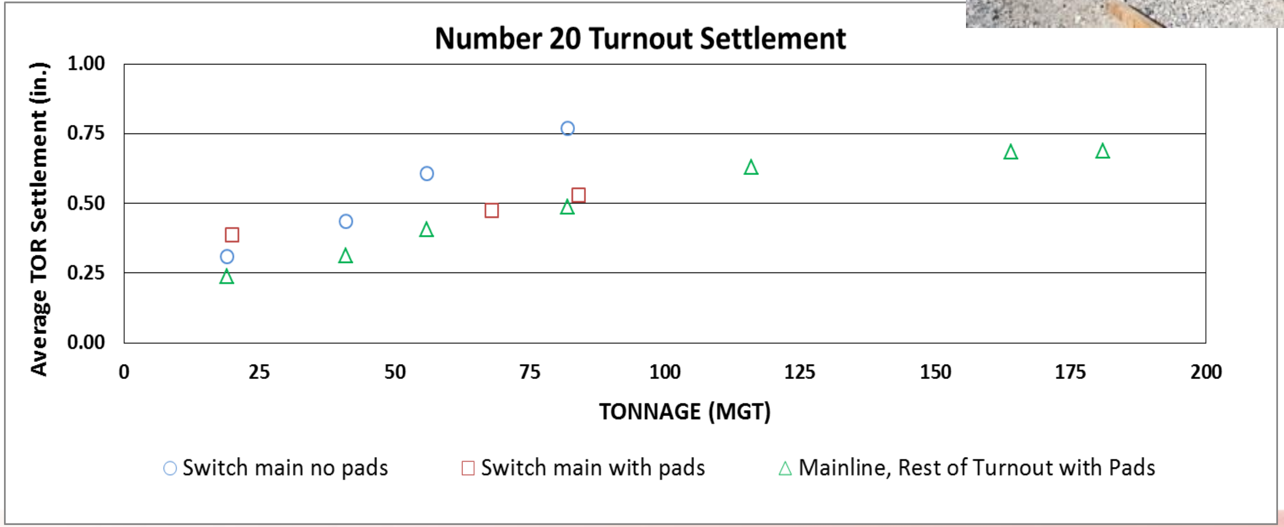


#20 Timber Tie Turnouts with RBM Frogs

Turnout Foundation Test

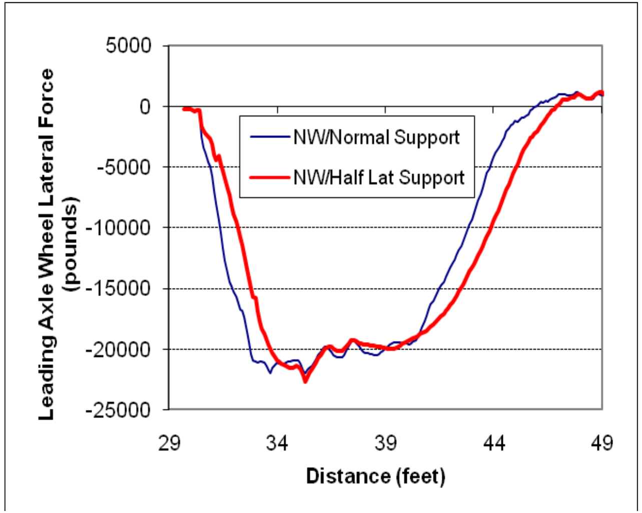
Preliminary Results

- ♦ Uniform stiffness 200,000 – 250,000 lbs./in.
- ♦ Reduction in settlement by ~33%
- ♦ More uniform settlement



Optimize Lateral Stiffness of Switch

- ♦ **Traditionally, lateral stiffness in switch is made as high as practicable**
  - Safety
  - Creates a "hard spot" in the track



- ♦ **Dynamic simulations show that there is an effect of lateral stiffness on maximum forces**
  - An optimal range of lateral stiffness may exist where forces are lower and safety is not compromised
    - Contact occurs later in switch (switch point is thicker)
    - Empty car forces should also be reduced

Optimize Lateral Stiffness of Switch

FAST Testing

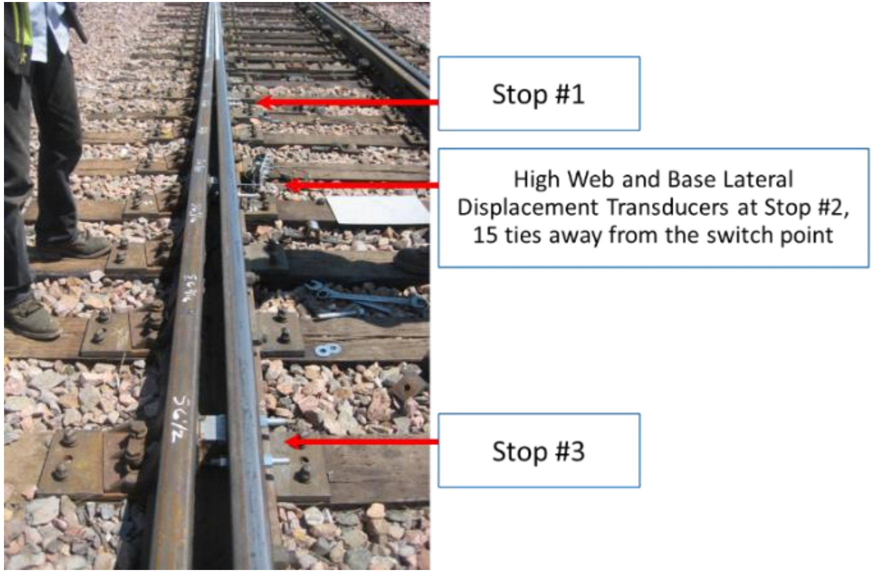
♦ **Effects of Lateral Stop Stiffness on Turnout Forces Preliminary Conclusions:**

- Lateral stiffness of switch point stop can reduce facing point lateral forces 10-15%
- Relatively low-cost modification can make a marginal improvement in performance
- Turnout footprint is often a rigid constraint
  - Can be applied to large entry angle switches

Compliant Switch Evaluation

FAST Testing

- ♦ **Effects of Lateral Stop Stiffness on Turnout Forces**
  - Six variations of switch point stops
  - Quantify lateral forces, L/V ratios, and rail displacements



Compliant Switch Evaluation

FAST Testing:

- ♦ **Lateral Stops Evaluated (2 of 6):**

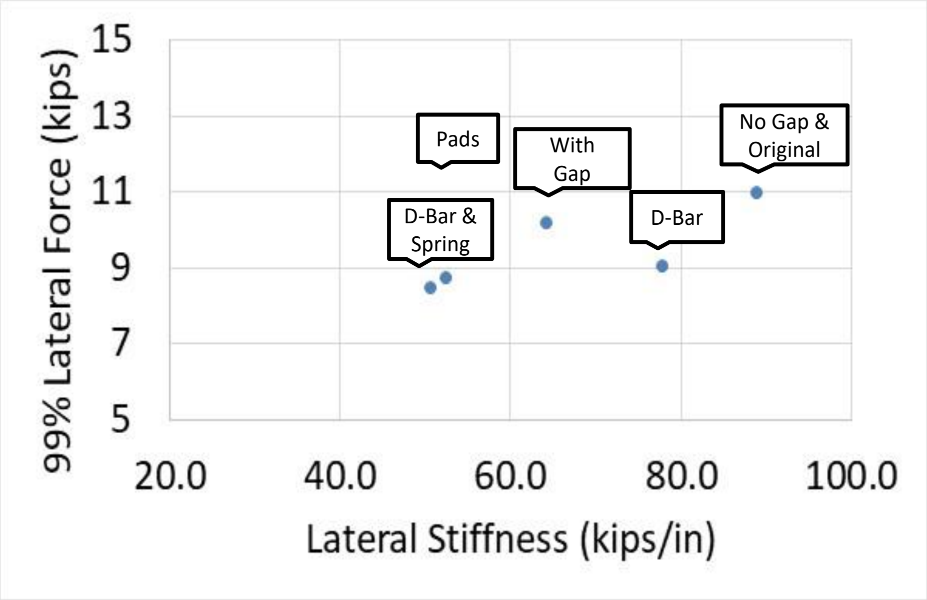
Standard Stop

Spring Stop: D Bar contact

Compliant Switch Evaluation

FAST Testing

- **Effects of Lateral Stop Stiffness on Turnout Forces**
  - Six variations of switch point stops



STW – Advanced Designs & Materials

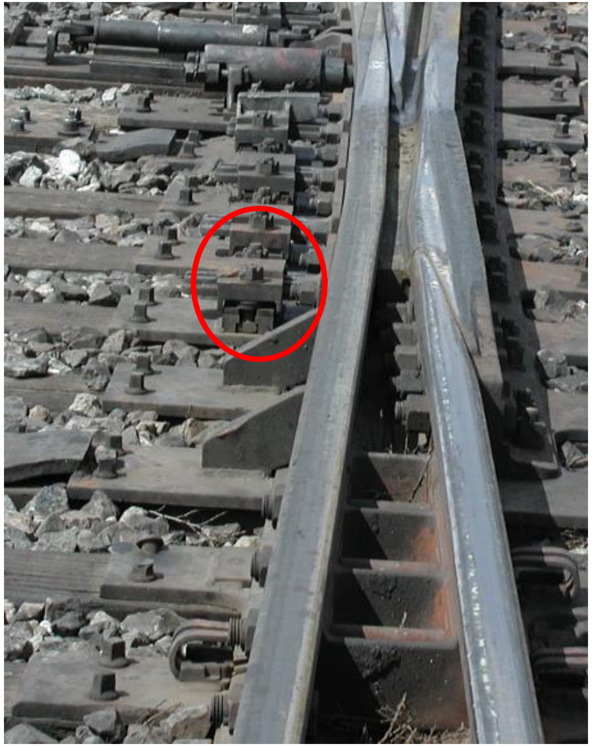
- **Key findings: Turnout maintenance under HAL**
- **Comparison of FAST maintenance effort 1980s to today**
  - Significant improvement in Labor Hours/ MGT

FAST Turnout	Turnout Maintenance (hr/MGT)	Component Replacement (hr/MGT)	Total Maint & Replacement (hr/MGT)
1980s T.O.	1.42	0.65	2.07
1990s T.O.	0.85	0.19	1.04
2000 AREMA T.O.	0.55	0.07*	0.63
2010 T.O.s	0.33	0.27	0.60

* Major component failure shortened turnout life and reduced component replacements

STW – Advanced Designs & Materials

- **Key Findings: Turnout Maintenance under HAL**
  - Biggest decrease in Turnout Maintenance hours
    - All fasteners accessible from the top (e.g. capture blocks)
    - Initial worn shapes reduce initial grinding required
    - Better dynamic performance has extended component life
  - General trend: running surface maintenance is taking a larger share of total maintenance
    - Other maintenance is decreasing due to lower dynamic loads



Turnout Design

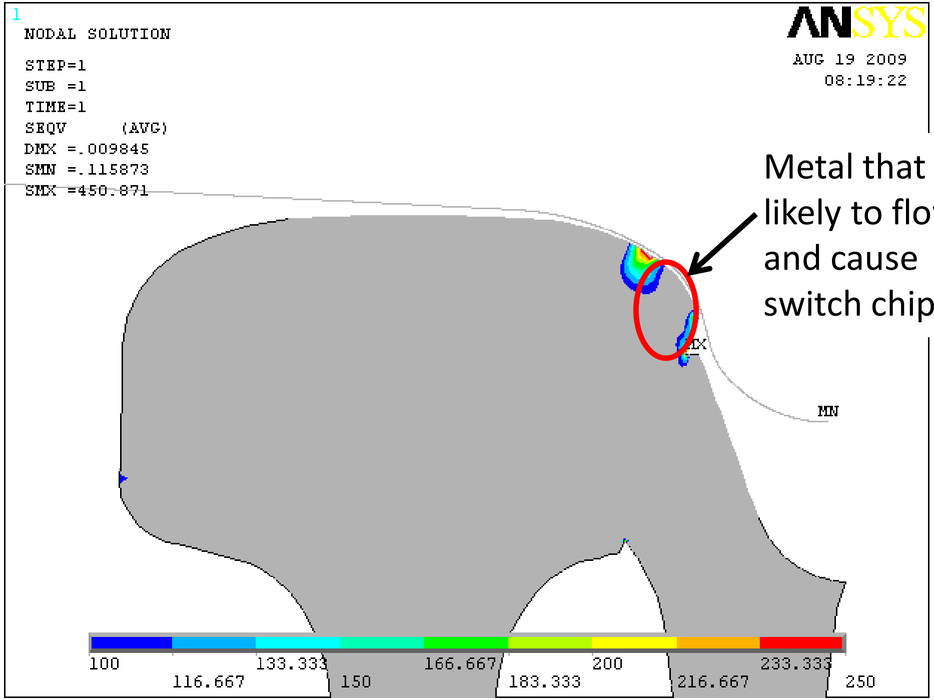
- **Future Work:**
  - Vertical switches
    - For low volume, low speed diverging traffic
    - Eliminate running surface discontinuities for mainline route
  - Frog materials
    - Reduce metal flow and fatigue cracking
    - Needed to improve Flange Bearing Frogs economics

Turnout Design

- **Future Work (2):**
  - Rail running in turnouts
    - Better handling of rail longitudinal forces
  - Switch point fatigue
    - Redesign switch point- stock rail interface
      - Stock rail flow and switch point twist create adverse contact

Future Work: Prevent Switch Point Chipping

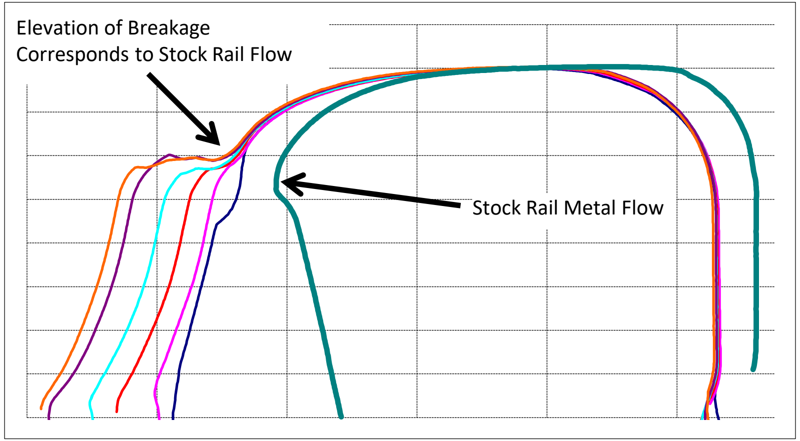
- **Stock Rail Flow Leads to Switch Point Chipping**



Metal that is likely to flow and cause switch chipping

Switch Failure Modes Analysis

- **Key Findings: Stock Rail/ Switch Point fit should be more robust**
- **Field survey**
  - Common height for chipped out points — indicates stock rail flow contact



TTCI Special Trackwork Team

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- Rafael Jimenez
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Thank you for your kind attention