Track Support: Resilient Materials, Applied Research & Experience

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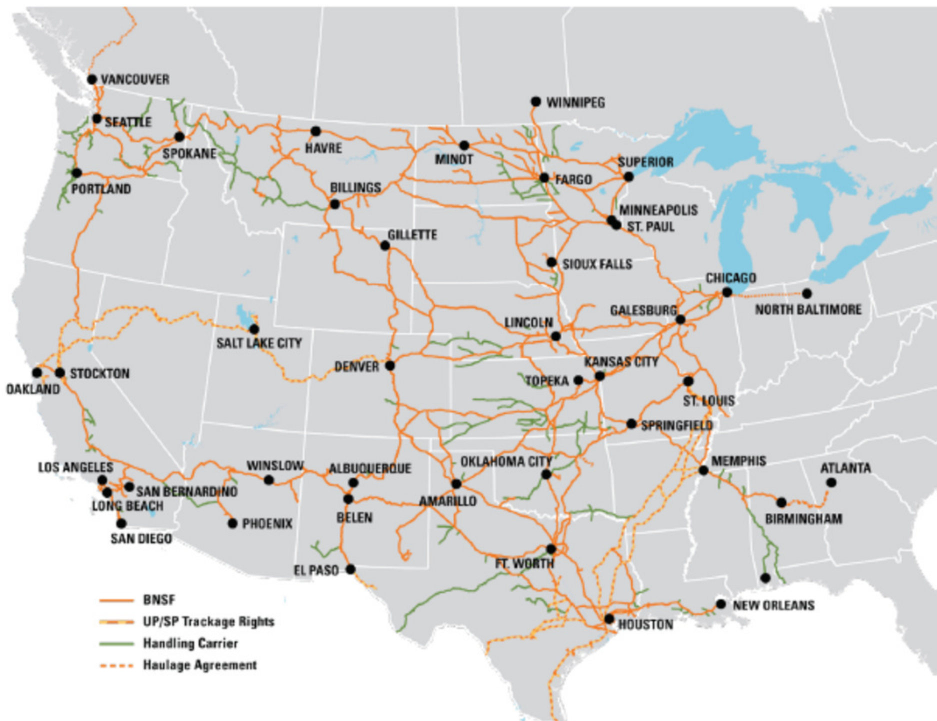
BNSF Railway At A Glance

BNSF Railway is one of North America's leading freight transportation companies, with a rail network of 32,500 route miles in 28 states and three Canadian provinces. BNSF is one of the top transporters of the products and materials that help feed, clothe, supply and power communities throughout America and the world. BNSF moves those goods more safely and efficiently, on significantly less fuel, with fewer emissions than the all-highway alternative.

History

BNSF's history dates back more than 170 years to 1849, when the 12-mile Aurora Branch Railroad was founded in Illinois. Over the next several decades, many additional rail lines were built and eventually became part of what is today's BNSF Railway. Some of BNSF's predecessor railroads were Atchison, Topeka & Santa Fe; Burlington Northern; Chicago, Burlington & Quincy; Frisco; Great Northern; Northern Pacific and Spokane, Portland & Seattle.

BNSF was created Sept. 22, 1995, from the merger of Burlington Northern, Inc. (parent company of Burlington Northern Railroad) and Santa Fe Pacific Corporation (parent company of the Atchison, Topeka & Santa Fe Railway). On Feb. 12, 2010, BNSF became a subsidiary of Berkshire Hathaway, Inc.



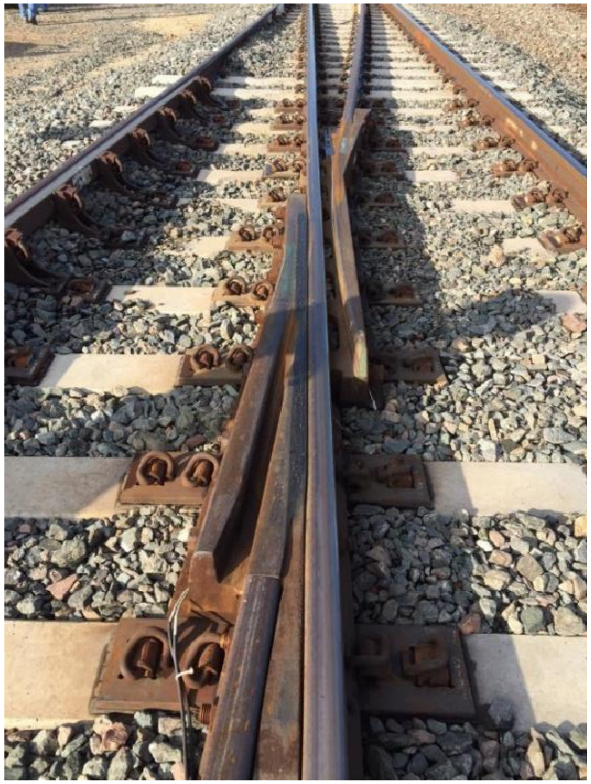
BNSF Facts

Length of network:	32,500
States in network:	28
Canadian provinces:	3
Employees:	~35,000
Headquarters:	Fort Worth, TX
Ports served:	40+
Intermodal facilities:	26
Average trains per day:	1,200
Locomotives:	~7,500
Capital investment (2021):	$2.97 billion
Bridges:	13,000+
Tunnels:	89
Grade crossings:	25,000+
Packages shipped during holiday season:	89 million
Carloads shipped in 2021:	10.1 million
Distance BNSF hauls 1 ton of freight on 1 gallon of diesel fuel:	~500 miles

Impact Reduction

Basis of Everything We Do

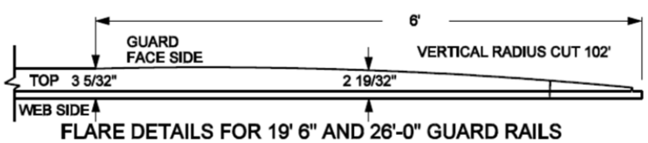
- Reduction or elimination of impacts has been the primary driver of innovation and adoption of Track Standards for BNSF Railway
- Design and innovation up to this point has been more of an iterative process with ideas coming from field issues being tested and rolled out
- BNSF has teamed with our suppliers, MXV, academia, other roads, FRA, our own research Dept, and our field personal to accomplish this
- More data is helping us drive more decisions based on predicted degradation and costs
- Today I will cover some of the improvements we have made with a focus on resilient materials along with what we look to do in the future

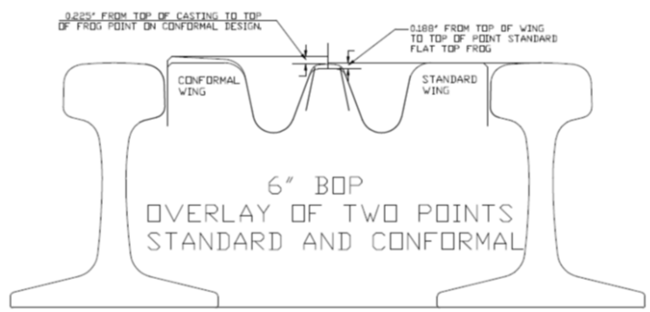


Past Has Been Largely Trackwork Focused

Implemented Improvements

- Tapered Universal Heel
- Conformal Casting w/ Heavy Point
- Lift Frog / Jump Frog
- Movable Point Frogs
- Improved Rail Steels & Lubrication
- Radiused Guard Rails

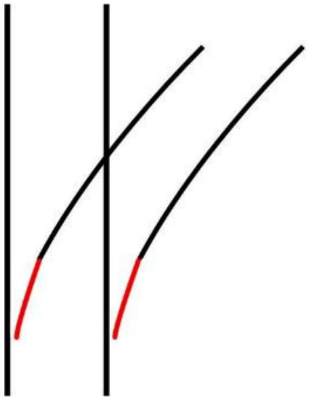




Past Has Been Largely Trackwork Focused

Continued Work to Eliminate Impacts (MXV, Suppliers, Academia, FRA, Internal)

- Full Flange Bearing Diamonds
- Higher Speed OWLs (one way low speed)
- Vertical Switches
- Ramped Frog Castings
- Geometries / Entries
- Padding Configurations



Route	Speed kph/(mph)	Maximum Lateral Force KN/(kips)	Maximum Vertical Force KN/(kips)
Vertical Switch Trailing, Diverging	8 (5)	89 (20)	258 (58)
#20 Split Switch Trailing, Diverging	8 (5)	89 (20)	222.4 (50)
Vertical Switch Trailing, Main	32 (20)	13.3 (3)	231.3 (52)
#20 Split Switch Trailing, Main	32 (20)	53.4 (12)	266.9 (60)

Introduction to Under Tie Pads & Ballast Mat

- Background
  - Great deal of work in the 80's and 90's for concrete tie pads (rail base / concrete tie interface) for attenuation & longevity.
  - Continued growth in demands for higher speed and HAL freight transportation
  - Accelerated degradation of track infrastructure components leads to consequently higher maintenance costs

  → Introduction of under tie pads & ballast mat

- What are under tie pads?
  - Elastic components that provide a conformal resilient layer under the crosstie
  - Typically consist of pads made of synthetic rubber or polyurethane elastomer

Benefits of UTP Application

- Increased contact area between tie and ballast
  - Contact area without UTP: around 3-5%
    → increased up to 35% with UTP implementation
  - Reduction in substructure stresses
    - Crosstie-ballast pressure and particle contact forces
    - Lower stress concentration → prevent ballast degradatior
  - Reduce track vertical settlement rates

- Noise and vibration mitigation
  - Reduces ground-borne noise by attenuating the vibration transmitted to the substructure
  - Typically effective for frequencies between 30-150 Hz

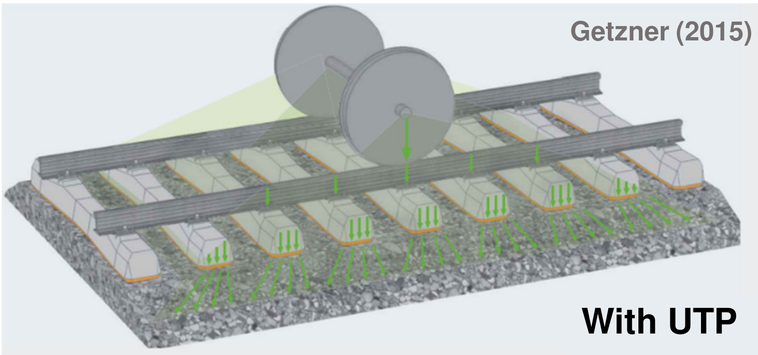
Unpadded crosstie **Padded crosstie**

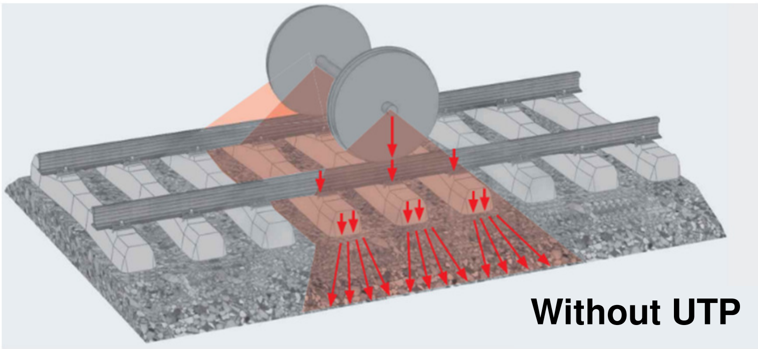
Benefits of UTP Application

Endless Possibilities

- Load distribution on a wider range
- Reduction of contact pressure and smaller variation of support stiffness along the track
  - More uniform track deformation under wheel loads
    - → Increases the pressure distribution area of track support layers

- UTPs can be applied in various track locations including:
  - Open track
  - Transition zones (e.g., bridge, tunnel, etc.)
  - Turnouts
  - Joints
  - Curves



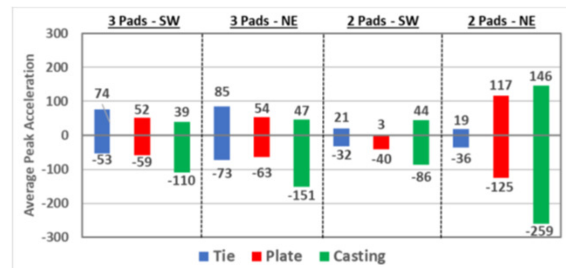


Diamonds – “The Single Most Demanding Piece of Trackwork” *Russ Hein*

First Location We Really Started to Implement Resilient Materials

MXV Rail Instrumental in the Study

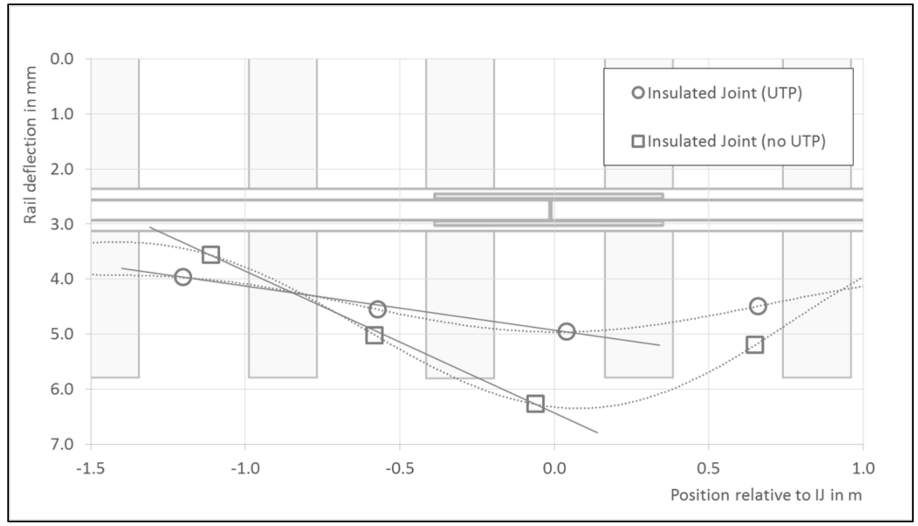
- Casting Pads – Impact Reduction at Casting However Too Much Acceleration & Resulting Issues
- Too Much Resiliency
- Two Pad Standard / Leveling plate pad and UTP

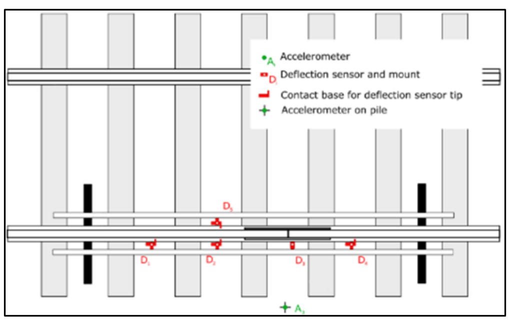


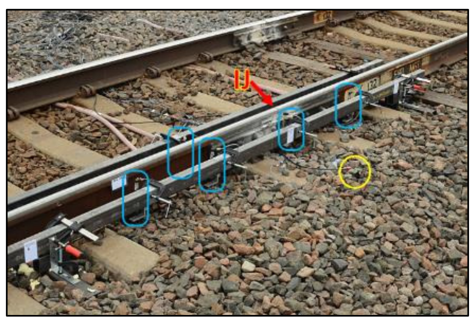
Insulated Joints and Concrete Ties

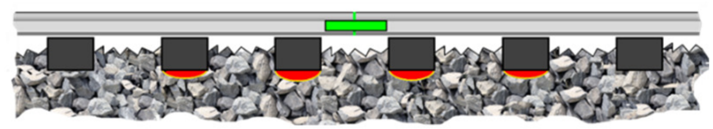
Getzner / LB Foster / BNSF

The IJs perform differently than the adjacent track. However, the IJ itself shows less deflection with UTPs compared to the control location. This phenomenon can be explained by looking at track alignment and surface over time. UTPs reduce ballast movement and furthermore preserve track surface. Development of track defects is prevented and as a consequence the deflection at the IRJ location remains steady over time.









Curve Movement / Breathing

UTPs and Lateral Track Resistance

This side benefit is equally important and has had been the solution on some of our curves

- Push Testing Work Continues Internally by our Data Team
- Padded Concrete Ties provide improved lateral resistance over wood and over standard concrete ties

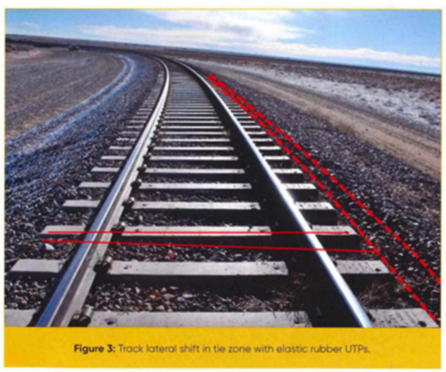
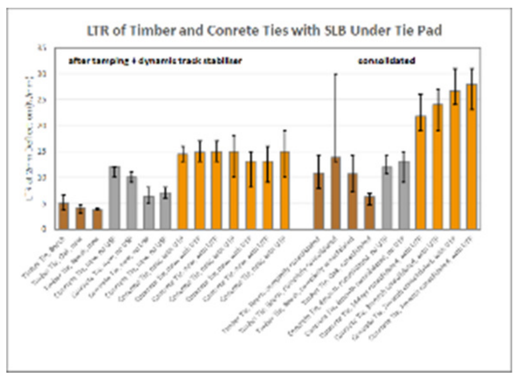


Figure 3: Track lateral shift in tie zone with elastic rubber UTPs.

Figure 4: Bottom surface of elastic rubber pad after 900 mgt.

Figure 5: Bottom surface of elastoplastic pad after 900 mgt.



Bridges / Transitions / Track Laying Machine Efficiency

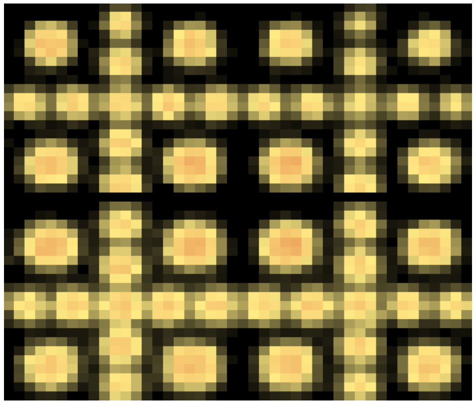
Internal Standards Change Driven In Part by Efficiency

- Prior practice was cutting out the TLM and laying wood tie panels across new bridges
- Addition of ballast mat for resiliency and reduced ballast breakdown
- Standard practice now for new track construction, some other bridges / Improved transitions




University of Illinois RailTEC / BNSF Resilient Material Research

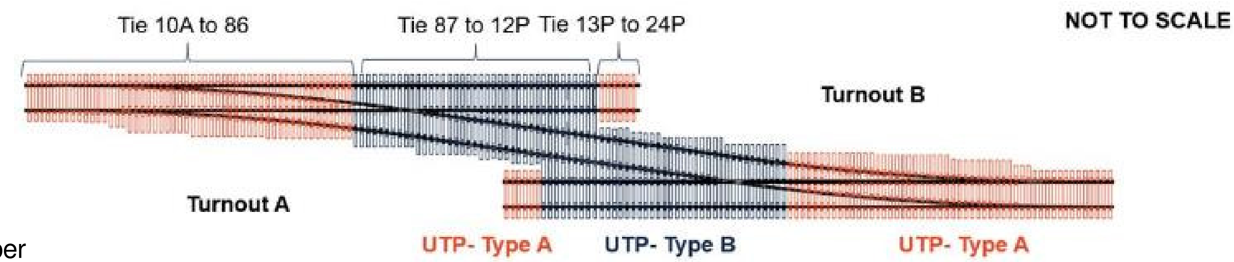
- Motivation:
  - Investigate effects of under tie pads on substructure stresses and track performance
- Objective:
  - Understand differences in Life Cycle Cost (LLC) associated with the inclusion of resilient materials in the track structure
    - Increase in asset service life
    - Reduction in maintenance cost

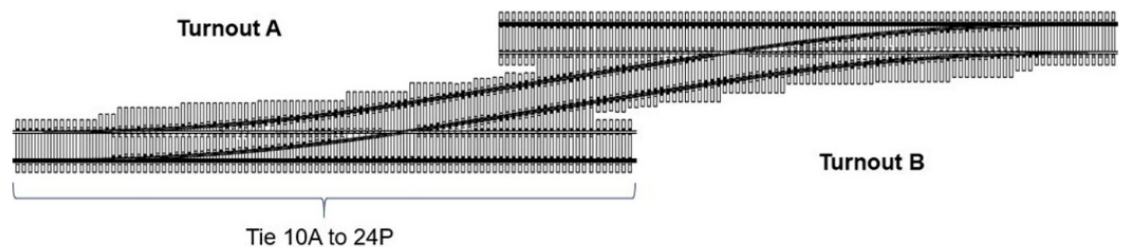


Turnouts - UTPs

Initial Success at TTCI

- Test Location
  - BNSF Mendota (IL) Subdivision
    - Double #20 RBM timber tie crossover: One padded,
      and one non-padded (control)
  - BNSF Avard (OK) Subdivision
    - One padded, and one non-padded (control) timber tie turnout
  - BNSF Emporia (KS) Subdivision
    - Padded timber tie crossover
- Primary Monitored Metrics
  - Vertical track deflection → Transient displacement amplitudes
  - Frog casting acceleration → Wheel impacts
  - Absolute track settlement → Rate of compaction and consolidation
  - Track Geometry Car Data → Geometry degradation rates





Emporia Subdivision Test Bed – Bridges, Curves, & Open Track

- Objective
  - Determine the effect of different types of UTPs on different aspects of track (e.g., bridges, curves, road crossings, etc.)
- Location
  - Segment of new track on Southern Transcon's Emporia (KS)
  - Subdivision with type 1, type 2, and non-padded ties
    - One bridge on each section
    - Curves on both padded sections
    - One road crossing on each section

Emporia Subdivision Test Bed

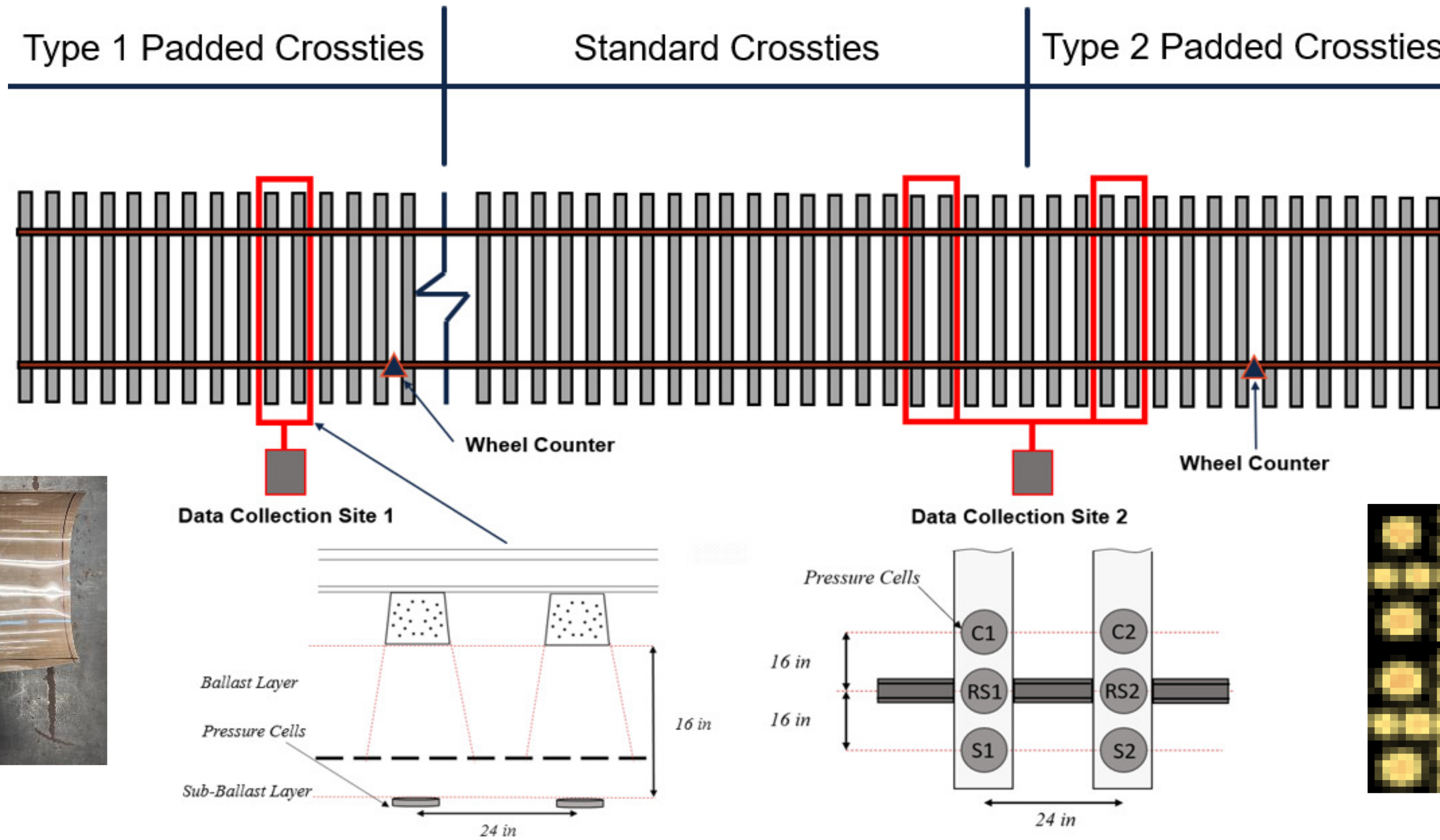
- Primary Monitored Metrics:
  - Level survey at bridge abutments → Absolute and differential settlement at bridge transitions
  - Crosstie bending tests → Crosstie performance / support condition
  - Single-tie push tests → Lateral resistance
  - Curve staking → Curve breathing
  - Geometry car data → Geometry degradation rates

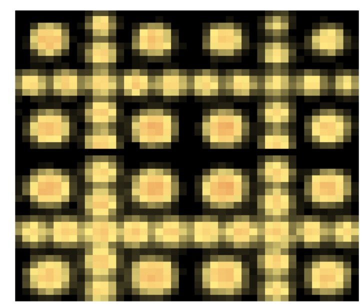
Open Track Bearing Pressure Study

- Objective
  - Quantify the effect of different concrete crosstie UTP types to substructure bearing pressures in a revenue service field environment
- Test Location:
  - BNSF Seligman Sub. - Southern Transcon
  - Three Test Sections:
    - Type 1, Type 2, and non-padded (i.e., Control)
- Instrumentation:
  - Vertical Wheel Load Circuits
  - Pressure Cells
  - Wheel Counter

Bearing Pressure Study – Truxton, AZ

Matrix based tactile surface sensors MBTSS – Digital output converted to engineering units





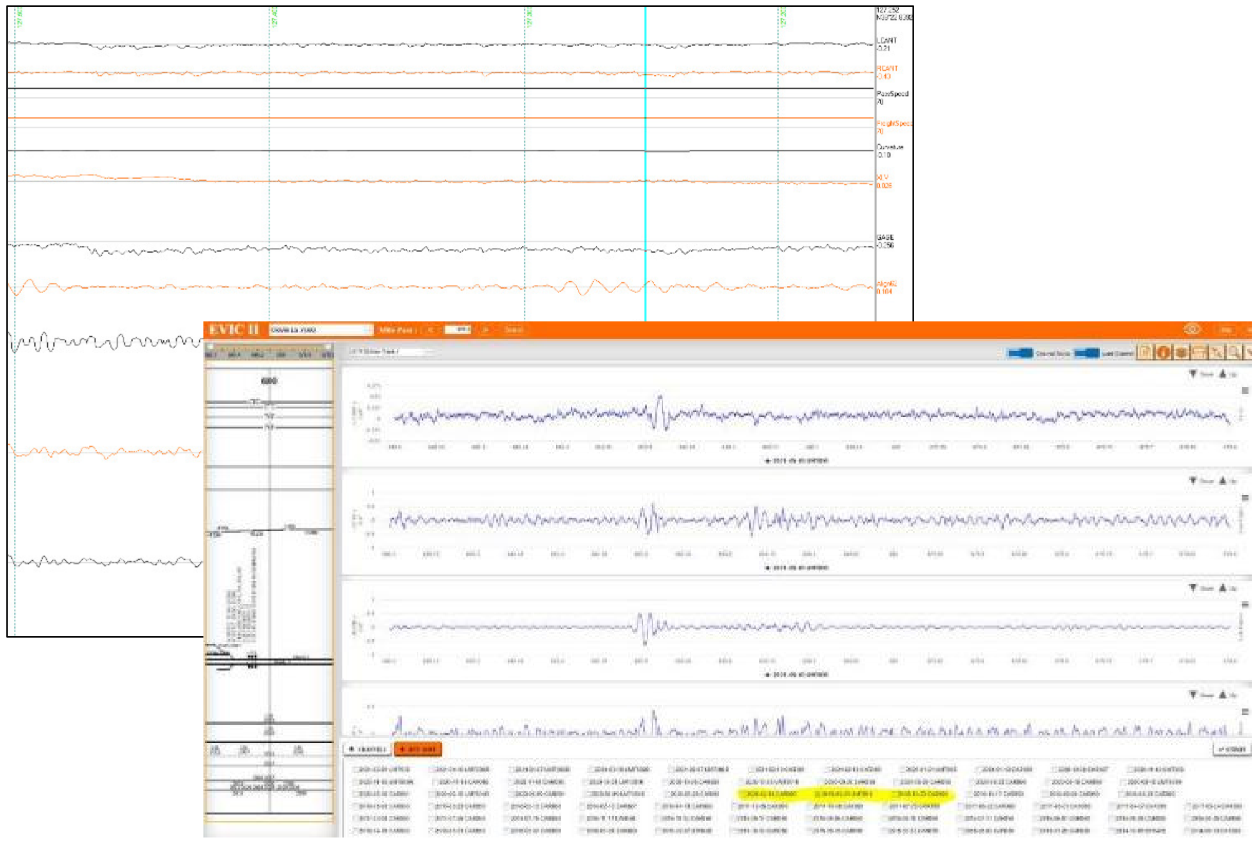
BNSF RAILWAY

Geometry Car Data / Run Over Run & Degradation

Comparative Analysis / Ft x Ft

	Surface		
	A	B	C
Feb 22'	0.168	0.106	0.120
Oct 22'	0.165	0.173	0.144

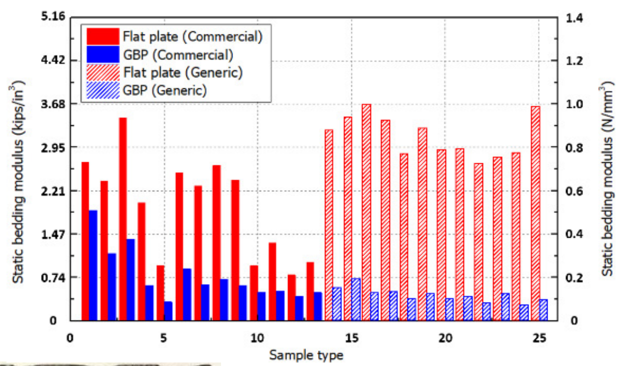
	Alignment		
	A	B	C
Feb 22'	0.050	0.047	0.039
Oct 22'	0.055	0.059	0.057

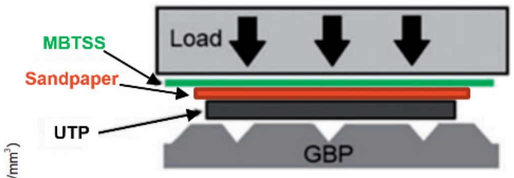


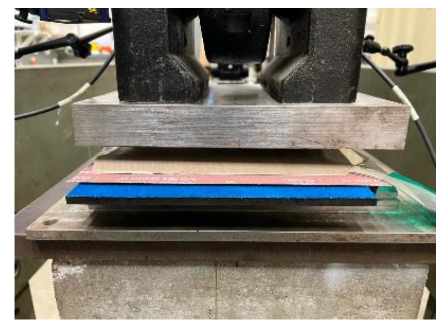
Lab Work

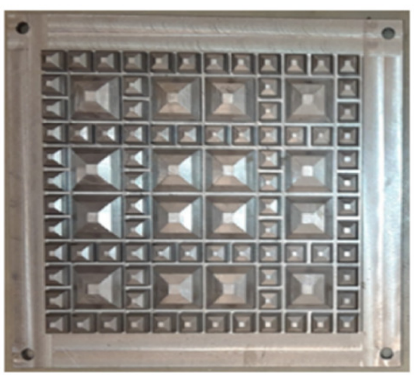
Many Choices To Evaluate, Cost is a Big Factor, AREMA Guidelines Developing, UIUC Work Below

- Flat plate
  - Evenly distributed load
  - Not representative of contact interface for UTPs in service
  - Well-known standard used to determine general material stiffness characteristics
- Ballast Plate
  - AREMA #4 ballast compacted and glued with epoxy coating
- Geometric Ballast Plate (GBP)
  - Specified by the European standard (EN 16730)
  - Machined steel plate with symmetrically arranged nodes
- Deutsches Institut fur Normung (DIN plate)
  - Specified by the German DIN 45673 standard
  - Cast iron plate with ballast-like shapes









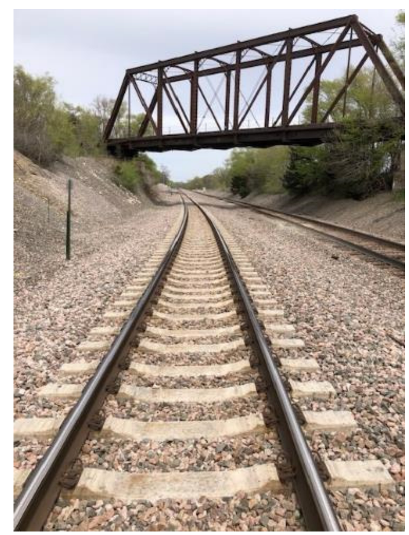
Loading Environment	Typical Axle Load (kips)	P_{max} (psi)	P_{min} (psi)	Loading Rate (psi/s)
Light rail	21.8	22.0	1.45	1.45 (±0.145)
Heavy rail	25.6	29.0		
Commuter rail	40.0	36.0		
Freight rail	68.0	60.0		

Future of Resilient Materials

Continued Studies & Expansion of Test Installs & Standardization of Use

- Addition Multiple Main Installs, Know Problem Locations & Turnouts
- Wood Tie / Concrete Tie Transitions
- Road Crossings
- Bridges & Bridge Ends

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