



Concrete Ties – The Amtrak Experience

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Presentation Outline



- Why concrete ties?
- Timeline of concrete tie manufacture
- Installation summary by year
- Concrete tie problems
- Summary of findings
- What is Amtrak Doing Now

Why Concrete Ties?



- **Manufactured product**
 - Uniformity
 - Better control of tolerances in rail seat leading to better track geometry
 - Well adapted for elastic fasteners
- **Better track stability**
 - Weighs 790 pounds compared to 240 for hardwood tie
 - Elastic fasteners control longitudinal rail forces better
 - Stiffer track promotes better track geometry
- **Track renewal installation provides benefits**
 - High quality track with fewer occupancies
 - Facilitates rail change in the process of tie replacement
- **50 Year Life Expectancy**



- First concrete tie manufactured & installed – 1978 to 1983
 - San Vel: 1978 to 1983 ~ 1.0 million
 - Started on High Speed Sections in RI and MA then moved to NEC between NY and DC
 - Basically First Design Concrete Tie Design Ran out of Aggregate
- Lone Star
 - New Design
 - Installed 300 K from 1983 to 1986
 - Including over 200 K on the NYD

Rocla Tie Plant Bear, DE



Concrete Tie Manufacturing



Rocla Tie Plant Bear, DE



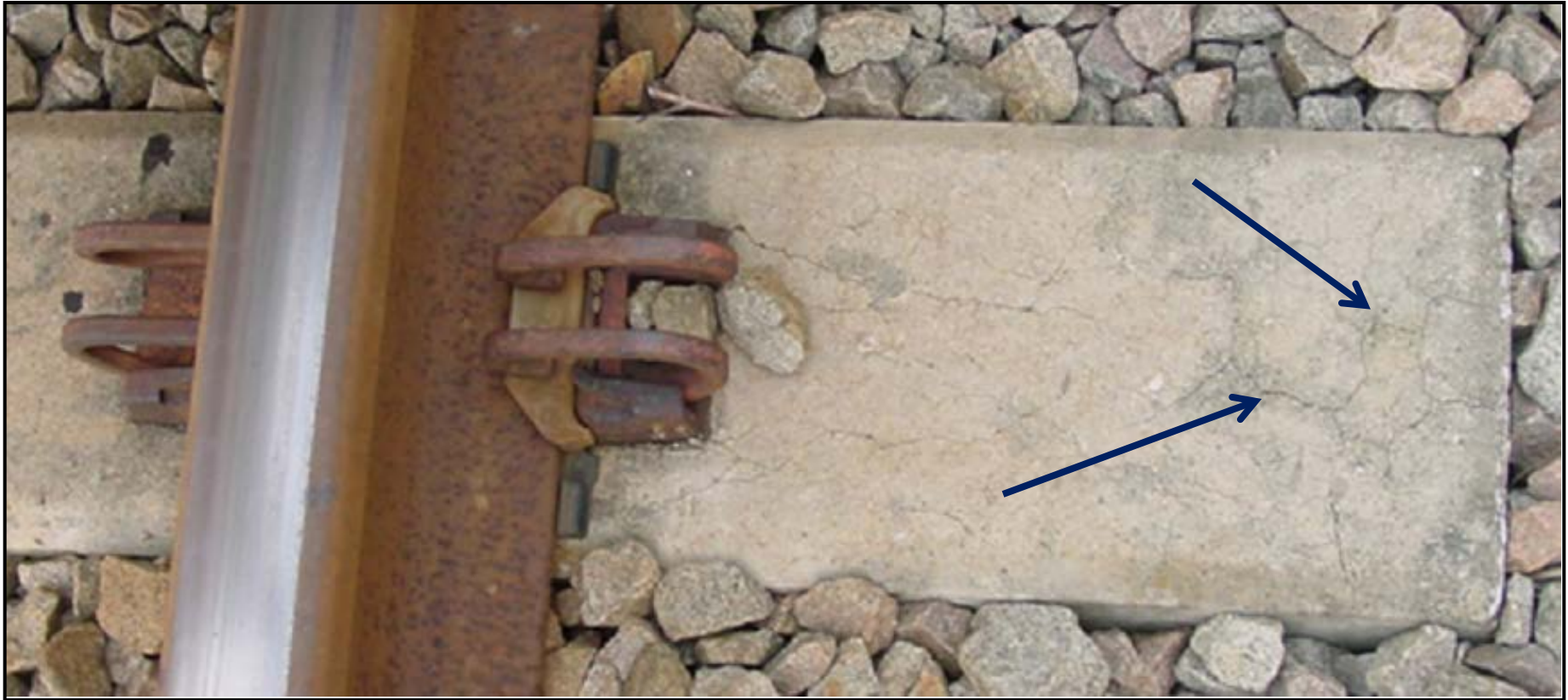
Concrete Ties Stacked



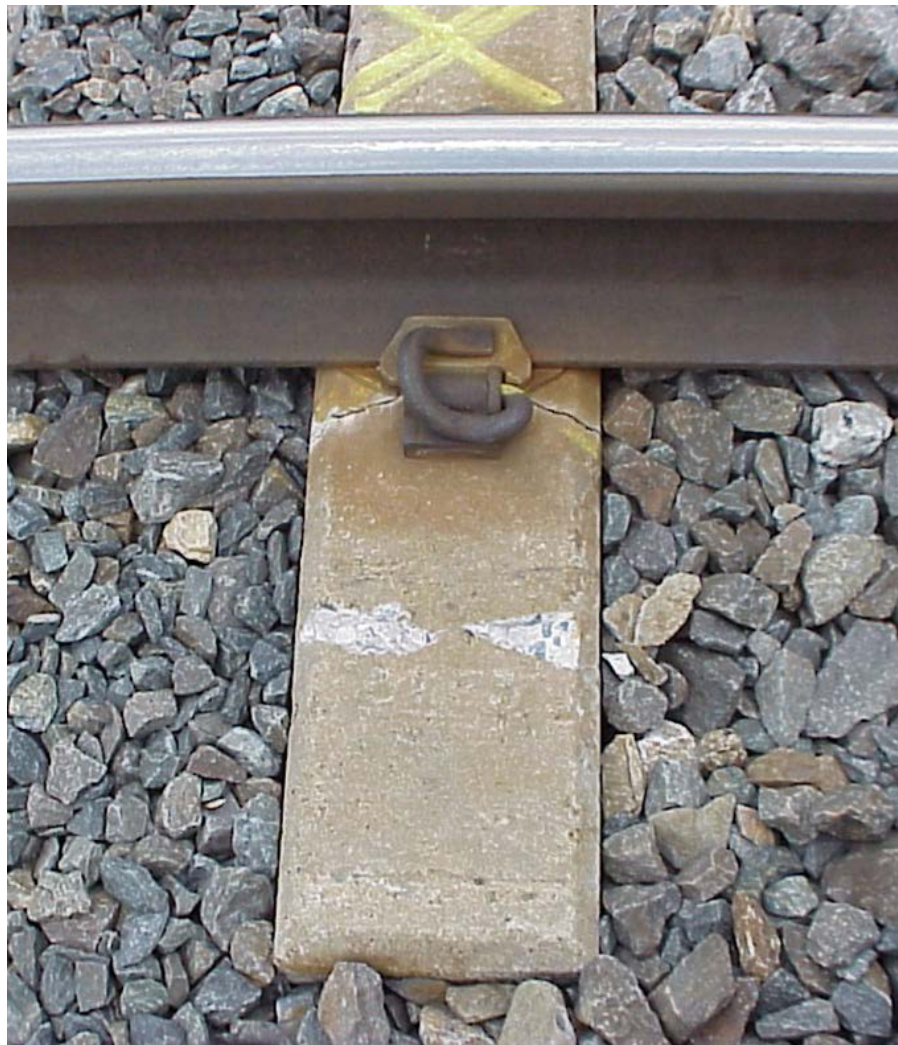
Amtrak TLS Tie Cars



Initial Appearance of ASR/DEF



Concrete Tie Failures



Concrete Tie Failures



Maintenance Problems



Breakage increases handling cost

- Regular production machinery cannot always handle
- Debris from breakage clutters right-of-way

Maintenance Problems



- Temporary solution to slow orders causes rework
- Laced wood ties also cannot be surfaced

Maintenance Problems

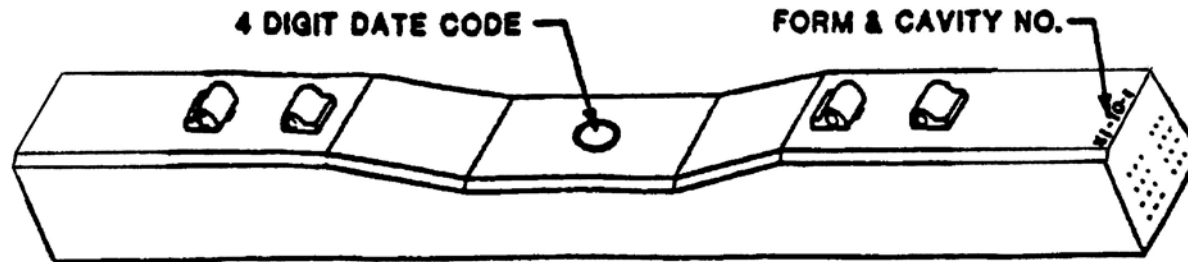


- Severity of speed drops
 - 1 failed tie – can run 150 MPH
 - 2 Consecutive failed ties – track slow ordered to 60 MPH
 - 3 Consecutive failed ties – track slow ordered to 15 MPH
 - 4 Consecutive failed ties – track out-of-service
- Ties often go directly from grade 2 to grade 5
- Cracks on side which eventually result in rail seat breakout cannot be seen without removing ballast in cribs
- Cast shoulder and tie depth make removal/insertion difficult
- Track with progressive failures cannot be easily surfaced for fear of disturbing ties that have cracks initiated

Amtrak's EP 1999 Grading

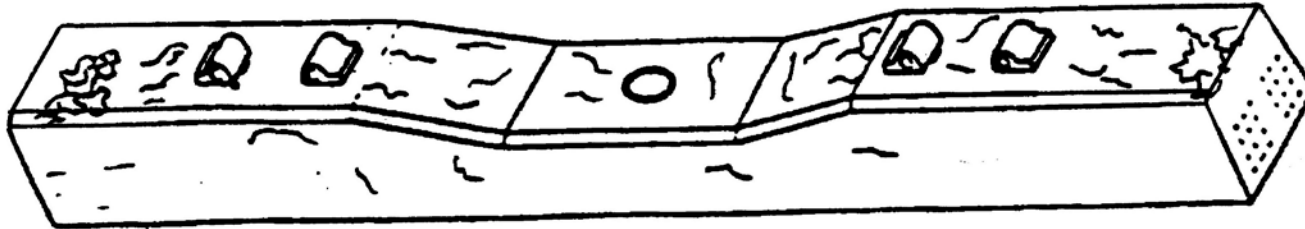


GRADE 1



Description: The tie shows no cracks, the shoulders are tight. This is an effective tie.

GRADE 2



Description: There is faint surface cracking on the surface of tie. The tie has the appearance similar to alligator skin. There is slight unconnected cracking near shoulders. The cracks are tight and concrete cannot be lifted out with a knife blade.

Amtrak's EP 1999 Grading



GRADE 3

A

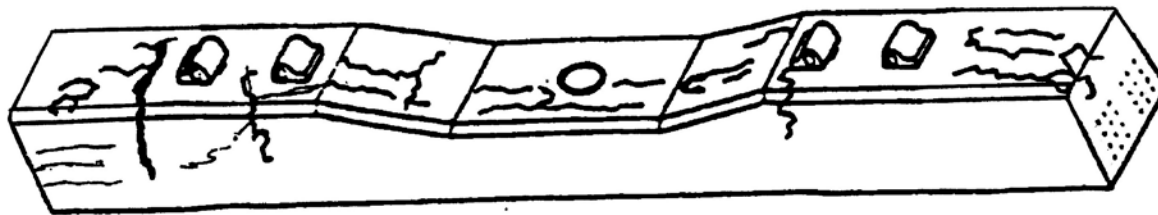
(end of tie to \perp bolster)

B

(\perp of bolster to \perp of bolster)

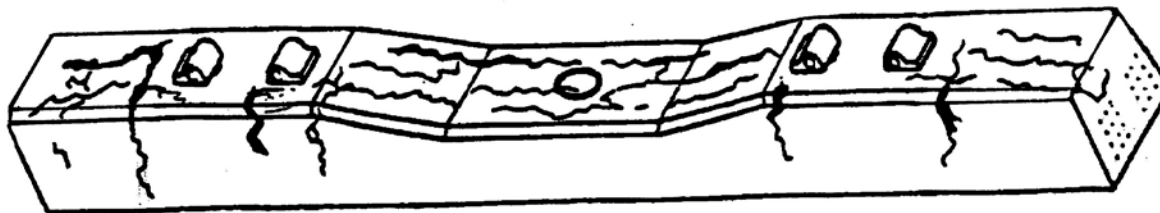
C

(\perp bolster to end of tie)



Description: There are multiple cracks, either longitudinal or connected, in sections A, B or C. There is no connection of cracks observed in the rail bearing area. Cracks are tight and do not go through tie.

GRADE 4

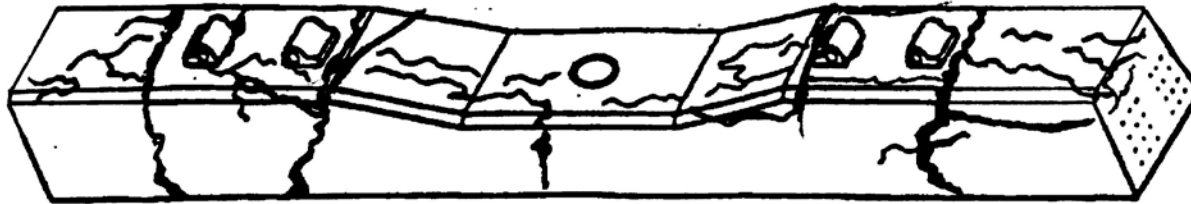


Description: There is a combination of longitudinal and transverse connected cracks in both directions. Multiple cracking exists on ends and through center of tie. Transverse cracks in the shoulder area have joined together, which is a possible indication that the tie will fail in a short period of time. Clips and shoulders are tight with no change in gage. This tie could deteriorate rapidly to total failure.

Amtrak's EP 1999 Grading



GRADE 5



Description: The concrete tie shows through transverse and/or longitudinal cracks. There is a loss of clip load. Cracks are wide. Large cracks in the shoulder area have joined together. The tie may also show crumbling or breaking apart in the shoulder/rail seat area. Expansion of gage may be evident. This tie is structurally ineffective, is considered defective and must be replaced.

... also

Engineering Practice Re-issued 12/9/11

Concrete Tie Problems – Lone Star



- Approx. 300,000 ties manufactured between 1982 and 1986
- Cracking first detected in 1988
- Spider cracking with slow progression to failure within a few years
- Attributed to an alkali-silicone reaction (ASR)
- A few panel installation locations remain
- Others similarly afflicted
 - CSX
 - LIRR
 - Transit Systems



- Rocla (1990-1992)
 - 326,000 ties manufactured between 1990 and 1992
 - Cracking first detected in 1999
 - Hairline cracking with a slow propagation rate in most ties
 - Attributed to ASR and DEF, result of contamination in the fine aggregate and high curing temperatures
 - Ties continue to fail, often in clusters requiring slow order placement by track inspectors

Concrete Tie Problems – Rocla I



- Rocla (1993-1994)
 - Approx. 323,000 ties manufactured in 1993 and 1994
 - Cracking first detected in 2006
 - Hairline cracking with a slow propagation rate in most ties

Concrete Tie Problems – Rocla I



- Rocla (1997):
 - Approx. 118,000 ties manufactured in 1997
 - Cracking first detected in 2001
 - Spider cracking with rapid deterioration to failure
 - Slow orders result from clusters detected by track inspectors
 - Attributed to high curing temperatures in summer months
 - Other purchasers impacted
 - Metro North
 - LIRR

Concrete Tie Problems – Rocla I



- Rocla (1998 and 1999)
 - 314,000 ties manufactured in 1998 and 1999
 - Cracking first detected in 2007
 - Hairline cracking
 - Slow propagation rate in some ties
 - Others appear to behave like 1997 ties and fail suddenly
 - Approx. 1000 ties sold to NJT

Concrete Failures



- Concrete failure because of ASR, DEF, poor curing
 - Failure is driven by moisture and freezing
 - Original ASR characterized by map cracking and eventual fastener pull-out
 - ASR has causes cracking along the top row of pre-stress wires
 - Curing problems accelerated failure via DEF on top of ASR
- Another Design Was Developed - ROCLA

Concrete Tie Problems – ASR



ASR results when cement alkalis react with certain soluble forms of silica in the aggregate component of a concrete, forming an alkali-silica gel at the aggregate's surface. This formation, often referred to as "reaction rim" has a very strong affinity for water, and thus has a tendency to swell. These expanding compounds can cause internal pressures sufficiently strong to cause cracking of the paste matrix which can then result in a compromised concrete having an open door to additional moisture and an increasing rate of deterioration

Concrete Tie Problems – DEF



Delayed Ettringite Formation (DEF) is a type of internal sulfate attack that occurs in concrete that has reached certain high temperature thresholds in the first few hours of placement. At these temperatures, normal formation of ettringite (calcium sulfoaluminate hydrate) is impeded until after concrete has hardened. When ettringite does form, it can cause deleterious expansion, resulting in cracking.



- Rocla manufactured 1.3 million ties between 1990 and 2000
- There are significant failures reported in 7 out of 11 years

Amtrak's Concrete Ties



- First concrete tie manufactured & installed – 1978

- Manufacturers:

– Santa Fe / San Vel:	1978 to 1983	~ 1.0 million
– Lonestar:	1983 to 1986	~ 300 K
– Rocla:	1990 to 2000	~ 1.3 million
– Rocla (New Spec):	2003 to 2007	~ 700 K
	2012	~ 60 K
	2013	~ 100 K
	2014	~ 70 K

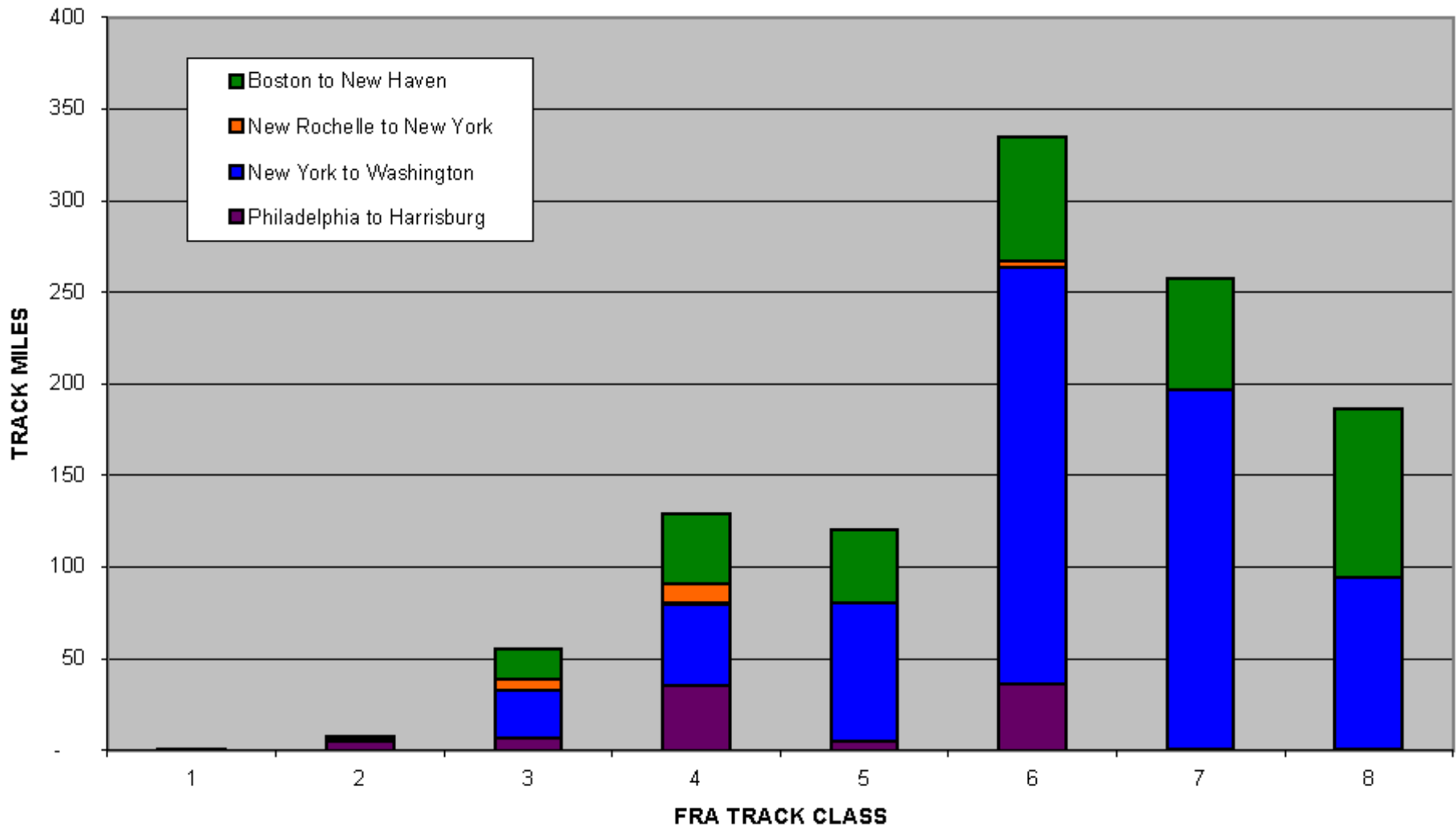
Changed to Date

930 K with 370 K Still to Go

- Total concrete ties purchased to date ~ 3.6 million
- Total concrete ties in track
 - 1056 miles NEC, 2.8 M and 114 miles Harrisburg Line, 300 K

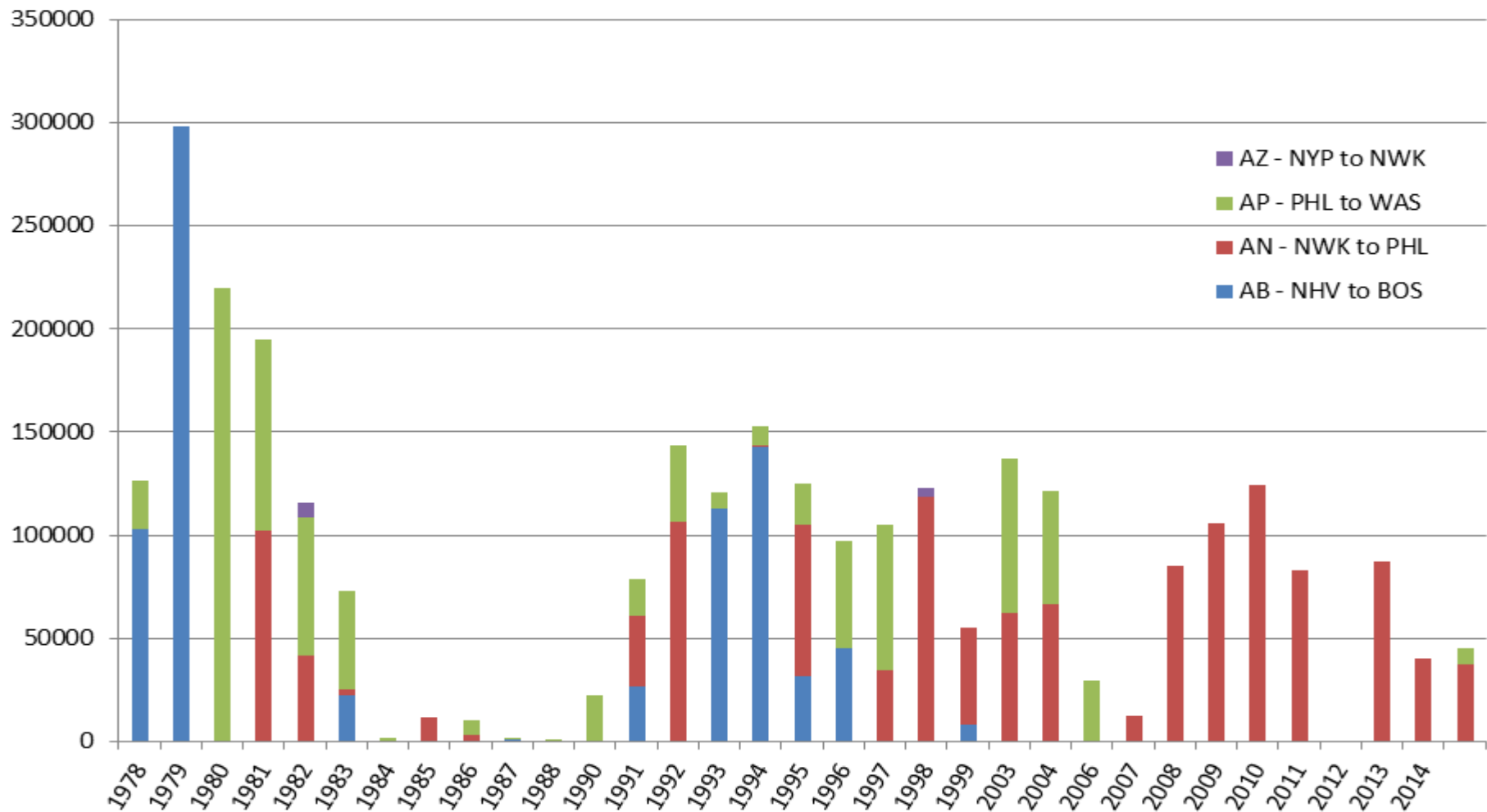


AMTRAK - CONCRETE TIES





Amtrak's Concrete Ties



Challenges



- Problem with speed restrictions
- Identified all years involved (years at risk)
- Decide on method of maintenance
 - Spot replacements
 - Out-of-face replacements
- Determine replacement priority
- Follow-up on selected basis to attempt to chart degradation rates

Challenges



- Tie evaluation done walking with track inspectors
 - Limited inspectors from HNTB to maintain consistency
- Ties are graded
 - Replaced ties noted
 - Interlaced wood ties noted
 - Remaining ties graded 2 thru 5

What We Are Doing



- Immediately
 - Engineering has spot replacement gangs going
 - There is no choice but to plan out-of-face replacement of worst stretches
 - A second TLM installed ties in FY 09 and FY 10
 - Some additional equipment was purchased
- We continue to monitor rate of degradation
 - Track degradation
 - Get better estimate of what stretches must be totally replaced and which can be handled with spot replacements
- Prioritize work



- Amtrak has to committed to a multi-year replacement program
 - Amtrak’s TLM and much of the supporting machinery (i.e. tie cars) are now 36 years old and was to be retired
 - Funding and track occupancies will compete with other needed track projects
 - Slow orders for defective concrete ties on our high speed routes substantially eliminated however we are still subject to speed restrictions on some of our outside tracks

Summary



- We have projected that it will take until 2018 to remove all the suspect ties
- We will still have approximately 50 K ties in track in “isolated” locations (open deck and switch installation locations and in short stretches within Interlockings)

2003 Changes to Tie Specification



- Engineering will reviewed Amtrak's Specifications
- Benchmarked to other RRs
- Benchmarked to best practice for reinforced concrete
- Used of experts to evaluate Rocla's concrete science

2003 Changes to Tie Specification



- Design change from 8 stranded reinforcing wires to 24 individual indented reinforcing wires to increase tensile strength of concrete
- Established tighter limitations on pre-set curing temperatures and a new temperature control system installed at Rocla for closely monitoring curing temperatures
- Use of a manufactured sand (fine aggregate portion) to eliminate potential reactive contaminants that could contribute to ASR/ DEF reactivity and potential cracking problems.

2003 Changes to Tie Specification



- Use of up to 15% fly-ash in the cementitious portion of the mix design for even greater resistance to the formation of ASR and DEF
- Additional 3rd party testing of materials and hardened concrete that can assure proper resistance to cracking problems later in concrete life

Concrete Tie Improvement Study



Disclaimer – WE ARE NOT HAVING ANY PROBLEMS WITH The PRESENT “POST 2003” CONCRETE TIE DESIGN

... but we do not want to repeat problems nor experience any new problems, so...

- Pre 2003 Concrete Tie Design and Failures Modes
- Post 2003 Concrete Tie Design Potential Weaknesses
- Recommendations for Improvements
- Make Samples Ties and Test for Degree of Improved Performance and Provided Documentation



Amtrak's Concrete Tie Experience



- Thank You