Assessment of Concrete Tie Life on US Freight Railroads

Report Submitted

To

Railway Tie Association

June 28, 2010

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This report presents the results of the project "Assessment of Concrete Tie Life on US Freight Railroads". As part of this activity, data was collected from all of the major US and Canadian Railways with concrete tie experience as well as from smaller US rail systems with concrete tie experience.

Specifically ZETA-TECH and the RTA collected available railroad and industry data on concrete cross-tie performance under railway operations in US and Canada. The resulting data was analyzed to provide an assessment of actual concrete tie life, as experienced in the North American railway environment.

In order to accomplish this goal, concrete tie performance (and life) was divided into three categories:

1. Premature manufacturing or chemical interaction related failures such as Alkali-Silica Reactivity (ASR), Alkali-Aggregate Reactivity (AAR), Delayed Ettringite Formation (DEF), inadequate Air-Entrainment, etc.

2. Mechanical (vehicle-track dynamic) or service related failures such as cracking under dynamic impact loads (rail seat cracking), cracking due to tie resonance, rail seat abrasion, etc.

3. General railroad service which includes:
   - Heavy axle load freight railroad
   - Passenger railroads and transit

The objective of this activity was to obtain estimates of concrete tie life based on the failure rates in each of these categories. An overall concrete tie life was obtained by mathematically weighting the failure rates in each of these three categories.

Appendix A presents the questionnaire that was used in this activity. This was sent to each of the major Class 1 Freight railway users of concrete ties.

In addition, concrete tie failure data was available to ZETA-TECH from other sources, to include earlier ZETA-TECH studies on transit and other rail systems that experienced concrete tie failures, and was included in this study. This includes concrete tie life and failure data from:

- Black Mesa and Lake Powell RR
- Metro North Rail Road
- New Jersey Transit
- MBTA, Boston MA
- MTA Light Rail, Baltimore, MD
- Tren Urbano, San Juan, Puerto Rico

Appendix B presents a tabular presentation of the individual railroad concrete tie experience which will be summarized below by railroad.

Major Class 1 Freight Railroads

Concrete tie installation and failure data was obtained from five of the major North American Railways.

CN

Canadian National was the earliest user of concrete ties among the major US and Canadian railroads with initial installation occurring in 1972. Approximately 700,000 concrete ties were installed by CN in the 1970s and another 2,800,000 ties in the 1980s. Subsequent to that initial installation, the rate of installation was primarily at a replacement rate of approximately 25,000 to 45,000 ties a year.

The initial installations, specifically those ties installed in the 1970s included a significant number of ties that had premature failure due to chemical or manufacturing related deficiencies to include Alkali Reactivity. Of the initial 700,000 ties installed, approximately 53% experienced failure and were replaced. Figure 1 presents a summary of the concrete tie failure rate by installation period.

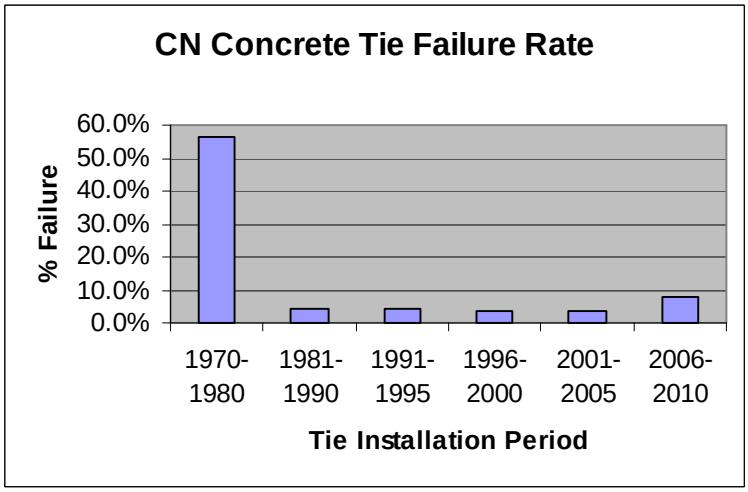

Figure 1. CN Concrete Tie Failure Rate

Analysis of the CN tie installation and failure data showed an average age of the concrete ties in track of 22.4 years. Of the 3,900,000 concrete ties installed by CN since the 1970s,

approximately 1,100,000 have failed[1] and been replaced, corresponding to a failure rate of 27.1%.

Using a linearized rate of failure, the corresponding median forecast life of concrete ties based on the CN experience is 41.3 years[2].

BN/BNSF

The Burlington Northern and subsequently the Burlington Northern Santa Fe (BNSF) also started installing concrete ties in the 1970s. Since then the BNSF has installed more than 10 Million concrete ties. The performance of the concrete ties has been good, with only minimal failures. Furthermore, related issues such as rail seat abrasion are known to be repaired in situ without having to remove or replace the ties. Based on data gleaned from R-1 reports, more than half of the total concrete ties have been installed within the last 15 years. Thus, the average age of the concrete ties in track is probably less than 15 years. While BNSF did participate and provide data for this study it has not been specifically cited due to internal proprietary guidelines. Thus, the information provided in this section is based on information in the public domain.

NS

Of the major US railroads, NS has had the smallest number of concrete ties installed, a total of approximately 38,000, included small test batches installed in the 1970s and 1980s, and larger test batches in the 1990s. However, because of their very active research department, they have been following the behavior and degradation of the concrete ties very closely and as such have very good statistics on the rate of failure of each of these installation batches. Figure 2, presents a summary of the ties installed and removed for premature failure, by installation period.

[1] In addition to the early chemical/mechanical failures, these included rail seat abrasion, rail seat cracking and a modest number of ties replaced because of damage from derailments or dragging equipment.
[2] Based on a median life of the concrete ties corresponding to 50% of the ties having failed.

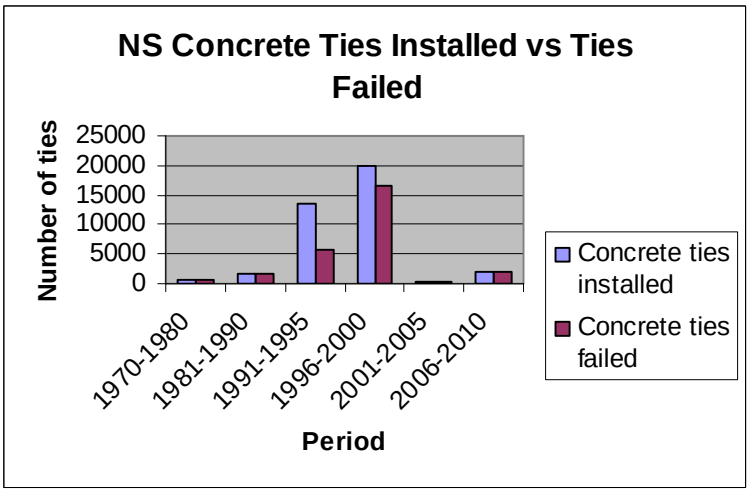

Figure 2: NS Concrete Tie Installation and Failure Rate

Figure 3 translates these figures into a failure rate by installation period.

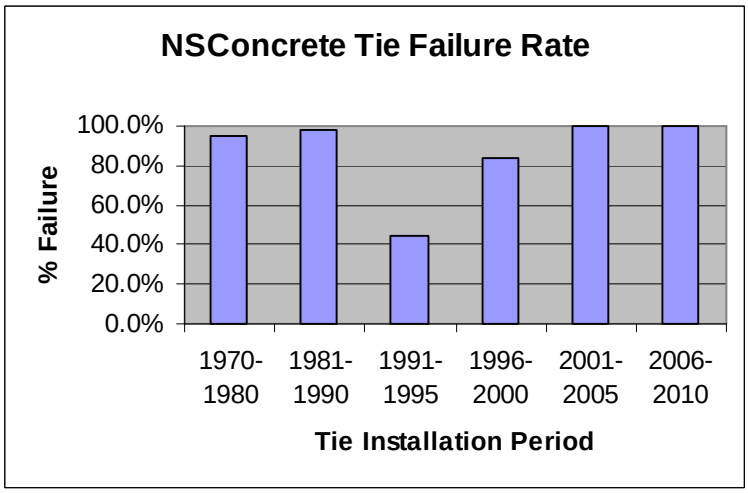

Figure 3: NS Concrete Tie Failure Rate

Note, these numbers include concrete ties replaced on account of failure in concrete quality.

NS internal analyses suggests that initial investment on concrete is not justified for the anticipated extended tie life over that of wood; in fact the ongoing maintenance expenditures, such as rail grinding, roadbed contamination, rail seat abrasion, fastener maintenance and continual surfacing make concrete less attractive in the long term. Heavier operating tonnages and higher speeds do play an important part in making this determination.

Overall, of the 38,036 concrete ties installed by NS, 27,310 ties or 71.8% of the ties were removed either for rail seat abrasion or rail seat cracking. Based on an average life in track of 14 years, the weighted forecast life of the concrete ties on NS was calculated to be 19.5 years.

CSX

CSX has been an active user of concrete ties since the 1980s with over 2 Million concrete ties installed. Figure 4 presents a summary of the instillation rate, by period, and the corresponding failure and replacement amounts. Figure 5 shows the corresponding failure rate. As can be seen from this figure, the ties installed in the 1980s had an approximately 10.6 % failure rate, primarily due to a large number of ties, approximately 29,000, that experience Alkali-Aggregate Reactivity (AAR) failure. Subsequent failure rate was lower and consisted primarily of rail seat abrasion and rail seat cracking problems, and the associated removal of the ties.

The overall concrete tie failure rate on CSX was 5.7%

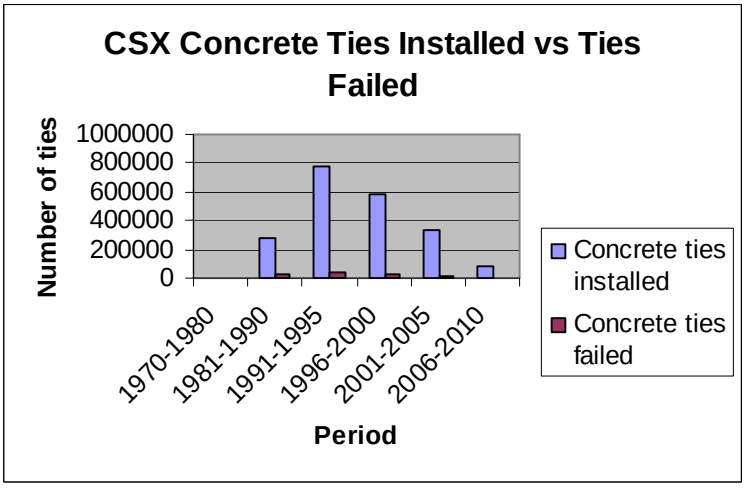

Figure 4: CSX Concrete Tie Installation and Failure Rate

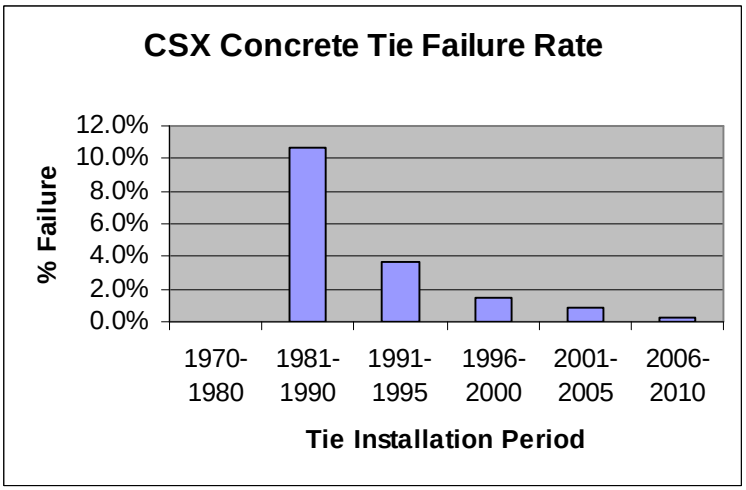

Figure 5: CSX Concrete Tie Failure Rate

UP

The Union Pacific is a major user of concrete ties with almost 8 Million concrete ties installed since the 1982. No failure data is available, since failed ties are usually removed by local forces and are not centrally reported. While there have been some failures due to manufacturing quality control issues in the last 10 years, these issues have been resolved.

Like the BNSF, the majority of the problems experienced[3], primarily rail seat abrasion related, are repaired in situ without having to remove or replace the ties. This is done normally as part of a regularly scheduled rail renewal operation[4] or by using a special rail seat abrasion repair gang.

Noting that more than 60% of the total concrete ties have been installed on the UP within the last 10 years, the calculated average age of the concrete ties in track is low at 7.6 years.

Other Passenger and Freight Railroads

Additional data was obtained from a group of passenger and freight railroads and transits. While this list is not complete, they do represent data that was available, particularly as related to concrete tie performance and failure.

Amtrak

[3] Previous tie pad designs were also found not to be up to the heavy axle load operations but new generation designs have addressed this problem.
[4] Tie pads and insulators are usually replaced at the same time.

Amtrak is a major user of concrete ties with approximately 3.4 Million ties in service (and with the highest percentage of track with concrete ties- approximately 65+ %).

While installation data is not available (it has been installing concrete ties since the late 1970s), Amtrak has experienced two major sets of concrete tie failure. The first was for approximately 355,000 ties installed in the 1980s that failed due to Alkali-Aggregate Reactivity (AAR). The second is a current set of manufacturing related failure[5] that affects approximately 800,000 ties, the vast majority of which have not yet been replaced. However the expectation is that a significant percentage (if not all) of these ties will be replaced. This would then correspond to a 22 to 34% [6]concrete tie failure rate.

Black Mesa and Lake Powell RR

Black Mesa and Lake Powell is a utility railroad carrying coal to a set of power plants in the Southwest US. Approximately 175,000 concrete ties were installed in the 1973, 100% of which were replaced in 2002, for Alkali-Silica Reactivity (ASR). This corresponded to a concrete tie life of 29 years.

Metro North Rail Road

Metro North is a commuter railroad in the New York City Metropolitan area. Approximately 50,000 concrete ties were installed in the mid-1990s, 100% of which were removed within a few years due to Delayed Ettringite Formation (DEF). An additional 260,000 concrete ties were installed in the last decade, all of which are scheduled to be replaced under the terms of a settlement with the manufacturer.

New Jersey Transit

New Jersey Transit is a commuter railroad in the New York City Metropolitan area. Approximately 27,000 concrete ties were installed in the mid-1990s, 100% of which were removed within a few years due to Delayed Ettringite Formation (DEF).

MBTA, Boston MA

MBTA is a commuter railroad in the Boston Metropolitan area. Approximately 150,000 concrete ties were installed in the mid-1990s (1997) , 100% of which are scheduled for removal in 2010 due to Delayed Ettringite Formation (DEF). This corresponded to a concrete tie life of 13 years.

MTA Light Rail, Baltimore, MD

MTA Light Rail is the light rail transit system of Baltimore. Approximately 202,000 concrete ties were installed in the early 2000s of which 0.1% have failed and been replaced to date.

[5] Believed to be Alkali-Silica Reactivity (ASR).

[6] Corresponding to 50% to 100% replacement of the current set of ties failing due to manufacturing related issues.

Tren Urbano, San Juan, Puerto Rico

Tren Urbano is the transit system of San Juan, Puerto Rico. Approximately 22,000 concrete ties were installed in the mid-1990s, of which 2000 (9.1%) have been replaced to date due to Alkali-Silica Reactivity (ASR). The ties continue to fail and the expectation is that the majority if not all of the remaining ties will need to be replaced over the next several years.

Summary

This study examined approximately 29 Million ties installed in US freight and passenger rail systems since the 1970s. The objective was to examine the failure history and to determine an expected 'life' value for concrete ties in US railway service.

Of these 29 Million ties, approximately 2.2 to 2.7 Million ties[7] were reported as failed and replaced (or scheduled to be replaced). This corresponds to a failure rate of 7.9 to 9.2 %. Since the average age of these ties is of the order of 13 years, it is difficult to project the life based on these numbers alone.

Therefore, the analysis examined the population of concrete ties in track for 20 or more years, i.e. installed in the 1970s and 1980s. This corresponds to a population of 7.4 Million ties, of which approximately 1.6 Million have been reported as failed and replaced, a failure rate of 22.2 %. Depending on the assumed life of the ties in track[8], this failure rate projects to a service life of concrete ties of between 40 and 50 years[9].

Noting, that the railroad with the longest average time in track, for concrete ties, CN, with a 22.4 year weighted average age, had a projected service life of 41.3 years, ***it appears that a reasonable estimate for concrete tie service life under North American railroad operating conditions is between 40 and 45 years.***

It should be further noted that concrete tie track will require repair for rail seat abrasion related degradation, when those ties are not removed from track (per BNSF and UP practice). This can be done either as part of a rail relay using a rail gang, often with tie pads and insulators also being replaced, or as a special purpose gang.

[7] The range is due to the large population of Amtrak ties that are failing but which have not yet 'failed' and are not yet scheduled for replacement.
[8] The installation dates for all of the ties were not available so a range of life was estimated.
[9] Based on a median life of the concrete ties corresponding to 50% of the ties having failed.

APPENDIX A

SURVEY OF NORTH AMERICAN CONCRETE TIE PERFORMANCE

Railroad _____
Total number of Track Miles _____
Total number of track miles with concrete ties _____

Installation History of Concrete Ties

1970- 1980	Number of concrete ties installed _____
1980- 1990	Number of concrete ties installed _____
1990- 1995	Number of concrete ties installed _____
1995- 2000	Number of concrete ties installed _____
2000- 2005	Number of concrete ties installed _____
2005-2010	Number of concrete ties installed _____

Performance/Failure History:
Premature manufacturing or chemical interaction related failures, which includes AAR, ASR, DEF, etc,

1970- 1980	No. of failed ties _____	Failure mode _____	Yr installed _____
1980- 1990	No. of failed ties _____	Failure mode _____	Yr installed _____
1990- 1995	No. of failed ties _____	Failure mode _____	Yr installed _____
1995- 2000	No. of failed ties _____	Failure mode _____	Yr installed _____
2000- 2005	No. of failed ties _____	Failure mode _____	Yr installed _____
2005-2010	No. of failed ties _____	Failure mode _____	Yr installed _____

Mechanical related failures such as rail seat abrasion, rail seat cracking, bottom abrasion, insert failure, and damage by derailment or other impact (tamper, regulator strikes etc.)

1970- 1980	No. of failed ties _____	Failure mode _____	Yr installed _____
1980- 1990	No. of failed ties _____	Failure mode _____	Yr installed _____
1990- 1995	No. of failed ties _____	Failure mode _____	Yr installed _____
1995- 2000	No. of failed ties _____	Failure mode _____	Yr installed _____
2000- 2005	No. of failed ties _____	Failure mode _____	Yr installed _____
2005-2010	No. of failed ties _____	Failure mode _____	Yr installed _____

General Performance History of Concrete Ties
Percentage of concrete ties installed in 1970- 1980 removed from service _____
Percentage of concrete ties installed in 1980- 1990 removed from service _____
Percentage of concrete ties installed in 1990- 1995 removed from service _____
Percentage of concrete ties installed in 1995- 2000 removed from service _____
Percentage of concrete ties installed in 2000- 2005 removed from service _____
Percentage of concrete ties installed in 2005-2010 removed from service _____

Average life of concrete ties currently in service _____