Crack Propagation of Railway Ties Prestressed with Single Strand Tendons: Project Proposal

Department of Civil and Geomatics Engineering
Rosa Serrano, Graduate Student
Advisor: Fariborz M Tehrani, Ph.D., PE, PMP

FRESNO STATE
Lyles College of Engineering

Background

Traditionally, railway ties were made of wood; however, concrete ties have replaced wooden ties because of their higher strength and resistance to adverse weather conditions. The substructure and superstructure are the two main components of train tracks. The substructure includes the ballast, subgrade, and ground formation while the superstructure includes rails, rail pads, fastening system, and railway ties, also known as sleepers.

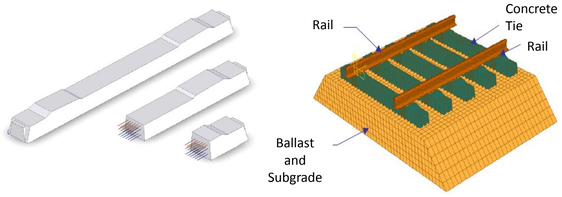

Figure 1. Concrete tie cross section (left) and railway cross section (right), (Kaewunruen, S. & Remennikov, A., 2000)

Literature Review

In concrete ties, cracks are caused by the infrequent but high magnitude loads produced by wheel abnormalities. Wheel abnormalities such as out-of-round wheels cause extreme loading conditions under which cracks develop. The rail seat design load is 22.5 kip (100 kN); however, studies indicate that extreme loading conditions create loads between 45-135 kip (200-600 kN). The extreme impact forces can be modeled as a shock pulse.

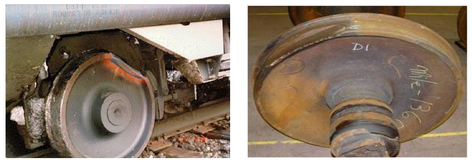

Figure 2. Wheel flat irregularities causing extreme loading conditions, (Transportation Safety Bureau of Canada, 2007)

Reinforcing concrete ties with single strand tendons provides advantages over 7-strand tendons:

- Flexibility in the quantity of steel used; reductions or increases can be done in smaller increments.
- Less steel required because single strand tendons do not require twisting.
- Increased bonding efficiency between tendon and concrete.

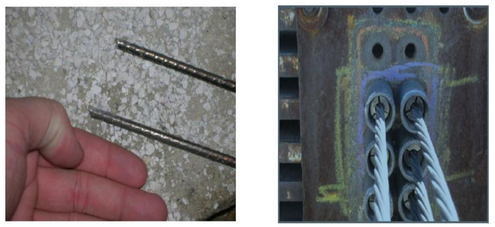

Figure 3. Single strand tendon 260ksi (left) and 7-strand tendon 270 ksi (right), (Lutch, R.H., 2009)

Research Needs

To further the knowledge in the field, this research project proposes the following to be done:

- Study the performance of concrete ties prestressed with single strand tendons by simulating extreme loads from a mass dropped from a predefined height.
- Compare performance with that of ties prestressed with 7-strand tendons.
- Conduct a life cycle analysis to determine the economical advantages of using ties prestressed with single strand tendons.

Materials

A total of 14 ties will be necessary to complete the research. Twelve ties are planned to be used for the experiment and two ties will be ordered as reserves for any repeated testing.

Table 1. Concrete tie testing information

Tie Number	Prestressing Tendon	Track Type	Force, kip (kN)
1	Single Strand Tendon	Soft Track	182 (810)
2			166 (740)
3			112 (500)
4		Hard Track	182 (810)
5			166 (740)
6			112 (500)
7	7 - Strand Tendon	Soft Track	182 (810)
8			166 (740)
9			112 (500)
10		Hard Track	182 (810)
11			166 (740)
12			112 (500)

Experimental Set Up

The drop weight will be a steel cylinder of a set weight of 1 kip (5 kN). By having a constant drop mass value, the only variable remaining is the height of the drop weight.

Assumptions:

- Rail transfers all dynamic load onto concrete tie
- 1 drop will simulate 1 year of service
- Different heights will represent different loads
- Heights will be determined using the following equation; $H = h_t / 0.98^2$ (Kaewunruen, S. & Remennikov, A., 2000)

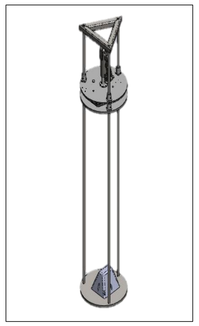

Figure 4. Impact attenuator testing rig, (Bennet, Muthwill & Van, 2012)

Data Analysis

The concrete tie will be observed after every drop. Crack length and width will be marked in order to draw conclusions. From the collected data the following graphs will be developed:

- Crack length versus number of blows on a soft track
- Crack length versus number of blows on a hard track

Plotting the data of the single-strand tendon and the 7-strand tendon concrete tie on the same graph will allow comparisons to be done between the two concrete ties.

Expected Results

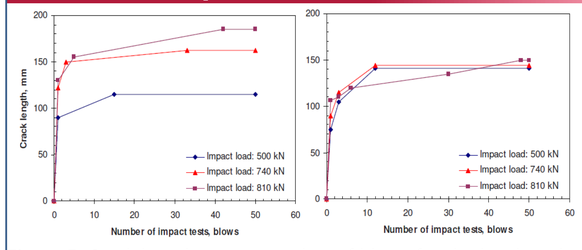

Figure 5. Crack length versus number of blows for the hard track (left) and soft track (right), (Kaewunruen, S. & Remennikov, A., 2000)

Similar crack patterns to those of tests conducted on 7-strand tendons concrete ties are expected to develop on ties prestressed with single-strand tendons because the tendons have similar strengths.

Schedule and Budget

A schedule of the project was developed with a Microsoft Project Gant Chart. For organizational purposes, the research project is divided into five phases: Introductory, Literature Study, Experimental, Analytical, and Conclusion Phase. In addition, each phase contains a plan-do-check section. The 'check' section ensures that extra time is allotted for unexpected issues.

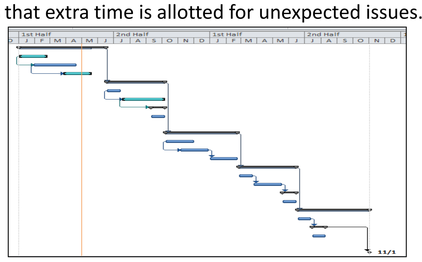

Figure 5. Estimated Project Schedule: 1.5 years

The manual labor will be conducted by a graduate student and student volunteers. The testing rig will be provided by the Civil and Geomatics Engineering Department. The goal will be to have materials donated by manufacturers. Materials include:

- Concrete ties or materials for mix design
- Steel Tendons
- Rail and rail Fastening System

Risk Analysis

A risk analysis of the proposed project serves as a plan for possible responses in the event of negative or positive risks.

Table 2. Risk analysis with identified risk and potential response

Identified Risk	Root Cause	Potential Response
Concrete ties could not be purchased	Price of concrete ties exceeds budget	Develop concrete mix and prestressing method in lab
Injury in lab	Lack of diligence	First aid kit, review safety procedures
Testing System Failure	Incorrect experimental set up	Repeat experiment with extra concrete tie
Difficulty obtaining a section rail	Rail not sold in small sections	Purchase long section of rail and cut into needed dimensions
Manufacturing plant tour	Manufacturing plant offer	Accept to gain better understanding of manufacturing procedure
Internship in railway design	Interested engineering firm	Accept to apply knowledge and improve skills

Beneficiaries

Beneficiaries and Stakeholders include:

- Railroad manufacturers
- Governments having right of way on railroads
- Civilians using railroads as a transportation source
- Government budgets

Deliverables

Throughout the duration of the research, the following deliverables will mark the progress of the work:

- Informal report every two weeks
- Monthly Progress Report
- Poster Presentation
- Final Slide Presentation
- Final Report

Conclusions

The Proposed research expects to conclude the the following:

- Performance of concrete ties prestressed with single-strand tendons compared to concrete ties prestressed with 7-strand tendons.
- Financial aspects of manufacturing concrete ties with signle-strand tendons.
- Suggest further research possibilities