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Laboratory investigation of the Skl-style fastening system's lateral load performance under heavy haul freight railroad loads

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ABSTRACT

Throughout the international railway community, there are many different designs of elastic fastening systems that have been developed to meet a variety of design specifications and performance expectations. Historically, in North America, the most common types of fastening systems used for concrete crossties are the Safelok I or e-clip systems. In recent years railroads have begun implementing the Skl-style (W) fastening system with concrete crossties in existing and new heavy haul freight railroad mainlines. The magnitude of lateral force applied to the Skl-style fastening system is important information for both design and application purposes. Despite this importance, the lateral force applied to the Skl-style fastening system in a heavy haul freight railroad environment has never been quantified to date. To better understand how the Skl-style system performs under the magnitude of lateral loads observed on heavy haul freight railroads, research was conducted by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC). The focus of this paper is on laboratory characterization of the lateral load path through the Skl-style fastening system using novel instrumentation techniques that are subjected to heavy haul freight railroad loading conditions. The investigation of fastening system performance included an evaluation of lateral load distribution through the track superstructure, and a single fastening system. Laboratory experimentation concluded that lateral wheel load is primarily distributed to three crossties, the relationship between lateral wheel load and lateral force resisted by field side angled guide plate is non-linear, and that the design of the Skl-style fastening system allows lateral force to be transferred into the crosstie below the worst case concrete compressive fatigue strength. The observations from this study will assist the rail industry in improving fastening system design and developing mechanistic track structure design method.

1. Introduction

1.1. Purpose of investigating Skl-style fastening systems

The concrete crosstie fastening system is a set of components that form the structural connection between the rail and concrete crosstie in the track superstructure [1]. These components help to resist movement of the rail, maintain track geometry, and distribute the loads imparted on the rail into the concrete crosstie and track substructure [2]. The loads on the rail that must be resisted by a fastening system are primarily caused by passing trains and temperature changes in the rail [3].

Increasing axle loads on North American heavy haul freight railroads, coupled with the demanding environments in which many of the track infrastructure components are required to perform, have presented engineering challenges for the design and performance of concrete crosstie fastening systems. Historically, in North America, the most common types of heavy haul fastening systems used for concrete crossties are the Safelok I or e-clip systems (Fig. 1a & b). However, in recent years railroads have been implementing Skl-style (W) fastening systems (Fig. 1c) with concrete crossties in both existing and new heavy-haul freight infrastructure. Although the systems are performing well in demanding North American track locations, little research has been conducted on Skl-style systems with respect to the lateral load demands placed on the components under heavy haul freight wheel loads.

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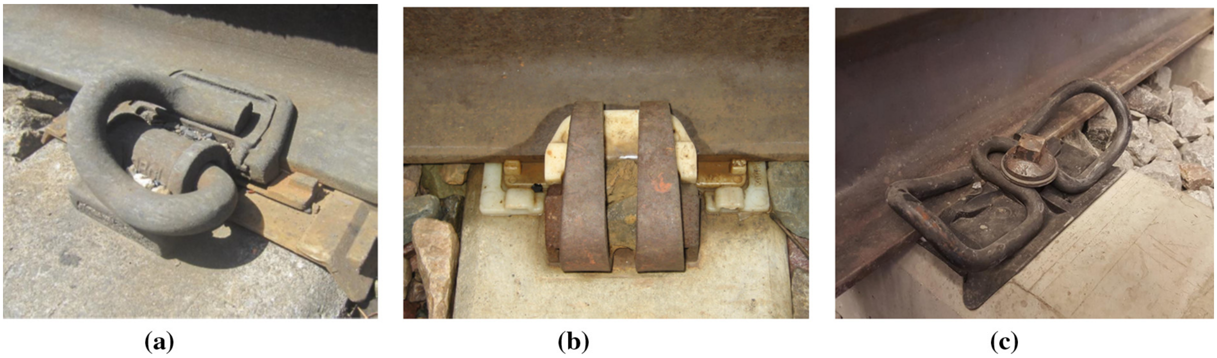

Fig. 1. Examples of common types of fastening systems on North American heavy haul freight railroad track a) e-clip b) Safelok I c) Skl-style.

Additionally, the variation of lateral load distribution through the track superstructure when equipped with the Skl-style system is a topic of interest to both designers and end users, especially in terms of comparing the performance to that of other systems. To address these voids in the current understanding of Skl-style fastening systems, laboratory experimentation was conducted by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC) to further understand the performance of the Skl-style fastening systems under lateral load.

1.2. Background

A survey conducted in 2012 by RailTEC determined that wear of fastening system components and rail seat deterioration (RSD) are two of the most critical problems observed in concrete crosstie track in North America [4]. Industry experts have hypothesized that one of the primary contributors to both of these problems is the high lateral load that is expected to occur within the track superstructure in certain heavy haul freight railroad locations. In addition to track component deterioration seen in heavy haul freight loading environments, it has become clear in recent years that train derailments due to gauge widening and rail rollover are principally due to the development of lateral forces that are either excessive or repetitive to the track superstructure [5]. Investigating the ability of a fastening system to transfer lateral force from the rail to the concrete crosstie is therefore important not only in the design of components that can mitigate wear and RSD, but also to help decrease the likeliness of derailments caused by the combination of track superstructure deterioration and high lateral forces seen in demanding heavy haul freight loading environments.

There have been several research endeavors conducted in the past that tried to better understand how the track structure is affected by lateral loading. In 1909, Stetson [6] presented the concept of L/V ratio where L is lateral force and V is vertical force applied to the rail head in an American Railway Engineering Association (AREA) report. In this report he discussed how varying the L/V ratio affected timber track performance and component failure. In 1961, Sato [7] conducted a series of experiments to investigate the lateral strength of timber track. Sato explained that the lateral strength of track can be modeled by three springs: a spring representing transverse displacement of the rail base on the crosstie, a spring representing the lateral displacement of the crosstie on ballast, and a torsional spring representing the reaction of the crosstie and fasteners to the twisting of the rail. In 1977, Zarembski [8] outlined the key laboratory and field experimentation conducted up until that point pertaining to the rail industry's knowledge of track performance under lateral loads. The work outlined in the paper primarily investigated the ability of timber crosstie fastening system to resist rail movement corresponding to applied lateral wheel loads. However, the magnitudes and distribution of lateral forces in the fastening systems or overall track superstructure was not specifically discussed.

In recent years, there has been progress in terms of quantifying lateral forces within the track superstructure. Williams et al. [9–12] presented work on the creation of a novel load cell called "lateral load evaluation device (LLED)" that could be placed inside a fastening system to quantify the lateral loads passing from the rail, into the fastening system and concrete crosstie. Through the use of the LLED, these studies were able to:

- Quantify the difference in lateral load placed on fastening system components by the leading and trailing axles of a truck as observed through field experimentation [9,10].
- Investigate the hypothesis that lateral wheel load applied to the track structure is primarily distributed to less than 5 crossties [9,10].
- Quantify a relationship between lateral wheel load and lateral force on the fastening system shoulder under varying freight train speeds [10].
- Compare the magnitude of lateral forces placed on track components positioned on the high and low rail [11].
- Investigated the importance of friction at the rail pad rail seat interface in resisting lateral load through a single fastening system [12].

In 2015, Holder et al. [13] studied how crosstie support conditions affect the lateral wheel load distribution through the track superstructure, and investigated how decreasing the coefficient of friction at the rail pad to rail seat interface globally alters lateral wheel load distribution through the track. These past experimentations with the LLEDs have been primarily focused on developing a detailed understanding of the lateral load demands placed on concrete crosstie track equipped with a single type of spring clip fastening system, the Safelok I. It is believed that the magnitude of lateral loads imparted on fastening system components and the distribution of lateral forces within the track superstructure are heavily dependent on the type of fastening system used on the track.

2. Materials and experimentation setup

2.1. Overview of W 40 fastening system

All experiments explained in this paper were performed on concrete crossties equipped with the W 40 HH AP fastening system (hereafter referred to as the "W 40" or "W 40 system") manufactured by Vossloh Fastening Systems, Inc. [14]. The W 40 system is an Skl-style fastening system designed for track with 136 RE