TECH NOTE NO: 4

TITLE: Load Path Map and Free Body Diagrams of Components Assuming all Bodies are Deformable

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1. Introduction

This technical note summarizes the results of an extensive discussion focused on the load path mapping and free body diagrams of individual components for a concrete crosstie fastening system, hereafter referred to as "Tech Note 4". The discussion proceeded and was completed on the basis of several assumptions, which can be found in **Section 3**. This discussion produced a complete load path map (with component free body diagrams) from the head of the rail, through the fastening system, to the concrete crosstie (**Figure 1**).

2. Objectives

a. Understand the demands placed on the concrete crosstie and selected fastening system components
b. Develop a load path map, under static loading, of the concrete crosstie and fastening system from the top of the rail head to the bottom of the crosstie
c. Identify and classify all forces acting on each component and internal forces within each component

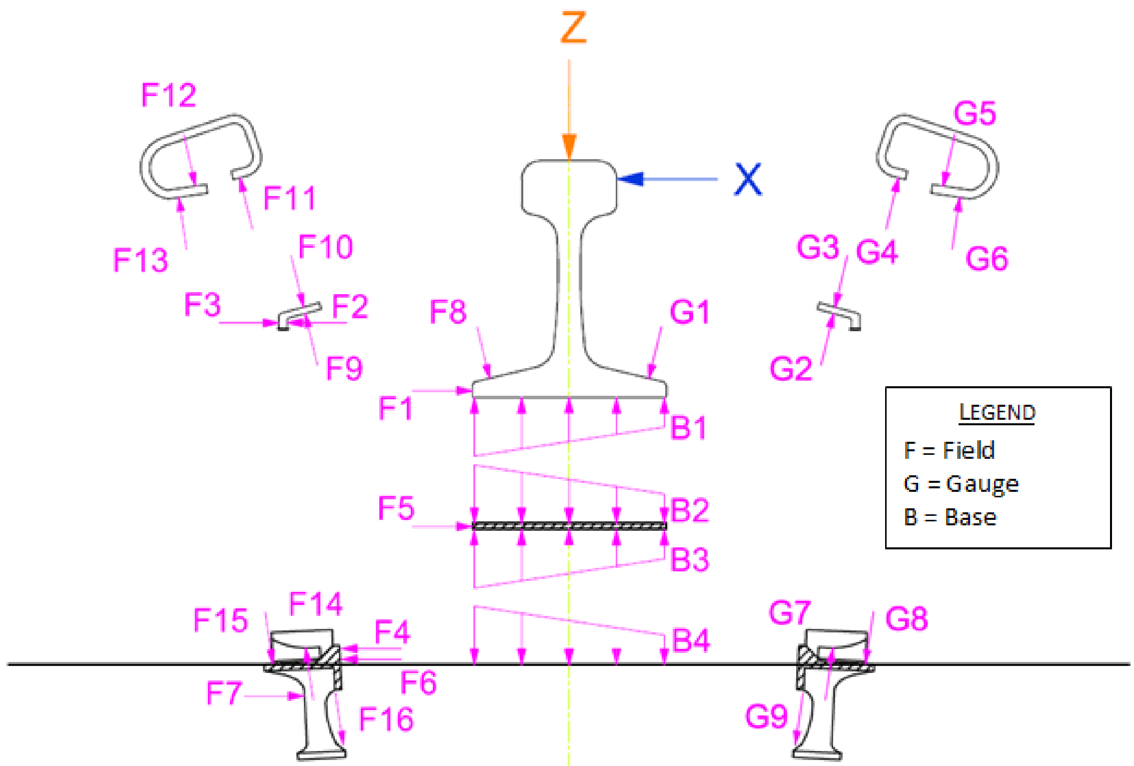

Figure 1 – Concrete Crosstie Fastening System Load Path Map and Component Free Body Diagram

3. Assumptions

The following assumptions were made to determine the load path map and component free body diagrams for this condition:

a. Include system and component deflections (i.e. components no longer idealized as rigid bodies)
b. Incorporate relative component stiffness into analysis
c. Neglect self-weight of each component
d. Fastening system consists of a single pad, two insulators, and two elastic clips (similar to the Safelok I)
e. The clip is driven and all fastening systems components are correctly installed
f. Axis orientation is as follows:
    i. Z-axis is normal to the inclination of the rail seat
    ii. X-axis is parallel to the inclination of the rail seat
    iii. Y-axis is parallel to the longitudinal direction of the rail
g. The base of the rail is infinitely stiff, thus producing an idealized pressure distribution at the rail seat
h. Neglect tangential forces; where they are necessary, substitute moments
i. The surface bond between the cast-in shoulder and concrete is idealized as a single point load to creates a balanced moment condition

4. Discussion

After accepting these assumptions, discussion moved to creating load path maps of the selected fastening system. To simplify the procedure and allow for a better understanding of individual loading, this process was separated into three distinctive load cases:

a. Clamping force only
b. Vertical external load only
c. Horizontal external load only
d. Summation of loads due to cases (a), (b), and (c)

Case (a) includes the forces within the fastening system due to the clamping force exerted by the driven clip (**Figure 2**). Case (b) includes the forces within the fastening system that can be attributed to purely a vertical external load applied to the rail head (**Figure 3**). Case (c) includes all the forces within the fastening system that exist due to a purely horizontal load applied tothe rail head (**Figure 4**).

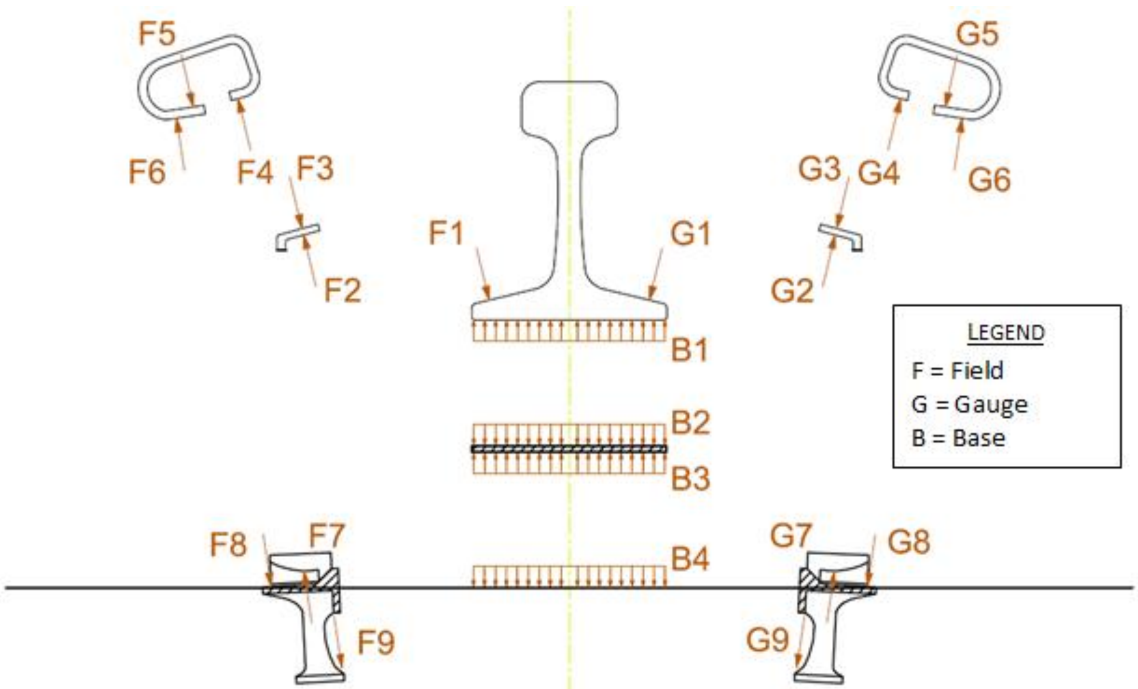

Figure 2 – Concrete Crosstie Fastening System Load Path Map and Component Free Body Diagram: Forces due to Clamping Force

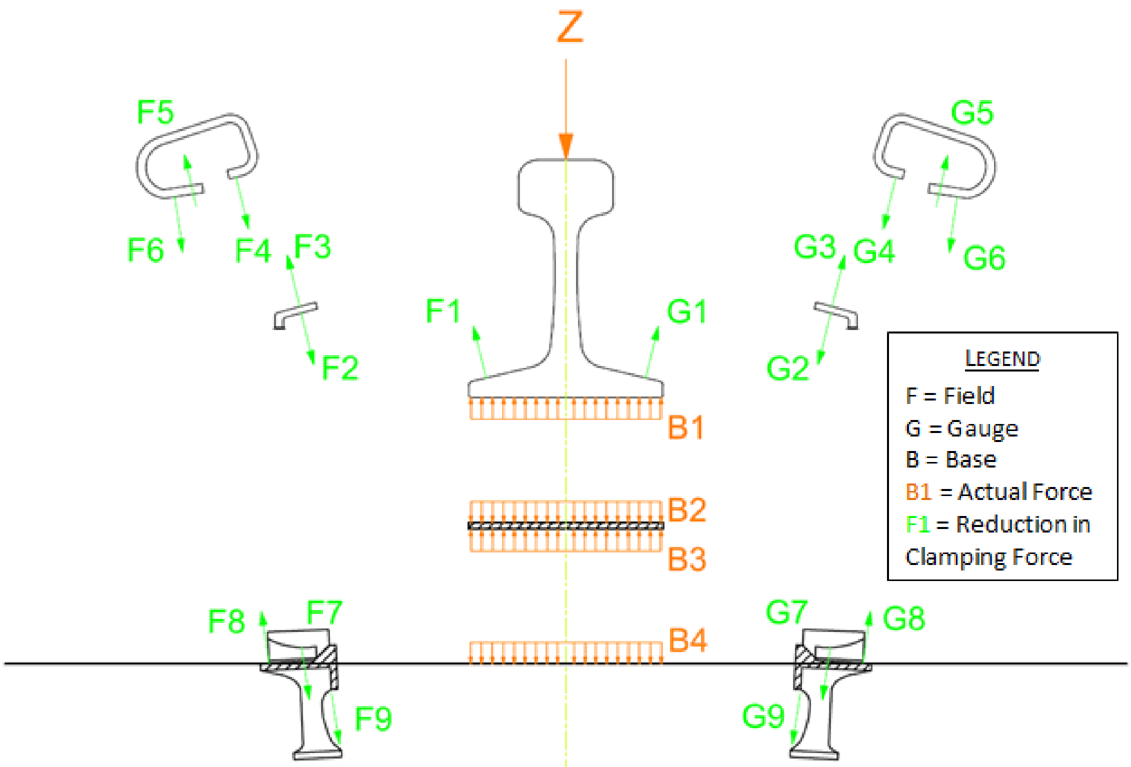

Figure 3 – Concrete Crosstie Fastening System Load Path Map and Component Free Body Diagram: Forces due to Vertical External Load

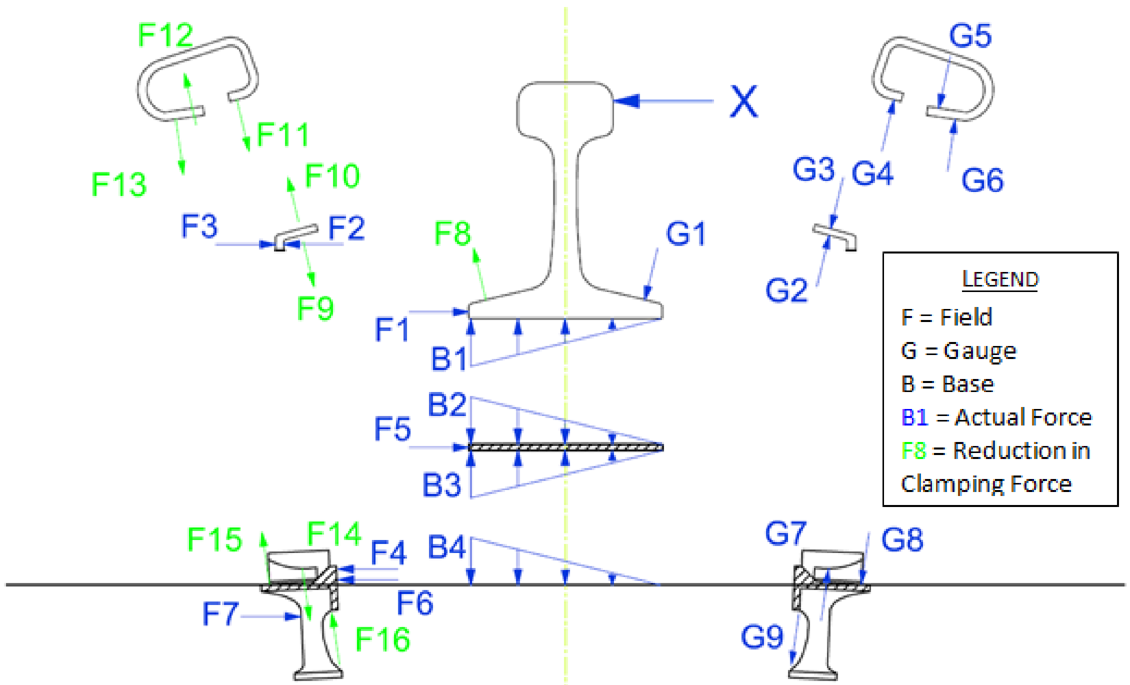

Figure 4 – Concrete Crosstie Fastening System Load Path Map and Component Free Body Diagram: Forces due to Lateral External Load

To complete the load path map and component free body diagrams, all three load cases were combined using the concept of superposition. This combination adequately models the field conditions of the fastening system. Where forces from multiple load cases exist at the same location, they were combined to concisely represent all forces acting externally on each component. See **Figure 1** for this result.

5. Final Remarks

The completion of this load path map is a step toward better understanding the demands placed on each component and achieving all the objectives set forth in **Section 2**. The next step to be executed is to begin calculating deflections of individual components using spring constants relating to the materials. Future applications of this work will include estimation of force distribution, correlation of analytical force distribution calculations and deflections to field and laboratory data, and the development of an initial framework for mechanistic analysis and design of the crosstie and fastening system components.