Mechanistic Behavior of Rail Pad Assemblies



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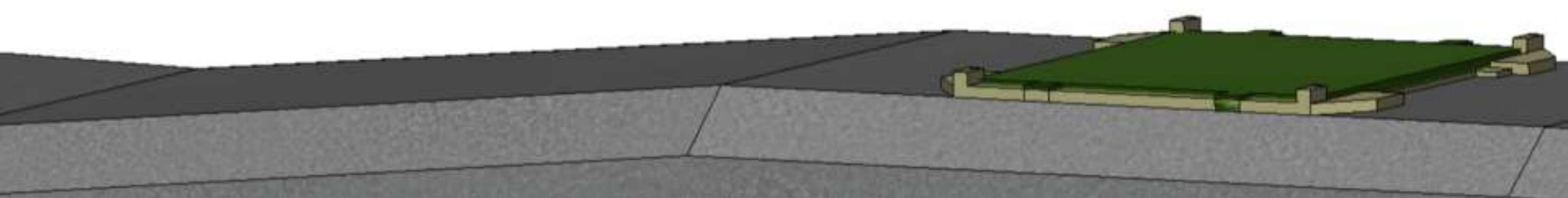
Outline

- Objectives
- Failure Modes
- Mechanics of Wear
- Preliminary Work and Analysis
- Conclusions
- Future Work
- Acknowledgements

Objectives

- Analyze the mechanics of rail pad assemblies to support the development of improved fastening systems
- Quantify pad assembly deformation and displacements
- Investigate the influence of material properties in the mechanistic behavior of rail pad assemblies
- Make design and material properties recommendations to enhance the safety and durability of rail pad assemblies



Rail Pad Assembly Design and Failure Modes

- Multiple suppliers and designs of concrete crosstie pads since 1980's.



1981 → **1991** → **2001+**

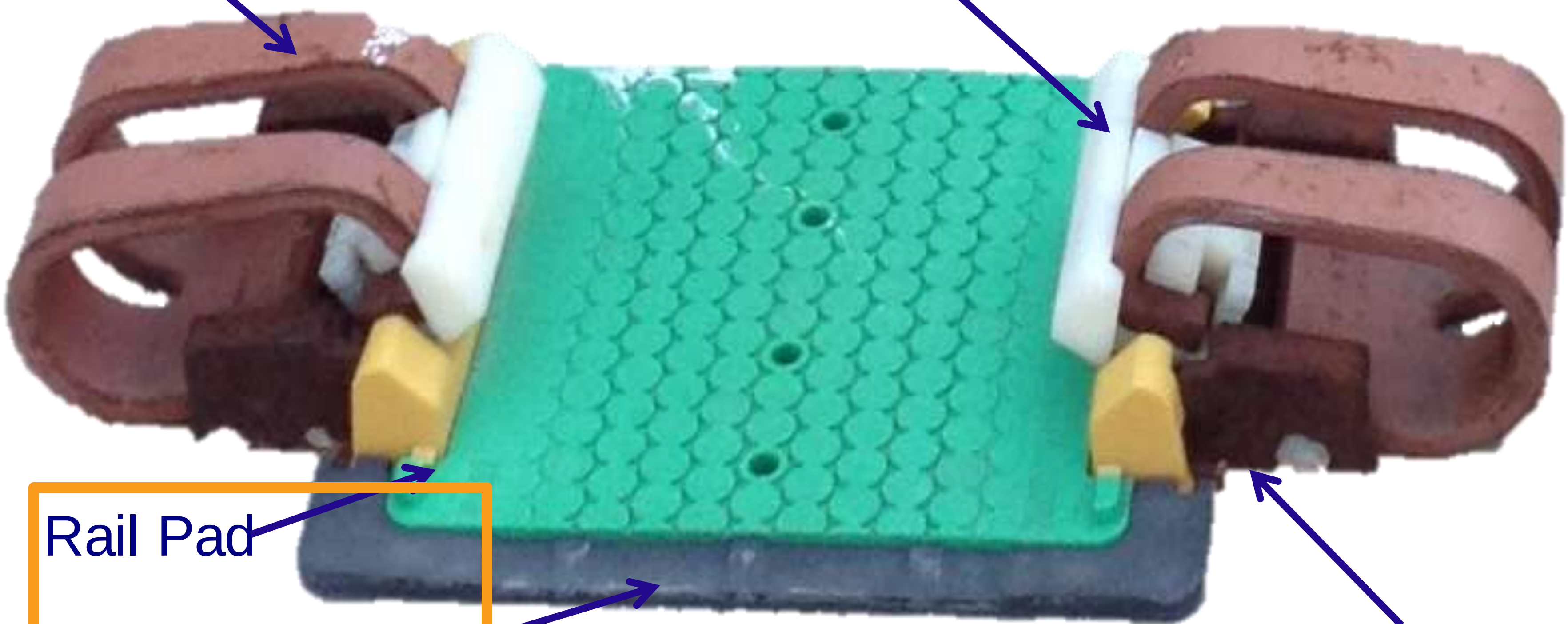



Critical Failure Modes

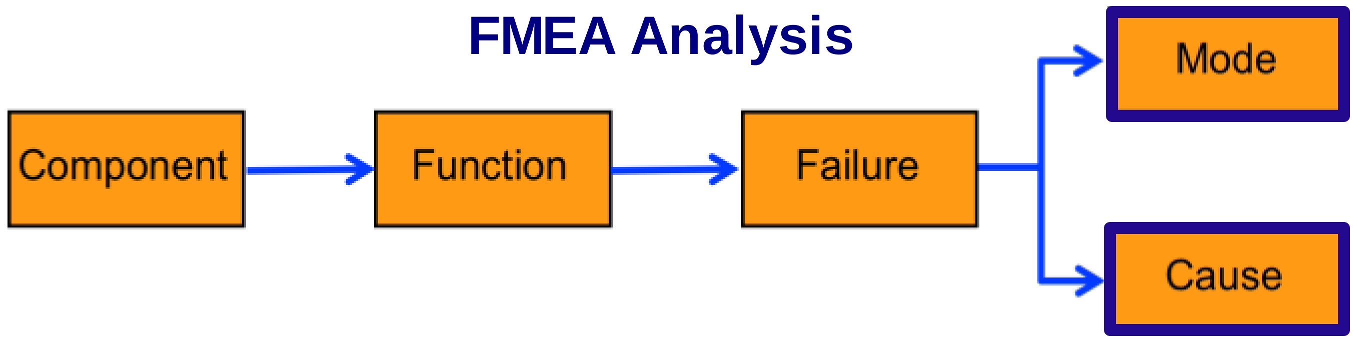
Adapted from UP Design Requirements and Research Outlook by Chris Rewczuk

Fastening System Configuration

- Typically composed by 5 components:



Failure Modes in Pad Assemblies



Failure Modes:

- Abrasion
- Crushing
- Slippage
- Tearing

Failure Causes:

- Relative displacement between rail pad assembly and rail seat
- Presence of moisture
- High localized compressive and shear stresses
- Presence of abrasive fines in the rail seat bearing area
- Large variation in temperature

Mechanics of Rail Pad Wear

Abrasion: process of wearing down by means of friction.

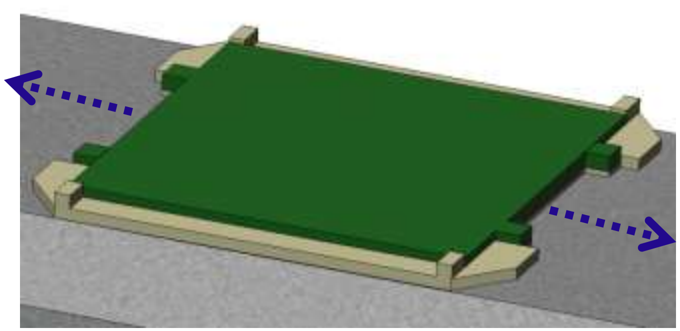
Abrasion

Cause by

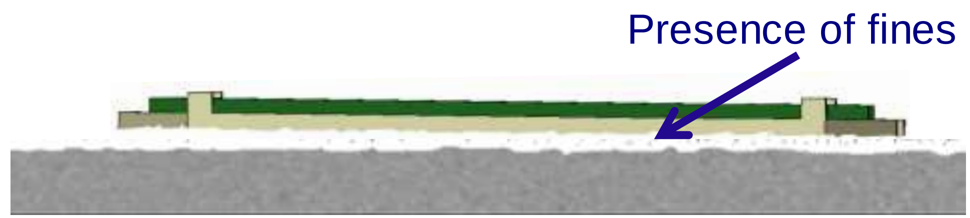
Relative displacement between pad and rail seat; Presence of fines

Results in

Loss of thickness; Loss of original geometry; Permanent deformation



Relative Displacement

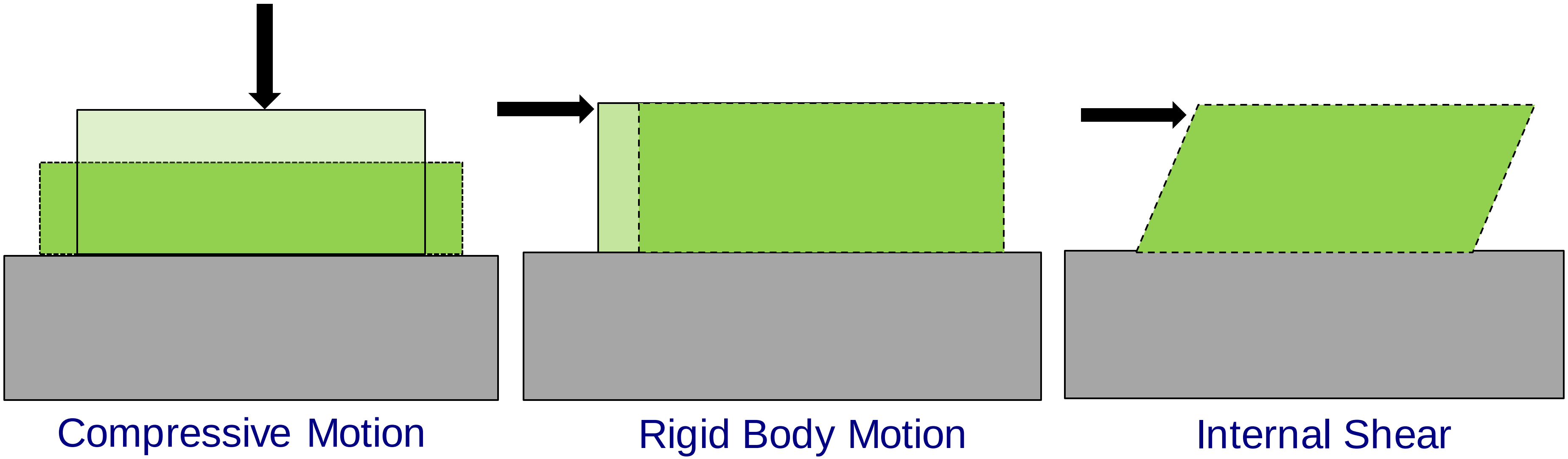


Abrasion Effects

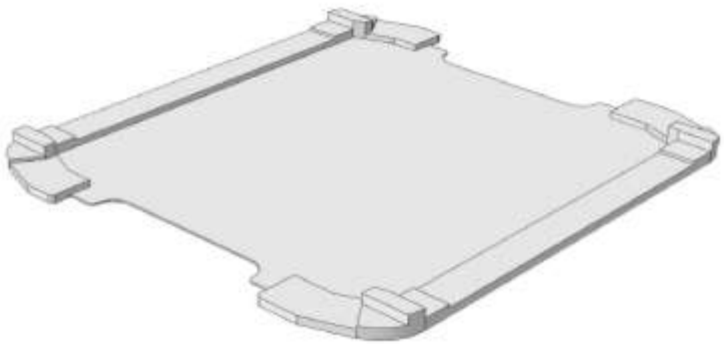
Characteristics of Pad Displacements

Types of motion at rail seat surface

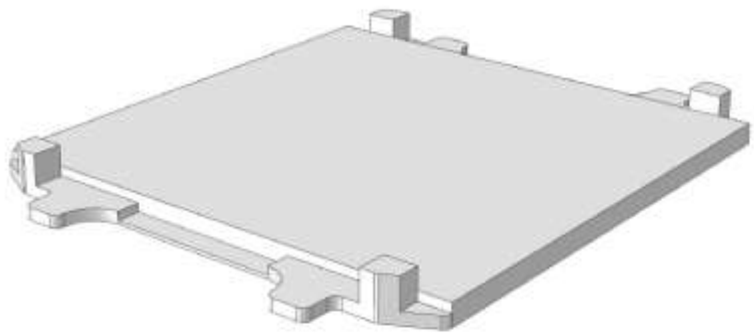
- Compressive motion (Poisson's Effect)
- Rigid body motion
- Internal Shear



Compressive Deformation of Rail Pad Assemblies



Abrasion Frame

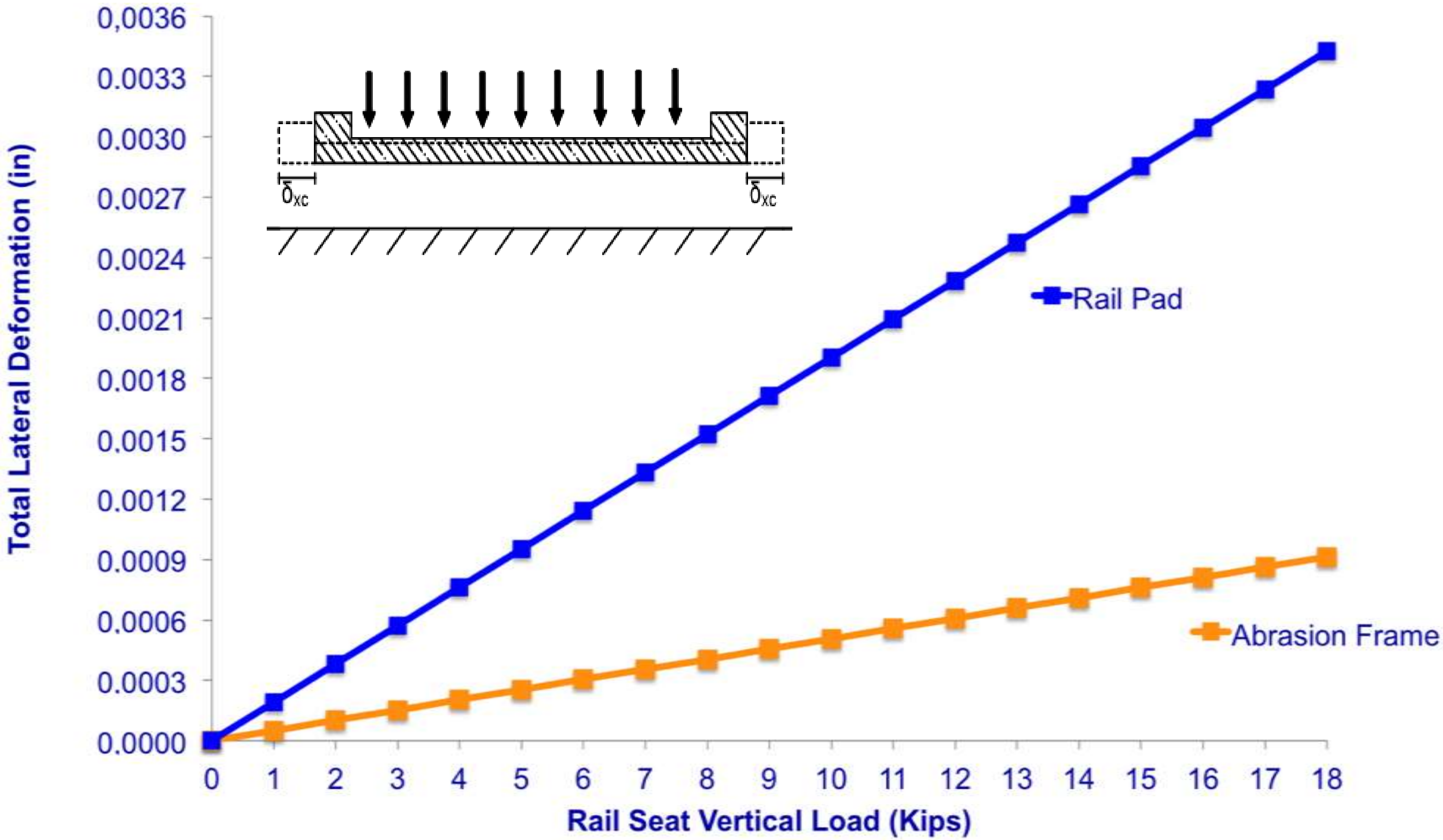


Rail Pad

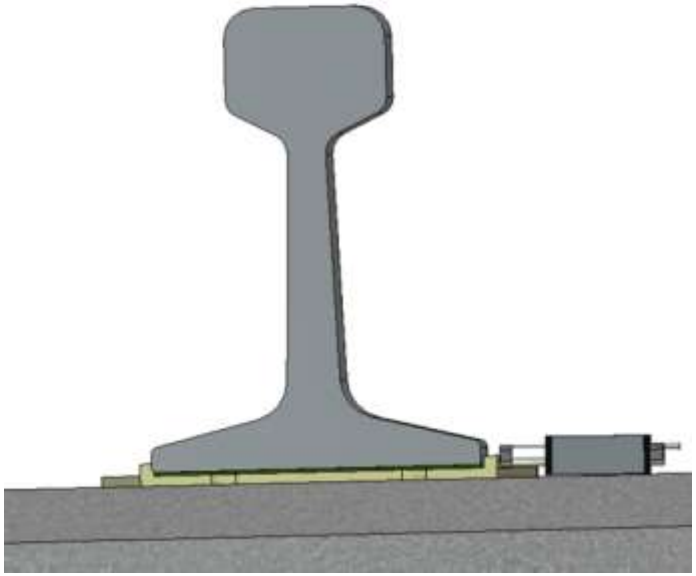
Component	Material	Young's Module (psi)	Poisson's Ratio	Area (in^2)	Mass Density (ln/in^2)
Abrasion Frame	Nylon 6/6	1090683.8	0.350	38.25	0.0488
Rail Pad	Polyurethane	345000	0.394	36.6	0.0368

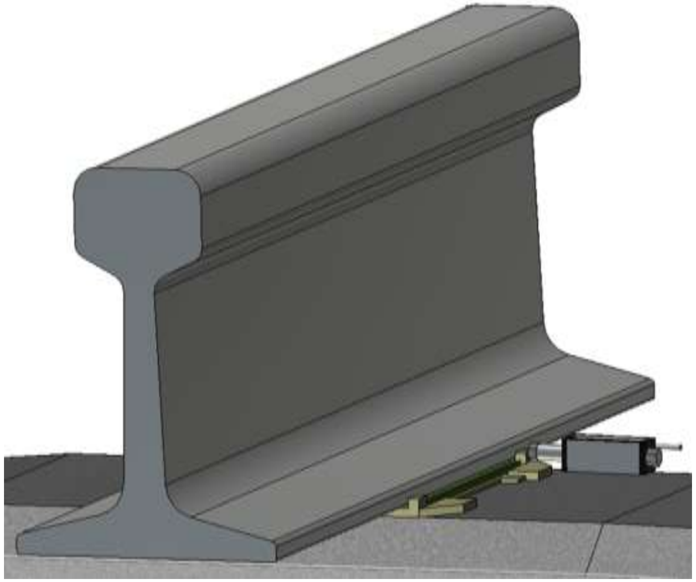
$$\begin{bmatrix}\sigma_{xx}\\\sigma_{yy}\\\sigma_{zz}\\\tau_{xy}\\\tau_{xz}\\\tau_{yz}\end{bmatrix}=\frac{E}{(1+v)(1-2v)}\begin{bmatrix}1-v & v & v & 0 & 0 & 0\\ v & 1-v & v & 0 & 0 & 0\\ v & v & 1-v & 0 & 0 & 0\\ 0 & 0 & 0 & 1-2v & 0 & 0\\ 0 & 0 & 0 & 0 & 1-2v & 0\\ 0 & 0 & 0 & 0 & 0 & 1-2v\end{bmatrix}\begin{bmatrix}\varepsilon_{xx}\\\varepsilon_{yy}\\\varepsilon_{zz}\\\gamma_{xy}\\\gamma_{xz}\\\gamma_{yz}\end{bmatrix}$$

Compressive Deformation of Rail Pad Assemblies



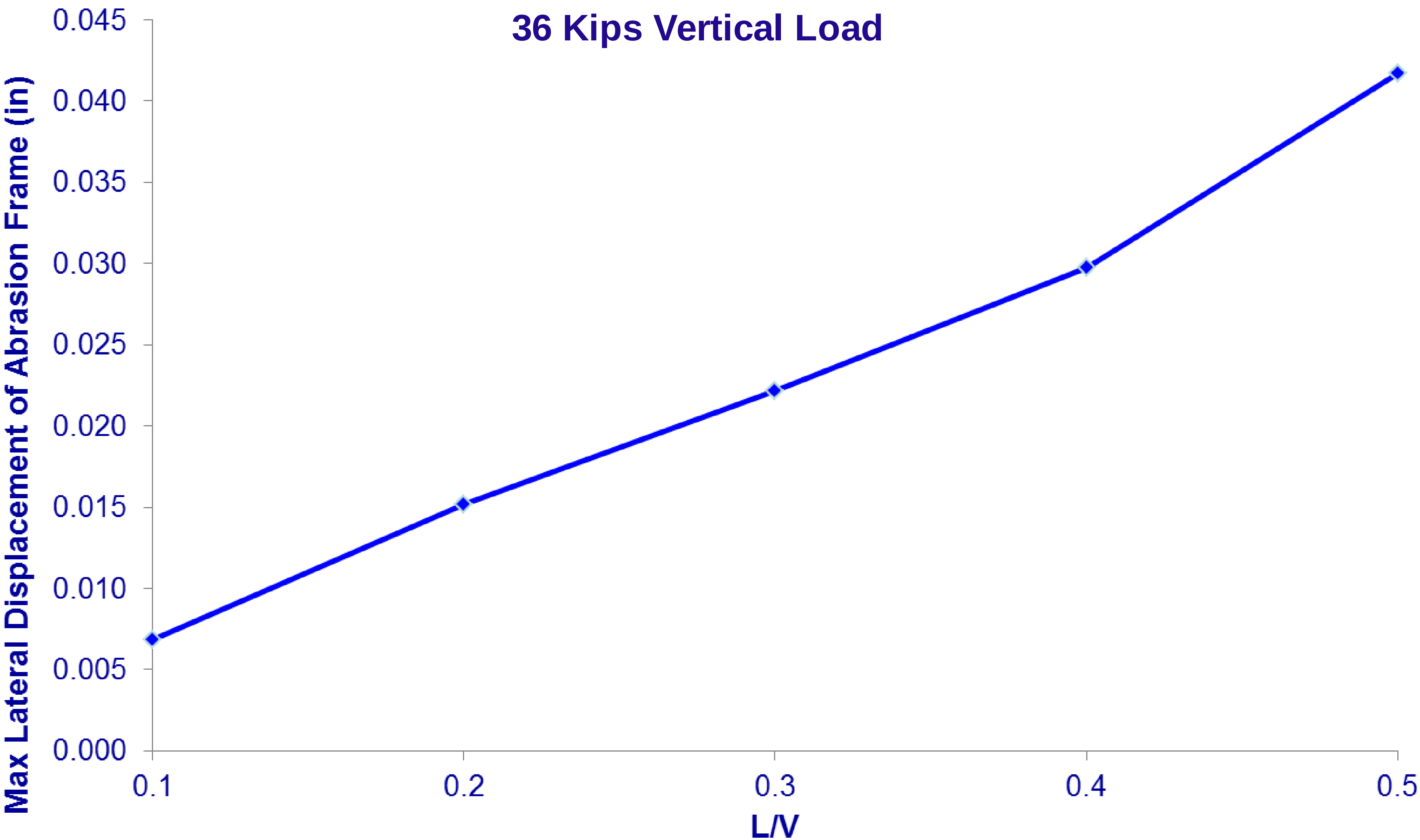
Investigation of Lateral Displacements



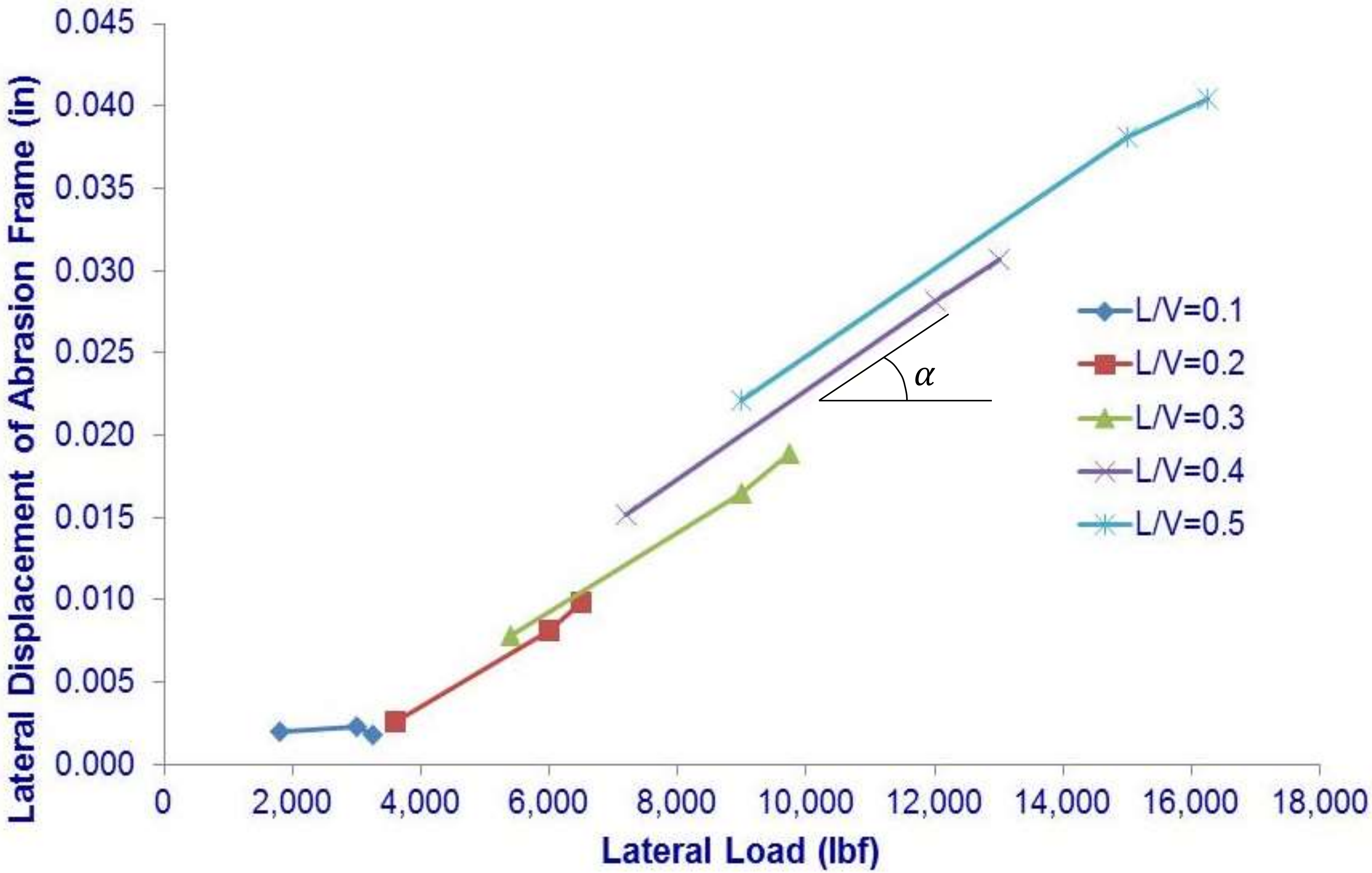


- Instrumented pad assembly tested on Pulsating Load Testing Machine (PLTM)
- High sensitivity potentiometer used to capture the total displacement of the abrasion frame
- Lateral load varied from 2,000 lbf to 18,000 lbf
- L/V ratio varied from 0.1 to 0.5
- Imposed dynamic loading at 3Hz
- Potentiometer fixed to the crosstie using a metal mounting bracket

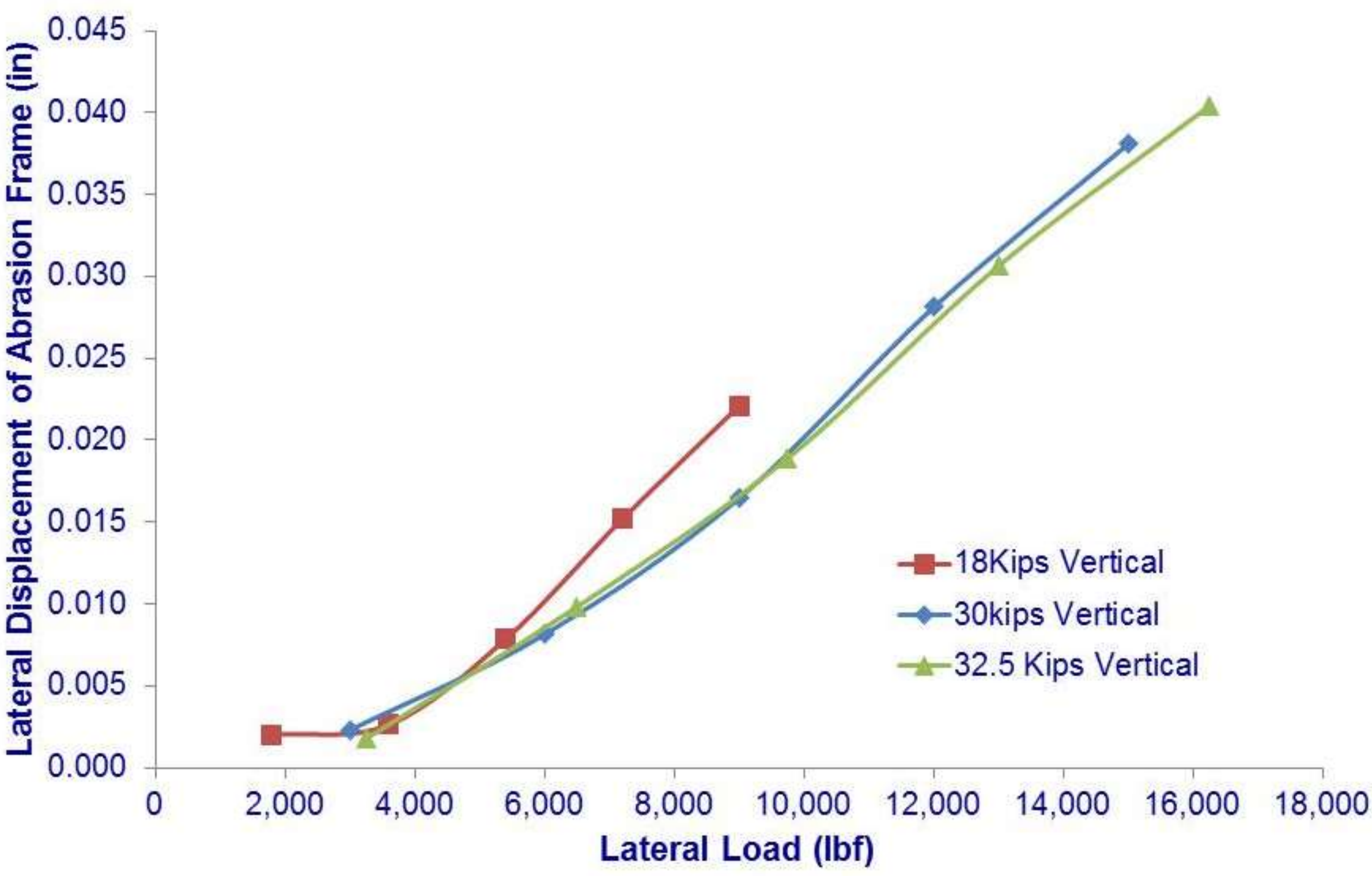
Investigation of Lateral Displacements



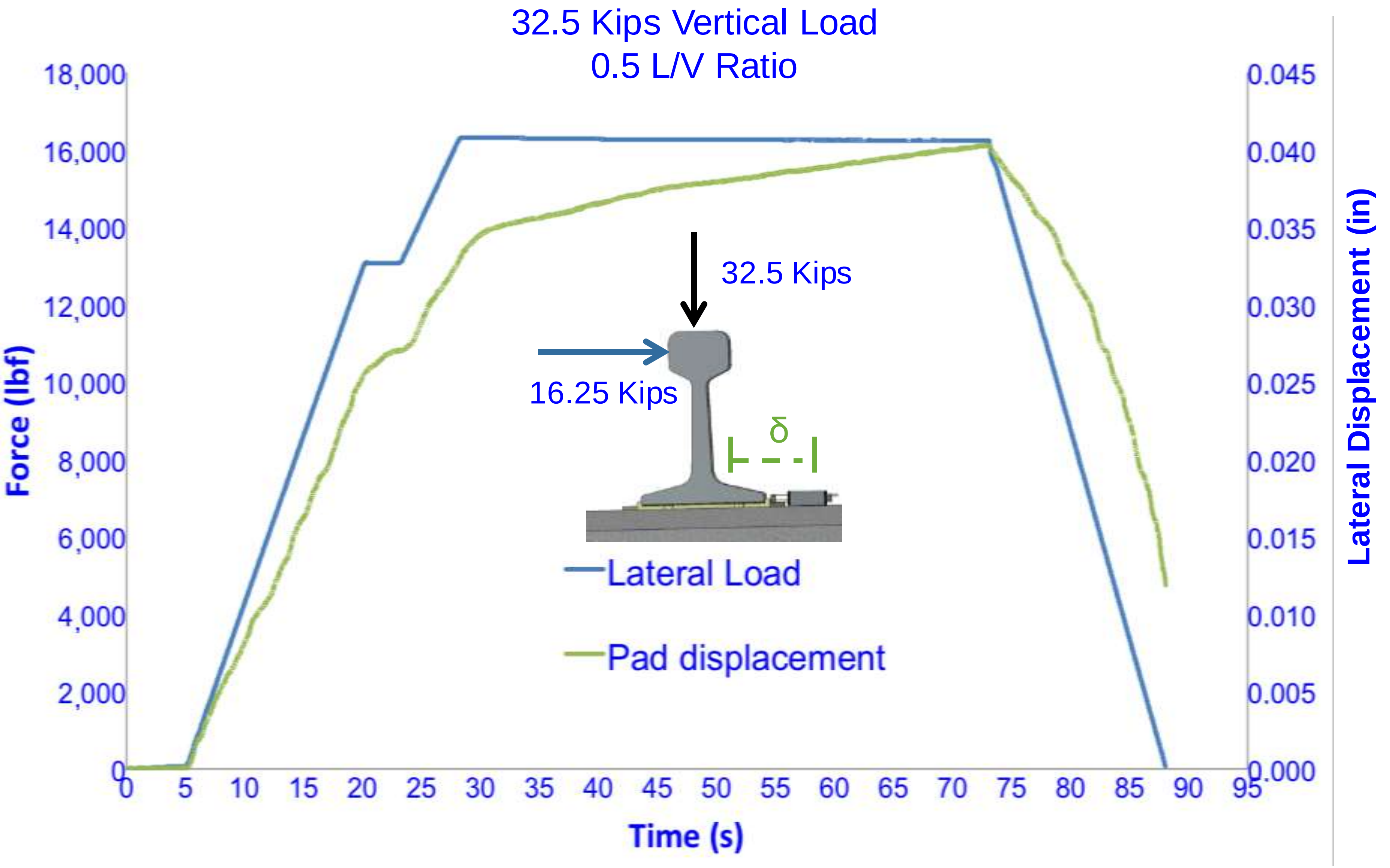
Investigation of Lateral Displacements



Investigation of Lateral Displacements



Lateral Rail Pad Displacement Test



Conclusions

- The total displacement of the pad assembly was measurable. The rigid body motion was the predominant displacement and responsible for approximately 98% of the total movement
- Pad displacement increases as lateral load increases
- From preliminary results, regardeless the L/V ratio the load is applied, the rate of change in total displacement is held constant. Further investigation can confirm if pad displacement is only a function of the lateral load
- Measuring displacements with potentiometers proved to be an efficient method to acquire such data
- Shoulders are capable to sucessfully restrain the movement of rail pad assemblies. Depending on how tight they fit on the rail seat area, there is a considerable variation of the displacement magnitude

Future Work

- Further laboratory testing with different types of pads at different levels of material degradation
- Field investigation at Transportation Technology Center (TTC) to measure lateral and longitudinal displacement of rail pad assemblies.
- Comparison between results acquired from laboratory instrumentation, field testing and FE analysis
- Recommend design improvements and optimized material properties to support the development of new fastening system components

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Questions?

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Thank you!