KENTRACK – A Railway Trackbed Structural Design Program

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KENTRACK

Version 2.0.1

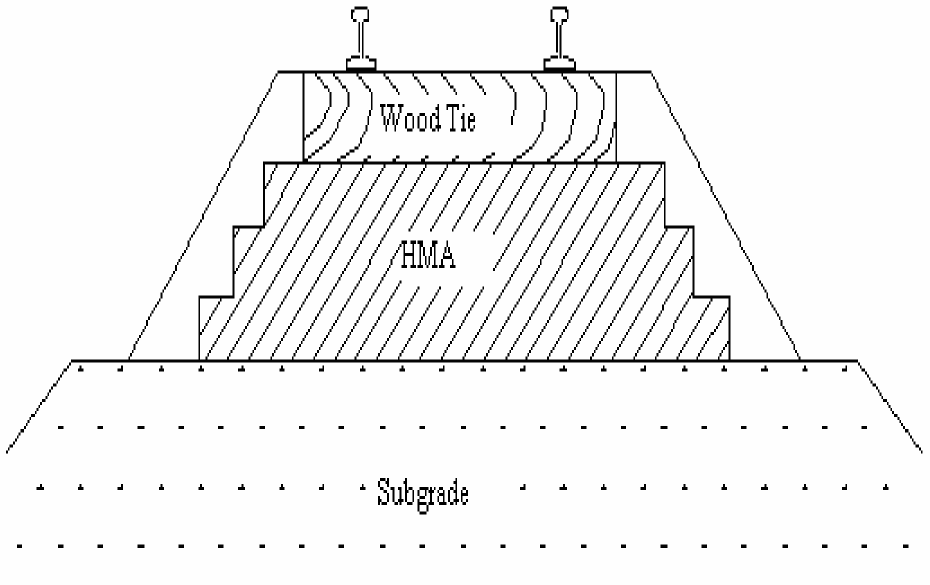
Railway Trackbed Structural Design Software

Introduction

- Railroads
- Track Superstructure
- Track Substructure – support system
- Research in the last 20 years

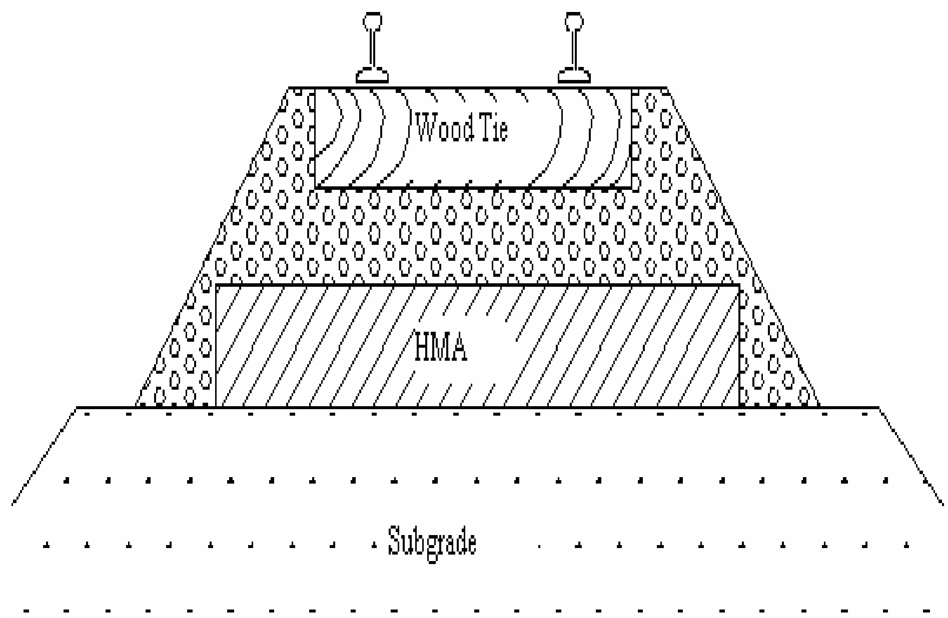
HMA Trackbeds

- Overlayment
  - Ties placed directly over asphalt
  - Ballast is only used for cribbing



HMA Trackbeds

- Underlayment
  - HMA layer present between ballast and subgrade
  - Preferred over overlayment
  - Better service life than overlayment



HMA Trackbeds

- Underlayment

HMA Trackbeds

- Stronger support layer
- Reduced stresses onto subgrade
- Waterproofing layer
- No subgrade pumping
- Confining layer for ballast

Background

- Theoritical method

  Bousinessq's Elastic Theory

  Deficiencies:

  Assumes the support system to be elastic, isotropic

Background

- Empirical equations

  - JNR Equation

$$P_c = \frac{50P_m}{10 + h^{1.35}}$$

  - Talbot's Equation

$$P_c = \frac{16.8P_m}{h^{1.25}}$$

Background

- ILLITRACK
  - Finite element method
  - Two dimensional
- GEOTRACK
  - Multilayered theory
  - Three dimensional model
  - It was developed to analyze all-granular trackbeds

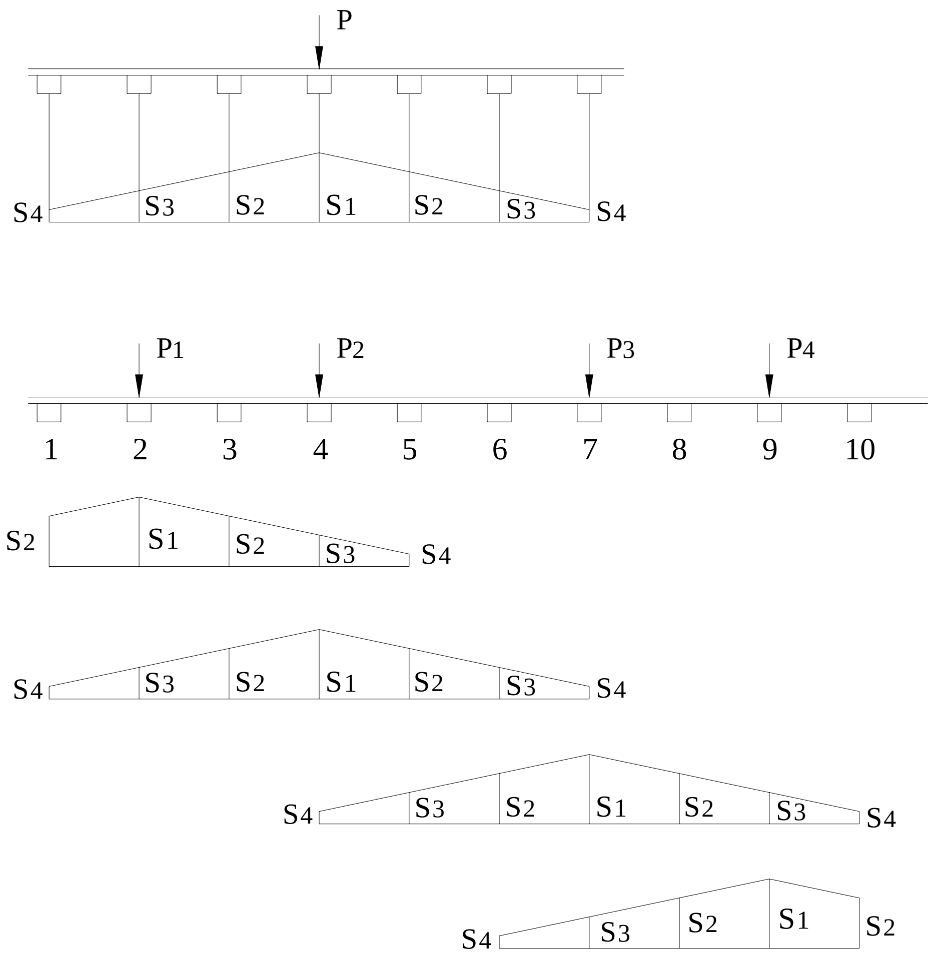
Background

- KENTRACK
  - Developed specifically to analyze HMA trackbeds
  - Has the versatility to analyze all-granular trackbeds
  - Initially a DOS based program
  - Upgraded to a windows based platform with a Graphic User Interface

Theory behind KENTRACK

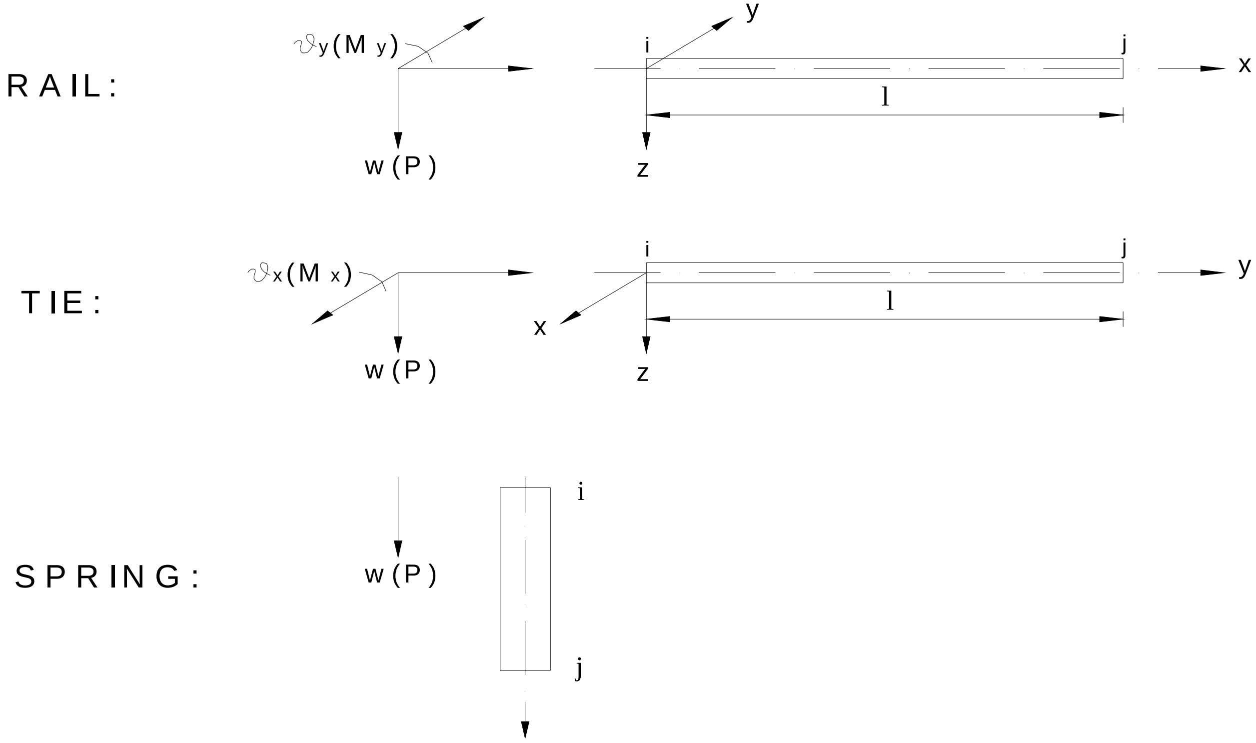
- Superposition of Loads

$$S_1' = S_2 \frac{P_1}{P} + S_4 \frac{P_2}{P}$$



Theory behind KENTRACK

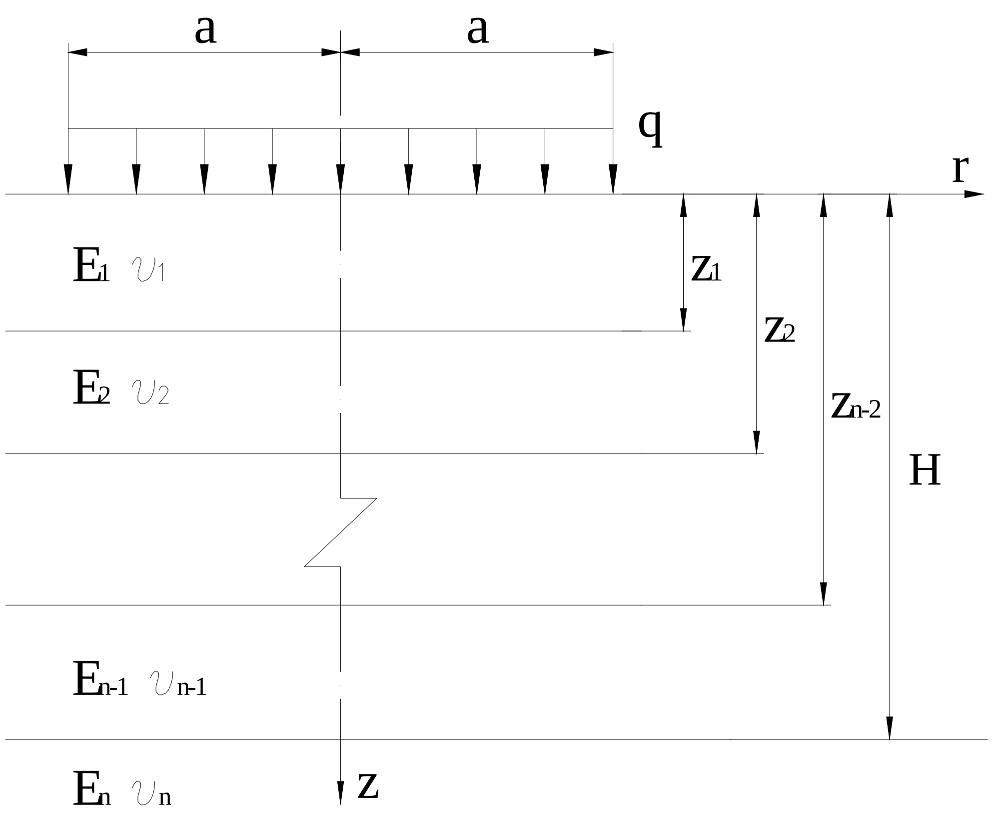
- Finite Element Method



- To calculate stresses and strains in rail and tie

Theory behind KENTRACK

- Multilayered System



- To calculate stresses and strains in the layers

Theory behind KENTRACK

- Material Properties

  - HMA trackbed is comprised of ballast, HMA and subgrade

  - All-granular trackbed is comprised of ballast, subballast and subgrade

  - Different equations are used to describe the material properties

Theory behind KENTRACK

- Ballast
  - In a new trackbed it behaves non-linearly
  - In an aged trackbed it behaves linearly

$$E = K_1 \theta^{K_2}$$

$$\theta = \sigma_1 + \sigma_2 + \sigma_3 + \gamma z(1 + 2K_0)$$

- Subgrade
  - Linearly elastic material

Theory behind KENTRACK

- Hot Mix Asphalt (HMA)
  Visco-elastic material

The dynamic modulus of HMA depends on

- Temperature
- Aggregate passing No. 200 sieve in %
- Volume of bitumen %
- Volume of air voids %
- Asphalt viscosity
- Load frequency

Theory behind KENTRACK

- Damage Analysis

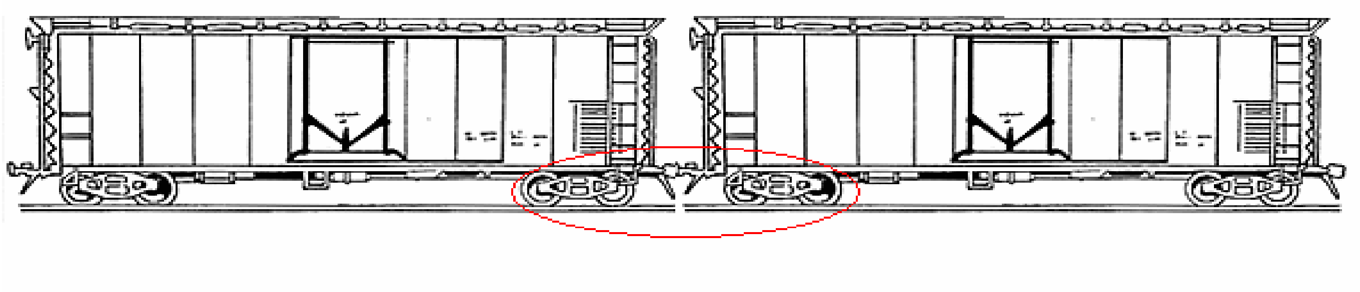
  - Based on minor linear damage analysis criteria

  - Performed by periods (seasons, months)

$$L = \frac{1}{\sum_{i=1}^{n} \frac{N_p}{N_a or N_d}}$$

Theory behind KENTRACK

- Predicted number of repetitions



Wheel Load	= 36000 lb/wheel
For one car the total weight	= 36000 lb/wheel x 8
	= 286,000 lb/rep / 2000
	= 143 ton/rep
The number of repetitions assumed per year	= 200,000 rep/yr
The traffic per year	= 200,000 rep/yr x 143 ton/rep
	= 28,600,000 GT/yr / 1 x 10^6
	= 28.6 MGT/yr

Theory behind KENTRACK

- HMA Damage Analysis
  - Fatigue cracking controls failure
  - Fatigue cracking is governed by the tensile strain at the bottom of HMA
  - Based on highway experience
  - Number of allowable repetitions (N_a) before failure

$$N_a = 0.0795\,\varepsilon_t^{-3.291} E_a^{-0.853}$$

Theory behind KENTRACK

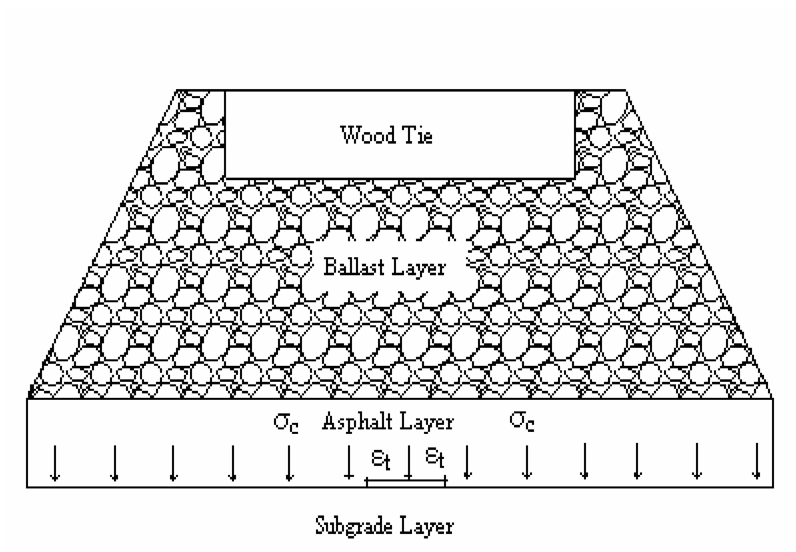
- Subgrade Damage Analysis
  - Excessive permanent deformation controls failure
  - Deformation is governed by the vertical compressive stresss on top of subgrade
  - Based on highway experience
  - Number of allowable repetitions (N_d) before failure

$$N_d = 4.837 \times 10^{-5} \sigma_c^{-3.734} E_s^{+3.583}$$

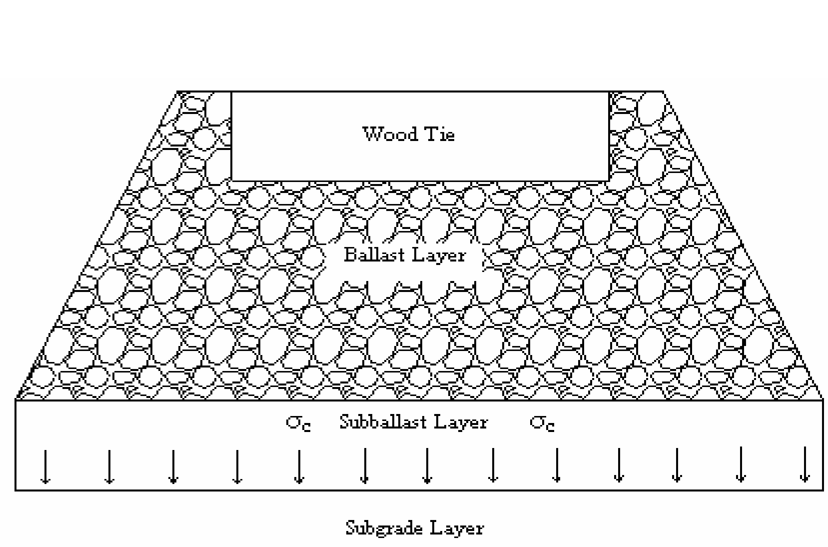
Theory behind KENTRACK

Stresses and Strains

Asphalt Trackbed

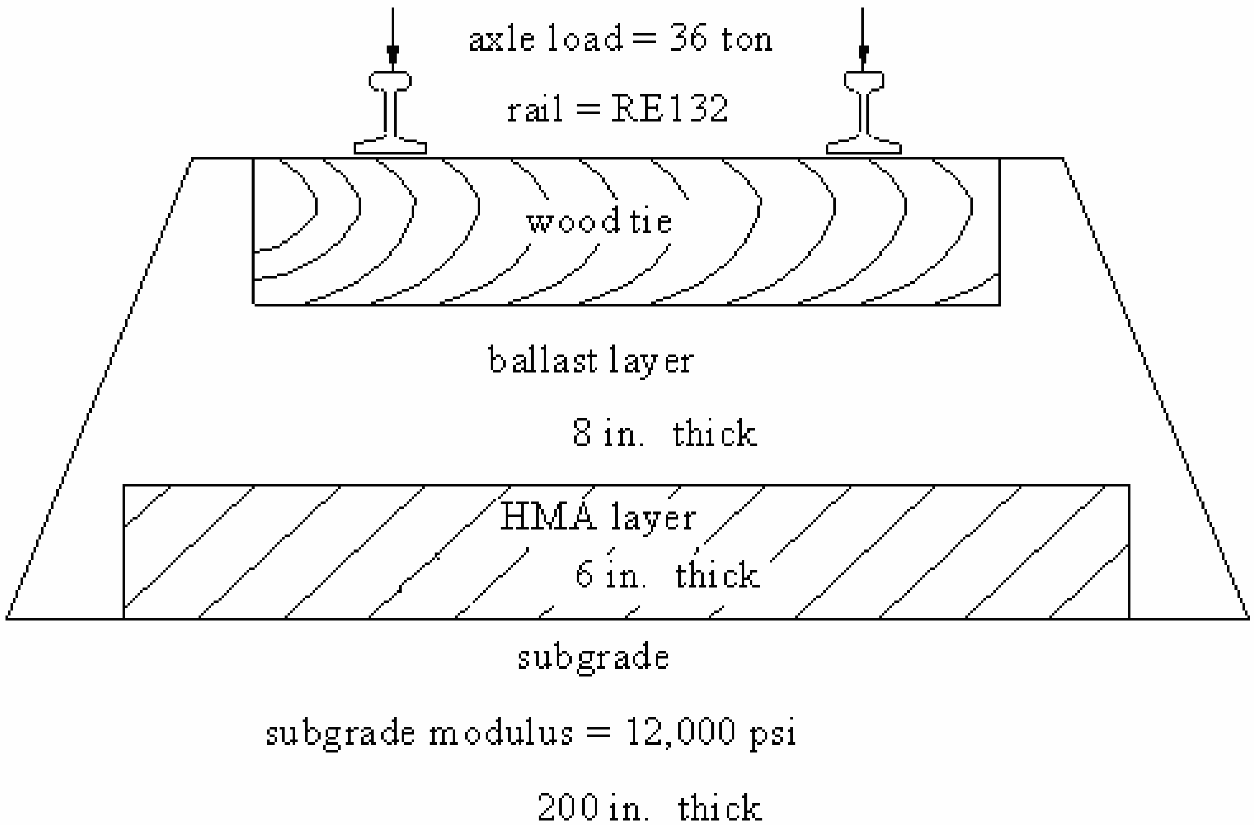


All-Granular Trackbed



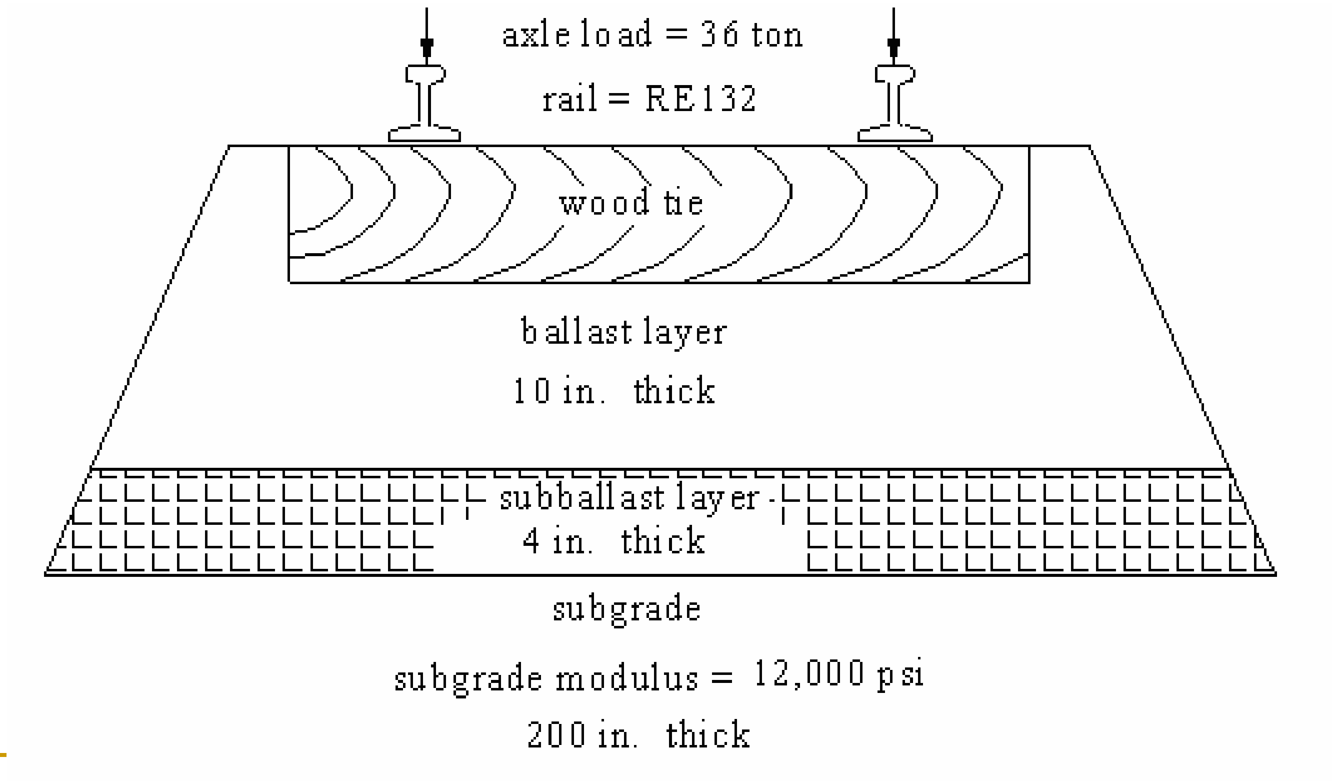
Methodology

- HMA trackbed cross-section



Methodology

- Ballast trackbed cross-section



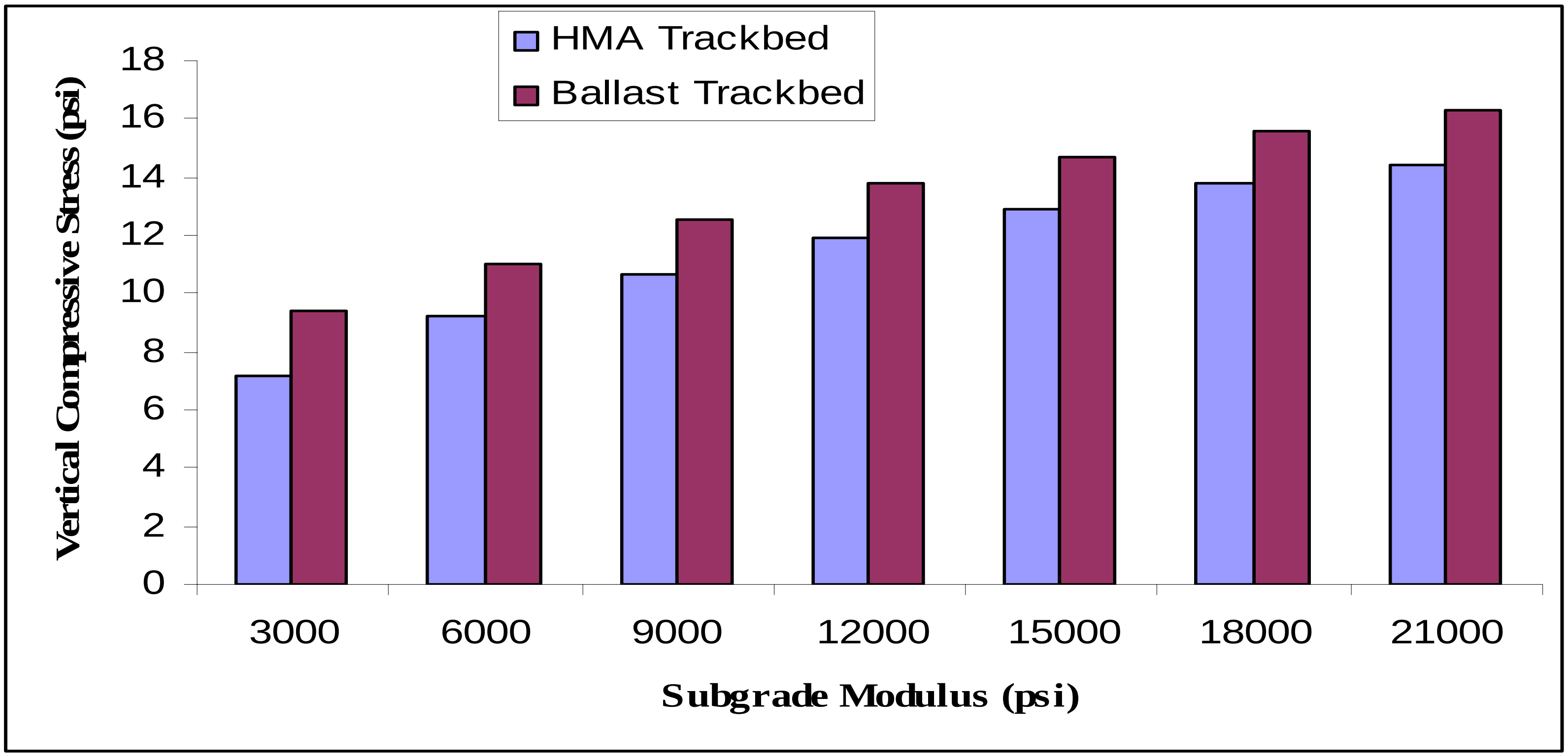
Methodology

- Critical outputs for the two sections

Critical Outputs		
Variable	Standard HMA trackbed	Standard Ballast Trackbed
Subgrade Vertical Compressive Stress (psi)	11.9	13.8
HMA Tensile Strain (in/in)	0.000183	N/A
Service life of Subgrade (yrs)	15.2	5.6
Service life of HMA (yrs)	19.8	N/A

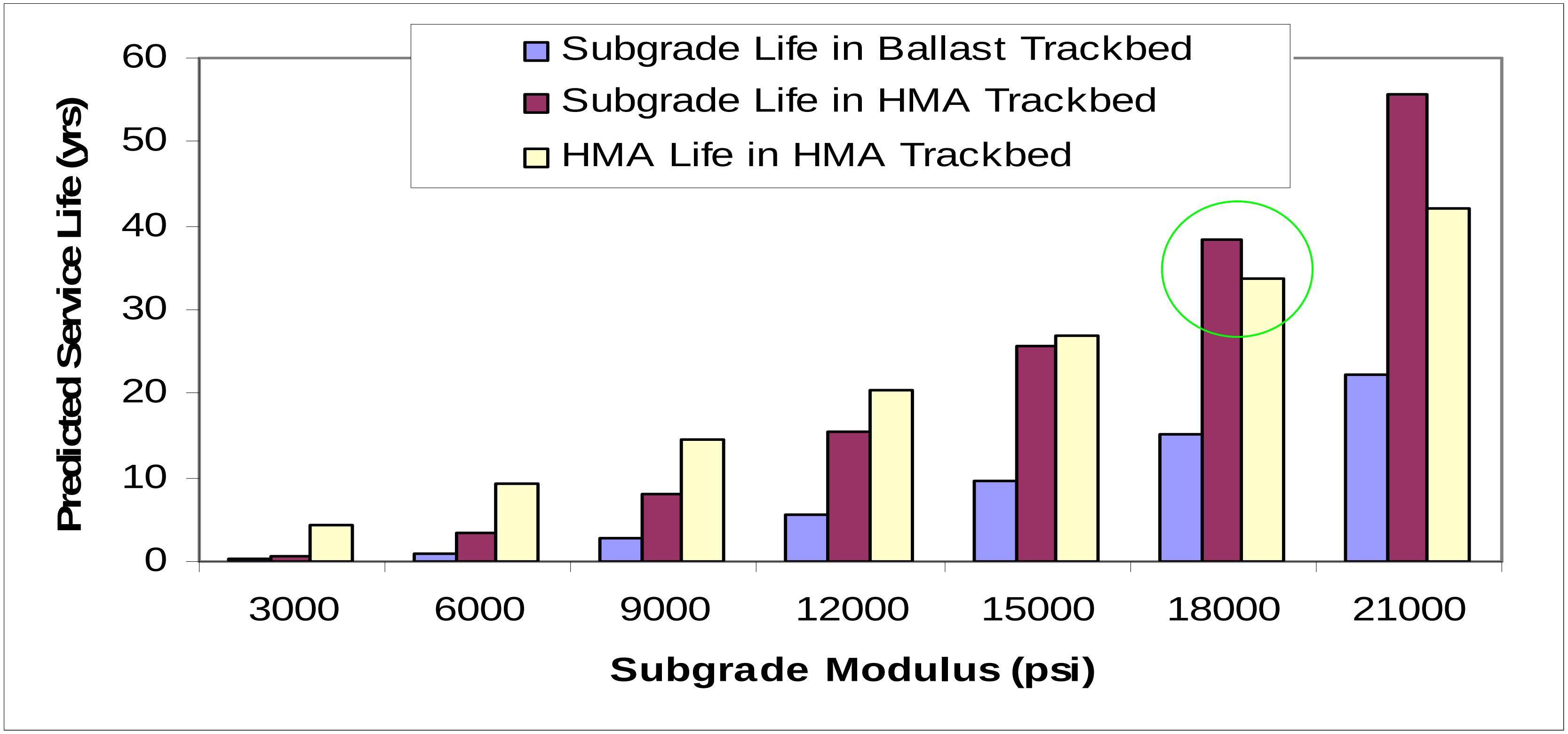
Effect of Subgrade Modulus on σ_c

Axle Load – 36 tons



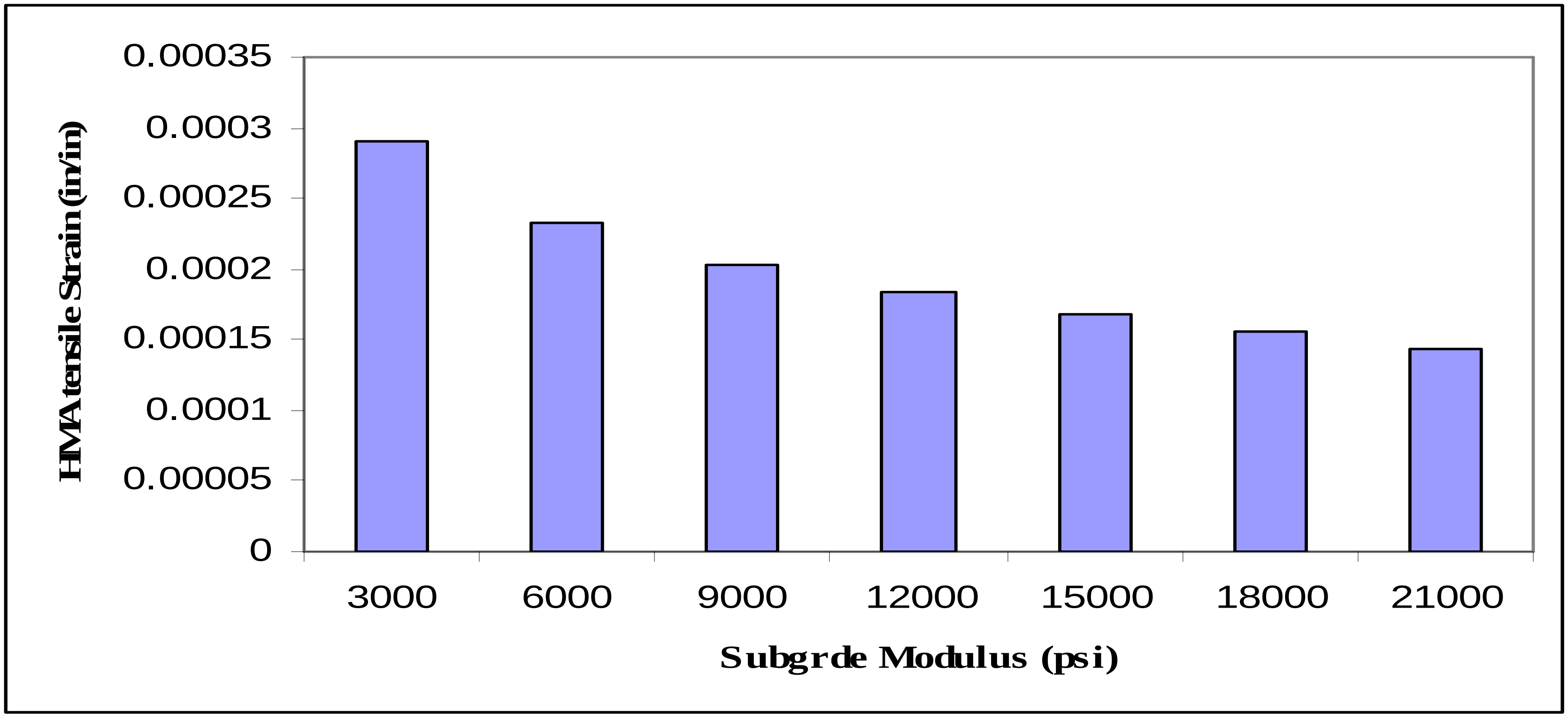
Effect of Subgrade Modulus on L

Axle load - 36 tons

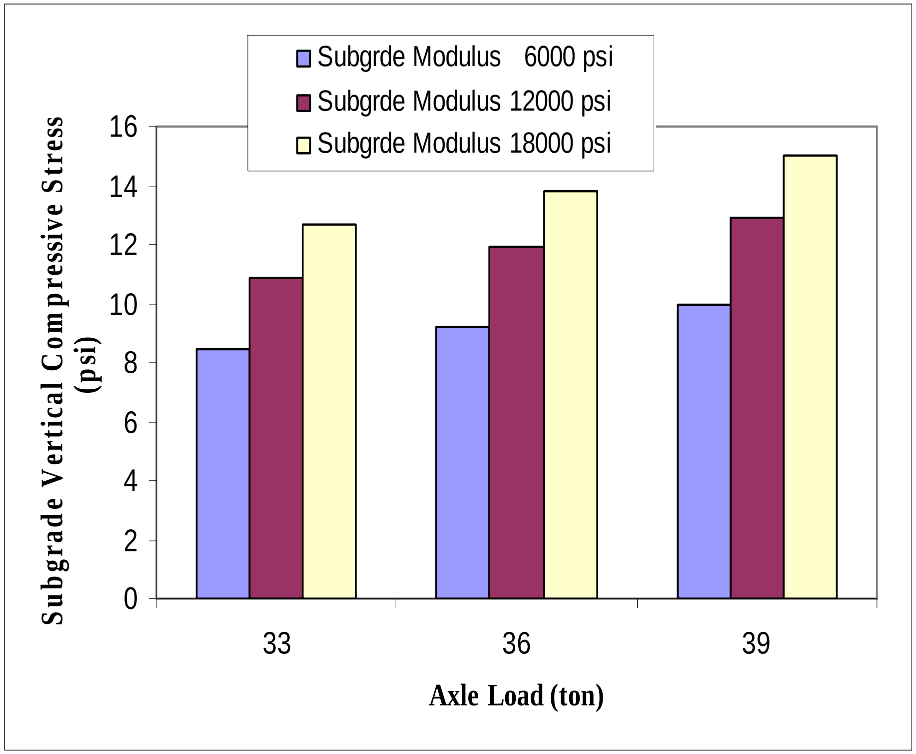


Effect of Subgrade Modulus on ε_t

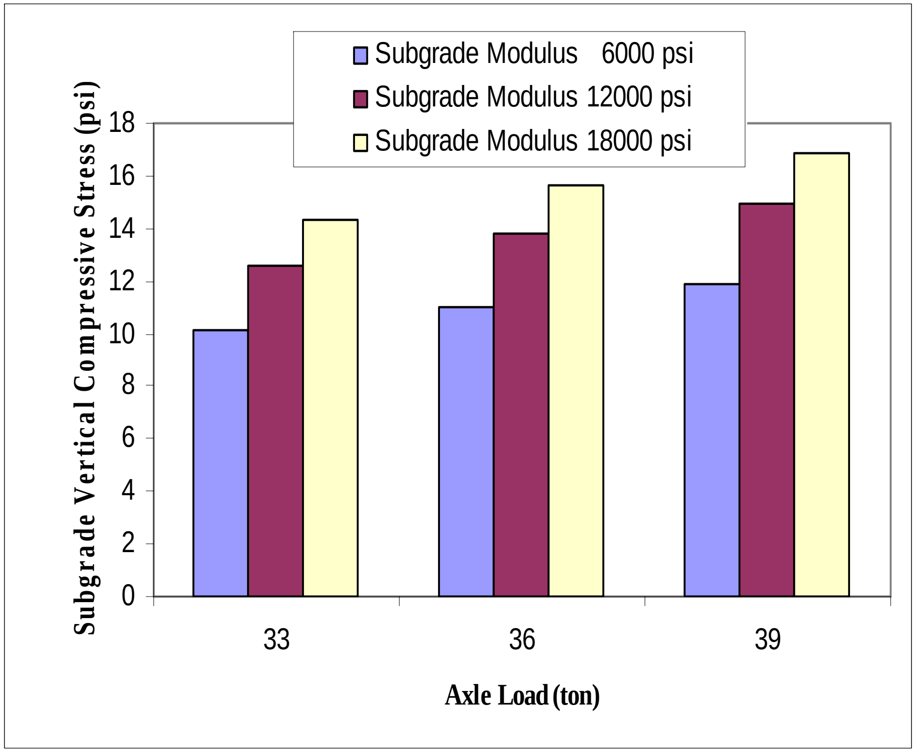
Axle load – 36 tons



Effect of Axle Load on σ_c

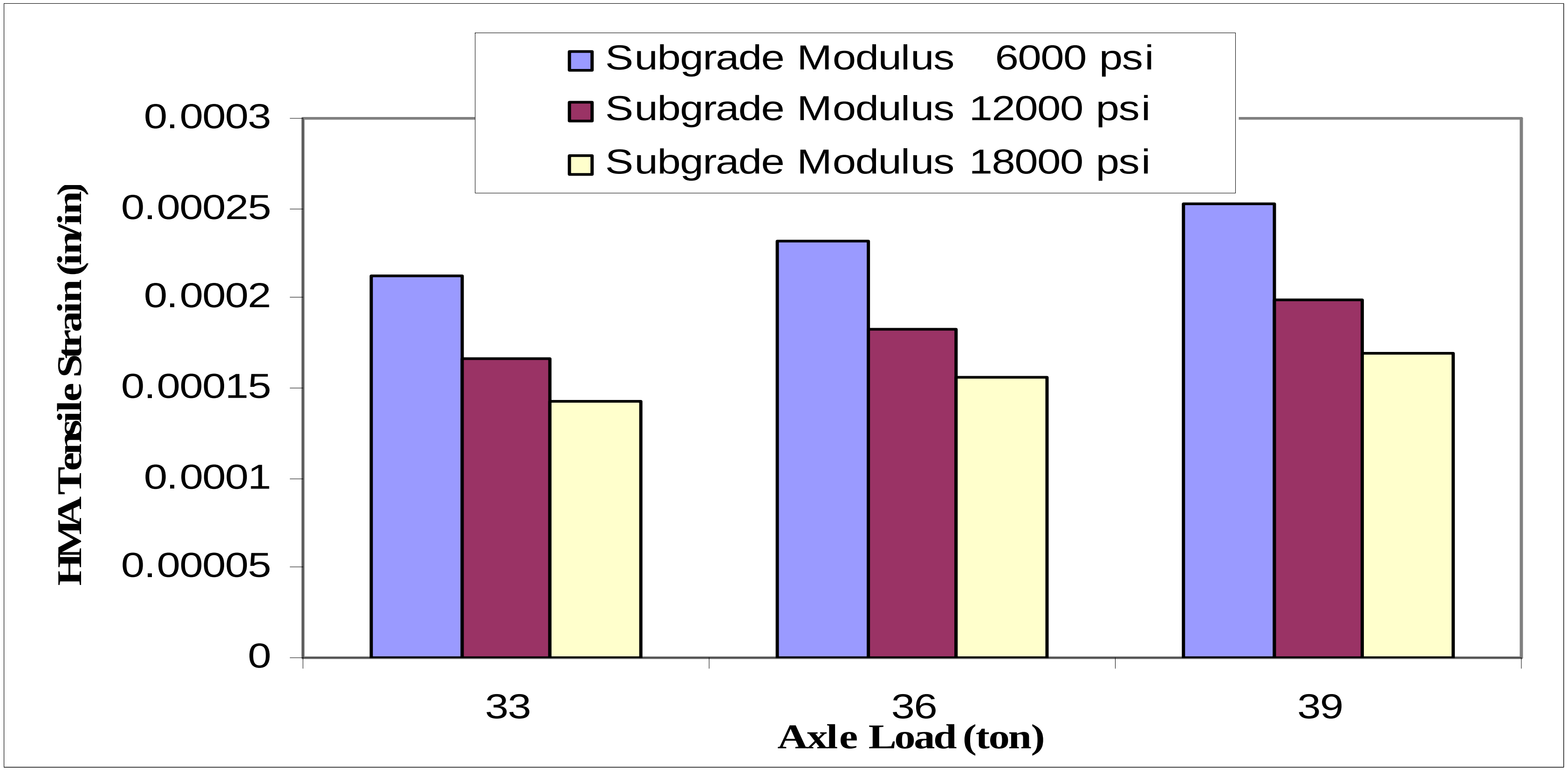


HMA Trackbed

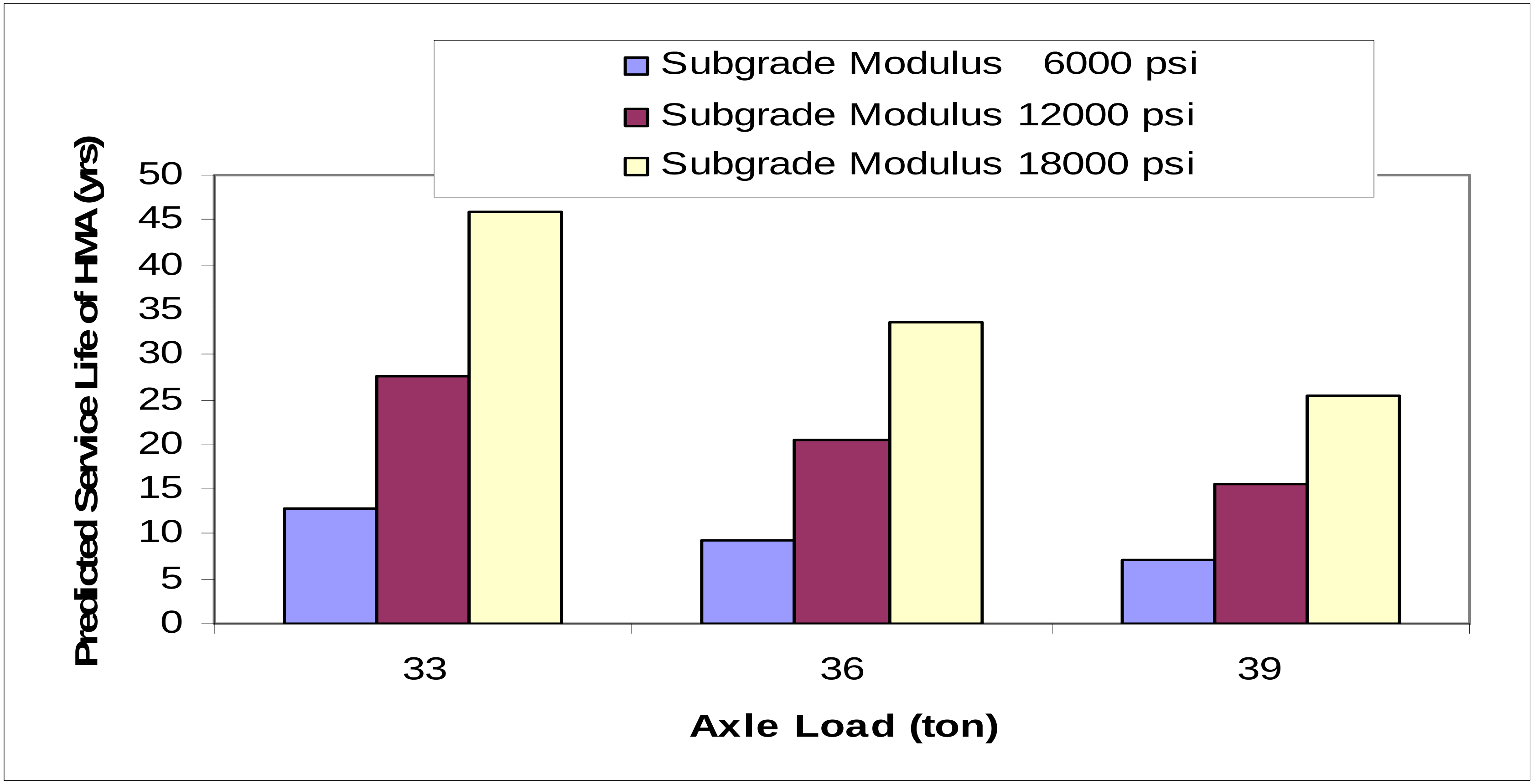


Ballast Trackbed

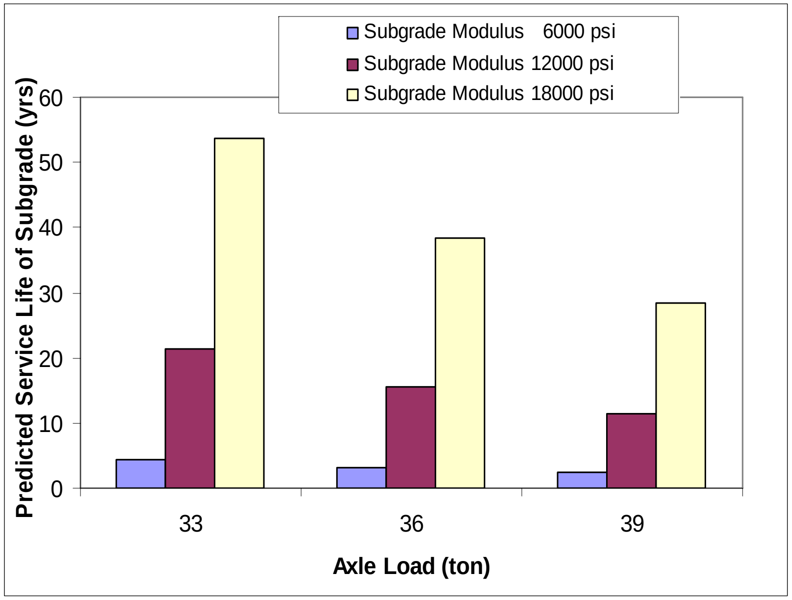
Effect of Axle Load on ε_t

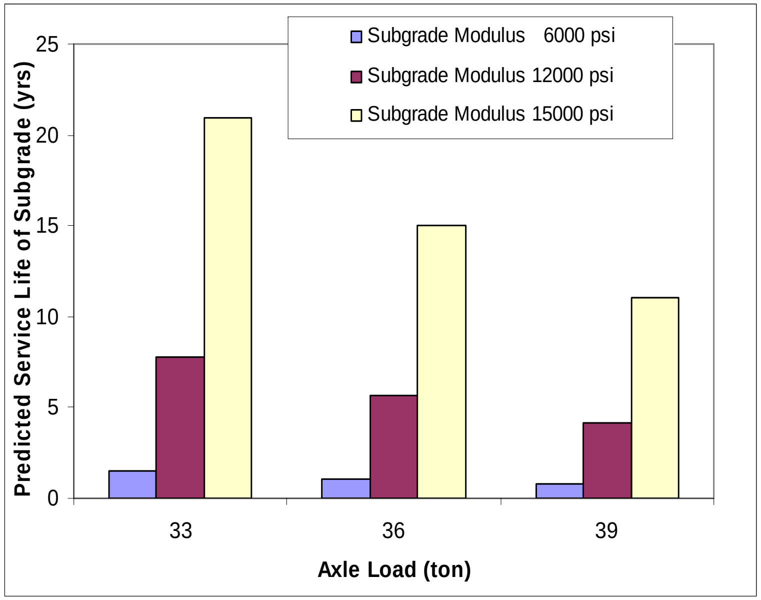


Effect of Axle Load on L_a



Effect of Axle Load on L_d





HMA Trackbed

Ballast Trackbed

Effect of Ballast Thickness

Asphalt Track Bed Subgrade Modulus 12000 psi, Axle Load 36 ton		
Asphalt Thickness - 4 Ballast Thickness - 10	Tensile Strain in the asphalt	0.000167
	Compressive Stress on Subgrade	12.6
	Service life of Asphalt Layer	23.77
	Service life of subgrade layer	10.36
Asphalt Thickness - 6 Ballast Thickness - 8	Tensile Strain in the asphalt	0.000183
	Compressive Stress on Subgrade	11.9
	Service life of Asphalt Layer	20.42
	Service life of subgrade layer	15.51
Asphalt Thickness - 8 Ballast Thickness - 6	Tensile Strain in the asphalt	0.000180
	Compressive Stress on Subgrade	11.0
	Service life of Asphalt Layer	22.37
	Service life of Subgrade layer	23.3

Effect of Ballast Thickness

Ballast Track Bed Subgrade Modulus 12000 psi, Axle Load 36 ton		
Subballast Thickness - 0 Ballast Thickness – 14	Compressive Stress on Subballast	N/A
	Compressive Stress on Subgrade	13.8
	Service life of Subballast Layer	N/A
	Service life of subgrade layer	5.56
Subballast Thickness - 6 Ballast Thickness - 8	Compressive Stress on Subballast	20.1
	Compressive Stress on Subgrade	13.7
	Service life of Subballast Layer	2.13
	Service life of subgrade layer	5.72
Subballast Thickness - 8 Ballast Thickness - 6	Compressive Stress on Subballast	23.4
	Compressive Stress on Subgrade	13.5
	Service life of Subballast Layer	1.26
	Service life of Subgrade layer	6.03

Predictive Values Versus In-track Data

Comparison of the KENTRACK Predictive values (KPV) Versus In-Track Data (ITD) for the CSX Mainline at Conway, Kentucky			
Thickness Ballast-HMA inches	Vertical Compressive Stress on **Ballast** KPV/TTD psi	Vertical Compressive Stress on **HMA** KPV/TTD psi	Vertical Compressive Stress on **Subgrade** KPV/TTD psi
10 / 5	47.9 / -	21.0 / 16.0	13.6 / -
10 / 8	48.7 / -	22.0 / 15.0	11.7 / -

Comparison of the KENTRACK Predictive values (KPV) Versus In-Track Data (ITD) at TTCI in Pueblo, Colorado			
Thickness Ballast-HMA inches	Vertical Compressive Stress on **Ballast** KPV/TTD psi	Vertical Compressive Stress on **HMA** KPV/TTD psi	Vertical Compressive Stress on **Subgrade** KPV/TTD psi
12 / 4	43.5 / -	11.7 / 14.9	8.3 / 8.0
8 / 8	47.0 / -	21.9 / 114.9	8.2 / 7.7

Summary

- KENTRACK is a versatile program that can be used to analyze HMA and all-granular trackbeds
- HMA trackbeds improve the service life and perform better than all-granular trackbeds
- Damage analysis values are conservative
- Subgrade modulus is a very important factor in trackbed design

Future Research

- Study the aging of HMA in railroad trackbeds.
- Develop damage analysis equations for HMA and all-granular trackbeds.
- Attempt to incorporate dynamic factors in the analysis.

KENTRACK Version 2.0.1

- Modified from DOS to Windows with a Graphic User Interface
- Values can be modified easier than the previous version
- Data files can be opened using the new version
- Input and output files can be accessed easily

KENTRACK Version 2.0.1

Contains:

- Program
- Help File
- Example Data Files

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Questions

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