

JRC2010-36067

**KENTRACK, A PERFORMANCE-BASED LAYERED ELASTIC RAILWAY TRACKBED
STRUCTURAL DESIGN AND ANALYSIS PROCEDURE – A TUTORIAL**

Jerry G. Rose
University of Kentucky
Lexington, KY USA

Nithin K. Agarwal
University of Kentucky
Lexington, KY USA

Justin D. Brown
University of Kentucky
Lexington, KY USA

Neeharika Ilavala
University of Kentucky
Lexington, KY USA

ABSTRACT

KENTRACK is a layer elastic finite element based computer program that can be utilized for a performance-based structural design and analysis of railway trackbeds. Kentrack was initially developed to analyze traditional all-granular layered trackbeds and asphalt layered trackbeds. The versatility was recently expanded to analyze trackbeds containing a combination of granular and asphalt layers. The principle factor in the analysis is to limit vertical compressive stresses on the subgrade. In addition, it is possible to consider the fatigue lives of the various layers relative to the effects of wheel loads, tonnages, environmental conditions and other factors.

The service lives of the individual components of the trackbed are predicted by damage analysis for various combinations of traffic, tonnages, subgrade support, component layer properties and thicknesses. The latest version, KENTRACK 3.0, is coded in C#.NET, a popular computer language for achieving accuracy and efficiency. The graphical user interface in the KENTRACK 3.0 provides a technique to analyze trackbeds as structures.

It is possible with KENTRACK 3.0 to select trackbed layers and associated thicknesses to satisfy roadbed and trackbed performance requirements. In addition, it is possible to performance-rank different track sectional designs based on the relative importance of the particular track section and track type. The types of roadbed and trackbed configurations are selected to meet each of the various performance ranks. The various steps involved in the calculations are highlighted during the tutorial phase of a sample design calculations and analysis.

INTRODUCTION

In order to develop a structural design and analysis procedure for railway trackbeds it is necessary to understand track behavior as a function of loading conditions, material properties, and track configuration. Starting in 1913 and continuing through 1942, the A. N. Talbot Joint Committee validated the basic theory of beam on elastic foundation and developed empirical equations as aids for track design (AREA, 1980). The model consists of a continuous beam representing the rail on an elastic Winkler-type foundation supported by the combined effect of ties, ballast, subballast, and subgrade. The foundation is assumed to have sufficient stiffness or track modulus to resist the imposed loadings on the rail.

Later, computer models were developed utilizing combinations of finite element analysis and layered systems. These include FEARAT (Fateen, 1972), ILLITRACK (Robnett, et al., 1976), and GEOTRACK (Chang, et al., 1980). Reference (Huang, et al., 1984) contains summary descriptions of these programs.

KENTRACK

Basic Theory

KENTRACK is a layer elastic finite element based computer program developed at the University of Kentucky in the early 1980s (Huang, et al., 1984). The program applies Burmister's Multi-Layer System Theory and Finite Element Analysis to calculate stresses and strains in railway trackbeds. Based on the critical stresses and strains in the trackbed, design lives for the various trackbed component layers can be predicted by the cumulative damage concept. This is based on the fatigue effects of the repeated loadings on the materials in the various layers.

In addition to analyzing all-granular trackbeds, KENTRACK was specifically developed for analyzing trackbeds containing a layer of asphalt. The primary failure criterion for the all-granular trackbed is the cumulative effects of the vertical compressive stresses on the subgrade leading to excessive permanent deformation. However, since an asphalt layer can resist deformation as a function of its tensile strength, an additional failure criterion – tensile strain at the bottom of the asphalt layer – was included in the analysis to limit cracking. The subgrade vertical compressive stress failure criterion is also applicable.

The loading configuration in KENTRACK uses the Superposition Principle and Track Symmetry for distributing the wheel loads over several ties (Huang, et al., 1984). The Damage Factors are calculated based on highway failure criteria used in the DAMA program (Asphalt Institute, 1982; Hwang & Witczak, 1979). This program is widely applied for the structural design and analysis of highway pavements. Additional aspects and discussion of the loading configuration and failure criteria analyses are presented in (Huang, et al., 1987), (Rose, et al., 2003), and (Rose and Konduri, 2006).

Development

The initial KENTRACK program was developed with FORTRAN language on Disk Operating System (DOS) platform. This was later modified to a Graphic User Interface (GUI) application running on a Windows platform (Rose and Konduri, 2006). This version, known as KENTRACK 2.0.1, allowed users to change various properties of the track structure more effectively than with the original version. No major changes were made to the FORTRAN code that was used to carry out the analysis.

The KENTRACK 2.0.1 version was validated by comparing predictive stress values at critical interfaces in the track structure with in-situ stress measurements. Geokon Earth Pressure Cells and Tekscan Piezoelectric Film Sensors, composed of a matrix-based array of force sensitive cells, were used to measure stress levels within the track structure. Multiple track sites were evaluated. The in-track measurements confirmed the predictive values from KENTRACK thus providing the program with a measure of credibility (Rose, et al., 2004).

Although the KENTRACK 2.0.1 program was made more user friendly by allowing the user to input and change values easily, it had several limitations. The program did not have a default set of values and the coding was done in FORTRAN which restricts any further developments since the FORTRAN language is not used by most software engineers. The program did not carry out validations for the input parameters and this often resulted in abrupt termination of the program. There were no separate analysis options for different trackbed analysis and users were required to enter all values irrespective of the analysis. Visual Studio platforms, such as the one utilized in the development of KENTRACK 3.0, have

proven to be more accurate, efficient, and easy-to-handle than FORTRAN.

MATLAB software, a numerical computing environment and fourth generation programming language widely utilized by engineers, was selected to evaluate the FORTRAN and Visual Studio accuracy of calculations. The differences in computed values were insignificant. This supports the fact that the 3.0 version is as or more accurate and efficient as the 2.0.1 version.

KENTRACK VERSION 3.0

KENTRACK 3.0 is developed entirely on .Net framework using C#. The core structure of KENTRACK 3.0 is similar to that of KENTRACK 2.0.1. The latest version has a similar GUI as the previous version but with additional features and benefits. KENTRACK 3.0 has inbuilt default set of parameters that are displayed once the user starts the program. The user is given the task to select minimum options from the drop down menu in limited places which gives the user the option to choose from a set of appropriate values rather than estimating or entering random numbers. Users can also enter any values desired other than the default numbers. This expands the versatility of the program. There is also a “Help” radio button on the top left side of frames that the user can click to open help files related to the software. Code is written to validate every tab frame to check if the user has selected at least one value for every parameter. An error message pops up if the user has not taken appropriate action. This avoids the abrupt termination of the program which was one of the main limitations of the previous 2.0.1 version. The performance of the application has been improved by implementing validations at the tab level. As in the previous version, this version also has provision to store the output in the hard drive of the active computer. This feature is enhanced by creating a link at the bottom of the result page which upon clicking directly opens the output file in Windows Notepad that can then be printed. For multiple analyses, users are required to save this Notepad under different File names since every analysis saves the output by default at the same location in the hard drive and by the same File name which basically is overwriting the older file. KENTRACK 3.0 clearly defines the different trackbed analyses by presenting an option in the first frame where the designer chooses among the three trackbed analysis options.

APPLICATION

KENTRACK 3.0 is applicable for analyzing three types of trackbed structures as depicted in Figure 1. The traditional All-Granular trackbed consists of four layers – ballast, subballast, subgrade, and bedrock. The primary failure criterion is the vertical compressive stress on the subgrade.

The Asphalt Underlayment trackbed contains a layer of asphalt in place of the granular subballast in a traditional trackbed. It also has four layers – ballast, asphalt, subgrade, and bedrock. Asphalt trackbeds are being widely accepted and

commonly considered as an alternate to the traditional all-granular trackbed. The asphalt layer is similar in composition to the asphalt mix used for highway pavements. Documented benefits are that the asphalt layer 1) strengthens trackbed support reducing subgrade stress, 2) waterproofs the roadbed to reduce subgrade moisture contents and fluctuations, and 3) provides a consistently high level of confinement for the ballast enhancing the shear strength of the ballast (Anderson and Rose, 2008), (Rose and Lees, 2008) (Rose and Bryson, 2009).

The Combination trackbed contains five layers – ballast, asphalt, subballast, subgrade, and bedrock. The subballast layer can be considered as an improved subgrade. This design is an alternate to the Asphalt Underlayment trackbed and contains subballast between the asphalt layer and subgrade.

MATERIAL PROPERTIES

The three trackbeds are comprised of combinations of ballast, asphalt, subballast, subgrade, and bedrock. These materials are considered elastic and different equations are used to describe their properties.

Ballast in a newly constructed trackbed behaves non-linearly and behaves linearly when considered in an aged trackbed that has become compacted. The resilient modulus of ballast is calculated using the following equation (Hwang and Witczak, 1979):

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

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

K_1 and K_2 = coefficients

$\sigma_1, \sigma_2, \sigma_3$ = the three principal stresses

γ = unit weight of the material

K_0 = lateral stress ratio

The dynamic modulus of asphalt is calculated using the method developed by the Asphalt Institute (Hwang and Witczak, 1979). To accurately model the asphalt, different temperatures should be used for the different periods since the dynamic modulus is dependent on the temperature.

Subballast and subgrade are always considered to be linearly elastic materials. The bottommost layer is bedrock which is considered to be incompressible with a Poisson's ratio of 0.5.

Damage Analysis

The service life of the layers is predicted by using the minor linear damage analysis criteria. The design life is calculated using (Hwang and Witczak, 1978):

$$L = 1 / \left(\sum_{i=1}^n \frac{N_p}{N_a \text{ or } N_d} \right) \quad (2)$$

Where, L = is the design life in years

N_p = predicted number of repetitions during each period

N_a or N_d = allowed number of repetitions during each period

N = number of periods

The passage of one car in a train is considered equivalent to one load repetition. This is based on extensive in-track test measurements for track deflections using extensimeters and layer interface pressures using earth pressure cells (Rose, et al., 2002) (Rose, 2008). The center portion of the car represents the “unloaded” phase. The predicted number of repetitions varies with the traffic that the trackbed is subjected. For an assumed $N_p = 200,000$ and 36,000 lb wheel load, the traffic would be 28.6 MGT. An illustration and calculations for the same are shown in Figure 2.

In the asphalt layer, the tensile strain at the bottom of the asphalt layer controls its service life. In subgrade soil, the permanent deformation controls its service life.

The number of allowable repetitions for the asphalt before the failure occurs is calculated using the following equation recommended by the Asphalt Institute (Asphalt Institute, 1982).

$$N_a = 0.0795 \varepsilon_1^{-3.291} E_a^{-0.853}$$

Where, ε_1 = horizontal tensile strain at the bottom of asphalt

E_a = elastic modulus of asphalt in psi

The equation was developed for asphalt layers for highway loadings and environments. The results are considered conservative relative to railway loadings and trackbed environments. The induced pressure on the asphalt layer is less in the trackbed (Anderson and Rose, 2008) and the degree of weathering of the asphalt is decreased significantly in the trackbed (Rose and Lees, 2008) relative to highway applications of asphalt.

The number of allowable repetitions for subgrade layer before failure occurs due to excessive vertical compressive stress is computed by the following equation (Huang, Lin, Deng, Rose, 1984).

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

Where, σ_c = vertical compressive stress on the top of subgrade in psi

E_a = subgrade modulus in psi, the primary failure criterion for all three types of trackbed structures

Thus the All-Granular Trackbed has only one primary failure criterion – vertical compressive stress on the top of the subgrade layer. Whereas, the other two types incorporating asphalt have an additional failure criterion – horizontal tensile strain at the bottom of the asphalt layer.

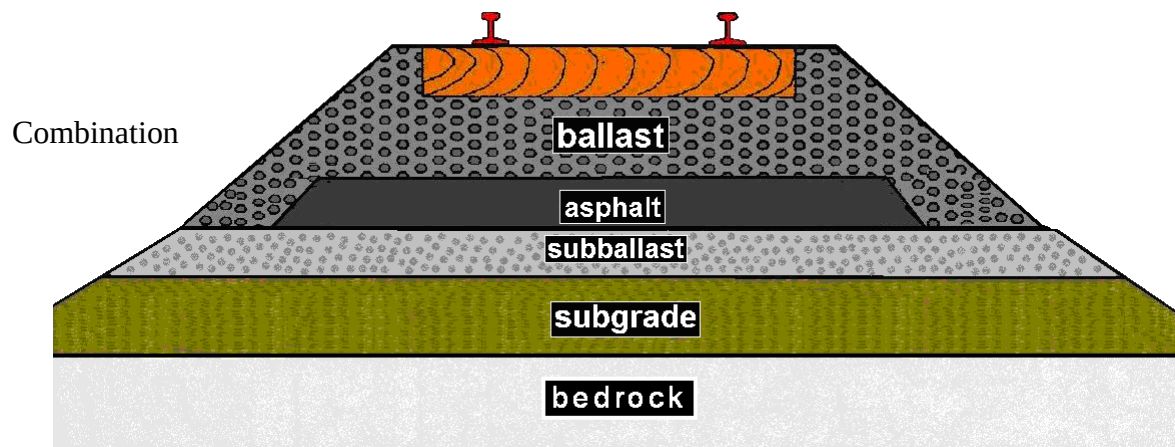
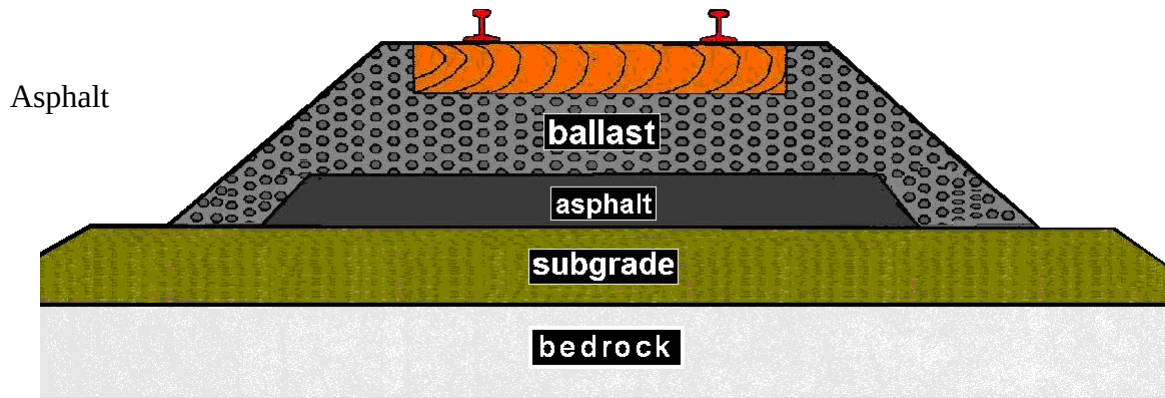
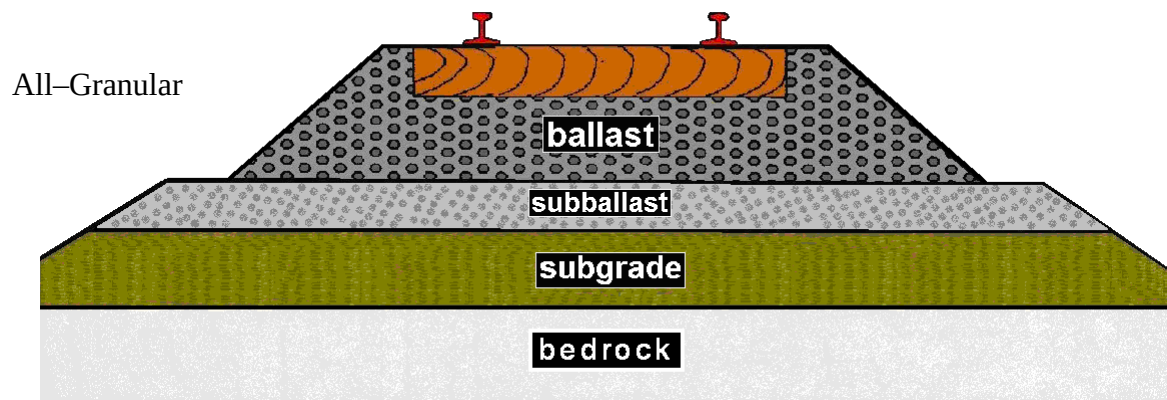
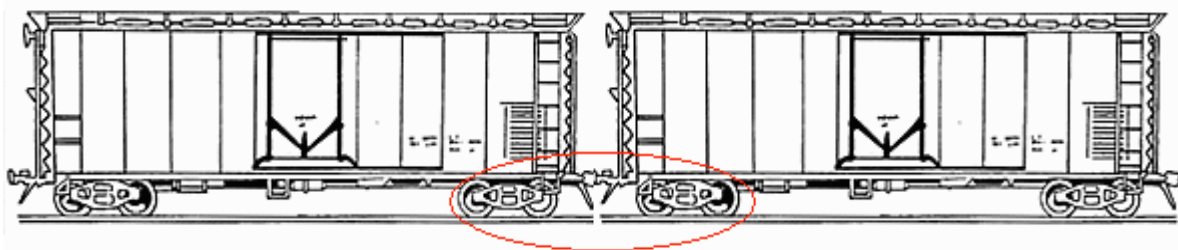


Figure 1. Three types of trackbed structures applicable for KENTRACK.



Wheel load	= 36,000 lb/wheel
For one car the total weight	= 36,000 lb/wheel x 8 = 286,000 lb/rep
	= 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
	= 28.6 MGT/yr

Figure 2. Million Gross Tons per year Calculation

STANDARD INPUT PARAMETERS

The Standard Input Parameters and associated Layer Properties for the All-Granular, Asphalt, and Combination trackbeds are presented in Appendix A as Tables A1, A2 and A3, respectively. Parameters denoted with an asterisk must be entered. Other parameters are entered as default values, but these can be replaced at the user's discretion.

TUTORIAL

Tutorial procedures and associated calculations for the three types of trackbeds are presented in Appendix B. Figure 3 identifies the various layers and default thicknesses for the three types of trackbeds used in the Tutorial. Wood ties and 136 RE rail are additional default values for the tutorial.

DATA PROTRAYAL

Data provided in Table 1 was obtained from the Tutorial for a subgrade modulus of 12,000 psi and an axle load of 36 tons, and is denoted by the bold data. Additional data obtained from varying subgrade modulus and axle load for the three types of trackbeds is also provided in Table 1. Subgrade modulus was varied from a moderately weak 6,000 psi to a reasonably strong 21,000 psi. Standard design axle loads of 33 and 36 tons and the anticipated 39 tons were selected for evaluation. This data is portrayed graphically in Figures 4 through 9.

EFFECTS OF VARIABLES

As demonstrated in the tutorial, KENTRACK is applicable for calculating stresses and strains in the trackbed and associated design lives for a specific set of design parameters. In addition, selected parameters can be varied in magnitude and the relative influences evaluated. Figures 4 through 9 depict several evaluations for assessing the effect of varying two variables – Subgrade Modulus and Axle Loads. The three track designs and associated layer dimensions, shown in

Figure 3, identify the X-sectional dimensions for the All-Granular, Asphalt, and Combination track designs. The combined thickness of 14 in. for the ballast and subballast/ asphalt layers was selected for the All-Granular and Asphalt designs. The Combination design utilizes the Asphalt design plus a 4-in. thick subballast layer for a total thickness of 18 in.

Effect of Varying Subgrade Modulus

Figures 4a and 4b show the Effect of Varying Subgrade Modulus on Subgrade Compressive Stress for the three track designs and on Asphalt Tensile Strain for the two asphalt track designs, respectively. Subgrade Compressive Stress increases as the Subgrade becomes stiffer. This fact is accepted based on previous analyses. However, the Tensile Strain at the bottom of the asphalt layer decreases as the subgrade becomes stiffer, since the asphalt deflects less with stiffer subgrades.

Figures 5a and 5b also show similar Effects of Varying Modulus and its effect on Design Life. Note in Figure 5a that as the subgrade becomes stiffer, the Subgrade Design Life increases significantly. This occurs even though the subgrade pressure increases (Fig. 4a). Also, the design lives for the two asphalt designs are significantly increased over that of the all-granular design. The importance of maintaining a stiff, high-modulus track support is readily apparent. Soft subgrades require frequent surfacing to correct track settlement and deformation, as indicated by the low design lives.

It is also apparent from Figure 5b that stiffer subgrades significantly increase the asphalt design lives for both the asphalt and combination trackbeds. A comparison of Figures 4a and 5a reveals that the two asphalt designs result in lower subgrade stresses and significantly longer design lives than the all-granular design.

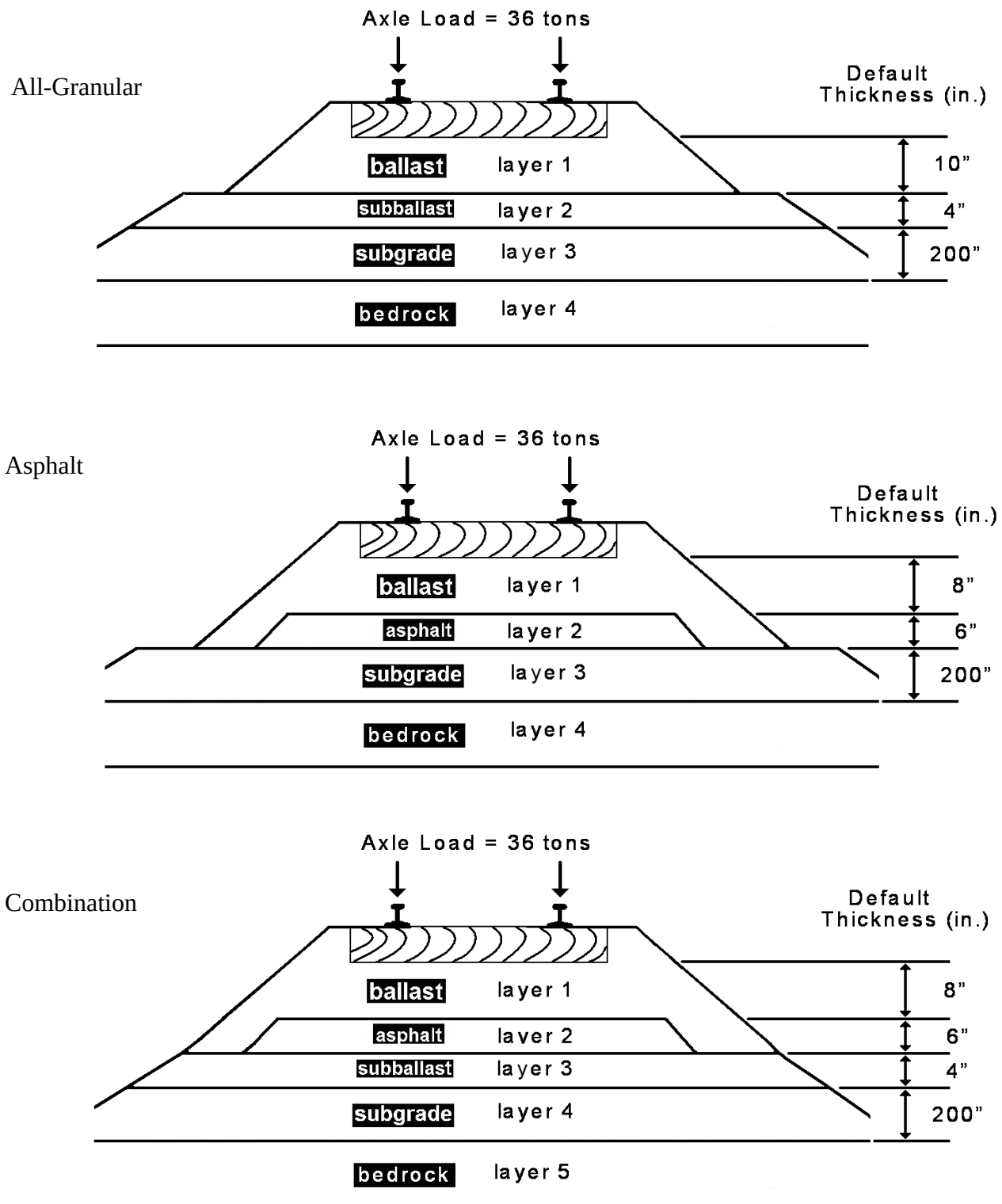


Figure 3. Default thicknesses for the trackbed layers utilized in the tutorial and data portrayal.

VISUAL STUDIO											
Trackbeds→		All-Granular Trackbed		Asphalt Trackbed				Combination Trackbed			
Axle Load (ton)	Subgrade Modulus (psi)	Layer 3 Subgrade Compressive Stress (psi)	Layer 3 Subgrade Life (years)	Layer 2 Asphalt Tensile Strain	Layer 3 Subgrade Compressive Stress (psi)	Layer 2 Asphalt Life (years)	Layer 3 Subgrade Life (years)	Layer 2 Asphalt Tensile Strain	Layer 4 Subgrade Compressive Stress (psi)	Layer 2 Asphalt Life (years)	Layer 4 Subgrade Life (years)
33	6000	9.63	1.77	0.000238	8.38	10.69	4.58	0.000205	7.70	15.04	5.73
	12000	12.28	8.52	0.000182	10.82	24.84	21.22	0.000150	9.63	39.28	30.42
	18000	14.23	21.02	0.000155	12.65	42.10	52.09	0.000119	10.80	70.41	82.01
	21000	15.06	29.59	0.000144	13.40	51.51	73.18	0.000112	11.35	85.40	118.44
36	6000	10.48	1.29	0.000261	9.09	7.99	3.39	0.000225	8.35	11.22	4.24
	12000	13.35	6.244	0.000199	11.76	18.85	15.68	0.000163	10.38	29.48	22.56
	18000	15.47	15.39	0.000169	13.76	31.26	38.05	0.000131	11.74	52.30	59.86
	21000	16.38	21.64	0.000158	14.58	38.21	53.37	0.000122	12.34	63.73	86.47
39	6000	11.32	0.97	0.000284	9.80	6.11	2.56	0.000245	9.01	8.54	3.22
	12000	14.41	4.69	0.000216	12.69	14.38	11.79	0.000177	11.20	22.49	16.97
	18000	16.71	11.56	0.000185	14.86	23.79	28.52	0.000142	12.67	39.94	44.90
	21000	17.68	16.24	0.000172	15.75	29.05	39.95	0.000133	13.33	48.71	64.79

Table 1. KENTRACK Output for Varying Axle Load and Subgrade Modulus.

Effect of Varying Axle Loads

Figures 6a, 6b, and 6c show similar data as contained in Figure 4a for the three designs, with additional data for 33 and 39-ton axle loads. The effect of increasing axle loads results in minimal increases in subgrade compressive stresses for a given subgrade modulus and trackbed design.

Figures 7a, 7b, and 7c show companion data to that in Figures 6a, 6b, and 6c, with the difference being as related to affecting Subgrade Design Life. The effect of increasing Axle Loads results in decreases in Subgrade Design Life for a given subgrade modulus and trackbed design.

Figures 8a and 8b show similar data as contained in Figure 4b for the two asphalt designs, with additional data for 33 and 39-ton axle loads. The effect of increasing Axle Loads results in minimal increases in Asphalt Tensile Strains for a given subgrade modulus and trackbed design.

Figures 9a and 9b show companion data to that in Figures 8a and 8b, except as related to affecting Asphalt Design Life. The effect of increasing Axle Loads results in decreases in Asphalt Design Life for a given subgrade modulus and trackbed design.

CLOSURE

The KENTRACK program, a layered elastic railway trackbed structural design procedure, has been described and presented using a Tutorial approach. The effects of varying track parameters on track stress/strain indices and predicted design lives of the track components have been demonstrated. The program provides the designer with an analytical procedure to aid the trackbed design process and for evaluating relative effects of varying track parameters. Further verification of the program's predictive values with in-track measurements will add additional credibility to the program.

ACKNOWLEDGEMENTS

Several graduate students have been involved with further development and updating of the program since the initial development. Those involved during the interim include – Charles Khoury, Bradley Long, Bei Su, Frank Twehues, Kumar Peddu, Karthik Konduri, and Shweta Padubidri. The National Asphalt Pavement Association and the Asphalt Institute participated during the initial development of the program. CSX Transportation has participated during the later development.

REFERENCES

- Anderson, J. and Rose, J. (2008). In-Situ Test Measurement Techniques Within Railway Track Structures, 2008 ASME/IEEE/ASCE Joint Rail Conference PROCEEDINGS, Wilmington, DE, 21 pages.
- AREA. (1980). Stresses in Railroad Track-The Talbot Reports, ASCE-AREA Special Committee on Stresses in Railroad Track, Reprinted as one volume by American Railway Engineering Association.
- Asphalt Institute. (1982). Research and Development of The Asphalt Institute's Thickness Design Manual (MS-1) Ninth Edition, Research Report 82-2, 150 pages.
- Chang, C.S., Adegoke, C.W., and Selig, E.T. (1980). GEOTRACK Model for Railroad Track Performance. *Journal of the Geotechnical Engineering Division*, ASCE, Vol. 106, No. GT 11, pp. 1201-1218.
- Fateen, S. (1972). *A Finite Element Analysis of Full Depth Asphalt Railway Track*, Master's Thesis, Department of Civil Engineering, University of Maryland.

Huang, Y.H., Lin, C., Deng, X. and Rose, J. (1984). KENTRACK, A Computer Program for Hot-Mix Asphalt and Conventional Ballast Railway Trackbeds, Asphalt Institute (Publication RR-84-1) and National Asphalt Pavement Association (Publication QIP-105), 164 pages.

Huang, Y.H., Rose, J. and Khoury, C. (1987). Thickness Design for Hot-Mix Asphalt Railroad Trackbeds, Asphalt Paving Technology 1987 AAPT, Vol. 56.

Hwang, D. and Witczak, M. (1978). Program DAMA (Chevron) User's Manual, Department of Civil Engineering, University of Maryland, September, pp. 9-11.

Hwang, D. and Witczak, M. (1979). Program DAMA (Chevron), User's Manual, Department of Civil Engineering, University of Maryland.

Robnett, Q.L., Thompson, M.R., Knutson, R.M., and Tayabji, S.D. (1975). Development of a Structural Model and Materials Valuation Procedures, Ballast and Foundation Materials Research Program, University of Illinois, report to FRA of US/DOT, Report No. DOT-FR-30038.

Rose, J. (2008). Test Measurements and Performance Evaluations of In-Service Railway Asphalt Trackbeds, Proceedings of the Transportation Systems 2008 Workshop, Phoenix, 17 pages.

Rose, J. and Lees, H. (2008). Long-Term Assessment of Asphalt Trackbed Component Materials' Properties and Performance, Proceedings of the 2008 AREMA Conference, 28 pages.

Rose, J., Li, D. and Walker, L. (2002). Tests and Evaluations of In-Service Asphalt Trackbeds, Proceedings of the 2002 AREMA Conference, 16 pages.

Rose, J. and Konduri, K. (2006). KENTRACK—A Railway Trackbed Structural Design Program, Proceedings of the 2006 AREMA Annual Conference, 31 pages.

Rose, J. and Bryson, L. (2009). Hot-Mix Asphalt Railway Trackbeds: Trackbed Materials, Performance Evaluations, and Significant Implications," 2009 International Conference on Perpetual Pavements, Ohio Research Institute for Trans. and Envir., Columbus, OH, 19 pages.

Rose, J., Su, Bei and Twehues, F. (2004). Comparisons of Railroad Track and Substructure Computer Model Predictive Stress Values and In-situ Stress Measurements, Proceedings of the 2004 AREMA Annual Conference, 17 pages.

Rose, J., Su, Bei and Long, W. (2003). KENTRACK: A Railway Trackbed Structural Design and Analysis Program, Proceedings of the 2003 AREMA Annual Conference, 25 pages.

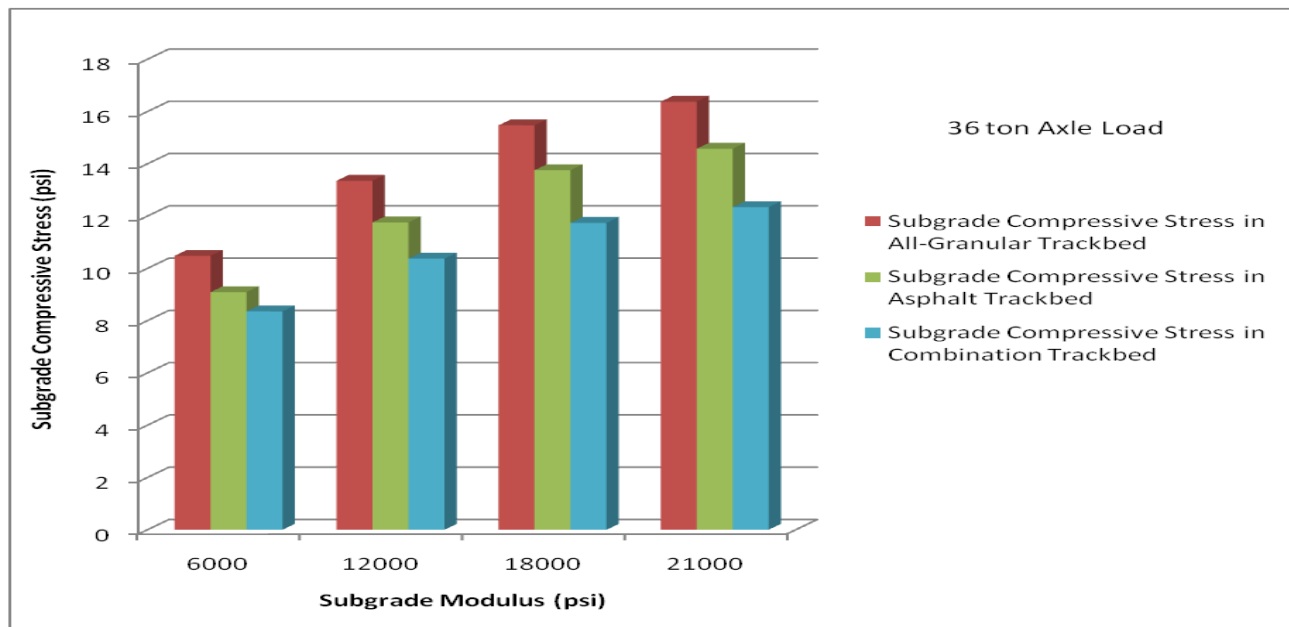


Figure 4a. Effect of Subgrade Modulus on Subgrade Compressive Stress

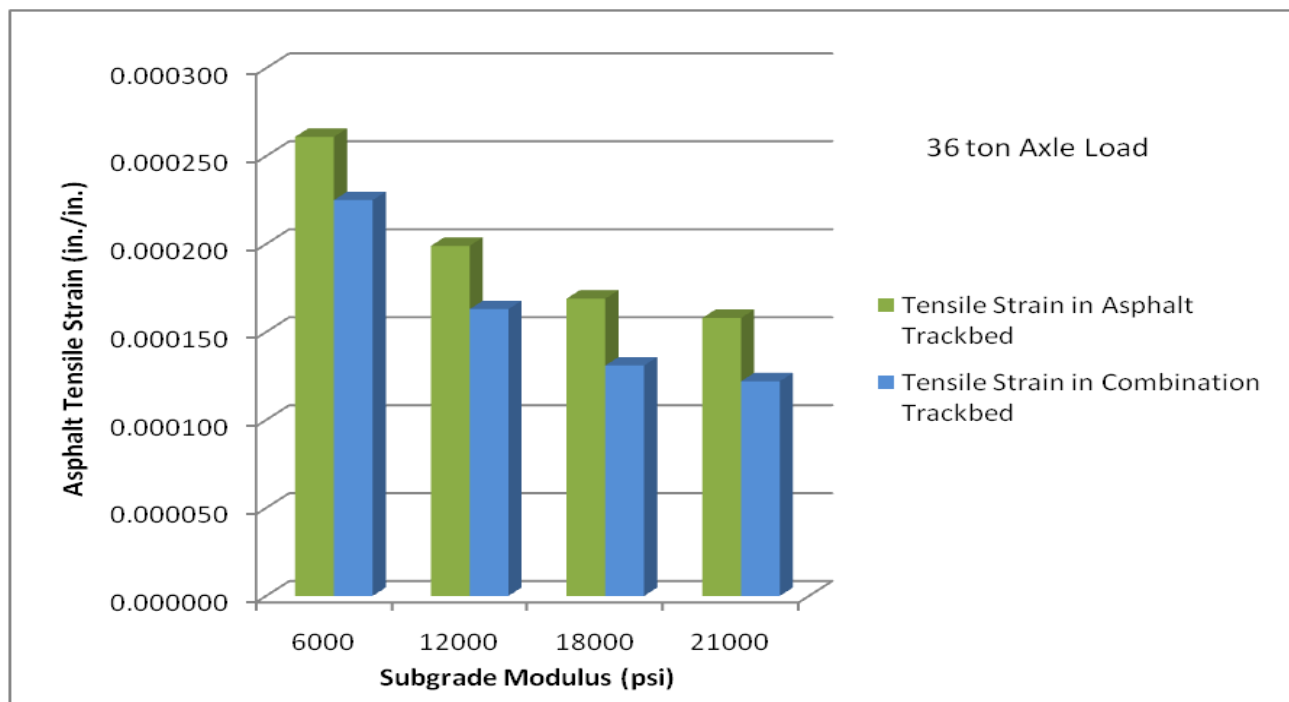


Figure 4b. Effect of Subgrade Modulus on Asphalt Tensile Strain

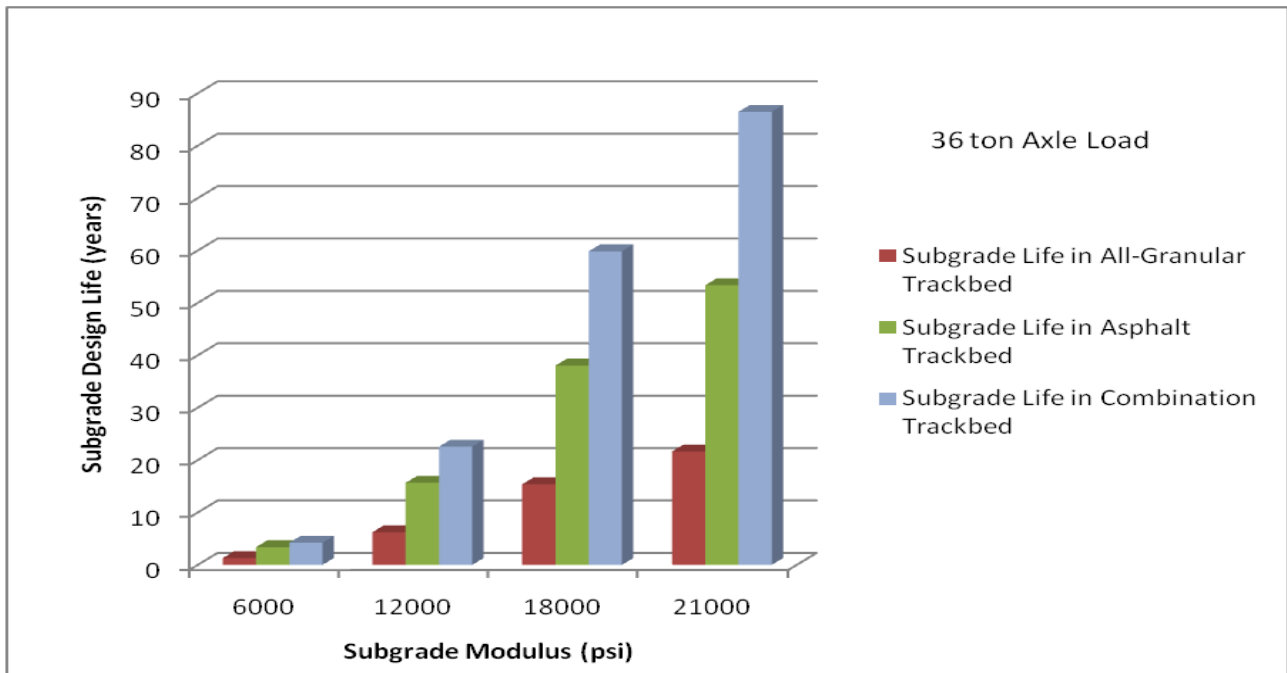


Figure 5a. Effect of Subgrade Modulus on Subgrade Design Life

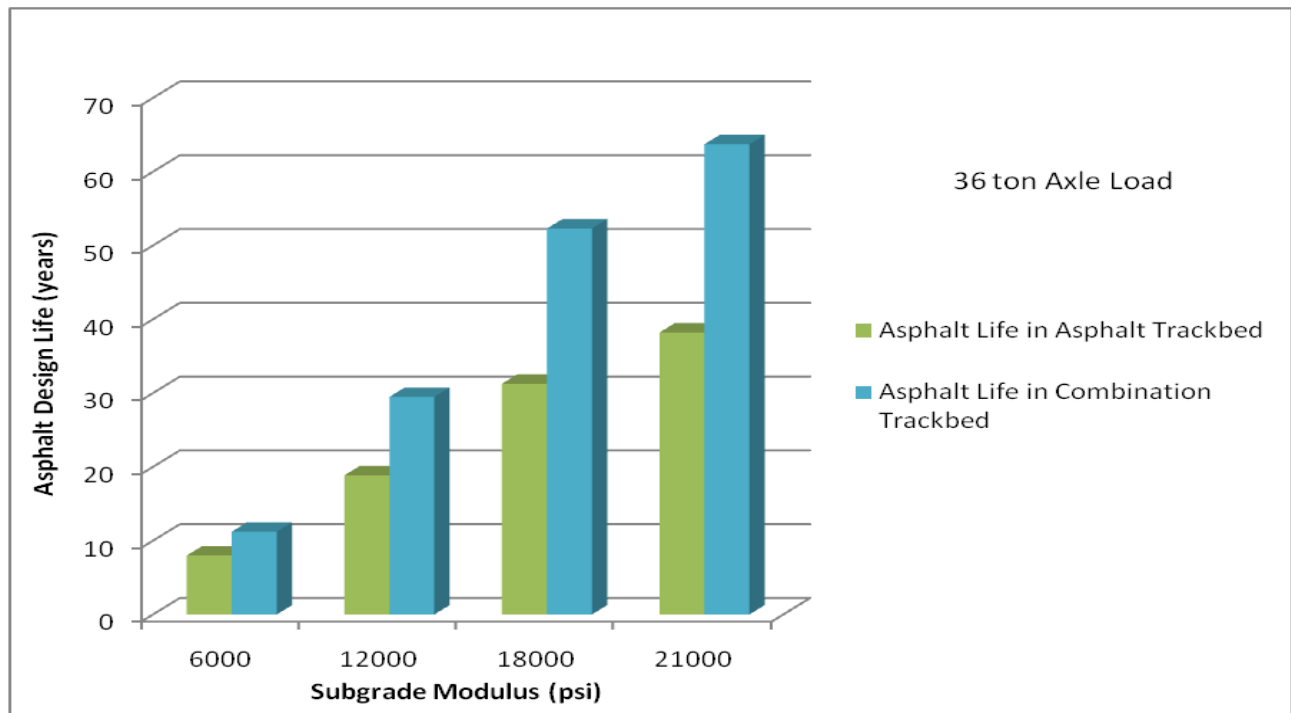


Figure 5b. Effect of Subgrade Modulus on Asphalt Design Life

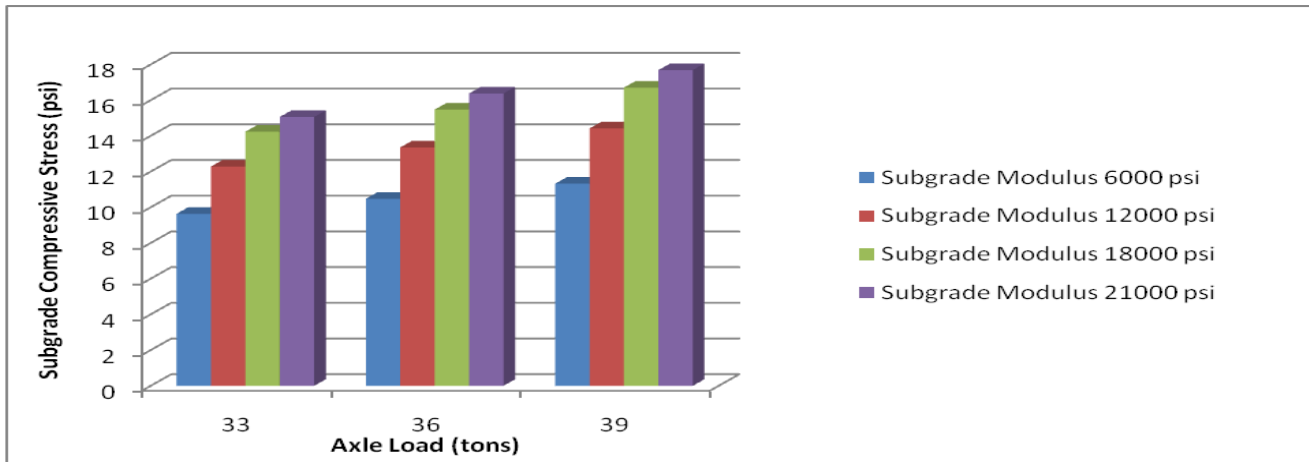


Figure 6a. Effect of Axle Load on Subgrade Compressive Stress in All-Granular Trackbed

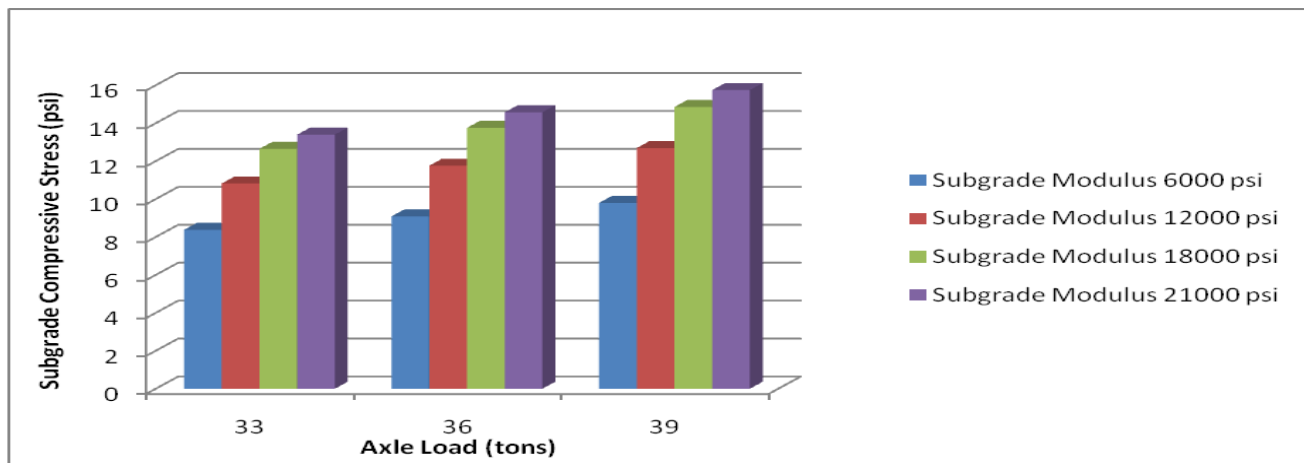


Figure 6b. Effect of Axle Load on Subgrade Compressive Stress in Asphalt Trackbed

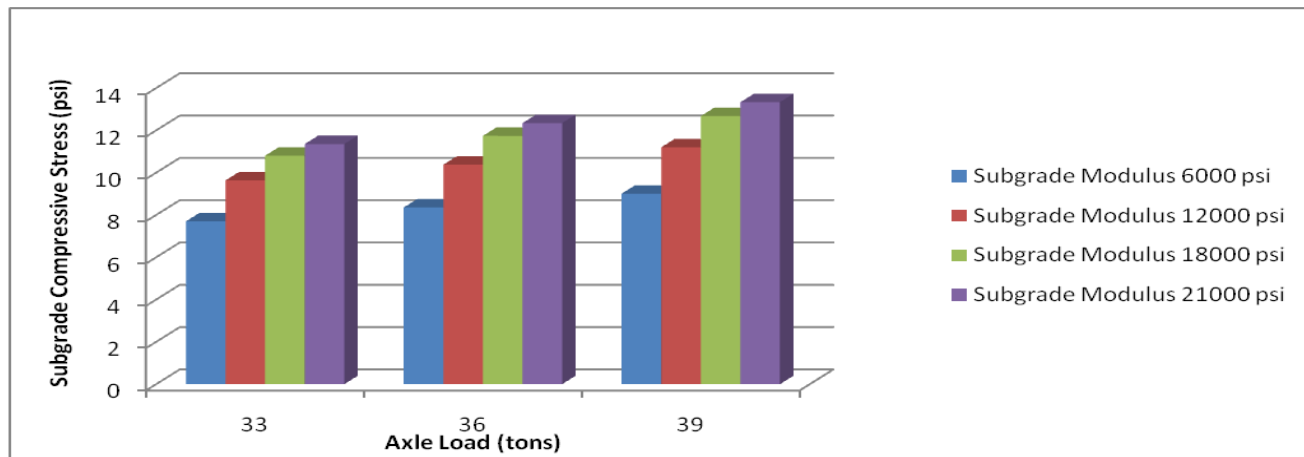


Figure 6c. Effect of Axle Load on Subgrade Compressive Stress in Combination Trackbed

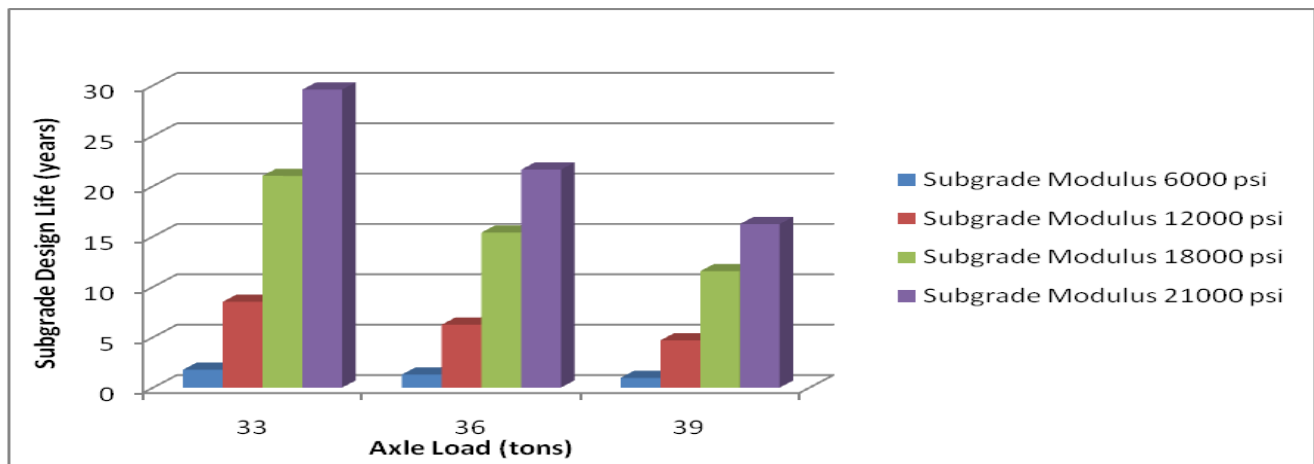


Figure 7a. Effect of Axle Load on Subgrade Design Life in All-Granular Trackbed

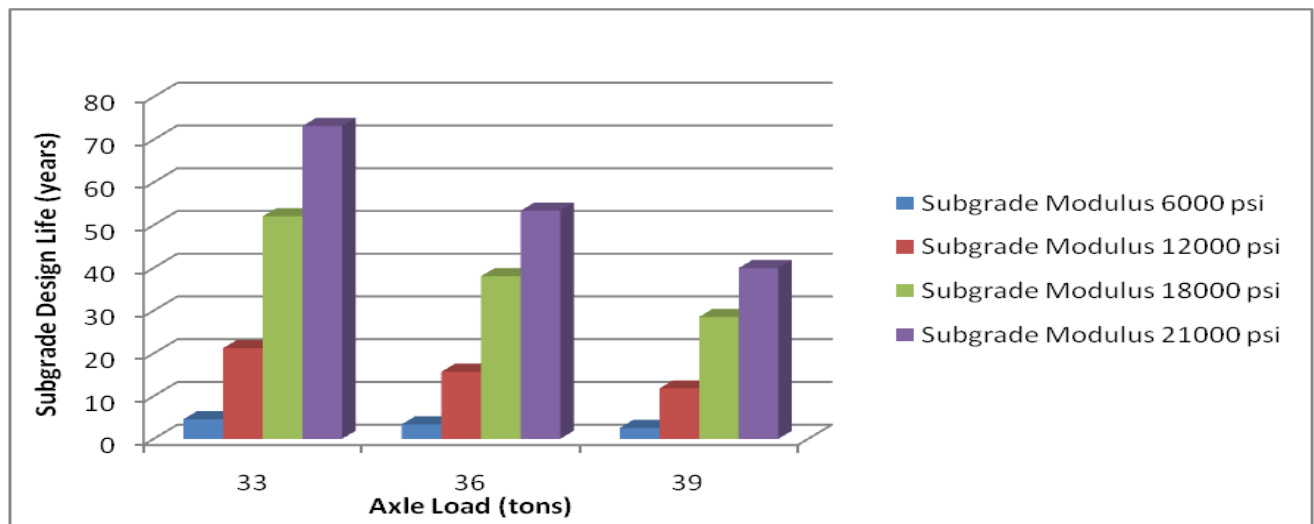


Figure 7b. Effect of Axle Load on Subgrade Design Life in Asphalt Trackbed

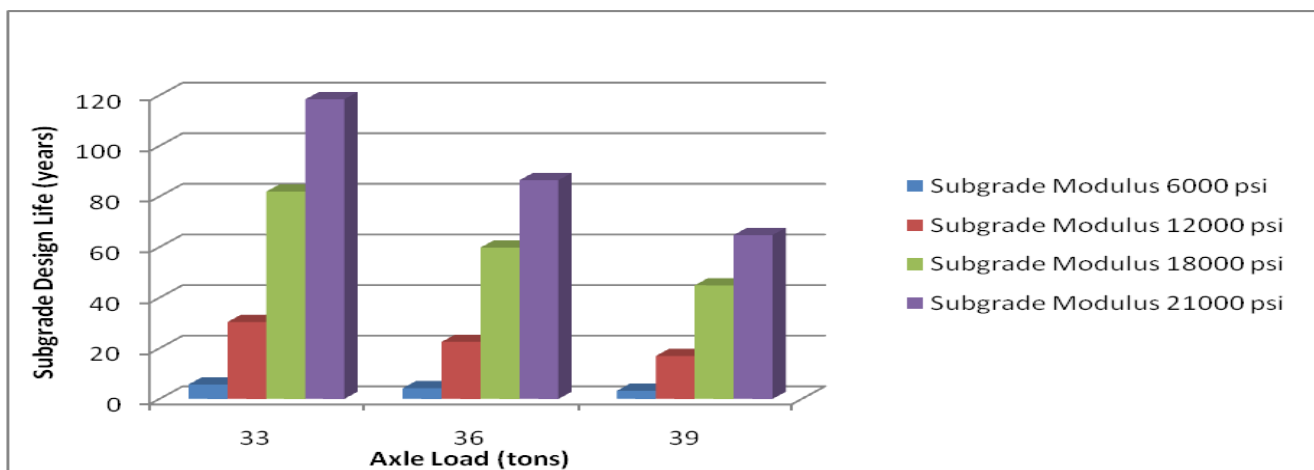


Figure 7c. Effect of Axle Load on Subgrade Design Life in Combination Trackbed

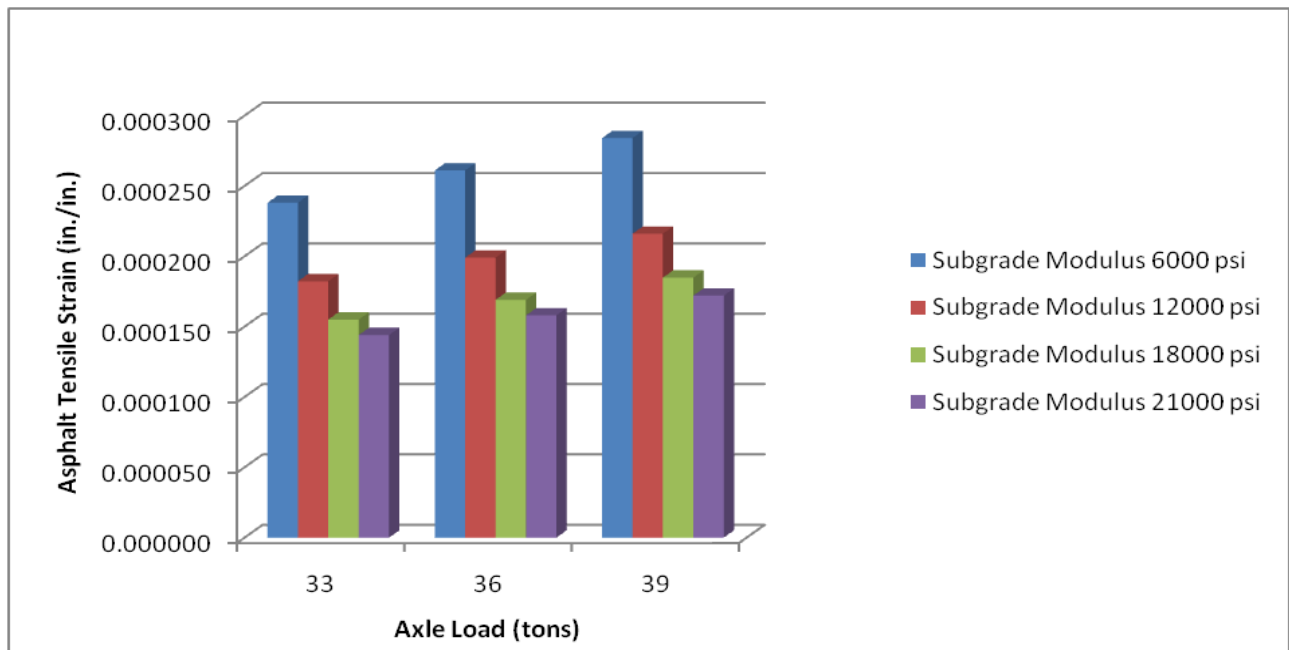


Figure 8a. Effect of Axle Load on Asphalt Tensile Strain in Asphalt Trackbed

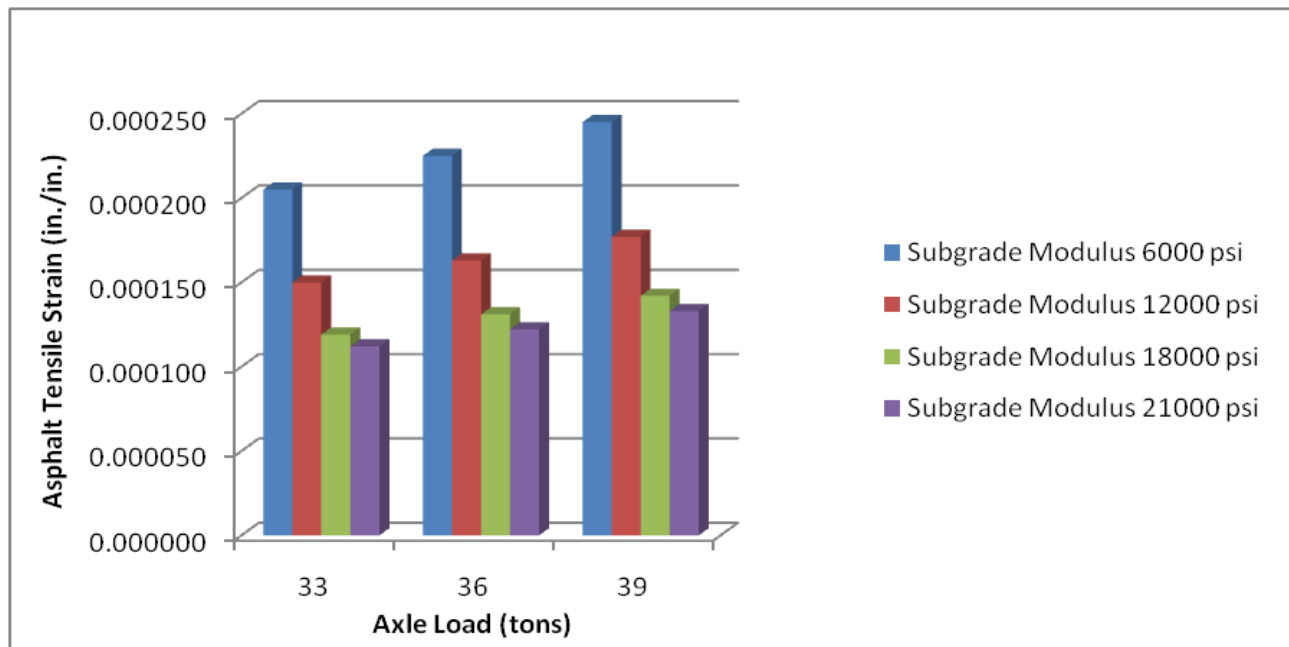


Figure 8b. Effect of Axle Load on Asphalt Tensile Strain in Combination Trackbed

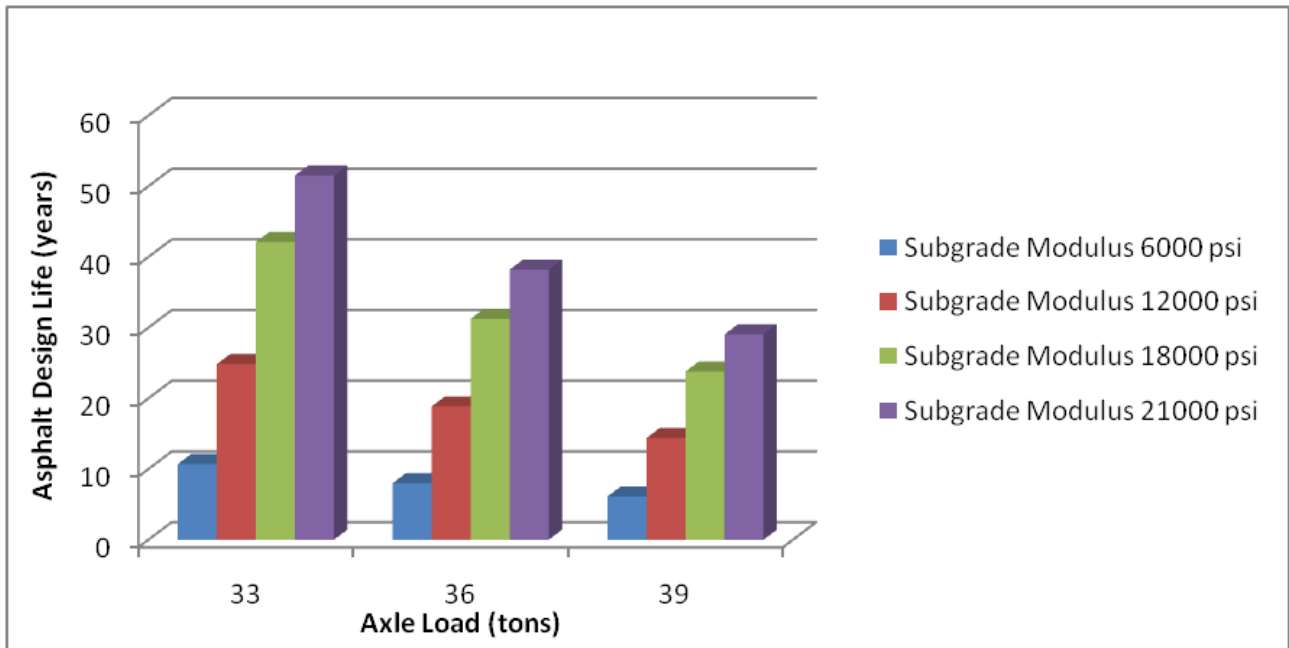


Figure 9a. Effect of Axle Load on Design Life of Asphalt Layer in Asphalt Trackbed

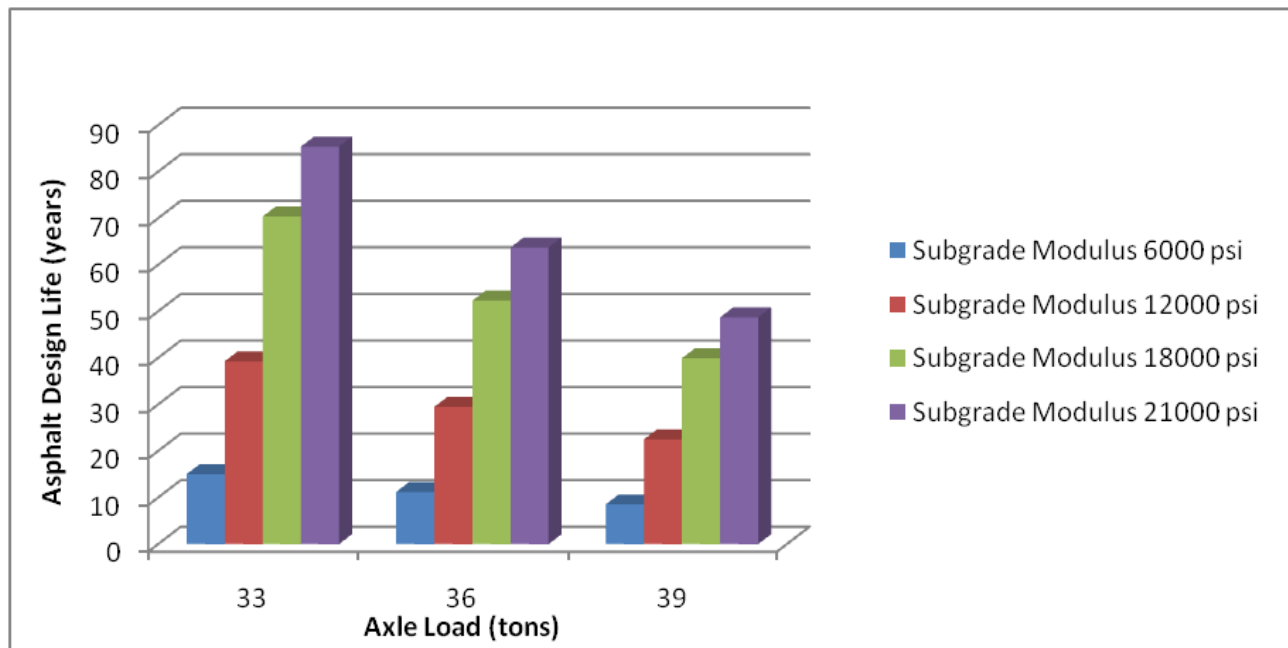


Figure 9b. Effect of Axle Load on Design Life of Asphalt Layer in Combination Trackbed

APPENDIX A1

TABLE A1a. STANDARD INPUT PARAMETERS FOR ALL-GRANULAR TRACKBED

PARAMETER NAME	STANDARD INPUT
Project Title	Test
Unit System	FPS
Model Type	Layer
Damage Analysis	Yes
Trackbed*	Granular
Rail Type	RE 136
Rail Section Modulus (in. ³)	23.9
Rail Young Modulus (psi)	30,000,000
Rail Moment of Inertia (in. ⁴)	94.9
Rail Tie Spring Constant (lb/in.)	7,000,000
Type of Tie*	Wood
Number of Transverse Points	7
Tie Thickness (in.)	7
Tie Width (in.)	9
Tie Moment of Inertia (in. ⁴)	257.25
Wood Tie Young Modulus (psi)	1,500,000
Tie Spacing* (in.)	20
Number of Periods*	4 (Spring, Summer, Autumn, Winter)
Select period for output*	Period 1
Location Number of Rail on Tie	4
Length of Tie (in.)	108
Center to Center Distance between Rails (in.)	59.5
Distance between Points 1 and 2 in Transverse Direction (in.)	15
First Tie Number for Superposition*	3
Last Tie Number for Superposition*	6
Cross Section	Uniform
Number of Axle Loads*	2
Number of Ties for Single Axle Analysis	6
Wheel Load (lb)	36,000
Number of Track Layers Including Subgrade	4
Tolerance for Vertical Deflection	0.00001
Tolerance for Tensile Stress	0.01
Number of Layers for Vertical Compression at Top*	1
Select Layers to Compute Compression at the Top*	Layer 3
Rail Weight per Unit Length (lb/in.)	3.78
Tie Unit Weight (lb/in. ³)	0.029
Cribbing Material Unit Weight (lb/in. ³)	0.064
Nonlinear Analysis Tolerance	0.01
Load Repetition	50,000
Deformation Parameter 1	0.00004837
Deformation Parameter 2	3.734
Deformation Parameter 3	3.583

TABLE A1b. LAYER PROPERTIES FOR ALL-GRANULAR TRACKBED

LAYER	POISSON'S RATIO	K2 COEF	YOUNG'S MODULUS (psi)	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
1 - Ballast	0.35	0.5	18000	18000	18000	18000	18000
2 - Sub-Ballast	0.35	0.5	20000	20000	20000	20000	20000
3 - Subgrade	0.4	0	12000	12000	12000	12000	12000
4 - Bed Rock	0.5	0	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹

LAYER	LAYER THICKNESS (in.)	MINIMUM YOUNG'S MODULUS (psi)	UNIT WEIGHT (lb/in. ³)	EARTH PRESSURE COEF
1 - Ballast	10	18000	0.064	0.8
2 - Sub-Ballast	4	200000	0.064	0.8
3 - Subgrade	200	12000	0.078	0.5

APPENDIX A2

TABLE A2a. STANDARD INPUT PARAMETERS FOR ASPHALT TRACKBED

PARAMETER NAME	STANDARD INPUT
Project Title	Test
Unit System	FPS
Model Type	Layer
Damage Analysis	Yes
Trackbed*	Asphalt
Rail Type	RE 136
Rail Section Modulus (in. ³)	23.9
Rail Young Modulus (psi)	30,000,000
Rail Moment of Inertia (in. ⁴)	94.9
Rail Tie Spring Constant (lb/in.)	7,000,000
Type of Tie*	Wood
Number of Transverse Points	7
Tie Thickness (in.)	7
Tie Width (in.)	9
Tie Moment of Inertia (in. ⁴)	257.25
Wood Tie Young Modulus (psi)	1,500,000
Tie Spacing* (in.)	20
Number of Periods*	4 (Spring, Summer, Autumn, Winter)
Location Number of Rail on Tie	4
Length of Tie (in.)	108
Center to Center Distance between Rails (in.)	59.5
Distance between Points 1 and 2 in Transverse Direction (in.)	15
First Tie Number for Superposition*	3
Last Tie Number for Superposition*	6
Cross Section	Uniform
Number of Axle Loads*	2
Number of Ties for Single Axle Analysis	6
Wheel Load (lb)	36,000
Number of Track Layers Including Subgrade*	4
Asphalt Layer*	Layer 2
Tolerance for Vertical Deflections	0.00001
Tolerance for Tensile Stress	0.01
Number of Layers for Vertical Compression at Top*	1
Number of Layers for Horizontal Tension at Bottom*	1
Select Layers to Compute Tension at the Bottom*	Layer 2
Select Layers to Compute Compression at the Top*	Layer 3
Asphalt Temperatures (°F)	50 (Spring) 67 (Summer) 33 (Autumn) 20 (Winter)
% Passing No. 200 Sieve	5.5
% Air Voids	5.7
% Volume of Bitumen	13.5
Asphalt Viscosity (X 10 ⁶ poise)	2.5
Load Frequency (Hz)	1
Rail Weight per Unit Length (lb/in.)	3.78
Tie Unit Weight (lb/in. ³)	0.029
Cribbing Material Unit Weight (lb/in. ³)	0.064
Nonlinear Analysis Tolerance	0.01

Load Repetition	50,000
Fatigue Parameter 1	0.0795
Fatigue Parameter 2	3.291
Fatigue Parameter 3	0.854
Deformation Parameter 1	0.00004837
Deformation Parameter 2	3.734
Deformation Parameter 3	3.583

TABLE A2b. LAYER PROPERTIES FOR ASPHALT TRACKBED

LAYER	POISSON'S RATIO	K2 COEF	YOUNG'S MODULUS (psi)	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
1 - Ballast	0.35	0.5	7000	7000	7000	7000	7000
2 - Asphalt	0.45	0	600000	698000	372000	1250000	2260000
3 - Subgrade	0.4	0	12000	12000	12000	12000	12000
4 - Bed Rock	0.5	0	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹

LAYER	LAYER THICKNESS (in.)	MINIMUM YOUNG'S MODULUS (psi)	UNIT WEIGHT (lb/in. ³)	EARTH PRESSURE COEF
1 - Ballast	8	7000	0.064	0.8
2 - Asphalt	6	600000	0.087	0.5
3 - Sub-Ballast	200	12000	0.078	0.5

APPENDIX A3

TABLE A3a. STANDARD INPUT PARAMETERS FOR COMBINATION TRACKBED

PARAMETER NAME	STANDARD INPUT
Project Title	Test
Unit System	FPS
Model Type	Layer
Damage Analysis	Yes
Trackbed*	Combination
Rail Type	RE 136
Rail Section Modulus (in. ³)	23.9
Rail Young Modulus (psi)	30,000,000
Rail Moment of Inertia (in. ⁴)	94.9
Rail Tie Spring Constant (lb/in.)	7,000,000
Type of Tie*	Wood
Number of Transverse Points	7
Tie Thickness (in.)	7
Tie Width (in.)	9
Tie Moment of Inertia (in. ⁴)	257.25
Wood Tie Young Modulus (psi)	1,500,000
Tie Spacing* (in.)	20
Number of Periods*	4 (Spring, Summer, Autumn, Winter)
Location Number of Rail on Tie*	4
Length of Tie (in.)	108
Center to Center Distance between Rails (in.)	59.5
Distance between Points 1 and 2 in Transverse Direction (in.)	15
First Tie Number for Superposition*	3
Last Tie Number for Superposition*	6
Cross Section	Uniform
Number of Axle Loads*	2
Number of Ties for Single Axle Analysis	6
Wheel Load (lb)	36,000
Number of Track Layers Including Subgrade*	5
Asphalt Layer*	Layer 2
Tolerance for Vertical Deflections	0.00001
Tolerance for Tensile Stress	0.01
Number of Layers for Vertical Compression at Top*	1
Number of Layers for Horizontal Tension at Bottom*	1
Select Layers to Compute Horizontal Tension at the Bottom*	Layer 2
Select Layers to Compute Compression at the Top*	Layer 4
Asphalt Temperatures (°F)	50(Spring) 67(Summer) 33(Autumn) 20(Winter)
% Passing No.200 Sieve	5.5
% Air Voids	5.7
% Volume of Bitumen	13.5
Asphalt Viscosity (X 10 ⁶ poise)	2.5
Load Frequency (Hz)	1
Rail Weight per Unit Length (lb/in.)	3.78
Tie Unit Weight (lb/in. ³)	0.029
Cribbing Material Unit Weight (lb/in. ³)	0.064
Nonlinear Analysis Tolerance	0.01

Load Repetition	50,000
Fatigue Parameter 1	0.0795
Fatigue Parameter 2	3.291
Fatigue Parameter 3	0.854
Deformation Parameter 1	0.00004837
Deformation Parameter 2	3.734
Deformation Parameter 3	3.583

TABLE A3b. LAYER PROPERTIES FOR COMBINATION TRACKBED

LAYER	POISSON'S RATIO	K2 COEF	YOUNG'S MODULUS (psi)	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
1 - Ballast	0.35	0.5	7000	7000	7000	7000	7000
2 - Asphalt	0.45	0	600000	698000	372000	1250000	2260000
3 - Sub-Ballast	0.35	0.5	3500	3500	3500	3500	3500
4 - Subgrade	0.4	0	12000	12000	12000	12000	12000
5 - Bed Rock	0.5	0	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹	(10) ¹⁹

LAYER	LAYER THICKNESS (in.)	MINIMUM YOUNG'S MODULUS (psi)	UNIT WEIGHT (lb/in. ³)	EARTH PRESSURE COEF
1 - Ballast	8	7000	0.064	0.8
2 - Asphalt	6	600000	0.087	0.5
3 - Sub Ballast	4	3500	0.064	0.8
4 - Subgrade	200	12000	0.078	0.5

APPENDIX B 1

Kentrack 3.0 Step-by-Step Procedure for All-Granular Trackbed

Step 1: Double - Click on Kentrack 3.0

Step 2: Enter Project Title

Step 3: Choose the Trackbed Value

Step 4: Click on Submit Button

The screenshot shows the 'INITIAL PROJECT SPECIFICATION' window in Kentrack 3.0. The window has a title bar with the text 'Kentrack' and standard window controls. The main area contains several input fields and radio button groups. Annotations with arrows point to specific elements:

- Step 2** points to the 'Project Title' label, which is circled in red. The adjacent text input field contains the word 'Test'.
- Step 3** points to the 'Trackbed' label, which is circled in red. The adjacent radio button group has three options: 'All- Granular' (selected), 'Asphalt', and 'Combination'.
- Step 4** points to the 'Submit' button, which is circled in red.

Other visible elements include the 'Unit System' group with 'SI' and 'FPS' radio buttons (FPS is selected), the 'Model Type' group with a 'Layer' radio button, and the 'Damage Analysis' group with 'Yes' and 'No' radio buttons (Yes is selected).

Step 5: Select the Rail Type Value From the Drop-Down Box

Step 6: Click Next

The screenshot shows the 'Kentrack Input' software window with the 'Rail' tab selected. The interface includes a dropdown menu for 'Select Rail type' and input fields for 'Rail Section Modulus', 'Rail Youngs Modulus', 'Rail Moment of Inertia', and 'Rail Tie Spring Constant'. The 'Next >>' button is located at the bottom right of the form.

Step 5 → Select Rail type

Rail Section Modulus (in³)

Rail Youngs Modulus (psi)

Rail Moment of Inertia (in⁴)

Rail Tie Spring Constant (lb/in)

Next >> **Step 6**

Step 7: Select Tie Type: Wood (or) Concrete

Step 8: Select Tie Spacing

Step 9: Select Number of Periods as: 4

Step 10: Select Period for Output

Step 11: Select Last Tie Number for Superposition as: 6

Step 12: Select 3 and 6 in the Cross Section

Step 13: Click Next Button

The screenshot shows the 'Kentrack Input' software window with the 'Tie' tab selected. The interface contains various input fields and checkboxes for configuring tie and cross-section parameters. Red circles and arrows highlight specific steps in the process:

- Step 7:** Points to the 'Type of Tie' dropdown menu, which is set to 'Wood'.
- Step 8:** Points to the 'Spacing' dropdown menu, which is set to '20' (in).
- Step 9:** Points to the 'Number of Periods' dropdown menu, which is set to '4'.
- Step 10:** Points to the 'Select Period for Output' section, where 'Period 2' is selected with a checked checkbox.
- Step 11:** Points to the 'Last Tie Number for Superposition' dropdown menu, which is set to '6'.
- Step 12:** Points to the 'Cross Section for output' section, where 'Cross_Section 3' and 'Cross_Section 6' are selected with checked checkboxes.
- Step 13:** Points to the 'Next >>' button at the bottom right of the window.

Other visible parameters include: Location Number of Rail on Tie (4), Length of Tie (108 in), Thickness (7.0000 in), Width (9.0000 in), Moment of Inertia (257.25 in⁴), Youngs Modulus (1500000 psi), Center to Center Distance between Rails (59.5 in), Distance between Point 1 and 2 in transverse direction (15 in), First Tie Number for Superposition (3), and Cross Section (Uniform).

Step 14: Select Number of Axle Loads as: 2

Step 15: Click Next Button

The screenshot shows the 'Kentrack Input' software window with the 'Load' tab selected. The 'Number of Axle Loads' dropdown menu is open, and the value '2' is selected and highlighted with a red circle. An arrow labeled 'Step 14' points to this selection. Below the dropdown is a table with the following structure:

	Load Number	Distance from Tie Centerline	Wheel Load
*			

At the bottom right of the window, the 'Next >>' button is highlighted with a red circle, and an arrow labeled 'Step 15' points to it. The '<< Previous' button is also visible.

Step 16: Select the Number of Track Layers Including Subgrade as: 4

Step 17: Select Number of Layers for Vertical Compression at Top as: 2

Step 18: Select Layers to Compute Compression at the Top as: Layer 2 & Layer 3

Step 19: Click Next Button

Step 16 → Number of Track Layers including subgrade: 4

Select Asphalt Layers: ☐ Layer 1, ☐ Layer 2, ☐ Layer 3

Tolerance for Vertical Deflections: 0.00001 (in)

Tolerance for Tensile Stress: 0.010000 (psi)

Number of layers for Vertical compression at top: 2

Select Layers to compute Compression at the top: ☒ Layer 2, ☒ Layer 3

Number of layers for Horizontal tension at bottom: 1

Select Layers to compute Tension at the bottom:

Layer	Poisson's Ratio	Coefficient K2	Assumed Youngs (psi)	Period
Layer 1	0.35	0.5	7000	7000
Layer 2	0.35	0.5	3500	3500

Layer	Layer Thickness (in)	Minimum Youngs (psi)	Unit Weight (lb/in^3)	L E P
Layer 1	10	7000	0.064	0.
Layer 2	4	9000	0.087	0.

Asphalt Temperature for the layers over different Months(°F)

Layer	Period 1	Period 2	Period 3
*			

Asphalt Properties for the layers over different Months

Layer	% Passing Number	% of Air Voids	% Volume of Bit
*			

<< Previous **Next >>** **Step 19**

Final Step: Click Result Button

Kentrack Input

Rail | Tie | Load | Layer | **Damage Analysis**

Layer System

Rail Weight per Unit Length: 3.7800 (lb/in)

Tie Unit Weight: 0.029000 (lb/in^3)

Cribbing Material Unit Weight: 0.064000 (lb/in^3)

Nonlinear Analysis Tolerance: 0.010000

Month	Load Repetition
Month 1	50000
Month 2	50000
Month 3	50000
Month 4	50000

Damage Analysis Parameters

Fatigue Parameters

Layer	Fatigue Parameter 1	Fatigue Parameter 2	Fatigue Parameter 3
Layer 2	0.0795	3.291	0.854

Deformation Parameters

Layer	Deformation Parameter 1	Deformation Parameter 2	Deformation Parameter 3
Layer 3	4.837E-05	3.734	3.583

<< Previous

Result

APPENDIX B2

Kentrack 3.0 Step-by-Step Procedure for Asphalt Trackbed

Step 1: Double - Click on Kentrack 3.0

Step 2: Enter Project Title

Step 3: Choose the Trackbed Value

Step 4: Click on Submit Button

The screenshot shows the 'Kentrack' application window titled 'INITIAL PROJECT SPECIFICATION'. The window contains the following fields and options:

- Project Title:** A text input field containing the word 'Test'. An arrow labeled 'Step 2' points to this field.
- Unit System:** Radio buttons for 'SI' and 'FPS'. 'FPS' is selected.
- Model Type:** A radio button for 'Layer', which is selected.
- Damage Analysis:** Radio buttons for 'Yes' and 'No'. 'Yes' is selected.
- Trackbed:** A group box containing three radio buttons: 'All- Granular', 'Asphalt', and 'Combination'. 'Asphalt' is selected. An arrow labeled 'Step 3' points to this group box.
- Submit:** A button at the bottom of the window. An arrow labeled 'Step 4' points to this button.

Each of the three target elements (Project Title, Trackbed group box, and Submit button) is circled in red in the original image.

Step 5: Select the Rail Type Value From the Drop-Down Box

Step 6: Click Next

The screenshot shows the 'Kentrack Input' software window with the 'Rail' tab selected. The interface includes a dropdown menu for 'Select Rail type' and input fields for 'Rail Section Modulus', 'Rail Youngs Modulus', 'Rail Moment of Inertia', and 'Rail Tie Spring Constant'. The 'Next >>' button is located at the bottom right of the form.

Step 5 → Select Rail type

Parameter	Value	Unit
Rail Section Modulus	RE 136	(in ³)
Rail Youngs Modulus	RE 136	(psi)
Rail Moment of Inertia	94.9	(in ⁴)
Rail Tie Spring Constant	7000000	(lb/in)

Next >> ← **Step 6**

Step 7: Select Tie Type: Wood (or) Concrete

Step 8: Select Tie Spacing

Step 9: Select Number of Periods as: 4

Step 10: Select Period for Output

Step 11: Select Last Tie Number for Superposition as: 6

Step 12: Select 3 and 6 in the Cross Section

Step 13: Click Next Button

The screenshot shows the 'Kentrack Input' dialog box with the 'Tie' tab selected. The dialog is divided into two main columns of input fields. Red circles and arrows highlight specific fields corresponding to the steps:

- Step 7:** Points to the 'Type of Tie' dropdown menu, which is set to 'Wood'.
- Step 8:** Points to the 'Spacing' dropdown menu, which is set to '20' (in).
- Step 9:** Points to the 'Number of Periods' dropdown menu, which is set to '4'.
- Step 10:** Points to the 'Select Period for Output' section, where 'Period 2' is selected with a checkmark.
- Step 11:** Points to the 'Last Tie Number for Superposition' dropdown menu, which is set to '6'.
- Step 12:** Points to the 'Cross Section for output' list, where 'Cross_Section 3' and 'Cross_Section 6' are checked.
- Step 13:** Points to the 'Next >>' button at the bottom right.

Other visible fields include: 'Location Number of Rail on Tie' (4), 'Length of Tie' (108 in), 'Center to Center Distance between Rails' (59.5 in), 'Distance between Point 1 and 2 in transverse direction' (15 in), 'First Tie Number for Superposition' (3), 'Moment of Inertia' (257.25 in^4), 'Youngs Modulus' (1500000 psi), and 'Cross Section' (Uniform).

Step 14: Select Number of Axle Loads as: 2

Step 15: Click Next Button

The screenshot shows the 'Kentrack Input' software window with the 'Load' tab selected. The 'Number of Axle Loads' dropdown menu is open, and the value '2' is selected and highlighted with a red circle. An arrow labeled 'Step 14' points to this selection. Below the dropdown is a table with columns 'Load Number', 'Distance from Tie Centerline', and 'Wheel Load'. The table has a header row and one data row with a '*' in the first column. At the bottom right, the 'Next >>' button is circled in red, with an arrow labeled 'Step 15' pointing to it. The '<< Previous' button is also visible.

Number of Axle Loads

Number of ties for Single Axle Analysis

Load Number	Distance from Tie Centerline	Wheel Load
*		

<< Previous Next >>

Step 16: Select the Number of Track Layers Including Subgrade as: 4

Step 17: Select Asphalt Layers as: Layer 2

Step 18: Select Number of Layers for Vertical Compression at Top as: 1

Step 19: Select Layers to Compute Compression at the Top as: Layer 3

Step 20: Select Number of Layers for Horizontal Tension at Bottom as: 1

Step 21: Select Layers to Compute Tension at Bottom as: Layer 2

Step 22: Click Next Button

The screenshot shows the 'Kentrack Input' software window with the 'Layer' tab selected. The interface includes various input fields, dropdown menus, and tables for layer properties. Red circles and arrows highlight specific elements corresponding to the steps:

- Step 16:** Points to the 'Number of Track Layers including subgrade' dropdown, which is set to 4.
- Step 17:** Points to the 'Select Asphalt Layers' section, where 'Layer 2' is selected with a checkmark.
- Step 18:** Points to the 'Number of layers for Vertical compression at top' dropdown, which is set to 1.
- Step 19:** Points to the 'Select Layers to compute Compression at the top' section, where 'Layer 3' is selected with a checkmark.
- Step 20:** Points to the 'Number of layers for Horizontal tension at bottom' dropdown, which is set to 1.
- Step 21:** Points to the 'Select Layers to compute Tension at the bottom' section, where 'Layer 2' is selected with a checkmark.
- Step 22:** Points to the 'Next >>' button at the bottom right.

Below the input fields, there are two tables:

Layer	Poisson's Ratio	Coefficient K2	Assumed Youngs (psi)	Period
Layer 3	0.45	0	600000	12000
Layer 4	0.5	0	100000...	100000...

Layer	Layer Thickness (in)	Minimum Youngs (psi)	Unit Weight (lb/in^3)	E P
Layer 2	6	600000	0.087	0.
Layer 3	200	12000	0.078	0.

At the bottom, there are two more tables:

Layer	Period 1	Period 2	Period 3
Layer 2	50	67	33

Layer	% Passing Number	% of Air Voids	% Volume of Bit
Layer 2	5.5	5.7	13.5

Final Step: Click Result Button

Kentrack Input

Rail Tie Load Layer **Damage Analysis**

Layer System

Rail Weight per Unit Length (lb/in)

Tie Unit Weight (lb/in^3)

Cribbing Material Unit Weight (lb/in^3)

Nonlinear Analysis Tolerance

Month	Load Repetition
Month 1	50000
Month 2	50000
Month 3	50000
Month 4	50000

Damage Analysis Parameters

Fatigue Parameters

Layer	Fatigue Parameter 1	Fatigue Parameter 2	Fatigue Parameter 3
Layer 2	0.0795	3.291	0.854

Deformation Parameters

Layer	Deformation Parameter 1	Deformation Parameter 2	Deformation Parameter 3
Layer 3	4.837E-05	3.734	3.583

<< Previous

Result

APPENDIX B3

Kentrack 3.0

Step-by-Step Procedure for Combination Trackbed

Step 1: Double - Click on Kentrack 3.0

Step 2: Enter Project Title

Step 3: Choose the Trackbed Value

Step 4: Click on Submit Button

The screenshot shows the 'Kentrack' application window with the title 'INITIAL PROJECT SPECIFICATION'. The window contains several input fields and radio button groups. Annotations with arrows point to specific elements:

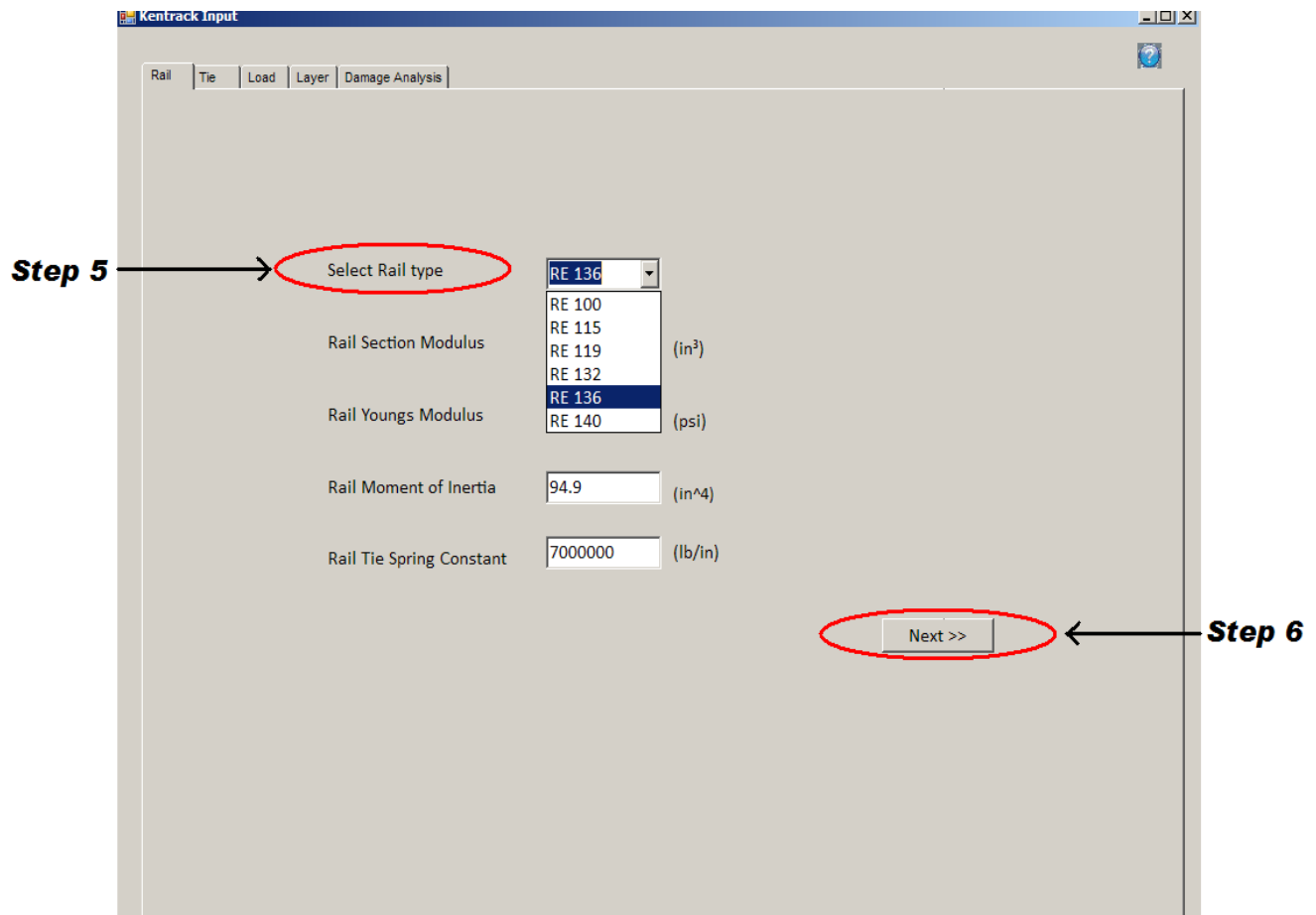
- Step 2** points to the 'Project Title' label, which is circled in red. The text 'Test' is entered in the adjacent text box.
- Step 3** points to the 'Trackbed' label, which is circled in red. The 'Combination' radio button is selected in the adjacent group.
- Step 4** points to the 'Submit' button, which is circled in red.

The form fields and options are as follows:

- Project Title:** Text box containing 'Test'.
- Unit System:** Radio buttons for 'SI' and 'FPS' (selected).
- Model Type:** Radio button for 'Layer' (selected).
- Damage Analysis:** Radio buttons for 'Yes' (selected) and 'No'.
- Trackbed:** Radio buttons for 'All - Granular', 'Asphalt', and 'Combination' (selected).
- Submit:** A button at the bottom of the form.

Step 5: Select the Rail Type Value From the Drop-Down Box

Step 6: Click Next



Step 7: Select Tie Type: Wood (or) Concrete

Step 8: Select Tie Spacing

Step 9: Select Number of Periods as: 4

Step 10: Select Period for Output

Step 11: Select Last Tie Number for Superposition as: 6

Step 12: Select 3 and 6 in the Cross Section

Step 13: Click Next Button

The screenshot shows the 'Kentrack Input' window with the 'Tie' tab selected. The interface is divided into several sections for inputting data. Red circles and arrows highlight the following fields:

- Step 7:** 'Type of Tie' dropdown menu, set to 'Wood'.
- Step 8:** 'Spacing' dropdown menu, set to '20' (in).
- Step 9:** 'Number of Periods' dropdown menu, set to '4'.
- Step 10:** 'Select Period for Output' section, where 'Period 2' is selected.
- Step 11:** 'Last Tie Number for Superposition' dropdown menu, set to '6'.
- Step 12:** 'Cross Section for output' section, where 'Cross_Section 3' and 'Cross_Section 6' are checked.
- Step 13:** 'Next >>' button.

Other visible fields include: 'Location Number of Rail on Tie' (4), 'Length of Tie' (108 in), 'Center to Center Distance between Rails' (59.5 in), 'Distance between Point 1 and 2 in transverse direction' (15 in), 'First Tie Number for Superposition' (3), 'Thickness' (7.0000 in), 'Width' (9.0000 in), 'Moment of Inertia' (257.25 in^4), and 'Youngs Modulus' (1500000 psi). The 'Cross Section' section has a 'Uniform' radio button selected.

Step 14: Select Number of Axle Loads as: 2

Step 15: Click Next Button

The screenshot shows the 'Kentrack Input' software window with tabs for 'Rail', 'Tie', 'Load', 'Layer', and 'Damage Analysis'. The 'Load' tab is active. It contains two input fields: 'Number of Axle Loads' and 'Number of ties for Single Axle Analysis'. A dropdown menu for 'Number of Axle Loads' is open, showing options from 1 to 8, with '2' selected and circled in red. An arrow labeled 'Step 14' points to this selection. Below these fields is a table with columns 'Load Number', 'Distance form Tie Centerline', and 'Wheel Load'. The table has a header row and one data row with a '*' in the first column. At the bottom right, there are two buttons: '<< Previous' and 'Next >>'. The 'Next >>' button is circled in red, and an arrow labeled 'Step 15' points to it.

Load Number	Distance form Tie Centerline	Wheel Load
*		

Step 16: Select the Number of Track Layers Including Subgrade as: 5

Step 17: Select Asphalt Layers as: Layer 2

Step 18: Select Number of Layers for Vertical Compression at Top as: 1

Step 19: Select Layers to Compute Compression at the Top as: Layer 3

Step 20: Select Number of Layers for Horizontal Tension at Bottom as: 1

Step 21: Select Layers to Compute Tension at Bottom as: Layer 2

Step 22: Click Next Button

Step 16 → Number of Track Layers including subgrade: 5

Step 17 → Select Asphalt Layers: ☒ Layer 2

Tolerance for Vertical Deflections: 0.00001 (in)

Tolerance for Tensile Stress: 0.010000 (psi)

Number of layers for Vertical compression at top: 1

Select Layers to compute Compression at the top: ☒ Layer 3

Number of layers for Horizontal tension at bottom: 1

Select Layers to compute Tension at the bottom: ☒ Layer 2

Step 18 ← Number of layers for Vertical compression at top: 1

Step 19 ← Select Layers to compute Compression at the top: ☒ Layer 3

Step 20 ← Number of layers for Horizontal tension at bottom: 1

Step 21 ← Select Layers to compute Tension at the bottom: ☒ Layer 2

Layer	Poisson's Ratio	Coefficient K2	Assumed Youngs (psi)	Period_
Layer 3	0.45	0	600000	12000
Layer 4	0.5	0	100000...	100000...

Layer	Layer Thickness (in)	Minimum Youngs (psi)	Unit Weight (lb/in^3)	E P
Layer 2	6	600000	0.087	0.
Layer 3	200	12000	0.078	0.

Asphalt Temperature for the layers over different Months(*F)

Layer	Period 1	Period 2	Period 3
Layer 2	50	67	33

Asphalt Properties for the layers over different Months

Layer	% Passing Number	% of Air Voids	% Volume of Bit
Layer 2	5.5	5.7	13.5

<< Previous **Next >>** **Step 22**

Final Step: Click Result Button

Kentrack Input

Rail Tie Load Layer **Damage Analysis**

Layer System

Rail Weight per Unit Length: 3.7800 (lb/in)

Tie Unit Weight: 0.029000 (lb/in³)

Cribbing Material Unit Weight: 0.064000 (lb/in³)

Nonlinear Analysis Tolerance: 0.010000

Month	Load Repetition
Month 1	50000
Month 2	50000
Month 3	50000
Month 4	50000

Damage Analysis Parameters

Fatigue Parameters

Layer	Fatigue Parameter 1	Fatigue Parameter 2	Fatigue Parameter 3
Layer 2	0.0795	3.291	0.854

Deformation Parameters

Layer	Deformation Parameter 1	Deformation Parameter 2	Deformation Parameter 3
Layer 3	4.837E-05	3.734	3.583

<< Previous

Result