SCHOOL OF ARCITECTURE,

COMPUTING & ENGINEERING

University of East London

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Module Code	**EG7032**
Module Title	**Highway & Railway Engineering**
Module Leader	**Dr Alex Apeagyei, CEng FIHE FHEA**
Assignment Tutor	**Dr Alex Apeagyei & Dr Rasha Mohammad**
Assignment Title	**Highway & Railway Engineering Individual Project**
Assignment number	**1**
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Student ID	**2771001**
Submission Date	**29 April 2025**

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INTRODUCTION:

As part of the ongoing commitment to modernising and improving the nation's transport infrastructure, has been appointed by the Transport Authority to provide comprehensive technical support in addressing complex engineering challenges affecting both highway and railway networks. The increasing pressures of urbanisation, climate change, technological advancement, and evolving transportation demands necessitate robust, efficient, and future-proof solutions that align with strategic transport objectives and sustainability goals.

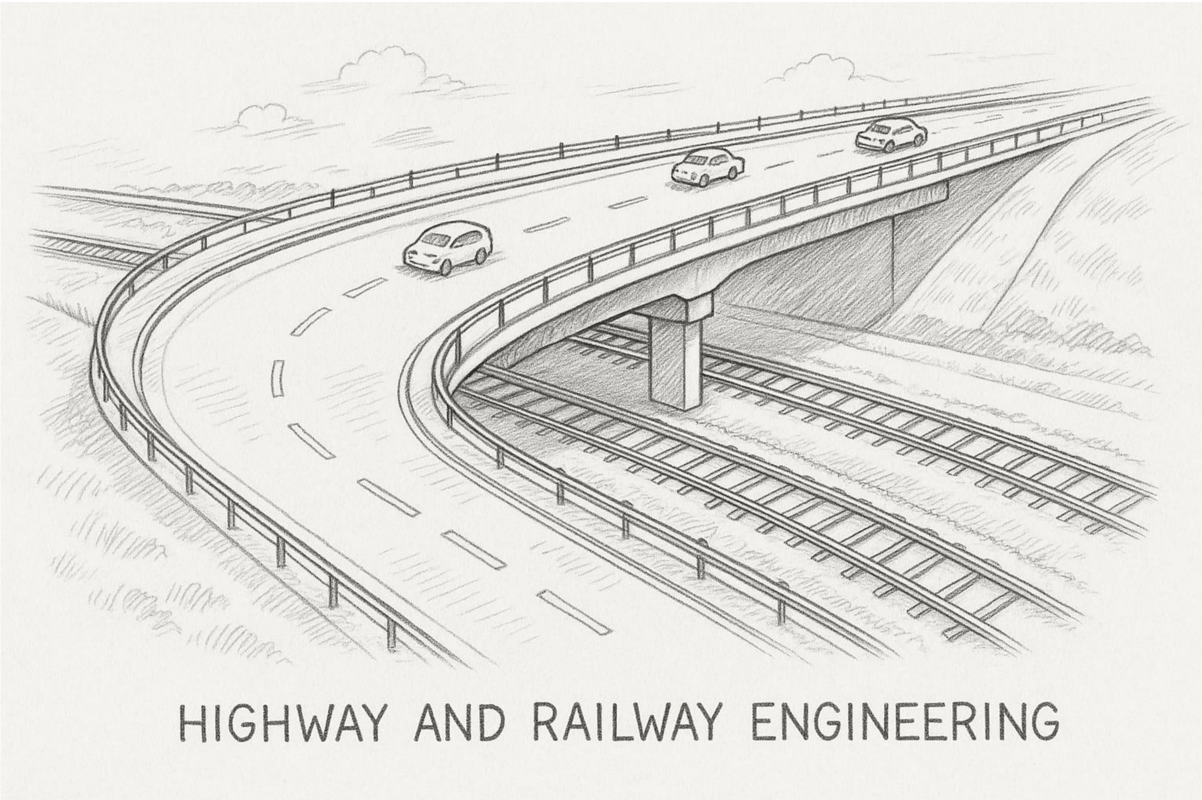

Fig. 1. Highway and Railway engineering

The UK's economy depends heavily on the highway and railway industries, which facilitate the flow of people, products, and services between urban and rural areas. Nevertheless, a few operational, structural, and capacity-related problems are presently plaguing both networks. Ageing infrastructure, network congestion, a lack of resilience to severe weather events, and inefficiencies in project delivery and maintenance are a few of these.

1. <u>Pavement Evaluation</u>

1A) Identification of Uniform Pavement Sections by cumulative sum method

By using cumulative sum technique, we find out the potential uniform sections for the subgrade. From the give data D7 is the subgrade.

Given data:

D7 – 0.87, 0.97, 0.99, 1.11, 1.21, 1.14, 1.52, 0.61, 0.96, 0.96, 1.6, 1.24, 1.56, 1.44, 1.4, 0.99, 1.13, 2.6, 0.98, 1.34

fx =H21+(I20-H22)

F	G	H	I	J
1A)	STATIONS	D7	CUMMULATIVE SUM	
	1	0.87	-0.361	
	2	0.97	-0.622	
	3	0.99	-0.863	
	4	1.11	-0.984	
	5	1.21	-1.005	
	6	1.14	-1.096	
	7	1.52	-0.807	
	8	0.61	-1.428	
	9	0.96	-1.699	
	10	0.96	-1.97	
	11	1.6	-1.601	
	12	1.24	-1.592	
	13	1.56	-1.263	
	14	1.44	-1.054	
	15	1.4	-0.885	
	16	0.99	-1.126	
	17	1.13	-1.227	
	18	2.6	0.142	
	19	0.98	-0.109	
	20	1.34	1.9984E-15	
		1.231		

Average value- 1.231

Cumulative Sum – 1.9984E-15

Graphical representation for Stations and Cumulative sum:

In dividing a project into uniform sections, a graph is plotted using cumulative sum against stations.

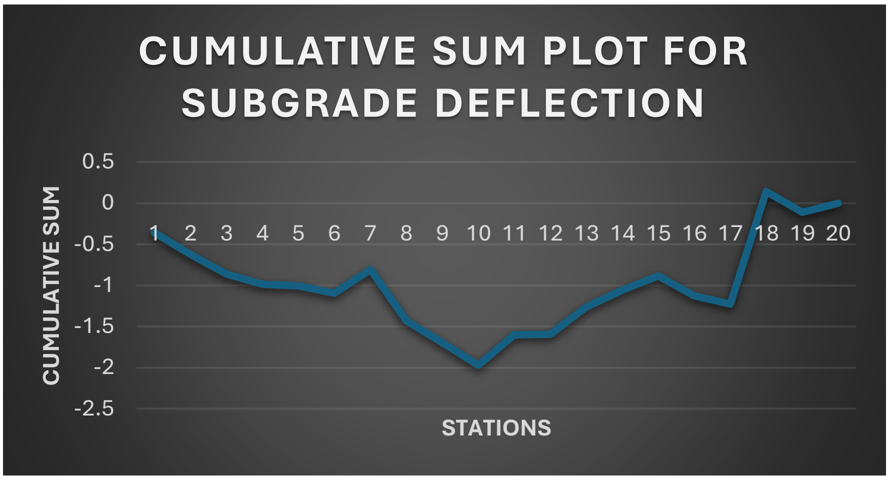

Fig. 2. Cumulative graph

Uniform Sections:

Section 1: ch 1-6

Section 2: ch 6-7

Section 3: ch 7-10

Section 4: ch 10-15

Section 5: ch 15-17

Section 6: ch 17-18

Section 7: ch 18-19

Section 8: ch 19-20

1B) Boussinesq's Equation:

We will use the following formula to estimate the subgrade modulus (E):

$$\mathbf{E = (1 - V^2) * P / r * d * \pi}$$

Where:

E- Subgrade modulus (psi) = (will calculate it)

v- Poisson's Ratio of subgrade = 0.35 (given)

P- Load from FWD Test = 9000 ibs

r – Distance of D7 Sensor Load Center = 72 in

d – Deflection at D7 (in inches) = D7 in mils / 1000

Station 1:

- D7 = 0.87 mils
- Convert miles to inches → d = 0.87/ 1000 = 0.00087 inches
- Now apply the formula

$$E = (1- 0.35^2) * 9000 / \Pi*72*0.00087$$
$$= 40131.74$$

Station 2:

- D7 = 0.97 mils
- Convert miles to inches → d = 0.97/1000 = 0.00097 inches
- Now apply the formula

$$E = (1- 0.35^2) * 9000 / \Pi*72*0.00097$$
$$= 35994.4$$

Station 3:

- D7 = 0.99 mils

$$E = (1- 0.35^2) * 9000 / \Pi*72*0.00099$$
$$= 35267.28$$

So, the subgrade modulus at station 1 is: 40131.74 psi and station 2 is: 35994.4 psi. Like that remaining as follows in the tabular format.

Stations	D7 (mils)	D (inches)	Modulus E (psi)
1	0.87	0.00087	40132
2	0.97	0.00097	35994
3	0.99	0.00099	35267
4	1.11	0.00111	31455
5	1.21	0.00121	28855
6	1.14	0.00114	30627
7	1.52	0.00152	22970
8	0.61	0.00061	57237
9	0.96	0.00096	36369
10	0.96	0.00096	36369
11	1.6	0.0016	21822
12	1.24	0.00124	28157
13	1.56	0.00156	22382
14	1.44	0.00144	24246
15	1.4	0.0014	24939
16	0.99	0.00099	35267
17	1.13	0.00113	30898
18	2.6	0.0026	13429
19	0.98	0.00098	35627
20	1.34	0.00134	26056

Table.1

15th percentile of the modulus:

=PERCENTILE.EXC(O2:O21,0.15)

STATIONS	D7 (MILS)	D (INCHES)	MODULUS E (PSI)	
1	0.87	0.00087	40132	
2	0.97	0.00097	35994	
3	0.99	0.00099	35267	
4	1.11	0.00111	31455	
5	1.21	0.00121	28855	
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17	1.13	0.00113	30898	
18	2.6	0.0026	13429	
19	0.98	0.00098	35627	
20	1.34	0.00134	26056	
			15TH PERCENTILE =	22470.2

Average Subgrade Modulus:

$$E_{avg} = \sum E / 20 = 30905 \text{ psi}$$

Conclusion and Interpretation

- Strong Subgrade: E > 40000 → Station 8
- Moderate: E = 30000-40000 → Station 1, 2, 3, 13, 15, 18, 19
- Weak Subgrade: E < 30000 → Remaining stations

Treatment required for weak zones:

Stabilization:

Method:

- Mix stabilizers like lime, cement, fly ash, or a blend into the weak soil.
- Compact it properly in layers.

Explanation:
Chemical reactions improve soil properties by increasing strength, reducing plasticity, and minimizing moisture sensitivity. Lime works well for clayey soils; cement is good for granular soils.

Replacement:

Method:

- Excavate the weak soil (typically 0.5 m to 1.5 m deep or as needed).
- Replace it with stronger material such as crushed rock, granular fill, or engineered fill.

Explanation:
This method physically removes the problematic material and replaces it with a better load-bearing material. It's simple but costly for large areas.

Geosynthetics:

Method:

- Place geotextiles, geogrids, or geocells over the weak subgrade before placing the base course.

Explanation:
Geosynthetics distribute loads over a wider area, reduce differential settlement, and improve load-carrying capacity without removing the existing weak soil.

1C) Backcalculation Procedures:

Assuming the pavement at station 2 consisting of four layers namely the asphalt surface of thickness 2in, granular base of thickness 8in, subbase thickness of 16in, and a clayey subgrade, estimate the values for each pavement layer through backcalculation procedures. State any other reasonable assumptions made.

Given data:

Assume the pavement at station 2

Four Layers-

1. Asphalt Surface thickness 2in
2. Granular base thickness 8in
3. Subbase thickness 16in
4. Clayey subgrade

Summary of Backcalculation Deflections

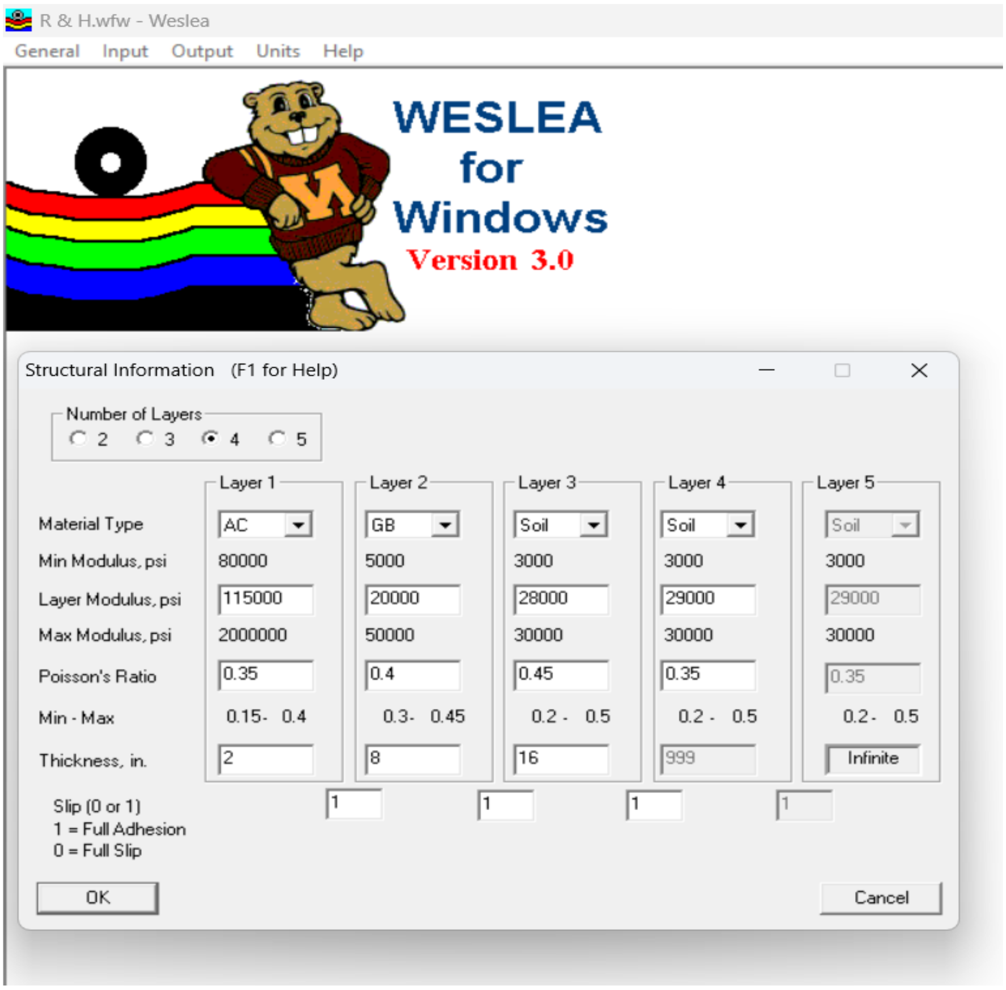
Offset Distance	FWD Deflection	Iteration #1 E_{ac}=500000si E_{gr}=20000si E_{su}=12000si E_{sg}=12000si	Iteration #2 E_{ac}=425000si E_{gr}=24000si E_{su}=12000si E_{sg}=12000si	Iteration #3 E_{ac}=450000si E_{gr}=24000si E_{su}=9000si E_{sg}=12000si	Iteration #4 E_{ac}=320000si E_{gr}=24000si E_{su}=9000si E_{sg}=12000si
0	30.67	37.6	35.88	35.37	39.87
12	7.82	17.07	16.54	18.32	18.29
24	5.16	8.39	8.46	9.02	9.01
36	2.81	5.49	5.54	5.6	5.59
48	1.77	4.1	4.13	4.05	4.05
60	1.27	3.3	3.31	3.23	3.24
72	0.97	2.77	2.77	2.72	2.73

Table.2. Backcalculation

Iteration #5 E_{ac}=300000si E_{gr}=30000si E_{su}=20000si E_{sg}=12000si	Iteration #6 E_{ac}=300000si E_{gr}=28500si E_{su}=20000si E_{sg}=12000si	Iteration #7 E_{ac}=100000si E_{gr}=40000si E_{su}=25000si E_{sg}=30000si	Iteration #8 E_{ac}=100000si E_{gr}=20000si E_{su}=30000si E_{sg}=30000si	Iteration #9 E_{ac}=115000si E_{gr}=24000si E_{su}=9000si E_{sg}=12000si
30.06	30.68	25.83	30.65	30.85
13.47	13.55	7.8	7.08	7.45
7.79	7.78	3.63	3.17	3.3
5.53	5.52	2.33	2.16	2.23
4.25	4.25	1.73	1.65	1.7
3.43	3.43	1.38	1.34	1.38
2.86	2.86	1.16	1.12	1.16

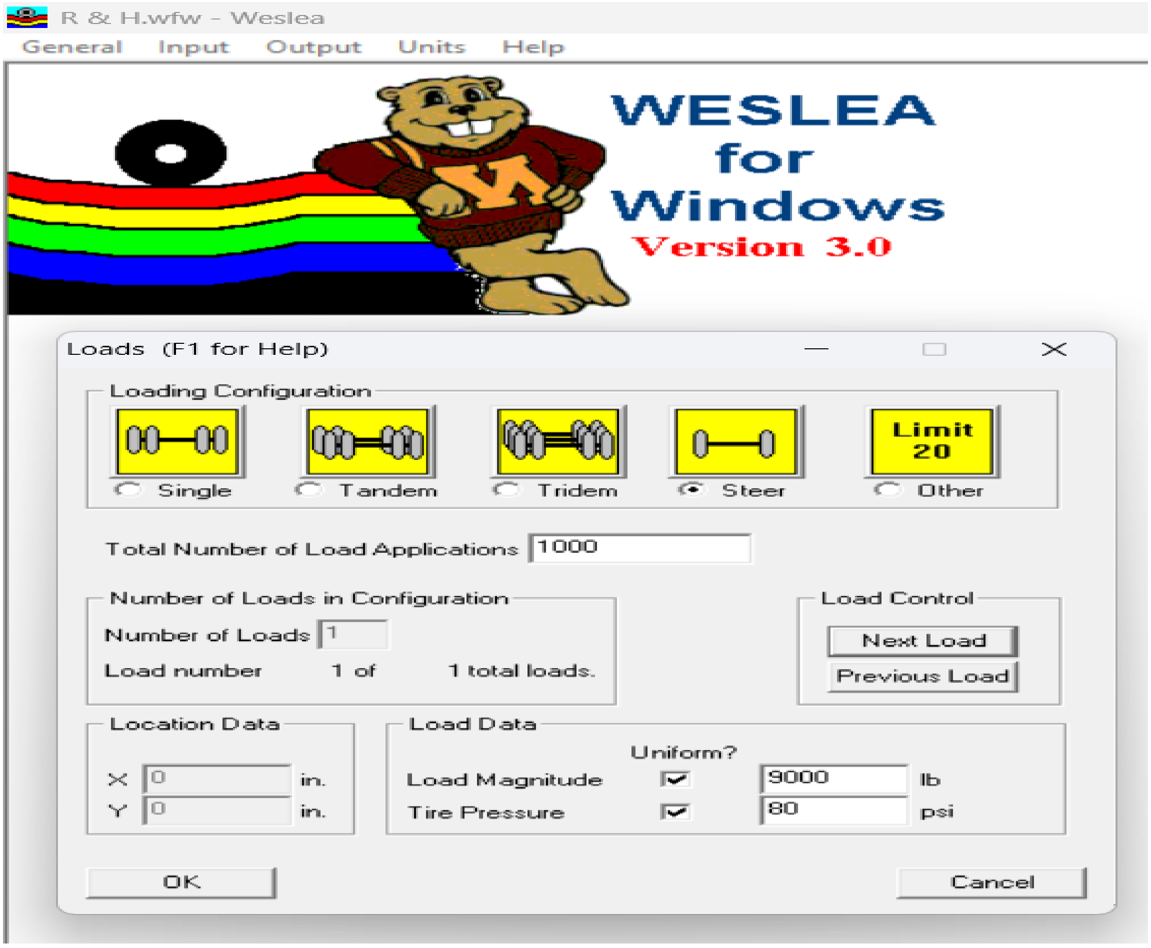
WESLEA SOFTWARE RESULTS:

Structural Information-

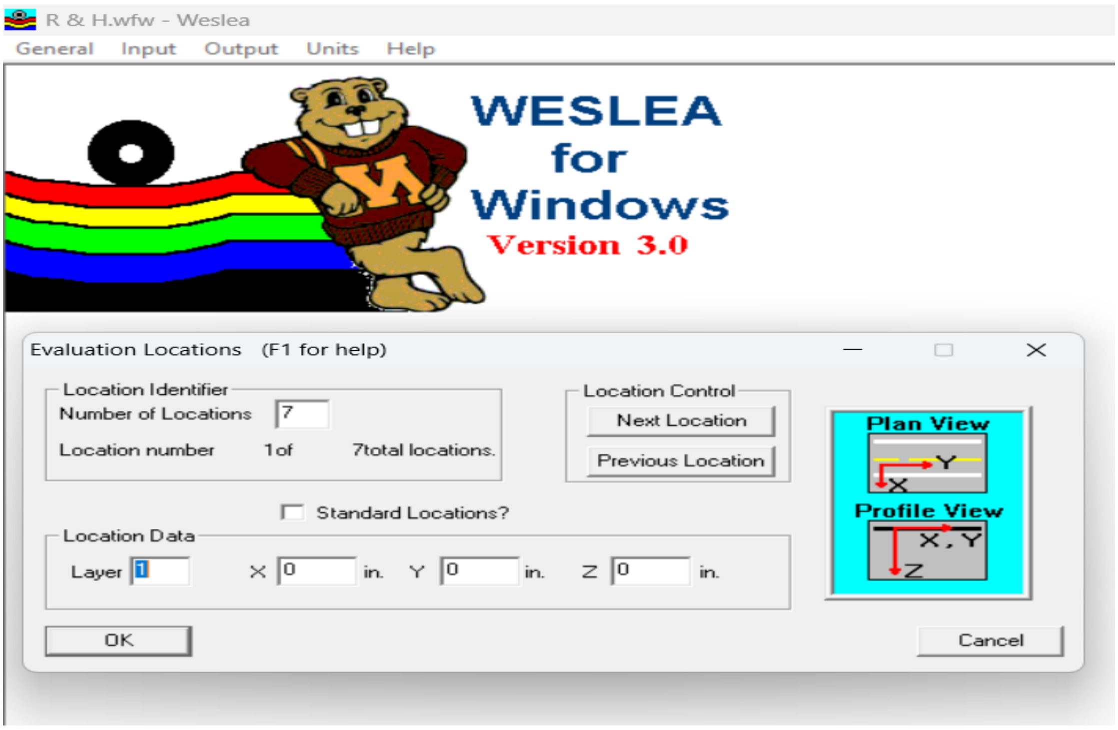


This example contains 4 layers

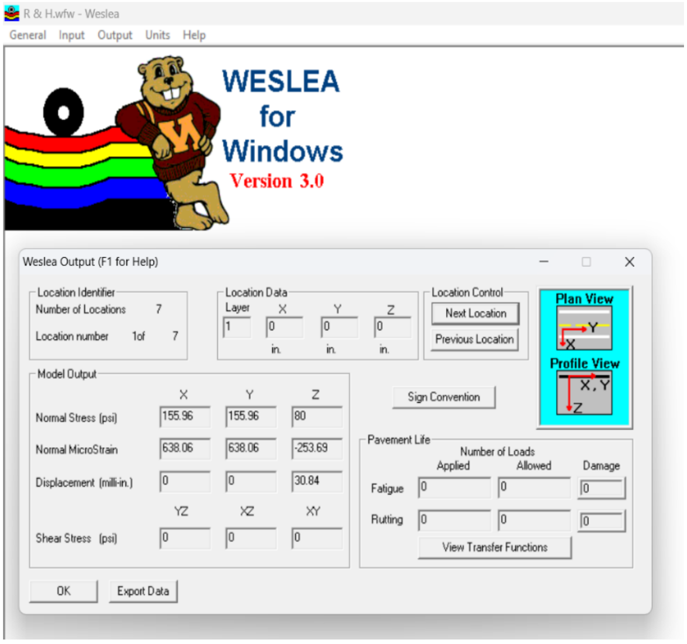
Loads-



Evaluation locations for responses-



OUTPUT-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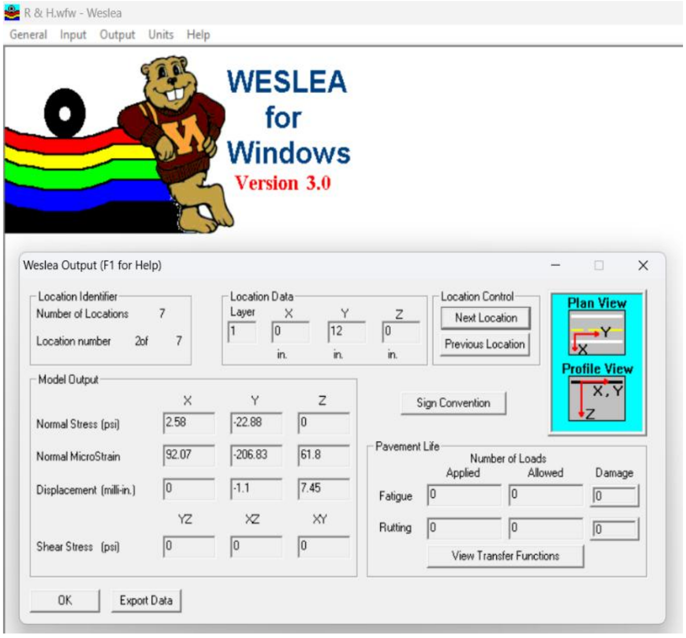
General Input Output Units Help
WESLEA
for
Windows
Version 3.0
Weslea Output (F1 for Help)
Location Identifier
Number of Locations 7
Location number 1of 7
Location Data
Layer X Y Z
1 0 0 0
in. in. in.
Location Control
Next Location
Previous Location
Plan View
Profile View
Model Output
X Y Z
Normal Stress (psi) 155.96 155.96 80
Normal MicroStrain 638.06 638.06 -253.69
Displacement (milli-in.) 0 0 30.84
YZ XZ XY
Shear Stress (psi) 0 0 0
Sign Convention
Pavement Life
Number of Loads
Applied Allowed Damage
Fatigue 0 0 0
Rutting 0 0 0
View Transfer Functions
OK
Export Data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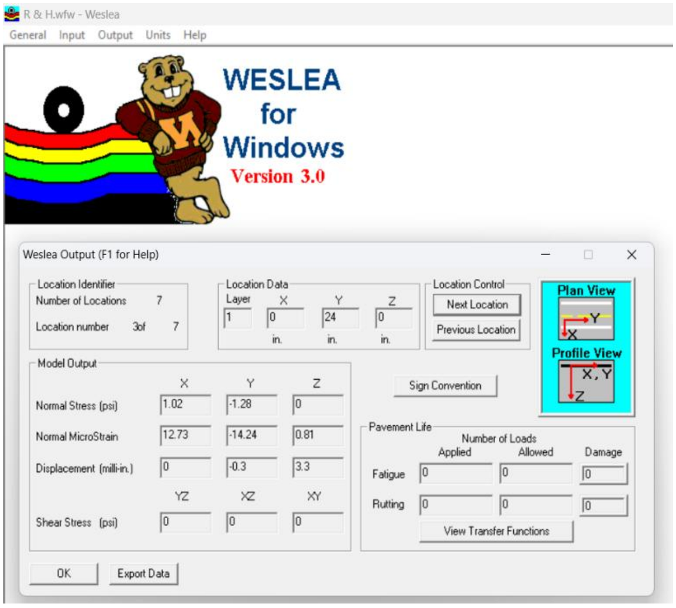
General Input Output Units Help
WESLEA
for
Windows
Version 3.0
Weslea Output (F1 for Help)
Location Identifier
Number of Locations 7
Location number 2of 7
Location Data
Layer X Y Z
1 0 12 0
in. in. in.
Location Control
Next Location
Previous Location
Plan View
Profile View
Model Output
X Y Z
Normal Stress (psi) 2.58 -22.88 0
Normal MicroStrain 92.07 -206.83 61.8
Displacement (milli-in.) 0 -1.1 7.45
YZ XZ XY
Shear Stress (psi) 0 0 0
Sign Convention
Pavement Life
Number of Loads
Applied Allowed Damage
Fatigue 0 0 0
Rutting 0 0 0
View Transfer Functions
OK
Export Data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General Input Output Units Help
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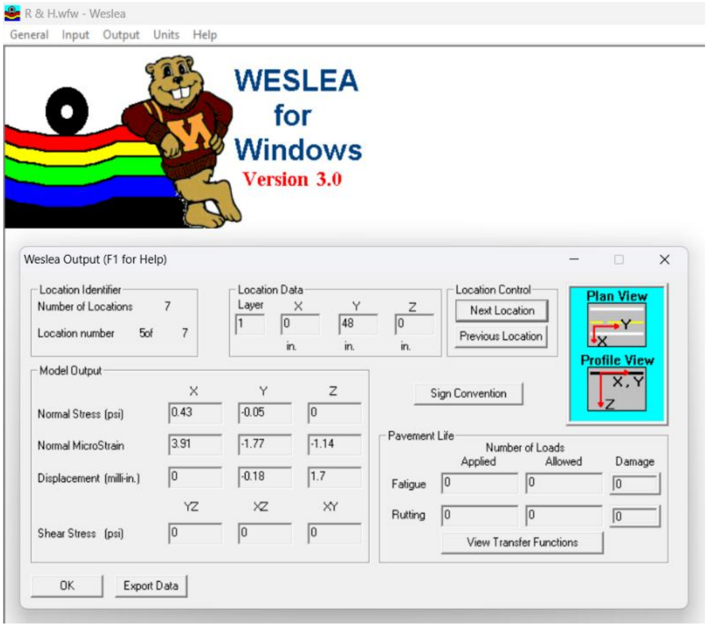
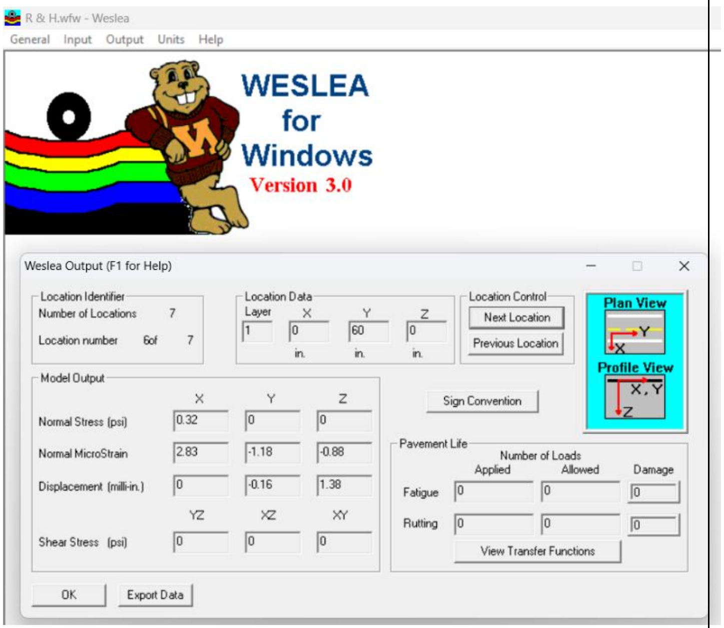
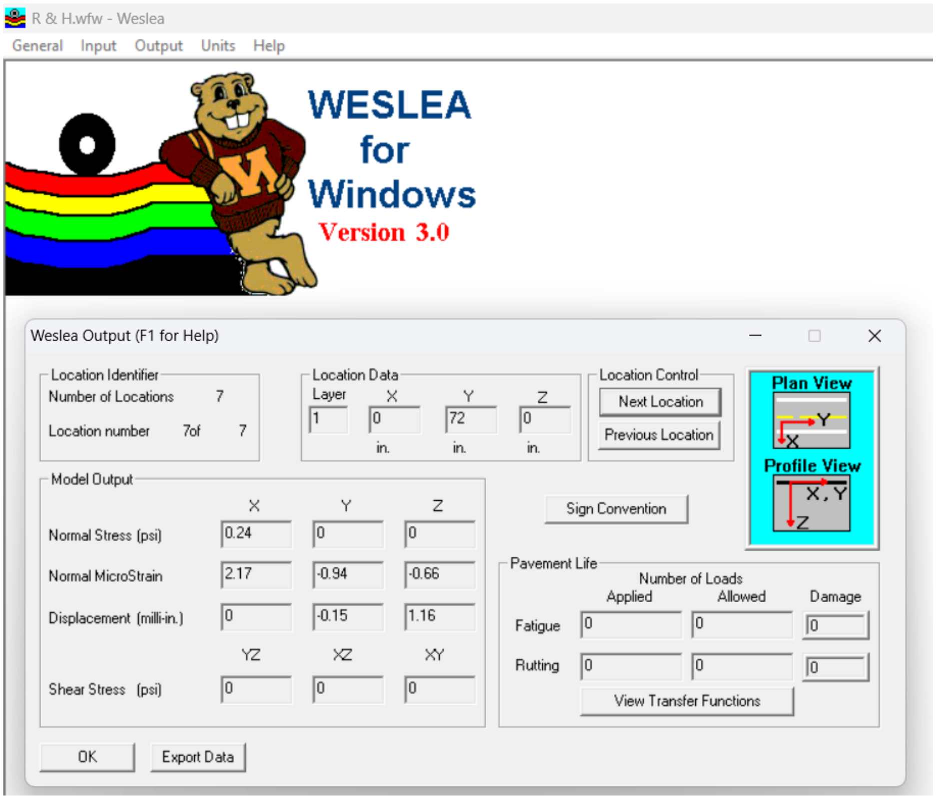
Windows
Version 3.0
Weslea Output (F1 for Help)
Location Identifier
Number of Locations 7
Location number 3of 7
Location Data
Layer X Y Z
1 0 24 0
in. in. in.
Location Control
Next Location
Previous Location
Plan View
Profile View
Model Output
X Y Z
Normal Stress (psi) 1.02 -1.28 0
Normal MicroStrain 12.73 -14.24 0.81
Displacement (milli-in.) 0 -0.3 3.3
YZ XZ XY
Shear Stress (psi) 0 0 0
Sign Convention
Pavement Life
Number of Loads
Applied Allowed Damage
Fatigue 0 0 0
Rutting 0 0 0
View Transfer Functions
OK
Export Data


R & H.wfw - Weslea
General Input Output Units Help
WESLEA
for
Windows
Version 3.0
Weslea Output (F1 for Help)
Location Identifier
Number of Locations 7
Location number 4of 7
Location Data
Layer X Y Z
1 0 36 0
in. in. in.
Location Control
Next Location
Previous Location
Plan View
Profile View
Model Output
X Y Z
Normal Stress (psi) 0.63 -0.2 0
Normal MicroStrain 6.09 -3.7 -1.28
Displacement (milli-in.) 0 -0.21 2.23
YZ XZ XY
Shear Stress (psi) 0 0 0
Sign Convention
Pavement Life
Number of Loads
Applied Allowed Damage
Fatigue 0 0 0
Rutting 0 0 0
View Transfer Functions
OK
Export Data







Output of analysis given at the specified locations in terms of stresses, strains and deflections.

2) Highway Pavement Analysis and Design

2A) Determine the effective thickness based on the information provided, use the asphalt institute approach in the determination of the effective thickness.

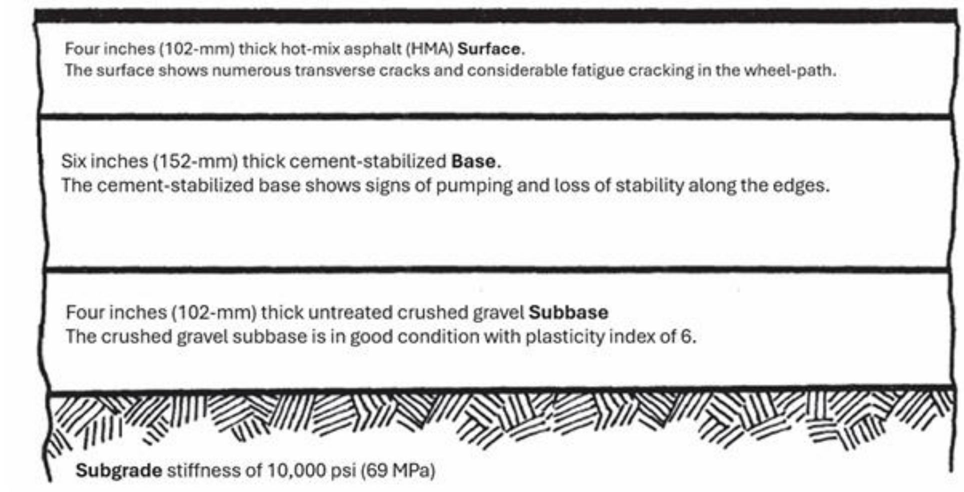


Figure Q2.1. Details of existing pavement.

Fig.3. Details of existing pavement

4 in height- HMA surface with numerous transverse cracks and fatigue cracking

4inc height = 4*0.3 = 1.2inc

6in height- cement stabilized base signs of pumping and loss of stability

6inc height = 6*0.5 = 3inc

4in height- subbase, the crushed gravel subbase is in good condition

4in height = 4*0.3 = 1.2inc

Total effective thickness = 1.2+3+1.2

= 5.4in

2B) Determine the effective thickness of overlay required:

Assuming pavement has a subgrade stiffness of 10000psi (69 MPa), overlay required to carry anticipated of 3.0msa using the effective thickness approach.

From the Asphalt institute design chart or graph, the point of intersection between subgrade stiffness modulus for full depth asphalt pavement of 10000psi and Equivalent single axle load (EAL)

Plotting the given data in the chart,

Subgrade stiffness = 10000psi = 10^4 psi

Project traffic loading = 3.0 msa = 3 X 10^4

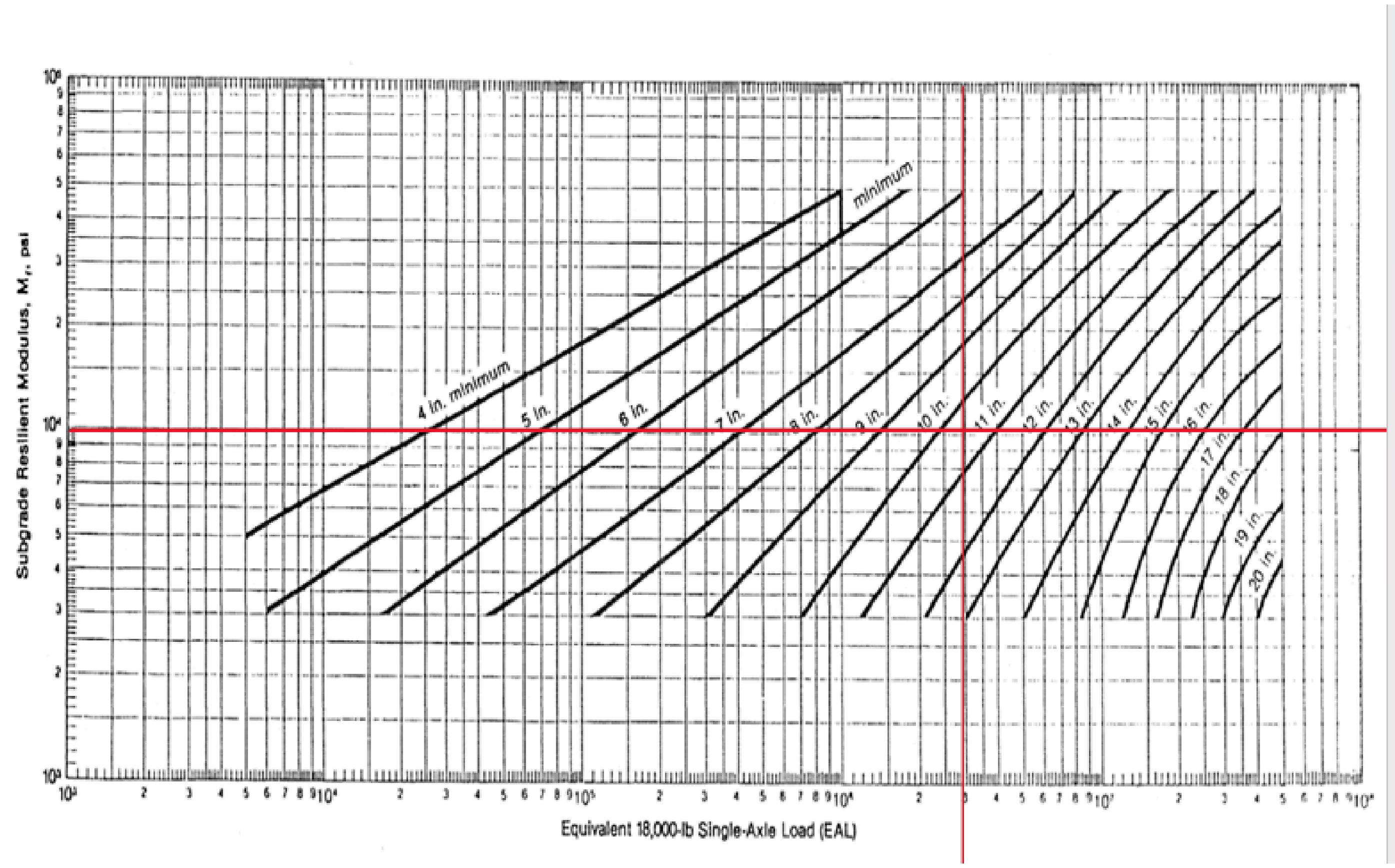


Fig.4. Asphalt institute design chart

h_{FD} (Full depth) = 10.5

H = Full depth – Total effective thickness

= 10.5 – 5.4 = 5.1

Therefore, Thickness of overlay h_{OL} = 5.1in

2C) Determine the Representative rebound deflection, the design rebound deflection and the required overlay thickness.

For the same pavement as in the above, a series of 10 deflection measurements by Benkelman beam.

Given data-

The pavement during a critical pavement during a critical period when the pavement temperature = 13°C

Assume the stiffness of the asphalt overlay = 500000 psi

.

Figure Q2.2. Benkelman beam deflections.

Fig.5. Benkelman beam deflection

`Locations	Deflections
1	0.033
2	0.035
3	0.040
4	0.025
5	0.028
6	0.026
7	0.02
8	0.035
9	0.034
10	0.027

Table.3

Mean value X = 0.033+0.035+0.040+0.025+0.028+0.026+0.02+0.035+0.034+0.027 / 10

= 0.0303

Design Deflection (Traffic-deflection Relationship):

- Deflection did not exceed 1.1mm in the spring
- Deflection did not exceed to 0.9mm in the fall

$$d_d = 1.0363(r_{18})^{-0.2438}$$

r_{18} = 80 Kn Standard axle repetition

- Thickness-Deflection Relationship:

$$d_{rrd} = \frac{1.5pa}{E_2}$$

d_{rrd} = Representative Rebound Deflection

P = Contact pressure in psi

A = Radius of loaded area and it's assumed to be 6.4

E_2 = Foundation Modulus in psi

- Expected Pavement Deflection after Overlay (d_d):

$$d_d = \frac{1.5pa}{E_2}\left[\left\{1 - \frac{1}{\sqrt{\left(1 + 0.8\left(\frac{h_1}{a}\right)^2\right)}}\right\}\frac{E_2}{E_1} + \frac{1}{\sqrt{1 + \left(0.8\frac{h_1}{a}\sqrt[3]{\frac{E_1}{E_2}}\right)^2}}\right]$$

$$d_{rrd} = (\bar{X} + 2s) * f * c$$

d_{rrd} = representative rebound deflection, in.
$\bar{X}$ = mean deflection, in.

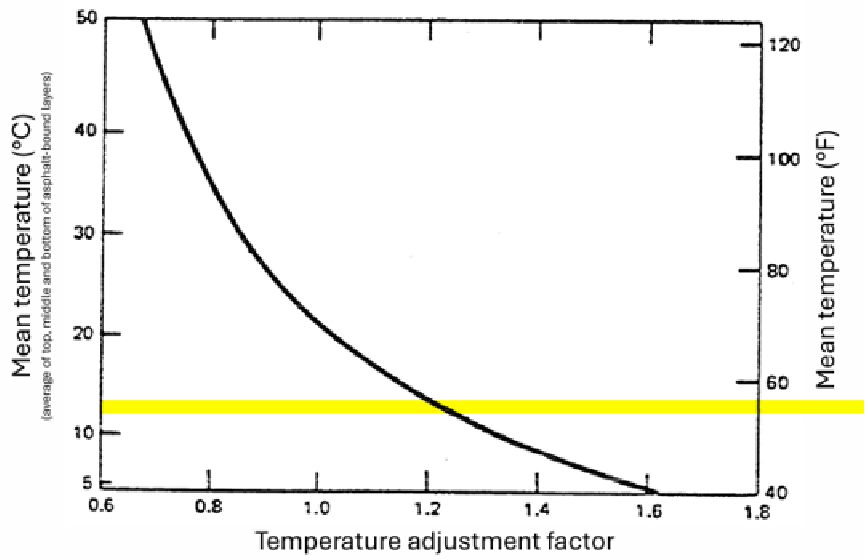
s = standard deviation

f = temperature adjustment factor (see next slide)

c =critical period adjustment factor (c = 1 if tested during the most critical period; c> 1 if tested during other periods

- Standard deviation using excel:

d_{rrd} = (X + 2S) *f * C
Mean (X) = 0.0303
From the temperature adjustment factor
Given 13°C (f) = 1.22 (from the graph)
C = 1 → during critical path



U14 | =(U12+2*U13)*V2*W2

	S	T	U	V	W	X
1	**2C)**	STATIONS	DEFLECTIONS	F	C	
2		1	0.033	1.22	1	
3		2	0.035			
4		3	0.04			
5		4	0.025			
6		5	0.028			
7		6	0.026			
8		7	0.02			
9		8	0.035			
10		9	0.034			
11		10	0.027			
12		AVG	0.0303			
13		S.D	0.006037844			
14		R.R.D	0.051698338			
15						

From the graph we get:

Mean (X) = 0.0303

Standard Deviation = 0.006037844

Representative Rebound Deflection (R.R.D) = 0.051698338

Now,

1. **d_{rrd}** = (0.0303 + 2*0.006) * 1.22 * 1

   = 0.051698338 ≈ 0.051606in

2. **Calculated the design Rebound Deflection**

   $d_{rrd} = 1.5pa / E_2$

   $E_2 = 1.5pa / d_{rrd}$

Given p = Contact pressure = 70psi

A = Radius Flow = 6.4m

Now, $E_2 = 1.5pa / d_{rrd}$

= 1.5 * 70 * 6.4 / 0.05161

= 13020.732 ≈ 13021psi

Assume –

H = 4 thickness of asphalt

E_1 = 500000psi (Stiffness of the asphalt overlay)

3. **Required Overlay Thickness (h_{OL}):**

$$h_{OL} = h_{FD} - h_e = 10.5 - 5.4 = 5.1in$$

3) Track Structure Analysis & Design

3A) Describe and Illustrate the four types of trackbed structures in common use indicating some of their advantages and disadvantages.

4. **Conventional Ballasted Track**

Description:
A traditional railway track structure where the rails are supported by sleepers (ties), which are laid in a bed of crushed stone (ballast).

Components:

- Rails
- Sleepers (concrete, timber, or steel)
- Ballast
- Sub-ballast (optional)
- Formation layer (subgrade)

Illustration:
Simple layered diagram showing ballast, sleepers, and rails on natural ground.

5. **Ballast less Track (Slab Track)**

Description:
Track structure where rails and sleepers are fixed directly to a concrete or asphalt slab without the use of ballast.

Components:

- Rails
- Fastening system
- Concrete slab
- Formation/subgrade

Illustration:
Show rails fastened onto a rigid concrete slab layer without ballast.

6. **Embedded Track**

Description:
Rails are embedded in a solid surface, often concrete, with the top surface flush with the surrounding pavement (typically seen in tramways or urban areas).

Components:

- Rail (often grooved)
- Elastomeric materials
- Concrete or asphalt embedding

Illustration:
Sketch showing a rail fully embedded in a concrete surface, with road or pedestrian path flush with rail top.

7. **Floating Slab Track**

Description:
Variation of ballast less track, where the track slab "floats" on elastomeric bearings or pads to reduce vibration transmission.

Components:

- Rails
- Concrete slab
- Vibration isolation elements (rubber pads or springs)
- Base slab

Illustration:
Sketch showing a slab on top of vibration-absorbing pads, with labels.

Here are some of the advantages and disadvantages:

Type of Trackbed	**Advantages**	**Disadvantages**
1. Conventional Ballasted Track	- Good drainage - Flexible and distributes loads well - Easy and inexpensive to maintain initially	- Requires frequent maintenance (tamping, realignment) - Ballast fouling and degradation over time - Less suitable for high-speed or heavy loads
2. Ballast less Track (Slab Track)	- Very low maintenance - High stability, good for high -speed trains- long service life (30–60 years)	- High initial construction cost - Difficult and expensive to repair - Needs very stable foundation
3. Embedded Track	- Smooth integration with urban environment - Reduced noise and vibration - Suitable for mixed traffic (trams, pedestrians, vehicles)	- Complex drainage requirements - Difficult access for maintenance - Higher construction costs
4. Floating Slab Track	- Excellent vibration and noise isolation - Ideal for sensitive areas (urban tunnels, hospitals) - Stable and durable structure	- Very expensive - Complex design and construction- Maintenance of vibration -isolating elements is challenging

3B) Determine the reduction in service life because of the change from wooden ties to concrete ties.

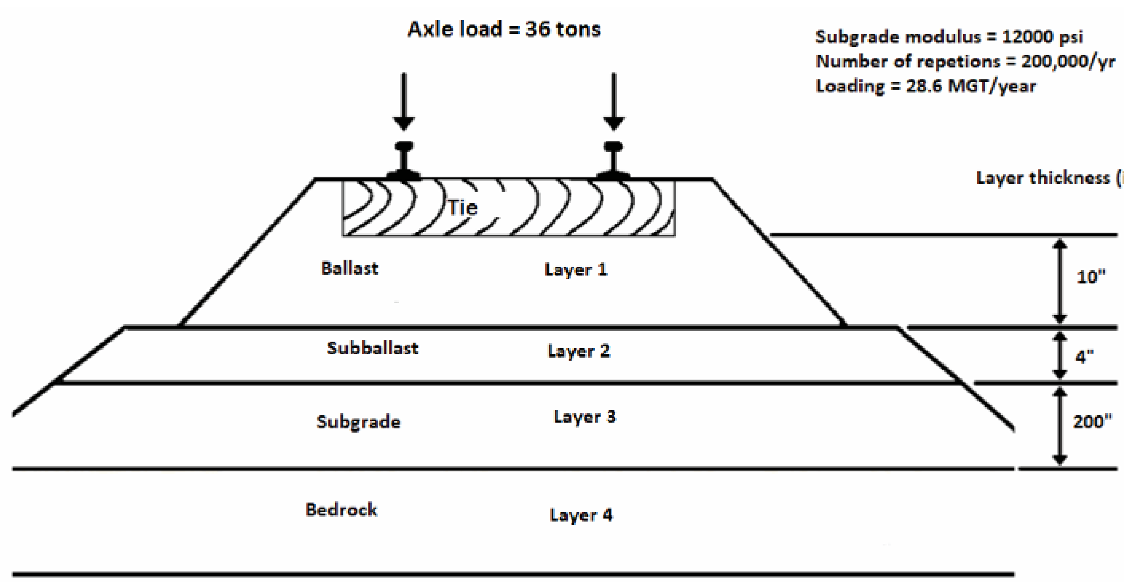


Figure Q3.1. Structure for a ballasted trackbed.

Fig.6. structure for a ballasted tracked

Given data:
Axle load = 36 tons
Subgrade modulus = 12000psi
No of repetitions = 20000/yr
Loading = 28.6 MGT/yr
By using kentrack software we can desire the service life to replace the concrete ties with wooden ties:

Kentrack results for wooden ties:

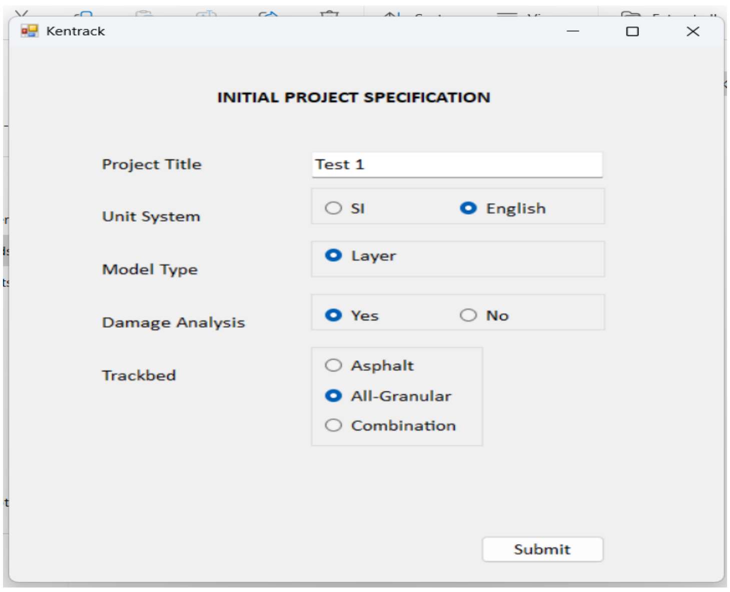
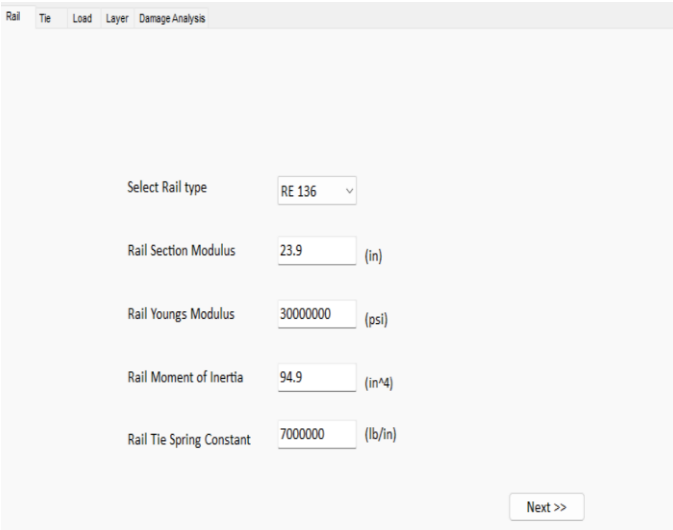
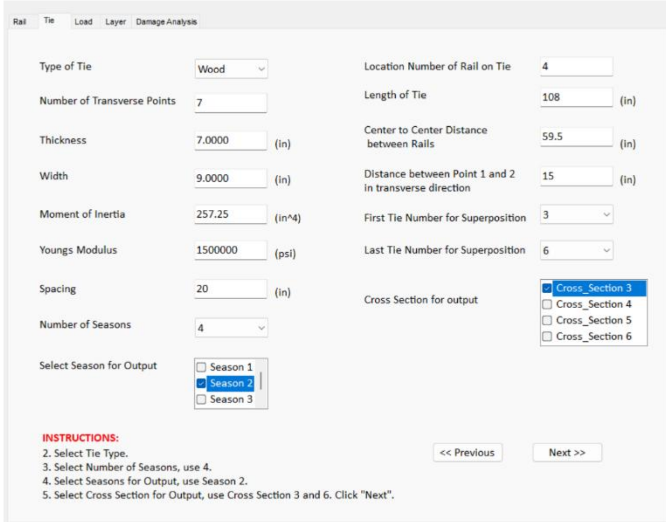
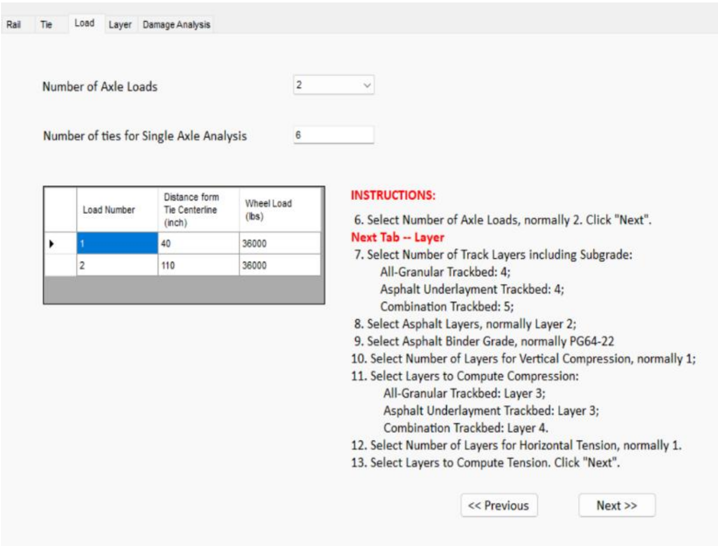
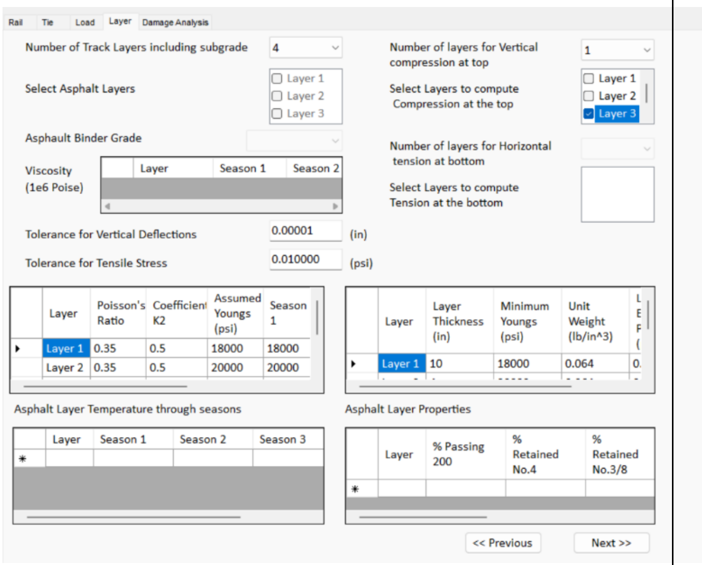


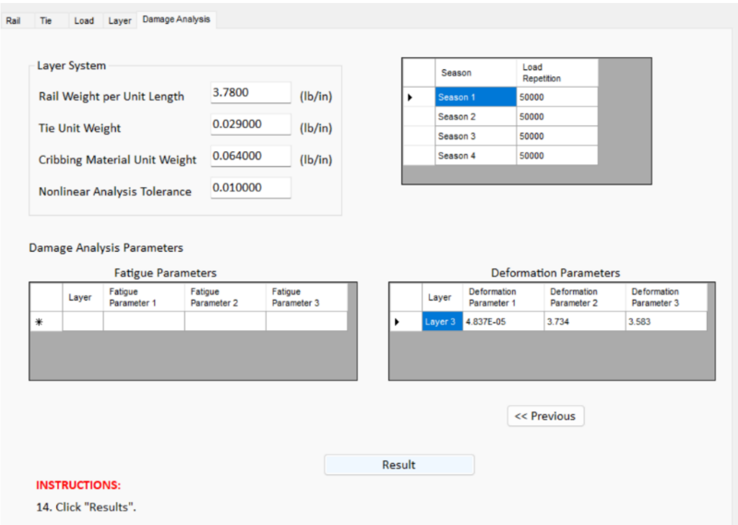
Fig.7.Kentrack results for wood and concrete ties

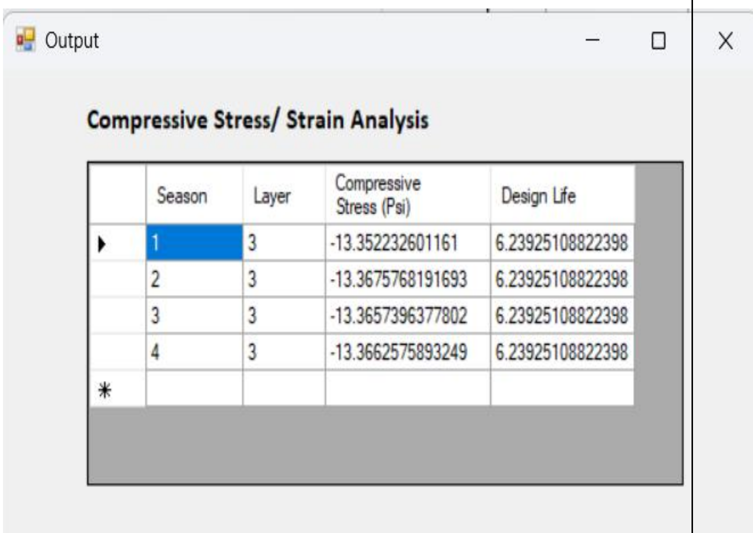

Rail
Tie
Load
Layer
Damage Analysis
Select Rail type
RE 136
Rail Section Modulus
23.9
(in)
Rail Youngs Modulus
30000000
(psi)
Rail Moment of Inertia
94.9
(in^4)
Rail Tie Spring Constant
7000000
(lb/in)
Next >>


Rail
Tie
Load
Layer
Damage Analysis
Type of Tie
Wood
Number of Transverse Points
7
Thickness
7.0000
(in)
Width
9.0000
(in)
Moment of Inertia
257.25
(in^4)
Youngs Modulus
1500000
(psi)
Spacing
20
(in)
Number of Seasons
4
Select Season for Output
Season 1
Season 2
Season 3
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
Last Tie Number for Superposition
6
Cross Section for output
Cross_Section 3
Cross_Section 4
Cross_Section 5
Cross_Section 6
INSTRUCTIONS:
2. Select Tie Type.
3. Select Number of Seasons, use 4.
4. Select Seasons for Output, use Season 2.
5. Select Cross Section for Output, use Cross Section 3 and 6. Click "Next".
<< Previous
Next >>

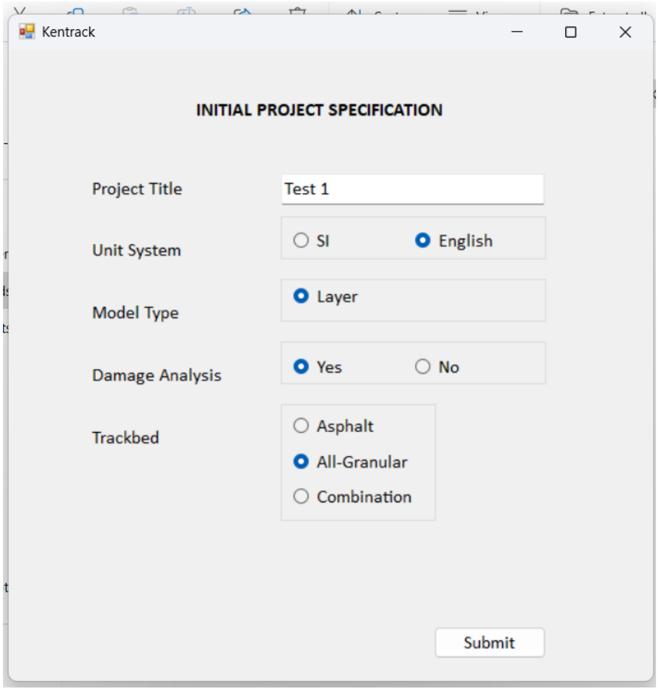

Rail
Tie
Load
Layer
Damage Analysis
Number of Axle Loads
2
Number of ties for Single Axle Analysis
6
Load Number
Distance form Tie Centerline (inch)
Wheel Load (lbs)
1
40
36000
2
110
36000
INSTRUCTIONS:
6. Select Number of Axle Loads, normally 2. Click "Next".
Next Tab -- Layer
7. Select Number of Track Layers including Subgrade:
All-Granular Trackbed: 4;
Asphalt Underlayment Trackbed: 4;
Combination Trackbed: 5;
8. Select Asphalt Layers, normally Layer 2;
9. Select Asphalt Binder Grade, normally PG64-22
10. Select Number of Layers for Vertical Compression, normally 1;
11. Select Layers to Compute Compression:
All-Granular Trackbed: Layer 3;
Asphalt Underlayment Trackbed: Layer 3;
Combination Trackbed: Layer 4.
12. Select Number of Layers for Horizontal Tension, normally 1.
13. Select Layers to Compute Tension. Click "Next".
<< Previous
Next >>

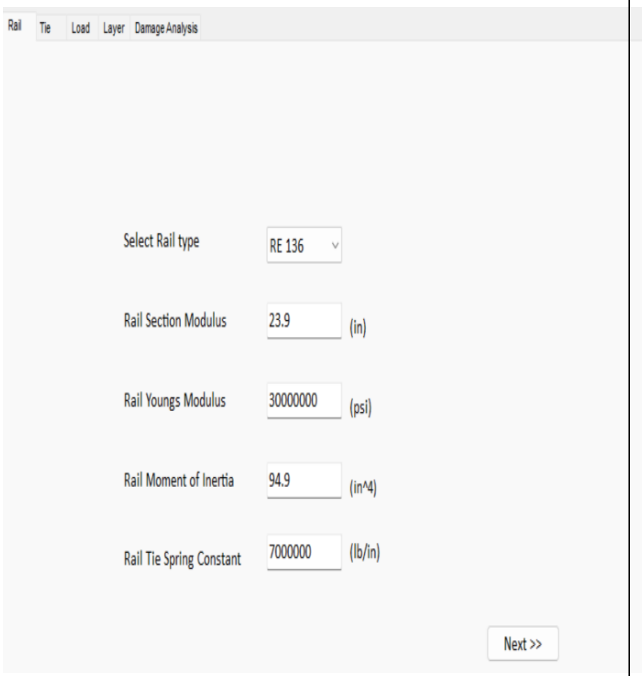

Rail
Tie
Load
Layer
Damage Analysis
Number of Track Layers including subgrade
4
Select Asphalt Layers
Layer 1
Layer 2
Layer 3
Asphault Binder Grade
Viscosity (1e6 Poise)
Layer
Season 1
Season 2
Tolerance for Vertical Deflections
0.00001
(in)
Tolerance for Tensile Stress
0.010000
(psi)
Number of layers for Vertical compression at top
1
Select Layers to compute Compression at the top
Layer 1
Layer 2
Layer 3
Number of layers for Horizontal tension at bottom
Select Layers to compute Tension at the bottom
Layer
Poisson's Ratio
Coefficient K2
Assumed Youngs (psi)
Season 1
Layer 1
0.35
0.5
18000
18000
Layer 2
0.35
0.5
20000
20000
Layer
Layer Thickness (in)
Minimum Youngs (psi)
Unit Weight (lb/in^3)
Layer 1
10
18000
0.064
Asphalt Layer Temperature through seasons
Layer
Season 1
Season 2
Season 3
Asphalt Layer Properties
Layer
% Passing 200
% Retained No.4
% Retained No.3/8
<< Previous
Next >>

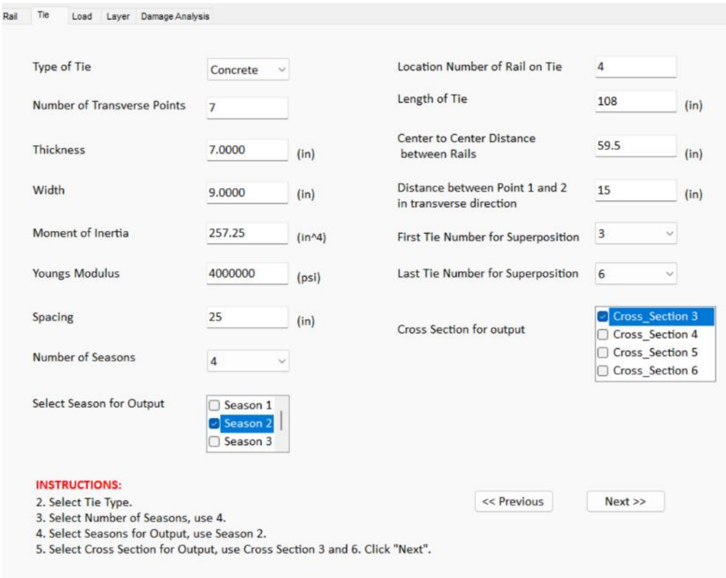

Rail
Tie
Load
Layer
Damage Analysis
Layer System
Rail Weight per Unit Length
3.7800
(lb/in)
Tie Unit Weight
0.029000
(lb/in)
Cribbing Material Unit Weight
0.064000
(lb/in)
Nonlinear Analysis Tolerance
0.010000
Season
Load Repetition
Season 1
50000
Season 2
50000
Season 3
50000
Season 4
50000
Damage Analysis Parameters
Fatigue Parameters
Layer
Fatigue Parameter 1
Fatigue Parameter 2
Fatigue Parameter 3
Deformation Parameters
Layer
Deformation Parameter 1
Deformation Parameter 2
Deformation Parameter 3
Layer 3
4.837E-05
3.734
3.583
<< Previous
Result
INSTRUCTIONS:
14. Click "Results".

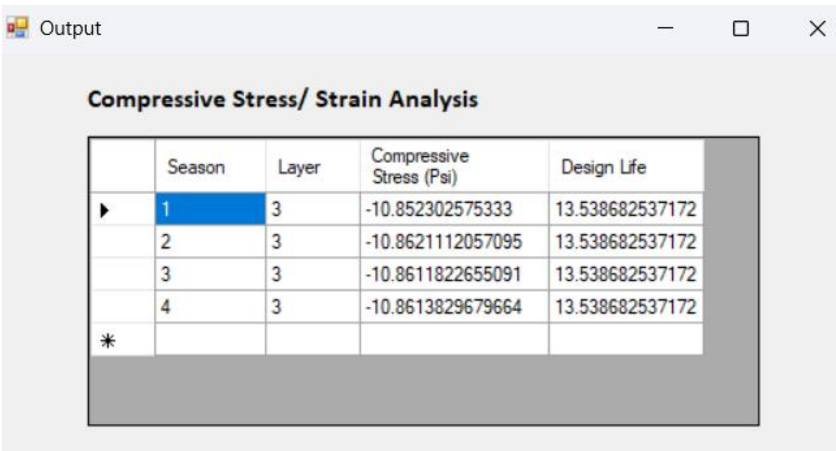

Output
Compressive Stress/ Strain Analysis
Season
Layer
Compressive Stress (Psi)
Design Life
1
3
-13.352232601161
6.23925108822398
2
3
-13.3675768191693
6.23925108822398
3
3
-13.3657396377802
6.23925108822398
4
3
-13.3662575893249
6.23925108822398

Results for concrete ties:









Compressive Stress/ Strain Analysis

Season	Layer	Compressive Stress (Psi)	Design Life
1	3	-10.852302575333	13.538682537172
2	3	-10.8621112057095	13.538682537172
3	3	-10.8611822655091	13.538682537172
4	3	-10.8613829679664	13.538682537172

2. **Service Life of Wooden Ties:**

Lwood = 6.23 years

3. **Service Life of Concrete Ties:**

Lconcrete = 13.53

4. **Change in Service Life:**

ΔL= Lconcrete – Lwood =13.53−6.23=7.3 years

So, concrete ties offer **7.3 years more** service life.

Summary Table:

Tie Type	**Service Life (Years)**	**Notes**
Wooden Ties	6.23	Shorter life, more maintenance
Concrete Ties	13.53	Longer life, durable
Change	**+7.3 years**	If switching to concrete
Reduction	**-7.3 years**	If reverting to wooden

Table.4. service life

Assumptions:

- Environmental and traffic conditions are constant.
- Installation quality is the same.
- Only tie material changes.
- Service life data is accurate and based on similar usage.

4) Environmental impacts

4.A) Mechanism of Ballast System Failure

The ballast in railway tracks serves to hold the track in place, distribute loads, and facilitate drainage. Over time, ballast can fail due to several interrelated mechanisms:

1. Ballast Fouling

Mechanism:

- Fine particles (dust, soil, broken ballast, or material from passing trains) accumulate between ballast stones.
- Reduces void space → poor drainage → water retention.
- Leads to pumping of fines, mud formation, and further degradation.

Result: Track becomes unstable and waterlogged.

2. Particle Breakage (Attrition)

Mechanism:

- Under repeated load cycles, sharp-edged stones crush or break.
- Loses interlock and reduces the shear strength of the ballast.

Result: Settlement, loss of track geometry, and uneven support.

3. Sleeper Movement and Settling

Mechanism:

- Ballast under the sleeper shifts due to lateral and vertical loads.
- Causes differential settlement and loss of alignment.

Result: Misalignment of track, requiring frequent tamping.

4. Poor Drainage and Water Ingress

Mechanism:

- If drainage is insufficient (e.g., due to fouling or design issues), water accumulates.
- Water reduces bearing capacity and may cause mud pumping.

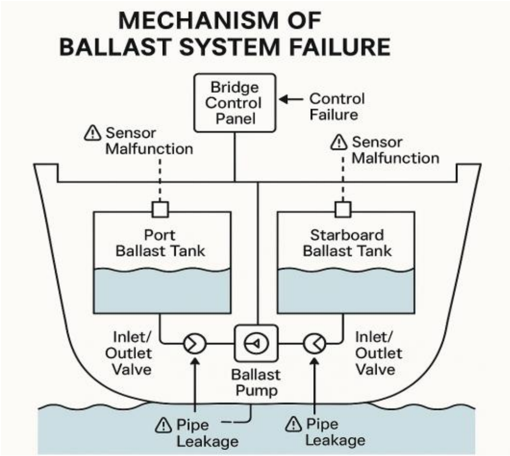
Result: Accelerates deterioration and causes rapid degradation.

5. Vegetation and Biological Growth

Mechanism:

- Weeds and plants grow in fouled ballast.
- Root systems hold moisture, accelerate fouling, and impede drainage.

Result: Track instability and maintenance problems.



Summary Table of Failure Mechanisms

Failure Mechanism	Cause	Effect
Ballast Fouling	Dust, debris, brake dust, sleeper wear	Poor drainage, pumping, instability
Particle Breakage	Repeated heavy axle loads	Settlement, loss of interlock
Sleeper Movement	Insufficient lateral resistance	Misalignment, uneven support
Poor Drainage	Clogged ballast, lack of slope	Waterlogging, rapid deterioration
Vegetation Growth	Lack of weed control	Moisture retention, fouling acceleration

Table. 5. Failure mechanisms summary

4B) Ballast failure in railway tracks can have significant implications for track stability, safety, and operational efficiency.

1. What is Ballast?

Ballast is a layer of crushed stones (usually granite, limestone, or basalt) placed beneath railway sleepers (ties) to:

- Distribute load from trains to the subgrade.
- Provide drainage.
- Prevent vegetation growth.
- Maintain track alignment and stability.

2. Causes of Ballast Failure

Ballast failure occurs due to degradation, contamination, or improper maintenance. Common causes include:

A. Degradation & Wear

- **Breakage of Aggregates:** Repeated dynamic loads from trains cause ballast stones to fracture, reducing their strength.
- **Abrasion:** Friction between particles leads to rounding and loss of angularity, reducing interlocking capability.

B. Contamination (Fouling)

- **Fine Particle Accumulation:** Dust, coal, soil, or decomposed ballast fills voids, reducing drainage and load distribution.
- **Mud Pumping:** Water infiltration mixes subgrade soil with ballast, creating a slurry that weakens the track.

C. Poor Drainage

- Water retention due to clogged ballast leads to:
    - **Subgrade softening** (loss of strength).
    - **Frost heave** (in cold climates).
    - **Accelerated corrosion** of track components.

D. Dynamic Load Effects

- High-speed or heavy-haul trains increase stress, accelerating ballast breakdown.
- Vibrations and impact loads from wheel defects (e.g., flat wheels) worsen degradation.

E. Inadequate Maintenance

- Lack of regular tamping (compaction adjustment).
- Delayed cleaning or replacement of fouled ballast.

3. Implications of Ballast Failure

A. Track Geometry Deterioration

- **Settlement & Uneven Track:** Leads to misalignment (warping, buckling).
- **Increased Maintenance Needs:** Frequent tamping or ballast renewal required.

B. Reduced Train Performance & Safety Risks

- **Speed Restrictions:** Poor track conditions force slower speeds.
- **Derailment Risk:** Excessive track movement increases derailment chances.
- **Ride Discomfort:** Passengers and cargo experience vibrations.

C. Structural Damage to Track Components

- **Sleeper Damage:** Increased stress causes cracks or splitting.
- **Rail Wear:** Uneven loading accelerates rail fatigue and defects.
- **Subgrade Failure:** Persistent ballast failure leads to subgrade erosion.

D. Higher Maintenance Costs

- Frequent repairs, ballast cleaning, or replacement increase expenses.
- Unplanned downtime affects railway operations.

E. Long-Term Infrastructure Degradation

- **Reduced Lifespan:** Continuous ballast failure shortens track life.
- **Need for Major Rehabilitation:** Complete track renewal may be required.

4. Mitigation & Solutions

To prevent ballast failure, the following measures can be taken:

A. Proper Ballast Selection

- Use hard, angular, and durable stones (e.g., granite).
- Ensure correct gradation (size distribution) for optimal load transfer.

B. Regular Maintenance

- **Tamping:** Adjust ballast compaction to restore track geometry.
- **Ballast Cleaning:** Remove fouled material using undercutting machines.
- **Drainage Improvement:** Install proper side drains and sub-ballast layers.

C. Geosynthetic Reinforcement

- Geogrids or geotextiles can stabilize ballast and reduce settlement.

D. Improved Subgrade Design

- Use capping layers (sub-ballast) to prevent fine material intrusion.

E. Monitoring & Inspection

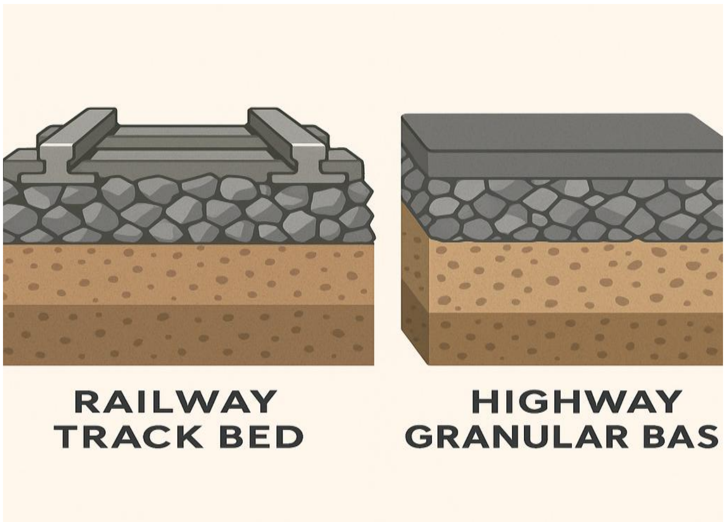
- Track geometry cars and ground-penetrating radar (GPR) detect early ballast fouling.

5. Conclusion

Ballast failure is a critical issue that compromises railway safety, efficiency, and longevity. Proper material selection, maintenance, and drainage management are essential to mitigate its effects. Neglecting ballast conditions can lead to costly repairs, operational disruptions, and increased accident risks.

4C) Differences between the aggregates for railway ballast and aggregate for highway granular base construction

Aspect	Railway Ballast Aggregates	Highway Granular Base Aggregates
Primary Function	Support and stabilize railway tracks; facilitate drainage	Distribute loads and provide a stable foundation for roads
Aggregate Size	Large (typically 25–63 mm)	Smaller (typically 5–40 mm, depending on the layer)
Shape	Angular with sharp edges to interlock tightly	Angular to sub-angular; some rounded particles accepted
Strength Requirements	Very high (resistant to crushing under repeated heavy loads)	High, but generally less stringent than for ballast
Durability	Extremely durable (resistant to weathering and attrition)	Durable, but slight degradation over time may be tolerated
Cleanliness	Very clean (minimal fines and dust)	Some fines allowed to aid compaction
Drainage Requirements	Excellent drainage essential	Good drainage desirable but less critical
Material Types	Hard rocks like granite, basalt, or hard limestone	Crushed stone, gravel, sand, and sometimes recycled materials
Compaction Behaviour	Minimal compaction (placed loose and vibrated lightly)	High compaction required for structural stability
Maintenance	Regular tamping and cleaning needed	Less frequent maintenance compared to ballast



4D) Discuss three factors that are critical to aggregates used for construction track ballast high speed rail applications.

Critical Factors for Aggregates in High-Speed Rail Track Ballast

1. Strength and Durability

- **Significance:** High-speed rail systems impose intense dynamic and repetitive loads on the track structure. The ballast must remain stable under these stresses to prevent deformation and maintain track geometry.
- **Key Requirements:**
  - High **crushing strength** to resist breakdown under load.
  - Low **Los Angeles Abrasion Value** to ensure long-term resistance to wear.
  - Resistance to **weathering** and **freeze-thaw cycles**.

2. Particle Shape and Size

- **Significance:** The interlocking ability of ballast particles is critical for lateral and vertical stability. Poorly shaped particles can lead to excessive movement or settlement.
- **Key Requirements:**
  - **Angular** and **rough-textured** particles to maximize interlock and friction.
  - **Uniformly graded** material, typically in the range of **25–63 mm**.
  - Low **flakiness and elongation index** to reduce the risk of particle rotation or shifting.

3. Cleanliness and Drainage Capability

- **Significance:** Effective drainage prevents water accumulation, which can weaken the subgrade and reduce the structural integrity of the track.
- **Key Requirements:**
  - Very low **fines content** (usually less than 1–2%) to avoid clogging.
  - Well-washed aggregates with no **clay, silt, or organic material**.
  - High **permeability** to ensure quick water runoff from the track bed.

Visual Aid: Cross-Sectional Comparison

Below is a diagram showing the structure of a typical high-speed rail ballast layer and its critical components:

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UIC (International Union of Railways) *UIC Code 719 – Earthworks and Track Bed Layers for Railway Lines*

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➤ European standard outlining grading, physical, and mechanical properties required for ballast in rail applications.

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European Standard (EN 13450): Specifies requirements for track ballast, including angularity and particle shape, emphasizing the importance of interlocking for stability.

Indraratna et al. (2011): *"Advanced Rail Geotechnology – Ballasted Track"* discusses how angular aggregates improve shear strength and reduce deformation under dynamic loads.

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Raymond (1985): *"Railway Track Ballast Evaluation"* highlights the importance of abrasion resistance in minimizing particle breakdown under repeated loading.

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