URS

Trackbed Evaluation and Design Using FWD Deflections as Performance Indicators

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Dr Bachar Hakim
Technical Director - Head of Pavement and Materials Consultancy
URS Infrastructure & Environment, Nottingham, United Kingdom

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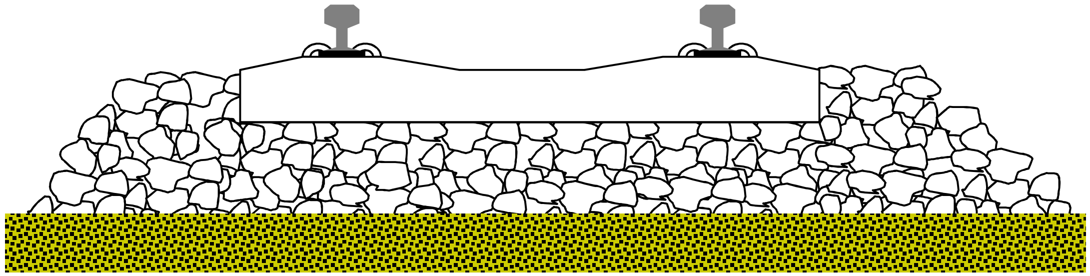
UK ballasted trackbed design



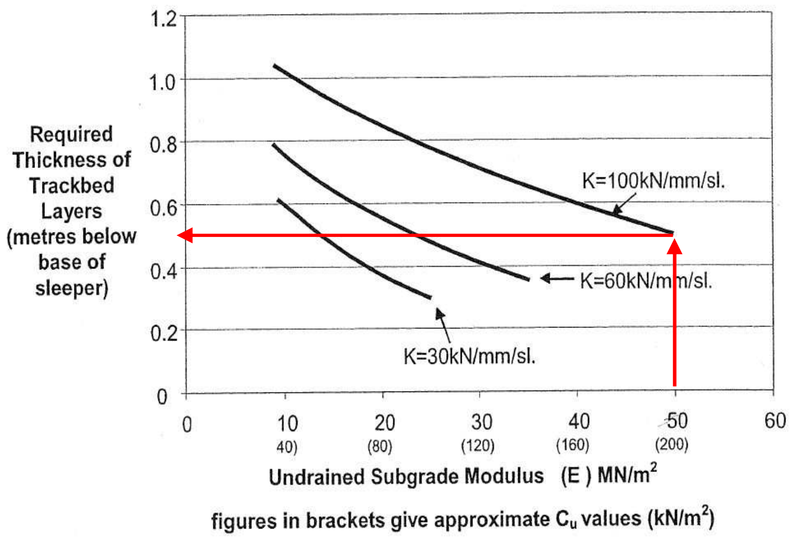


Figure 2 – Required Thickness of Trackbed Layers

- Based on past performance
- Subgrade strength/stiffness
- Design speed
- Granular materials thickness
- Typically top 300mm is ballast

Influence of Trackbed Stiffness on Track Quality

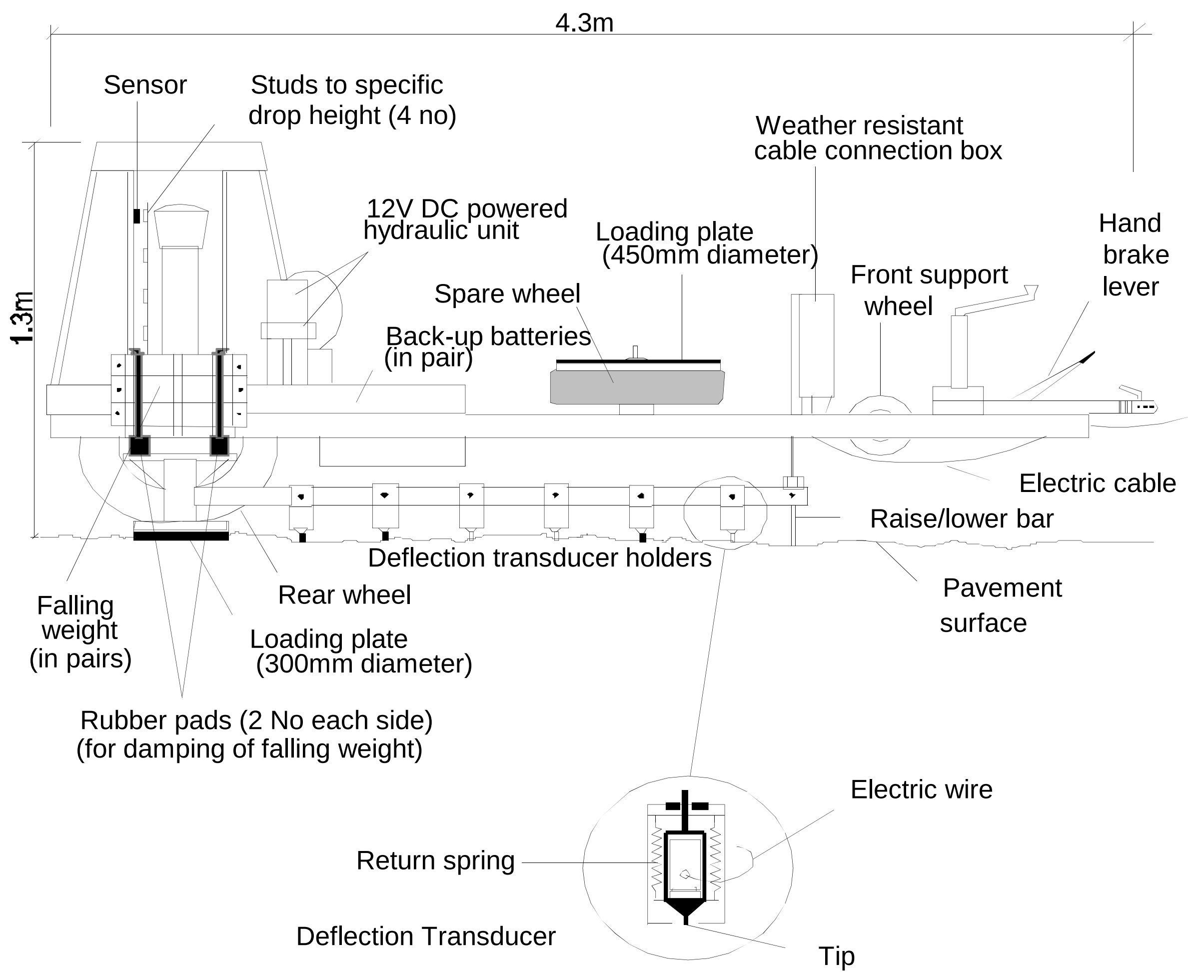
- Trackbed condition and ride quality deteriorate with time and loading
- Good track geometry requires stiff uniform formation
- Most tracks in UK 150 years old (trackbed not suitable for high speed)
- Trackbed stiffness is historically difficult to determine
- Sampling and testing subgrade is not commercially viable, theoretically based design unsuitable for existing railway
- Can use Plate Bearing Tests (PBT's) - expensive and time consuming
- Elastic Modulus is dependent on rate of loading - PBT's apply static loading
- Falling Weight Defectometer can be used to measure stiffness and critical velocity

Trackbed evaluation using the Falling Weight Deflectomter

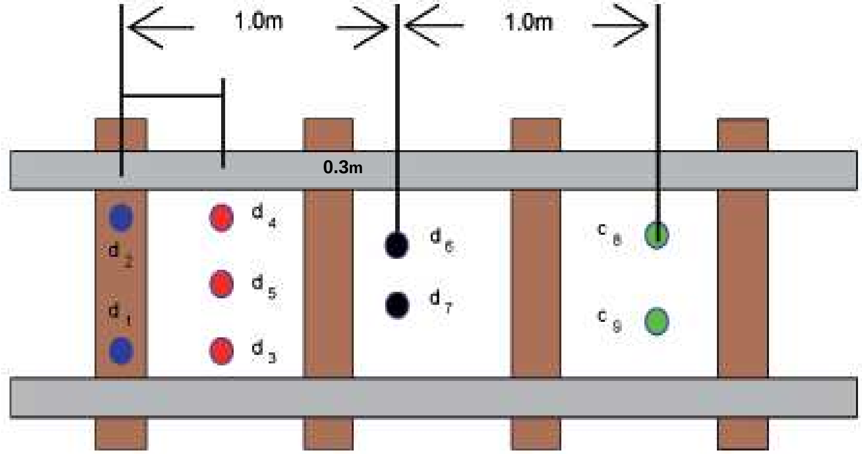
Falling Weight Deflectometer

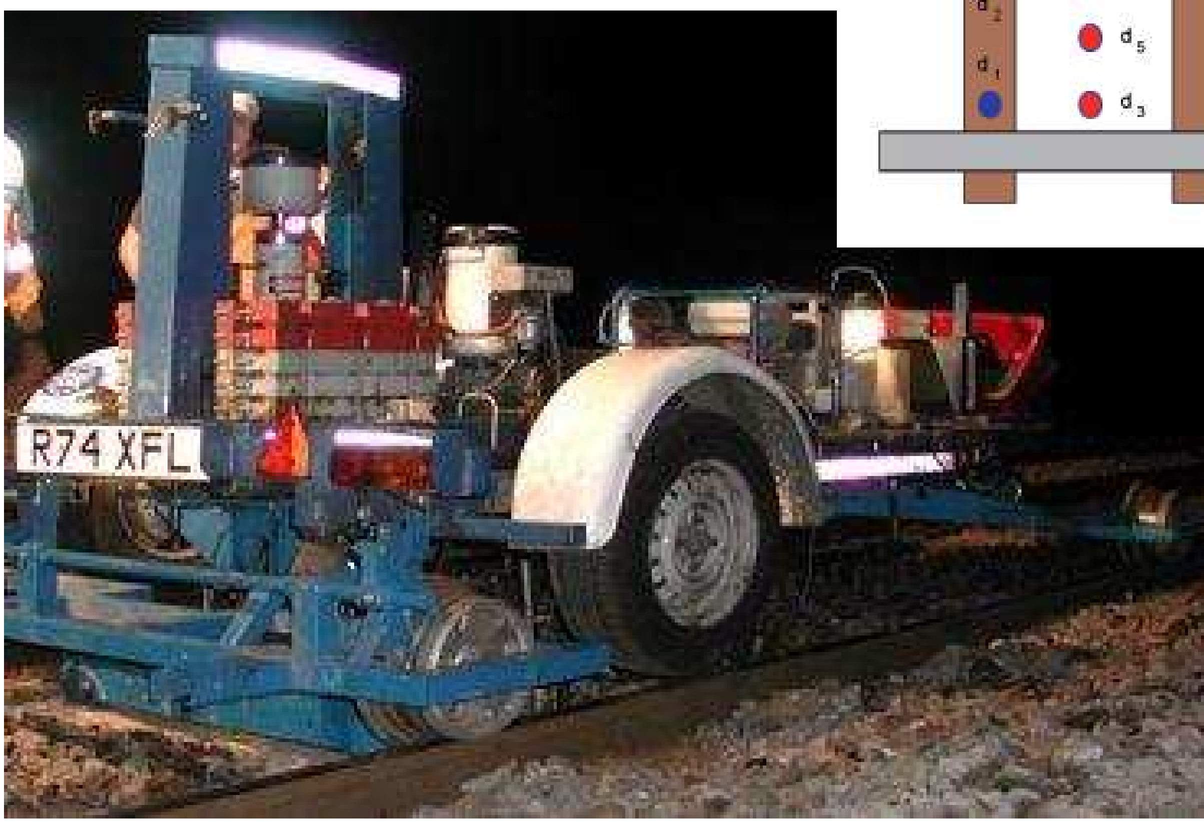
- Measures deflections under dynamic load – developed for pavement analytical evaluation
- Determined layer stiffnesses to estimate residual life

FWD loading plate and geophone

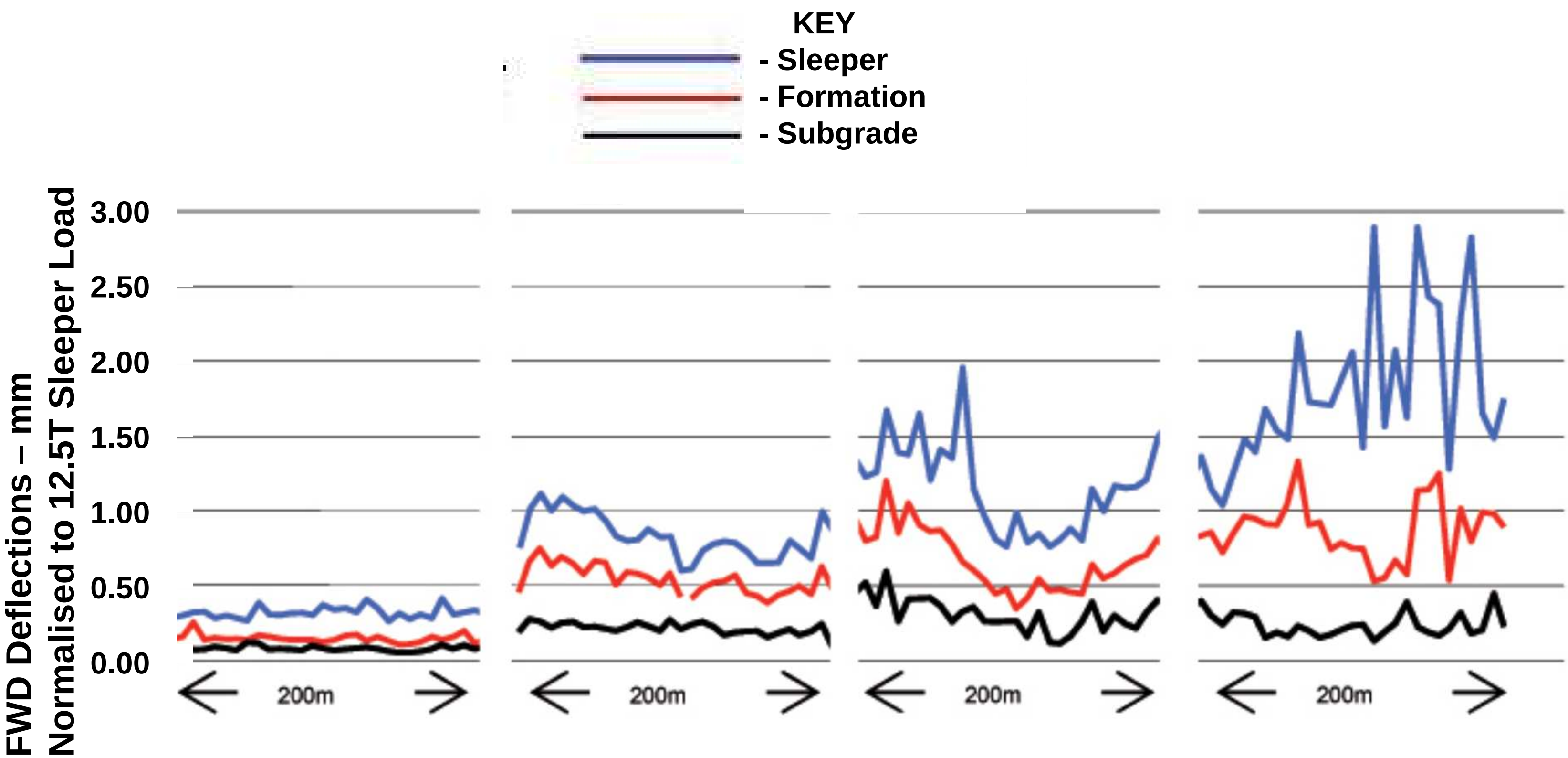


FWD Adapted for Railways





Relationship Between Stiffness and Track Quality



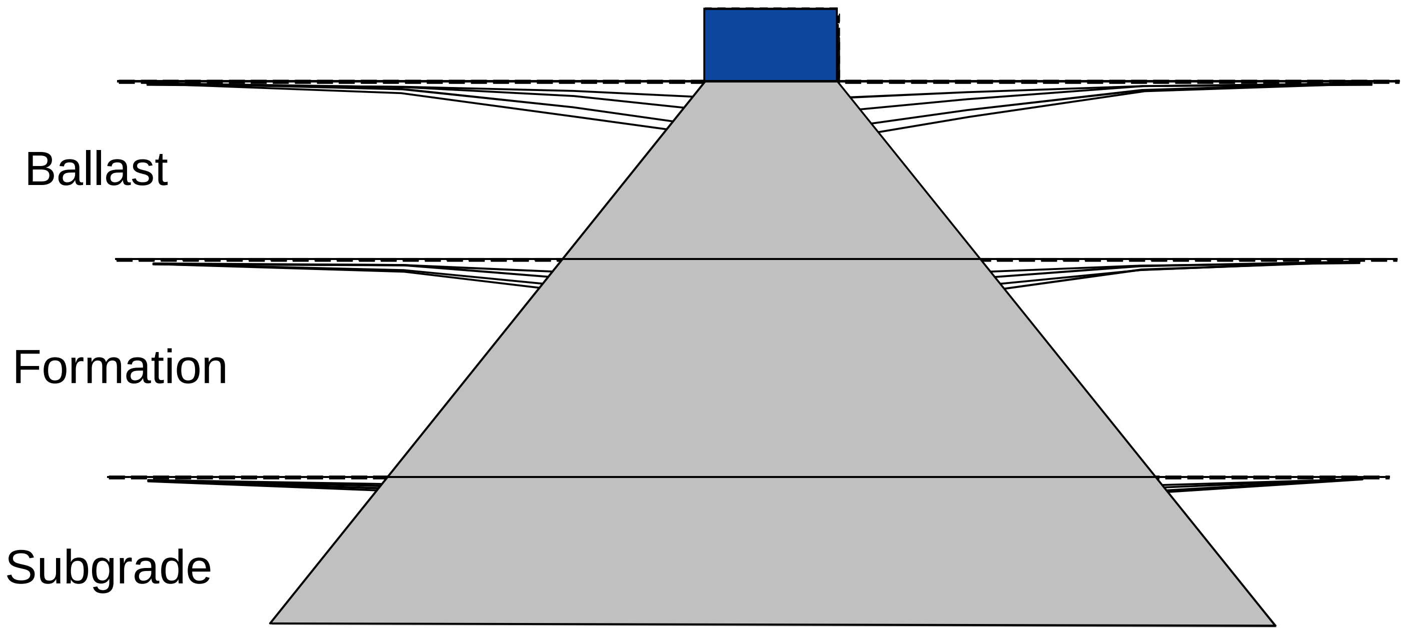
New High Speed Line SD 0.7mm

UK Main Line Good TQ SD 1.5mm

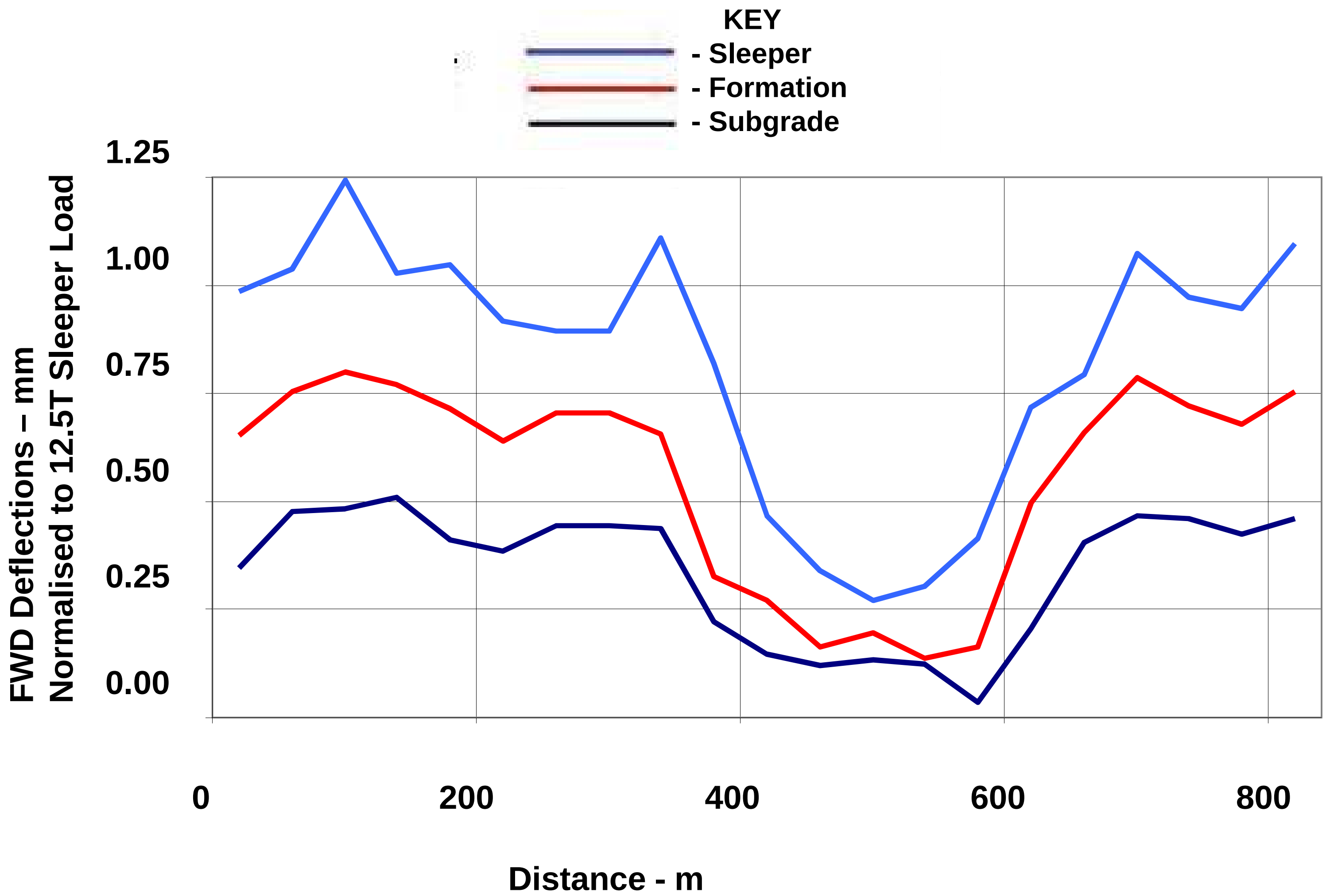
UK Main Line Poor TQ SD 2.5mm

Secondary Line Very Poor TQ SD >5.0mm

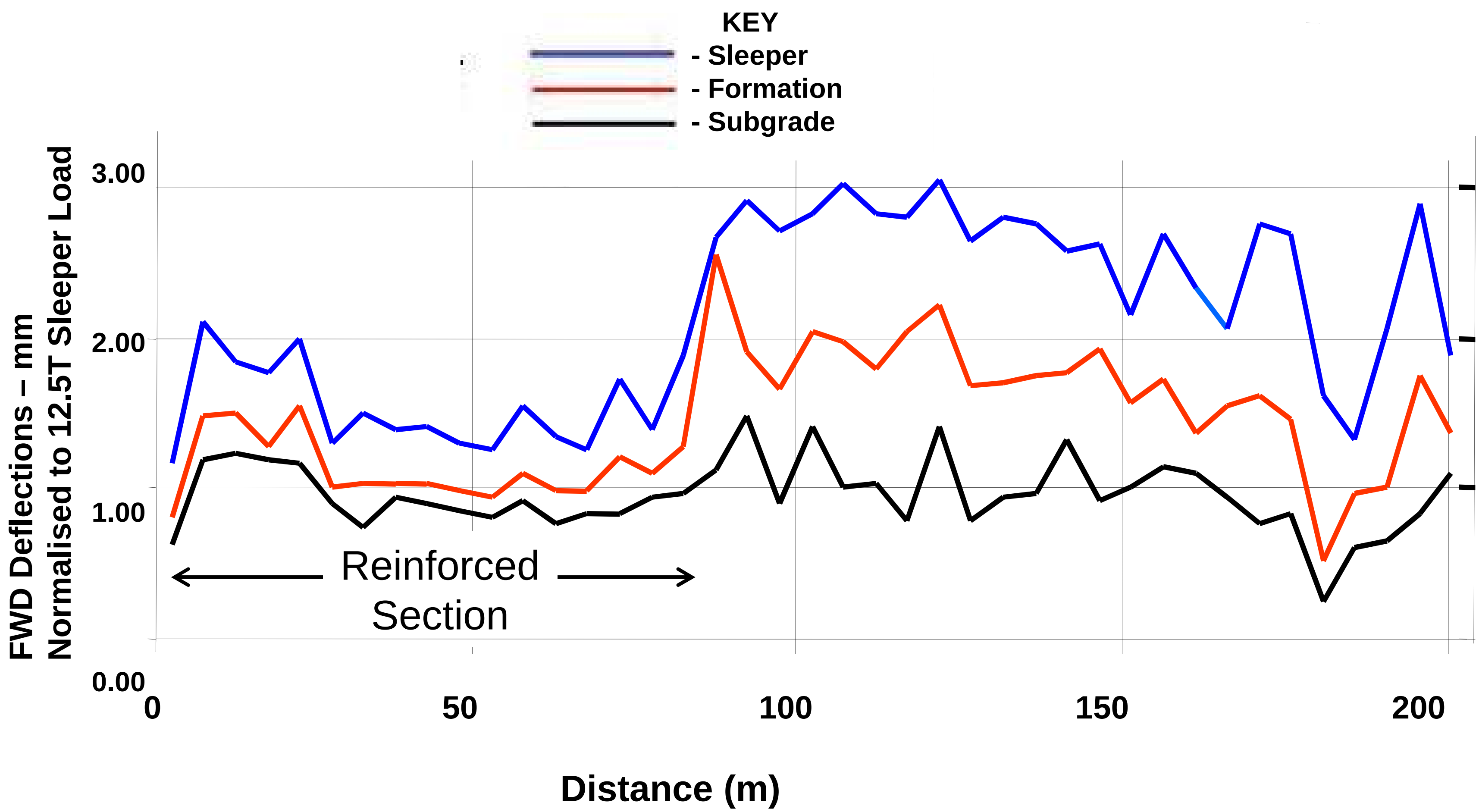
Simplified Trackbed Model



Motorway Underbridge



Reinforced Trackbed



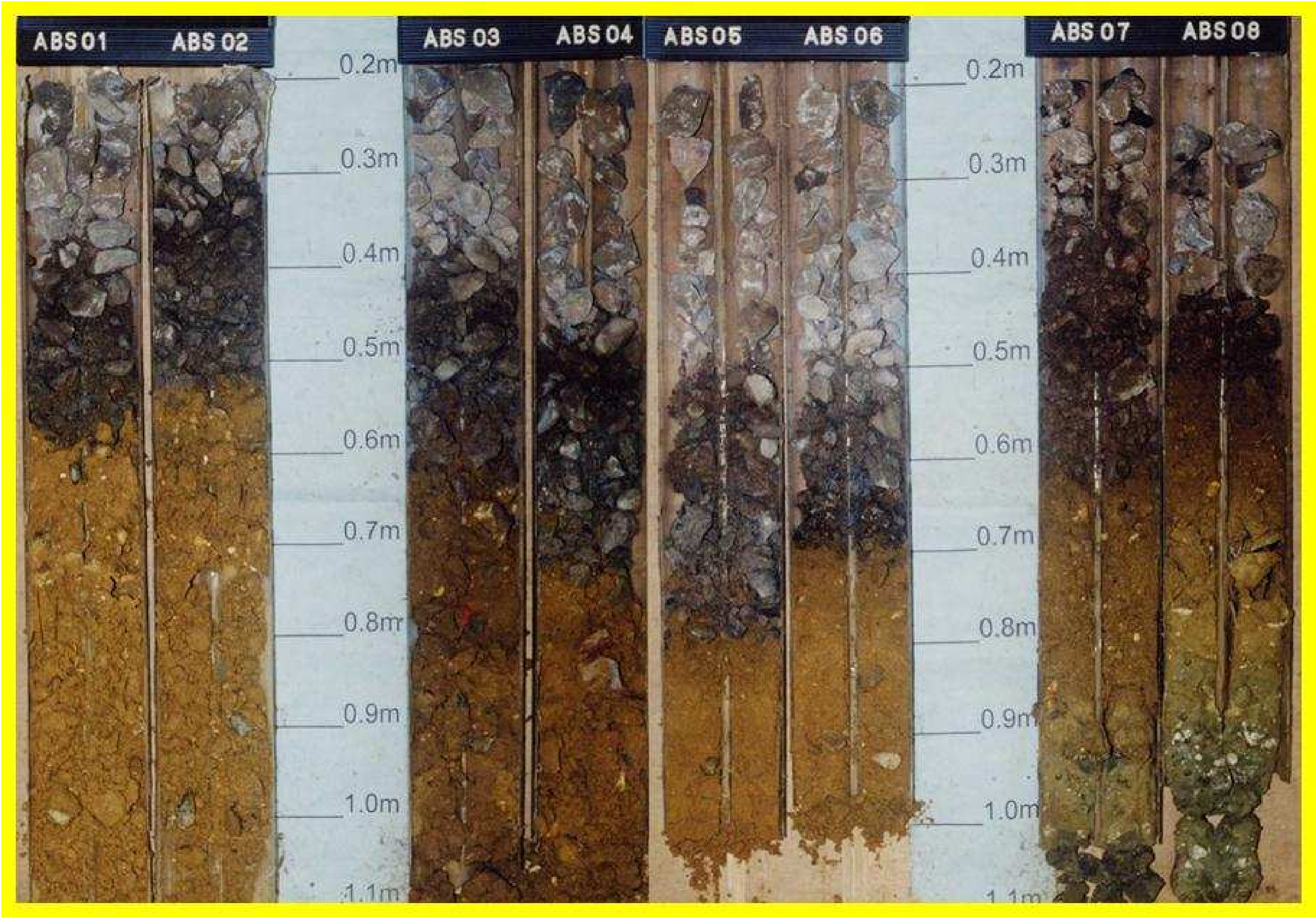
Deflections as performance indicators

- Technique well established in UK and Ireland (more than 100miles since 1998)
- FWD deflections can be used as performance indicators
  - Sleeper defection d0 – Overall trackbed condition
  - Defection at 300mm – ballast condition
  - Deflection at 2m – subgrade

- FWD deflections can be analysed to determine layer stiffness (material condition), requires layer thicknesses

Automatic Ballast Sampling

Automatic Ballast Sampling:
through core holes to determine unbound materials and subgrade

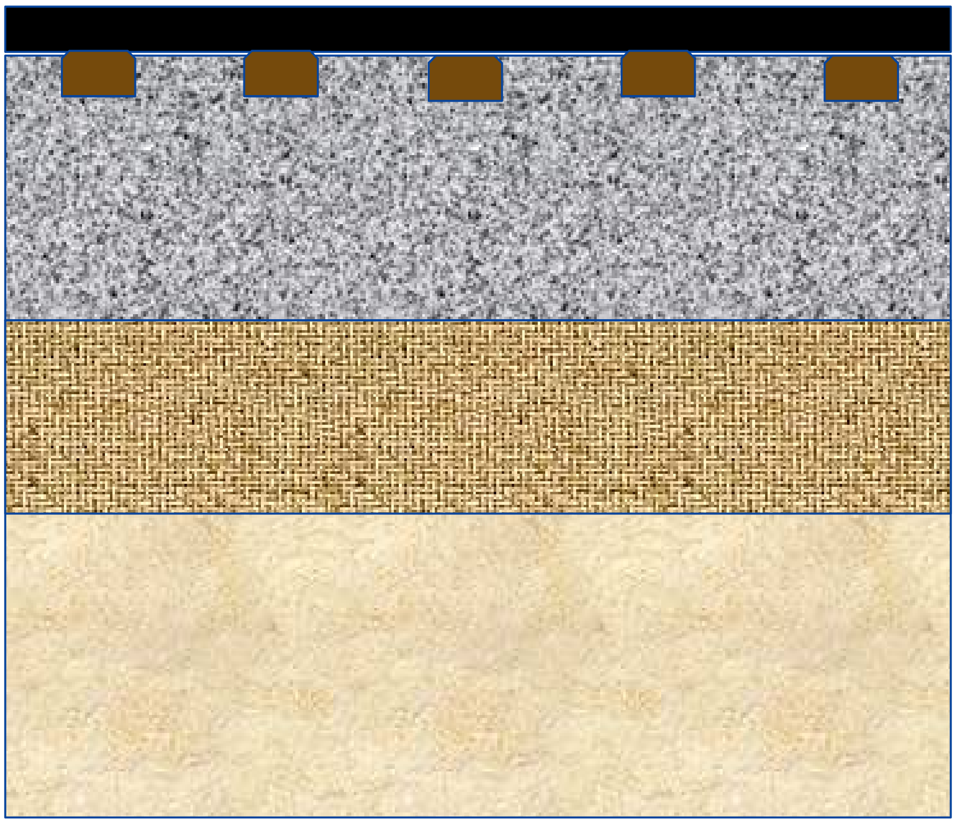


Analytical design and performance calibration

Analytical trackbed design

- Model the trackbed as a multilayered elastic system
- Specify trackbed layer and subgrade stiffnesses
- Calculate deflections under FWD loading applied on one sleeper
- Calculate maximum stress in subgrade under actual axle loading applied on multiple sleepers
- Compare calculated deflection with the design values based on the desire Track Quality (e.g. <1mm for UK Mainline Good TQ)
- Compare the subgrade shear stress to the allowable material strength (e.g. limit the stress to 50% of the material strength)
- Compare results with current standards/reference structure

Theoretical model – multi-layered elastic model



Typical Stiffness (Young Modulus) E- MPa

(normally assume Poissons Ration to be 0.4- 0.5)

Ballast

100 – 200 MPa

Blanket

100 - 300

Subgrade

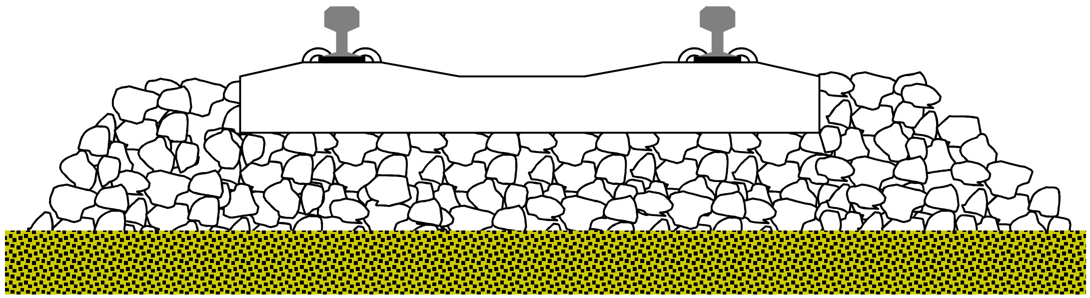
Peat 10

Clay 30

Chalk >200

Additional materials such as geoweb, stabilised and asphalt can be considered to improve track stiffness over poor subgrade

Analytical trackbed design based on UK chart
to develop tailored solutions



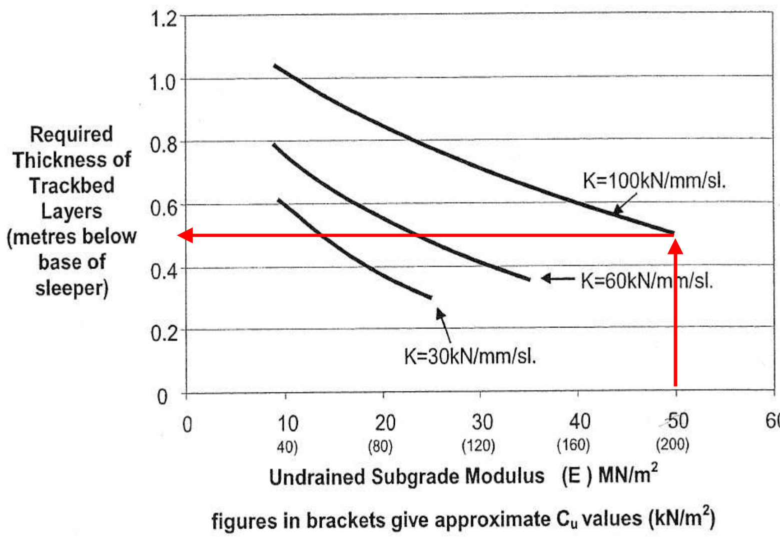
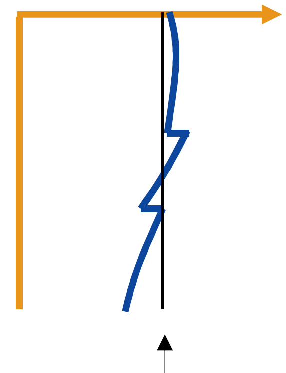


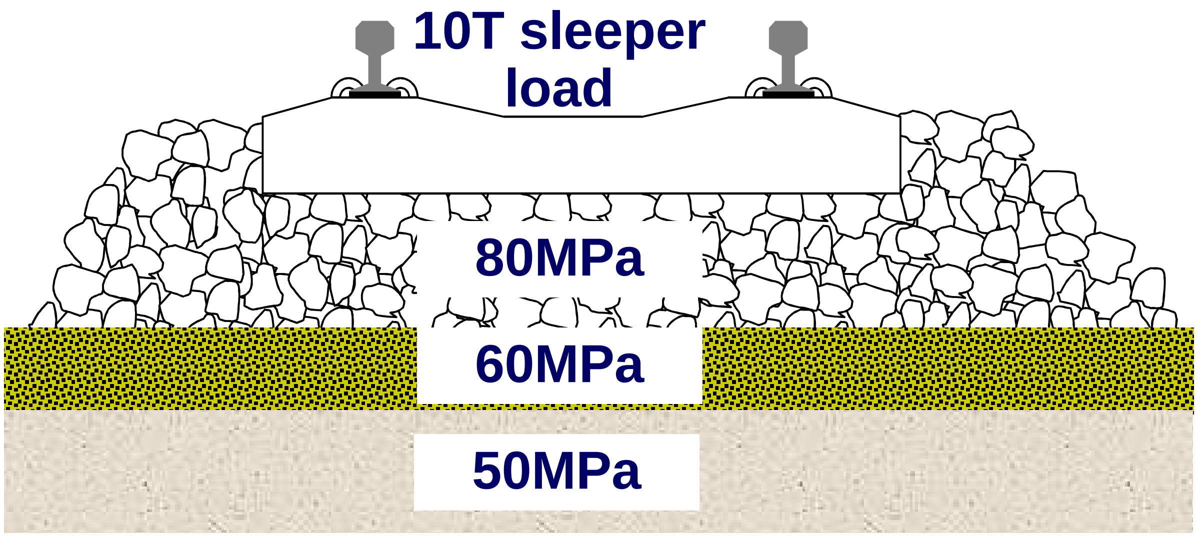
Figure 2 – Required Thickness of Trackbed Layers

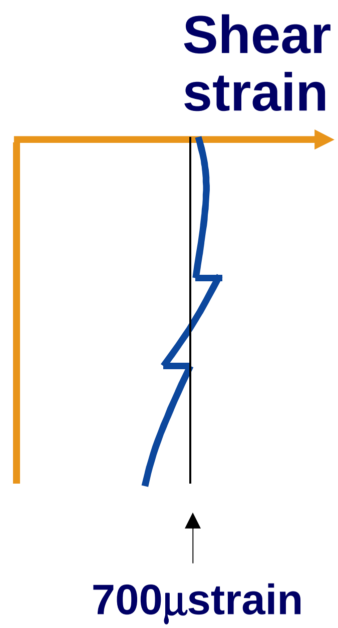
Shear strain



- Maximum Axle Load = x tonne
- Wheel Spacing = y mm
- Sleeper Spacing = z mm
- Sleeper Size = u mm * w mm
- Train Speed = v mph

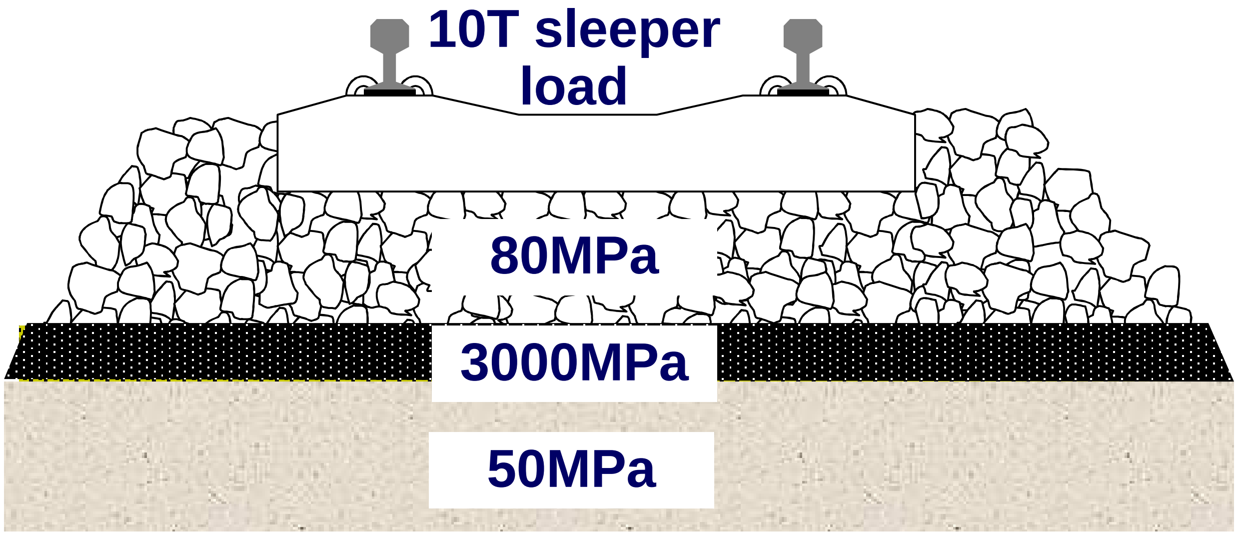
Analysis - Conventional:

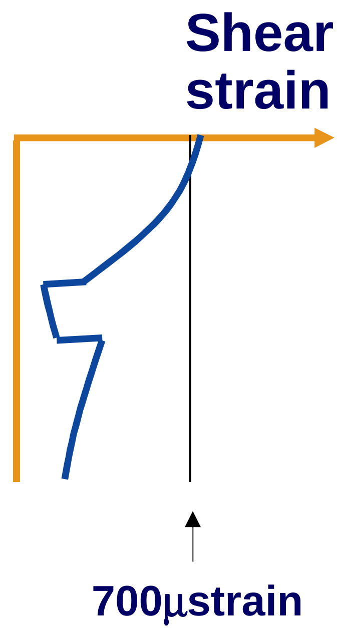




- high shear strain in ballast
- high shear strain in subgrade

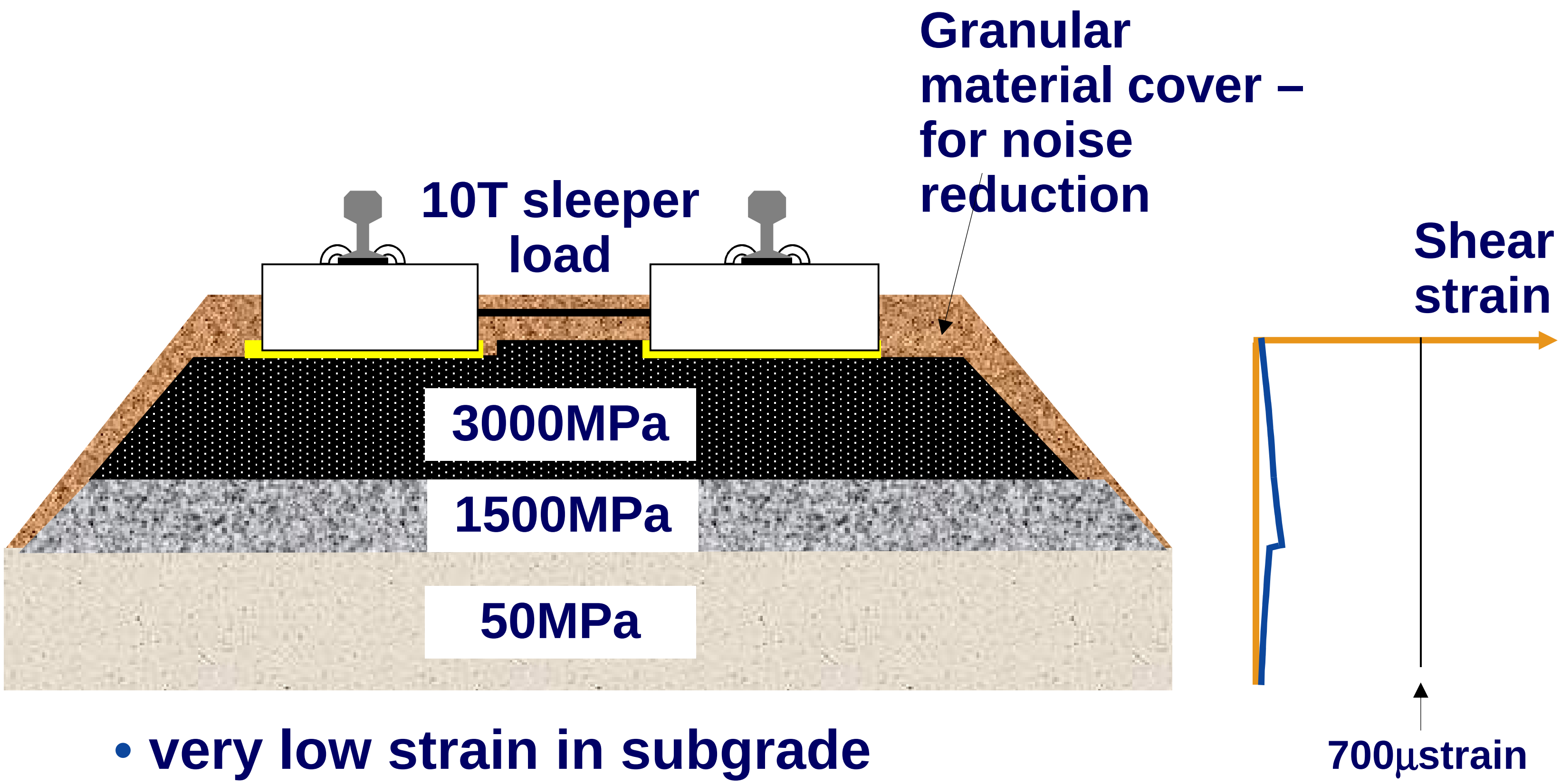
Analysis - Asphalt Underlay:





- reduced shear strain in ballast
- low shear strain in subgrade
- design issue is cracking of asphalt

Analysis - Asphalt Trackbed:



- very low strain in subgrade
- design issue is deformation in asphalt

Case Studies

Case study 1

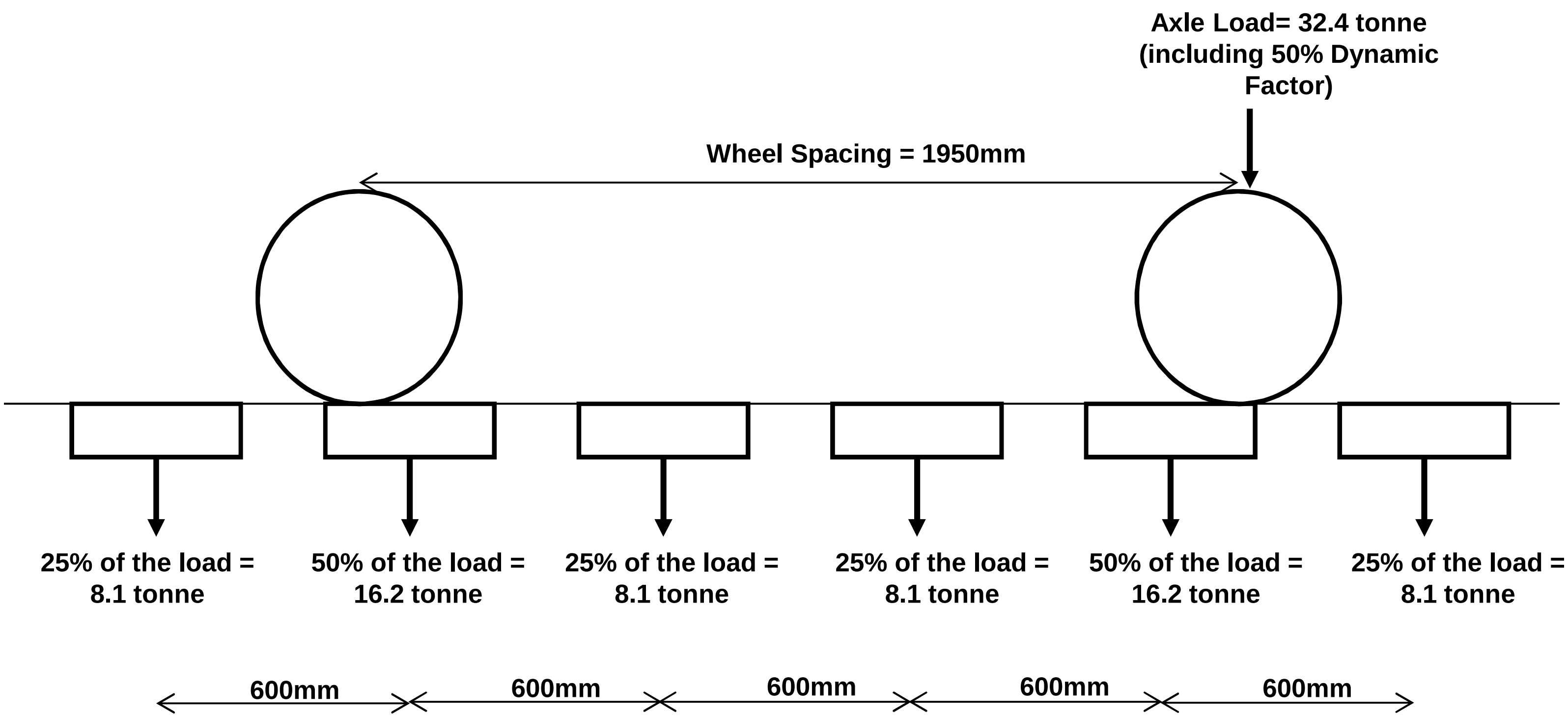
- Poor track quality due to poor subgarde and drainage
- Level constraints
- Alternative strengthening designs using stabilised clay and asphalt materials
- Design checked analytically to match the reference structure

Track and loading information

- Maximum Axle Load = 21.6 tonne
- Wheel Spacing = 1950mm
- Sleeper Spacing = 600mm
- Sleeper Size = 2500mm*200mm
- Train Speed > 100 mph

- Assumptions: Dynamic Factor = 50%

Track and loading information

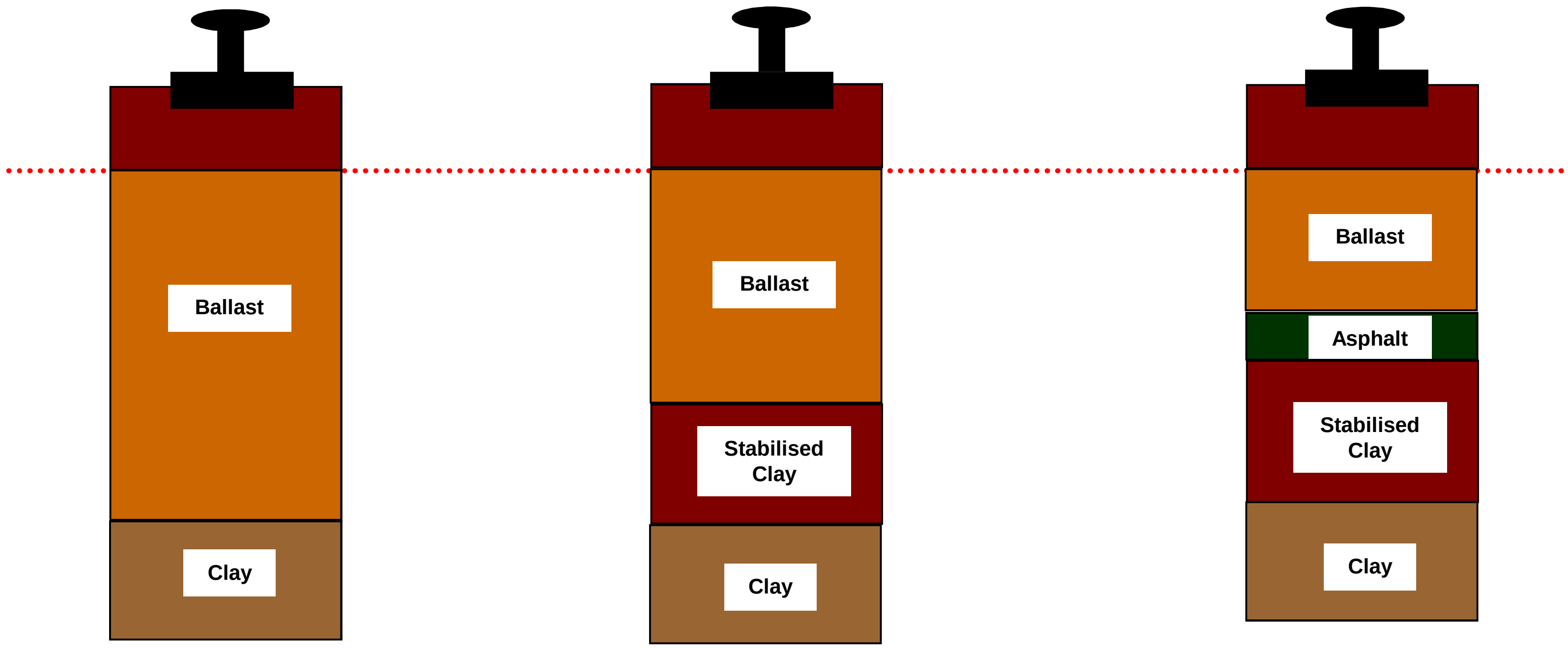


Trackbed Designs

- Multilayer Linear Elastic System Analysis using the following stiffnesses:
  - Ballast Stiffness = 120 MPa
  - Granular Material Stiffness = 100 MPa
  - Asphaltic Layer Stiffness = 3000 MPa
  - Stabilised Clay = 120 MPa
  - Subgrade = 30 - 50 MPa

- Design considers surface deflection and subgarde shear stress

Alternative Designs



Reference Structure

- Remove 700-1000mm of existing material
- Place 800mm Ballast

Option 1

- Remove 400-700mm of existing material
- Stabilise 300mm Clay
- Place 500mm Ballast

Option 2

- Remove 300-600mm of existing material
- Stabilise 300mm Clay
- Place 100mm Asphaltic material
- Place 300mm Ballast

Case study 2

- Trackbed improvement is required
- Two sections were considered (worst and best cases, with soft clay and sand and gravel formations respectively)
- Two treatment options were considered (raising the track by 500mm and using a Geoweb)
- Deflections under FWD loading controlled to match the reference structure
- Subgarde shear stress limited to 50% of material strength

Geowebs and Geogrids

Trackbed construction options

Status	Worst Case	Best Case
Current Situation	300mm Ballast 500mm Soft Clay 3000mm+ Firn Clay	300mm Ballast 3000mm Sand and Gravel 1000mm+ Firm Clay
Design Option A (Geoweb)	300mm Ballast 200mm GeoWeb 100mm Sand 200mm Soft Clay 3000mm+ Firn Clay	300mm Ballast 200mm GeoWeb 2800mm Sand and Gravel 1000mm+ Firm Clay
Design Option B (Track Lift 500mm)	800mm Ballast 500mm Soft Clay 3000mm+ Firn Clay	800mm Ballast 200mm GeoWeb 2800mm Sand and Gravel 1000mm+ Firm Clay

Design parameters and output results

Assumptions on foundation	Assumptions on material	Assumptions on trackbed
• CBR 23-27% • Cu = 47 KPa	• Ballast (old) = 80MPa • Ballast (New) = 100MPa • Soft Clay = 30MPa • Firm Clay = 50MPa • Sand and Gravel = 80MPa • Geoweb = 1000MPa*	• Standard sleeper dimentison = 0.3 x 2.6 m^2 • Sleeper spacing = 0.62m • Single wheel load spread across 3 sleepers – 50% on centre sleeper and 25% on each adjacent sleepers

Problem (Cases) No.	Description	Deflection (mm)
1	Current Situation – Worst Case	2.08
2	Option A – Worst Case	1.41
3	Option B – Worst Case	1.50
4	Current Situation – Best Case	1.32
5	Option A – Best Case	1.03
6	Option B – Best Case	1.06

Reference Model	Ref. deflection (mm)
300mm Good Ballast 100MPa 200mm Old Ballast 80MPa Subgrade Firn Clay 50MPa	1.6

Problem (Cases) No.	Description	Max Shear Stress (KPa)
1	Current Situation – Worst Case	56.7
2	Option A – Worst Case	17.3
3	Option B – Worst Case	19.4
4	Current Situation – Best Case	77.1
5	Option A – Best Case	23.5
6	Option B – Best Case	13.9

Thank you

bachar.hakim@urs.com