

Masterclass in Practical Cold Recycling and BSM Pavement Design

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Introduction

- Bitumen stabilised materials for cold recycling
 - Existing granular or previously stabilized materials
 - Bitumen emulsion or foamed bitumen
- How we do pavement design for BSMs
- Design methods

Secret



- Pavement Design is the easier part
- Materials characterization and design assumptions & inputs are the challenge!

If you don't want to do materials investigations, don't bother with pavement design

Materials Investigation

- Investigate whole pavement, not just BSM layer
- Get as much materials data as possible



Information Types

- Background info
 - Pavement age, as-builts, maintenance and rehab, climate, geometry
- Visuals, rutting and roughness
- Deflections
- Dynamic cone penetrometer (DCP)
- Trial pits
 - Lab testing



So what? How classify materials for design?



- Material specifications
 - Most countries have their own
 - Often not with BSM criteria
- Traditional specifications do not account for existing materials in a pavement
 - In situ density and moisture conditions
 - Support under the layer
- *Need to use what you have got, not specifying a new material*

DEMAC

- Design Equivalent Materials Classification System
- In situ material equivalency in terms of shear strength and stiffness
 - Considers in situ conditions
 - Not rigid like traditional specifications
 - What experienced designers do with materials data



Technical Guideline: Bitumen Stabilised Materials

A Guideline for the Design and Construction of Bitumen Emulsion and Foamed Bitumen Stabilised Materials

TG2 Third Edition August 2020



excellence in bituminous products

DEMAC Tests

Soaked CBR	(0.25)
Percent passing 0.075 mm sieve	(0.3)
Relative density	(0.3)
DCP penetration	(0.4)
FWD stiffness	(0.3)
Linear shrinkage	(0.35)
Plasticity index	(0.3)
PI of P0.075 mm	(0.3)
Relative moisture	(0.4)
Grading	(0.45)
Grading modulus	(0.2)
Fractured faces	(0.3)
Consistency	(0.2)
Visible moisture	(0.2)
Historical performance	(0.2)

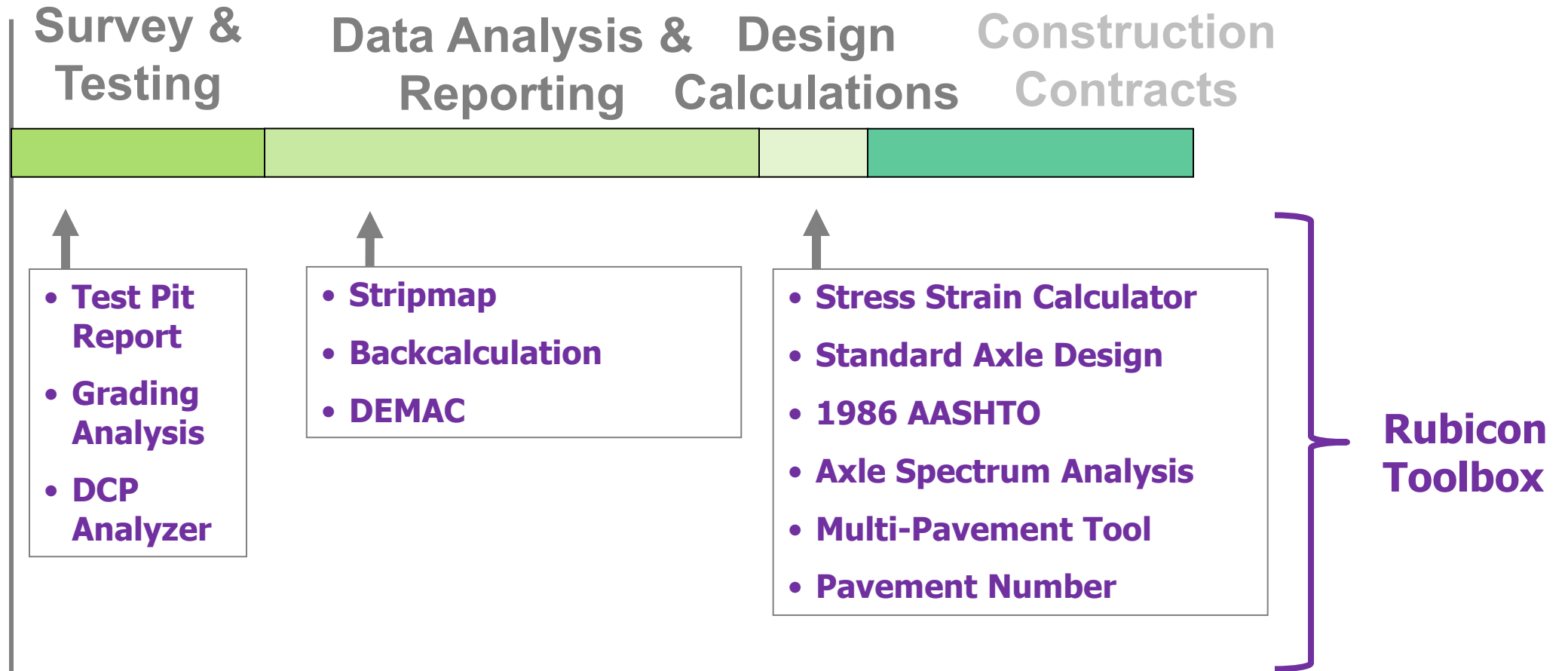
BSM Mix Design

- Once know available materials
- Careful BSM mix design
 - Add better quality materials?
 - Add fines?
 - Filler type and quantity?
 - BSM type and quantity?
 - BSM class (BSM1 and 2)

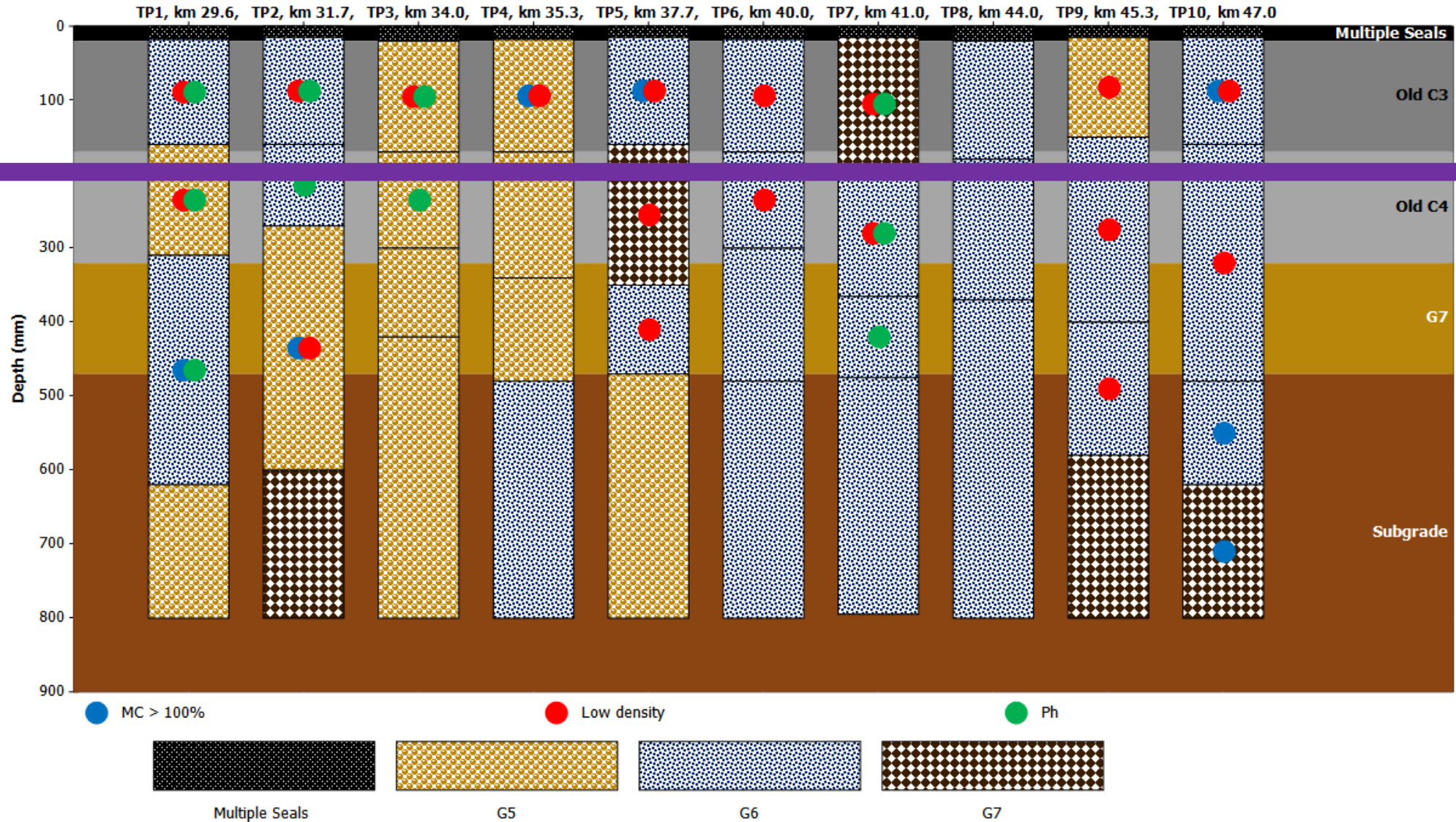


- Remember, BSM only as good as parent materials

Rehabilitation Design Process



Test Pit Summary



Pavement Design

- AASHTO
- Mechanistic-Empirical
- Pavement Number

AASHTO BSM Layer Coefficient for BSM

Wirtgen Cold Recycling Manual

SUGGESTED STRUCTURAL LAYER COEFFICIENTS FOR BITUMEN STABILISED MATERIAL (BSM)									
STRUCTURAL LAYER COEFFICIENT (per inch)									
0.18		0.23				0.28		max 0.35	
INDIRECT TENSILE STRENGTH (ITS) AFTER STABILISATION									
<u>100 / 150mm ϕ specimens</u>									
ITS _{DRY} (kPa)		125	175			225			
ITS _{WET} & ITS _{SOAK} (kPa)		50	75			100			
<u>150mm ϕ specimens</u>									
ITS _{EQUIL} (kPa)		95	135			175			
<u>Indicated shear properties</u>									
Cohesion (kPa)		50	100			250			
Angle of Friction (°)		25	30			40			
MATERIAL CBR VALUE BEFORE STABILISATION (at 100% compaction)									
Materials with CBR < 20% not recommended		20	40			80			
ANTICIPATED APPLICATION RATE OF BITUMEN FOR STABILISATION (% by mass)									
		2.5 - 4.0		2.0 - 3.0		1.8 - 2.3			

BSM Performance under Repeated Loads

Flexural cracking?

i.e. behave like asphalt
and cement stabilised layers

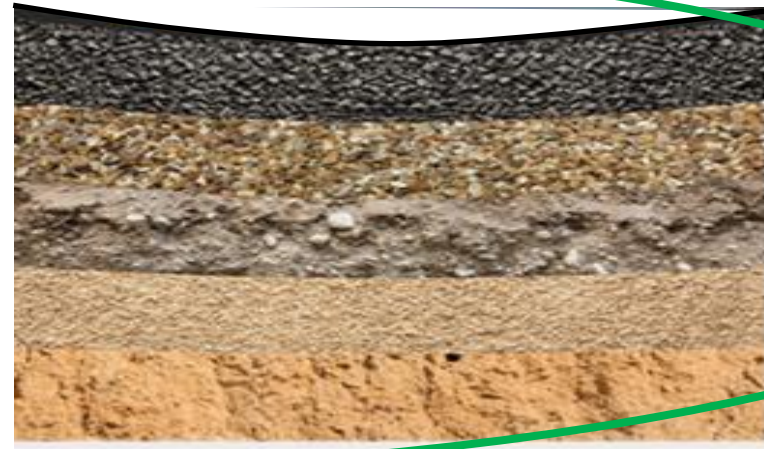
Continuously Bound



Or, gradual consolidation ?

i.e. behave like granular material

Unbound or Non-continuously Bound

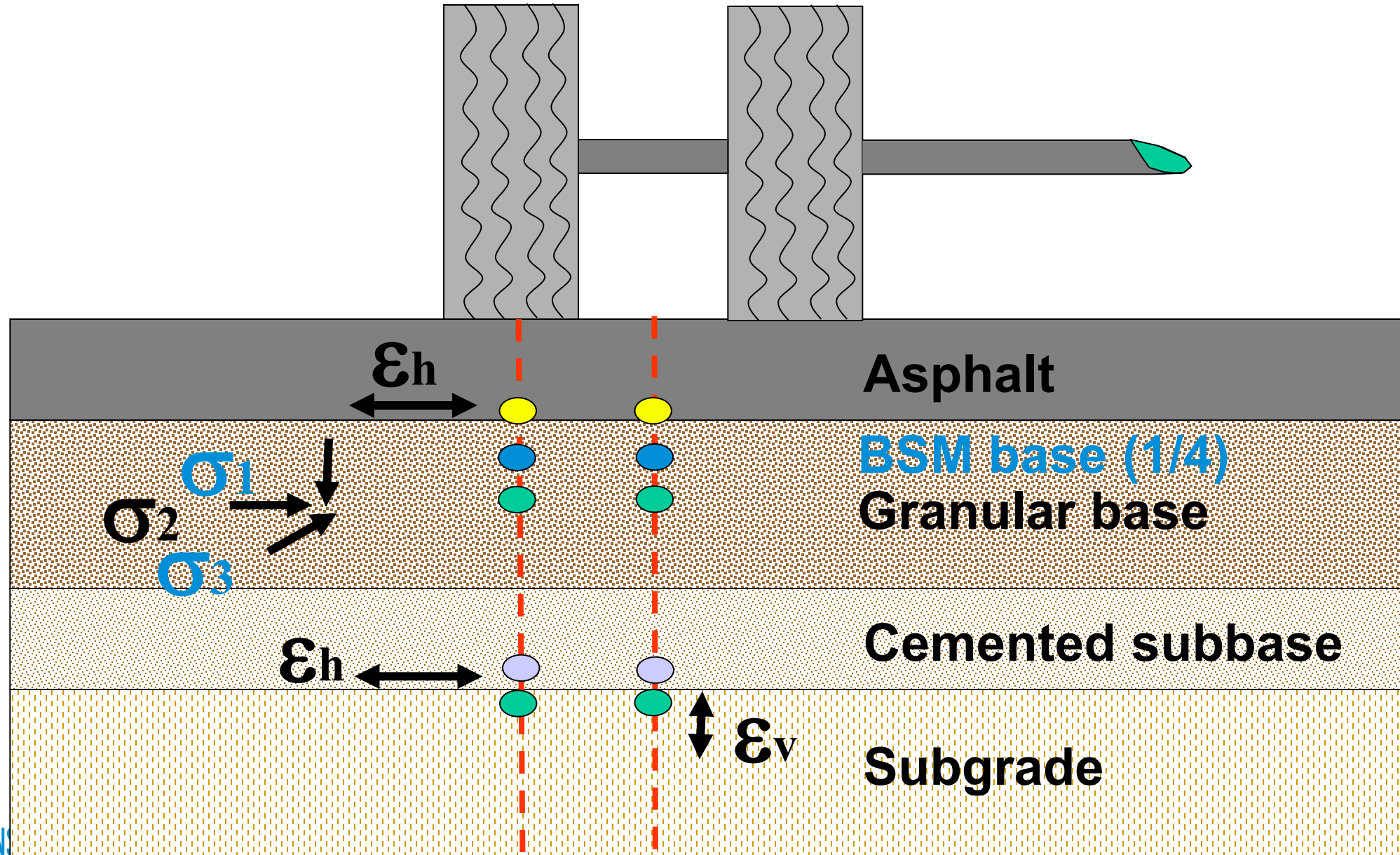


Granular with increased cohesion

Mechanistic-Empirical

- Stress and strain calculations
- Materials inputs:
 - Stiffness/Resilient Modulus
 - Poisson's Ratio
- Transfer Functions/Failure Criteria

Pavement Analysis Positions

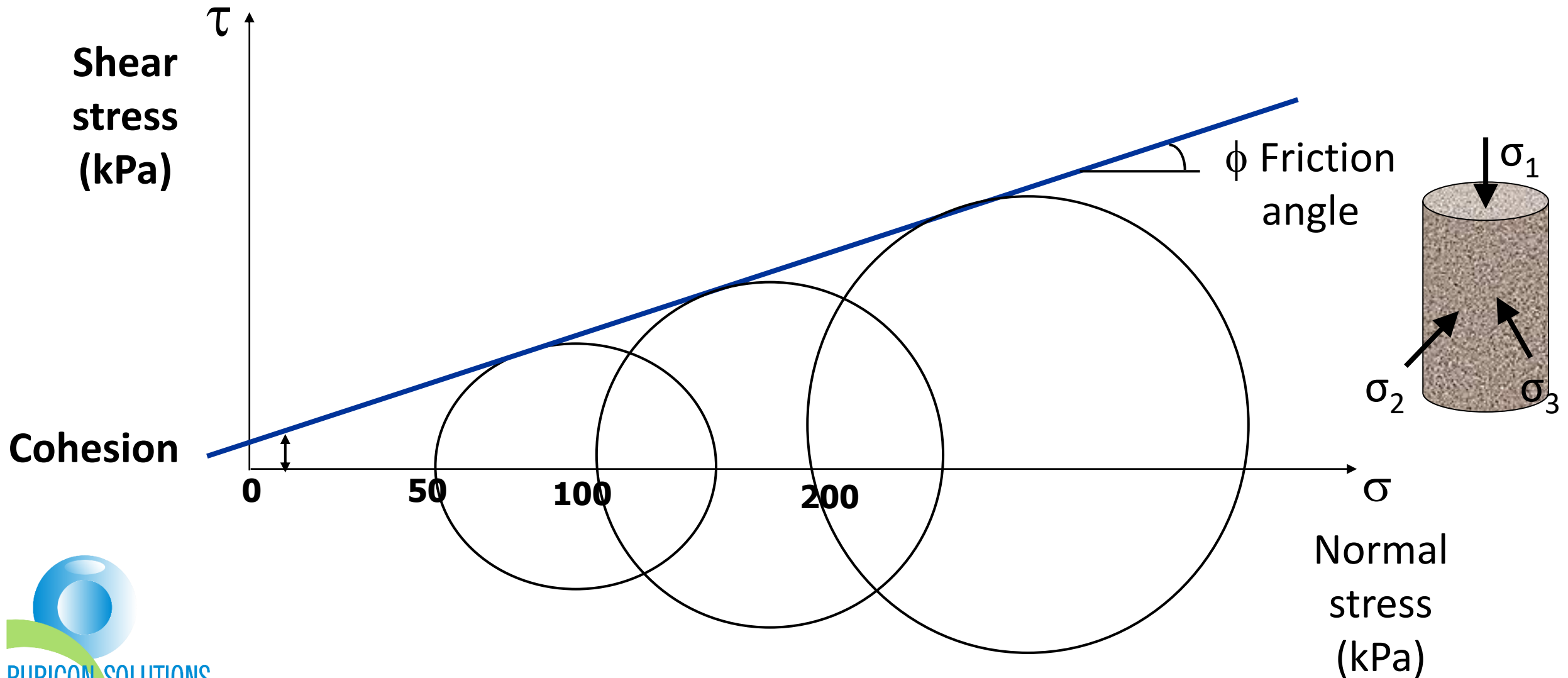


Shear Strength

Triaxial



Shear Strength



$$\text{Deviator Stress Ratio} = \frac{\sigma_d}{\sigma_{d,f}}$$

Shear stress

ϕ **Friction angle**

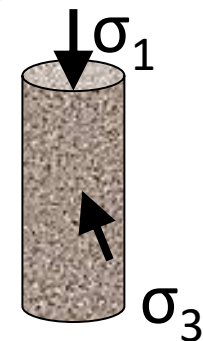
C
Cohesion

$$\sigma_{1,f} = \frac{(1 + \sin \phi) \cdot \sigma_3 + 2 \cdot C \cdot \cos \phi}{(1 - \sin \phi)}$$

$$\sigma_d = \sigma_1 - \sigma_3$$

$$\sigma_{d,f} = \sigma_{1,f} - \sigma_3$$

Normal stress

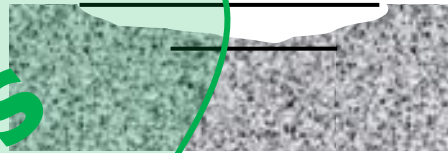


$$\text{Deviator Stress Ratio} = \frac{\sigma_d}{\sigma_{d,f}}$$

$< 0.3 \text{ (30\%)}$

Stellenbosch ME Transfer Function

Reliability	Road Category	A	Rut Limit (mm)
95%	A	1.71113	10
90%	B	1.79873	15
80%	C	1.88732	20
50%	D	2.0044	25



$P_{MDD} = \% MDD$
(Moist AASHTO)

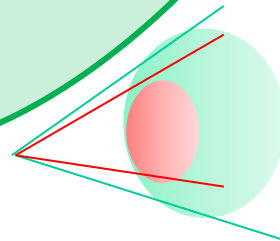


Density

$$\log N = A - 57.286(DSR)^3 + 0.0009159(P_{MDD} \cdot RetC)$$

Deviator Stress Ratio

Shear



Retained Cohesion

Moisture Sensitivity

After (Biermann, Stellenbosch University)

Retained Cohesion

- Triaxial test
 - Equilibrium moisture content
 - Saturated for 24 hours
- *How much cohesion remains with "wet" materials*

Pavement Situation At Start of Phase 1 of 1
Layered Elastic Evaluation for Standard Axle

Rubicon Toolbox Standard Axle Tool

Design Name:

Axle Details: Dual Tyre, 20kN each, 750 kPa Pressure, 350 mm Spacing

Effective Structural Capacity for All Phases = 22.6 million Standard Axles

Time to Exceed Capacity for All Phases: 44.75 Years

Effective Structural Capacity for this Phase Only = 22.6 million Standard Axles

Time to Exceed Capacity for THIS Phase only: 44.75 Years

Thickness = 50 mm Asphalt Surfacing Stiffness = 3000 MPa; Poisson = 0.4 Criterion: RSA AC Medium Elastomer Modified Fatigue Cat B None	Maximum Horizontal Tensile Strain = 158 Critical Position: Bottom of Layer/Load Centreline Basic Axle Capacity: 63.41 million Effective Axle Capacity: 63.41 million Damage in this Phase from 0.00 to 0.36
Thickness = 200 mm BSM1 Stiffness = 700 MPa; Poisson = 0.35 Criterion: BSM Stellenbosch 90% (Cat B) RD = 100%; Ret-Coh = 75%; C = 250 kPa; Phi = 40	Deviator Stress Ratio = 0.284 Critical Position: 25% Layer Depth/Load Centreline Basic Axle Capacity: 22.58 million Effective Axle Capacity: 22.58 million Damage in this Phase from 0.00 to 1.00
Thickness = 250 mm RSA EG4 Dry Stiffness = 300 MPa; Poisson = 0.35 Criterion: RSA Granular Shear Cat B Cohesion = 31.2 kPa; Angle of Friction = 41.8955	Shear Stress Safety Factor = 2.09 Critical Position: Middle of Layer/Between Loads Basic Axle Capacity: > 100 million Effective Axle Capacity: > 100 million Damage in this Phase from 0.00 to 0.22
Thickness = 150 mm RSA G7 Stiffness = 120 MPa; Poisson = 0.35 Criterion: RSA Subgrade Rut, 10mm, Cat B None	Vertical Compressive Strain = 248 Critical Position: Top of Layer/Between Loads Basic Axle Capacity: > 100 million Effective Axle Capacity: > 100 million Damage in this Phase from 0.00 to 0.22
Thickness = Semi-Infinite; RSA G9 Subgrade Stiffness = 70 MPa; Poisson = 0.35 Criterion: RSA Subgrade Rut, 10mm, Cat B None	Vertical Compressive Strain = 251 Critical Position: Top of Layer/Between Loads Basic Axle Capacity: > 100 million Effective Axle Capacity: > 100 million Damage in this Phase from 0.00 to 0.22

Load Details:

Setup: Dual Tyre, 20kN each, 750 kPa Pressure, 350 mm Spacing; Daily Count = 500

Growth Rates: Yr 0 to 5 = 4% ; Yr 5 to 10 = 4% ; Yr 10 to End = 4%

Pavement Notes:

Pavement Number (PN) Design

AASHTO Structural Number *on Steroids*

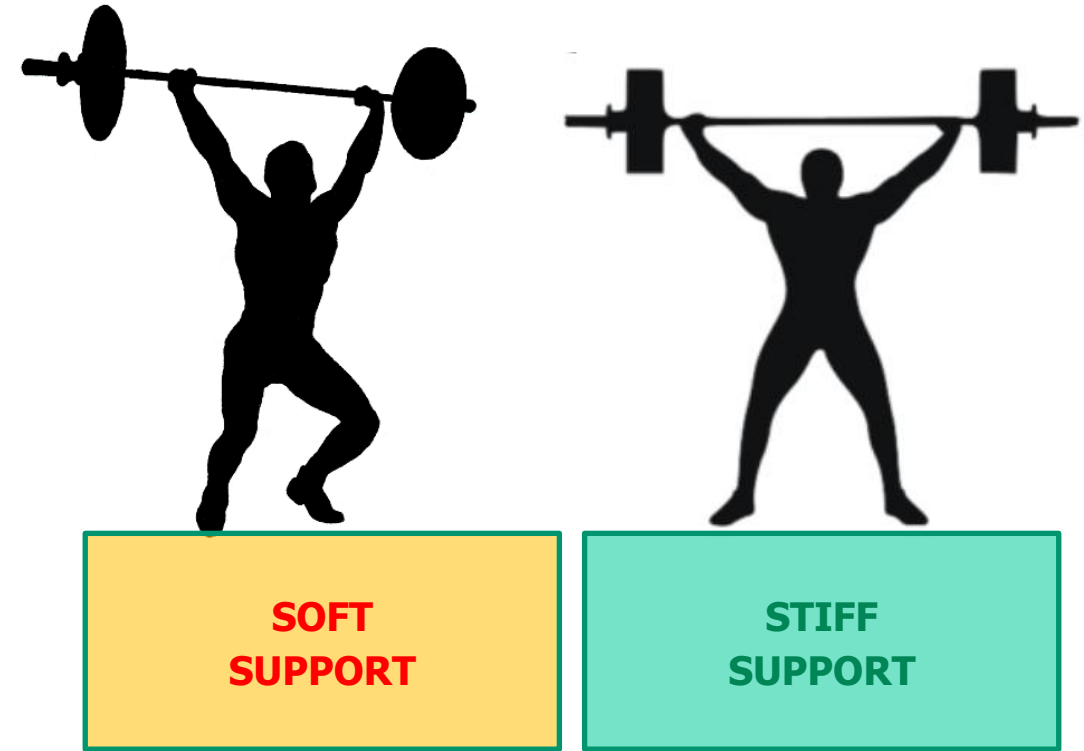
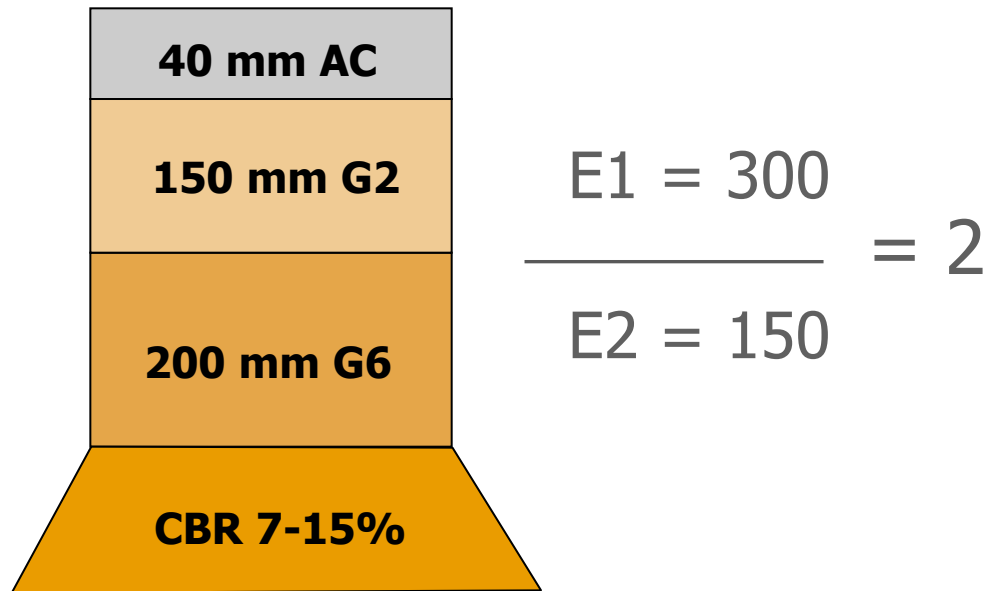
- Robust and easy to use
- Clear, strong links to field testing (DEMAC material classification) and specifications
- Data from
 - 69 field sites
 - Construction, maintenance & performance information
 - Local southern African Catalogues
- Not really calibrated for High RAP BSMs

Pavement Number

- No stress and strain calculations
- Inputs
 - Material classes (DEMAC), Climate (dry, moderate, wet)
- Builds stiffness of layers from bottom up
 - Material class
 - Effective long term stiffness (ELTS)
 - ELTS of layer underneath (Modular Ratio)
 - $PN \approx \text{thickness} \times \text{ELTS} + \text{few other factors}$
- Calibrated from real LTPP pavement structures & catalogues

Modular Ratio

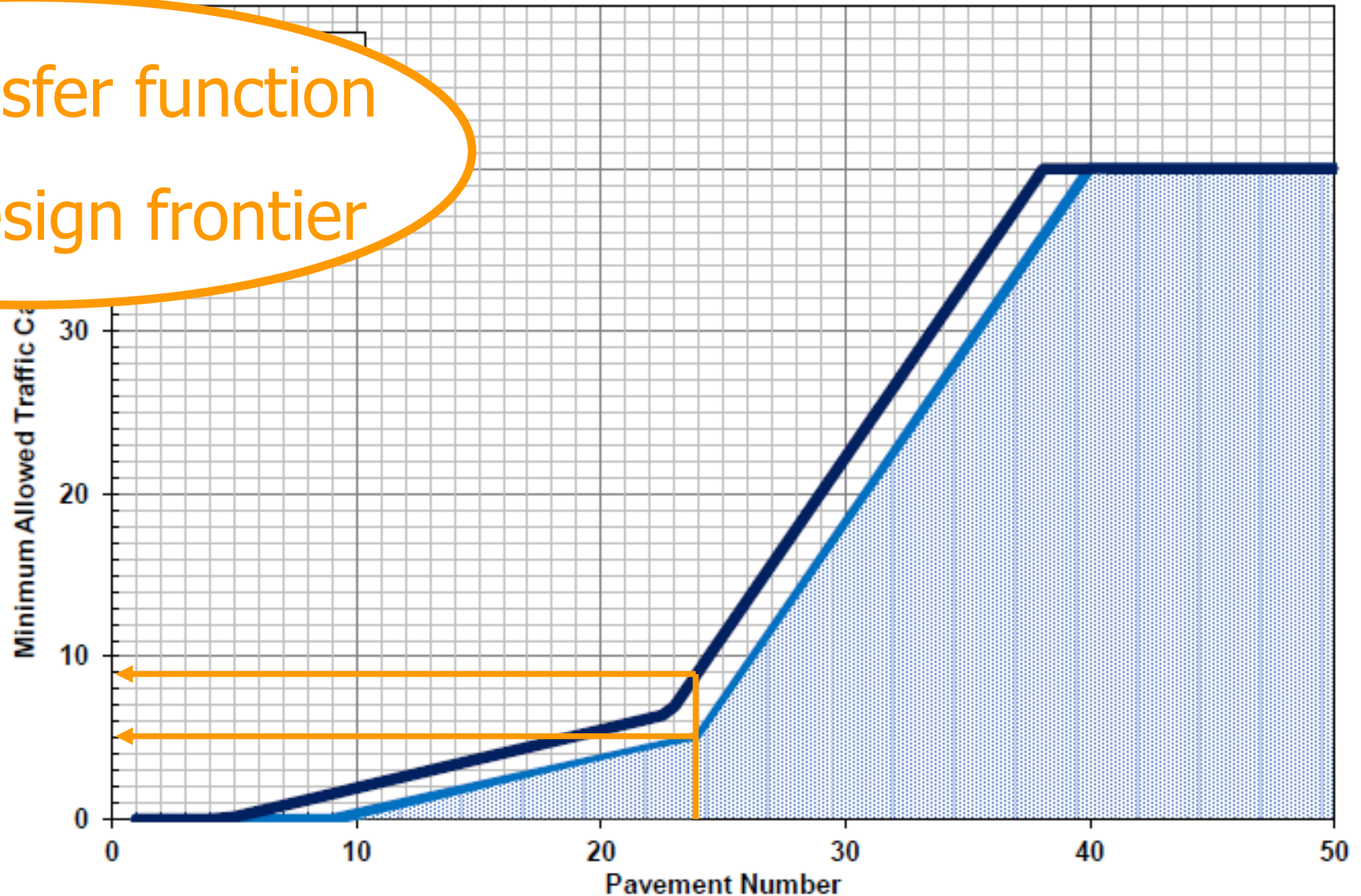
- The stiffness of one layer as a ratio of the layer underneath



Pavement Balance

Design Criteria

Not a transfer function
Rather, design frontier



In brief

- Do detailed materials and pavement investigations
- Several structural design techniques available
- All are flawed - Use more than 1 to get a ball park
- Be careful!

GIGO

Garbage In, **Gospel** Out