BRINGING BSM TECHNOLOGY TO THE WORLD

TECHNOLOGY UPDATE: RECYCLING TECHNOLOGY/BITUMEN STABILISATION

Pavement Design

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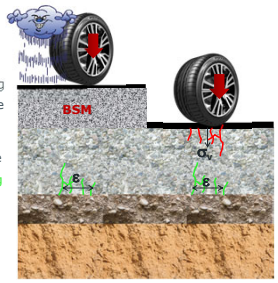
IMPORTANT: FAILURE MECHANISMS!

Water damage!
Thin asphalt surfacing
Crushed stone base

Cement stabilised subbase
Fatigue Cracking



Asphalt surfacing
Crushing+Shrinkage
Cement stabilised base
Fatigue Cracking

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BSM STRUCTURAL DESIGN

Three methods:
- AASHTO
- Pavement Number
- Mechanistic-Empirical

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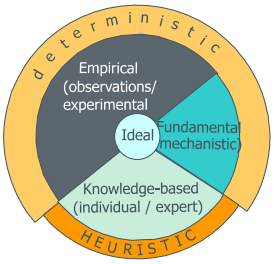
Design Methods



Empirical
- CBR Cover
- AASHTO SN
- Maximum Deflection: TRRL, AI
- DCP Design Method

Mechanistic-Empirical
- SAMDM

Knowledge-Based
- PN Method

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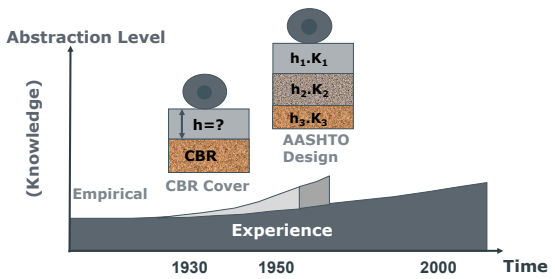
Evolution of Pavement Design



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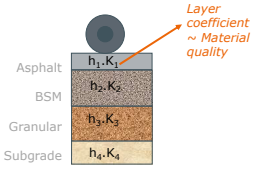
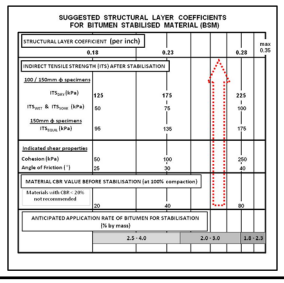
AASHTO STRUCTURAL NUMBER



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				
100 / 150mm ϕ specimens				
ITS_{DRY} (kPa)	125	175	225	
ITS_{WET} & ITS_{TOW} (kPa)	50	75	100	
150mm ϕ specimens ITS_{TOW} (kPa)	95	135	175	
Indicated shear properties				
Cohesion (kPa)	50	100	200	
Angle of friction (°)	35	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	1.5 - 2.5	

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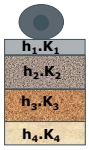
Pavement Design — SN DESIGN EXAMPLE

SN DESIGN TRAFFIC
= 8.5 x 10^6 STANDARD AXLES (80kN)

Wirtgen: K_{BSM} = 0.30 to 0.35
VDOT on I81 has K_{BSM} = 0.37 to 0.44 ...be careful!



Layer Type	Layer coefficient a(i) (per inch)	Drainage coefficient Cd	Layer thickness t (mm/inch)	a(i) x Cd x t
Asphalt surfacing	0.44	1.0	40/1.5	0.66
Bitumen stabilised base	0.30	1.0	200/8	2.40
Granular subbase	0.10	0.9	370/14.5	1.31
Selected subgrade	0.10	0.9	300/12	1.08
			SN_{ACT}	4.37

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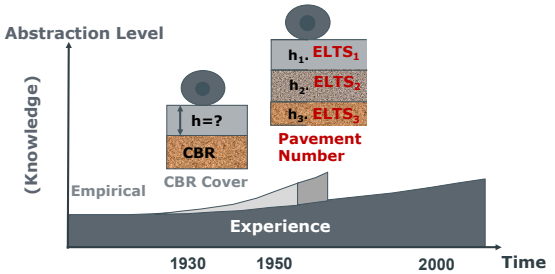
Evolution of Pavement Design



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PAVEMENT NUMBER (PN)

- Structural Number on Steroids
- First released 2009, 2020 update
- Robust and easy to use
- Clear, strong links to field testing (DEMAC material classification) and specifications
- Data Sets
  - 69 field sections in South Africa, BSM-foam and emulsion
    - *All flexible pavement types*
    - *Construction, maintenance, performance & traffic information*
  - TRH4 & SATCC Catalogues (South and Southern Africa)
- Two key differences between PN and AASHTO Methods
  - Modular Ratio
  - ELTS

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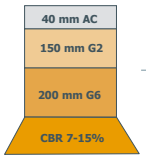
Modular Ratio

The stiffness of above layer as a ratio of the layer beneath



$$\frac{E1 = 300}{E2 = 150} = 2$$

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Effective Long Term Stiffness (ELTS)

- Represents the **average stiffness** of the material over the design life
- Depends on the **material type/quality**
- **Model-specific** parameter
  - *Not measured in the lab or field*
- To calculate:

Given values for DEMAC

Modular Ratio x *Support Stiffness*

Maximum Allowable Stiffness

Minimum

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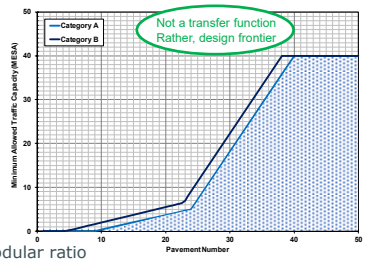
PAVEMENT NUMBER (PN)

- Inputs:
  - Material class
  - Thickness
  - Climate
    - *Dry*
    - *Moderate*
    - *Wet*
- Reliability
  - 90 or 95%
- Subgrade cover
- Pavement balance through modular ratio
- Pavement life through Frontier Curve



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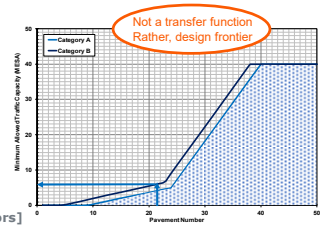
BSM PN DESIGN EXAMPLE, MODERATE REGION

10 Seal	ELTS = 800; PN = 10 x 800/10000 = 0.8
150 BSM2	Thick. Adj. = 1.0, BCF 0.7, ELTS = 600 PN = 150 x 600 x 1.0 x 0.7/1000 = 6.3
200 C4	Thick. Adj. = 1.4, ELTS = 400 PN = 200 x 400 x 1.4/10000 = 11.2
180 G6	ELTS = 214 PN = 180 x 214/10000 = 3.8
G7	



7. Layer PN = thickness * ELTS * [factors]

8. PN = Σ layer PN
= 0.8 + 6.3 + 11.2 + 3.8
= 22.1

9. Structural Capacity
Cat A (95%) = 4.4 MESA
Cat B (90%) = 6.3 MESA

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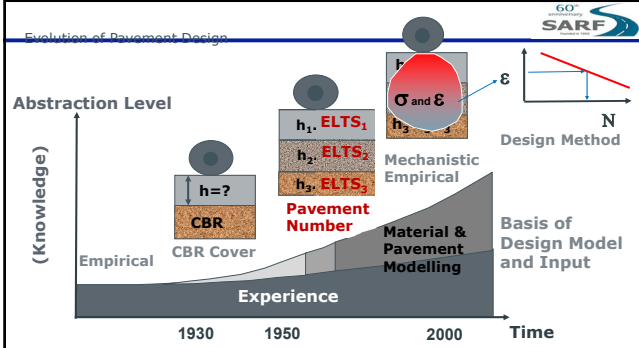
Evolution of Pavement Design



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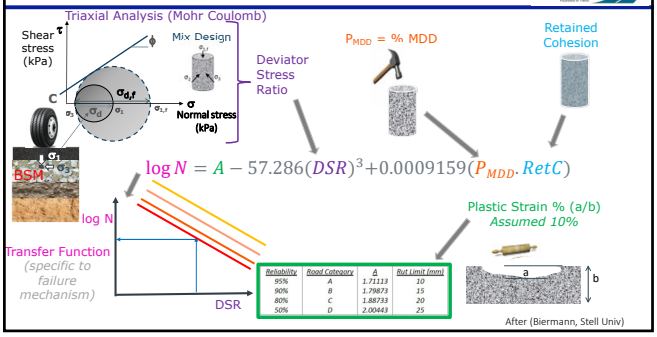
NEW MECHANISTIC EMPIRICAL STRUCTURAL DESIGN FUNCTION



Reliability	Road Category	A	Rut Limit (mm)
95%	A	1.71113	10
90%	B	1.79873	15
80%	C	1.88733	20
50%	D	2.00443	25

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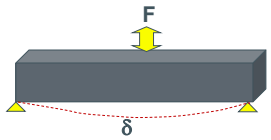
Why is layer thickness important???



$$\delta = \frac{Fl^3}{48EI} \qquad I = \frac{bh^3}{12}$$

Thickness has a 3rd power effect

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DESIGN MODEL INPUTS AND CLASSIFICATION

Specification limits

Applying the Guideline Limit (lowest) for all 3 shear parameters, is over-conservative!

Default values are recommended

Class	Percent of Reclaimed Asphalt	ITS (kPa)		Triaxial		
		ITS_{DRY}	ITS_{WET}	Cohesion (kPa)	Friction Angle (°)	Retained Cohesion (%)
BSM 1	< 50%	225	125	250 – 300 (250)	40 – 50 (40)	70-85 (75)
	50 – 100%	225	125	265 – 350 (265)	38 – 45 (38)	75-90 (75)
BSM 2	< 50%	175	100	200 – 250 (225)	38 – 40 (39)	65-75 (70)
	50 – 100%	175	100	225 – 250 (238)	35 – 40 (37)	70-85 (75)

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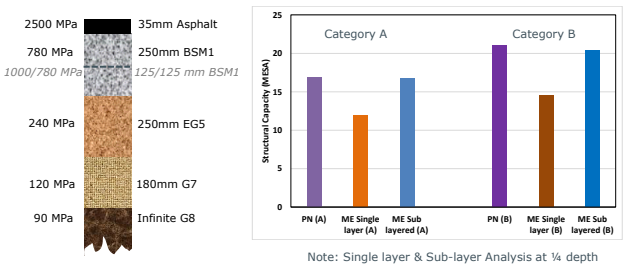
COMPARISON OF PN AND ME DESIGNS



Note: Single layer & Sub-layer Analysis at ¼ depth

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SUMMARY

Range of Methods available:

- AASHTO
- Pavement Number (2020)
- Mechanistic-Empirical

- None are perfect
  - *Use them all – holistic design*
  - *Use your knowledge to assess*
  - *Spend time understanding materials and layers in existing pavement*
  - *Do careful mix design*

Good luck!

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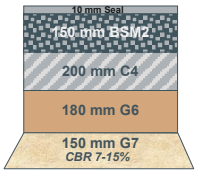
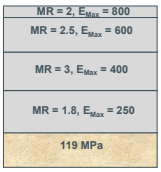
BSM PN DESIGN EXAMPLE, MODERATE REGION

Effective long term stiffness

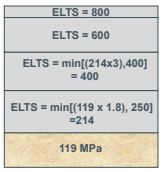
1. Material Classes



4. Assign modular ratio's and Maximum Emods



5. Calculate Layer ELTS Values



2. Determine subgrade stiffness (140 MPa)

3. Adjust for climate & cover (119 MPa)

6. ELTS = min ($E_{support}$*MR , Emax)

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