BRINGING BSM TECHNOLOGY TO THE WORLD

DEMAC

Design Equivalent Material Classification System

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Acknowledge:
Dr Arno Hefer
Dr Fenella Johns

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Background

- **TG2 (2002)**
  - *Uncomfortable with structural design method*
  - *Conservative designs*
  - *Loose links between mix and structural design*
  - *Wanted to use real field performance (LTPP)*
- **SAMDM (Mechanistic-Empirical)**
  - *Powerful, but many flaws*
  - *Loose guidelines for inputs*
  - *Very difficult to validate new criteria (transfer functions) with real field data*

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Background

- **TG2 (2009)**
  - *Relook at methods*
  - *Sponsored by SABITA and Gauteng (GDPTRW)*
  - *Started process in 2005*
  - *Much discussion with relevant role players*
- **Priorities**
  - *Use real field data to develop and validate structural design methods*
  - *Robust systems, not open to abuse*
  - *Strong links between mix design, structural design and specifications*
  - *Clear guidelines for use*

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Background

- **Resulted in DEMAC Material Classification and Pavement Number Methods**
  - *Formally published in TG2 (2009)*
  - *Not only applicable to BSMs*
- **TG2 updated in 2020**
  - *Includes updates on DEMAC and PN*
  - *Sponsored by Sabita*

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Why a Material Classification System?

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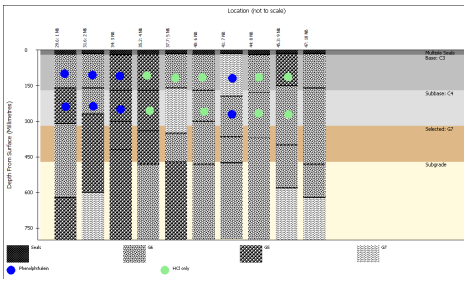
Model Thicknesses and Material Class?



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DEMAC Material Classification System

Allows engineers to make a **rational** and **consistent** decision about the material class to use for design purposes, based on routine materials tests and indicators

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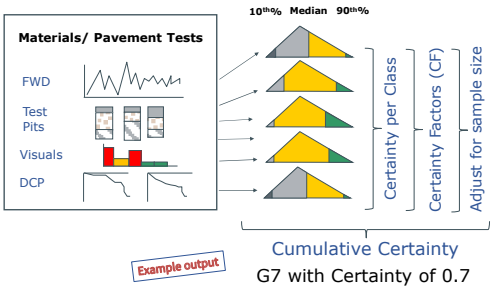
Demac System - Recap



G7 with Certainty of 0.7

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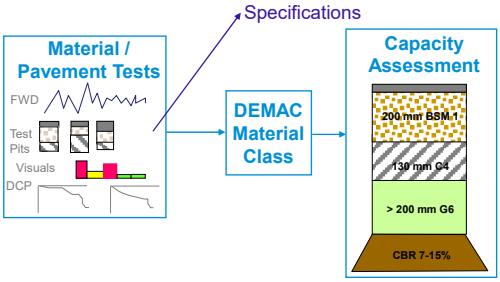
The Design Process



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Material Classes

- Granular materials
  - *DE-G1 to DE-G10*
- Cemented materials
  - *DE-C3, DE-C4, DE-EG4, DE-EG5*
- BSM not included in DEMAC 2020

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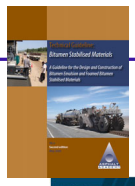

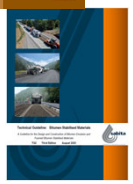

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BSM

- Existing System
  - *Evaluates suitability of material for BSM stabilisation*
- New classification based on updated Mix Design process & criteria
- Suitability of in situ material for stabilisation
  - *Based on Granular System*
- Old BSMs will be classified as DEMAC in Granular System

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Difficulties in Data Analysis

- Variability in available evidence
  - *Uncertainty*
- Small sample sizes
- Risk is poorly defined
- All tests are indicators
  - *What do test results actually say about material behaviour?*
- Interpretation is vague and subjective

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Handle Difficulties by

- Encouraging a holistic approach
  - *Incorporate many test/indicator types*
- Specially relevant for small sample sizes

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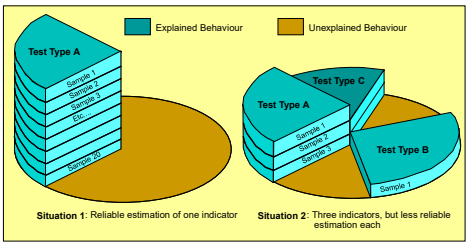
Holistic Assessment

- Reliability versus Completeness



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Handle Difficulties by

- Clear guidelines for interpreting test results
- Method to synthesize results
  - *uses Certainty Theory and Fuzzy Logic*

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DEMAC

- Design Equivalent Material Class
  - *Shear strength and stiffness properties similar to new material of same class*
  - *May not meet all specification tests*
- Used for design purposes, not specification!
- Denote: DE-G1

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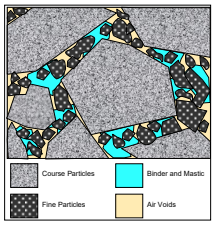
Assumed Material Behaviour

- Mohr-Coulomb model
- Materials are mixture of
  - *Course particles*
  - *Fine particles*
  - *Bitumen*
  - *Air voids*
- Generally applicable to pavement materials



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Material Model

- Strength and stiffness determined by:
- Cohesion
  - *Determined by mastic (fines and binder)*
- Friction Angle
  - *Inter-particle friction*
  - *Compressive stresses holding fine and coarse particles*

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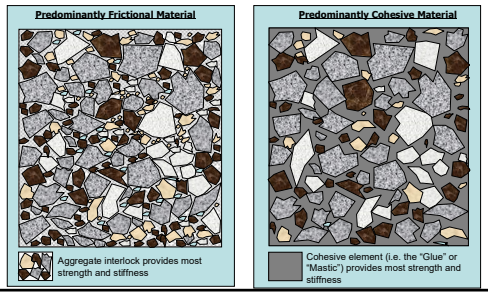
Material Model



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Tests for Classification

- All tests try to capture the cohesion and/or friction of a material
  - *Some do it better than others*
- Examples:
  - *Plasticity Index:* *cohesion*
  - *Grading:* *friction*
  - *Triaxial:* *both cohesion and friction*

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Certainty Factor

- Reliability of test or indicator
  - *Experience / industry confidence*
  - *Ability of test to capture material behaviour*
- Ranges from 0.2 to 0.45
- Developed using Bayesian Theory to determine appropriate values

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Classification Parameters and Certainty Factors: Granular

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)

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Classification Parameters and Certainty Factors: Cemented

Soaked CBR	(0.2)
DCP penetration	(0.3)
FWD stiffness	(0.3)
FWD maximum deflection	(0.35)
Visual condition	(0.35)
Plasticity index	(0.2)
Grading	(0.2)
Evidence of active cement	(0.3)
Consistency	(0.2)

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Visual Condition: Cemented

Test or Indicator	DE- C3	DE-C4	DE-EG4	DE-EG5	CF
Visual Condition	< 1.5 - Rutting < 5 mm. Transverse, longitudinal and/or block cracking present.	1.5 to 2.5 - Rutting < 8 mm. Transverse, longitudinal and/or block cracking present.	2.5 to 3.5 - Rutting > 8 mm. Moderate to high degree block cracking.	>3.5 - Rutting > 15 mm. High degree block to crocodile cracking.	0.35

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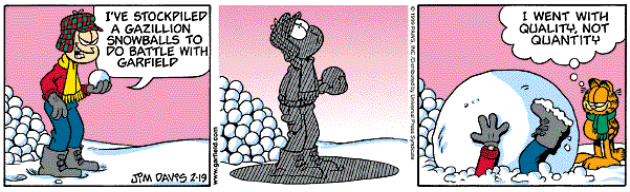

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Clear Guidelines

- Clear guidelines for interpretation
- Either
  - *Direct test result (e.g. DCP, CBR)*
  - *Rating (e.g. Grading)*
- Data processed statistically

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Guidelines for Interpretation - Granular PI -

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Material	PI of Material Passing 0.425 mm Sieve						
Crushed Stone	< 4	2 - 6	2 - 6	2 - 6	6 - 10	10 – 15	
Natural Gravel			< 6	2 to 6	4 - 10	8 - 12	> 12
Gravel-Soil						< 12	4 - 14
Sand, Silt, Clay							< 12
Class	DE-G1	DE-G2	DE-G3	DE-G4	DE-G5	DE-G6	DE-G7

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Material Type for Granular Assessment

Fraction Type	Fraction Definition
% Coarse Gravel (CG)	> 20 mm
% Gravel (G)	P20 – 2.00 mm
% Sand (S)	P2.00 – 0.075 mm
% Silt and/or Clay (SC)	< 0.075 mm
Fraction-based Material Type Rule	**Outcome**
CG+G+S ≥ G+S+SC AND visual/profile confirms crushed stone	Crushed Stone (CS)
CG+G+S ≥ G+S+SC	Natural Gravel (NG)
G+S+SC > CG+G+S AND S+SC < 65%	Gravel Soil (GS)
S+SC ≥ 65%	Sand-Silt-Clay (SSC)

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Guidelines for Interpretation - Cemented -

Test	DE-C3	DE-C4	DE-EG4	DE-EG5
CBR @ 95%	> 45	25 - 45	30 - 80	< 30
FWD Max Deflection	< 350	350 - 450	450 - 800	> 600

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Interpretation of Grading

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How does the DEMAC system work?

- Obtain all available data
- Convert to rating if necessary
- Calculate
  - *Number of observations*
  - *10th percentile*
  - *Median*
  - *90th percentile*
- Obtain limits for possible material classes
  - *Tables and figures in TG2*
- Construct "triangle"
- Calculate certainty that belongs to material class
- Adjust for certainty factor
- Calculate cumulative certainty

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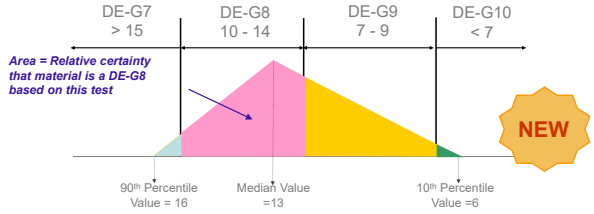
Example: CBR (SSC, 93% MDD)



Certainty that falls in class	0.03	0.74	0.21	0.01

Adjusted for test certainty factor

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Cumulative Certainty

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| Road: Example Road ABC | | | |

Project Information

- P66 between N12 and North West and Gauteng border
- 2 lanes, single carriageway
- 26 km
- Category B
- Moderate climate
- Pavement structure from 1964:
  - *Seals*
  - *150 crushed stone*
  - *150 C3*
  - *150 G7*
  - *G9 subgrade*
- Carried between 1.7 to 4.3 MESA

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Visual Condition

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Available Data

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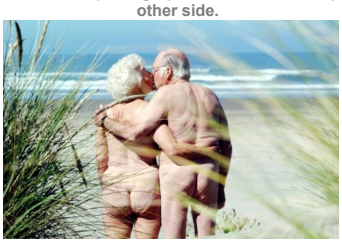
Every day we have something to be thankful for

Today we are thankful the photographer did not take the photo from the other side.



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Rubicon Toolbox Software

www.rubicontoolbox.com

- Online Tools
- DEMAC 2009 and 2020

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