

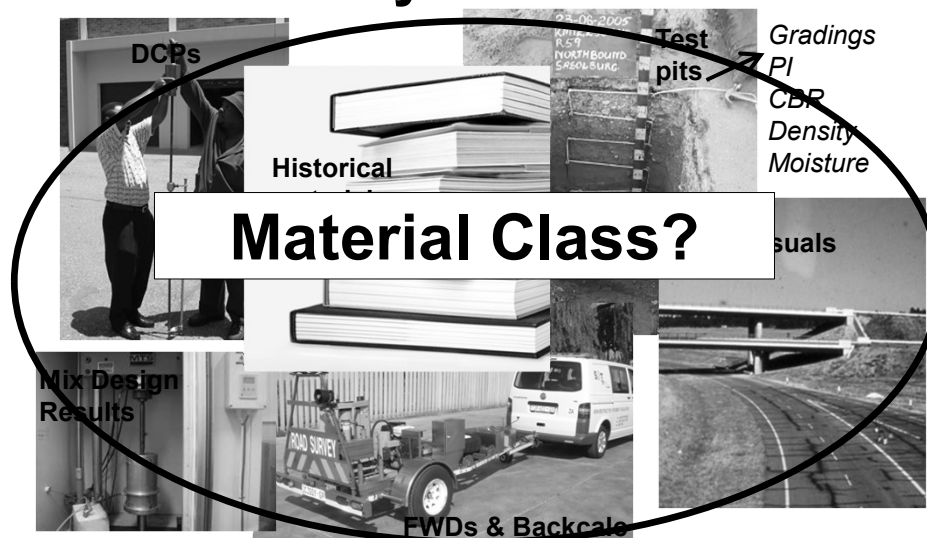
# Design Equivalent Material Classification System - DEMAC -

## *Acknowledgements*

Dr Fritz Jooste  
Dr Arno Hefer

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## Why a Material Classification System?



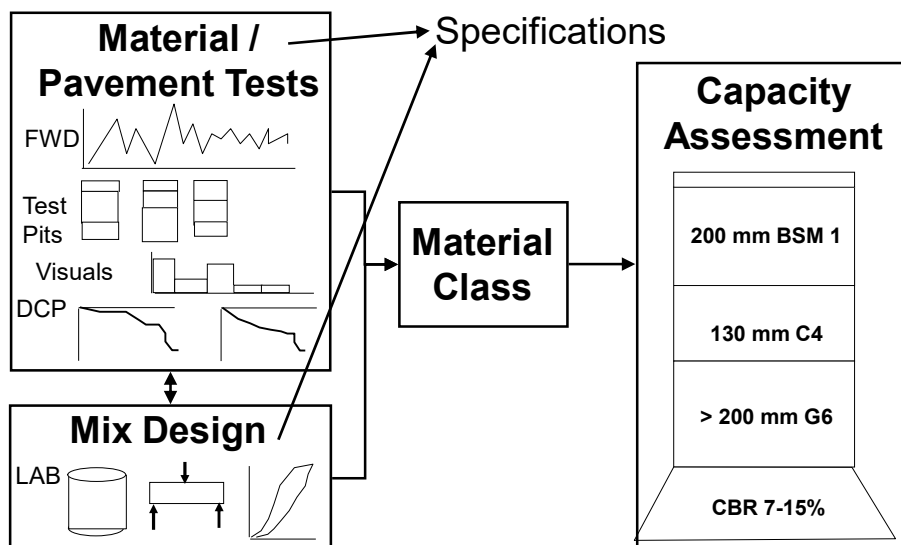
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# Material Classification System

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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## 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

**NEW**

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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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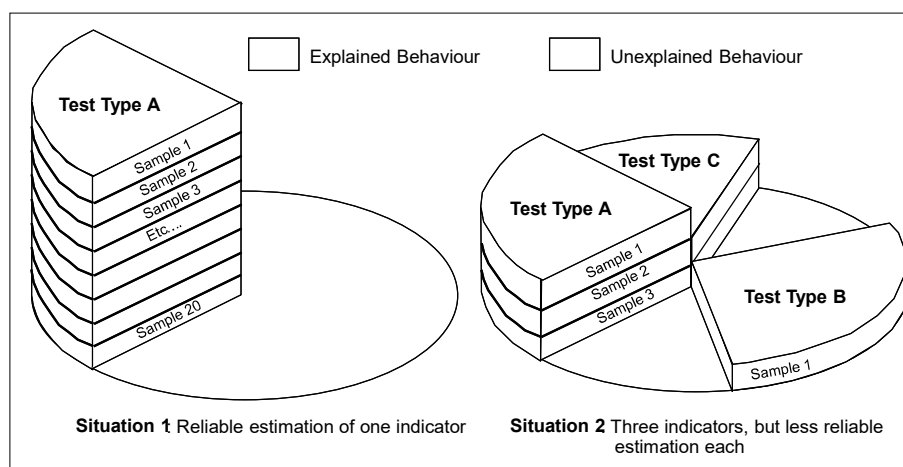
## Handle Difficulties by

- 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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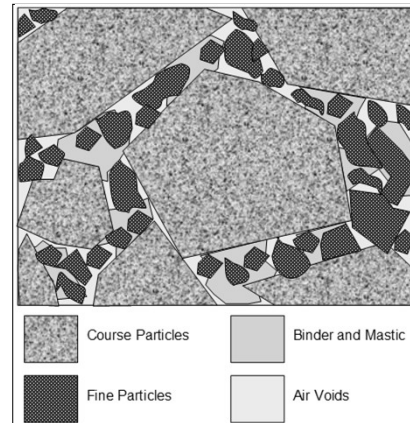
## DEMAC

- 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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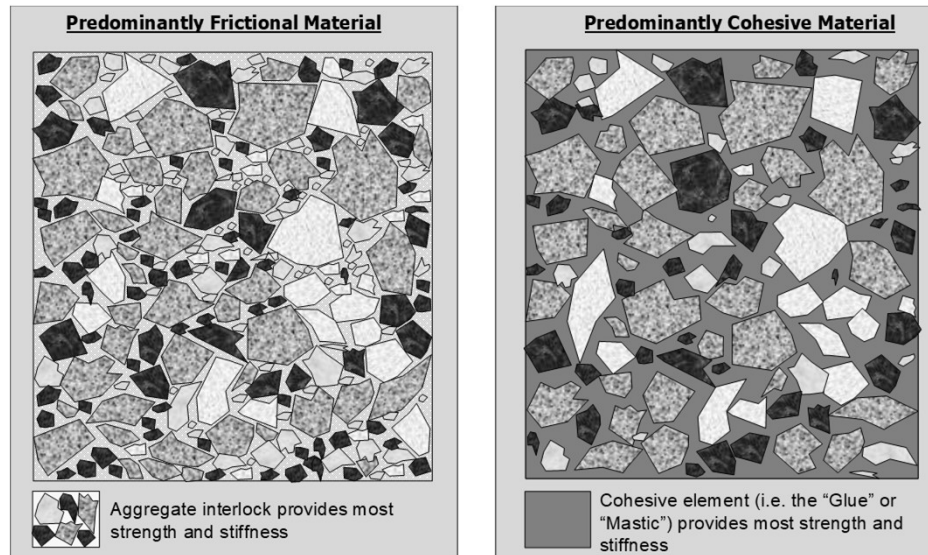
## Material Model

- 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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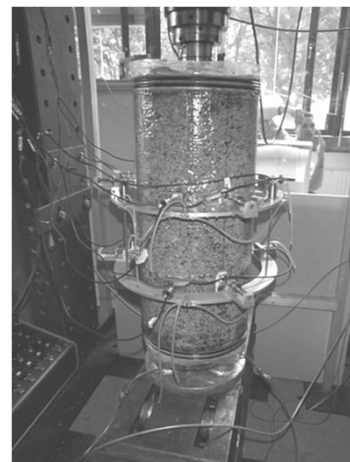
# Material Model



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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



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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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## 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)

**NEW**

**NEW**

**NEW**

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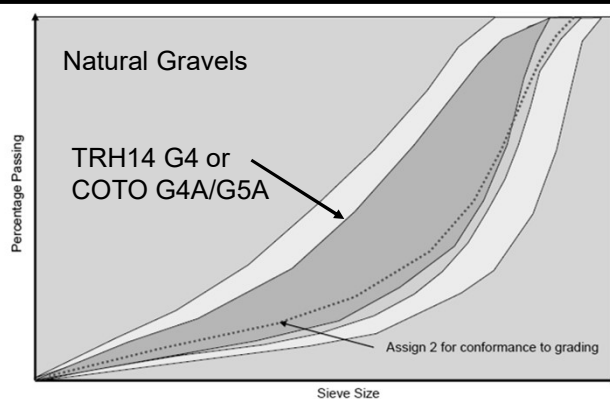
## Guidelines for Interpretation - Cemented PI -

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

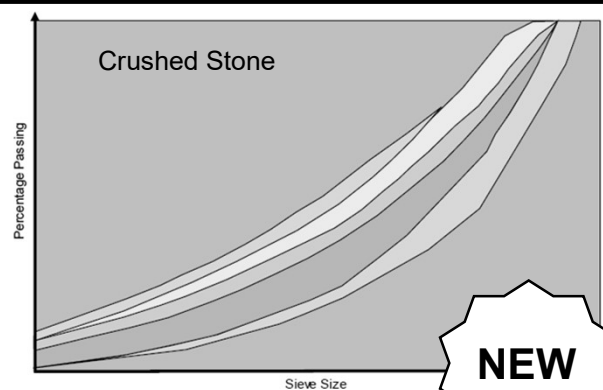
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## Interpretation of Grading



- 1 Inside Grading Envelope
- 2 Just coarse of envelope, but follows envelope closely (well-graded)
- 3 Fine of envelope, or significantly coarse of envelope
- 4 Significant deviation from specified envelope



- 1 Within G1 envelope
- 2 Just fine of G1 envelope, within G2/3 envelope
- 3 Just fine of G2/3 envelope, within G3 envelope
- 4 Just outside G3 envelope, within G4A/G5A envelope
- 5 Significant deviation from G4A/G5A envelope

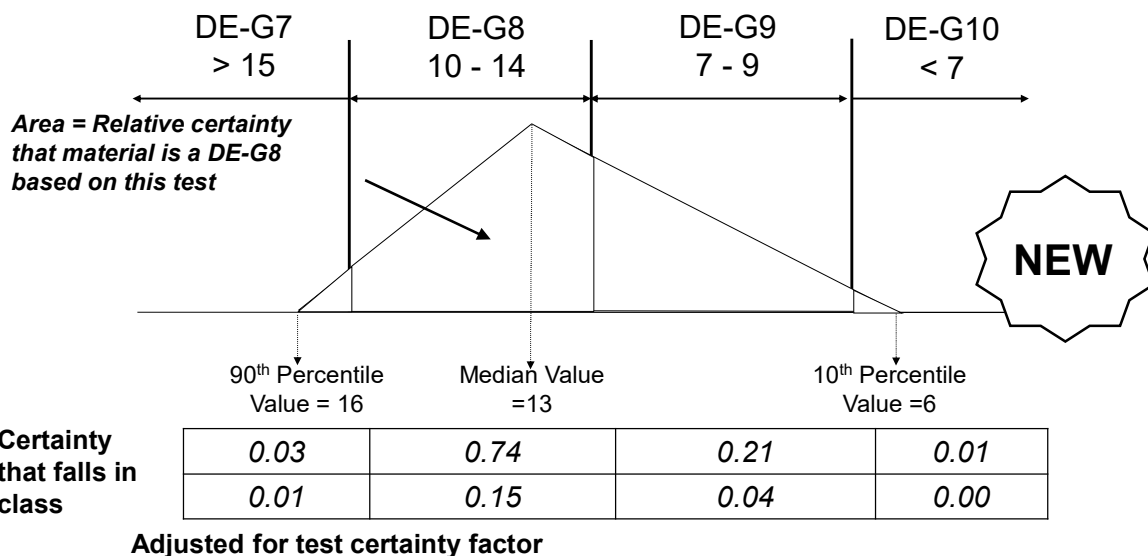
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## How does the system work?

- Obtain all available data
- Convert to rating if necessary
- Calculate
  - Number of observations
  - 10<sup>th</sup> percentile
  - Median
  - 90<sup>th</sup> 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%)



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## Cumulative Certainty

Road: Example Road ABC						Direction: EB															
Lane: slow						Subsection: All															
Results for Layer: BSM						TG2 (2020) Constants Version															
Test or Indicator Type	10th%-(Median)-90th% [Obs]	Certainty That Result Belongs to Class:										Cumulative Certainty That Material Is Class:									
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
P075 % NG	4.0-(5.0)-9.0 [6]	-	-	-		-	-	-	-	-	-	-	-	-	.21	-	-	-	-	-	-
Grading Rating NG	1.5-(3.0)-3.0 [6]	-	-	-			-	-	-	-	-	-	-	-	.21	.14	.18	-	-	-	-
Visible Moisture Rating NG	3.0-(3.8)-4.0 [6]	-	-			-	-	-	-	-	-	-	-	.05	.28	.14	.18	-	-	-	-
Consistency Rating NG	4.0-(4.0)-4.0 [6]	-	-	-	-	-	-	-	-	-	-	-	-	.05	.38	.14	.18	-	-	-	-
Plasticity Index NG	0.0-(0.5)-5.0 [6]	-	-	-		-	-	-	-	-	-	-	-	.25	.44	.15	.18	-	-	-	-
Linear Shrinkage NG	0.0-(1.0)-2.5 [5]	-	-	-			-	-	-	-	-	-	-	.43	.52	.16	.19	-	-	-	-
Grading Modulus NG	2.4-(2.5)-2.7 [6]	-	-	-				-	-	-	-	-	-	.43	.52	.16	.29	-	-	-	-
Relative Density (%)	89.0-(96.3)-100.9 [27]	-	.00	.01	.01	.01	.01	.01	.01	.01	.01	-	.00	.45	.54	.27	.34	.07	.06	.06	.06
DCP Pen (mm/blow)	1.1-(1.5)-2.1 [11]											-	.08	.25	.48	.54	.27	.34	.07	.06	.06

**Most likely Materials Class is a G4 Design Equivalent Class.**

Relative Certainty associated with this outcome = 0.54

Confidence associated with outcome is Medium.

Suitable for situations where the existing pavement condition and age is such that structural rehabilitation is unlikely, or for which the condition and/or other factors predetermines the treatment type.

The recommended design reliability associated with this certainty is 80% (Category C roads).

Rule Version Date: 09-Jun-2020

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## Confidence in Final Results

Final Certainty	Confidence	Recommended Application
< 0.3	Very low	Inadequate
0.3 to 0.5	Low confidence	Category D Roads
0.5 to 0.7	Medium confidence	Category C Roads 0.5 to 0.6
		Category B Roads 0.6 to 0.7
> 0.7	High confidence	Category A Roads

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## Validation

**NEW**

- 2009:
  - *Data processed for real materials*
    - Granular
    - Cemented
  - *Compared to Engineers interpretation*
  - *Limits adjusted*
- 2020:
  - *Took experience from 2009*
  - *Adjusted with new Industry Standards*
    - New COTO Specs
    - New tests
  - *Adjusted certainty factors based on Bayesian Theory*
    - Objective now, rather than subjective

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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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## Software

- [www.rubicontoolbox.com](http://www.rubicontoolbox.com)
- Online Tools
- DEMAC 2009 and 2020