

Design Equivalent Material Classification System - DEMAC -

Acknowledgements

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1

Why a Material Classification System?



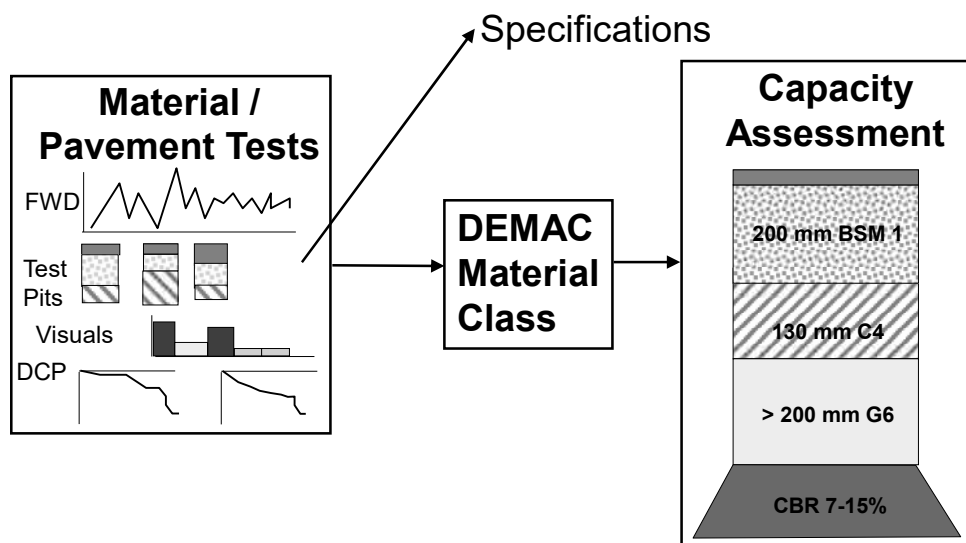
2

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

3

The Design Process



4

DEMAC 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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5

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



6

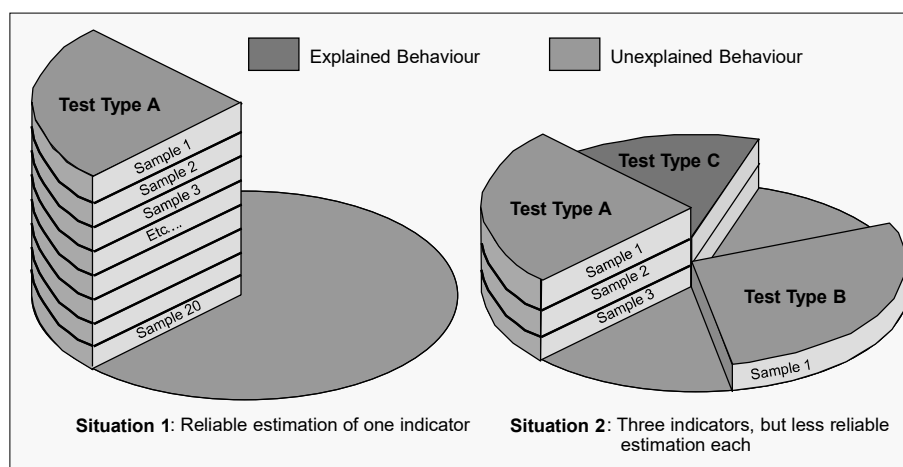
Handle Difficulties by

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

7

Holistic Assessment

- Reliability versus Completeness



8

Handle Difficulties by

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

9

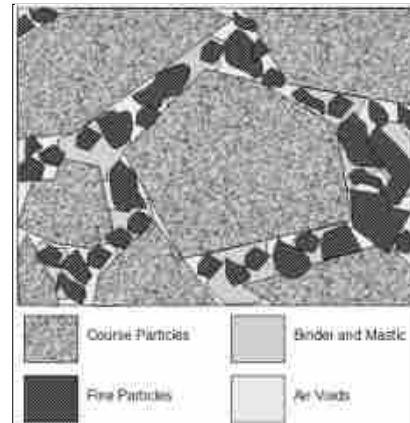
DEMAC

- 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

10

Assumed Material Behaviour

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



11

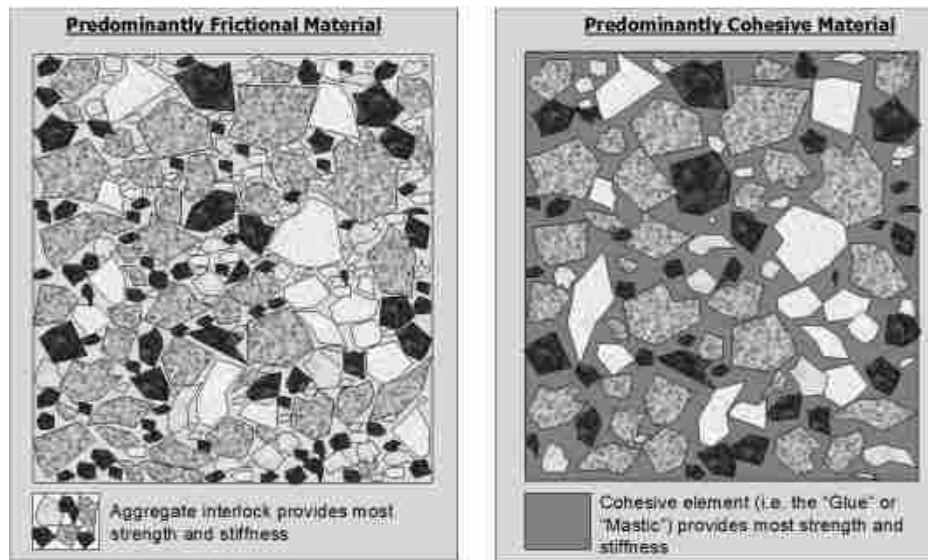
Material Model

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



12

Material Model



13

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*



14

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



15

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)



16

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)



17

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



18



19

Clear Guidelines

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

20

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

21

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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22

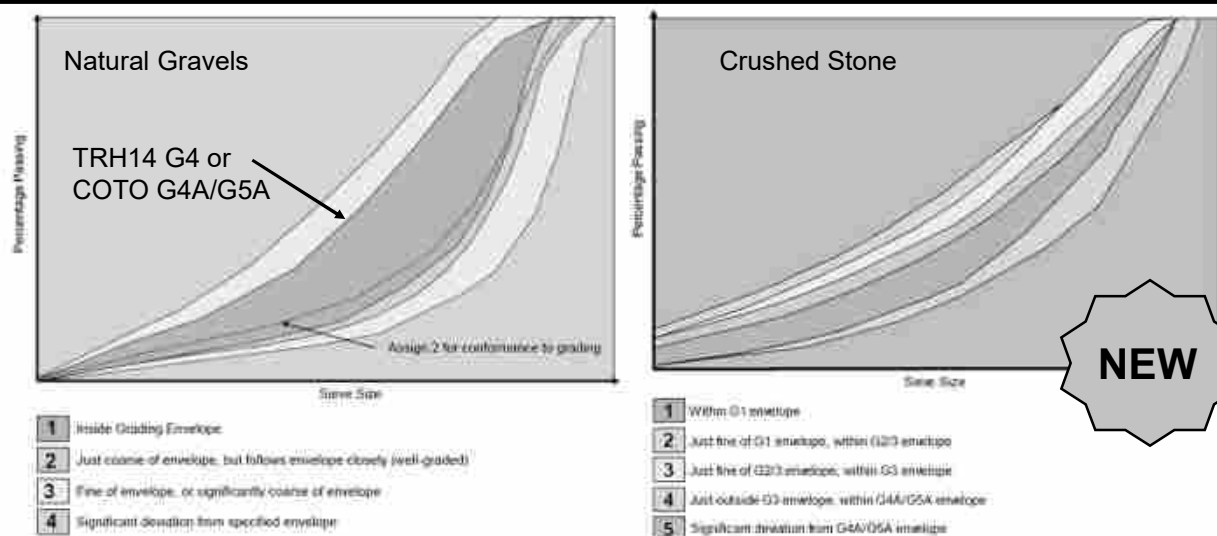
Guidelines for Interpretation - Cemented -

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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23

Interpretation of Grading



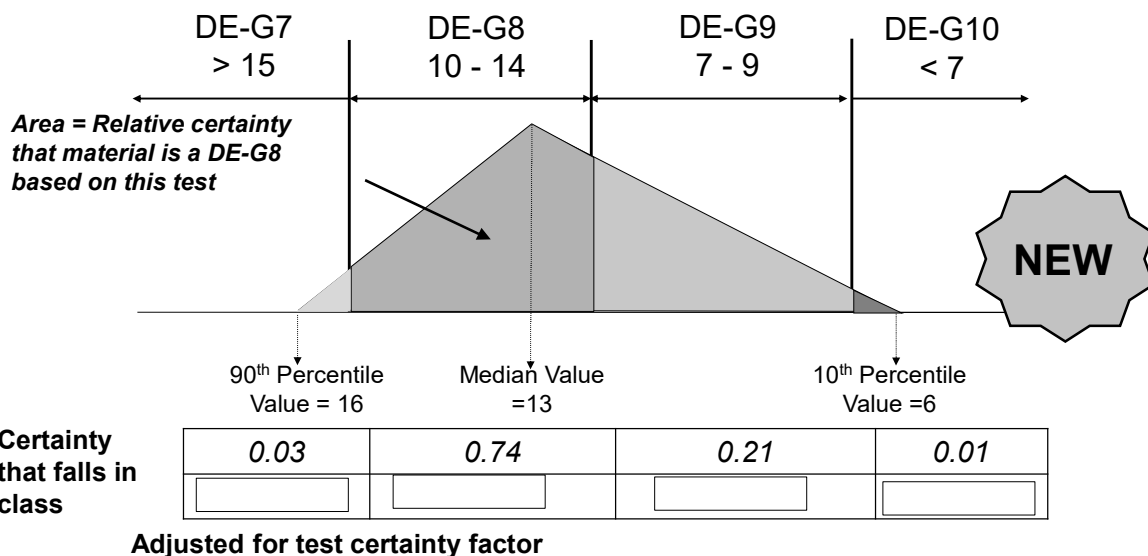
24

How does the 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

25

Example: CBR (SSC, 93% MDD)



26

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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 % [lb/ft]			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	[6]		-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	52	16	19	-	-	-
Grading Modulus NG	2.4 (2.5) 2.7	[6]		-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	52	16	29	-	-	-
Relative Density (%)	69.0 (86.3) 100.9	[27]		-	-	-	-	-	-	-	-	-	-	-	-	-	-	00	46	54	27	34	07	06
DCP Pen (mm/blow)	1.1 (1.5) 2.1	[11]		-	-	-	-	-	-	-	-	-	-	-	-	-	-	08	25	48	54	27	34	07

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: 04-Jun-2020

27

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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28

Validation

- 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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29

Every day we have something to be thankful for

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



30

Software

- www.rubicontoolbox.com
- Online Tools
- DEMAC 2009 and 2020