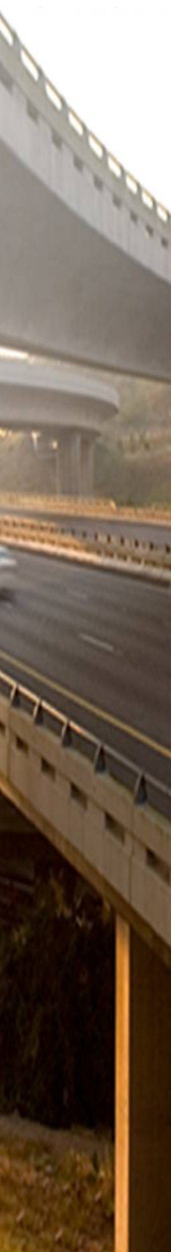
RPF May 2010:
Progress Report on the SAPDM

Damage models for stabilised material

H L Theyse

Current activities

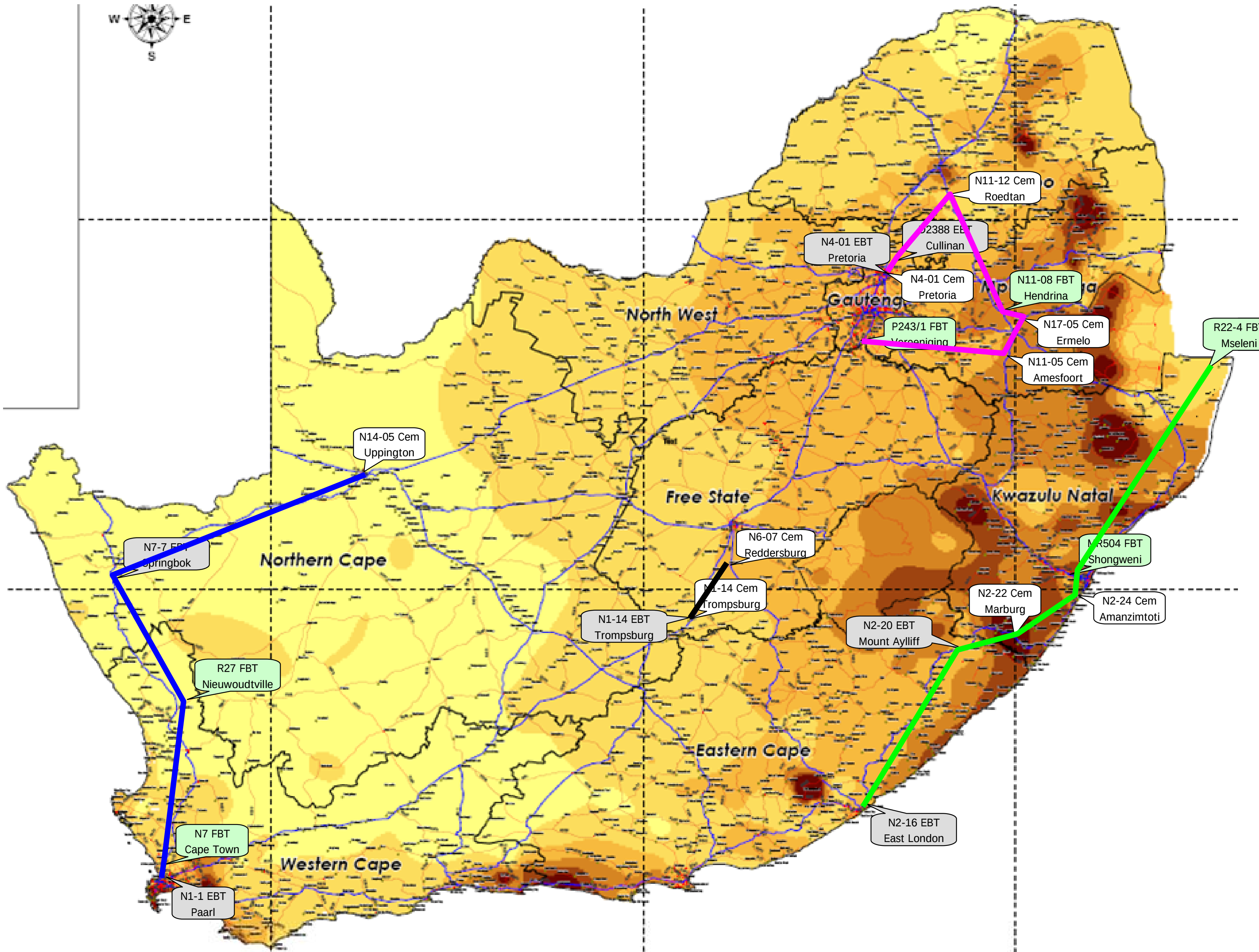
- Preliminary investigation
  - Site visits
- Damage models
  - Initial plastic strain models
    - Yield strength models



Project SAPDM / D-3
Damage modelling of stabilised material

Preliminary investigation site visits

Site selection



N2-24 Amanzimtoti

- Moist sub-humid area
- Structure
  - 138 mm HMA layers
  - 200 mm C2
  - 150 mm C3
- Constructed 1964
- ADT 18 000 to 30 0000
- Cracks with pumping but often on inner wheel-path!

N11-12 Roedtan

- Semi-arid area
- 150 C3 on 150 C4
- Constructed 1961
  - Short section north of Roedtan reconstructed
- Cracks with pumping but often on inner wheel-path!

N17-5 Ermelo - Carolina

- Dry sub-humid area
- 100 C3 on G5 – km 0 to 9
  - 1958
- 100 C3 on 100 C3 km 9 to 25
  - 1968
- Fatigue and pumping in cut on 1st section, deep rut
- Wide 20 mm rut on second section

N14-5 Upington

- Arid area
- Structure
  - 16 mm seals
  - 100 mm C3
  - 100 mm C4
- Constructed 1935
- ADT 455
- Cracks with pumping but often on inner wheel-path!

N1-1 Kraaifontein

- Dry sub-humid area
- Original CTB pavement
  - Recycled 1984
- Structure
  - 40 mm gap on 40 mm continuous
  - 100 mm ETB (1 % residual)
  - 100 mm CT subbase
- Surfacing milled and replaced
  - 1994
  - 2010

N2-16 East London

- Dry sub-humid area
- Constructed 1980/81
- Structure
  - 40 mm gap
  - 140 mm ETB sandstone (1 % residual, 1 % cement)
  - 150 mm subbase (1.5 % lime, 1.5 % slagment)
- Surfacing milled and replaced
  - 1994
  - 2010

N2-20 Mount Frere

- Dry sub-humid area
- Constructed 1999/2000
- Structure
  - 35 mm AC
  - 180 mm ETB (1.75 % cement and 1.5 % residual bitumen)
  - 120 mm old C4 base
  - 150 mm old C4 subbase
- ADT = 2300
- Condition
  - Cracks and pumping in vicinity of Mt Frere
  - Better condition towards Mt Ayliff

N4-1 100 mm ETB on old CTB

- Dry sub-humid area
- Original 200 mm C1 CTB pavement
  - Constructed 1969
  - UCS on cores 25 years after construction – 13 MPa
- Upper 100 mm recycled with ETB in late 1990s on the slow lane
  - Fast lane still CTB
- High traffic volume
- Block cracks sealed
- No fatigue and pumping

D2388 100 mm ETB on “cemented” subbase

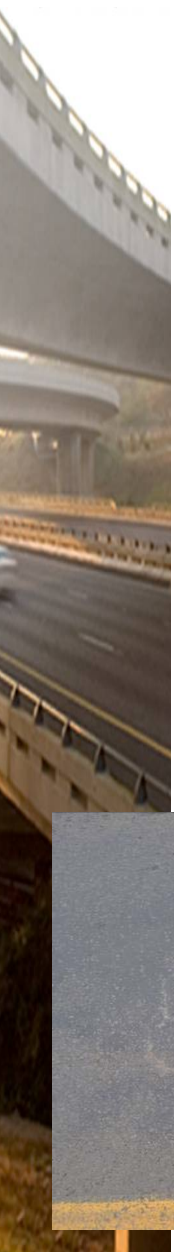
- Dry sub-humid area
- Constructed in 1997
  - 0.9 % residual binder
  - 1 % cement
- Very little traffic
- No structural distress

N7-07 Kammieskroon

- Arid area
- Constructed in 1987
- Structure
  - Seals
  - 150 mm ETB (2 % emulsion, 1 % cement)
  - 50 mm old CT subbase
- Very little traffic
- No structural distress

N11-08 Hendrina

- Moist, sub-humid
- 180 mm foamed bitumen treated dolerite
  - Constructed 2003/04
  - 1.5 % foam
  - 1 % cement
- Localised shear failure
- Rutting on inner wheel-path



P243 Vereeniging

- Dry sub-humid
- 250 FTB
  - Constructed 2000
  - 1.8 % foam
  - 2 % cement
- Localised shear failure
- No structural distress on remainder of section

R27 Nieuwoudtville

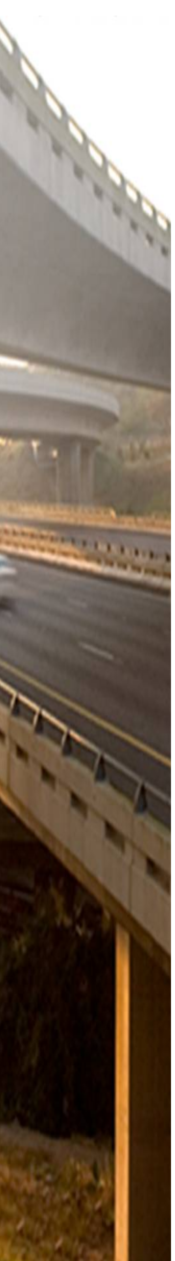
- Arid area
  - Appears wetter than Upington and Kammieskroon
- Constructed in 2003
- Structure
  - Double seal
  - 200 mm FTB
    - 2.5 % foam
    - 1 % cement
- Cracking and pumping in inner wheel-track

P504 Cliffdale Road

- Moist sub-humid area
- Constructed in 1995
- Structure
  - Slurry seal
  - 175 mm FTB
    - 3.5 % foam
    - 1 % lime
  - Decomposed granite subbase and in situ
- AC overlay 3 years after construction
- Condition
  - Surface disintegration but little material loss from base
  - Substantial deformation in places

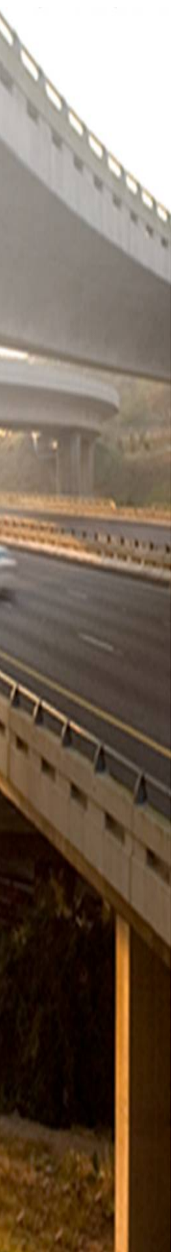
R22 Mseleni

- Semi-arid area
- Constructed in 2002
- Structure
  - Coarse slurry seal
  - 250 mm FTB
    - 4 % foam
    - 2 % lime
  - Sand and calcrete mixture in base
- Double seal 4 years after construction
- About 10 mm rut but overall sound structural condition



Preliminary investigation: Closing comments

- Site visits completed
- Field testing and sampling to start on selected sites
- Emulsion seems to be doing well
  - All sections in arid to dry sub-humid areas
- Cemented section classical block cracks with secondary cracks and pumping
  - Very old sections also in wetter areas
- Foam
  - Appears to have moisture susceptibility in <u>some</u> cases

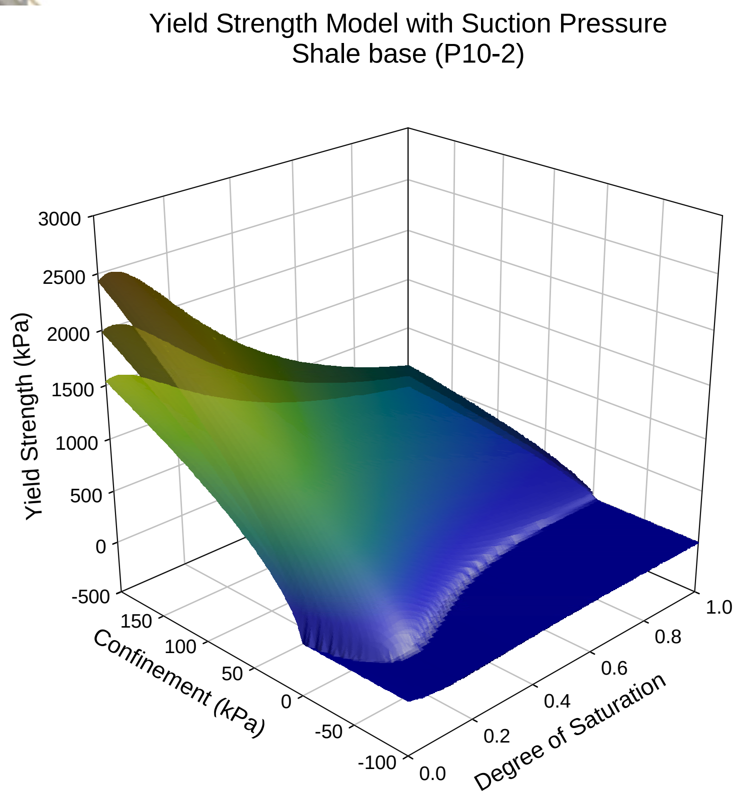


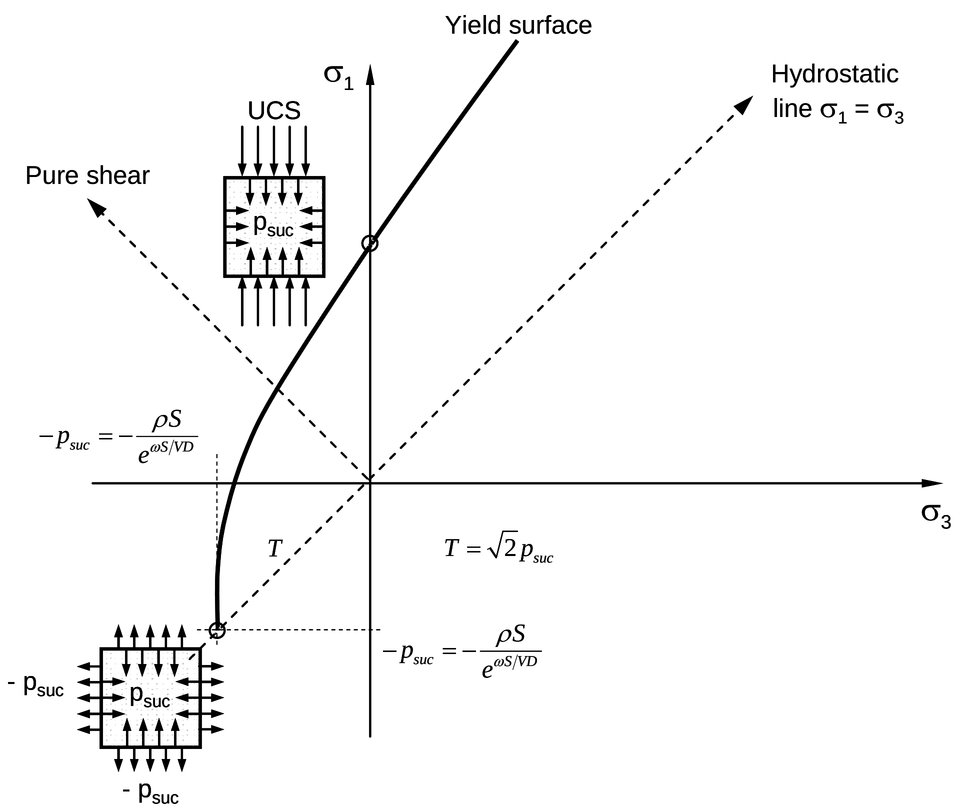
Project SAPDM / D-3
Damage modelling of stabilised material

Yield strength model

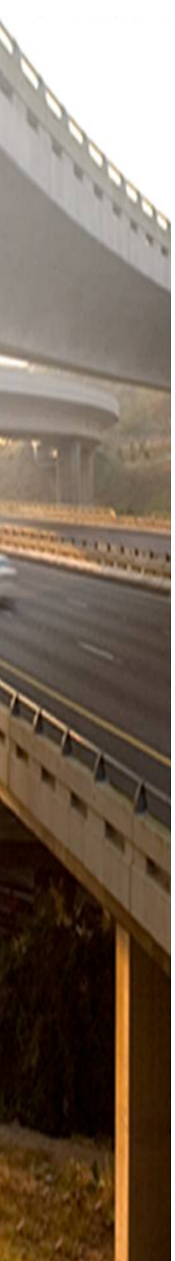
Unbound material yield strength model

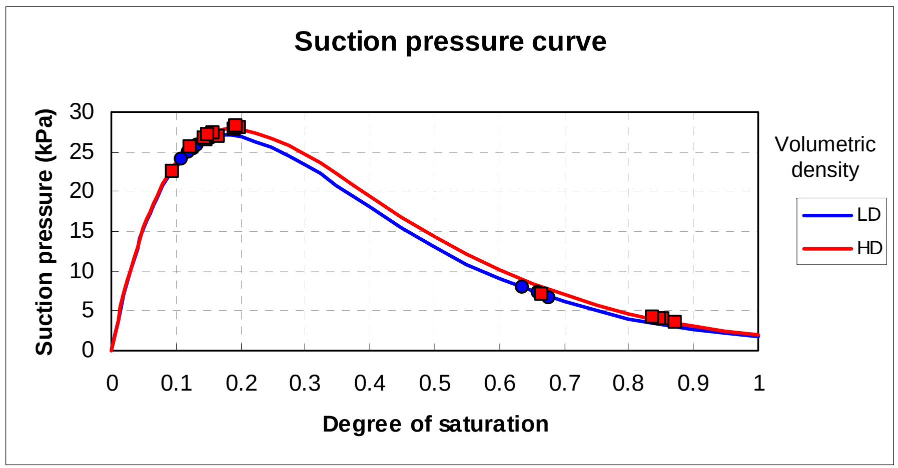
$$\sigma_1^y = \frac{e^{aVD}}{e^{bS}}\left(\sigma_3 + p_{suc}\right)^c - p_{suc} \quad if\ \sigma_3 \geq -p_{suc}$$





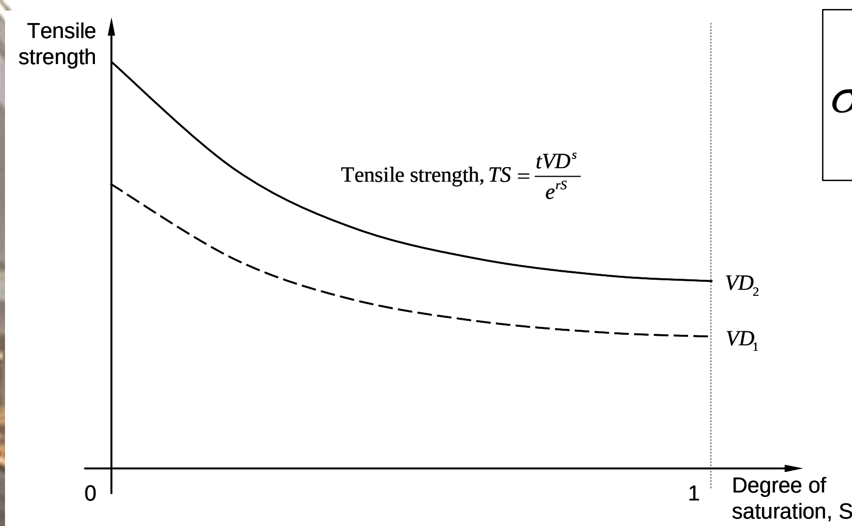
Unbound material, suction pressure – “apparent” tensile strength



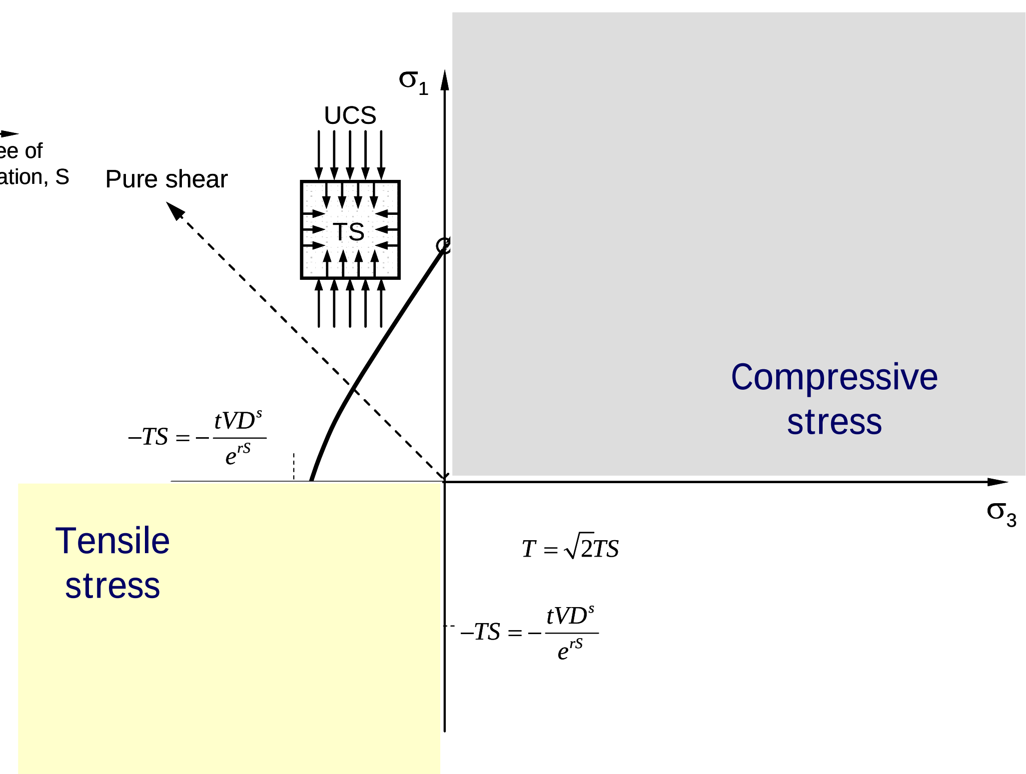


$$p_{suc} = \frac{\rho S}{e^{\omega S / VD}}$$

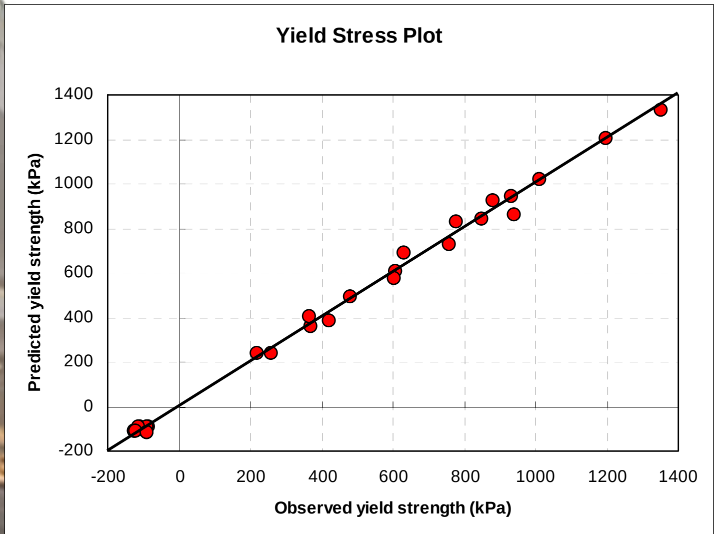
Stabilised material – true tensile strength



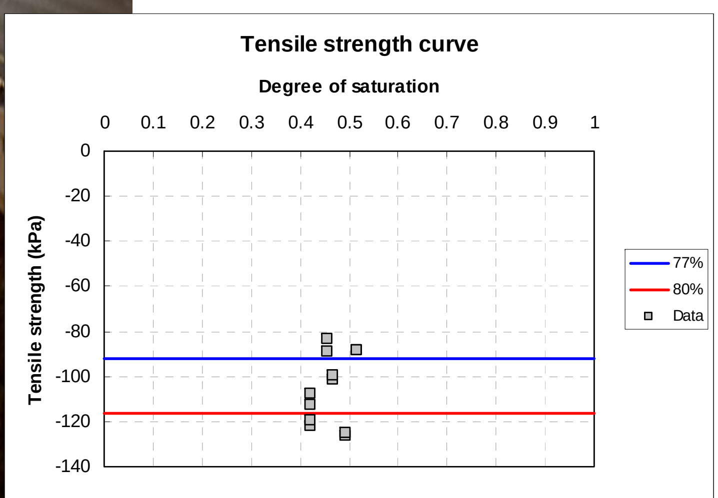
$$\sigma_1^y = \frac{e^{aVD}}{e^{bS}}\left(\sigma_3 + \frac{tVD^s}{e^{rS}}\right)^c - \frac{tVD^s}{e^{rS}} \quad if\ \sigma_3 \geq -\frac{tVD^s}{e^{rS}}$$

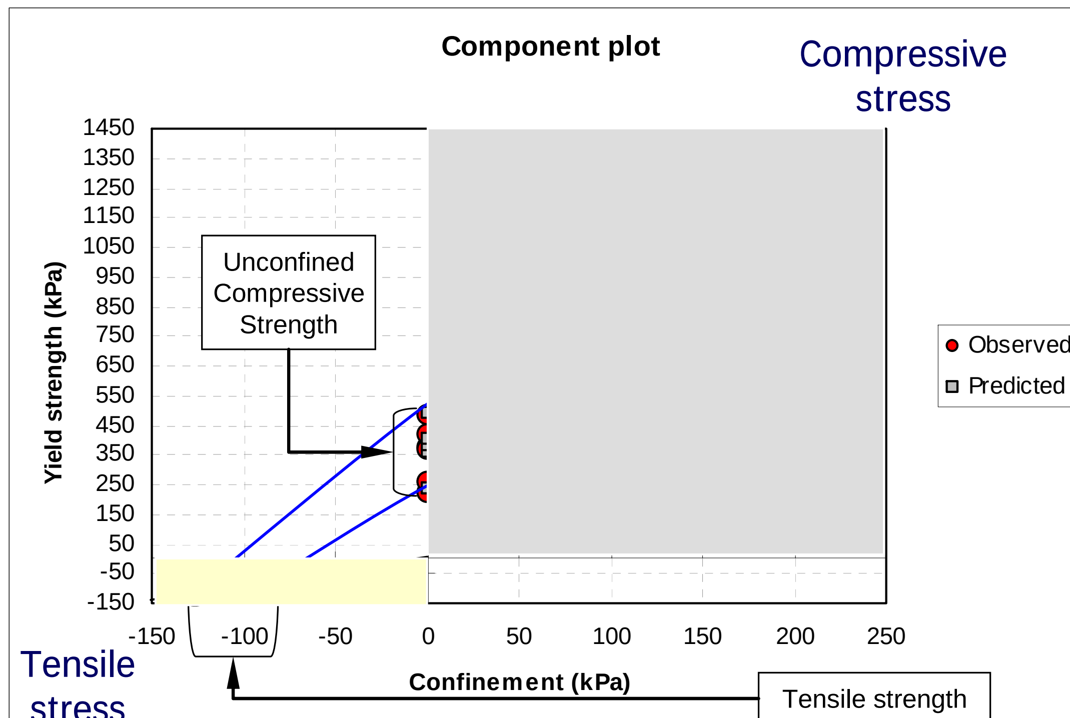


Sand-calcrete mix – 5 % binder, 1 % cement

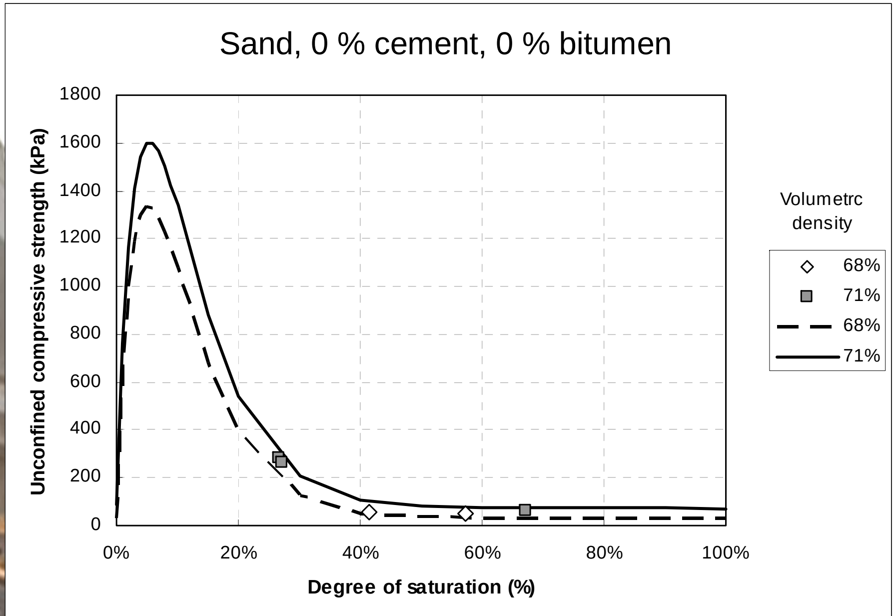


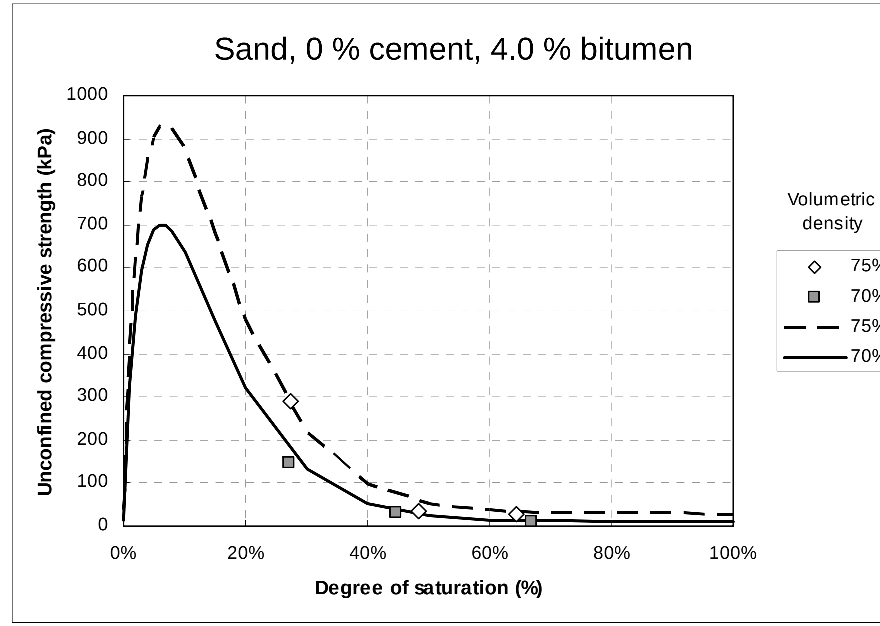
$$\sigma_1^y = \frac{e^{aVD}}{e^{bS}}\left(\sigma_3 + \frac{tVD^s}{e^{rS}}\right)^c - \frac{tVD^s}{e^{rS}} \quad if \ \sigma_3 \geq -\frac{tVD^s}{e^{rS}}$$

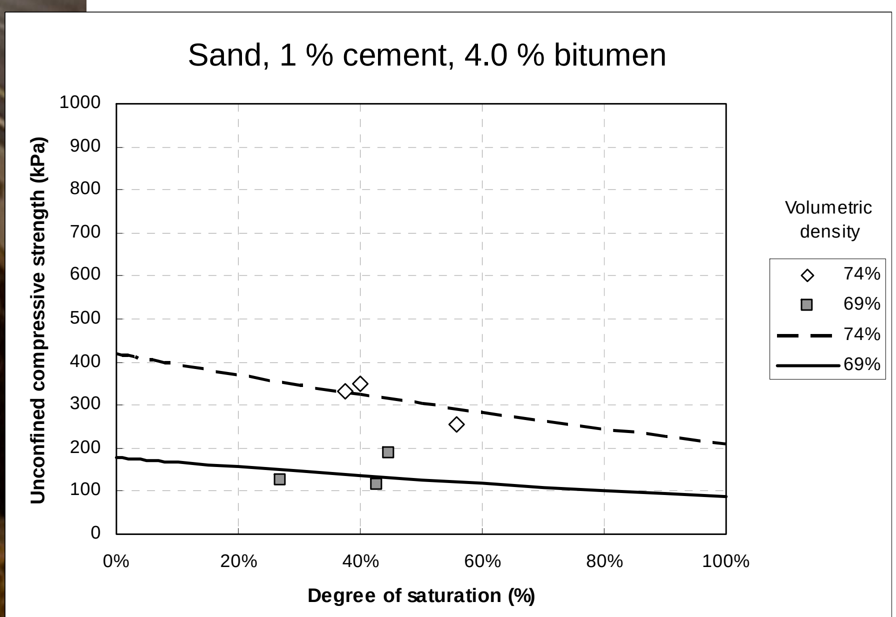


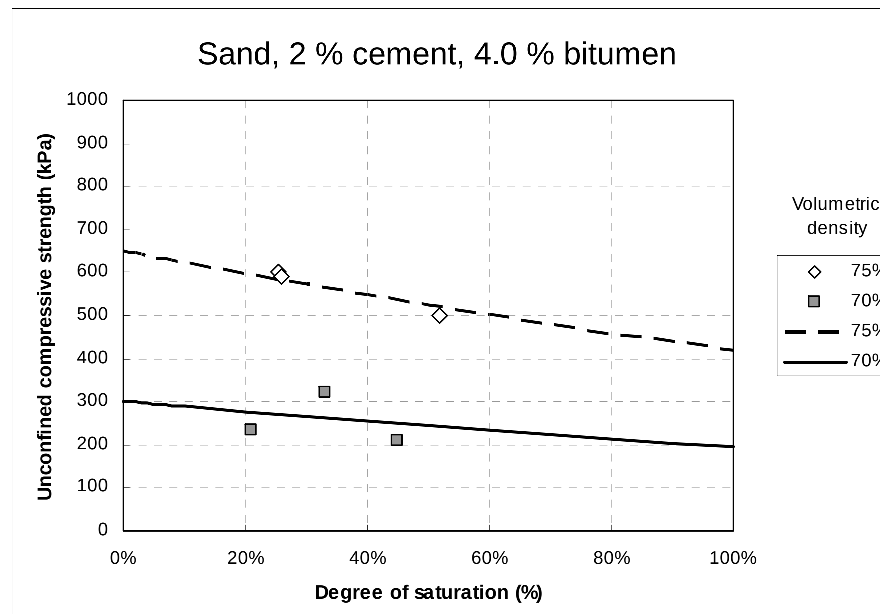


Effect of bitumen and cement

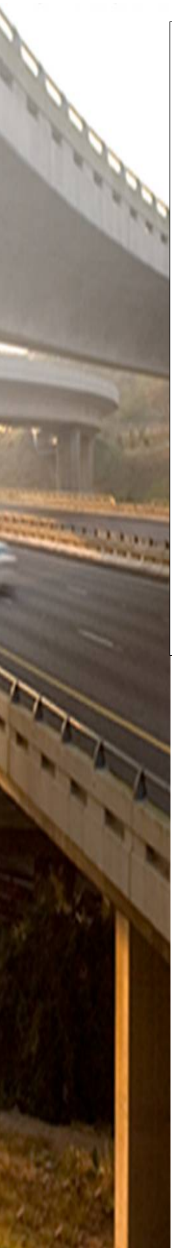


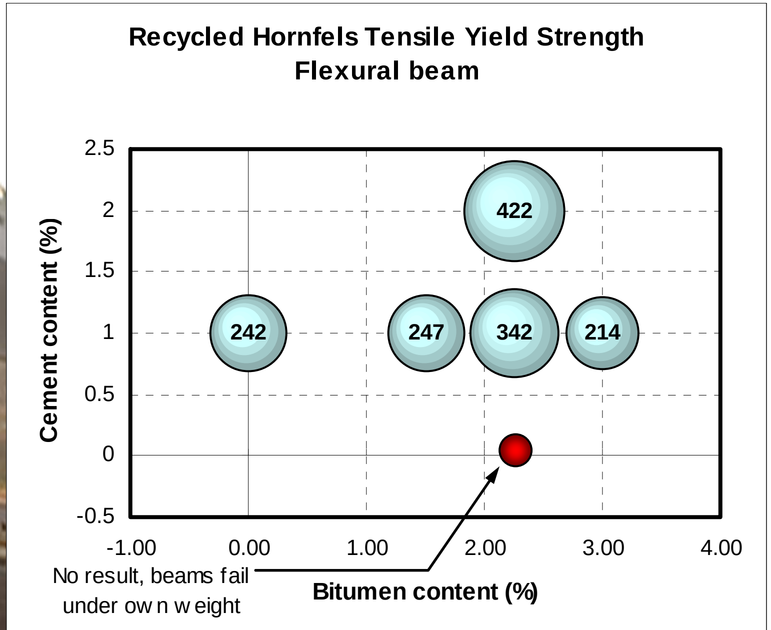


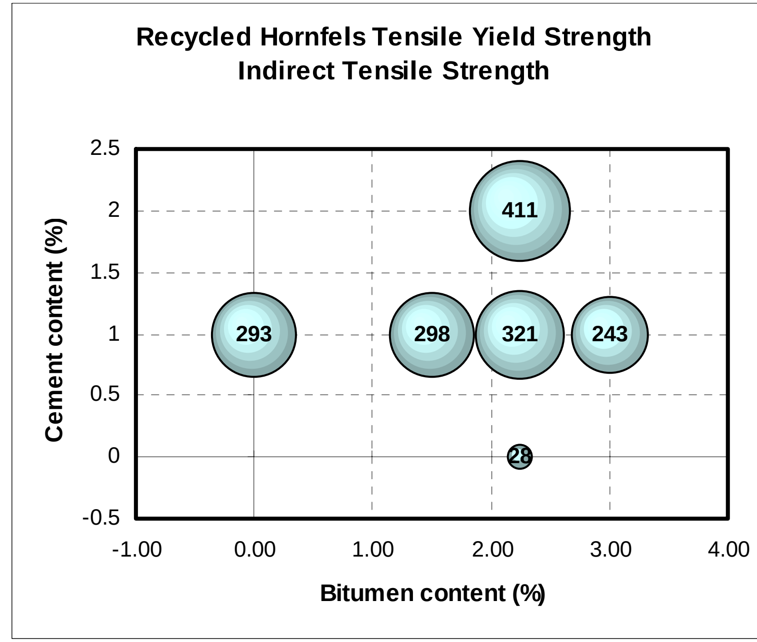


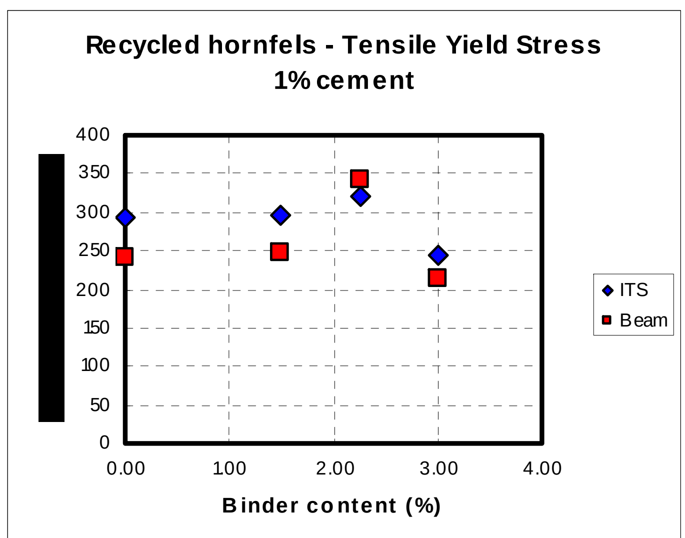


Tensile strength – beam or ITS?



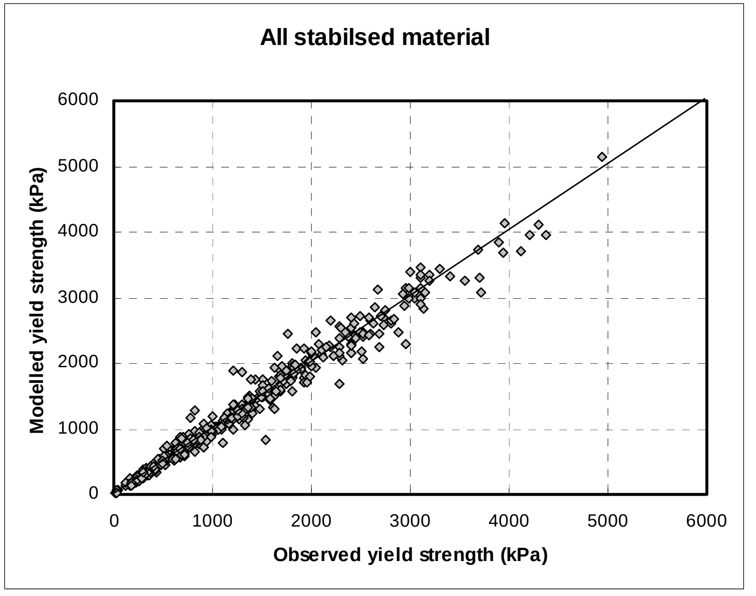




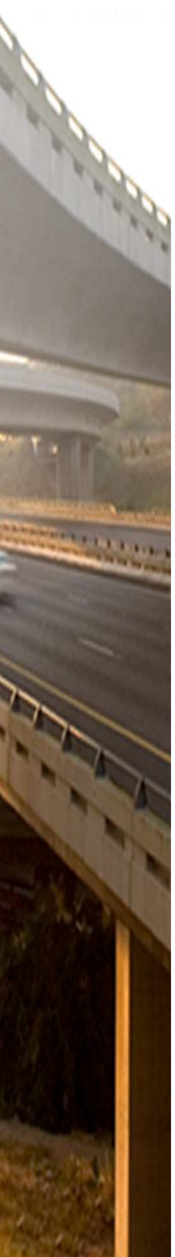


General yield strength model

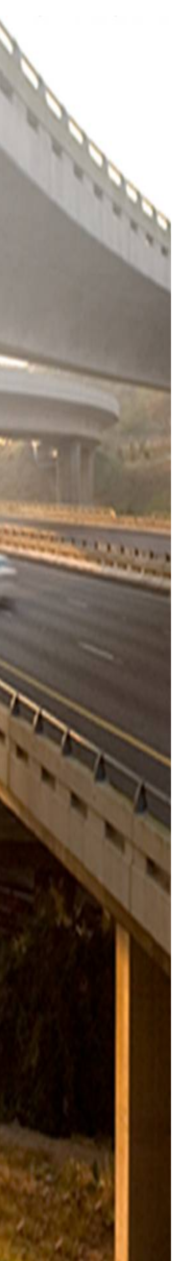
- Model calibrated for each combination of aggregate, bitumen and cement individually shows good accuracy
- Complex interaction between aggregate, bitumen and cement difficult to model
  - Routine ITS and UCS tests?
  - **No cement – no tensile nor compressive strength**



Plastic strain damage models: Closing comments



- Initial yield strength models sufficient to start with PS model development
- Memory-less PS model formulation completed based on Markov property of PS evolution
- Model development and calibration require more effort than past approach but the plastic strain damage model will be far more powerful in a recursive application



Additional damage models: Closing comments

- Crushing failure of cement-treated base layers
- Stiffness reduction linked to deflections on field sections
- Material loss/erosion linked to durability testing