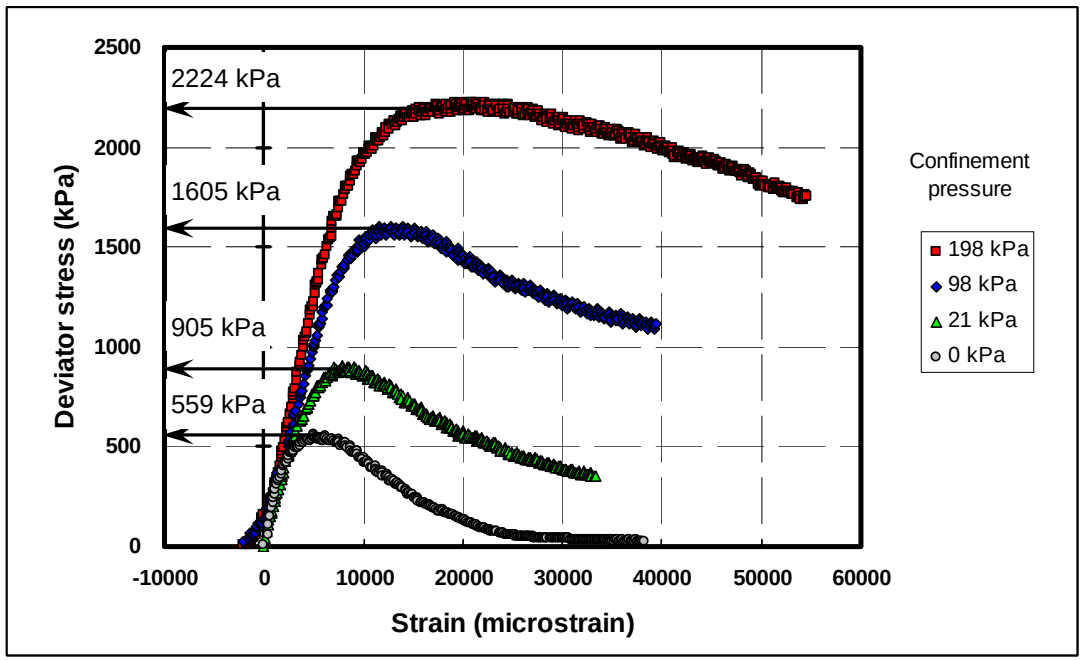
RPF May 2010:
Progress Report on the SAPDM

Primary Pavement Response Models:
Stress-dependent solutions

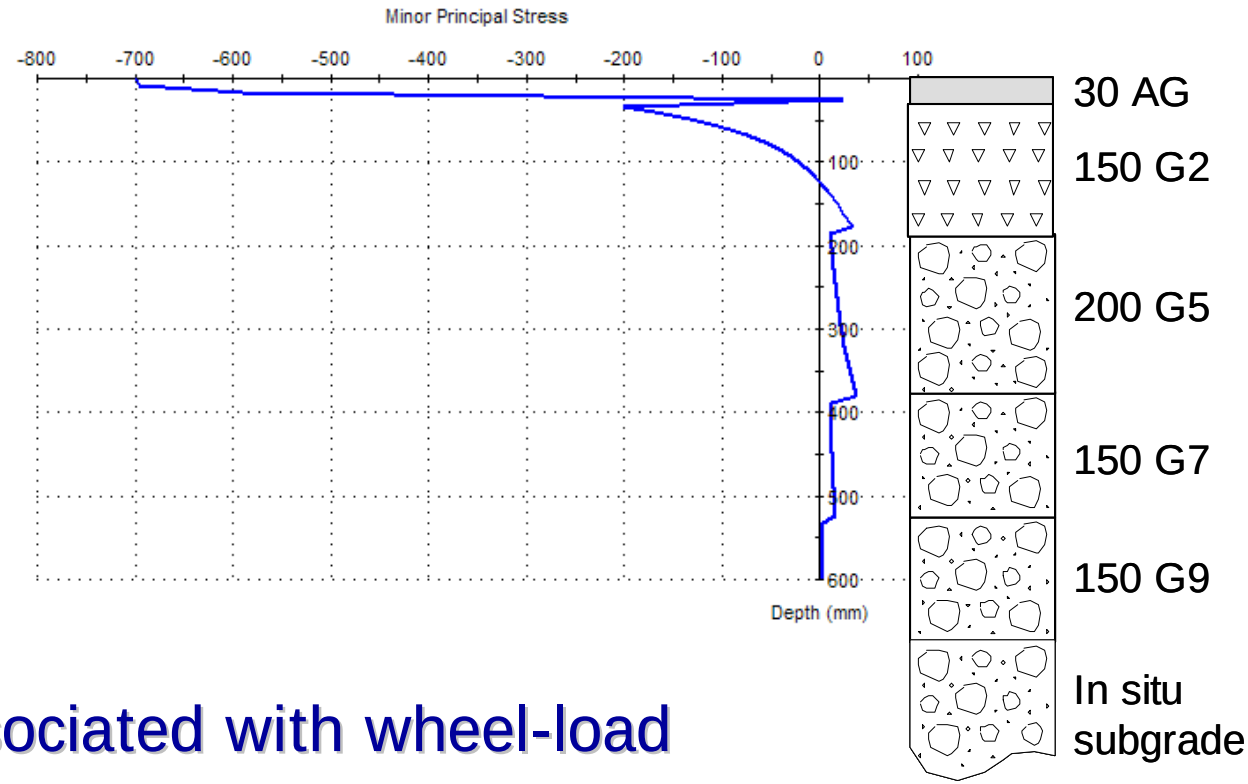
H L Theyse

Why stress-dependent solutions?

- Unbound material
  - Non-linear behaviour
- MLLE
  - Linear
- Stress-dependent solution is an attempt to introduce non-linearity in MLLE
- 2 components
  - Stress stiffening
  - Stress softening



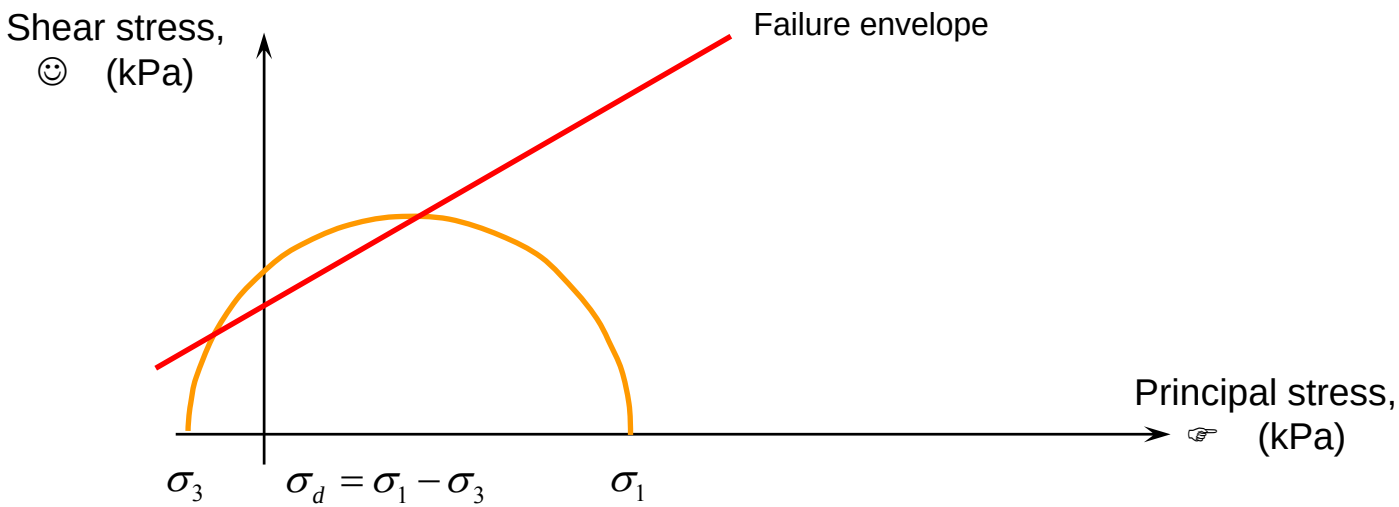
Problem with MLLE analysis



- Stress associated with wheel-load
  - Tensile stress in unbound material
  - FoS approach excellent in laboratory but did not work in design application
- **What did we do wrong?**

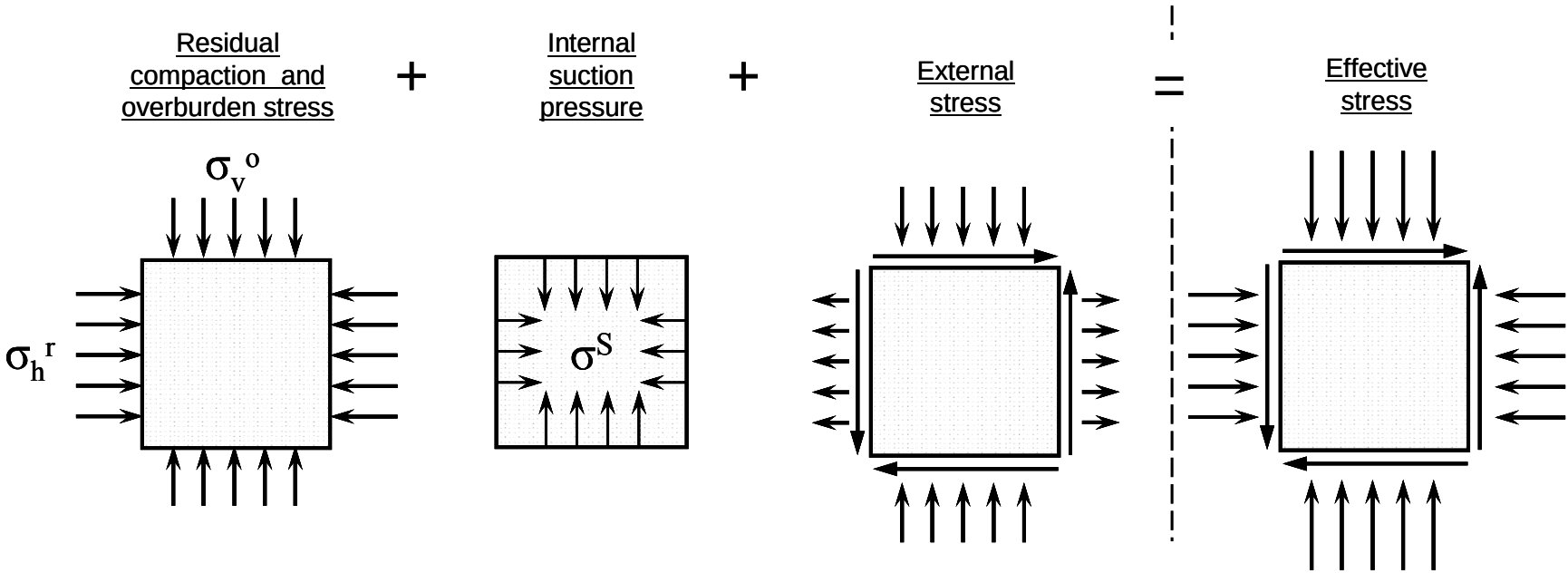
SAMDM'96 - Inadmissible stress

- Past ME design only considered stress associated with the external load
  - Inadmissible stress



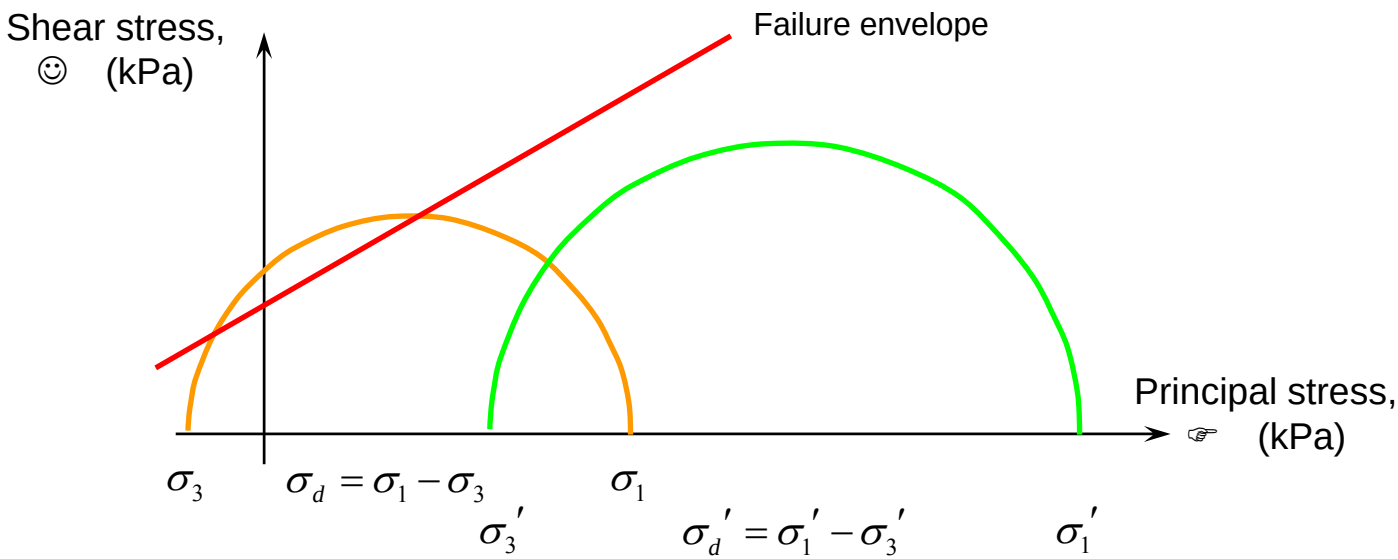
Effective stress

- Integral transformation solution (BISAR, ELSYM, GAMES, etc) of Multi-Layer, Linear Elastic system only provides for
  - Stress caused by the wheel-load
- Excludes
  - Suction pressure
  - Overburden stress
  - Residual compaction stress



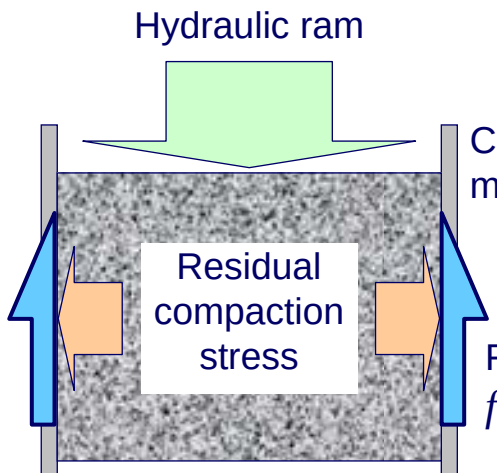
Effective stress

- Effective stress
  - Completely different stress regime



Residual compaction stress

- How do we know it exists?
  - "*It has been suggested by Prof Burmister and others that a "pre-stress" exist in road structures in practice. A study of this subject was made in South Africa during 1957 and from the results of laboratory tests it was concluded that some small "pre-stress" – a horizontal compressive stress residual from the compaction – may in fact occur*."
    George Dehlen, Ann Arbor 1962
  - Dehlen recorded values from 20 to 70 kPa in the 1950s
  - Specimens remain stuck in compaction moulds after compaction



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Residual compaction stress in SAPDM

- Residual compaction stress is a passive stress equilibrium with the horizontal stress **FAR** exceeding the vertical stress
- Calculation techniques available for implementation in SAPDM
- Preliminary results
  - Crushed stone
    - About 95 kPa horizontal residual compaction stress
  - Natural gravel
    - About 45 kPa horizontal residual compaction stress
- Results extremely sensitive to the OCMC
  - Shear strength at OCMC determines the residual stress

P_m^c

Suction pressure

- How do we know it exists?
  - Sandcastle experiment
    - Completely dry sand – material runs down
    - Completely wet sand – material slumps down
    - Moist sand – the sandcastle stands!
  - It is accepted in geotechnical engineering

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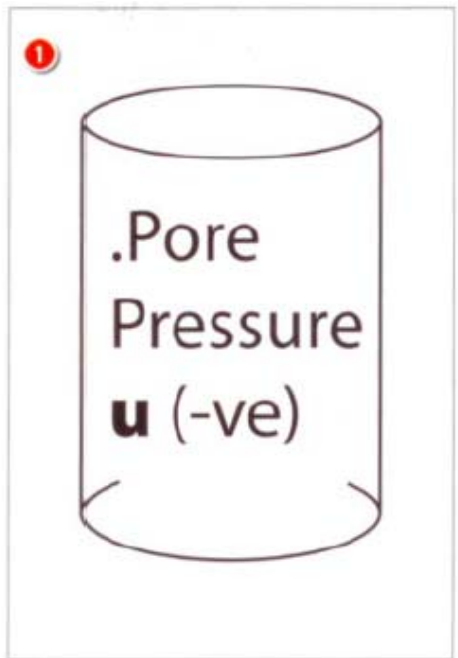
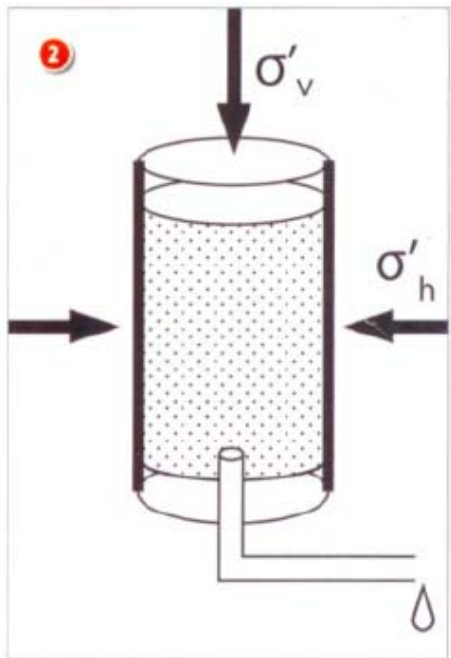
SUPERPOSITION OF SUCTION AND EXTERNAL APPLIED STRESSES

A sample located at some depth in the soil could be subjected to a pore water suction (-u) as in Figure 1 and also the imposed stresses σ'_v and σ'_h (as in Figure 2) which are caused by the weight of the overburden or by stresses from a foundation above this sample.

The effect of u and the effect due to the applied stresses are both effective pressures, and can be added together.

The combined average effective stress in the sample due to both causes is u* in Eq (2).





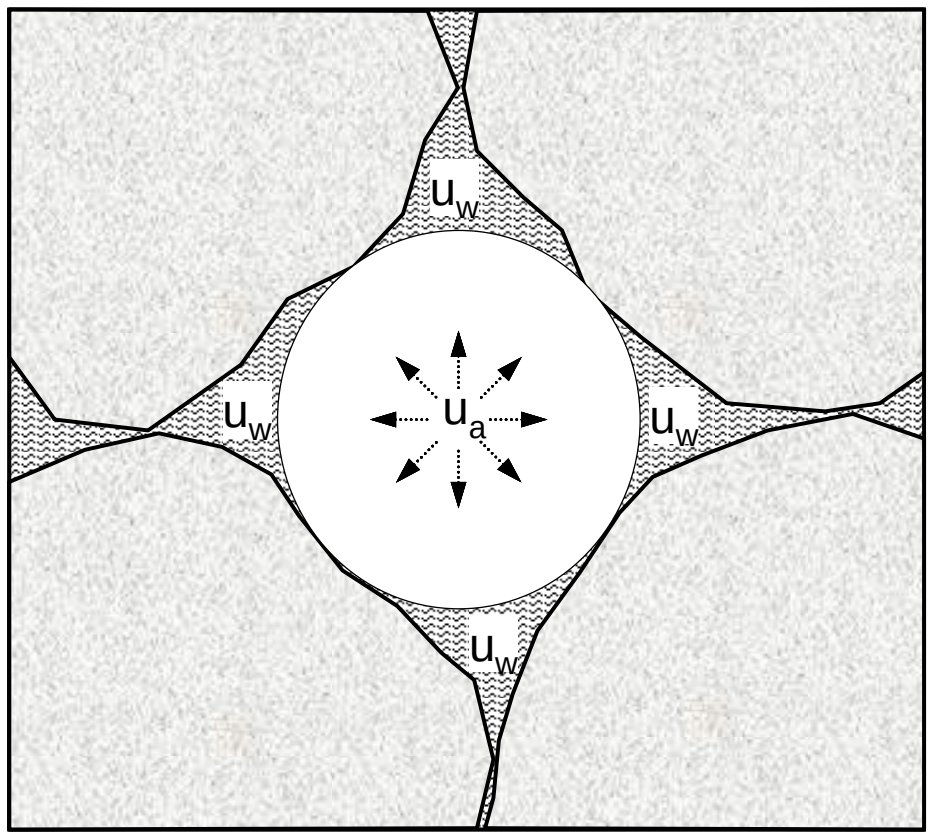
1 Saturated clay sample permitted to dry out to the atmosphere in the soil laboratory (isotropic consolidation)

2 Drained sample in rubber jacket in triaxial cell

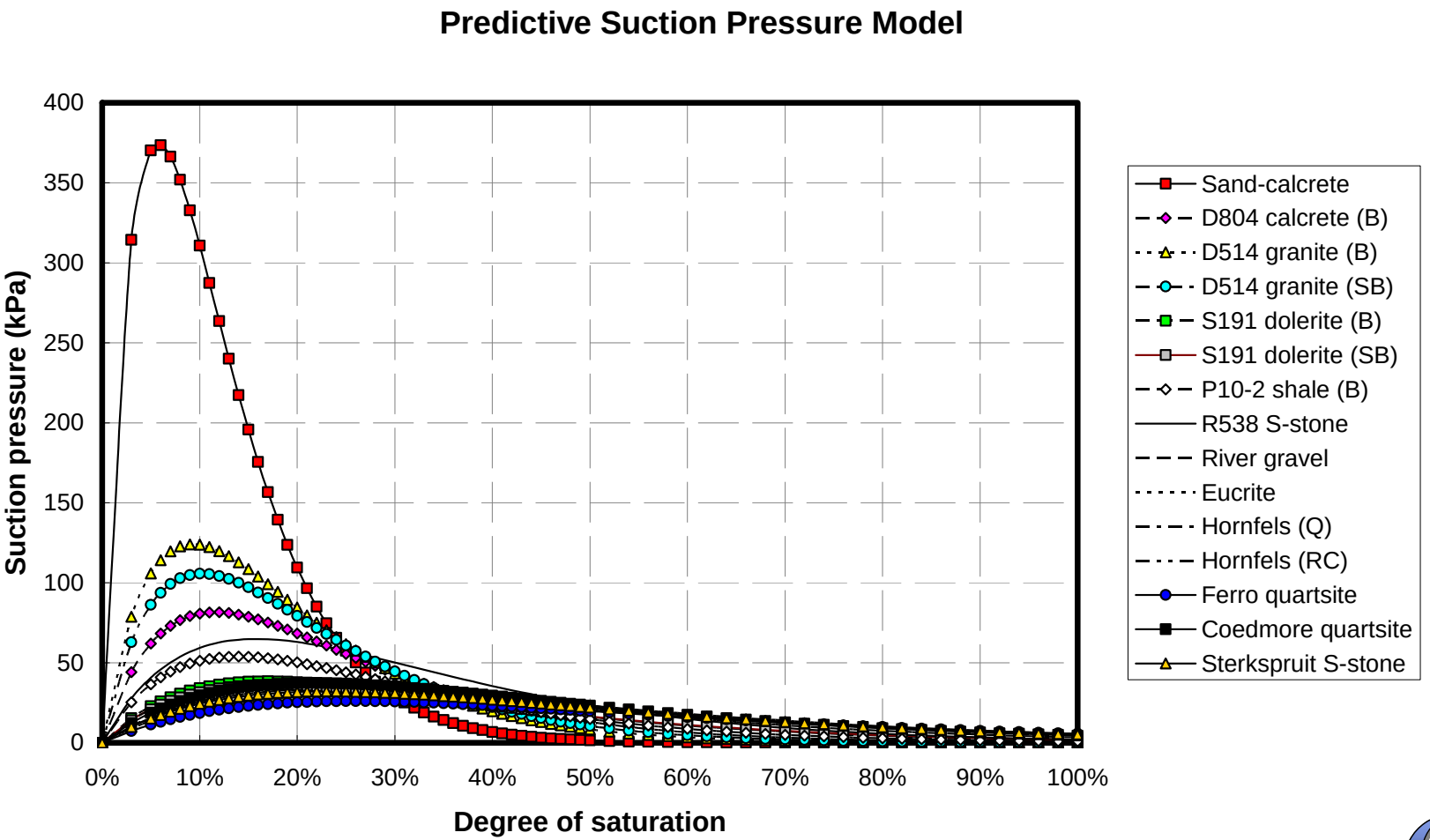
Suction pressure, matric suction, SWCC?

$$matric\ suction = (u_a - u_w)$$

- Matric suction
  - A measure of how easy or difficult it is to expel water from a material
- Suction pressure
  - A function of matric suction

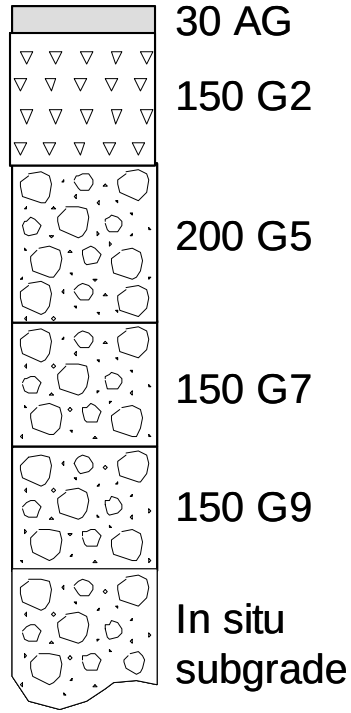


Suction pressure models in SAPDM



Effective stress analysis

- G5 subbase confinement stress
  - External stress = -19 kPa (TENSILE!)
  - Residual compaction = 45 kPa
  - Suction pressure = 20 kPa
  - **Effective confinement stress = 46 kPa**
  - **Not -19 kPa as used in SAMDM'96**
- Residual compaction stress also applies to HMA and stabilised layers
  - A form of pre-stressing of pavement layers
  - Lost when shear failure occurs



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Stress-dependent solutions

- Implemented in SAPDM based on effective stress
  - Stress-dependency becomes less important and density/saturation effects more important
- Internationally accepted UZAN model
  - Violate statistical requirements for model calibration
  - Numerically unstable during implementation
- Alternative model formulated
  - Adheres to statistical requirements and is stable during implementation
  - Coded into software

Closing statements

- Theory and practical evidence suggest that suction pressure and residual compaction stress exist in partially saturated unbound granular material
  - Experimental work continues under the SAPDM to quantify the magnitude of suction pressure and residual compaction stress for design purposes
- Effective stress including suction pressure, residual compaction stress and the stress associated with the external load affects the stress regime for pavement design significantly
  - Past problem associated with modelling unbound material eliminated
  - ME-design calculations that ignore effective stress are fictitious and a waste of time
- Effective stress principle also applies to other material types