



RPF May 2010: Progress Report on the SAPDM

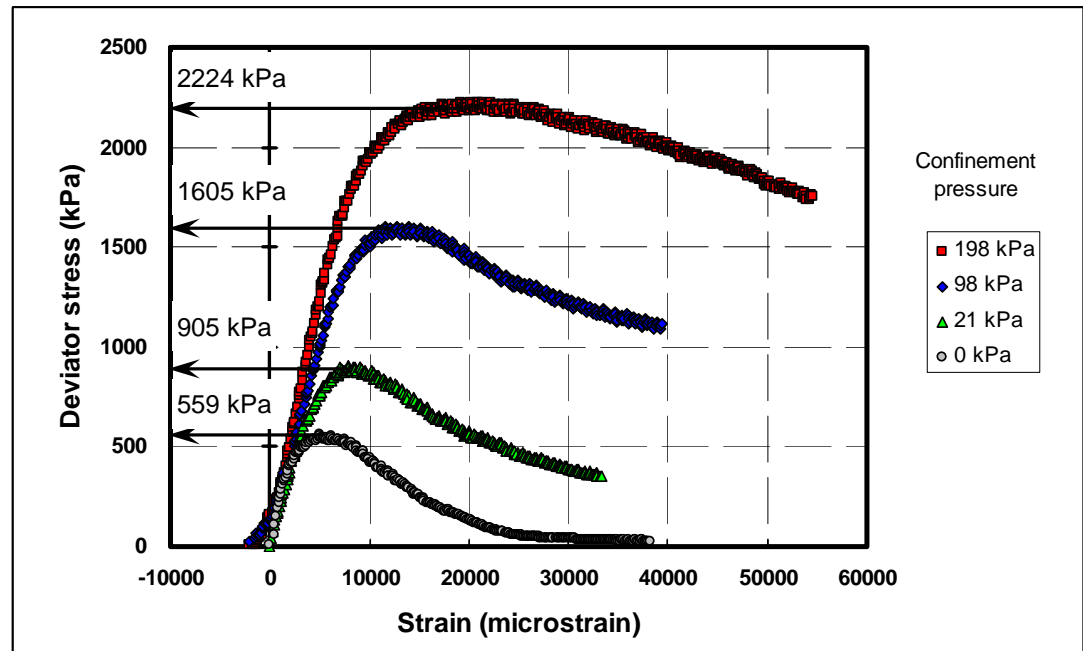
Primary Pavement Response Models: Stress-dependent solutions

H L Theyse

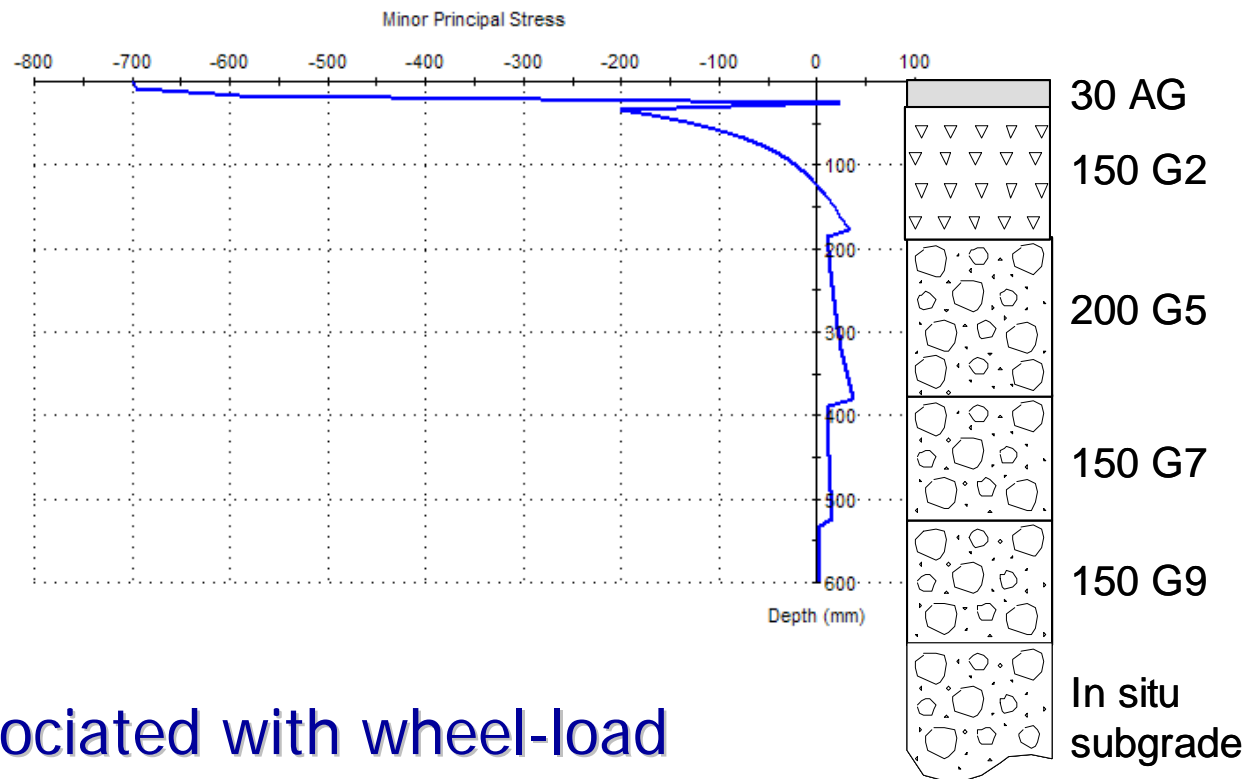
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Why stress-dependent solutions?

- 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 MLE analysis

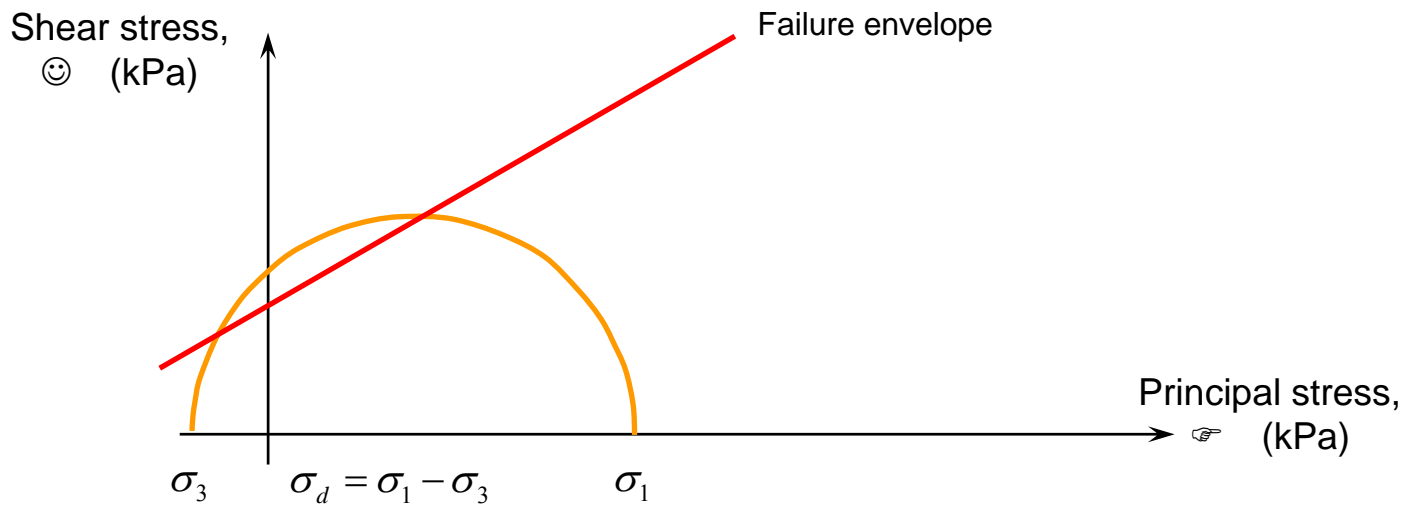


- Stress associated with wheel-load
 - Tensile stress in unbound material
 - FoS approach excellent in laboratory but did not work in design application
- What did we do wrong?

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SAMDM'96 - Inadmissible stress

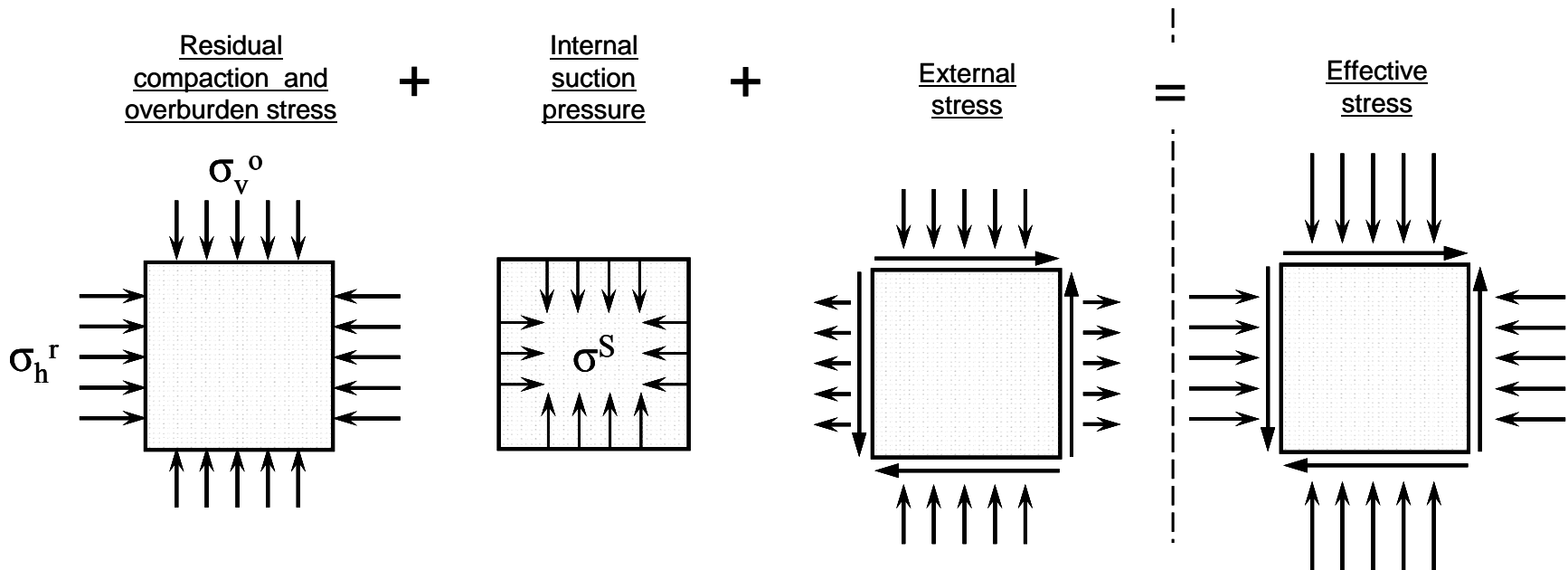
- Past ME design only considered stress associated with the external load
 - Inadmissible stress



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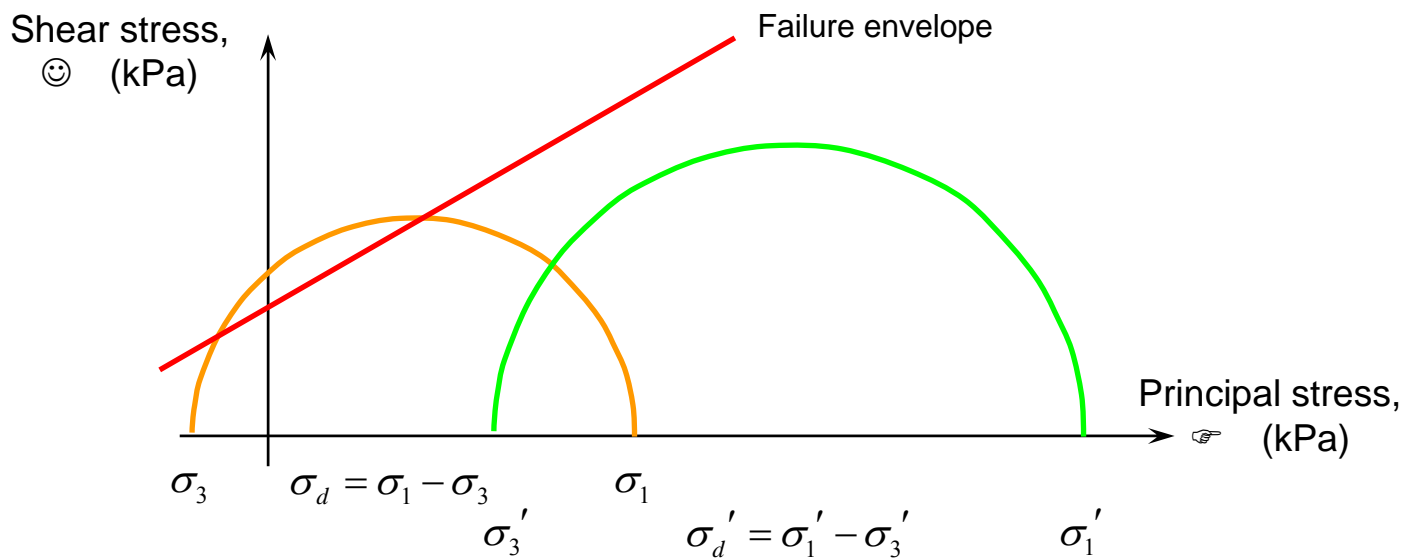
Effective stress

- 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



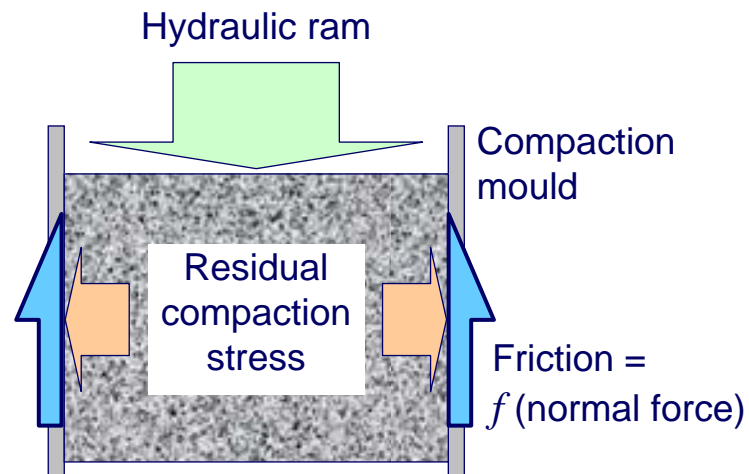
Residual compaction stress

- 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



$$P_m^c$$

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

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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

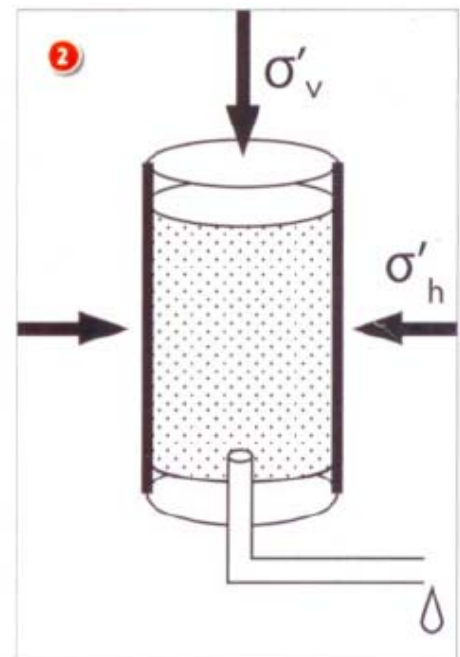
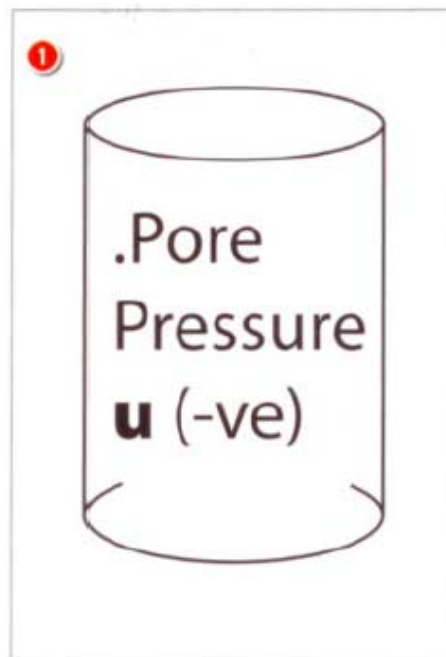
A sample located at some depth in the soil could be subjected to a pore water suction ($-u$) as in Figure 1 and also the imposed stresses σ'_v and σ'_h (as in Figure 2) which are caused by the weight of the overburden or by stresses from a foundation above this sample.

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).

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

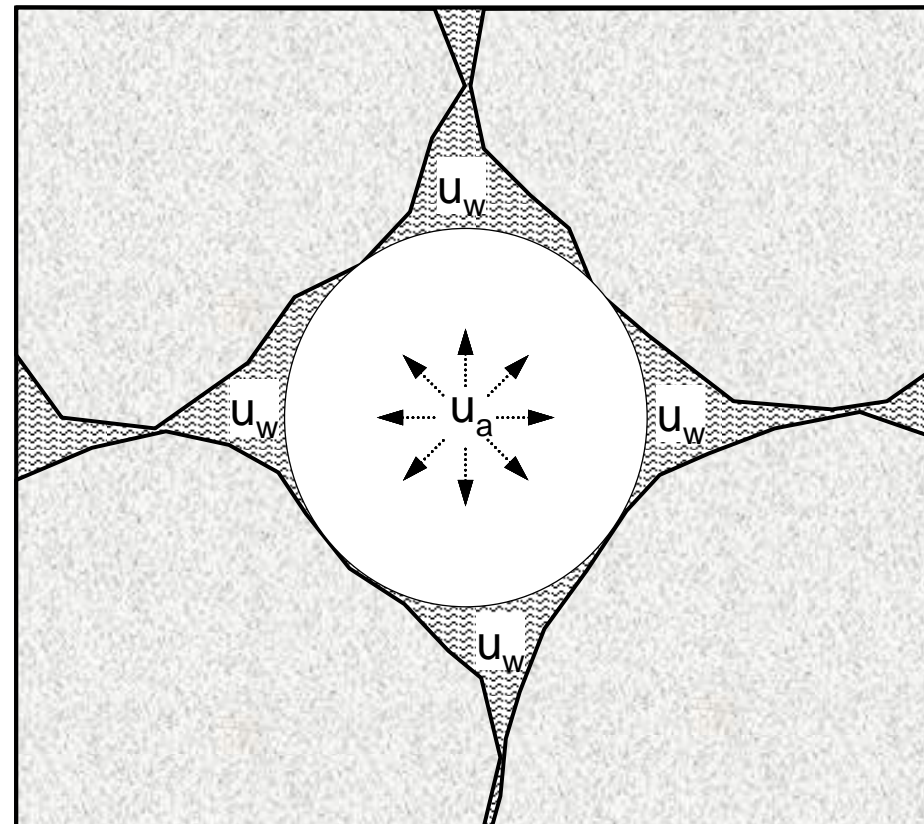
❷ Drained sample in rubber jacket in triaxial cell



Suction pressure, matric suction, SWCC?

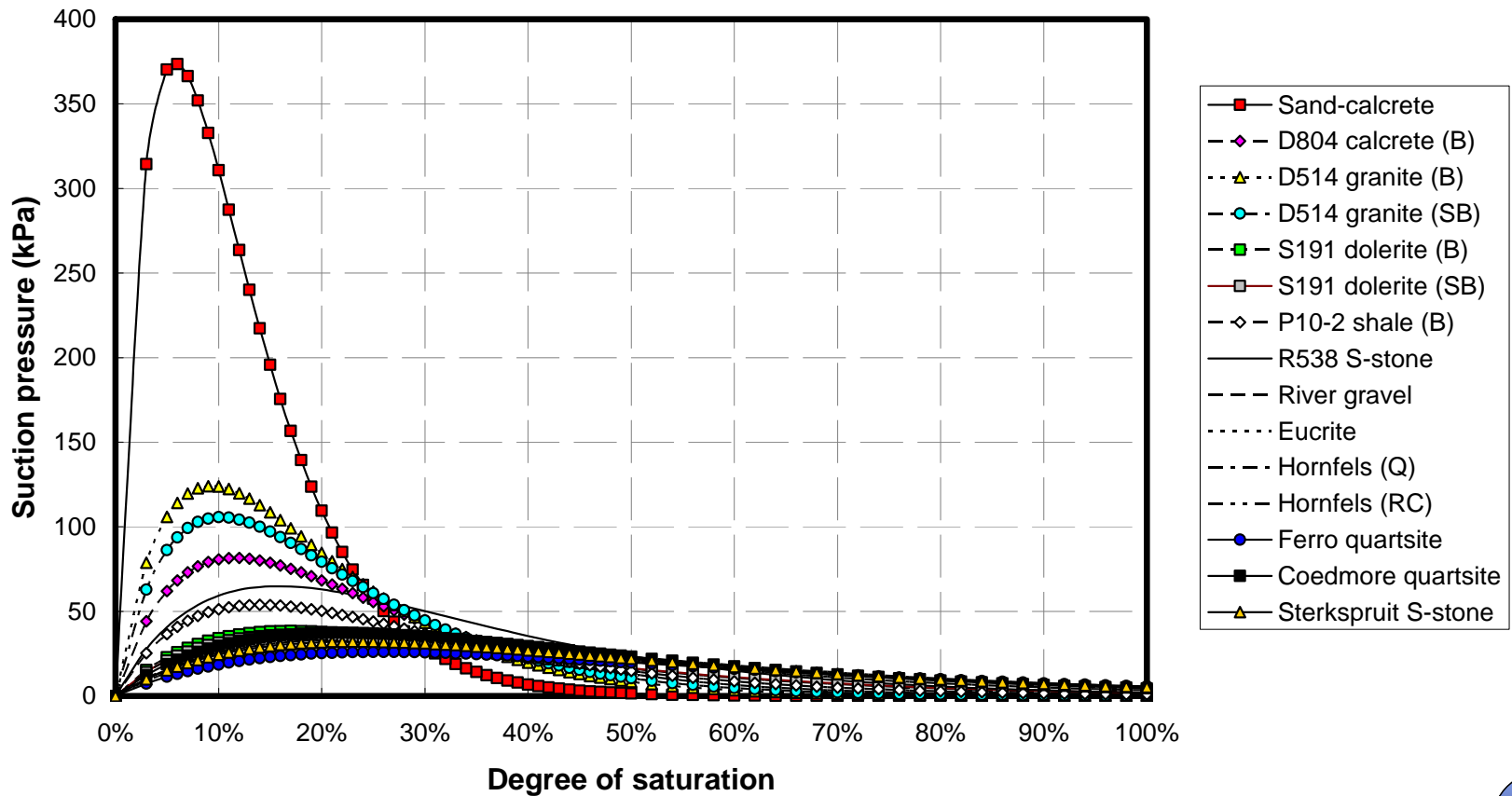
$$\text{matric suction} = (u_a - u_w)$$

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



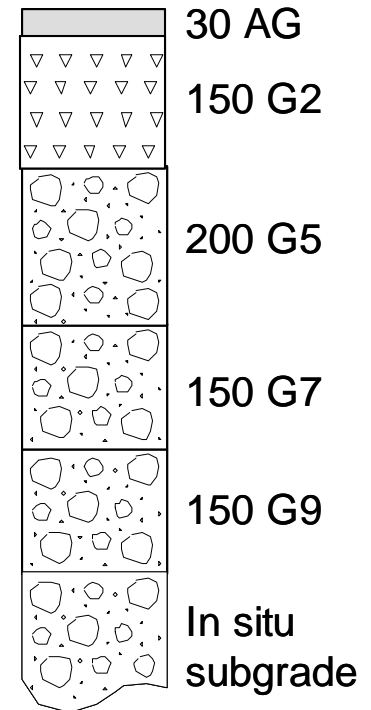
Suction pressure models in SAPDM

Predictive Suction Pressure Model



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



$$P_m^c$$

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

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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

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