THE USE OF RECYCLED AGGREGATES IN UNBOUND ROAD PAVEMENTS

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MY BACKGROUND

- Masters by research – *expansive clays*
- Researcher at CSIRO
  - Expansive clays and footings; tree drying
- Uni South Australia; *wider research interests, e.g.*
  - Impact of suction on clay subgrades
  - Bio-engineering – rail corridors
  - Collapsing soils, e.g. Khon Kaen & South Australia
  - Flexible pipes in sand backfill/ construction traffic (PhD)
  - Finite Element Analysis
  - Thermal conductivity of soil

REFLECTION ON EXPERIENCE

Widening of research interest has been of benefit; elements of some projects invariably find their way into new projects

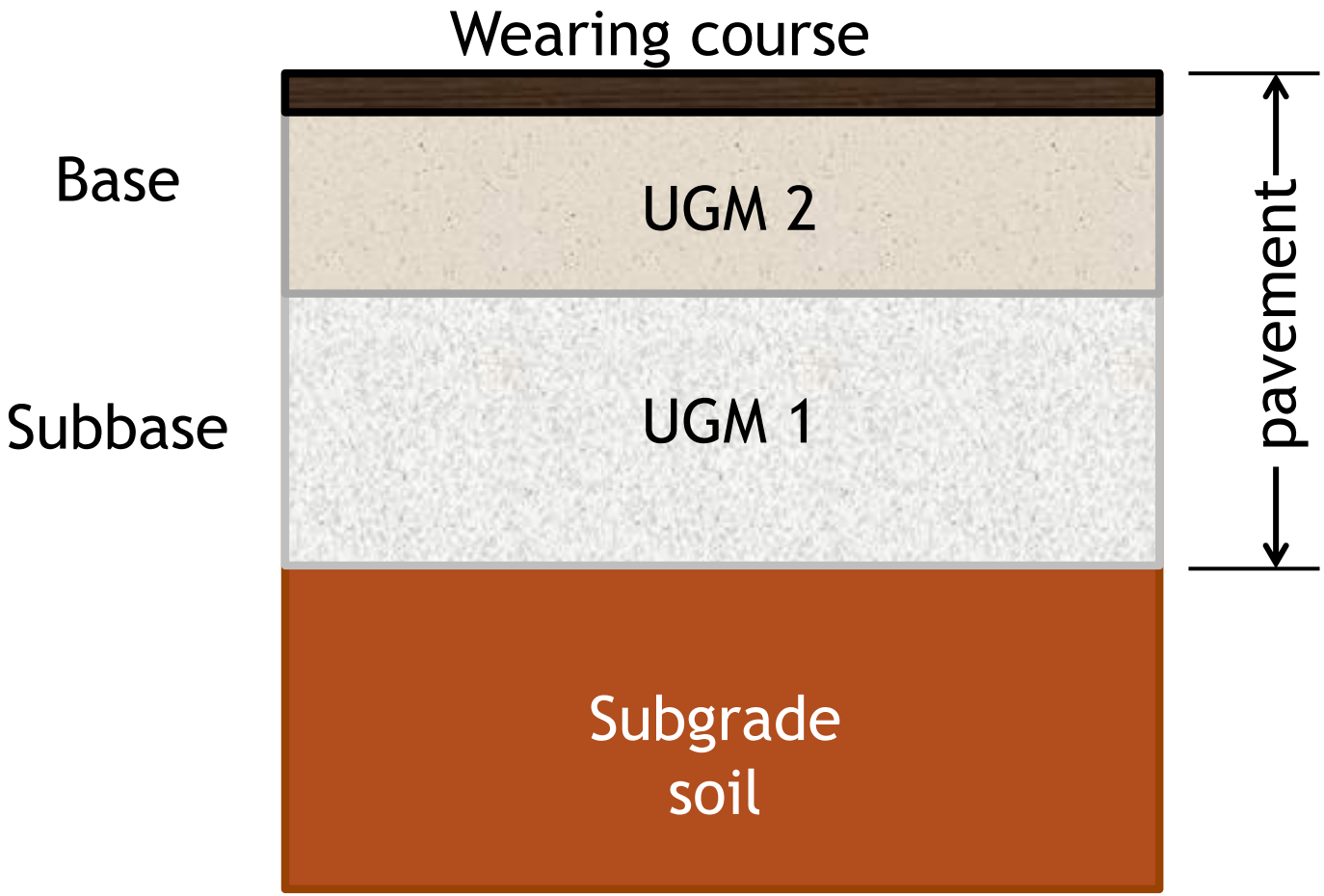
The sustainable aggregate research in this presentation has benefitted from experience with soil suction & finite element analysis

SUSTAINABLE AGGREGATE RESEARCH

SOUTH AUSTRALIAN EXPERIENCE

- Relatively new industry
- Crushed concrete (RCA) & Crushed fired Clay Masonry (RCM)
- 4^{+} years of research into suitability as base or subbase

TERMINOLOGY – FLEXIBLE PAVEMENTS, UNBOUND GRANULAR MATERIAL (UGM)



BACKGROUND

- Dominant aggregate is quartzite in Adelaide
- Landfill cannot afford to take C&D waste
  - can supplement crushed rock supplies
- Use of C&D waste in roads allowed, but specifications are part prescriptive with some performance-based clauses (DPTI 2011)
  - Repeated Load Triaxial Testing (RLTT) for permanent strain (ε_p) and resilient modulus (M_r)

PRIMARY SOURCE MATERIALS

PLANT TO PRODUCE:

RECYCLED CONCRETE AGGREGATE (RCA)

RECYCLED CLAY MASONRY (RCM)

RESEARCH MATERIALS

- **A & B**: 2 RCA base products, nom. 20 mm
- **A20:** RCA with 20% by mass of RCM
- **B10, B20 and B30:** Product B blended with RCM to 10%, 20% and 30%

SOME KEY REQUIREMENTS

NOTE: CLASS 1 = BASE, CLASS 2 = SUBBASE

ITEM	REQUIREMENT	COMMENT
Particle size distribution	Specified max & min values	Can be met
Plasticity of fines - ***Liquid Limit***	Maxm 25% Class 1 Maxm 28% Class 2	**All B** - products **A** - products
LA Abrasion	Maxm 30% Class 1 or 2	

OTHER PROPERTIES

Permeability

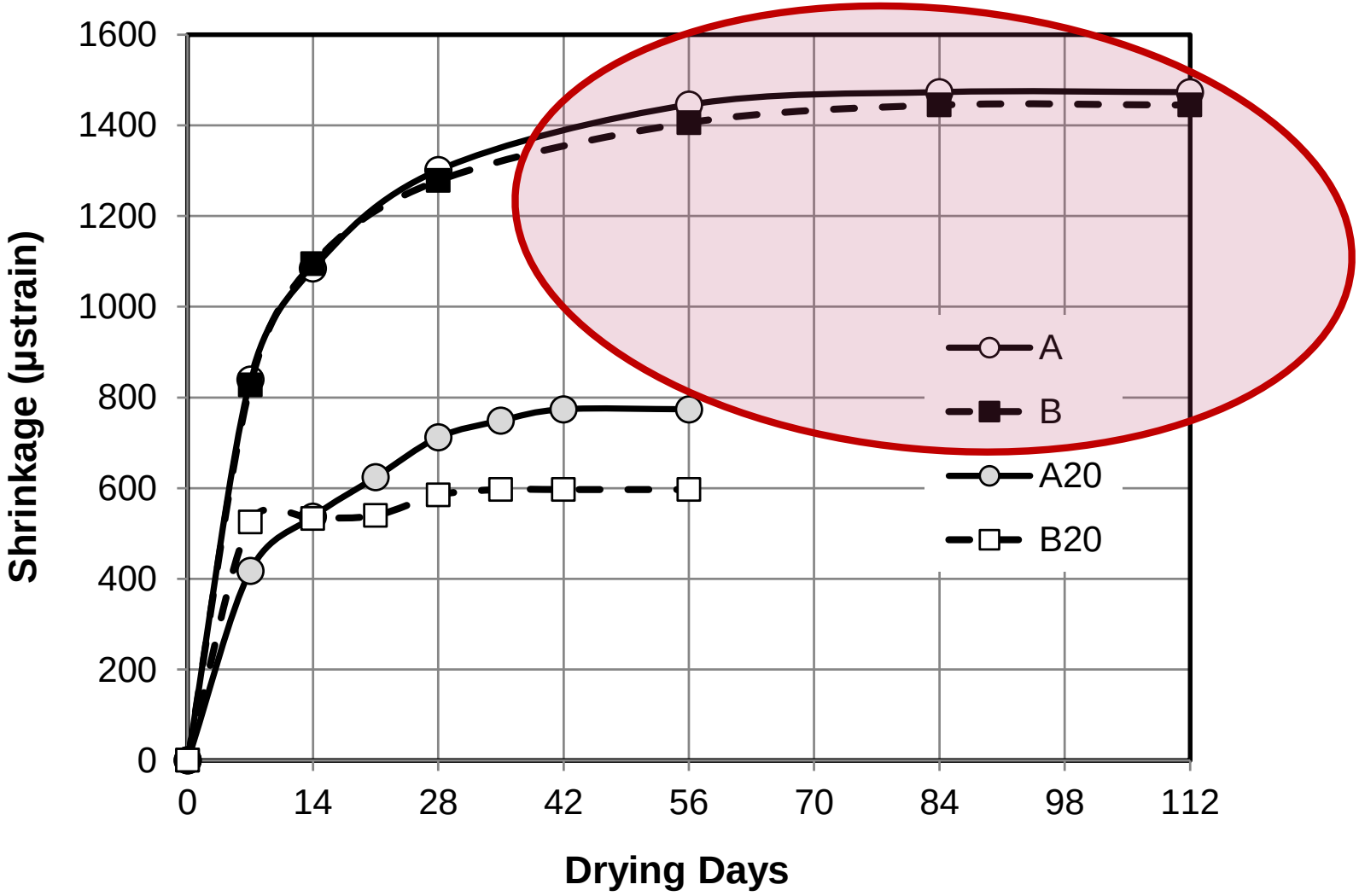
- A20 ten times more permeable
- As moulding moisture content is reduced, permeability increases

Shrinkage

- Cementitious agents remain in RCA
- Some concern about cracking of asphalt

MEASUREMENT OF SHRINKAGE

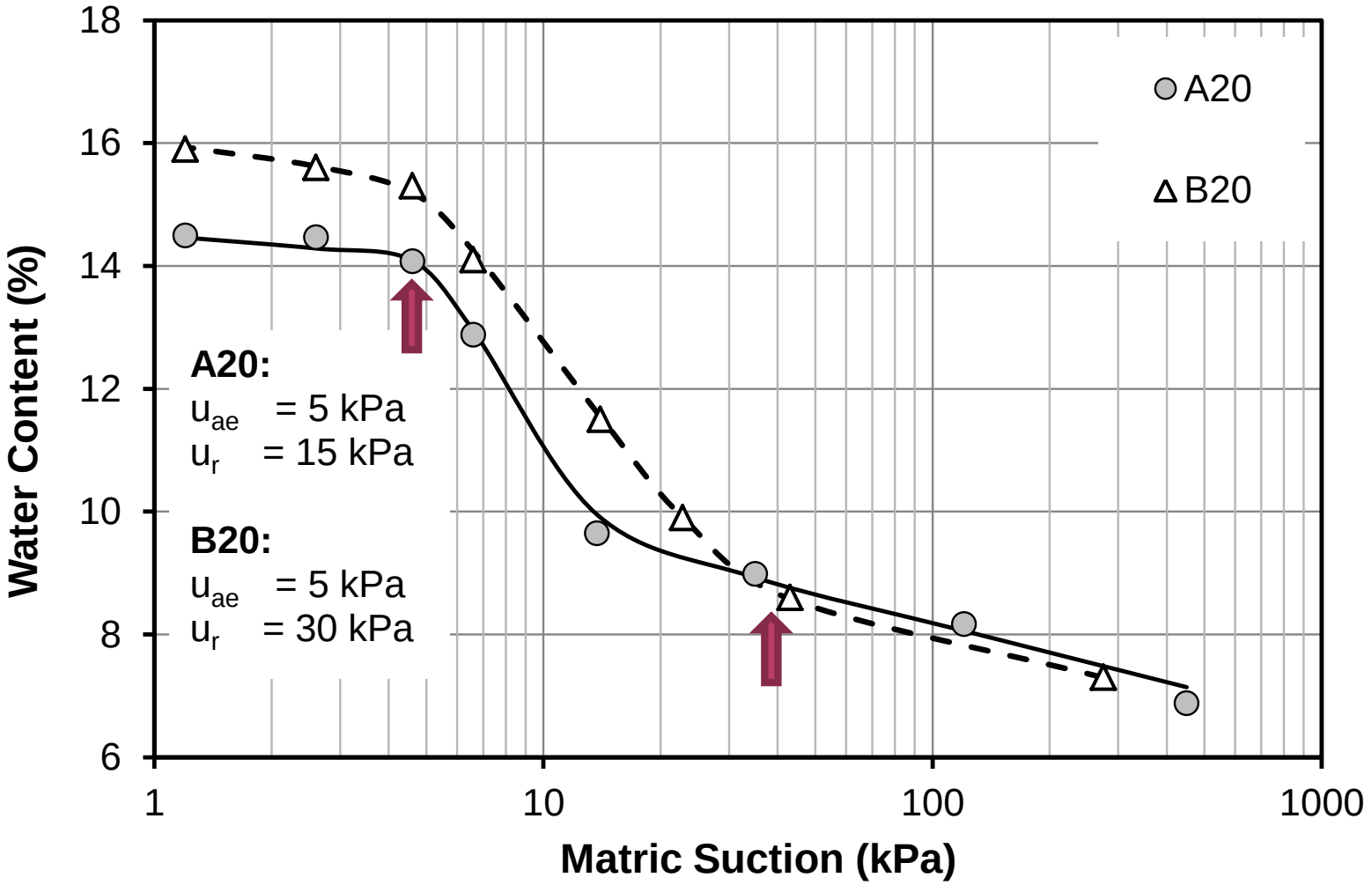
SHRINKAGE CURVES



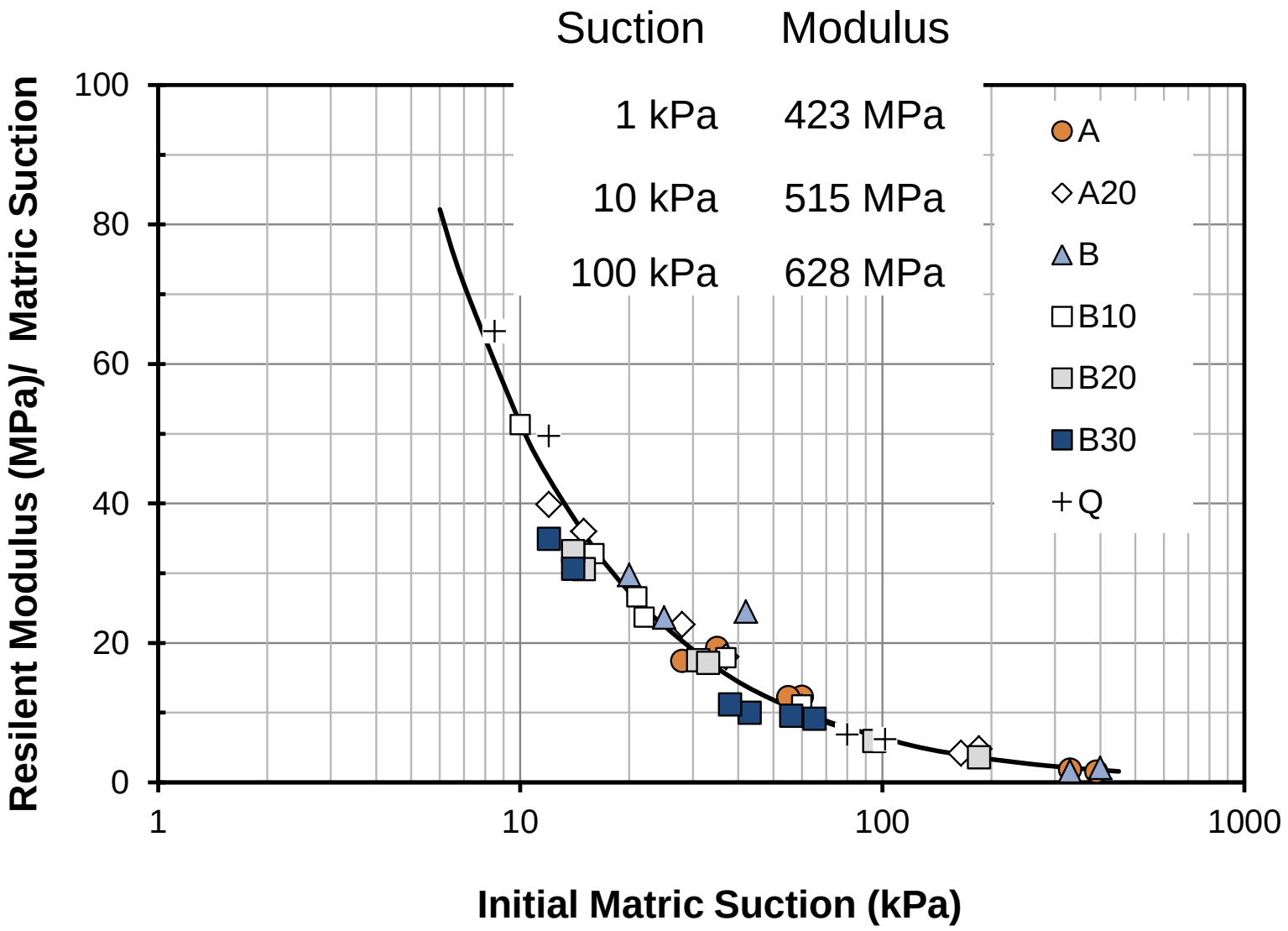
RETENTION OF SOIL WATER

- Important in clays, much less so for sands
- Granular pavement materials are coarse granular materials, with sand & some fines
- Tensile pore water pressure or “suction” developed in soil when partially saturated
- Suction can increase strength & stiffness

SOIL WATER RETENTION CURVES FOR 80:20 RCA:RCM



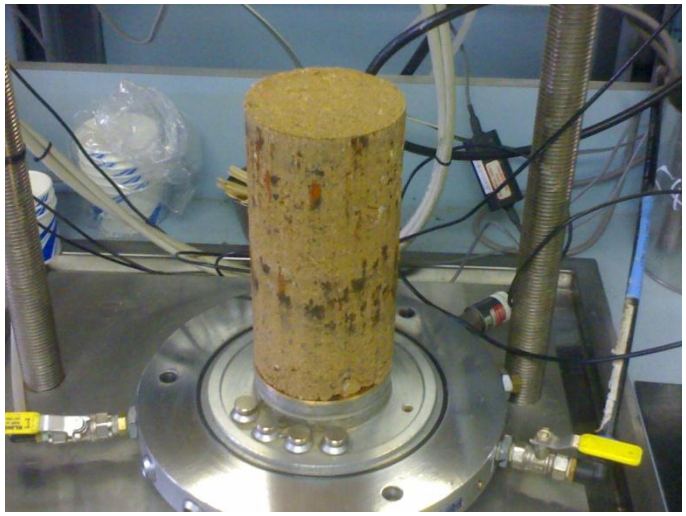
SMALL SUCTIONS … BUT THEY HAVE IMPACT..



SIMPLE RLT TESTING

Single stage procedure

- Constant confining stress of 196 kPa
- Pulsing load of 460 kPa
- 50,000 load pulses



Compacted sample

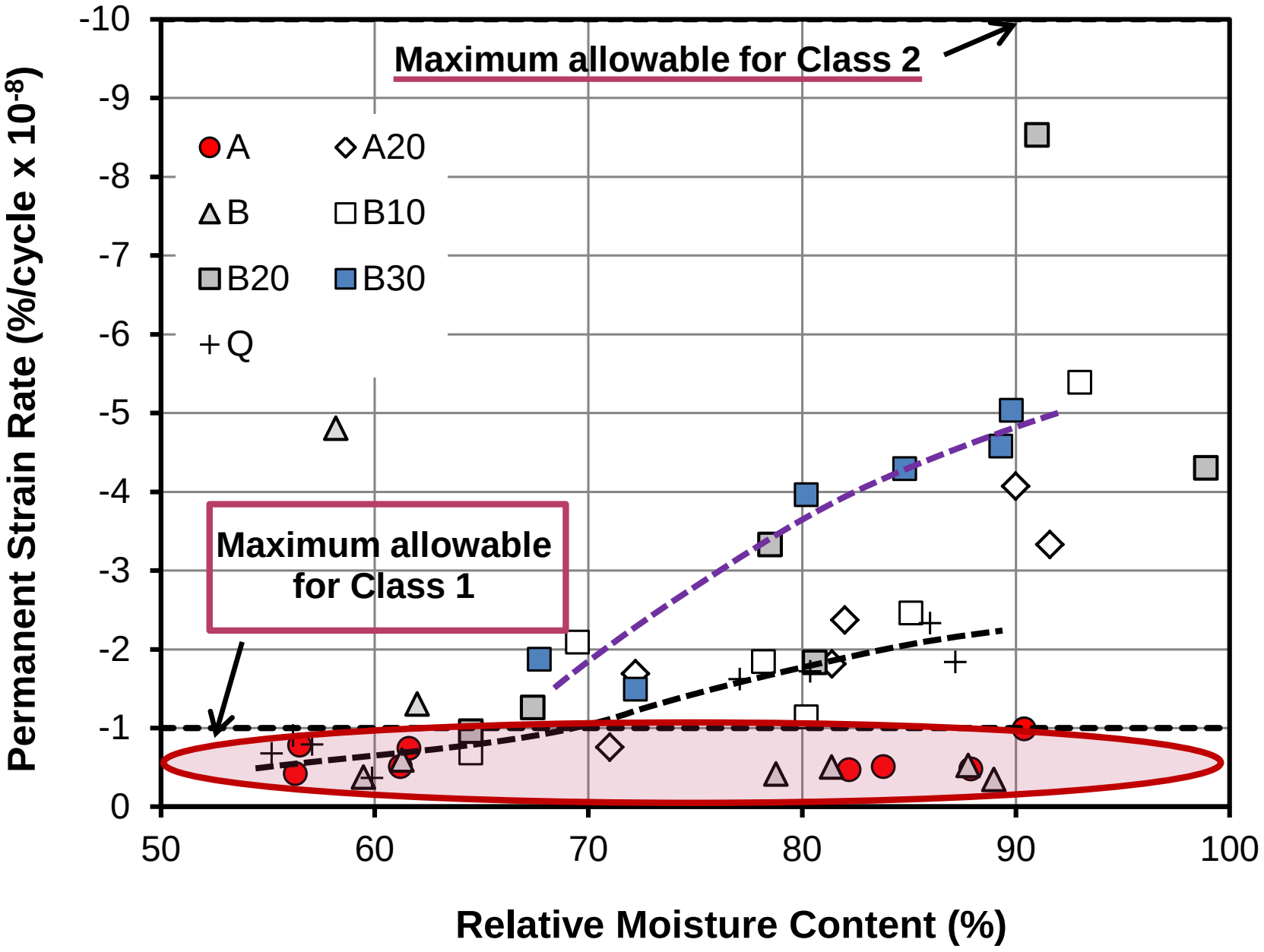
RLT - BASED REQUIREMENTS IN SOUTH AUSTRALIA

- Resilient modulus for bases

  - 300 MPa minimum

  Readily met over usual compaction range

- Permanent strain rate limits over last 30,000 load cycles


Maximum allowable for Class 2
Maximum allowable for Class 1
A
A20
B
B10
B20
B30
Q
Permanent Strain Rate (%/cycle x 10-8)
Relative Moisture Content (%)
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
50
60
70
80
90
100

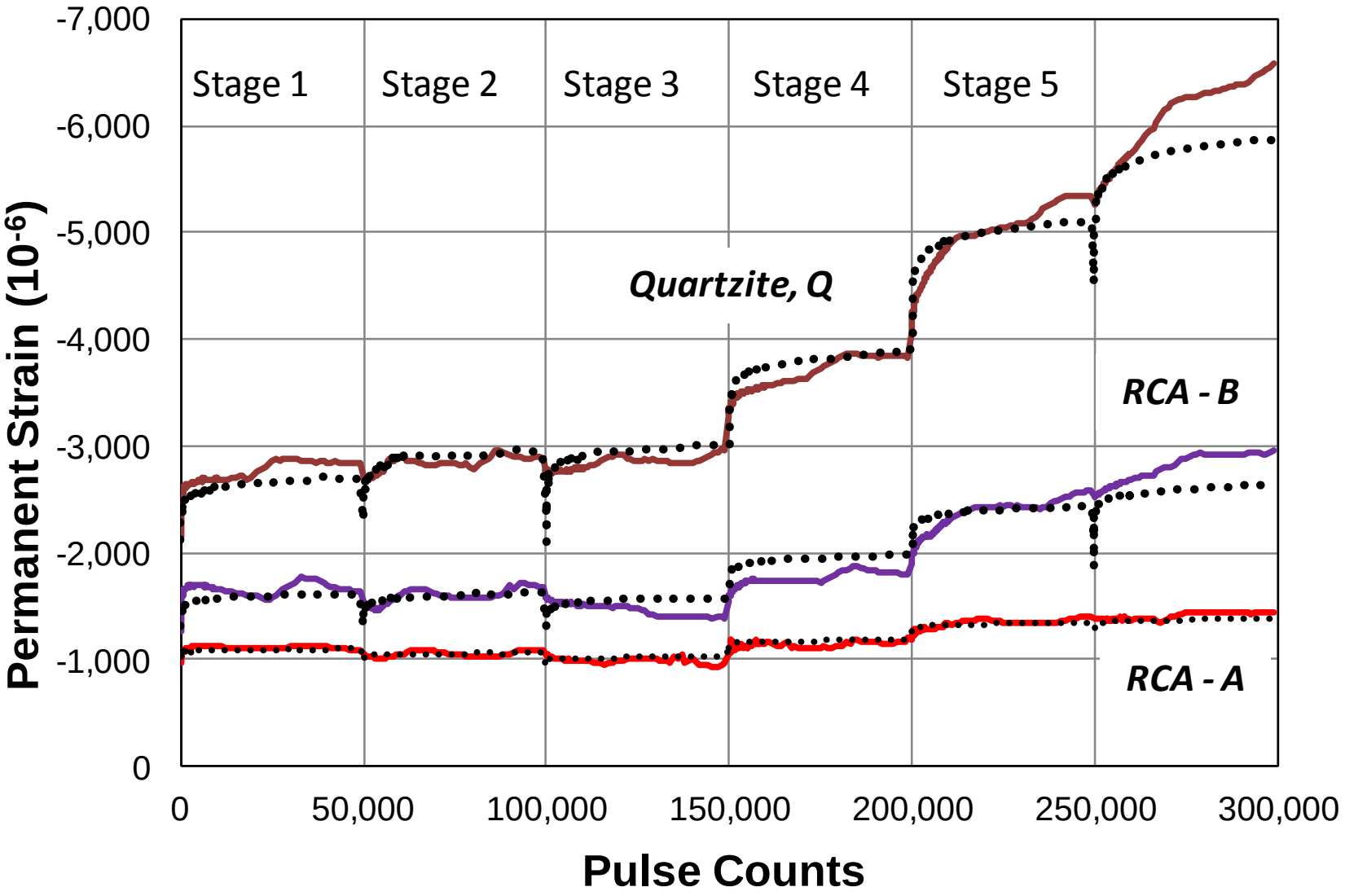
PERMANENT STRAIN RATE ISSUES

- Virgin aggregate (Q) performance dropped to Class 2 for mc $\geq$ 75% OMC
- RCA generally fine for Class 1
- RCA:RCM blends mostly Class 2 performance

EMPIRICAL PREDICTION OF ε_p

- Gabr & Cameron 2012, model from three stage RLTT for A, B and Q
  - moisture content, w & dry density, ρ_d
  - weighted plasticity index, wPI
  - compaction parameters, MDD & OMC
  - mean stress, σ_m
  - shear stress : maxm available strength
  - number of cycles, N
- Single formulation for all 3 materials

PREDICTED ε_p - *FOR MORE STAGES*



CONCLUSIONS

- Performance specifications and prescriptive requirements not well matched
- **A & B**: generally Class 1
  - outperformed Q!
- **A & B**: shrinkage may need to be considered
- **A20, B10, B20 & B30**: Class 2 or subbase

CONTINUING RESEARCH

1. General predictive models with matric suction for both M_r and ε_p
   - stress state changes included for ε_p
2. Pavement design incorporating UGM rutting
   - FEA for initial stress state
   - prediction of ε_p from initial stresses
3. Wheel load testing of pavements

MORE INFORMATION?

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Sustainable Aggregates South Australia website:

http://www.sustainableaggregates.com.au/