Road Construction Materials for Low Volume Roads

David Toll
Durham University, UK
and
National University of Singapore

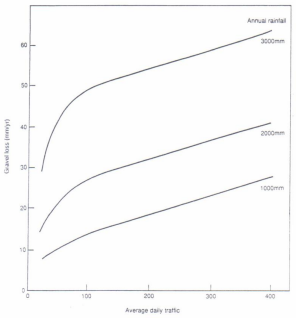
Griffith University
David Toll, February 2007

Low Volume Roads

- Unsurfaced ("gravel") roads
  - Dust
  - Gravel loss
  - Corrugations
- Bituminous surfacing
  - Provides all-weather surface
  - Appropriate specifications
  - Use of local materials
- Unsaturated Soil approach
  - Role of suction
  - Field strengths different to laboratory measurements
  - Unsaturated Permeability
  - Infiltration

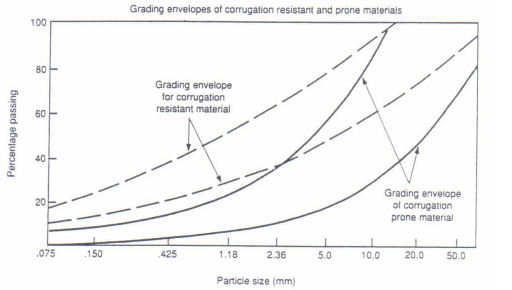
Griffith University
David Toll, February 2007

Gravel Loss



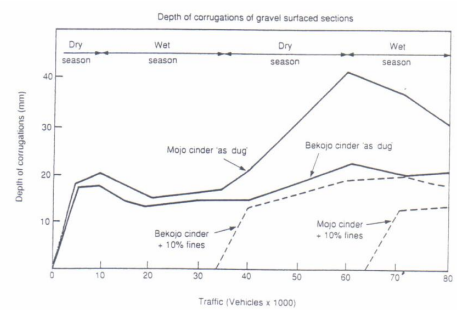
Millard, R.S. (1993) *Road Building in the Tropics*, London:HMSO

Corrugation Resistance



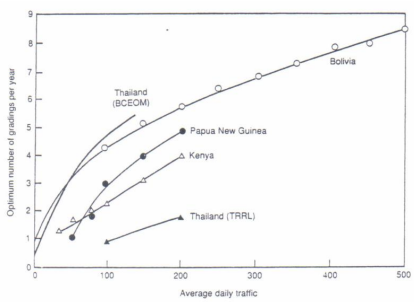
Millard, R.S. (1993) *Road Building in the Tropics*, London:HMSO

Depth of Corrugations

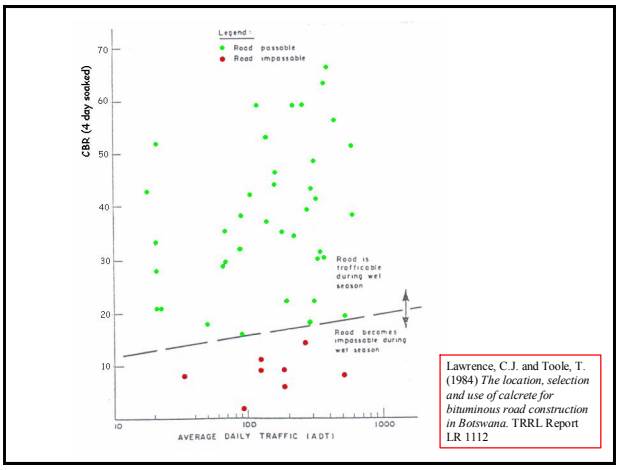


Millard, R.S. (1993) *Road Building in the Tropics*, London:HMSO

Preventing Corrugations

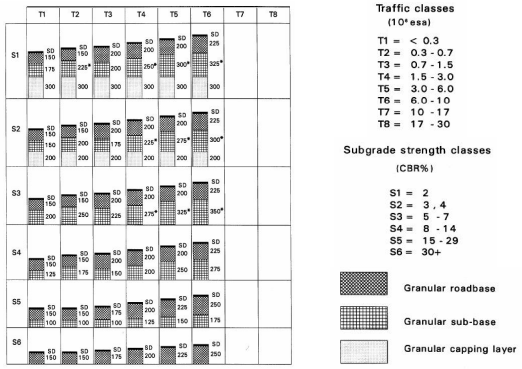


Millard, R.S. (1993) *Road Building in the Tropics*, London:HMSO

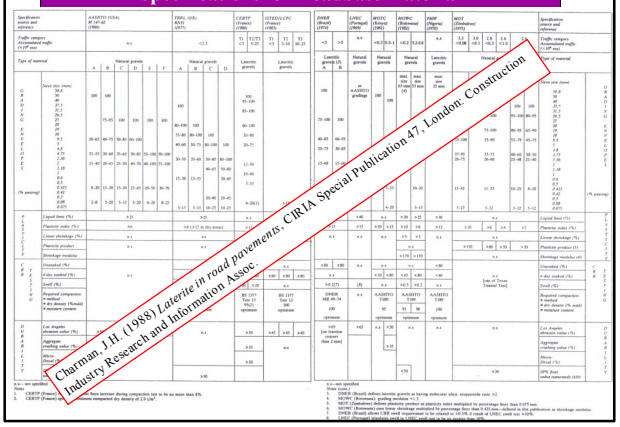


Lawrence, C.J. and Toole, T. (1984) *The location, selection and use of calcrete for bituminous road construction in Botswana.* TRRL Report LR 1112

TRL Overseas Road Note 31



Specifications for Roadbase material



Charman, J.H. (1988) *Laterite in road pavements*, CIRIA Special Publication 47, London: Construction Industry Research and Information Assoc.

Recommended material selection criteria for lateritic gravel sub-bases and road-bases under thin bituminous surfacings in the tropics

Use	Road-base			Sub-base
Type of road	Minor	Major rural and urban		All
Traffic ($\times 10^6$ esa)	<0.3	0.3–1	1–3	<3
Grading	Grading modulus <1.5 (1)	Refer to current specifications in Tables 9 & 10		
Plasticity index (%)				
• Moist, wet tropical	>12	>10	>6	>25
• Seasonal tropical	>15	>12	>10	
• Semi-arid & arid	>20	>15	>12	
Plasticity modulus (2)				
• Moist, wet tropical	>300	>200	>150	>500
• Seasonal tropical	>400	>250	>200	>750
• Semi-arid & arid	>500	>350	>250	>1250
CBR (%)	<45(3)	<65(4)	<80(4)	<25(3)
Durability				
• Los Angeles abrasion value (%) (5)	>65	>50		n.s
• 10% fines value (saturated) (kN)	n.s	<50		n.s

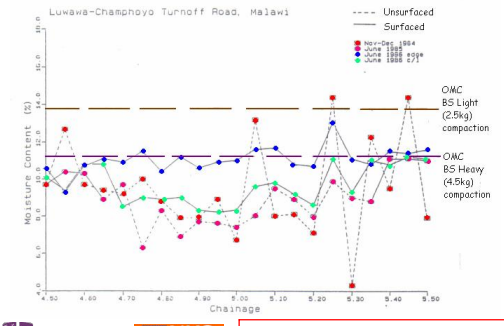
n.s–not specified

Notes

1. Grading modulus $= \frac{300 - (F_1 + F_{150} + F_{75})}{100}$ where F_1 is percentage passing 2 mm sieve, F_{150} is percentage passing 0.425 mm sieve, F_{75} is percentage passing 0.075 mm sieve. Values of grading modulus are between 0 and 3.
2. Plasticity modulus = plasticity index multiplied by percentage finer than 0.425 mm sieve.
3. CBR on samples compacted to 95% m.d.d. of modified AASHTO or BS (heavy) compaction and soaked for 4 days.
4. CBR on samples compacted to 100% m.d.d. of modified AASHTO or BS (heavy) compaction and soaked for 4 days.
5. Los Angeles abrasion value on fraction coarser than 2 or 2.36 mm.

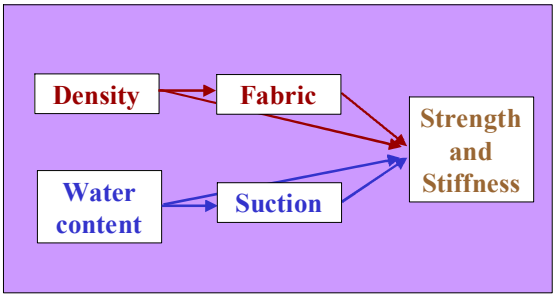
Charman, J.H. (1988) *Laterite in road pavements*, CIRIA Special Publication 47, London: Construction Industry Research and Information Assoc.

Equilibrium Water Content



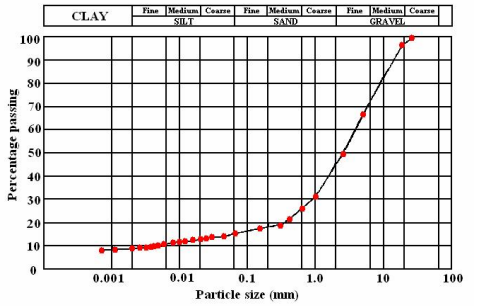
Toll (1988) *The behaviour of unsaturated compacted naturally occurring gravel*, PhD thesis Imperial College, University of London

Road Construction Materials



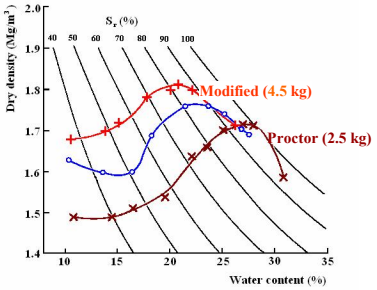
Toll, D.G. (1991) *Towards Understanding the Behaviour of Naturally-Occurring Road Construction Materials*, Geotechnical and Geological Engineering, 9, 3/4, pp 197-217.

Kiunyu Gravel – Particle Size



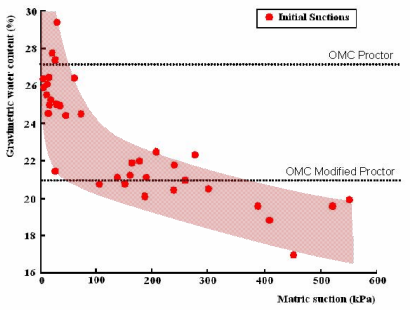
Griffith University
David Toll, February 2007

Kiunyu Gravel - Compaction



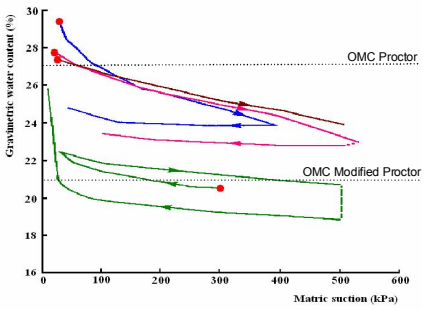
Griffith University
David Toll, February 2007

Initial Suctions in Compacted Samples



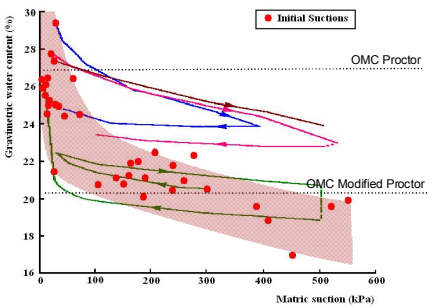
Griffith University
David Toll, February 2007

Soil Water Retention Curves



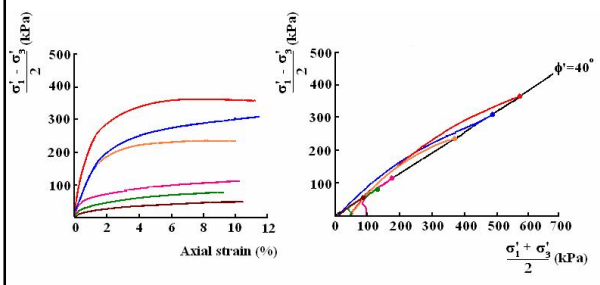
Griffith University
David Toll, February 2007

Suction-Water Content Relationships



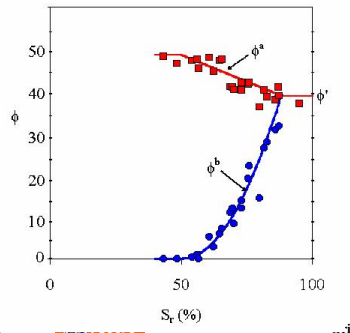
Griffith University
David Toll, February 2007

Saturated Tests



Griffith University
David Toll, February 2007

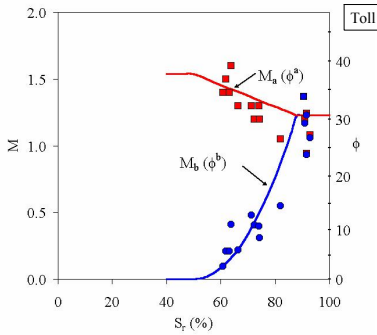
Angles of friction (Kiunyu Gravel)



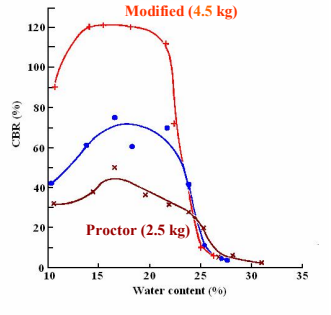
Durham University

Griffith University
David Toll, February 2007

Critical State Stress Ratios (Jurong Soil)



Kiunyu Gravel - CBR

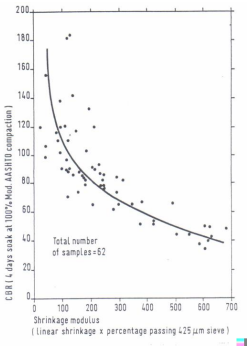


Durham University

NUS

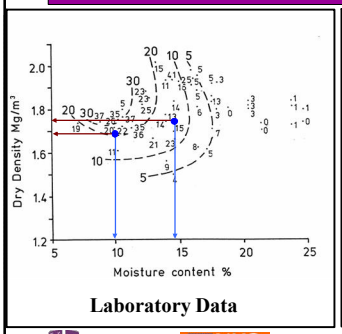
Griffith University
David Toll, February 2007

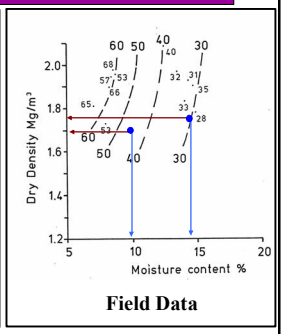
CBR vs Shrinkage modulus



Lawrence, C.J. and Toole, T. (1984) *The location, selection and use of calcrete for bituminous road construction in Botswana.* TRRL Report LR 1112

Clegg Impact Hammer – Kiunyu Gravel



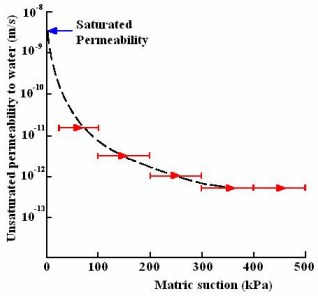


Durham University

NUS

Griffith University
David Toll, February 2007

Unsaturated Permeability – Kiunyu Gravel

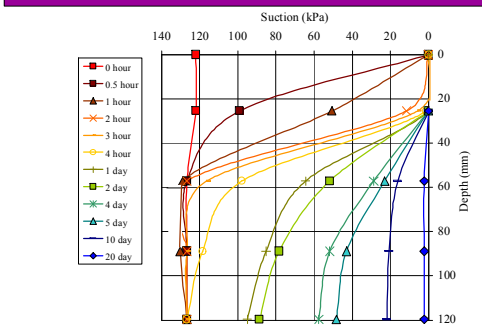


Durham University

NUS

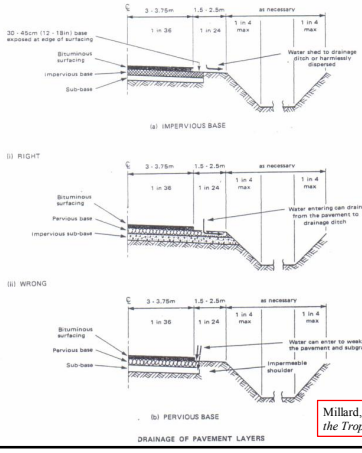
Griffith University
David Toll, February 2007

Infiltration – suction profiles



Durham University NUS

Griffith University
David Toll, February 2007



Millard, R.S. (1993) *Road Building in the Tropics*, London:HMSO

Conclusions (1)

- A non-structural bituminous surfacing ("spray and chip") provides an all-weather road surface. It prevents dusting, gravel loss and corrugations.
- There is a tendency to apply a higher standard of specification to bituminous surfaced roads than to unsurfaced "gravel" roads. This often eliminates naturally occurring gravels from being used.
- Naturally occurring gravels generally have greater quantities of fines than traditional crushed rock aggregates, and the fines are more plastic. This means that soil suction and fabric are major factors controlling their behaviour. Therefore, their behaviour is more complex and more difficult to predict.
- Trials using "non-standard" lateritic gravels that do not fit specifications have proved successful in Kenya and Malawi where they have performed better than traditional crushed stone.
- A good material for a road base in a sub-tropical or tropical climate will have sufficient fines to allow significant suctions to develop and also produce low permeability. Suctions can be significant in natural gravels, even those with small amounts of clay (<10%). This small amount of clay can be beneficial.

Durham University NUS

Griffith University
David Toll, February 2007

Conclusions (2)

- The fines content should not be so great as to suppress the dilatent tendency of the granular fraction or to significantly reduce the angle of friction. Also, any clay present should have low activity in order to restrict shrinkage and swelling.
- The fines should be well distributed throughout the fabric if they are to support high suctions and provide a strong binder, holding the granular fraction together. This also contributes to low permeability.
- There can be a significant range of possible suctions at any water content, so water content alone is not a good indicator of behaviour. Strengths in the field can be twice those measured in the laboratory at the same density and water content, because of differences in suction
- Permeabilities can be low even for predominantly granular materials. The unsaturated permeabilities are even lower. However, changes in suction due to infiltration can still be noticeable because of the small water content changes needed
- Natural gravels can perform better than crushed stone construction. The clay content can be an advantage as it allows suction to contribute to strength and reduces infiltration.

Durham University NUS

Griffith University
David Toll, February 2007