Why has it Turned out Different?

"The Ingredients are all the Same?!"

ALLEN BROWNE
Hiway Group Technical Manager

Overview

Typical Laboratory Mix Design Approach
Typical Pavement Design Parameters
Typical Stabi Products for Pavement Layers
Observations of Constructed Layer Properties
Key Differences
Lessons Learnt
Solution Going Forward?

Typical Laboratory Stabi Mix Design Approach

- Representative sample
- Various binder types depending on material, position in pavement, layer requirement / design philosophy
- NZTA T/19 Mix Design protocol
- NZTA / Austroads Pav. Design
- NZTA B/5 Construction spec

Documents


NZ TRANSPORT AGENCY
WAKA KOTAHI
Characterisation and use of stabilised basecourse materials in transportation projects in New Zealand
December 2011
NZ Transport Agency research report 461
NZ TRANSPORT AGENCY
WAKA KOTAHI
Pavement and Rehabilitati
Design Workshop
Best practice guide for pavement stabilisation
August 2017
W Gray
Opus International Consultants Limited
ansport Agency research report 622
icted research organisation – Opus International Consultants Limited
Austroads
GUIDE TO PAVEMENT TECHNOLOGY
Part 4D: Stabilised Materials
Austroads
New Zealand guide to pavement evaluation and treatment design
Martin Gribble
12/4/2018
VERSION 1.1
NZ TRANSPORT AGENCY
New Zealand guide to pavement structural design
Martin Gribble
12 April 2018
VERSION 1.1
NZ TRANSPORT AGENCY
New Zealand Government
Allens Copy
Pls Return
PAVEMENT RECYCLING AND STABILISATION GUIDE
2015 2ND EDITION
AustStab
TESTING SMARTER NOT HARDER:
THE NEXT GENERATION
Auckland | 8th - 10th August 2018
CETANZ

Unbound, Modified or Bound?

- Unbound – no tensile capacity
- Modified - no significant tensile capacity – i.e. small quantity of lime or cement for plasticity mitigation
- Lightly Bound – cementitious binders usually ≤2% - not strong enough to propagate cracking.
- Bound – cementitious binders usually ≥ 4% - not favoured for basecourse due to thermal shrinkage (block) and fatigue crack risk. Common for subbase layers as excellent load transfer
  - ***Requires approval for BC from NZTA Pavements team***
- Same material can achieve **all four** - all about the quantity of binder

2 – 4% cementitious binder notably excluded

Typical Stabi Products for Pavement Layers

Table 3.1: Types of stabilisation

Category of stabilisation	Indicative laboratory strength after stabilisation	Common binders adopted	Anticipated performance attributes
Subgrade	CBR[1] > 5% (subgrades and formations)	▪ Addition of lime ▪ Addition of chemical binder	▪ Improved subgrade stiffness ▪ Improved shear strength ▪ Reduced heave and shrinkage
Granular	40% < CBR[1] < +100% (subbase and basecourse)	▪ Blending other granular materials which are classified as binders in the context of this Guide	▪ Improved pavement stiffness ▪ Improved shear strength ▪ Improved resistance to aggregate breakdown
Modified	0.7 MPa < UCS[2] < 1.5 MPa (basecourse)	▪ Addition of small quantities of cementitious binder ▪ Addition of lime ▪ Addition of chemical binder	▪ Improved pavement stiffness ▪ Improved shear strength ▪ Reduced moisture sensitivity, i.e. loss of strength due to increasing moisture content ▪ At low binder contents can be subject to erosion where cracking is present
Bound	UCS[2] > 1.5 MPa (basecourse)	▪ Addition of greater quantities of cementitious binder ▪ Addition of a combination of cementitious and bituminous binders	▪ Increased pavement stiffness to provide tensile resistance ▪ Some binders introduce transverse shrinkage cracking ▪ At low binder contents can be subject to erosion where cracking is present

Notes:

1. Four day soaked CBR.
2. Values determined from test specimens stabilised with GP cement and prepared using Standard compactive effort, normal curing for a minimum 28 days and 4 hour soak conditioning.

Austroads Guide to Pavement Technology Part 4D: Stabi Materials

Typical Stabi Products for Pavement Layers

TABLE 3.2 GUIDE TO SELECTING A METHOD AND TYPE OF STABILISATION BINDER

PARTICLE SIZE	MORE THAN 25% PASSING 0.425 mm			LESS THAN 25% PASSING 0.425 mm		
PLASTICITY INDEX	PI≤10	10<PI<20	PI≥20	PI≤6 WPI≤60	PI≤10	PI>10
BINDER TYPE						
Cement and cementitious blends*	Usually suitable	Doubtful or supplementary binder required / Requires lime as a pre-treatment	Usually not suitable / Requires lime as a pre-treatment	Usually suitable	Usually suitable	Usually suitable
Lime	Doubtful or supplementary binder required	Usually suitable	Usually suitable	Usually not suitable	Doubtful or supplementary binder required	Usually suitable
Bitumen	Doubtful or supplementary binder required	Doubtful or supplementary binder required	Usually not suitable	Usually suitable	Usually suitable	Doubtful or supplementary binder required
Bitumen/ cement blends	Usually suitable	Doubtful or supplementary binder required	Usually not suitable	Usually suitable	Usually suitable	Doubtful or supplementary binder required / Requires lime as a pre-treatment
Granular	Usually suitable	Doubtful or supplementary binder required / Requires lime as a pre-treatment	Usually not suitable / Requires lime as a pre-treatment	Usually suitable	Usually suitable	Doubtful or supplementary binder required / Requires lime as a pre-treatment
Dry Powdered Polymers	Usually suitable	Usually suitable	Usually not suitable / Requires lime as a pre-treatment	Usually suitable	Usually suitable	Usually not suitable
Miscellaneous Chemicals**	Usually not suitable	Usually suitable	Usually suitable			

KEY: Usually suitable; Doubtful or supplementary binder required; Usually not suitable; Requires lime as a pre-treatment

* The use of some chemical binders as a supplementary addition can extend the effectiveness of

** Should be taken as a broad guideline only. Refer to trade literature for further information.

Australia Treatment Selection: Austroads / AustStab

Table 3.4 Guide to selecting common stabilisation binder types in New Zealand

Characteristic pavement material particle size		Fine grained pavement material > 25% passing 0.425 mm sieve			Coarse grained pavement material <25% passing 0.425mm sieve		
Plasticity index (PI)		PI<=10	10<PI<20	PI>=20	PI<=6	PI<=10	PI>10
Binder type	Cement and cementitious blends*	Usually suitable	Doubtful or supplementary binder required: Lime pre-treatment desirable	Doubtful or supplementary binder required: Lime pre-treatment essential	Usually suitable	Usually suitable	Doubtful or supplementary binder required: Lime pre-treatment desirable
	Lime as hydrated or burnt lime (CaO)	Doubtful or supplementary binder required: Additional drying action with CaO	Usually suitable: Additional drying action with CaO	Usually suitable: Additional drying action with CaO	Usually suitable: Additional drying action with CaO	Usually suitable: Additional drying action with CaO	Usually suitable: Additional drying action with CaO
	Hot bitumen	Doubtful or supplementary binder required	Usually not suitable	Usually not suitable	Usually suitable	Usually suitable	Doubtful or supplementary binder required
	Bitumen emulsion**	Doubtful or supplementary binder required	Doubtful or supplementary binder required	Usually not suitable	Usually suitable	Usually suitable	Doubtful or supplementary binder required
	Foamed bitumen**	Usually suitable	Doubtful or supplementary binder required: Lime pre-treatment desirable	Usually not suitable: Lime pre-treatment essential	Usually suitable	Usually suitable	Doubtful or supplementary binder required: Lime pre-treatment
	Granular	Doubtful or supplementary binder required	Doubtful or supplementary binder required: Lime pre-treatment desirable	Usually not suitable: Lime pre-treatment essential	Usually suitable	Doubtful or supplementary binder required: Lime pre-treatment desirable	Doubtful or supplementary binder required: Lime pre-treatment desirable
	Polymer***	Usually suitable	Doubtful or supplementary binder required	Doubtful or supplementary binder required	Doubtful or supplementary binder required	Doubtful or supplementary binder required	Usually suitable

KEY

Usually suitable

Doubtful or supplementary binder required

Usually not suitable

Notes: * Includes fly ash ** Bitumen emulsion and foamed bitumen can be used with other binders (typically small qualities of cement) *** Includes proprietary polymer materials used as dust suppression and finer soil particle modifier

NZ Treatment Selection: Best Practice Guide for Pavement Stab. Aug 2017 W Gray

SUITABILITY FOR STABILISATION - PROJECT

Selection discussed on previous slides, but also need consideration of:

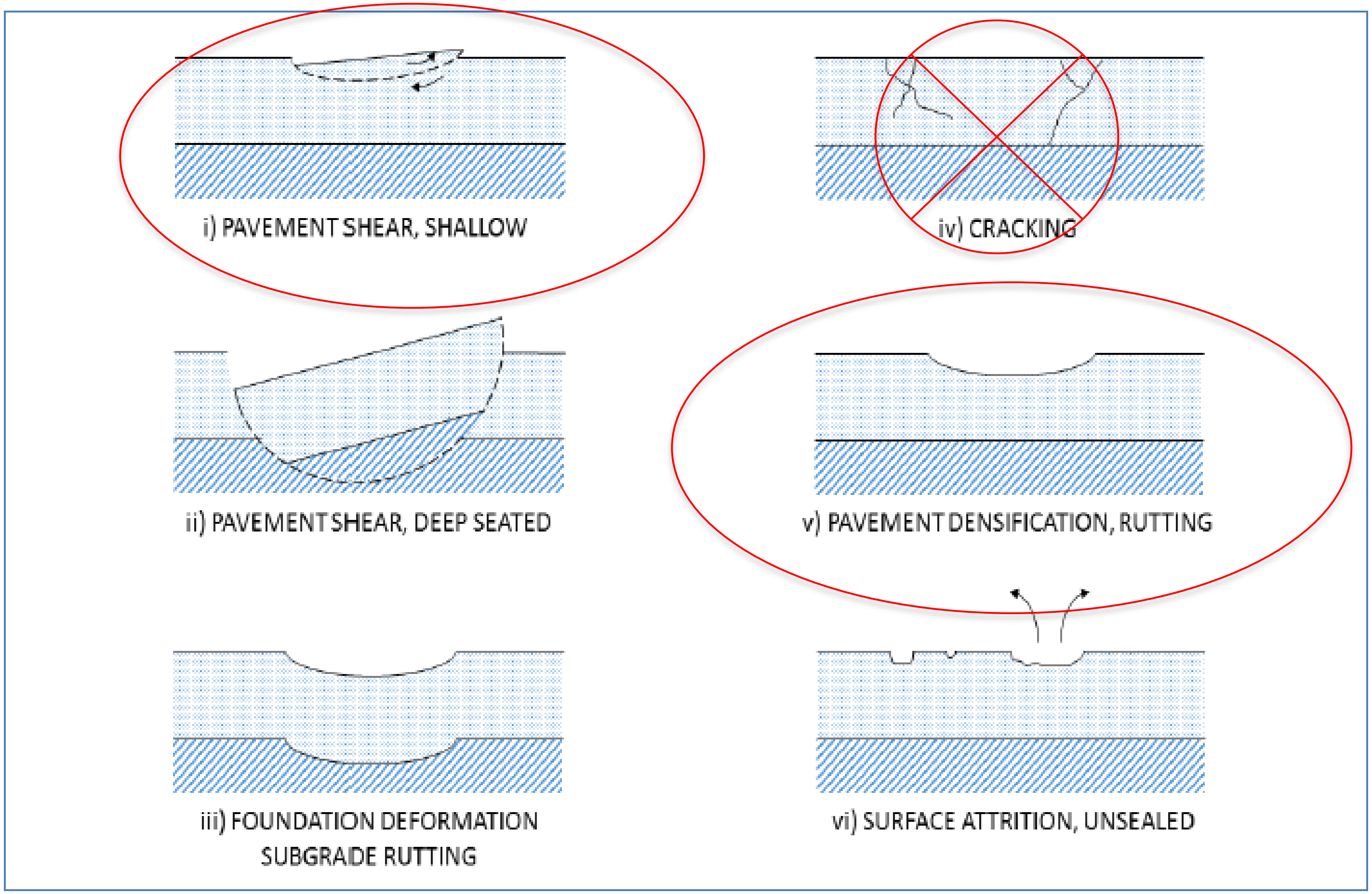
- Level constraints relative to existing pavement – kerb and channel? Geometric improvements?
- Ability to overlay – urban vs. rural (localised digouts?)
- Presence of services within treatment zone
- Sensitivity of services/structures to construction / compaction
- Time of year for construction
- Traffic loading
- ***Traffic management through construction***
- What is the failure mode? Will proposed treatment remedy?

Constructed Stabi Basecourse Stiffness

- Common to seek benchmark stiffness and focus often on minimum or threshold strength.
- Important to understand stiffness ‘bands’ – not just minimum stiffness – but maximum also.
- Inadequate stiffness – rutting, shallow shear, layer deformation
- Excessive stiffness – block cracking

Modified / Lightly Bound Basecourse Seeks to Eliminate:

Figure 3.1 Pavement defects



Source: National Roads Board (1987)

Not just minimum qualifying stiffness – also MAX – or risk cracking

Typical Properties for Unbound, Lightly Bound and Bound

Table 4.1 Typical properties using cement stabilisation

Material	Design thickness (mm)	Cement content (% of dry mass)	Strength[2] (MPa)	Resilient modulus (MPa)
Unbound (modified)	Varies	< 1%, depending on plasticity in treated material	UCS < 1MPa ITS < 200kPa	< 1,000MPa
Lightly bound	200mm to 300mm	1% to 2%	1MPa < UCS < 2MPa ITS < 600kPa	≤2,000MPa
Bound	> 300mm, built in two layers	> 2%	UCS > 2MPa ITS > 600kPa	3,500 to 15,000MPa

Are we happy that a small change in ITS provides lightly bound or bound and avoids the 2,000 to 3,500MPa "Grey area"?

[2] Sample compaction to NZ Standard NZS 4402 (test 4.1.1)

Thanks to W Gray – NZTA RR 622 - Best Practice Guide for Pavement Stabilisation April 2017

NZTA Research Report 498 – The Design of Stabilised Pavements in New Zealand

KEY FINDINGS Test 2 Conclusions (Test Track Outcomes)

- RLT testing does not distinguish well for cement contents over 1%
- Transition from modified to bound difficult to determine, and suggests ITS of 600kPa is sensible mix design limit to prevent bound behaviour.
- The report recommends that 2% cement is a reasonable limit to prevent bound performance and risk of fatigue type cracking
- Good correlation between laboratory mixed and field mixed UCS values – however the field results were ~80% of the laboratory values
- Good correlation between laboratory mixed and field mixed ITS values – however the field results were ~70% of the laboratory values.
- Without exception the stabilised sections performed better than the unbound control section.
- Pre-cracking of cement bound basecourse did not 'heal' and the 4% cement behaved in a similar manner to 1% cement 'uncracked'.
- Basecourse modulus from initial FWD testing showed a good relationship with load carrying capacity of the pavement

Note – CAPTIF Research facility permits curing prior to activating loading

NZ Guide to Pavement Evaluation & Treatment Design V1.1 Apr 2018 - (NZTA Rehab Guide)

In situ Stabi (modified) with overlay hoed in: UCS < 1 MPa

	Cause of Pavement Distress					
Treatment	**Subgrade Rutting**	**Aggregate Rutting A (poor when dry)[1]**	**Aggregate Rutting B (good when dry)[1]**	**Aggregate Rutting C (poor when wet)**	**Construction Risk**	**Maintenance risk**
In situ* Stabilisation (Modified) – with inclusion of an overlay hoed in (Low Binder content generate a UCS < 1 MPa) (Design traffic 15 MESA) – *(note that the overlay material may change the aggregate rutting to good performance)	Low Risk *(increase pavement depth designed specifically to protect subgrade). Stabilised overlay reduces risk further compared with an unbound overlay.*	High Risk (*light modification only tidies up fines and improves wet rut resistance, dry rut resistance relies on stone on stone contact which is poor). This assumes the mixture of overlay and existing aggregate has been assessed as still showing poor performance.*	Low Risk (*light modification only tidies up fines and improves wet rut resistance, dry rut resistance relies on stone on stone contact which is good*)	Medium Risk *(the increase in pavement depth will give added protection for the weak subbase). Ideally overlay needs to be designed to protect the subbase.*		Risk of shrinkage and block cracking depending on interaction between chemical modifier used, aggregate(s), surfacing included and water content added during process.

Pavement rehabilitation treatment type	When this treatment would be considered	Design method and assumptions
3. Modified Treatment - *In situ* stabilisation designed specifically to result in a modified material where the binder is used to tidy up the fines to ensure adequate rut resistance should the pavement become wet. An overlay of aggregate can also be added. The overlay is usually large good quality crushed rock hoed in during the stabilisation process to improve the grading of the finished base layer for better rut resistance.	This treatment is needed where the existing aggregate is good quality in terms of good rut resistance when dry (i.e. good grading and properties similar to NZTA M4 Basecourse Specification). The rut resistance is reliant on the stone-on-stone contact rather than the cement bonds. The binder (e.g. cement, lime or bitumen) purpose is to tidy up the fines to prevent failure when wet. *Note: the key for this treatment's success is the in situ aggregate must have a good grading and rut resistance that can be estimated using the RLT apparatus. If needed the source aggregate quality can be improved by top-up aggregate. The ITS of the stabilised mix is then used to multiply the life of the source aggregate found by RLT testing (NZTA T/15).*	Mechanistic design method using CIRCLY with unbound pavement design assumptions to check the total pavement depth. In addition, the stabilised base mix rutting life is checked. To check, use the rutting life of the unbound source aggregate multiplied by a factor dependent on the ITS value of the stabilised mix. An example is *in situ* stabilisation using foamed bitumen or low cement content. (*See Sections 7.7 and 7.9 respectively)*

Table 8 - NZ Guide to Pavement Evaluation & Treatment Design V1.1 Apr 2018

NZTA Research Report 498 – The Design of Stabilised Pavements in New Zealand

Understand the continuum from unbound (no binder), modified (small amounts of binder) to bound (high amounts of binder) behaviour.

- Bound behaviour clearly occurred at 3-4% cement contents.
- At 3% cement contents in the field, classical fatigue failures were observed.
- At CAPTIF 4% cement showed little rutting but significant losses of stiffness and stiffness tended to a value observed at 1% cement.
- Prudent limit for at 2% cement contents, (a soaked ITS over 600KPa when mixed and tested in the lab).

NZTA RR 498

Ideal ITS for Cement Modification

11.6.3 Cement modification of basecourse

The suitability for the cement modification of the basecourse material in the existing carriageway and the proposed imported M/4 basecourse material should be confirmed prior to construction through laboratory testing. Cement modification of the basecourse shall be enough to ensure that the ITS shall not exceed 400 kPa. The level of modification shall be tested by the contractor prior to construction, to ensure strength in the required range can obtained, while excessive strength gains, with increased risk of block cracking, are not realised.

Representative samples of the materials to be included in the stabilised layer shall be tested according to NZS 4402: test 4.1.3 to determine the optimum water content and the likely maximum dry density target. In addition, the solid density of the representative stabilised material shall be determined according to NZS 4407: test 3.7.1.

Testing certificates shall be provided to the Engineer prior to construction confirming: the basecourse material satisfies the above strength characteristics; the optimum water content; the maximum dry density; and the solid density.

NZ Guide to Pavement Evaluation & Treatment Design V1.1 Apr 2018

Lab ITS to Field ITS?

- Whether 600kPa or 400kPa ***maximum*** desired ITS for mix design – what if the laboratory ITS is substantially greater than the achieved field ITS?
- What is the appropriate design to field correction factor?
- If binder dosage determined from lab testing with no field correction what is risk of inadequate stiffness?
- RLT test on natural material intended to indicate rut resistance adequate. Not so helpful for cement treated

Contributors to Lab Vs Field Difference

Commonly understood drivers towards Stabilisation "Failure":

- Lack of support of stabilised base – weak subgrade, poor modular ratio. Compromise density and corresponding layer strength. Stiffness deteriorates quickly
- Inadequate thickness stabilised layer
- Material unsuitable for stabilisation due to variability, poor grading, weak strength experiencing breakdown, moisture high plasticity
- Poor construction quality control, inadequate binder placed
- Poor construction plant
- Excess binder causing bound condition

Contributors to Lab Vs Field Difference

Less Commonly Considered Impact on Achieved Stiffness

- A phenomenon experienced in insitu modified/lightly bound stabi in non-greenfields site is:
- ***Reduced stiffness achieved in field from Lab mix design when all factors are controlled and meet best practice / stringent control.***

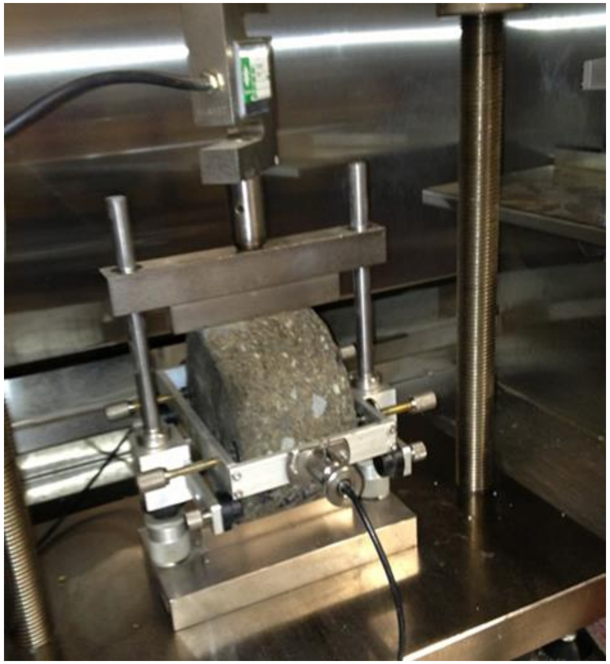
- Theory…….
- Lab procedure – Compact then bench/oven/water bath curing. **Curing under static conditions – no loading**
- Field procedure – compact then load (unless greenfields)
- Live road stabilisation requires traffic loading soon after construction complete. **Curing under Dynamic loading**.
- Stiffer overall structure and better the basecourse properties – < flexing magnitude and < potential impact

We don't load a cement bound layer until sufficiently cured

Contributors to Lab Vs Field Difference

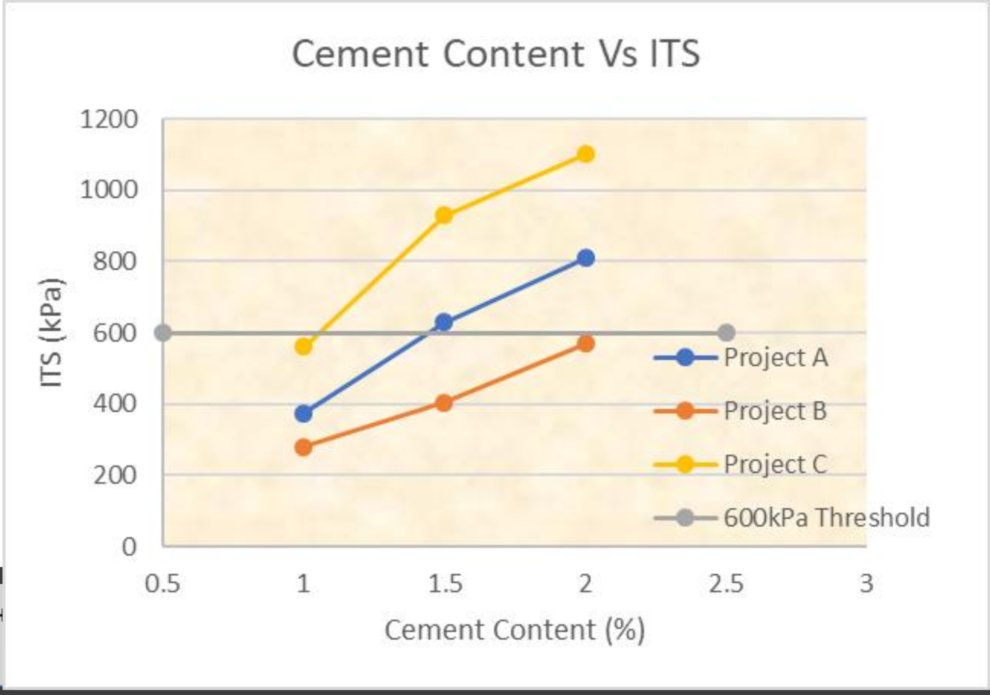
Less Commonly Considered Impact on Achieved Stiffness

- There have been a number of laboratory T/19 (or prev procedures) mix designs where small binder additives have generated huge stiffness
  - For example 1% cement generating ~ 600kPa
  - Several years ago application rates reduced correspondingly – and poor rut/ shear resistance occurred
  - Post construction FWD similarly indicated basecourse modulus less than desired
- Problem = bulk field samples compacted < 2 hours also provide good outcome [*field compaction far sooner with less risk of hydration / binder consumption*]
- Clegg Hammer used as preseal strength indicator
- No easy sampling method for modified/lightly bound (Air coring improving outcome - but when best time to core?)



Challenges of Static Lab versus Dynamic Field Curing

- Lab procedures are intended to provide controlled testing environment - relativistic
- Results are not absolute – rely upon calibration of lab versus field. Insitu testing – sampling and lab testing
- Do we require a “construction factor” or recognition of a stiffness reduction where dynamic loading through early cure where looking for lightly bound outcome.
- Is it common for mix designs to receive a 0.25% / 0.5% construction adjustment ?
    - Or Zero??



Early Loading "Factor" vs Construction Tolerance

Construction tolerance – 0% to 0.25% additional dosage lab to field .
comprising application spread / materials variability / moisture control/various constraints. Consider appropriate for greenfields sites or extended closure.

Early Loading Factor – Frequent trucks running through site consider 0.5%
some observed stiffness loss (rutting where reducing binder to 1.0 & 1.3%), not observed crack/shrinkage issues with 2% cement on state highway (TC requires trafficking within 2 – 8 hours).

Rehab – often aged / variable or composite grading of differing proportions of insitu aged and imported fresh basecourse aggregates

Need to determine the sensitivity of mix design to binder adjustment. **Easy.**

Need to understand the sensitivity of field stiffness to amount and frequency of flexure **Hard**

Caveat - this is a renewal treatment with proper structural design – DO see some cracking in maintenance renewals / patches on occasion - typically poor underlying structure

Resolution ?

Bulk QA Samples Confirm relative to Mix Design – but also not subject to early trafficking "dynamic flexing"

Require insitu testing or delayed sampling

Attempted low strain pulse loading during laboratory curing to gauge impact …. Tricky with unconfined 'green' sample ….

Demonstrated reduction in stiffness – flexing definitely compromises bonds which may not heal (similar to CAPTIF pre-cracking)

Easy option = FWD testing on recently constructed cement / FB sites to observe the inferred modulus (requires interpolation)

Harder option = Coring to undertake ITS (direct correlation)

Or Revert to reliance upon RLT of untreated material – may limit innovation

Resolution?

To move forward - main object is to determine the following

1) ***Is ≤2% cement universally safe for early trafficked sites***
2) ***Determine some relationship between laboratory ITS and field ITS/initial then sustained modulus in early trafficked sites***
3) ***Should we define appropriate construction tolerance(s)?***

Research undertaken (RR461 "Characterisation & Use of Stabilised Basecourse Materials" W Gray 2011) suggests that lightly to medium bound cement stabilised BC hit their peak stiffness at 12-24 months and then enter a period of gradual stiffness reduction.

We don't want to consume design stiffness prematurely

Consulting a number of pavement designers and maintenance engineers - it is very unusual to experience block or fatigue cracking in a ≤2% cement modified / lightly bound basecourse

This could then be the basis for some ongoing research on stiffness through early cure time with site loading.


Thanks!
Questions?