NOTES TO SPECIFICATION FOR IN-SITU STABILISATION OF BOUND SUB-BASE LAYERS

(These notes are for guidance of the supervising officers and consultants commissioned to draft tender documents and must not be included in contract documents)

1. SCOPE

The purpose of this specification is to have a framework to ensure best practises when specifying stabilisation activities on the state highway network.

There are two in situ stabilisation specifications of pavement layers, these being:
- Stabilisation of modified pavement layers (TNZ B/5:2008)
- Stabilisation of bound sub-base layers (NZTA B/6:2012)

Before using the in situ stabilisation specifications, the user needs to be aware of what the stabilisation activity is intended to achieve. This Specification covers bound sub-base layers aimed at providing significant support for the layers above and reducing the stresses in the subgrade below by distributing loads over a larger area than is possible with unbound aggregate layers.

Unlike modified materials, strongly bound pavement layers present the risk of shrinkage cracks and / or fatigue induced cracking, which can reflect through bound base and surface layers above. Where the shrinkage cracks are fine (less than 3 mm), they will normally not adversely affect the pavement performance, however, wider cracks can result in poor load transfer with increased stresses in the layers below, eventually leading to performance problems. Wide cracks also allow water infiltration and subsequent pumping in the lower pavement layers and subgrade.

Sub-base layers can be designed with reflective crack mitigation measures that are much more difficult to achieve with base layers and therefore, this specification is suitable for the stabilisation of sub-base layers, both in new construction and in maintenance work of a substantial size, such as pavement rehabilitation treatments. It is therefore not suitable for use in maintenance patch-type operations.

The NZTA intends to provide an appropriate surface for the travelling public to use at all times. The Contractor should ensure that road users' vehicles are protected from deleterious effects of the binders used in construction at all times. Reasonable options for managing operations can include:

- stopping vehicles travelling on a freshly spread binder
- stopping vehicle movement on a wet surface slurry if speed restrictions alone cannot prevent splashing
- controlling the amount of water used in the construction process
- positive traffic control in accordance with COPTTM

- enhanced signage in advance of the site focusing on keeping vehicle speeds down
- construction of part of the carriageway at a time
- approved traffic detours of a reasonable length

The use of "cement/lime splashes clean your car" signs alone is not an acceptable practice.

Design considerations

Bound sub-base layers require specific design for two main aspects of the layer performance as follows:

- Layer performance under trafficking, which will be dictated by the layer modulus prior to fatigue cracking and the retained layer modulus after fatigue cracking.
- Mitigation of reflective cracking in the pavement layers above the sub-base.

It is imperative with this type of stabilisation treatment, that the design intention is reflected in the specific project requirements of the specification. Construction issues such as water content, cement content, compaction, curing and pre-cracking will all influence the performance of the sub-base under traffic loading and also the risk of reflective cracking. Reflection cracking mitigation techniques, (e.g. pmb chip seal interlayer, geotextile interlayer, unbound granular layer, etc.) will also be required to relieve the stress concentrations that result from cracks in the stabilised sub-base.

In addition to a site specific pavement design, a mix design will be required, based on the site and / or imported materials and the results from laboratory testing with the materials and binder agent(s) to be used.

A guide to mix design is contained in NZTA T/19. This guideline should be followed when undertaking pavement rehabilitation design projects.

2. TERMINOLOGY

Some typical stabilisation terms that are used throughout the Specification and Notes are defined as follows:

Stabilisation
Any chemical or physical treatment of a road pavement material that enhances the engineering properties and thus the ability to perform its function in the pavement. Within the upper layers of a pavement, stabilisation is used to increase the shear strength of the aggregate by the reactions of cementation and/or modification.

Cementation
When water is added to cement millions of fine molecular strings "grow" from each particle of cement, which join together around the aggregate and thus bind the entire matrix together, thus also known as a hydraulic reaction.

Bound Pavement Layers

Bound stabilised materials are those to which significant quantities (greater than 3% by dry weight) of binders are added to provide a bound material with an elevated resilient modulus and measurable tensile strength. Such materials are associated with fatigue and/or shrinkage induced cracking.

This stabilisation type is adopted when it is desirable to provide a high stiffness, strongly bound layer of material with significant load spreading capability.

Modification

Modified stabilised materials are those to which small quantities of binders (less than 2% by dry weight) are added to improve the performance attributes of the material whilst still maintaining the properties of an unbound granular material.

This stabilisation type is adopted when it is desirable to increase bearing capacity, stiffness and/or decrease moisture susceptibility at the same time maintaining flexible pavement characteristics

The two distress mechanisms of modified stabilised pavement materials are vertical deformation and shear. The materials should not exhibit excessive shrinkage cracks and / or fatigue induced cracking, which are associated with strongly bound pavement layers.

Cement

Cement is a mixture of mainly Portland cement clinker (65 to 100%) and other additives, such as slag, pozzolan, volatile ashes, fired slate or limestone. Portland cement clinker is a substance consisting of at least two-thirds calcium silicates, the remainder being aluminium-oxide, iron oxide and other elements.

The main task of cement is to bind the mineral mixes, thereby increasing their stability. Cement also contains a certain percentage of calcium oxide, which modifies the clay molecules of plastic materials. The percentage of calcium oxide in cement is much lower than that of lime. Therefore, generally, cement should only be used with aggregates, which have a plasticity index of less than 10.

Lime

Several terms are used to describe different forms of lime in stabilisation. It is important to understand the meanings of these terms from the outset so that no mistake is made interchanging one form of lime for another. The two most common forms of lime available are:

- Burnt Lime (Calcium Oxide) – produced by burning high quality limestone at elevated temperatures. The resulting product is then crushed and screened to specific sizes as required. The resulting product is stable but will react violently with water releasing considerable heat and steam. The fine burnt lime is very suitable and effective in drying and conditioning soils in bulk earthwork operations and modifying marginal aggregates. This product must be kept dry until used.

- **Hydrated Lime (Calcium Hydroxide) – produced by the reaction of burnt lime with enough water to form a white powder. The product is then separated into different particle sizes through air separators in order to meet the manufacturer's specifications. The resulting product is stable and should be kept dry until use.**

Chemical Stabilising Agent Blends

Different blends of lime and cement for various applications are available on the market. Those with higher lime content are mainly used for modification, while those with higher cement content are mainly used for cementation. It is anticipated that a bound sub-base layer will use either cement or cement / lime blended as a stabilising agent.

Hoeing

Hoeing is another term for stabilising, which is the physical in-situ operation of mixing the aggregate with the stabilising agent(s) and, in most cases, water by means of a mechanical Stabiliser or Hoe that is equipped with a horizontally spinning stabilising drum that has many paddles or pointed tools attached to it.

Pre-Hoeing

Pre-Hoeing is the physical on site operation of loosening the existing road with a Hoe without the addition of stabilising agents. Pre-hoeing is carried out for many reasons. For example, where the profile (cross-section and long-section) of the road changes significantly, or where the moisture content is suspected to change substantially within a particular rehabilitation treatment length, or where the hoe does not granulate the existing road in a satisfactory manner.

3. MATERIALS

As defined above, insitu stabilisation is used to improve the physical properties, primarily shear strength, of the aggregate supplied for the pavement. These materials may be premium quarry supplied, marginal quarry supplied, or materials salvaged from an existing formation (including seal), OR a blend of these materials. One can and should however, make sure that the treated material, will exhibit targeted characteristics of a bound subbase depending on what is being supplied.

In-situ Materials

Because of the load bearing capacity expected from a bound layer, the layer must be reasonably uniform in character as any section of the layer with significantly less strength than the design expectation will fail prematurely. If insitu, rather than an imported material is to be used it must be reasonably uniform in nature. If large variations in material properties are evident in the candidate material, it is unlikely to be a suitable for this type of treatment.

To ensure that adequate information is available to design the pavement and to draft a tender document it is essential to carry out preliminary investigation of the existing road or network. This investigation is outside the scope of this Specification. However,

as a minimum requirement for stabilisation purposes, the following pavement investigations (test pit) and laboratory tests for each section should include:

- Detailed description of each layer within the existing pavement structure up to and including the subgrade;
- Sampling using in-situ milling where possible to replicate the stabilisation process in the subsequent laboratory tests
- Scala penetrometer test to a minimum depth of 1 m from the top of the subgrade;
- Grading and plasticity of the material from the pavement layer(s) that will be hoed by stabilising operations;
- Moisture content(s) of each layer at the time of the investigation and
- NZTA T/19 strength testing at varying additive contents.

Imported Natural Materials
Natural material (sand, gravel, etc.) and/or crushed stone products may be required to mix with the existing road pavement materials for the purpose of:

- Altering the grading of the post-stabilised material;
- For mechanical modification; and/or
- Supplementing the stabilised material for shape correction.

These imported materials should comply with the requirements of TNZ M/4: *Specification for basecourse aggregates*. However, as a minimum, materials must meet the requirements of Appendix 1 where the Engineer provides suitable grading.

4. STABILISING AGENT

Stabilising agents may include either cement or a blend of lime and cement. The type of stabilising agent to be employed shall be detailed in the Project Specifications. The choice of stabilising agent or combination of stabilising agents is outside the scope of this specification and NZTA T/19 should be referred to.

Cement that is suspected of not being stored to protect it from deterioration shall be tested for loss of ignition in accordance with AS 2350.2 or Appendix B of NZS 3122. Cement with a loss of ignition test result greater than determined by the cement manufacturer shall not be used.

Before considering the use of cement (or cement/lime blends) for sulphate-bearing soils, i.e. those with Total Potential Sulphate (TPS) content greater than or equal to 0.25% SO4, refer to the Britpave Technical Guideline *Stabilisation of sulphate-bearing Soils*. [1]

5. WATER

Caution and common sense need to be exercised when sourcing water other than public supply. The main components in water that could affect the setting time, strength and durability are salts, sugars and suspended matter such as oil, clay, silt, leaves, and vegetable debris. Sugars are rarely found in water ways and salts could be found in waterways that are close to oceans and are under tidal influence. If water is sourced from these water ways and/or there is a suspicion of potential contamination, then that water shall be used in the mix design test. Typically the ITS will be used. The results of these ITS tests shall be greater than 90% of the results from the ITS test carried out with the same material using water from a public water supply.

In addition, sound practise, such as avoiding silty areas and drawing from the bottom of the source, should be used while drawing water from water sources other than public supply.

7. CONSTRUCTION

7.1 Limitations

7.1.1 Weather limitations

Temperature
If work is undertaken outside the temperatures given in clause 7.1.1 of the Specification, there is a risk that at low temperatures hydration of the cement will not occur and at excessively high temperatures curing will be too rapid. Both scenarios may result in the treated materials not developing their full mix designed physical properties, thus potentially causing early pavement failure.

Dryness, wind
These weather conditions will cause excessive dust, a situation which has to be controlled.

The main reasons for preventing excessive dust are:

- Safety – excessive cement/lime dust can cause a safety hazard in the construction site
- Health – excessive cement/lime dust can cause a health risk to the workers and general public.
- Environment – agricultural and environmental harm

Therefore consideration should be given to the following conditions:

- Seasonal and regional wind direction, speeds, etc.
- Agriculturally sensitive areas
- Urban environments with high pedestrian usage nearby.

In these cases plant that has dustless capability (i.e. does not create dust) should be specified.

7.1.2 Time limitations

The time limitations for the stabilising agents are specified in this Specification to ensure that the mix designed physical properties are achieved and maintained in the field. Where these limits are exceeded the Engineer shall review the density achieved at that time and approve the kind of remedial action to be taken.

7.2 Before Stabilisation Commences

7.2.1 Initial Laboratory Testing

Where a mix design already exists, the Contractor should use representative samples of the granular sub-base material to be used in the stabilised pavement layer, and to carry out laboratory tests according to NZS 4402: 1986 Test 4.1.3 to confirm the OWC and likely MDD targets for the expected mix which includes the cement stabilising agent.

7.2.2 Surface preparation

Where test pit results show that the in situ moisture content of the material to be stabilised is in excess of the moisture limitations described in clause 7.4 of the Specification, pre-treatment before stabilising will be necessary. The Project Specifications will describe the requirements of such preparations that are anticipated.

Where surface defects are to be corrected and/or modifications made to the grade line of the pavement surface, the Project Specifications should detail the new surface level requirements. These may be achieved before stabilising by either pre-milling to remove in-situ material, or by importing material and spreading it accurately on the existing road surface. It is imperative that the shape is corrected before the actual stabilisation takes place as any change in surface shape after hoeing by grading will change the final stabilised pavement layer thickness and thus influence the pavement's long-term performance.

In cases were the geometry of the road is critical to the safety of the user, the required geometric alignment should be specified and controlled. For example to prevent flattening or steepening of cambers in high-speed cambered corners.

It is critical to the success of the pavement that the minimum design depth of the bound sub-base be achieved. Therefore very careful attention needs to be paid to achieving the required grade line of the sub-base before stabilisation, otherwise it will not be possible to achieve the tolerances required in Table 3 of the specification.

7.2.4 Supply of aggregate to site.

Should the thickness of imported material exceed the intended stabilising depth, then the existing pavement's seal shall be scarified to ensure adequate drainage. In addition, scarification shall be considered in the case of bound layers, where the potential of excessive moisture being trapped above the bound layer could adversely affect the performance of the pavement. To provide continuity and consistency of the materials, the scarified material should be granulated by a rotary spinning drum such as those found on a milling machine or hoe. If a grader is used then care should be taken to remove all particles larger then the nominal size allowed for that particular layer.

Occasionally material for shape correction and material modification will be required. In which case both shape correction and material modification operations will be required.

7.3 Spreading Stabilising Agent

The binder for bound sub-base layers is normally cement, however, there can be cases where the material to be stabilised has elevated plasticity and the addition of lime is beneficial. It is expected that the lime will be blended with the cement prior to stabilisation and the use of two separate binders in two separate passes of the stabiliser will not be required.

The quantity of stabilising agent specified in the Project Specifications is normally expressed as Kg / m^2 required to be applied to the surface of the layer to be stabilised. The tolerances given in Table 1 of the Specification for the mat test are measured by placing a mat on the sub-base surface during a run of the spreader for every 400 m^2 stabilised and weighing the quantity of stabilising agent spread on the mat; e.g. if the specified rate is 20 Kg / m^2, the quantity weighed on the mat should be 20 +/- 0.5 Kg or within the range 19.5 – 20.5 Kg. An average usage test is carried out when the spreader or bulk tanker has been emptied by dividing the tonnes used (from the delivery docket) by the measured area that has been spread with stabilising agent. E.g. if the quantity of stabilising agent spread is 10 tonne the measured area over which the stabilising agent has been spread must be 10000/20 +/- 2.5% or within the range 487 – 513 m^2.

7.5 Insitu Mixing

7.5.1 Control of cut depth

A bound layer is usually the greatest load bearing layer and it is critical that this layer has the same depth as designed and same material properties as those determined in the laboratory. Therefore, it should be noted that clause 7.5.1 tightly controls the depth of the cut so that the design depth is the minimum achieved. Also the introduction of any sub-grade material into the bound sub-base layer material will usually detract from the stabilised material strength, unless the addition of the subgrade material has been assessed during the design phase. Unless specifically allowed in the project specification, the depth of cut shall not intrude into a sub-grade layer and the design depth of granular sub-base material covering the sub-grade shall allow for the tolerances given in Table 3 of the Specification plus a safety margin, which will require the sub-base material to be approximately 50mm greater depth than the design depth of cut with the hoe.

7.5.7 Mixed Material testing

During construction, the Contractor shall take a pair of representative samples of material from behind the stabilizer and shall have these samples prepared into a pair of compaction moulds for each day's mixing (preferably on site to avoid changes in moisture content). The freshly mixed material must be allowed to cure for one hour before compacting in the moulds at NZ Vibrating Hammer Compaction in the laboratory. Specimens should be tested in accordance to NZTA T/19.

The designer will need to be assured that the bound sub-base layer has achieved the design strength before the construction of the basecourse. In combination with the lab ITS testing, testing should be carried out for the final layer strength after the curing period, (e.g. Benkelman beam or FWD). The testing should be specified in the project specification and scheduled in the tender documents.

Should the testing indicate that the layer has not met the design strength, it will be imperative that all of the QA Plan requirements have been met during construction before the failure to meet the design strength becomes a potential design issue.

7.5.8 Grading of plant mix

During the stabilization sample bags will be taken on site behind the stabilizer to ensure aggregate gradings comply with specified grading requirements. Wet sieve analysis will be completed within 4 hours of mixing to ensure all particle sizes can be washed off prior to cementing.

7.6 Compaction

The compaction requirements generally follow TNZ B/02. It should be noted however, that initial compaction may require the use of a pad foot roller where the bound sub-base layer is overlying a weak sub-grade or is greater than 250mm in depth. At depths greater than 250mm a normal vibrating roller will not be able to adequately compact the lower part of the layer.

7.7 Pre-cracking

Pre-cracking is likely to have a significant effect on the design modulus of the bound sub-base and should only be carried out if the designer has allowed for this in the design and has specified it in the Project Specifications.

7.8 Protection, Curing and Maintenance before Overlaying

It is very important for the stabilised layer to be kept moist during the curing period so that the additive can fully hydrate and reach the design strength within the curing period. General construction traffic should be kept off the layer during the curing period and subsequent compaction of overlying layers should be done with the minimum amount of vibratory rolling possible. The bound sub-base provides a very good anvil on which to compact a granular or AC base layer and usually only three to four passes of a vibratory roller is required, with compaction being finished by static rolling.

If the designer has allowed for pre-cracking this can be done as per clause 7.7 of the specification. The project specification may also allow pre-cracking to be carried out as part of the vibratory rolling when constructing the base layer, however, the number of passes of the vibratory roller will need to be limited so that the cement bound sub-base is only finely cracked and still maintains a relatively high modulus.

Under no circumstance should thin lenses of material be added to a surface. If more material is required, the area under consideration shall be hoed and finished.

8. ACCEPTANCE CRITERIA OF THE CONSTRUCTED LAYER

8.1 Compaction

The objective of the compaction process is to ensure that the subbase layer is compacted to a uniform, dense, stable condition. The procedure for determining the maximum dry density (MDD), optimum water content (OWC) targets and the number of roller passes to achieve MDD at OWC for the spread paved layer shall be as described below;

The initial compaction should be carried out with plant which will achieve a stability suitable for subsequent compaction without causing undue displacement (shoving) of the material or deformation of the layer. The rolling pattern must be so designed as to retain the shape of the layers. The compaction equipment and techniques must be capable of producing the specified surface finish and density without any interruption.

The compaction target (MDD) at the laboratory determined optimum water content should be achieved by the minimum necessary number of passes of the compaction plant. Initial field compaction must be achieved by compaction equipment only and not by traffic.

Moisture Content

During construction of the pavement layer, the Contractor should check water contents over the mat using an IANZ endorsed NDM. The NDM measured water contents must be corrected as described by NZS 4402. The layer should not be slushed or over wetted. And any water added during or after the compaction process, should be to prevent surface dryback, and be carefully controlled as excessive application of water can not be allowed.

Target Maximum Dry Density

During construction following the first run, the target maximum dry density (MDD) for the material should be agreed by the Contractor and Engineer using the test data obtained from the laboratory testing before construction, and the insitu plateau density testing of the trial run during construction.

The laboratory based target OWC and target MDD should be determined for the subbase layer at minimum frequency of one OWC/MDD test per 5000 m^2 of material. If the aggregate source, processing method, or materials are expected to change then a new OWC and target MDD should be determined.

8.2 Construction Tolerances

With this type of pavement layer there can be no remedial grading after the time limitations set out in 7.1.2 of the Specification. Also clause 8.2.2 very tightly controls the vertical tolerances and final layer depth after trimming so that the design depth is the minimum to be achieved. Any surface level or shape defects or damage of any nature, occurring during the construction or maintenance of the pavement layer before the overlaying layers are constructed, shall be made good by re-stabilising the layer with the addition of a suitable stabilising agent as directed by the Engineer.

10. BASIS OF PAYMENT

10.1 Extra over or under Clause 10.4 for the supply and spreading stabilising agents

At times mix designs or pavement designs have not been carried out at the time of tendering. In these situations the designer will typically specify an assumed depth, binder content and materials properties being envisaged for stabilisation. These are defined as the scheduled amounts.

The design binder contents and/or depth may however change from the scheduled content. In these cases it is practical to have the extra or lesser amount of design binder priced. The quantity shall be calculated by the difference between the scheduled theoretical total amount of binder scheduled in clause 10.4, and the amount calculated with the new design binder content as follows:

$$Q_{EO\ or\ EU} = \frac{(A_{Act} \times B_{Act}) - (A_{Sched} \times B_{Sched})}{1000}$$

Where:

Q EO or EU	-	**Extra or lesser binder quantity**	**[tonne]**
A_{Sched}	-	**Scheduled area at tender**	**[m^2]**
A_{Act}	-	**Design Actual area stabilised**	**[m^2]**
B_{Sched}	-	**Scheduled application rate**	**[kg/m^2]**
B_{Act}	-	**Design application rate**	**[kg/m^2]**

And

$$B_{Sched} = t_{Ass} \times C_{Ass} \times D_{Ass}$$

and

$$B_{Act} = t_{Act} \times C_{Act} \times D_{Act}$$

t_{Ass}	-	**Scheduled Hoe depth**	**[m]**
t_{Act}	-	**Design hoe depth**	**[m]**
C_{Ass}	-	**Scheduled binder content**	**[%]**
C_{Act}	-	**Design binder content**	**[%]**
D_{Ass}	-	**Scheduled density**	**[kg/m^3]**
D_{Act}	-	**Design density**	**[kg/m^3]**

REFERENCES

[1] Britpave, the British In-situ Concrete Paving Association. 2005. Technical guidelines: Stabilisation of sulphate bearing soils. *Technical data sheet BP/16*. Britpave, Camberley, Surrey.

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- GHD

APPENDIX 1:

Imported Aggregate Project Specification

Scope

This Appendix sets out requirements for the aggregate intended for use as one or more of the following (Informative, tick whichever is applicable, can be more than one):

Purpose	Tick
Correction in the longitudinal profile of the existing road	
Correction in the transverse profile of the existing road	
Correction in the Particle Size Distribution	

Proportion of Broken Rock

In each of the aggregate fractions between the 63.0mm and 4.75mm sieves greater than 50% by weight shall have two or more broken faces. It shall be free of organic matter.

Crushing Resistance

The crushing resistance shall not be less than 110kN when the aggregate is tested according to NZS 4407:1991 Test 3.10 "The Crushing Resistance Test".

Weathering Resistance

The aggregate shall have a quality index of AA, AB, AC, BA or CA when tested according to NZS 4407:1991 Test 3.11 "Weathering Quality Index Test".

Sand Equivalent

The sand equivalent shall not be less than 25 when the aggregate is tested according to NZS 4407:1991 Test 3.6 "Sand Equivalent Test". The sand equivalent test may be neglected if the grading test shows less than 4% passing the 75 micron sieve.

Plasticity

The sand and/or filler (aggregates less than 2mm), when added for the purpose of altering the particle size distribution, shall be non-plastic.

Particle size distribution

When tested according to NZS 4402:1986 Test 3.8.1 “Standard Method by Wet Sieving”, the grading of the aggregate, prior to hoeing, shall fall within their respective envelopes defined below:

Sieve Size (mm)	% of Weight Passing (%)		
	Section 1 Envelope	Section 2 Envelope	Section 3 Envelope
63			
37.5			
19			
9.5			
4.75			
1.18			
0.075			