AustStab Technical Note

No.5 March 2012

Cement Stabilisation Practice

1 Introduction

Cementitious stabilisation has been used in Australia for many years. The development of supplementary cementitious materials has broadened the range of cementitious products from just GP Cement.

The applications for cementitious stabilisation are:

- Strengthening of existing pavements.
- Improving low quality pavement material to make suitable for subbase or base.
- Reduce thickness of base to achieve required design strength
- Drying out wet pavements

The pavement material type and the condition of the existing pavement will determine the binder type and application rate.

This Technical Note aims to highlight:

- Different blends available for cementitious stabilisation
- Description of cement and supplementary binders
- Mix design and application rate
- Mixing operations
- Cementitious products availability

2 Types of Cementitious Binders

In the past GP cement was the only available binder for use in non plastic soils. However now almost all cementitious stabilisation is carried out using blends of cement with various supplementary materials.

There are many blends available in Australia but not all blends are available in all states.

The reason that blends are now preferred is for a number of reasons:

- Slower setting times resulting in
  - Longer working time
  - Greatly reduced chance of cracking
- Use of recycled products, so making more environmentally friendly
- Reduced cost as recycled products are cheaper than GP cement.

2.1 Cement

Cement blends are effective stabilising binders applicable to a wide range of soils and situations. Cement has two important effects on soil behaviour:

- It greatly reduces the moisture susceptibility of some soils, giving enhanced volume and strength stability under variable moisture conditions.
- It can cause the development of interparticle bonds in granular materials, endowing the stabilised material with tensile strength and high elastic modulus.

Cement used for stabilisation should conform to AS 3972, 'Portland and Blended Cements' and NZS 3122 Specification for Portland and blended cements (general and special purpose).

2.2 Types of cement

2.2.1 General

'Cement' is a generic term used to describe a wide variety of organic and inorganic binders. The most widely used binders are those known as hydraulic cements – finely ground inorganic materials which possess a strong hydraulic binding action, i.e. when mixed with water they harden to give a stable, durable product.

There are a variety of cement types and blends, which are commercially produced, and each has different properties and characteristics. The principal cement types available are as follows:

Type GP – General purpose portland cement

Type GB – General purpose blended cement

General purpose cements are produced from a mixture of calcium carbonate, alumina, silica and iron oxide which, when calcined and sintered at high temperatures gives a new group of chemical compounds capable of reacting with water. The composition of individual cements can vary depending on the nature and composition of the raw materials being used.

2.2.2 General purpose portland cement

Portland cement is defined in AS3972 (portland and blended cements) as a hydraulic cement which is manufactured as a homogeneous product by grinding together Portland cement clinker and calcium sulphate, and which, at the discretion of the manufacturer, may contain up to 7.5% of mineral additions.

The cement hydrates in the presence of water to form hydrated silicates and aluminates and calcium hydroxide.

2.2.3 General purpose blended cement

Blended cement is defined as a hydraulic cement containing Portland cement and a quantity comprised of one or both of:

- Greater than 5% of fly ash or ground granulated iron blast furnace slag, or both
- Up to 10% silica fume.

Both types of cement can be used in stabilisation but in recent years, blends are almost always used.

2.3 Supplementary cementitious materials

2.3.1 General

Fly ash, pulverised blast furnace slag or other pozzolanic type materials may be combined with lime, or cement to form supplementary cementitious materials.

Supplementary cementitious materials provide an alternative to GP cement, on the grounds of economy or for extended working time for compaction and finishing. For these reasons especially with the increased stabilised depths achieved with modern equipment, it is recommended that these blends are used where technically and economically feasible. The resultant pavement gains higher strength over time and has reduced cracking.

2.3.2 Types of cementitious binders

There are a wide variety of cementitious binders suitable for use in stabilisation.

2.3.3 Lime

For lime properties, refer to AustStab Technical Note “Lime Stabilisation Practice” and “What is Lime”.

Table 1 A typical range of cementitious binders available.

Slag/lime blends
85% slag, 15% lime
30% slag, 70% lime
50% slag, 50% lime
60% slag, 40% lime
70% slag, 30% lime
Cement / fly ash blends
75% GP cement, 25% fly ash
80% GP cement, 20% fly ash
50% GP cement, 50% fly ash
90% GP cement, 10% fly ash
Slag/cement blends
60% slag, 40% GP cement
50% slag, 50% GP cement
Cement/lime blends
80% slag/lime, 20% lime
50% slag/lime, 50% lime
Fly ash/lime blends
50% fly ash, 50% slag/lime
75% fly ash, 25% lime
Triple blends
50% slag, 20% lime, 30% fly ash
50% slag, 30% lime, 20% fly ash
30% slag, 50% lime, 20% fly ash
60% GP cement, 20% slag, 20% fly ash
25% slag, 25% lime, 50% fly ash
20% slag, 40% GP cement, 40% fly ash
40% slag, 40% GP cement, 20% fly ash
40% slag, 20% lime, 40% fly ash

2.3.4 Pozzolans

2.3.4.1 General

A pozzolan is a siliceous or alumino siliceous material that, in finely divided form and in the presence of moisture, chemically reacts at ordinary room temperatures with calcium hydroxide released by the hydration of Portland cement or lime to form compounds possessing cementitious products.

2.3.4.2 Ground granulated blast furnace slag (GGBFS)

Granulated blast furnace iron slag (GBFS) is formed when high-pressure, high-volume water sprays hit molten slag when leaving the blast furnace. The combined heat energy contained in the molten slag and water causes the molten slag to explode and instantly forms granulated particles. On casual examination the slag is similar to river sand with a maximum particle size of about 0.7 mm. This material is ground to form ground granulated blast furnace slag (GGBFS), commonly known as slag.

GGBFS which will act as a slow-setting hydraulic cement by itself, reacts exceptionally well with lime and so is an excellent pozzolanic material and is treated as such. Some ground slag materials already contain small amounts of free lime.

Some common properties of GGBFS are:

- Bulk density is 2.93 t/m3
- pH is 10.5 to 12
- a minimum of 20% of GP cement is required to activate the slag, or
- a minimum of 10% of hydrated lime is required to activate the slag.

The most common combination of slag/lime blends is (85:15). These types of materials have been tested successfully using the accelerated loading facility (ALF), the results of which indicate a long life when utilised with deep-lift situ pavement recycling (ARRB 1994, Moffatt et.al. 1998).

2.3.4.3 Fly ash

Fly ash is a product of the power generation industry. The type of coal used and the mode of operation of the plant determine the chemical composition and particle size distribution. Consequently, not all fly ashes are suitable for stabilisation. Generally, fly ash derived from burning black coal is high in silica and alumina and low in calcium and carbon and is well suited for use in stabilisation. Fly ash derived from burning brown coal contains large percentages of calcium and magnesium sulphates and chlorides and other soluble salts and is unsuitable for use in stabilisation.

Unburned organic carbon breaks the continuity of contact in the cementitious reactions and should be limited to about 10%.

Fly ash should conform to AS 3582.1.

Other ash products, such as power station bottom ash, have also been successfully used in lime stabilisation (e.g. Chapman and Youdale 1982; Jameson et al. 1996; Francis 1994; Symons and Poli 1996; Ash Development Association of Australia 1997).

Bottom ash comprises about 10% of the ash produced at coal fired power stations and, while it has a similar chemical composition to fly ash, it contains greater quantities of carbon and is relatively inert because it is coarser and more highly fused than fly ash.

3 Reaction of Soil and Cementitious Stabilising Binders

The primary reaction is the hydration of the cementitious stabilising binder with the water in the soil which leads to the formation of cementitious material (calcium silicate and aluminium hydrates as in concrete). These reactions occur almost independently of the nature of the soil.

The hydration reaction releases hydrated lime (about 30% by mass of the added cement in the case of general purpose cement stabilisation) which can cause secondary reactions with any pozzolans (usually clay) within the soil. The secondary reaction produces cementitious products similar to those from the primary reaction.

The hydration reaction starts immediately on contact of the cementitious stabilising binder with water. It proceeds rapidly particularly if cement is used and there are very significant strength gains in the first day. The secondary reactions produced using cement is similar to those that occur in lime stabilisation and proceed slowly with time.

The reactions that occur with the use of supplementary cementitious materials are similar to the secondary reactions that occur with cement and take place more slowly than occurs with cement.

Pozzolanic reactions are usually slow but continue over a long period provided that adequate moisture is present. Reactions are also temperature sensitive, the rate of reaction increasing with increasing temperature. Organic material and sulphates may cause retardation of the reaction.

The best results from stabilisation with supplementary cementitious material depend on the amounts of lime, pozzolan and pavement material.

For fly ash, a ratio of about one part of lime to two parts of fly ash by volume will produce maximum strength of the paste.

Usually the amount of lime plus flyash added to a pavement material should not exceed about 5% by mass of pavement material. These proportions should be confirmed by testing.

4 Types of cementitiously–stabilised materials

Soil properties progressively change with increasing cementitious binder content.

The differing properties gained by varying cementitious binder content necessitate a range of evaluation procedures to ensure that they are correctly utilised. While continuity of properties is emphasised, three broad categories of cementitiously stabilised material can be identified. These are:

- Modified materials – where only small amounts of cement are used and the resulting materials may be characterised as an unbound granular material for pavement design purposes.
- Lightly bound materials – where the stiffness and tensile strength is improved slightly with negligible cracking.
- Bound materials – where the stiffness and tensile strength of the materials are sufficiently enhanced by the addition of cement to have a practical application in stiffening of the pavement. This is taken into account as part of the pavement design procedure.

Table 2 Typical Properties of modified, lightly-bound and heavily-bound materials

Material Type	**Layer Thickness (mm)**	**Design Strength (MPa)[1, 2]**	**Design Modulus (MPa)**
Modified	Applicable for any thickness	UCS ≤ 1.0	≤ 1500
Lightly Bound	Generally ≤ 250 mm	UCS: 1-2 (7 day strength: 1-2)	1500 – 2000
Heavily Bound	General > 250 mm	UCS ≥ 2	2000 – 20,000

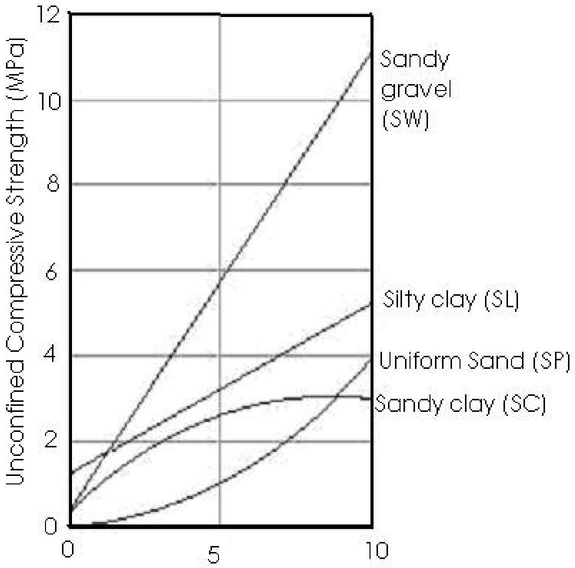

Figure 1 Strength of various soils stabilised with general purpose cement (cured for7 days at 25°C and constant moisture content (after Metcalf 1977).)

4.1 Modified materials

Small cementitious binder contents are primarily used to reduce the moisture susceptibility of soils and to increase the shear and bearing strengths, without significantly increasing the tensile strength and modulus. The modified material usually exhibits a very close spaced network of finely spaced cracks and does not develop a network of widely-spaced open cracks like some bound materials. Modified materials are treated as unbound materials for the purposes of pavement design.

Lime is usually a better additive to consider for modifying plastic materials as cementitious binders have a tendency to bind particles together even at very low additive contents.

Finely-graded gravels, clayey gravels, silty sands (> 50% passing 425 µm sieve) and other materials without significant particle interlock are not suitable for use as base materials when modified, as they deteriorate rapidly with use. The life of these materials will generally be short and rapid disintegration of the pavement may happen with the onset of cracking.

4.2 Bound materials

Bound materials are designed to withstand tensile stresses imposed by traffic and environment over the design life of the pavement.

Heavily bound materials have moduli typically in the range 2,000 to 10,000 MPa and their use may lead to a reduction in pavement thickness when compared to unbound materials resulting in savings in materials, depending on relative costs.

Heavily bound cementitious materials sometimes exhibit a regular pattern of widely-spaced cracks (0.5 m to 7.0 m) caused primarily by the combination of high tensile strength, drying shrinkage and subgrade constraint. However, with the use of slow-setting binders, careful curing and early trafficking, this greatly reduces. With polymer modified bitumen sprayed seals, and crack sealing technology, cracking patterns can be adequately controlled to achieve good long-term performance of cement-bound materials.

The use of lightly bound cementitiously-bound materials (UCS between 1 and 2 MPa) with the above technologies, not only reduces the possibility of cracking but can also effectively eliminate the detrimental effects of any cracking to the pavement. For this reason many State Main Road Authorities and councils use a lightly bound pavement with a thin wearing covers as an economical method of road construction.

Bound materials are characterised for pavement design purposes by their elastic modulus and Poisson's ratio (usually assumed to be 0.20) and their performance estimated from their fatigue resistance.

5 Properties of cementitiously-bound materials

5.1 General

The following sections provide information on the effect of cementitious binders on soil properties. As the effect of cementitious binders on soils depends on the type of binder, the type of soil and its environment, these discussions should be regarded in broad terms only and testing for individual circumstances will be required.

5.2 Volume and moisture stability

Small additions of cementitious binders have large effects on the volume stability of expansive materials without necessarily leading to significant strength gains. Cementitious binders, by binding the particles, will greatly reduce moisture induced shrinkage as well (see Figure 2).

Cementitious binders provide improved stability against freeze-thaw and cyclic wetting and drying. Materials satisfying these criteria would normally require an unconfined compressive strength of at least 3 MPa.

Therefore, while the plastic properties are widely used to classify the volume stability of pavement materials, they are not appropriate for cementitiously-bound materials.

5.3 Cracking

Cracking has been seen as a problem with cement stabilised pavements. While this has been a problem for the early stabilization projects the problem has been removed over recent years.

This has been achieved by

(a) Introduction of modern cementitious binders
(b) Improved stabilization plant and equipment achieving accurate binder efficient mixing and compaction
(c) Use of two pass mixing to ensure correct mixing
(d) Use of modern binders and reinforcing in the seals including polymer modified binders, geotextiles and SAMI seals

There are two principal forms of cracking in cementitiously-bound materials:

- shrinkage cracking from hydration and drying, and
- fatigue cracking.

Cracking created from within the layer is mainly of concern in base courses although reflection cracking from lower courses may occur.

Cracking is controlled by:

- the use of slow setting binders
- reducing the amount of cementitious material
- modern "fit for purpose" equipment that obtains adequate mixing
- strict control of the moisture content so as not to have high water cement ratios (usually 1 to 2% below optimum moisture content is preferred)
- proper compaction, and
- a proper curing regime.

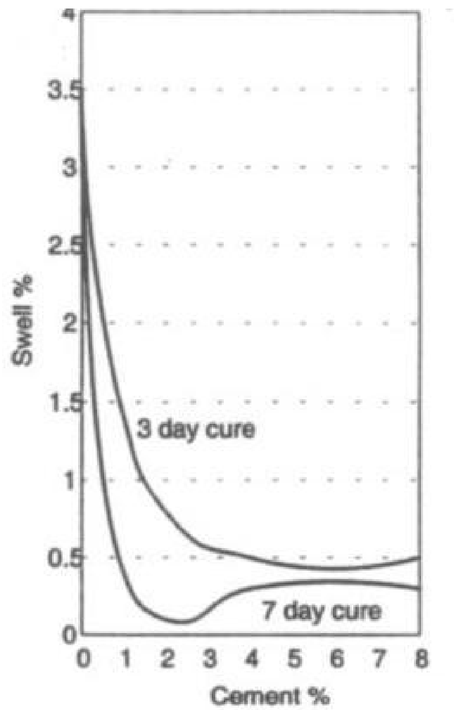

Figure 2 Volumetric stability of expansive clay stabilised with cement (OMC and Standard Maximum Dry Density). (NAASRA1986)

As cementitious stabilisation gives tensile strength to pavements there will be cracking however with the advent of slow setting binders and improved plant and equipment this can be controlled without deleterious effects on the pavement.

5.3.1 Shrinkage cracking and erosion

A combination of high shrinkage and tensile strengths in heavily bound cementitious bases can cause widely spaced (commonly 0.5 to 5.0+ m) transverse and/or block cracking to occur. Though this may reduce the ride quality of the pavement it usually does not lead to serious structural problems provided the cracks are less than 2 mm wide and are sealed or a polymer modified or scrap rubber binder wearing surface applied. Geotextile reinforced seals have also been used successfully to mitigate the effects of cracking.

On heavily-trafficked roads the application of 50mm of polymer modified asphalt will lessen the impact loading of vehicles on the cracks reducing the fretting of the cracks at the surface.

Not sealing any cracks will lead to moisture entry into the pavement, which may lead to pumping of fines from erosion and rapid deterioration of the pavement under the action of traffic.

The likelihood of pumping of fines from the base, subbase and subgrade can be minimised by ensuring an adequate binder content for the stabilised layer(s) that is above the erodability limits (Howard 1990; Wong 1992 – see Figure 3)

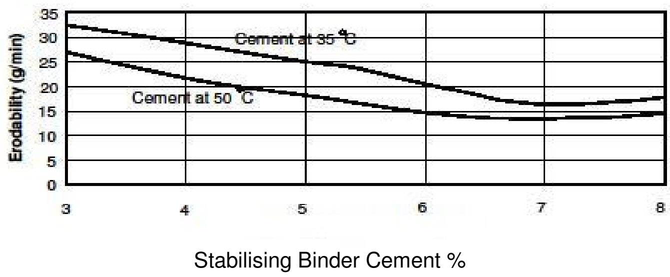

Figure 3 An example of erodability test results (from Howard 1990)

Even if significant cracking does occur, provided moisture ingress into the pavement can be prevented, there may still be considerable life left in the pavement in the post cracking phase, where the cementitiously-bound layer acts as an unbound layer or a modified layer. This is particularly so if the layer is a subbase layer. This post-cracking phase life can be quantified using the design procedures in the Austroads Guide Pavement Technology Part 2.

Early trafficking of cementitiously-stabilised layers is considered beneficial as it facilitates the development of closely spaced fine cracks which are easier to manage than widely spaced large cracks which tend to occur without early trafficking (Yamanouchi 1975).

5.3.2 Fatigue cracking

Fatigue cracking occurs when the number of repetitions of tensile strain induced in the cementitiously-bound layer by the passage of traffic exceeds the capacity of that layer.

Prevention of fatigue cracking is the principal criteria for the design of cementitiously-bound pavement courses.

Cementitiously-bound pavement courses that are thin and have a high modulus are particularly prone to fatigue cracking.

The fatigue resistance of cementitiously-bound layers is very sensitive to the thickness of the course and the stiffness of the layer. As an approximation, a 10% reduction in either thickness of stiffness of a cementitiously-bound layer could lead to about a 90% reduction in fatigue life. The thorough incorporation of the correct binder content, adequate compaction, suitable construction tolerances, thickness and curing are therefore all critical to the fatigue performance of cementitiously-bound materials.

The use of lightly bound cementitiously stabilised layers also greatly reduces the possibility of any adverse effects of shrinkage cracking.

6. Strength parameters

6.1 Shear and bearing strength

Shear and bearing strength tests such as the modified texas triaxial test and the California bearing ratio (CBR) test have some application to modified materials but little application to bound materials. Small additions of cementitious binders to well graded granular materials commonly lead to large and meaningless increases in the results from these tests. Both these tests are ultimate strength tests and hence measure parameters at high strains, well above the working strains in cementitiously-bound materials. The most commonly used specification test for determining the strength of cementitiously-bound materials is the unconfined compressive strength (UCS) test. This is a relatively simple test and the results vary considerably depending on the curing and conditioning of the samples. Test methods used for curing and testing UCS samples vary considerably throughout Australasia and so care should be taken when comparing UCS test results.

Curing conditions used for the UCS test should attempt to model likely field conditions.

The results of the UCS test can be used to give a preliminary estimate of the modulus of cementitiously-bound materials. There are numerous relationships relating UCS and modulus (e.g. MRD Queensland 1982); however, they have been developed for particular materials stabilised with particular binders and prepared and cured in a particular way.

Care should therefore be exercised in extrapolating any of these relationships to other circumstances.

6.2 Tensile strength and strain

Tensile strength and strain tolerance are of primary significance in the design of bound pavement courses.

Cementitiously-bound materials (heavily bound) are relatively brittle, with a high modulus and very low tensile strain at failure. Their behaviour under triaxial compression fits the Mohr-Coulomb theories (shear failure criteria) for modified materials and tends to better fit the Griffith crack theory or modifications of it for bound materials.

The failure of cementitiously-bound materials under traffic loading is consistent with fatigue tensile failure.

6.3 Elastic properties

The elastic properties required for pavement design are elastic modulus and Poisson's ratio.

Cementitiously-bound materials are considered to be isotropic for the purposes of pavement design.

Typical moduli for well-graded cementitiously-bound material for use as base materials are in the range 2,000 to 20,000 MPa compared with about 200 to 500 MPa for unbound materials. However, fine-grained materials will normally have lower moduli than well-graded materials.

The moduli of cementitiously-bound materials are not particularly temperature sensitive. However, moisture sensitivity may be important.

Presumptive elastic characteristics are given in Table 3 The usual range of Poisson's ratio values for cementitiously-bound material is 0.1 to 0.3, with 0.2 being commonly used for design purposes.

Figure 4 Determining elastic properties using repeated load triaxial testing apparatus

Table 3 Elastic characteristicsof pavements

Property	Lean mix concrete	Base 4- 5% cement	Subbase quality crushed rock 2-4% cement	Subbase quality natural gravel 4- 5% cement
Range of modulus (MPa)	5000-15000	3000-8000	2000-5000	1500-3000
Typical modulus (MPa)	7000 (Rolled) 10000 (Screeded)	5000	3500	2000
Degree of anisotropy2	1	1	1	1
Range of Poisson's ratio (vertical, horizontal and cross)	0.1-0.3	0.1-0.3	0.1-0.3	0.1-0.3
Typical value of Poisson's ratio	0.2	0.2	0.2	0.2

1. Although Figures are only quoted for cement, other cementing binders such as lime, lime fly ash, cement fly ash and granulated slag may be used. The stiffness of such materials should be determined by testing

2. Degree of anisotropy = Vertical modulus / Horizontal modulus

7. Conditions appropriate for Cementitious Stabilisation

There are two main factors to be considered for cementitious stabilisation:

- Material factors, dealing with the composition of the untreated material and its response to cementitious binders, and
- Production factors concerned with the quality and nature of the cementitious binder and water and the methods used to produce the stabilized material.

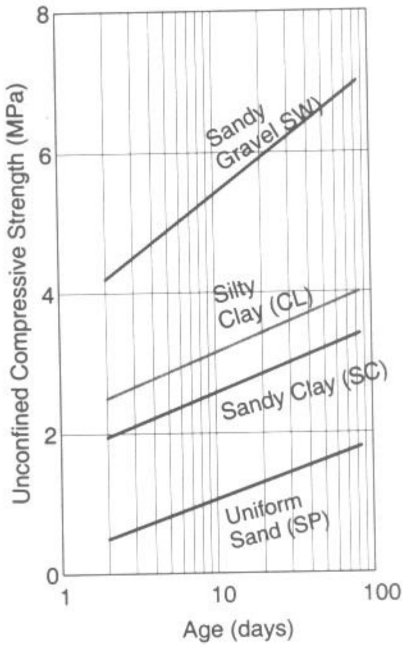

Figure 5 Effect of Age on Strength of Various Materials Stabilised with 5% Cement (after Metcalf)

7.1 Material Factors

Materials, which have a low volume of voids when compacted, will usually require the addition of relatively small amounts of cement compared to poorly-graded high void content material.

Table 4 provides a guide to the broad categories of material in which cementitious binders may be a satisfactory and economic addition.

Certain material constituents can be quite detrimental in the formation of stabilized materials. Sugars and reactive organic compounds can retard the hydration process and prevent the hardening of the binder. In some circumstances, soluble sulphates can cause the disruption of the hardened paste.

Table 4 Guide to property limits for effective cement stabilization

Property	Limit
Particle Size	
Maximum particle size	75 mm *
Passing 4.75 mm	> 50%
Passing 425 µm	> 15%
Passing 75 µm	< 50%
Finer than 2 µm╬	< 30%
Plasticity	
Liquid Limit	< 40
Plastic Limit	< 20
Plasticity Index	< 20

* Depends on mixing plant
╬ At upper limit may need pre-treatment with lime

7.2 Production factors

The quality of the compacted stabilised material is very dependent on the production processes including:

- breakdown and mixing
- quality of the water used
- compaction, and
- curing conditions.

7.21 Breakdown and mixing

It is important that there is an even distribution of binder throughout the full design depth of the bound material to ensure that performance matches design. An even distribution of binder ensures its most economic use and provides the most uniform material parameters.
It is usual to increase the laboratory determined binder content (usually by 0.5%) to allow for mixing inefficiencies. The effect of such variations should be investigated during the laboratory testing program

Plant mixing and insitu mixing can both produce quality stabilised mixes with proper levels of control and may be specified when high quality materials are required. For field mixing, two passes of the stabiliser are required to produce optimum mixing results. Additional passes of the stabiliser may produce excess fines and be deleterious to the stabilisation process.

The required degree of breakdown is usually only a matter of concern with cohesive materials such as clays and sandy clays. Where these materials are used for pavement layers (usually only to subbase level) it is desirable to have a high degree of breakdown. This also helps the diffusion of the lime products of the cementitious binder into the lumps, thus enhancing the stabilisation.

For subgrade materials, high early strength is often not needed as long as a reduction in moisture susceptibility is achieved. Subgrade materials should be broken down so that a substantial proportion of the clay lumps pass the 19 mm sieve.

Pre-conditioning with small amounts of hydrated lime or quicklime often benefits the break-down of plastic clay soils. Where this is proposed it should be taken into account in the laboratory testing program.

7.2.2 Water quality

Water for cement stabilisation should be in principle clean, free from organic material and contain less than 0.05% sulphates.

Where possible, the actual water source to be used in the field should be used for the laboratory testing program.

The water source for curing cement stabilised materials should also be assessed. Care should be taken when using saline waters for curing as they can cause a build up of surface salts which can interfere with the adhesion of future seal coats.

7.2.3 Compaction

Adequate compaction is essential to obtain the strength and performance from stabilised materials. This is illustrated in Figure 7.

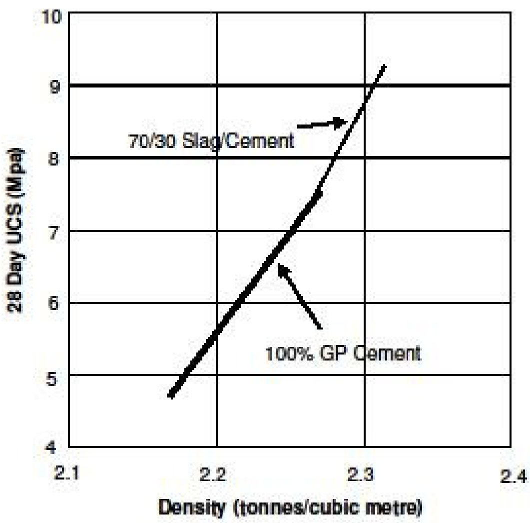

Figure 6 typical effect of density on strength of a fine crushed rock (VicRoads1995)

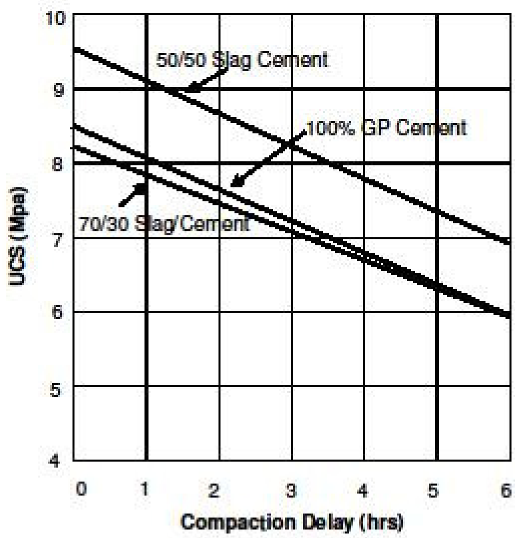

Figure 7 Loss of strength due to delay in compaction for fine crushed rock stabilised with 3% slag/cement mixtures (VicRoads1995)

Increased resistance to compaction occurs as a result of the rapid formation of cementitious bonds that provide resistance to the applied compactive effort. Compaction should therefore be completed as soon as possible after the addition of the binder.

Delays in compaction, after the addition of binder and water, particularly when the binder is cement, will result in reduced densities and subsequent reduced strengths (see Figure 7), therefore slow setting binders should always be used.

7.2.4 Curing conditions

Curing is necessary to ensure that:

- the required strength is achieved in the stabilised material
- there is always adequate water for the hydration reactions to proceed, and
- drying shrinkage is limited while the hydration reactions are proceeding and the material is strengthening.

As water will normally be continuously lost to the atmosphere it is good practice to apply a curing membrane such as a prime or primer seal to prevent the stabilised materials from drying out before completion of the hydration reactions.

If this is not practical, then the pavement must be kept damp for up to four to seven days by frequent surface watering or by covering with another pavement layer. It is important not to over water cementitiously stabilised layers or leaching will occur. With over watering a slurry can form on the surface causing delamination.

Premature drying will prevent the development of strong cementitious bonds and can greatly increase the severity of shrinkage cracking. In such circumstances, the material will have low tensile strength and too many closely-spaced wide cracks to develop significant slab action to resist traffic loading.

Curing is also important for laboratory specimens and should model likely field conditions. Samples should be kept in sealed, airtight bags at a constant temperature. The validity of any accelerated curing at raised temperatures should be validated by comparison with normal curing conditions.

7.3 Application of cementitiously-bound materials

7.3.1 Subgrade

Subgrade stabilisation is usually carried out to:

- Improve subgrade strength, thus allowing for the possible reduction of the overlying pavement thickness.
- Provide a working platform for construction equipment.
- Convert material of subgrade quality to that of lower subbase quality.
- Reduce construction problems associated with variable subgrade strengths.
- Provide a water-resistant subbase for permeable or jointed pavements, keeping in mind that this may introduce a permeability reversal into the pavement which should be taken into account during design.

A permeability reversal occurs between two pavement layers when the permeability of the lower layer is in the order of 100 times lower than the layer above. The implications of this are that should moisture infiltrate the pavement, it will form a perched water-table on the top of the lower layer. The lower layer should therefore have adequate wet strength to withstand any softening caused by the moisture.

For more plastic clay subgrades, hydrated lime or quicklime will be more suitable than cementitious binders. However, cementitious binders can have application for these materials where wet conditions are encountered, as the high rate of reaction of these binders may be beneficial in these situations. In addition, any stabilised subgrade layer will generally prevent penetration of the subgrade into a coarse subbase thus maintaining the structural effectiveness of the sub base.

It should also be noted that it might be difficult to achieve full compaction of a layer as a result of the subgrade layer below having a low bearing capacity or not being fully compacted.

7.3.2 Subbase

Subbase stabilisation can be used to:

- upgrade the quality of existing materials to permit their use as a modified subbase
- improve the working platform qualities of a subbase
- reduce the total pavement thickness and optimise the pavement design, and
- provide a material that has reduced moisture susceptibility.

Cementitiously-bound materials can be used in heavy duty pavements to provide a stiff, load bearing layer. Typically, these are placed at such a depth within the pavement so that reflection cracking is minimised.

One advantage of using a cementitiously-bound subbase instead of a cementitiously-bound base is that reflection cracking from the subbase to the wearing surface can be minimised. The use of 150 mm of unbound granular basecourse has been found, in most cases, to be an effective means of eliminating reflection cracking.

7.3.3 Base course

Cementitiously-treated materials can be used in base courses as either modified or bound materials. Modification can be used to:

- upgrade a slightly deficient material
- improve low cohesion base materials that deform and shove when subjected to traffic, and
- reduce moisture sensitivity.

Extra care should also be exercised in mixing low binder contents to ensure uniform mixing is obtained and to minimise the variability of material properties; otherwise, their use:

- can lead to reflection cracking of the pavement wearing surface, thus allowing moisture ingress into the pavement
- can often leave materials susceptible to pumping and erosion in the presence of moisture and traffic, and
- may not adequately address pavement structural inadequacies.

The use of cementitiously-bound bases may be advantageous in the following applications:

- lightly bound low trafficked roads especially for local government
- moderately- to heavily-trafficked roads on low-strength subgrades
- improving the load-carrying capacity of a pavement, particularly where options may be restricted by levels and/or the presence of services
- areas subjected to frequent flooding
- where life-cycle costs can be minimised, and
- recycling of inadequate existing pavements.

If cementitiously-bound base materials are constructed in more than one layer, it is essential that full bonding, to achieve adequate shear strength between layers, be achieved or significant reduction in fatigue resistance will occur. Techniques that can be used to attempt to bond cementitiously-bound pavement layers include the use of cement slurry or a bituminous seal interlayer (Kadar et al. 1986). However, if possible, construction of cementitiously-bound courses in single layer or in thick multi layers is preferable in order to eliminate any risk of de-bonding and subsequent loss of performance.