INFORMATION BULLETIN: IB 89

Cement Stabilisation

Introduction

Over the last ten years heavy vehicle traffic in New Zealand has doubled, putting increasing demands on our road pavements. As a result, more and more pavements now fail before they reach the end of their design life. Cement stabilisation is one method to prevent these failures.

The drive to minimise waste and to conserve our natural resources has focussed attention on the use of our aggregate resources. Cement stabilisation is an ideal method to enhance the properties of marginal materials so that they can be used instead of premium quality aggregates even in the highest stressed areas of a pavement. Both new aggregates and aggregates in existing pavements can be stabilised.

Although cement stabilisation has been used for over 60 years in New Zealand, improvements in stabilising equipment have led to a recent resurgence of interest. Between 2002 and 2005 alone the amount of cement used in cement stabilisation increased by more than 70%.

In response, specifications are changing to acknowledge and allow innovative uses of alternative materials and plant to produce cement stabilised mixes that are suitable for highly trafficked roads.

The Stabilising Working Group, comprising engineers from the New Zealand Transport Agency, contractors, consultants and suppliers, is currently developing several specifications for cement stabilised pavements. These include specifications for in-situ stabilisation of modified pavement layers (TNZ B/5: 2008), in-situ stabilisation of strongly bound pavement layers (TNZ B/6; in press at time of writing), subgrade stabilisation, plant mixed materials and fully bound in-situ stabilisation.

This Information Bulletin outlines the principles of cement stabilisation, including in-situ and plant mix processes, modified and bound materials and the principles of designing stabilised pavements.

CCANZ's publication on Road Recycling and Construction using cement Stabilisation (CCANZ, 1993) gives several examples of cement stabilised roads in New Zealand.

What is Cement Stabilisation?

Cement stabilisation is the process of adding cement and water to pavement aggregates to enhance the engineering properties of the pavement. The cement reacts with water in the same way as it does in concrete, and the resulting cement hydration products bind the aggregate particles together.

Cement stabilisation typically increases the pavement's load bearing capacity and stiffness, and reduces its sensitivity to moisture. It can be used in the construction of new pavements and the rehabilitation of existing pavements.

Benefits

Cement stabilisation of road pavements offers economic and environmental benefits as well as improved pavement performance:

- Lower quality aggregates can be used, thus conserving premium quality materials.
- Existing pavement materials can be recycled in-situ, minimising waste and reducing the need to transport aggregates to the site.
- Reducing the need to transport aggregates to the site or into a region with no local high quality aggregate sources reduces aggregate

costs, fuel consumption, pavement wear and traffic congestion.

- Stabilised subgrades can be trafficked during construction if necessary. If the construction programme is delayed then costs associated with unforeseen disruption to traffic can be minimised.

- The reduced moisture sensitivity of stabilised layers reduces risks associated with loss of bearing capacity in wet conditions. Resistance to rutting and other deformations is thereby improved.

- More efficient pavement configurations can be achieved in new pavements by incorporating cement stabilised pavement layers to reduce overall pavement thickness.

- The moisture resistance of unsealed road surfaces can be improved by stabilisation with small amounts of cement. This reduces softening of the pavement caused by moisture penetration, and reduces erosion of the softened surface. The road surface is therefore more durable and requires less maintenance to maintain good ride quality.

Principal Features

Depending on the quantity of added cement the resultant aggregate can be defined as modified or bound. The general classification is illustrated in **Figure 1**. The Stabilising Working Group is currently defining the quantities of cement and the characteristic properties of each these categories.

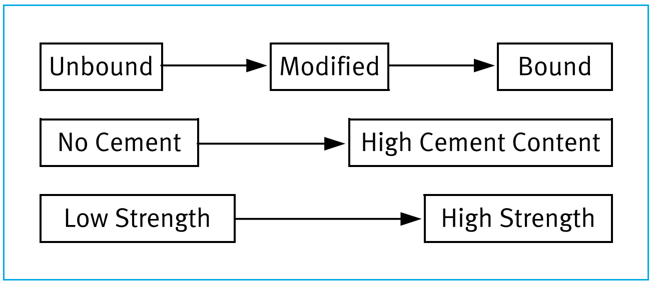


Figure 1: Classification of stabilisation types.

The physical property that distinguishes the various groups is tensile strength. An unbound material (an aggregate containing no cement or other binders) has no tensile strength.

Materials containing a relatively high proportion of cement will (i.e. bound materials) have high shear strength, but when placed in the road may fail by fatigue cracking under repeat flexural load. A fully bound material will also shrink while curing, which will lead to transverse cracking at 3-4 metre intervals.

However, there are methods to reduce/eliminate this type of cracking – see page 6.

Modified materials offer a significant increase in shear strength, but their tensile strength is low enough to prevent fatigue cracking. Modified materials are more prone to shear than bound materials.

Modified and bound materials both have their place in pavement structures. The task of the pavement designer is to utilise the enhanced properties of each material and to place it in the pavement structure in such a way that properties such as shrinkage and fatigue cracking are given due consideration.

Cement stabilised pavement materials can be incorporated in a variety of pavement configurations. The base and/or the sub-base may be stabilised. The examples in **Figure 2** illustrate the common pavement configurations for stabilised pavement materials.

Stabilised layers may be directly overlaid by concrete or asphalt. Alternatively they may be overlaid by a granular layer to prevent shrinkage and fatigue cracks reflecting to the surface.

Stabilised materials may be mixed in-situ or at a quarry or other production facility. The relationships between the types of material, production methods and implications for placing are shown in **Figure 3**.

Basecourse or Sub-base Materials

The source aggregates may be high quality crushed rock meeting the requirements for weathering and crushing properties specified in Transit New Zealand specification TNZ M/4. Alternatively, marginal or recycled aggregates may be used, provided that the stabilised material meets the requirements for wetting and drying specified in TNZ M/22.

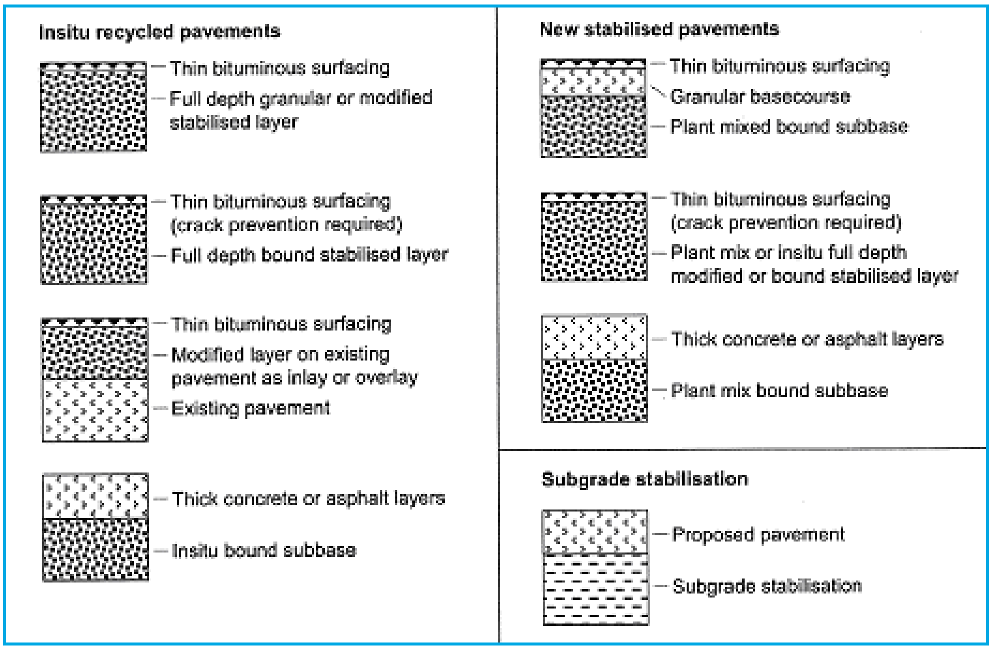
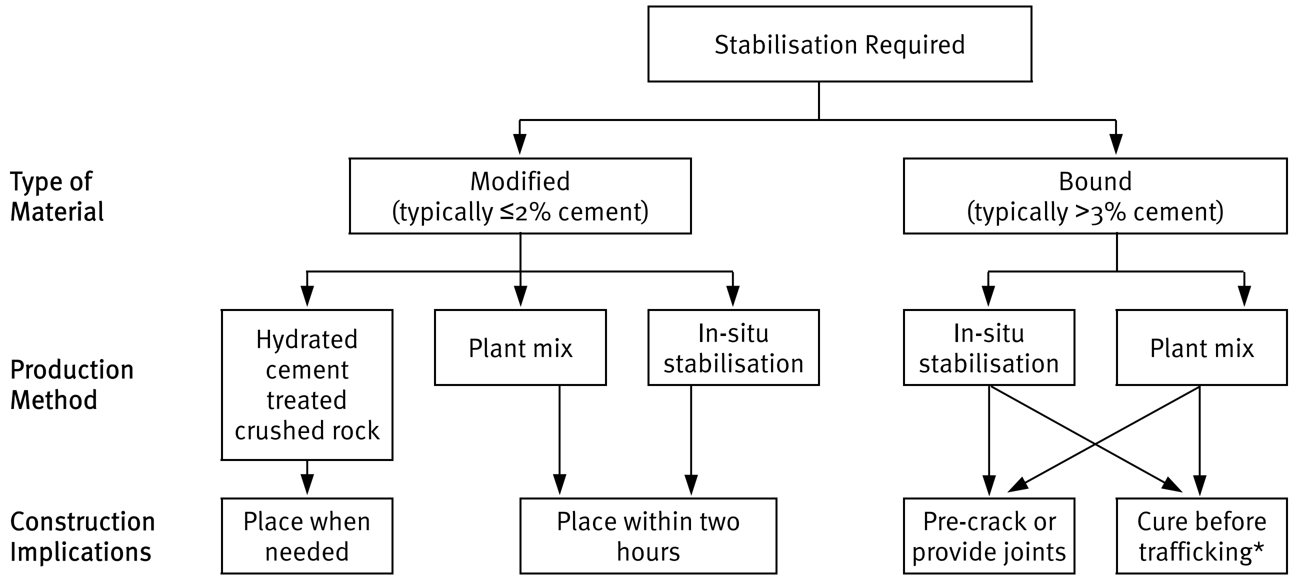


Figure 2: Typical configurations incorporating stabilised pavement layers and subgrades (Austroads 2006).



* There are methods used overseas to determine if the stabilised material can be trafficked immediately – see the Britpave (2005) publication in **References and Further Reading**.

Figure 3: Relationships between the types of material types, production methods and placing.

Table 1: Suitability of materials for cement stabilisation (Austroads 2006).

MORE THAN 25% PASSING 75 µm			LESS THAN 25% PASSING 75 µm		
PI ≤ 10	10 < PI < 20	PI ≥ 20	PI ≤ 6 PI x % passing 75 µm ≤ 60	PI ≤ 10	PI > 10
Usually suitable	Doubtful	Not Suitable	Usually Suitable		

The Plasticity Index (PI) and quantity of fines (material passing a 75 µm sieve) can be used as a guide for determining whether or not material from a particular source is suitable for cement stabilisation as illustrated in **Table 1** (Austroads 2006).

Most pavement materials and low plasticity subgrade soils can be stabilised with Portland cements meeting NZS 3122 Type GP, Type GB or Type LH requirements.

High plasticity soils like silts, clays and organic materials cannot be stabilised with cement alone, but a mixture of lime and cement may provide satisfactory stabilisation. Lime by itself will not significantly improve load bearing capacity but will react slowly with clay and reduce the moisture susceptibility of the material. The addition of cement provides early strength.

The amount of cement required is determined by the desired strength and other performance properties, and by the type of material being stabilised. **Table 2** indicates typical properties for modified and bound materials. The cement content may be optimised by testing materials representing

Table 2: Features of cement stabilised materials

	Modified	Bound
Typical Properties	Cement content 0.5 – 2%$^{(1)}$ 80 < CBR < 300 0.7<UCS$^{(2)}$<1.5 MPa Tensile Strength < 80kPa RLTT$^{(3)}$ = adequate rutting resistance	Cement content > 3%$^{(1)}$ UCS$^{(2)}$ > 3.0 MPa
Materials/ Layer Stabilised	Quarried granular material or recycled in-situ pavement.	Quarried granular material.
Construction Methodology	Cement and water are plant mixed with quarried granular materials. The mixed modified material is stockpiled for 7 days then turned and moved to a second stockpile, where it can be stored for a further 90 days. OR Cement and water are mixed by hoeing in-situ with either quarried granular materials or existing pavement layers.	Cement and water are plant mixed with quarried granular materials and used in the pavement within 2 hours of manufacture. OR Cement and water are mixed by hoeing in-situ with either quarried granular materials or existing pavement layers.
Applications	An intermediate option bridging the gap between an unmodified and structural pavement for improving resistance to deformation and rutting. Enables the use of lower quality aggregates. State Highways with high traffic volumes.	Typically used to provide a sub-base with high strength over a weak substrate to support the overlying chip seal surfacing on thick asphalt pavement layers. Commonly used under rigid concrete pavements. High volume or heavily loaded roads.
Anticipated Performance Attributes	A flexible pavement with improved shear strength and resistance to rutting and deformation when wet.	Improved base or sub-base strength, but subject to tensile fatigue cracking if the bound layer is not thick enough. Also susceptible to transverse shrinkage cracking. A minimum cover of granular material or asphalt should be provided to prevent cracks reflecting to the surface.

Notes to Table 2:

1. Typical range of cement contents by mass.
2. Typical range of Characteristic Unconfined Compressive Strength. Determined from test specimens prepared using Standard compactive effort and air cured for a minimum 28 days and 4 hour soak conditioning.
3. Repeated Load Triaxial Test. Deformation curves are obtained for a range of stress conditions to develop models for predicting rutting and thereby determining the suitability of aggregates for use in high, medium or low traffic volume roads in either wet or dry conditions. When saturated, the stabilised material must demonstrate equivalent rutting resistance to a high quality granular material.

a range of cement contents for one or more of these properties. The Stabilising Working Group is currently developing appropriate test regimes that may include unconfined compressive strength, tensile strength, tensile modulus and resilient modulus.

The target strength depends on the application and the position of the material in the pavement. Bound materials have relatively high cement contents and may be prone to cracking, and are therefore suitable for use as sub-base materials covered by granular, structural asphaltic or rigid concrete. If designed using the Austroads method they must be at least 250 mm thick to prevent fatigue cracking. In New Zealand, modified materials are more popular than bound materials because they are less likely to crack and are less expensive because they use less cement and thinner layers.

Pavement Design

The 2004 Austroads Pavement Design Guide (Austroads, 2004) together with the 2007 Transit New Zealand Supplement (Transit New Zealand, 2007) and the Austroads guide to stabilised materials (Austroads, 2006), specifies the design method for pavements incorporating cement stabilised layers. For both pavement rehabilitation and new pavements the structural design is based on a mechanistic approach, whereby the pavement layers are modelled to compute tensile and vertical strains at critical locations within the pavement as detailed in Figure 4.

The Pavement Design Guide gives procedures for calculating the tensile strain in the bound layer and the compressive strain on the subgrade. The calculations in Australasia are performed using the elastic layer analysis software package Circly.

The pavement designer has to determine the thickness of the pavement layers such that the compressive strain, imposed by a standard truck axle, on the subgrade is maintained below a value such that rutting does not occur within the design life.

If the upper pavement layers (sub-base or basecourse) contain enough cement to classify the material as "bound" the pavement may be susceptible to fatigue cracking. The designer therefore should select a layer thickness such that the tensile strain at the bottom of the bound layer is below a value such that fatigue failure does not occur within the design life.

Design of pavements with one or more cement stabilised layers generally involves the following processes:

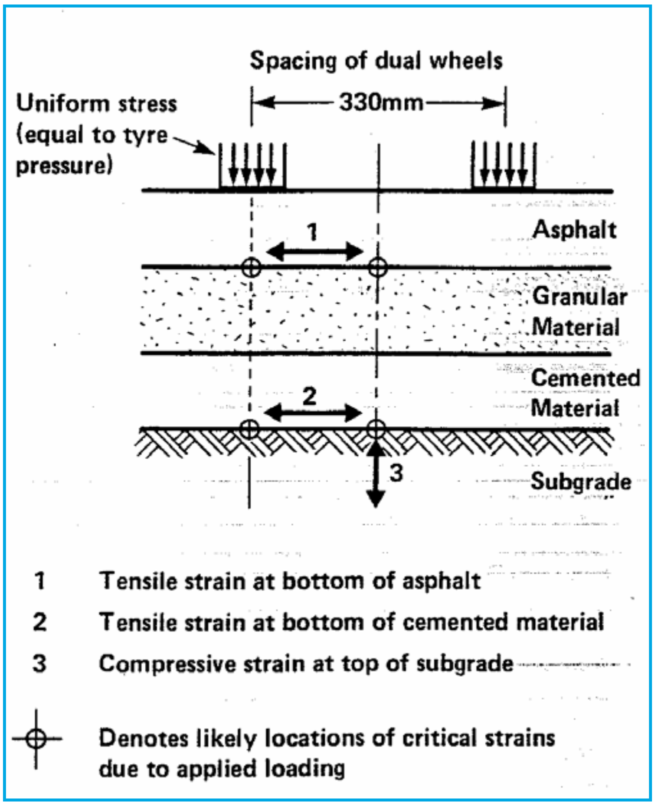


Figure 4: Critical locations of strain for pavement design (Austroads 2004).

- **Site Investigation:** Define the existing subgrade, and the existing pavement where applicable. Determine material strengths, depths and suitability for cement stabilisation by coring, laboratory testing of site samples (see Tables 1 and 2), Falling Weight Deflectometer tests on existing pavements, and subgrade California Bearing Ratio (CBR) tests.

- **Laboratory Mix Design:** Determine the quantity of cement required to produce the type of stabilised pavement selected (see Table 2).

- **Pavement/Structural Design:** Determine the thickness of pavement to meet the design traffic loading.

- **Bituminous Seal Design:** Determine whether the stabilised pavement layer will be sealed with thin asphalt/spray seal, concrete or asphalt.

- **Ancillary Designs:** Determine ancillary aspects of design associated with enhancing pavement performance, e.g. drainage and shoulder treatments.

- **Specification Development:** Determine the quality assurance required for both materials supply and construction to ensure compliance with design assumptions and recommendations.

Pavement Rehabilitation

When designing an in-situ stabilisation option for pavement rehabilitation, stiffness (resilient modulus) and thickness of the existing pavement layers and subgrade need to be determined. This enables the pavement to be modelled to establish the performance of various stabilised depths with or without an overlay. The information required can be obtained from Falling Weight Deflectometer tests to measure pavement surface deflections and pavement coring, and/or test pits, to determine thickness. Core samples may be tested in the laboratory to determine whether or not the in-situ materials are suitable for use with cement (see Tables 1 and 2), and to measure properties such as unconfined compressive strength, indirect tensile strength and resilient modulus.

Transit NZ B/5 Notes recommends:

> "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;
> - Scala penetrometer test to a minimum depth of 1 m from the top of the subgrade;
> - Grading and plasticity of the material from the upper pavement layer(s) that will be hoed by stabilising operations; and
> - Moisture content(s) of each layer at the time of the investigation."

The depth of pavement that can be stabilised in-situ in one pass has increased with the availability of more powerful equipment. A depth of stabilisation of up to 500 mm is possible with equipment currently in New Zealand. The depth may increase in future with further developments in equipment technology and capital investment.

Where the materials in a pavement requiring rehabilitation are poor they can sometimes be modified with the addition of a small quantity of cement. More typically the pavement depth needs to be increased to support higher traffic volumes and the grading of the in-situ materials will not be optimum. In this case a quantity of "make up" aggregate is laid on top of the pavement and then mixed into the underlying material – again with the addition of cement. A typical New Zealand basecourse has a maximum stone size of 40 mm, but it will be crushed to a smaller maximum size by the stabilising machine. To counteract this, a 65 mm maximum sized aggregate is used as a make up aggregate so that the desired aggregate grading for the stabilised basecourse is obtained on completion of the stabilisation process.

New Pavements

The design of new pavements in accordance with Austroads' Pavement Design Guide begins with determining the subgrade properties as defined by the 10th percentile subgrade CBR. Different pavement configurations and layer thicknesses over the subgrade are then modelled to identify combinations that achieve the required pavement design life.

Table 3 describes the advantages and disadvantages of various combinations of granular and stabilised base and sub-base layers.

For new pavements the subgrade soil can be stabilised to significantly increase its strength. This stabilised subgrade soil is referred to as a subgrade improvement layer (see **Figure 5**). Cement can be used as the stabilising agent for non-plastic subgrade soils (see **Table 1**). Lime or a blend of lime and cement may be used to stabilise high plasticity subgrade soils. In some cases a blend of cement and lime is used as a binder to cover the range of soils found on site.

Reducing/Eliminating Cracking

Cement stabilised pavements made with bound materials, i.e. those containing relatively high cement contents, are susceptible to two types of cracking:

Table 3: Cement Stabilised Pavement Options

	Type of Pavement		
	Modified Base	**Cemented Sub-base**	**Modified Base and Cemented Sub-base**
Base	Modified	Granular	Modified
Sub-base	Granular	Bound	Bound
Advantages	Improved resistance to moisture leads to reduced rutting and fewer potholes. Can utilise lower quality aggregates. Hydrated plant mixes allow cement modified aggregates to be prepared in advance, thus avoiding problems associated with time constraints for placing.	Unbound granular cover guards against cracks reflecting through to surface. Cemented sub-base provides a solid base for compaction, and reduces pavement depth over soft subgrades.	As for modified base. Cemented sub-base provides a solid base for compaction, and reduces pavement depth over soft subgrades. Modified base is resistant to failure if water gets trapped.
Disadvantages	Not all aggregates are suitable for stabilisation. Granular sub-base layers may be prone to rutting. Cement content is critical. Adding too much cement will produce a bound material, which may crack. Adding too little cement will increase the risk of rutting and other deformations.	Water trapped in granular base layers can cause rutting failure.	Precautions need to be taken to prevent cracks reflecting through the surfacing. Base and sub-base both susceptible to shrinkage cracking. Precautions needed to prevent cracks reflecting through the surfacing.
Comments	Appropriate laboratory testing is critical to determine the most suitable mix proportions (particle size distribution, cement content and water content) and method of manufacture (hydration in place or prehydrated) for optimum performance, and to avoid potential deformation and cracking of pavement.		

- Transverse cracking: transverse cracks approximately every 3-4 metres, caused by shrinkage of the cement stabilised material;
- Alligator cracking: closely spaced hexagonal cracks, caused by fatigue of the stabilised layer under trafficking. Occurs faster in thin layers over weak soils.

To reduce the risk of cracks reflecting through the road surface, either use low cement contents (i.e. modified material) in the base layer and/or overlay the cemented material with an unbound granular layer. Polymer modified chipseals (e.g. rubberised seal) reduce reflective seal cracking and are commonly used over cement stabilised bases.

Pre-cracking (also known as micro-cracking) reduces the number and width of large transverse cracks. Pre-cracking is the process of generating microcracks during construction by applying controlled heavy traffic loads immediately after placing and compacting the stabilised material.

Subsequent shrinkage movement is then accommodated by minute movements in the closely spaced microcracks rather than by generating large transverse cracks.

Construction

Cement and water can be blended with the aggregate on site ("in-situ stabilisation") or at a separate processing plant ("plant mix" and "HCTCRB").

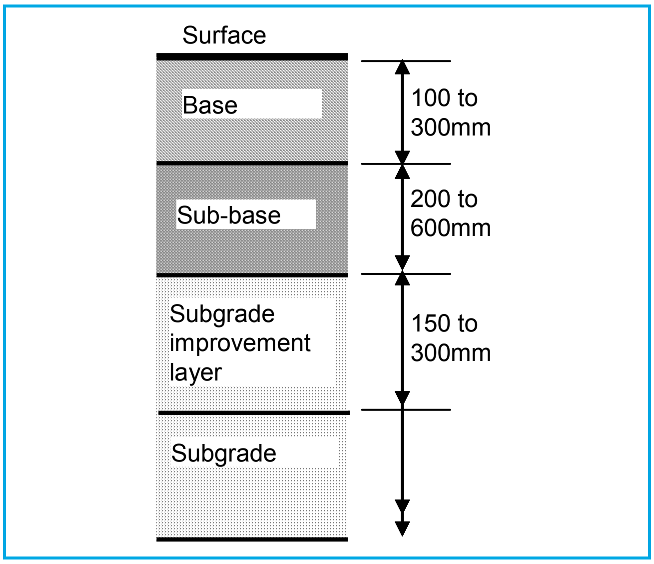


Figure 5: Pavement Layers in New Pavements.

In-situ Stabilisation

In-situ stabilisation is the process of mixing cement and water in place on the road (**Figure 6**). Cement is placed on top of a pre-dampened granular layer or existing road and then mixed in by hoe to a specified depth. Extra water is then applied from a following truck to provide the water needed to hydrate the cement. Finally, the layers are compacted by several passes of a vibrating roller.

In-situ stabilisation is common for pavement rehabilitation and can be used for new pavements using imported granular materials. Additional coarse aggregate and cement may be needed to allow for breakdown of aggregates. Laboratory testing of the hoed material is recommended to ensure that the cement stabilised material achieves the required strength.

Although the required cement can be spread in front of the stabiliser it tends to be added separately from the water in a self contained mixing chamber.

Plant Mix

Plant mix is produced by continuous feed mixing or in a pugmill at static mixing plants (**Figure 7**). Electronic weighing systems and automated batching improve control over the mix proportions of aggregates, binders, water and additives.

Plant mix provides tighter control of batch quantities than in-situ mixing. Consequently it is more suitable for new modified basecourse layers. Plant mix needs to be placed within two hours of manufacture.

Figure 6: Insitu Stabilisation (Austroads 2006).

Figure 7: Static batch mixing plant (Austroads 2006).

Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Hydrated Cement Treated Crushed Rock Base (HCTCRB) was developed by Main Roads Western Australia as an alternative to modified basecourse produced by in-situ or plant mixing as described above. It enables modified basecourse to be stockpiled at a central plant for up to three months before it is placed, thus avoiding the time constraints associated with normal plant mix.

Cement and water are mixed with aggregate in a pugmill at the quarry. The mixture is stockpiled for a day, turned after 24 hours to break the cementitious bonds, then stockpiled until use. During the first seven days the stockpile is kept moist to ensure the cement is hydrated. Low plasticity clay may be added to the mixture to improve workability and cohesion, hold added moisture and assist compaction.

A related process involves blending aggregate with waste fresh concrete from ready mix concrete plants, adding extra cement if necessary. The resulting material is known as Concrete Waste Road Base (CWRB).

Further information on these processes is available from CCANZ.

Laying and Compaction

Transit NZ specifications TNZ B/2 and B/5 specify requirements for laying and compaction.

Conclusion

Cement stabilisation is a proven technique for improving the life to road pavements, thus minimising waste, conserving resources and helping to provide a sustainable outcome.

By adopting appropriate materials and methods, cement stabilisation can prolong the life of new or existing road pavements in a cost effective manner.

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