7. CEMENT AND LIME-STABILISED MATERIALS

7.1 INTRODUCTION

This chapter gives guidance on the manufacture and use of cement and lime-stabilised materials in roadbase, sub-base, capping and selected fill layers of pavements. The stabilising process involves the addition of a stabilising agent to the soil, intimate mixing with sufficient water to achieve the optimum moisture content, compaction of the mixture, and final curing to ensure that the strength potential is realised. The subject has been reviewed by Sherwood (1993).

Many natural materials can be stabilised to make them suitable for road pavements but this process is only economical when the cost of overcoming a deficiency in one material is less than the cost of importing another material which is satisfactory without stabilisation.

Stabilisation can enhance the properties of road materials and pavement layers in the following ways.

- A substantial proportion of their strength is retained when they become saturated with water.
- Surface deflections are reduced.
- Resistance to erosion is increased.
- Materials in the supporting layer cannot contaminate the stabilised layer.
- The effective elastic moduli of granular layers constructed above stabilised layers are increased.
- Lime-stabilised material is suitable for use as a capping layer or working platform when the in situ material is excessively wet or weak and removal is not economical.

Associated with these desirable qualities are several possible problems:

- Traffic, thermal and shrinkage stresses can cause stabilised layers to crack.
- Cracks can reflect through the surfacing and allow water to enter the pavement structure.
- If carbon dioxide has access to the material, the stabilisation reactions are reversible and the strength of the layers can decrease.
- The construction operations require more skill and control than for the equivalent unstabilised material.

Methods of dealing with these problems are outlined in Section 7.7.

The minimum acceptable strength of a stabilised material depends on its position in the pavement structure and the level of traffic. It must be sufficiently strong to resist traffic stresses but upper limits of strength are usually set to minimise the risk of reflection cracking. Three types of stabilised layer have been used in the structural design catalogue and the strengths required for each are defined in Table 7.1.

7.2 THE STABILISATION PROCESS

When lime is added to a cohesive soil, calcium ions replace sodium ions in the clay fraction until the soil becomes saturated with calcium and the pH rises to a value in excess of 12 (a highly alkaline). The quantity of lime required to satisfy these reactions is determined by the initial consumption of lime test (ICL) (British Standard 1924 (1990)).

The solubility of silica and alumina in the soil increases dramatically when the pH is greater than 12 and their reaction with lime can then proceed producing cementitious calcium silicates and aluminates. Amorphous silica reacts particularly well with lime. The cementitious compounds form a skeleton which holds the soil particles and aggregates together (NITRR (1986)).

The primary hydration of cement forms calcium silicate and aluminates, releasing lime which reacts with sodium components, as described above, to produce additional cementitious material.

### TABLE 7.1

Properties of cement and lime-stabilised materials

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Unconfined compressive strength* (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB1</td>
<td>Stabilised roadbase</td>
<td>3.0 - 6.0</td>
</tr>
<tr>
<td>CB2</td>
<td>Stabilised roadbase</td>
<td>1.5 - 3.0</td>
</tr>
<tr>
<td>CS</td>
<td>Stabilised sub-base</td>
<td>0.75 - 1.5</td>
</tr>
</tbody>
</table>

* Strength tests on 150 mm cubes (see Section 7.4)
7.3 SELECTION OF TYPE OF TREATMENT

The selection of the stabiliser is based on the plasticity and particle size distribution of the material to be treated. The appropriate stabiliser can be selected according to the criteria shown in Table 7.2 adapted from NAASRA (1986).

Some control over the grading can be achieved by limiting the coefficient of uniformity to a minimum value of 5. The coefficient of uniformity is defined as the ratio of the sieve size through which 60 per cent of the material passes to the sieve size through which 10 per cent passes (D60/D10 in the nomenclature of Section 6.2.3). If the coefficient of uniformity lies below this value, the cost of stabilisation will be high and the maintenance of cracks in the finished road could be expensive. Except for materials containing amorphous silica e.g. some sandstones and chert, material with low plasticity is usually best treated with cement. However, reactive silica in the form of pozzolans can be added to soils with low plasticity to make them suitable for stabilisation with lime. If the plasticity of the soil is high, there are usually sufficient reactive clay minerals which can be readily stabilised with lime. Cement is more difficult to mix intimately with plastic materials but this problem can be alleviated by pre-treating the soil with approximately 2 per cent of lime to make it more workable.

If possible, the quality of the material to be stabilised should meet the minimum standards set out in Table 7.3. Stabilised layers constructed from these materials are more likely to perform satisfactorily even if they are affected by carbonation during their lifetime (Section 7.7.3). Materials which do not comply with Table 7.3 can

### TABLE 7.2

<table>
<thead>
<tr>
<th>Type of stabilisation</th>
<th>More than 25% passing the 0.075 mm sieve</th>
<th>Less than 25% passing the 0.075 mm sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pl≤10</td>
<td>10&lt;Pl≤20</td>
</tr>
<tr>
<td>Cement</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lime</td>
<td>*</td>
<td>Yes</td>
</tr>
<tr>
<td>Lime-Pozzolan</td>
<td>Yes</td>
<td>*</td>
</tr>
</tbody>
</table>

Notes. 1. * Indicates that the agent will have marginal effectiveness
2. PP = Plasticity Product (see Chapter 6).

### TABLE 7.3

Desirable properties of material before stabilisation

<table>
<thead>
<tr>
<th>BS test sieve (mm)</th>
<th>Percentage by mass of total aggregate passing test sieve</th>
<th>CB1</th>
<th>CB2</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td>85 - 100</td>
<td>80 - 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>60 - 90</td>
<td>55 - 90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>30 - 65</td>
<td>25 - 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20 - 50</td>
<td>15 - 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.425</td>
<td>10 - 30</td>
<td>10 - 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>5 - 15</td>
<td>5 - 15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum allowable value

<table>
<thead>
<tr>
<th></th>
<th>CB1</th>
<th>CB2</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>6</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>LS</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Note. It is recommended that materials should have a coefficient of uniformity of 5 or more.
sometimes be stabilised but more additive will be required and the cost and the risk from cracking and carbonation will increase.

Some aspects of construction must also be considered in selecting the stabiliser. It is not always possible to divert traffic during construction and the work must then be carried out in half-widths. The rate of gain of strength in the pavement layer may sometimes need to be rapid so that traffic can be routed over the completed pavement as soon as possible. Under these circumstances, cement stabilisation, with a faster curing period, is likely to be more suitable than lime stabilisation.

Certain types of organic compounds in soils can affect the hydration of cement and inhibit the gain in strength. It is recommended that the effects of organic matter are assessed by strength tests as outlined below.

### 7.4 CEMENT STABILISATION

#### 7.4.1 Selection of cement content

The cement content determines whether the characteristics of the mixture are dominated by the properties of the original soil or by the hydration products. As the proportion of cement in the mixture increases, so the strength increases. Strength also increases with time. During the first one or two days after construction this increase is rapid. Thereafter, the rate slows down although strength gain continues provided the layer is well cured. The choice of cement content depends on the strength required, the durability of the mixture, and the soundness of the aggregate.

The minimum cement content, expressed as a percentage of the dry weight of soil, should exceed the quantity consumed in the initial ion exchange reactions. Until research into the initial consumption of cement (ICC) is completed, it is recommended that the percentage of cement added should be equal to or greater than the ICL. If there is any possibility that the material to be stabilised is unsound e.g., weathered basic igneous materials, then the Gravel ICL Test (NITRR (1984)) is preferred. In this test the aggregate is ground up to release any active clay minerals and the total sample tested.

The durability of the stabilised mixture which satisfies the strength requirements for the particular layer should also be assessed. Mixtures produced from sound materials complying with the minimum requirements of Table 7.3 can be assumed to be durable if they achieve the design strength. Mixtures produced from other materials should be checked using the wet-dry brushing test (ASTM (1987)) which gives a good indication of the likelihood that a stabilised material will retain adequate strength during its service life in a pavement (Paige-Green et al (1990)).

Additional stabiliser is normally incorporated to take account of the variability in mixing which occurs on site. If good control is exercised over the construction operations, an extra one per cent of stabiliser is satisfactory for this purpose.

#### 7.4.2 Preparation of specimens

The optimum moisture content and the maximum dry density for mixtures of soil plus stabiliser are determined according to British Standard 1924 (1990) for additions of 2, 4, 6 and 8 per cent of cement. These specimens should be compacted as soon as the mixing is completed. Delays of the order of two hours occurring in practice and changes taking place within the mixed material result in changes in their compaction characteristics.

To determine the sensitivity of the stabilised material to delays in compaction, another set of tests must be conducted after two hours have elapsed since the completion of mixing.

Samples for the strength tests should also be mixed and left for two hours before being compacted into 150 mm cubes at 97 per cent of the maximum dry density obtained, after a similar two hour delay, in the British Standard (Heavy) Compaction Test, 4.5 kg rammer. These samples are then moist cured for 7 days and soaked for 7 days in accordance with BS 1924.

Two methods of moist curing are described in the Standard. The preferred method is to seal the specimens in wax but if this is not possible, they must be wrapped in cling film and sealed in plastic bags. The specimens should be maintained at 25°C during the whole curing and soaking period.

When the soaking phase is completed, the samples are crushed, their strengths measured, and an estimate made of the cement content needed to achieve the target strength.

If suitable moulds are not available to produce cube specimens then 200 mm x 100 mm cylinders, 115.5 mm x 105 mm cylinders or 127 mm x 152 mm cylinders may be used and the results multiplied by the following correction factors to calculate equivalent cube strengths.

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mm x 100 mm diameter</td>
<td>1.25</td>
</tr>
<tr>
<td>115.5 mm x 105 mm diameter</td>
<td>1.04</td>
</tr>
<tr>
<td>127 mm x 152 mm diameter</td>
<td>0.96</td>
</tr>
</tbody>
</table>

As an alternative, the strength of stabilised sub-base material may be measured by the CBR test after 7 days of moist curing and 7 days of soaking. A minimum strength of 70 CBR is recommended.

When the plasticity of the soil makes it difficult to pulverise and mix intimately with the cement, the workability can be improved by first pre-treating the sod with 2 to 3 per cent of lime, lightly compacting the mixture, and leaving it to stand for 24 hours. The material is then repulverised and stabilised with cement. If this method is used, the laboratory design procedure is modified to include the pre-treatment phase before testing as described above.
7.5 LIME STABILISATION

7.5.1 Properties of lime-stabilised materials

When lime is added to a plastic material, it first flocculates the clay and substantially reduces the plasticity index. This reduction of plasticity is time dependent during the initial weeks, and has the effect of increasing the optimum moisture content and decreasing the maximum dry density in compaction. The compaction characteristics are therefore constantly changing with time and delays in compaction cause reductions in density and consequential reductions in strength and durability. The workability of the soil also improves as the soil becomes more friable. If the amount of lime added exceeds the ICL, the stabilised material will generally be non-plastic or only slightly plastic.

Both the ion exchange reaction and the production of cementitious materials increases the stability and reduces the volume change within the clay fraction. It is not unusual for the swell to be reduced from 7 or 8 per cent to 0.1 per cent by the addition of lime. The ion exchange reaction occurs quickly and can increase the CBR of clayey materials by a factor of two or three.

The production of cementitious materials can continue for ten years or more but the strength developed will be influenced by the materials and the environment. The elastic modulus behaves similarly to the strength and continues to increase for a number of years. Between the ages of one month and two to three years there can be a four-fold increase in the elastic modulus.

7.5.2 Types of lime

The most common form of commercial lime used in lime stabilisation is hydrated high calcium lime, Ca(OH)$_2$, but monohydrated dolomitic lime, Ca(OH)$_2$.MgO, calcitic quick lime, CaO, and dolomitic quicklime, CaO.MgO are also used.

For hydrated high calcium lime, the majority of the free lime, which is defined as the calcium oxide and calcium hydroxide that is not combined with other constituents, should be present as calcium hydroxide. British Standard 890 requires a minimum free lime and magnesia content, (CaO + MgO), of 65 per cent.

Quicklime has a much higher bulk density than hydrated lime and it can be produced in various aggregate sizes. It is less dusty than hydrated lime but the dust is much more dangerous and strict safety precautions are necessary when it is used.

For quicklime, British Standard 890 requires a minimum free lime and magnesia content, (CaO + MgO), of 85 per cent.

Quicklime is an excellent stabiliser if the material is very wet. When it comes into contact with the wet soil the quicklime absorbs a large amount of water as it hydrates. This process is exothermic and the heat produced acts as a further drying agent for the soil. The removal of water and the increase in plastic limit cause a substantial and rapid increase in the strength and trafficability of the wet material.

In many parts of the world, lime has been produced on a small scale for many hundreds of years to make mortars and lime washes for buildings. Different types of kilns have been used and most appear to be relatively effective. Trials have been carried out by TRRL in Ghana (Elks (1974)) to determine the output possible from small kilns and to assess the suitability of lime produced without commercial process control for soil stabilisation. Small batch kilns have subsequently been used to produce lime for stabilised layers on major road projects.

7.5.3 Selection of lime content

The procedure for selecting the lime content follows the steps used for selecting cement content and should, therefore, be carried out in accordance with British Standard 1924 (1990). The curing period for lime-stabilised materials is 21 days of moist cure followed by 7 days of soaking.

In tropical and sub-tropical countries the temperature of the samples should be maintained at 25°C which is near to the ambient temperature. Accelerated curing at higher temperatures is not recommended because the correlation with normal curing at temperatures near to the ambient temperature can differ from soil to soil. At high temperatures the reaction products formed by lime and the reactive silica in the soil can be completely different from those formed at ambient temperatures.

7.6 POZZOLANS

One of the primary sources of pozzolan is the pulversed fuel ash (PFA) collected from the boilers of coal-fired electricity generating stations.

PFA is usually mixed with lime in the proportions of 1 of lime to 3 or 4 of PFA but ratios of 1 to 2 up to 1 to 10 are used. The proportion depends on the reactivity of the particular fly ash which varies substantially from source to source. Lime and fly ash treated layers have a similar performance to cement treated layers constructed from the same aggregate material. The final mixtures should be chosen after a series of laboratory tests carried out after 21 days of moist cure and 7 days of soaking to determine the optimum ratio of lime to fly ash and the optimum lime content (expressed as a percentage of dry soil).

In many tropical countries there are substantial quantities of bagasse (the fibrous residue from the crushing of sugar cane) and husks from rice. Both are rich in silica. When burnt, their ash contains a substantial amount of amorphous silica which reacts with lime (Cook and Suwanvitaya (1982), Mehta (1979)).

Lime and rice-husk ash mixtures gain strength quickly during the early period of curing but little additional strength is obtained after 28 days of moist curing. The long-term strength depends on the stability of the calcium...
silicate hydrates. Under certain conditions lime leaching can occur and eventually the strength will be reduced, but the presence of excess lime (free lime) can stabilise the calcium silicate hydrate. Mixtures of lime and rice-husk ash in the proportions 2:3 are the most stable and have the highest strength but the durability may be improved by increasing the lime content to give a 1:1 mixture.

7.7 CONSTRUCTION

7.7.1 General methodology

The construction of stabilised layers follows the same procedure whether the stabilising agent is cement, lime or mixtures of lime Pozzolan. After the surface of the layer has been shaped, the stabiliser is spread and then mixed through the layer. Sufficient water is added to meet the compaction requirements and the material mixed again. The layer must be compacted as soon as possible, trimmed, re-rolled and then cured. The effect of each operation on the design and performance of the pavement is discussed below.

Spreading the stabiliser. The stabiliser can be spread manually by ‘spotting’ the bags at predetermined intervals, breaking the bags and then raking the stabiliser across the surface as uniformly as possible. Lime has a much lower bulk density than cement and it is possible to achieve a more uniform distribution with lime when stabilisers are spread manually. Alternatively, mechanical spreaders can be used to meter the required amount of stabiliser onto the surface.

Mixing. Robust mixing equipment of suitable power for the pavement layer being processed is capable of pulverising the soil and blending it with the stabiliser and water. The most efficient of these machines carry out the operation in one pass, enabling the layer to be compacted quickly and minimising the loss of density and strength caused by any delay in compaction. Multi-pass machines are satisfactory provided the length of pavement being processed is not excessive and each section of pavement can be processed within an acceptable time. Graders have been used to mix stabilised materials but they are inefficient for pulverising cohesive materials and a considerable number of passes are needed before the quality of mixing is acceptable. They are therefore very slow and should only be considered for processing lime-stabilised layers because of the greater workability of lime-stabilised materials and the subsequent diffusion of lime through the soil aggregations (Stocker (1972)).

Plant pre-mixing gives the possibility of better control than in- place spreading and mixing provided that the plant is close enough to the site to overcome possible problems caused by delays in delivery. This can often be justified by the lower safety margins on stabiliser content and target layer thicknesses that are possible.

Compaction. A stabilised layer must be compacted as soon as possible after mixing has been completed in order that the full strength potential can be realised and the density can be achieved without over stressing the material. If the layer is over stressed, shear planes will be formed near the top of the layer and premature failure along this plane is likely, particularly when the layer is only covered by a surface dressing.

Multi-layer construction. When two or more lifts are required to construct a thick layer of stabilised material, care must be taken to prevent carbonation at the surface of the bottom lift. It is also important that the stabiliser is mixed to the full depth of each layer. A weak band of any type can cause over stressing and premature failure of the top lift followed by deterioration of the lower section.

In general, the thickness of a lift should not be greater than 200 mm or less than 100 mm.

Care should be taken to reduce the density gradient in the layer because permeable material in the lower part of the layer makes it more susceptible to carbonation from below. If necessary, a layer should be compacted in two parts to make the bottom less permeable.

The compaction operation should be completed within two hours and the length of road which is processed at any time should be adjusted to allow this to be achieved.

Curing. Proper curing is very important for three reasons:

- It ensures that sufficient moisture is retained in the layer so that the stabiliser can continue to hydrate.
- It reduces shrinkage
- It reduces the risk of carbonation from the top of the layer

In a hot and dry climate the need for good curing is very important but the prevention of moisture loss is difficult. If the surface is sprayed constantly and kept damp day and night, the moisture content in the main portion of the layer will remain stable but the operation is likely to leach stabiliser from the top portion of the layer. If the spraying operation is intermittent and the surface dries from time to time (a common occurrence when this method is used), the curing will be completely ineffective.

Spraying can be a much more efficient curing system if a layer of sand, 30 to 40 mm thick, is first spread on top of the stabilised layer. If this is done the number of spraying cycles per day can be reduced and there is a considerable saving in the amount of water used. After seven days, the sand should be brushed off and the surface primed with a low viscosity cutback bitumen.

An alternative method of curing is to first apply a very light spray of water followed by either a viscous cutback bitumen, such as MC 3000, or a slow-setting emulsion. Neither of these will completely penetrate the surface of the stabilised layer and will leave a continuous bitumen film to act as a curing membrane. It is essential that all traffic is kept off the membrane for seven days. After this time, any excess bitumen can be absorbed by sanding the surface.
A prime coat cannot serve as a curing membrane. Research has shown that a prime penetrates too far into the layer and insufficient bitumen is retained on the surface to provide the necessary continuous film (Bofinger et al (1978)).

7.7.2 Control of shrinkage and reflection cracks

There is no simple method of preventing shrinkage cracks occurring in stabilised layers. However, design and construction techniques can be adopted which go some way to alleviating the problem.

Shrinkage, particularly in cement-stabilised materials, has been shown (Bofinger et al (1978)) to be influenced by

- Loss of water, particularly during the initial curing period.
- Cement content.
- Density of the compacted material.
- Method of compaction.
- Pre-treatment moisture content of the material to be stabilised.

Proper curing is essential not only for maintaining the hydration action but also to reduce volume changes within the layer. The longer the initial period of moist cure the smaller the shrinkage when the layer subsequently dries.

When the layer eventually dries, the increased strength associated with a high stabiliser content will cause the shrinkage cracks to form at increased spacing and have substantial width. With lower cement contents, the shrinkage cracks occur at reduced spacing and the material will crack more readily under traffic because of its reduced strength. The probability of these finer cracks reflecting through the surfacing is reduced, but the stabilised layer itself will be both weaker and less durable.

In order to maximise both the strength and durability of the pavement layer the material is generally compacted to the maximum density possible. However, for some stabilised materials it is sometimes difficult to achieve normal compaction standards and any increase in compactive effort to achieve them may have the adverse effect of causing shear planes in the surface of the layer or increasing the subsequent shrinkage of the material as its density is increased. If it proves difficult to achieve the target density, a higher stabiliser content should be considered in order that an adequately strong and durable layer can be produced at a lower density.

Laboratory tests have shown that samples compacted by impact loading shrink considerably more than those compacted by static loading or by kneading compaction. Where reflection cracking is likely to be a problem, it is therefore recommended that the layer should be compacted with pneumatic-tyred rollers rather than vibrating types.

Shrinkage problems in plastic gravels can be substantially reduced if air-dry gravel is used and the whole construction is completed within two hours, the water being added as late as possible during the mixing operation. It is generally not possible to use gravel in a completely air-dry condition, but the lower the initial moisture content and the quicker it is mixed and compacted, the smaller will be the subsequent shrinkage strains.

Having accepted that some shrinkage cracks are inevitable in the stabilised layer, the most effective method of preventing these from reflecting through the bituminous surfacing is to cover the cemented layer with a substantial thickness of granular material. This is the design philosophy in Charts numbered 2, 4 and 6 in Chapter 10. When cemented material is used as a roadbase (Chart 8) a flexible surfacing such as a double surface dressing is recommended. Experience in a number of countries has shown that a further surface dressing applied after 2-3 years can partially or completely seal any subsequent cracking, particularly where lime is the stabilising agent.

7.7.3 Carbonation

If cement or lime-stabilised materials are exposed to air, the hydration products may react with carbon dioxide thereby reducing the strength of the material by an average of 40 per cent of the unconfined compressive strength (Paige-Green et al (1990)). This reaction is associated with a decrease in the pH of the material from more than 12 to about 8.5. The presence and depth of carbonation can be detected by testing the pH of the stabilised layer with phenolphthalein indicator and checking for the presence of carbonates with hydrochloric acid (Netterberg (1984)). A reasonable indication of whether the material being stabilised will be subject to serious carbonation can be obtained from the wet/dry test for durability (Paige-Green et al (1990)).

Good curing practices, as outlined in Section 7.7.1, are the best means of preventing carbonation in roadbases. The risk of carbonation can be reduced by taking the following precautions:

- Avoid wet/dry cycles during the curing phase.
- Seal as soon as possible to exclude carbon dioxide.
- Compact as early as possible to increase the density and to reduce the permeability.
- Reduce the possibility of reflection cracks.

There may be some conflict between the last two points and care should be taken not to over compact the layer.

Checks should be made during construction and if the depth of carbonated material is more than 2 to 3 mm the carbonated layer should be removed by heavy brushing or grading before the surfacing is applied.
7.8 QUALITY CONTROL

A high level of quality control is necessary in the manufacture of cement and lime-stabilised materials, as with all other materials used in the road pavement, but several factors need special consideration.

**Storage and handling of stabilisers.** Unless cement and lime are properly stored and used in a fresh condition the quality of the pavement layer will be substantially reduced. Cement must be stored in a solid, watertight shed and the bags stacked as tightly as possible. Doors and windows should only be opened if absolutely necessary. The cement which is delivered from the manufacturer first should also be used first. Even if cement is properly stored the following losses in strength will occur:-

- After 3 months 20% reduction
- After 6 months 30% reduction
- After 1 year 40% reduction
- After 2 years 50% reduction

Lime should be packed in sealed bags, tightly stacked and stored under cover or at least under a watertight tarpaulin. If it becomes contaminated or damp, it can only be used as a filler. Lime which is older than 6 months should be discarded.

**Distribution of stabiliser.** After the layer has been properly processed, at least 20 samples should be taken for determination of the stabiliser content. The mixing efficiency is acceptable if the coefficient of variation is less than 30 per cent. Great care is necessary in multi-layer construction to ensure that good mixing extends to the full depth of all the layers.

**Opening to traffic.** Insufficient research has been carried out to determine the precise effects of opening a road to traffic before the completion of the curing period but it is considered that allowing traffic on the pavement during the first two days can be beneficial for some stabilised layers provided the traffic does not mark the 'green' surface and all traffic is kept off the pavement from the end of the second day until one week has elapsed (Williams (1986)). Early trafficking has a similar effect to that of pre-cracking the layer by rolling within a day or two of its construction but rolling is preferred because it ensures even coverage of the full width of the carriageway.

Layers which are pre-cracked or trafficked early must be allowed to develop sufficient strength to prevent abrasion of the edges of each crack before the layer is opened to general traffic. The slab strength of these layers is effectively destroyed and it is recommended that early trafficking is only acceptable for layers of cemented roadbase type CB2.