The IPWEA’s biennial Conference, Darwin 11-15 August 2013

Title; GUIDE FOR PAVEMENT STABILISER

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Reviewed by; Prof A Yeung Hong Kong University and Prof Tai Sik Lee Hanyang University.

ABSTRACT

I have been charged by Asian Civil Engineering Co-ordinating Committee to prepare a guide for pavement stabiliser additives for various sub-grade characteristics, and loadings and conditions. There are numerous manuals to guide practitioners as to standards and types of additive or additives to be used for road, rail and dam construction but fall short in other construction areas. I have discovered that there is little information to guide engineers as to the type of additive or additives for various soil characteristics and the standards required for construction working platforms. There has been here in Australia a lack of attention paid to permeability flows and differential movement while other concerns include a guide for minimum depth for a stabilised pavement. It is intended to set standards for the types of additives to be used to meet the various soils and conditions. Erosion testing methodology for embankments subject to water flows must be established and include the method of application for environmental pavements to be applied to embankments. The terminology “pavement” is usually associated with the various layers of quarry products that makeup either a road or rail projects. For terminology can also be applied to aerodromes, water containment areas, landfills, working platforms in commercial/industrial projects, flood mitigation works and slope erosion control.

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Testing is to be carried out by Hong Kong University, Hanyang University in Korea, Taiwan University of Science and Technology, University of Melbourne. All this testing is to be managed by myself and audited by A/Prof Albert Yeung Hong Kong University

PREAMBLE

Engineers have a duty of care to enhance the environment and when they leave this world it should be a better place to live in than the one first entered.

Stabilisation assists engineers to achieve a better environment an enhanced amenity for the world’s citizens, by being less reliant on natural resources. It is also an achievable and worthwhile goal that where possible designs should specify the use of recycled materials such as concrete and asphalt in both construction projects and particularly for stabilised sub-grades.

Standards for stabilised pavements for roads and rail are well documented in technical publications by Vic Roads, ARRB, Australian Roads and Standards Australia. Shortage of natural materials globally, together with the Carbon Tax in Australia, has led to the increased need for sub-grade stabilisation for stronger, denser compaction, minimisation of differential movement and reduced permeability in sub-grades in road construction, aerodromes, slope erosion control, dam and landfill construction and commercial/industrial working platforms. Pavement stabilisation is a scientific approach to improve pavements in strength, permeability and deflection, this work should be designed and supervised by qualified engineers and the pavement mix tested by an experienced geo-technical engineer.
STABILISED BINDERS

- Lime
- Cement
- Enzymes
- Blends
  - Cement/lime
  - Slag/lime
  - Cement/lime/asphalt
  - Enzyme/cement
  - Bitumen/cement
  - Lime/fly/ash
- Foamed bitumen
- Dry powdered polymers

The most commonly used binders are:

- Lime
- Cement
- Dry powdered polymers
- Enzymes

Enzymes

An enzyme is a protein or a RNA (ribozymes) which is capable of initiating a chemical reaction, that involves changes (both formation and/ breakage) in chemical bonds. This method creates an interaction between the enzyme and the soil bacteria and is a replication of the natural construction of termite mounds. Enzyme soil stabilisation is based on reducing surface tension in soil particles through an ionic reaction, allowing increased soil compaction to occur. After the absorbed water is reduced through the compaction efforts, the soil particles agglomerate and as a result of the relative movement between particles, the surface area is reduced and less absorbed water can be held, which in turn reduces the swelling capacity. Source: R Valasquez University of Minnesota 2005

![Figure 1 Model Representation of a Typical Enzyme](image)

Table 1 Types of Stabilisation and Applicable Binder Applicable

<table>
<thead>
<tr>
<th>Binder</th>
<th>Subgrade</th>
<th>Type of Stabilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Modified</td>
</tr>
<tr>
<td>Lime</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Cement</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
<td>Bitumen</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
GEO-TECHNICAL ANALYSIS

Soil stabilization is the process that enhances an in-situ soil to support loads well in excess of those normally possible under natural conditions. Normal soil loading is approximately 200 to 600 kPa depending on the soil characteristics and classification. Loading capacities in excess of 1.5-3.0 mPa are easily obtained with stabilizing additives in conjunction with the use of proper soils, gradations and application of the aggregates, sands, fines. **Source: University of West of England, Bristol.** But it is imperative that geotechnical analysis of soil samples collected from prospective stabilized sites are carried out

Soil samples should be taken from the field from each different soil classification that is observed. In a road situation a rule of thumb application would be that samples should be taken every 300m, or less if there appears to be an inconsistency within the sampled area. Moisture content within the sample bore is also a good measure for indicating a change in soil characteristics. In a remote area then the use of geotechnical maps will assist in the location of samples if required.

In all projects where moisture has entered a pavement then permeability of the designed pavement mix MUST be tested in the laboratory to ensure specification requirements are either met or exceeded.

For Polymer applications testing required is:
(1) Grading minimum of 35% passing a 2.36mm sieve,
(2) Plastic Index ranging from NP to 20%
(3) CBR, best compared (soaked) against parent material.
(4) Capillary rise and swell- best if compared against parent material
(5) Optional RLT testing

For lime and cement applications testing required is:
(1) Grading
(2) Atterberg tests
(3) Swell
(4) Soaked CBR
(5) Unconfined compressive strength

For enzyme applications testing required is:
for natural soils
(1) gradation
(2) Atterberg limits
(3) pH
(4) Maximum density/optimum moisture
(5) California Bearing Ratio (CBR)
(6) Permeability.

In preparation of a pavement design further testing of the designed soil mixture with additives should comply with the normal pavement strengthening procedures

**Plastic Index** of 6 to 15 - Minimum 18% non granular cohesive fines passing the .075 micron sieve

**Maximum Density/Optimum Moisture**, this test will determine the amount of enzyme required to obtain maximum results. **Test method ASTM D-1557 modified proctor.** Enzyme rates ( based on trade name product Eko-Soil ) of 0.15,0.20,0.25,0.35,0.50 **Source: Tonji study and use as a guideline for this test,** this relates to 1-1.5 litres of enzyme to 30 cubic metres of compacted pavement

Moisture content to achieve maximum compaction should be 1-2% below optimum moisture content.

**Bearing strength or CBR.** **Test method ASTM D 1883.** This test will gauge the increase in the load bearing effectiveness of enzyme in comparison to the natural soil **Source Yeung field testing Hong Kong University 2012 that increased CBR in marine clay from 3% to 80% In the laboratory.** In the laboratory
testing the bearing test is non-conforming as to replicate field conditions. Mixed, compacted samples must be allowed to air dry for 72 hours before submersing in water

CONSTRUCTION

Enzyme pavements in the field are constructed in a similar manner to conventional stabilisation methods, using water tankers, motor graders with rippers and 12 tonne vibrating steel roller. Additives should be verified for weight/square metre to ensure that the quantity of additive meets specification. For speed of construction and to ensure an homogenous mix, self-propelling and towing mixing machines are recommended. Both types of machines can be fitted with a computer water feed system and in a recent project the author was involved with, 7000 square metres of 300mm deep stabilized was achieved in an eight hour day. Should rock or cement be required as part of the geo-tech design for addition to the pavement mix, this should be placed and mixed prior to the stabilisation process.

Cross fall should be at least 3% and side drains should be cut into the pavement. Just as the pavement is losing its plasticity a skim of one size crushed rock (10mm-) should be rolled into the top layer to provide a skid resistant surface. Light traffic can be allowed to traverse the pavement as soon as the wheel marks of the stabilisation equipment disappear. Full curing is achieved in 72 hours and after which the road may be opened to all traffic.

FLOOD MITIGATION

Stabilised pavements subject to inundation must be tested in the laboratory to ensure permeability either achieves or exceeds specification. Enzymes, or an enzyme blend with up to 3% cement, in laboratory and field testing has achieved specification, but has the advantage over clay pavements due to its residual tensile strength. This prevents cracking in the pavement once the water recedes. Stabilised pavements must envelope the road, or dam wall as experiences from in the recent floods at Maryborough in Victoria, when the decommissioned town water holding basin overflowed and scouring occurred on the down side of the dam wall. A catastrophe was averted by sandbagging the top of the wall.
CONCLUSION

1. It is imperative that geo-technical analysis of the pavement must be undertaken during construction to ensure that compaction Appendix A, strength Appendix B and permeability Appendix C specification standards are either met or exceeded. Deflection testing should be undertaken on large construction sites. Reactive clay sub-grades, land survey levels should be undertaken on the working platform surface on a monthly basis over at least a six month period.

2. In large commercial/industrial working platforms, must be graded to 0.5% to ensure drainage of the surface. Before placing a slab above a working platform, ensure a drainage membrane is in place. Trial and error experience has indicated that a 50mm depth of 19mm nominal size fine crushed rock spread over the surface of the working platform, is satisfactory not only for drainage but to ensure there is no machine skidding on the surface.

3. Test roll the sub-grade to assist in the assessment of sub-grade conditions. Any un-stabled areas should be rectified prior to re test rolling. Should the unstable area exceed 20% of total area then the whole area should be ripped.

4. Cover requirements on(capping layer) over reactive clays should be a minimum of 400mm.

5. Impervious capping layers are essential for sub-grade improvement in reactive clays and filled sites.

6. Using capping layers brings economies, (In the 65,000 square metres example in Figure 12 on page 12, the saving through using stabilisation of in-situ material over imported crushed rock was $750,000. At 2012 prices, the crushed rock option costed out at $1.5 million.

7. Capping layers/ working platforms for larger sites can provide for a pavement depth reduction. This site example on page 12, Figure 12, resulted in a reduction of slab depth from 200mm to 150mm due to the support from the high strength platform in the stabilised sub-grade.

8. Properly stabilised working platforms can eliminate differential settlement in the sub-grade and in so doing avoid potential for pavement cracking. In the reactive clay environment at the site in Figure 12, the conventional design south 1.0 metre depth of crushed rock while the enzyme stabilised option achieved a better result from 400mm of enzyme stabilisation.
The 6th Civil Engineering Conference in the Asian Region

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O’Donnell – Page 1 of 19
Pavement stabilisation is a scientific approach to better pavements and this work should be designed and supervised by qualified engineers and the pavement mix tested by an experienced geo-technical engineer

**OBJECTIVES**

- To provide a stronger, impervious, cost effective platform under a rigid or flexible pavement.
- To provide an all weather safe unbound pavement that is impervious, dust resistant, and cost effective and maintenance free for at least 15 years.
- To provide an impervious capping layer over reactive soils
- Promote the use of recycled materials such as asphalt and concrete where applicable
- Reduce construction time in unbound pavements, working platforms and capping layers as compared to conventional construction methods.
- Flood mitigation construction

**STABILISED BINDERS**

- Lime
- Cement
- Enzymes
- Blends
  - Cement/lime
  - Slag/lime
  - Cement/lime/asphalt
  - Enzyme/cement
  - Bitumen/cement
  - Lime/fly/ash
- Foamed bitumen
- Dry powdered polymers

The most commonly used binders are;

- Lime
- Cement
- Dry powdered polymers
- Enzymes

**Lime**

Hydrated lime in the presence of water creates an alkaline substance in which the lime with any Pozzolans (Materials containing reactive silica and alumina) Source: Auststab Pavement Recycling and Stabilisation Guide.

Lime can also be effectively used in drying out over-saturated subsoils prior to the stabilisation process. Lime is used in high content cohesive soils in many parts of the world today. This method was used in the belief that lime would reduce the soil’s affinity for water. Recent university tests reveal that lime stabilisation will not lower permeability as previously thought.
Enzymes

An enzyme is a protein or a RNA (ribozymes) which is capable of initiating a chemical reaction, that involves changes (both formation and breakage) in chemical bonds. This method creates an interaction between the enzyme and the soil bacteria and is a replication of the natural construction of termite mounds. Enzyme soil stabilisation is based on reducing surface tension in soil particles through an ionic reaction, allowing increased soil compaction to occur. After the absorbed water is reduced through the compaction efforts, the soil particles tend to agglomerate and as a result of the relative movement between particles, the surface area is reduced and less absorbed water can be held, which in turn reduces the swelling capacity. Source; R Valasquez University of Minnesota 2005

Cement

Cement is a combination of lime, silica, alumina, and other metal oxides, the components of which form a cement paste. This is cement stabilisation. Under proper conditions cement stabilization has been effectively used under proper conditions in soils that contain high amounts of silts.

Dry Powered Polymers (DPP)

DPP create a soil matrix that reduces permeability. DPP is highly attracted to clay, silt and soil particles. Common stabilising powders, consists of a polymer thermally bound to an inert “fine carrier” which is then mixed with hydrated lime. The lime is not coated with the polymer. The function of the lime is to flocculate and prepare clay particles for adhesion to the polymer. Source; Auststob Pavement Recycling and Stabilisation Guide.

<table>
<thead>
<tr>
<th>Binder Type</th>
<th>Subgrade</th>
<th>Type of Stabilisation</th>
<th>Bound</th>
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<tbody>
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<tr>
<td>Blumen</td>
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<tr>
<td>Blumen/ cement blends</td>
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<td>Granular</td>
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<td>Dry Powered Polymers</td>
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<tr>
<td>Miscellaneous Chemicals**</td>
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Table 1 Types of Stabilisation and Applicable Binder Applicable

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<thead>
<tr>
<th>Lime</th>
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<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
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<tr>
<td>Cement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
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<tr>
<td>Cementitious</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bitumen</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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For **Polymer applications** testing required is:
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(2) Plastic index ranging from NP to 20%
(3) CBR, best compared (soaked) against parent material.
(4) Capillary rise and swell- best if compared against parent material
(5) Optional RLT testing

For **lime and cement applications** testing required.
(1) Grading
(2) Atterberg tests
(3) Swell
(4) Soaked CBR
(5) Unconfined compressive strength

![Figure 3: General Guidelines for Road Construction](image-url)
Enzymes are best suited to cohesive clays adhering to the specification as stated below.

For enzyme applications testing required is:
for natural soils
(1) gradation
(2) Atterberg limits
(3) pH
(4) Maximum density/optimum moisture
(5) California Bearing Ratio (CBR)
(6) Permeability.
In preparation of a pavement design further testing of the designed soil mixture with additives should comply with the following;

Figure 3 Typical Laboratory and Field Apparatus
Plastic Index of 6 to 15 - Minimum 18% non granular cohesive fines passing the .075 micron sieve

Maximum Density/Optimum Moisture, this test will determine the amount of enzyme required to obtain maximum results. Test method ASTM D-1557 modified proctor. Enzyme rates (based on trade name product Eko-Soil) of 0.15, 0.20, 0.25, 0.35, 0.50 Source; Tonji study and use as a guideline for this test, this relates to 1-1.5 litres of enzyme to 30 cubic metres of compacted pavement.
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**Permeability** – Test method ASTM D – 5084 with the addition of enzyme, reduction in moisture directly affects the design of the structural section of the pavement. Reductions of up to 100-fold are achieved.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Permeability Coefficient k</th>
<th>Relative Permeability</th>
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</thead>
<tbody>
<tr>
<td>Coarse gravel</td>
<td>&gt; 10-1 cm/sec</td>
<td>High</td>
</tr>
<tr>
<td>4 CBR Load Test Machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand, clean</td>
<td>10-1- 10-3 cm/sec</td>
<td>Medium</td>
</tr>
<tr>
<td>Sand, dirty</td>
<td>10-3 – 10-5 cm/sec</td>
<td>Low</td>
</tr>
<tr>
<td>Silt</td>
<td>10-5-10-7 cm/sec</td>
<td>Very Low</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;10-7 cm/sec</td>
<td>Impervious</td>
</tr>
<tr>
<td>Enzyme soil treated</td>
<td>10-8 – 10-11 cm/sec</td>
<td>Impervious</td>
</tr>
</tbody>
</table>

Source; William Scruggs 2010

**Unconfined Compressive Strength** is also used to ensure that the pavement strength is between the range of 0.5MPa and 1.5MPa should the UCS exceeds this range it could be classified a rigid pavement and subject to cracking.
LATERITIC GRAVELS

Figure 5 Sources of Lateritic Materials in Tropical Regions  Source: ARRB

Lateric gravels, or ridge gravels, form from intense leaching of almost all silicates in well drained soils in tropical areas. Extensive testing by the US Corps of Engineers, in testing for aircraft landing pads in the tropics, established that gravels form a very good pavement without any additives.

Mechanical processing such as grading, excavating and compaction of the gravels may change the engineering characteristics of the soils. Further research with stabiliser binders maybe prove fruitful.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
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</thead>
<tbody>
<tr>
<td><strong>DESIGN CBR</strong></td>
<td>100*</td>
<td><strong>80</strong></td>
<td>70*</td>
</tr>
<tr>
<td><strong>LIQUID LIMIT (%) ASTM D 4318</strong></td>
<td>≤35**</td>
<td>≤40**</td>
<td>≤50**</td>
</tr>
<tr>
<td>LL x (% Fines)</td>
<td>≤600*</td>
<td>≤900*</td>
<td>≤1200*</td>
</tr>
<tr>
<td>Plasticity Index (%) ASTM D 4318</td>
<td>≤10</td>
<td>≤12</td>
<td></td>
</tr>
<tr>
<td>P' x (% Fines)</td>
<td>≤200*</td>
<td>≤400*</td>
<td>≤600*</td>
</tr>
<tr>
<td>Aggregate Crushing Value</td>
<td>&lt;35*</td>
<td>35-40*</td>
<td>40-50*</td>
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<tr>
<td>LA Abrasion ASTM C 131 and C 533</td>
<td>&lt;65**</td>
<td>&lt;65**</td>
<td></td>
</tr>
</tbody>
</table>

* Building and Road Research Institute, Ghana  ** Departamento Nacional de Estradas de Rodagem, Brazil.
+ equivalent to the design CBR of a crushed rock.

Source: ARRB
CONSTRUCTION

Figure 6 Typical Mixing Machine and water truck combined

Enzyme pavements in the field are constructed in a similar manner to conventional stabilisation methods, using water tankers, motor graders with rippers and 12 tonne vibrating steel roller. Additives should be verified for weight/square metre to ensure that the quantity of additive meets specification. For speed of construction and to ensure an homogenous mix, self-propelling and towing mixing machines are recommended. Both types of machines can be fitted with a computer water feed system and in recent projects the author was involved with, 7000 square metres of 300mm deep stabilized was achieved in an eight hour day. Should rock or cement be required as part of the geo-tech design for addition to the pavement mix, this should be placed and mixed prior to the stabilisation process.

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FLOOD MITIGATION
Figure 7: Typical Cross-section for Road Pavement Subject to Flooding

Stabilised pavements subject to inundation must be tested in the laboratory to ensure permeability either achieves or exceeds specification. Enzymes, or an enzyme blend with up to 3 % cement, has in laboratory and field testing has achieved specification, but has the advantage over clay pavements due to its residual tensile strength. This prevents cracking in the pavement once the water recedes. Stabilised pavements must envelope the road, or dam wall as experiences from in the recent floods at Maryborough in Victoria, when the decommissioned town water holding basin overflowed and scouring occurred on the down side of the dam wall. A catastrophe was averted by sandbagging the top of the wall.
Figure 9: Example of appearance of engineering geology and treated with different concentrations of O'Donnell and 5 g/cm³ in the Page 1 rainfall erosivity of 1900 on the Test.

Source: Bulletin of Engineering Geology and the Environment
EMBANKMENTS AND SLOPES

Enzymatic soil stabilisation can be successfully used in stabilisation of embankments and slopes. Preliminary work is presently under way for problems with some high plastic soils (fatty clays, colloidal clays) that are highly expansive along the "Great Canal" of China. These soils contain fatty clays and fine gravel, sands and silts. Plasticity Index is in the range of 45-80.

In making calculations for the enzymatic stabilisation application in these types of soils, the ratio of cohesive fines is much different to the standard gradation specification. Normal gradation is calculated on 18% - 30% cohesive fines. Translating this to these expansive clays, results in a greater amount of cohesive materials being present. The enzymatic composition works on the molecules within these expansive clays and not the other materials present. The standard application of 1 litre per 30 cubic metres of compacted pavement must be increased to compensate for the increased amounts of cohesive fines. The standard rate for high amounts of expansive is calculated on the same ratio basis as a standard application. An example of rate of application for soils containing 48% cohesive fines would be 1 litre per 15 cubic metres of compacted stabilised slope pavement.

Recommended thickness for slopes are:
- Up to 30 degrees, 150 mm
- 30 degrees to 50 degrees, 150 mm to 225 mm
- 50 degrees to 65 degrees, 250 mm to 350 mm
- 65 degrees above must be used in conjunction with soil nails

Compaction has always been a difficult on slope construction. In recent years new mechanical attachments have been introduced into compaction of trenches, slopes and embankments. Compaction load is applied by the back hoe. A filtration membrane, mostly likely sand, must be placed between the slope and the pavement. Weep holes are placed in the pavement at locations as directed by an experienced engineer. Recent compaction equipment introduced into slope stabilisation enhances the ability to compact slopes at much steeper angles than was previously possible.

Hydro Seeding
This method is used on embankments due to its environmental friendly, economical and speed of application attributes. This methodology can be applied to near vertical and uneven slopes. A bonded fibre matrix of wood fibre/wood mulch materials are joined by an adhesive to create an erosion control blanket that adheres to the soil surface. This method retains existing vegetation and holds on to near vertical surfaces.

Soil Nails;
Soil nails have been used for many years in slope stabilisation. The normal soil nail is constructed using concrete and steel reinforcement. This can be an expensive additional cost in embankment stabilisation projects.
It has been observed that concrete soil nails will catch water on their upper surface allowing water to penetrate around the soil nail loosening adjacent soil and aggregate materials resulting in loss of support of surrounding materials.
Enzymatic stabilised soil nails are an economic alternative. Similar to concrete soil nails they can be pre-manufactured or constructed on site. As with concrete soil nails, enzymatic soil nails are recommended to be reinforced with vinyl coated reinforcement rods. Rods are recommended to extend approximately 30% below the bottom of the soil nail for anchoring into the in situ material. Enzymatic soil nails are recommended to be pre-formed and pressed into pre-bored holes that are slightly undersized. It is also recommended that these enzymatic soil nails be placed into the slope after being dampened with a 1:10,000 mist of enzymatic composition and water.

An alternating pattern of rows should be used. Spacing of the nails and the rows should be approximately 1 ½ times the diameter of the soil nails. An experienced Civil Engineer in slope stabilisation should design the use of soil nails.

Construction and replacement of soil nails should be done in favourable construction climatic conditions. Avoid freezing and wet weather conditions.

**Enzymatic Composition Blocks (Hollow Blocks/Cement Blocks) and bricks**

Construction of cement, cinder and crushed shell blocks can be achieved with the aid of enzymatic composition. General manufacturing procedures remain the same. A reduction of approximately 5% in the use of water will be realized and a reduction of mould breakage rate of between 35% and 50% results. This is an economical savings for any manufacturing process. *Source: W Scruggs*

Enzymatic stabilised soils have been used to construct solid construction blocks designed for interior wall construction and low retaining wall construction. These were manufactured using small fractured gravels and cohesive fines within standard gradation specification minus the gravel sizes above 13 mm. They proved to be exceptionally strong, durable and easily constructed with a hand operated lever style press and a steel mould

More efficient methods are used for manufacture of these enzymatic stabilised blocks/bricks, where facilities are available. Hydraulic power units have the capacity to produce 6,000-8,000 blocks per shift per machine; curing time in low temperature sites is between 48-72 hours.

Mortar for joining the enzymatic stabilised blocks and bricks should be a combination similar to the makeup of the blocks/bricks (without the larger aggregate) and applied as normal mortar to all connecting surfaces. Curing times of the mortar joints will be in the order of 24 hours.

**WORKING PLATFORMS**

This section is based on laboratory and field testing undertaken on a 65,000 square metres white goods site, Clayton, south east of Melbourne. Working platforms are applicable to roads, large industrial/commercial building sites and most civil infrastructure sites. They are useful for sub-grade improvement over reactive clays to stabilise the sub-grade moisture and swell, and to limit differential movement in the sub-grade. Fill sites benefit from sub-grade differential movement. In both cases the compaction density of the sub-grade achieves results in excess of 100%, Strength of the sub-grade, field
Field testing:
- Generally assess the structural strength of the existing soils with a dynamic cone penetrometer pursuant to Australian Standard AS 1289.6.3.2.
- Soil classification pursuant to Australian Standard AS 1726.
- Identify locations within the site for soil sampling.

Laboratory Testing to include:
- Moisture Content
- Maximum dry density MDD and Optimum Moisture Content OMC.
- Laboratory soil classification including Atterberg limits and sieve analysis.
- Laboratory soaked CBR.
- Testing to be carried out by an accredited laboratory.

### UCS Laboratory Testing

<table>
<thead>
<tr>
<th>Inferred In-situ Additive</th>
<th>Field Description</th>
<th>Sample</th>
<th>Sample Number</th>
<th>UCS (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-1 (C08/1830 – 1)</td>
</tr>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-2 (C08/1830 – 2)</td>
</tr>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-3 (C08/1830 – 3)</td>
</tr>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-4 (C08/1830 – 4)</td>
</tr>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-5 (C08/1830 – 5)</td>
</tr>
<tr>
<td>3% Cement &amp; 0.002% Enzyme</td>
<td>mixture of cohesive clay &amp; granular material</td>
<td>0</td>
<td>0.150</td>
<td>S1295-6 (C08/1830 – 6)</td>
</tr>
</tbody>
</table>
## Comparison of Pavement Mix CBRs

<table>
<thead>
<tr>
<th>Test Location</th>
<th>Sample Description</th>
<th>Std. MDD (t/m³)</th>
<th>Std. OMC (%)</th>
<th>CBR Swell (%)</th>
<th>CBR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvey Norman Homemaker Centre</td>
<td>CH, Silty CLAY, Orange and 20% Supplied Crushed Concrete</td>
<td>1.57</td>
<td>25.5</td>
<td>0.5</td>
<td>9.0</td>
</tr>
<tr>
<td>-</td>
<td>CH, Silty CLAY, Orange (stabilised with 3% lime and 20% Supplied Crushed Concrete)</td>
<td>1.56</td>
<td>25.5</td>
<td>0.0</td>
<td>12.0</td>
</tr>
<tr>
<td>-</td>
<td>CH, Silty CLAY, Orange (stabilised with 3% lime and 20% Supplied Crushed Concrete &amp; Enzyme)</td>
<td>1.53</td>
<td>26.2</td>
<td>0.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

### Pavement Engineering and reporting
- Report and graphically represent engineering log data.
- Report and summarise visual conditions observed.
- Provide recommendations on suitable sub-grade/ sub-base preparation treatment
- Prepare a report presenting the factual findings of the investigation together with the comments relating to preparation options for the proposed works.

It should be noted that the existing CBR of the existing soils was a CBR of 9, this reasonable result could be attributed to the spreading crushed concrete prior to testing. Addition of 3 % lime improved the strength of the sub-grade to a CBR of 12. A CBR of 19 was achieved by the addition of 3 % lime and enzyme to the sub-grade.

**Design CBR Value Explanation;**
A 300mm thick layer with a CBR of 15% is placed over a 700mm thick layer with a CBR 6% - the formulae will give a multi-layered sub-grade design CBR value of 8%. From experience a CBR greater than 5% is required to provide an adequate working platform for earth work and pavement construction.

Should the sub-grade be oversaturated then add lime to pavement and leave for several days to allow the lime to dissipate. This drying procedure was achieved in the field testing For the Hong Kong Housing Department on a saturated marine clay..

**Working Platform under a concrete pavement to achieve;**
- Provision of a stable “working platform” on which to operate construction equipment.
- Facilitate the provision of a uniform bearing surface under the pavement.
- Reduce deflection at joints, thus ensuring effective long-term load transfer across joints by interlock (especially if no other load-transfer devices provided).
- Assist in the control of excessive shrinking and swelling of expansive sub-grade soils.
- Prevent ‘pumping” at joints and pavements edges.
- Minimum cover(capping layer) over reactive soils is 400mm *Source Vic roads*
Figure 12 Minimum Cover over Expansive Materials

- Permeability for capping layers should be in $10^{-8}$ to $10^{-11}$ cm/sec
- Minimise differential deflection within the sub-grade
- Where there is cut and fill the sub-grade, the treatment to the whole site sub-grade should be of the same design pavement mix
- Surface of the sub-grade should be graded to 1% to ensure proper surface of drainage.

Field testing obtained from samples during construction;

<table>
<thead>
<tr>
<th>Pavement Section</th>
<th>Characteristic Deflection (mm)</th>
<th>Tolerable Deflection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-situ Stabilised Materials as Found (Chainage 00km to 0.210km)</td>
<td>1.486</td>
<td>1.500</td>
</tr>
<tr>
<td>Unstabilised Existing Subgrade Materials as Found (Chainage 00km to 0.220km)</td>
<td>2.157</td>
<td>1.500</td>
</tr>
</tbody>
</table>
The graph shows that the stabilisation of the on-site materials has provided some benefit in terms of structural support. Computer modelling through the Circly indicates that the Young’s modulus of the cemented material would be between 250MPa to 500MPa. These values also appear consistent with published relationships between unconfined strength and Young’s modulus.

**CAPPING LAYER**
An example of the need to use capping layers especially where there is subgrade reactive soils.

![Figure 15: Outlook Court, constructed 2007. This photograph taken February 2013.](image)
CONCLUSION

1. Stabilisation is an engineered design and field supervised methodology of pavement construction. Engineers must design and field supervise pavements. It is imperative that geo-technical analysis of the pavement must be undertaken during construction to ensure that compaction appendix A, strength Appendix B and permeability Appendix C specification standards are either met or exceeded. Deflection testing should be undertaken on large construction sites. Reactive clay subgrades, land survey levels should be undertaken on the working platform surface on a monthly basis over at least a six month period.

2. In large commercial/industrial working platforms, must be graded to 0.5% to ensure drainage of the surface. Before placing a slab above a working platform, ensure a drainage membrane is in place. Trial and error experience has indicated that a 50mm depth of 19mm nominal size fine crushed rock
spread over the surface of the working platform, is satisfactory not only for drainage but to ensure there is no machine skidding on the surface

3. Test roll the sub-grade to assist in the assessment of sub-grade conditions. Any un-stabled areas should be rectified prior to re test rolling. Should the unstable area exceed 20% of total area then the whole area should be ripped.

4. Cover requirements on (capping layer) over reactive clays should be a minimum of 400mm

5. Impervious capping layers are essential for sub-grade improvement in reactive clays and filled sites.

6. Using capping layers brings economies, (In the 65,000 square metres example in Figure 12 on page 12, the saving through using stabilisation of in-situ material over imported crushed rock was $750,000. At 2012 prices, the crushed rock option costed out at $1.5 million.

7. Capping layers/working platforms for larger sites can provide for a pavement depth reduction. This site example on page 12, Figure 12, resulted in a reduction of slab depth from 200mm to 150mm due to the support from the high strength platform in the stabilised sub-grade.

8. Properly stabilised working platforms can eliminate differential settlement in the sub-grade and in so doing avoid potential for pavement cracking. In the reactive clay environment at the site in Figure 12, the conventional design south 1.0 metre depth of crushed rock while the enzyme stabilised option achieved a better result from 400mm of enzyme stabilisation.
CALIFORNIAN BEARING RATIO, C.B.R.
(Field - in - place method)
AS 1289.6.1.3

Report Number: RM1454-07.10
Project: HAUL RD, HARVEY NORMAN SITE, SPRINGVALE
Client: STABLE ROADS PTY LTD
Address: PO Box 350 WARRAGUL VIC 3820
Report Issue Date: 22/02/2008
Page: 1 of 3

SAMPLE DETAILS:
Sample Number: 0744081
Sample Description: OBSC + 1.5% CEM + ENZYME
Date Sampled: 20/02/2008
Sample Location: SITE 1 (CLAY)
Additive: 1.5% CEMENT & ENZYME

Percentage Ret. On 19.0mm Sieve: 0%
Notes: SAMPLE MIXED BY CLIENT, TEST LOCATIONS APPROVED BY CLIENT
Sampling in accordance with AS 1289.1

COMPACTION DETAILS:
Compaction Energy: AS 1289 5.1.1 Standard Compaction
Maximum Dry Density: 1.63 t/m3
Optimum Moisture Content: 23.5%
Peak Wet Density: 2.02 t/m3

FIELD PENETRATION SITE DETAILS:
Adjacent Soil Dry Density: 1.94 t/m3
Adjacent Soil Moisture Content: 12.5%
Surcharge Mass: 4.5kg

AFTER PENETRATION DETAILS:
Top 30mm moisture content: 10.4%

Californian Bearing Ratio: 80 %
Penetration Depth: 5.0mm

NOTES:
2. Test methods: Moisture content: AS 1289.2.1.1

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Mornington Laboratory - Accreditation Number 1407
10 Latham Street Mornington Vic. 3931
Mitcham Laboratory - Accreditation Number 790
7/38 Thornton Crescent Mitcham Vic. 3132

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APPROVED SIGNATORY

CIV-DOC-001-602 Issue #3  21/10/2005
CALIFORNIAN BEARING RATIO, C.B.R.
(Field - in - place method)
AS 1289.6.1.3

Report Number: RM1454-07.10
Project: HAUL RD. HARVEY NORMAN SITE, SPRINGVALE
Client: STABLE ROADS PTY LTD
Address: PO Box 350 WARRAGUL VIC 3820
Report Issue Date: 22/02/2008
Page: 2 of 3

SAMPLE DETAILS:
Sample Number: 0745081
Sample Description: OBSC + 20mm NDCR + 1.5% CEM + ENZYME
Client: STABLE ROADS PTY LTD
Sample Date: 20/02/2008
Sample Location: SITE 2 (20mm NDCR)
Additive: 1.5% CEMENT & ENZYME

COMPACATION DETAILS:
Compaction Energy: AS 1289 5.1.1 Standard Compaction
Maximum Dry Density: 2.04 t/m3
Optimum Moisture Content: 10.5%
Peak Wet Density: 2.25 t/m3

FIELD PENETRATION SITE DETAILS:
Adjacent Soil Dry Density: 2.07 t/m3
Adjacent Soil Moisture Content: 8.0%
Surcharge Mass: 4.5kg

AFTER PENETRATION DETAILS:
Top 30mm moisture content: 7.6%

Californian Bearing Ratio: 110 %
Penetration Depth: 2.5mm

NOTES:
2. Test methods: Moisture content: AS 1289.2.1.1

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CALIFORNIAN BEARING RATIO, C.B.R.
(Field - in - place method)
AS 1289.6.1.3

Report Number: RM1454-07.10
Project: HAUL RD, HARVEY NORMAN SITE, SPRINGVALE
Client: STABLE ROADS PTY LTD
Address: PO Box 350 WARRAGUL VIC 3820
Report Issue Date: 22/02/2008
Page: 3 of 3

SAMPLE DETAILS:
Sample Number: 0746081
Sample Description: OBSC - NATURAL SITE
Client: STABLE ROADS PTY LTD
Sample Location: SITE 3 (NATURAL)
Additive: RAW

COMPACTION DETAILS:
Percentage Ret. On 19.0mm Sieve: 0%
Compaction Energy: AS 1289 5.1.1 Standard Compaction
Maximum Dry Density: -
Optimum Moisture Content: -
Peak Wet Density: -

FIELD PENETRATION SITE DETAILS:
Adjacent Soil Dry Density: -
Adjacent Soil Moisture Content: -
Surcharge Mass: 4.5kg

AFTER PENETRATION DETAILS:
Top 30mm moisture content: 24.8%

Californian Bearing Ratio: 30 %
Penetration Depth: 2.5mm

NOTES:
2. Test methods: Moisture content: AS 1289.2.1.1

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10 Latham Street (P O Box 537) Mornington 3931
also at: Mitcham (03) 9874 5844 Wonthaggi (03) 5672 3900 and Mildura (03) 5023 2870
## CompaCtion Control Test

**Client:** STABLE ROADS  
PO Box 350, WARRAGUL VIC 3820  

**Operator:** G GIBBS  

**Report No:** RM1454-07.9  

**Issue Date:** 22-02-08  

**Ref:** GNG / GNG  

**Project:** HAUL RD, HARVEY NORMAN SITE, SPRINGVALE  

**Date of Test:** 21-02-08  

**Time:** 8:30 AM  

**Layer Tested:** Subgrade  

**Depth of Layer:** 175 mm  

**Testing Method:**  
- Field Density Determination  
  AS 1289  
- Moisture Determination  
  AS 1289 2.1.1  
- Test Method  
  AS 1289 5.4.1  

### Laboratory Compaction AS1289

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Test Site Location</th>
<th>Sample Number</th>
<th>Sample Description</th>
<th>Max. Dry Dens. t/m³</th>
<th>Opt. Mois. Cont. %</th>
<th>Mould Type A/B</th>
<th>Field Wet Dens. t/m³</th>
<th>Field Dry Dens. t/m³</th>
<th>Field Mois. Cont. %</th>
<th>Rel. Moist. Ratio %</th>
<th>Rel. Moist. Var’n From OMC %</th>
<th>Wet/Dry</th>
<th>Rel. Dens Ratio %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>HAUL RD SITE 1 (20mm NDCR)</td>
<td>0742081</td>
<td>ORANGE BROWN Silty CLAY + 20mm NDCR + 1.5% CEM + ENZYME</td>
<td>2.04</td>
<td>10.5</td>
<td>A</td>
<td>2.23</td>
<td>2.07</td>
<td>8.0</td>
<td>76.0</td>
<td>2.5</td>
<td>DRY</td>
<td>101.5</td>
</tr>
</tbody>
</table>

**Note:** Deviation from test method, MDD & OMC determined from curves: RM1454-07.8 0531081 & RM1454-07.8 0530081.

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Mobile Laboratory - Accreditation Number 13660  

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