Centre for Pavement Excellence Asia Pacific Limited

Cementitious Additive Protocol
for Earthworks, Filling and for Stabilised Pavement

SECTON 1

1.1 Scope

Pavement is defined as a compacted surface. This Specification gives guidance on the specification, execution, and control testing of earthworks and associated site preparation works for the use cementitious additives in stabilised pavement.

The Specification gives guidance on the interpretation and application of the relevant test methods specified in the AS 1289 series of Standards. This sets out the Principal's requirements for the control of earthworks of soils, granular materials (including stabilisation) associated with construction.

1.2 Requirements for this Specification

Correct control and compaction is a critical success factor for the Principal's projects. Incorrect filling and compaction by contractors causes the Principal to incur risks associated with backfill subsidence and collapse such as:

- Customer inconvenience and dissatisfaction
- Damage to customer and Principal assets
- Damage to other authorities' infrastructure
- Hazards to road users and pedestrians
- Costs associated with rectifying damage
- Costs associated with litigation for damages

Compliance with this Specification will reduce or eliminate these risks by assisting contractors to:

- Understand that soils are like any other construction material
- Different soil types have differing properties, and require different construction techniques to ensure optimum performance.
- Comply with basic quality control and supervision procedures to ensure a suitable outcome.

The use of an independent testing laboratory certified for this work by an organisation accredited by NATA, level of responsibility to AS 3798 Appendix B: Level 1 is required.

The geotechnical testing authority is to provide a full-time inspection and testing service on all earthworks (including stripping, proof rolling and associated operations), on the project and decides the locations and timing of sampling and testing operations.

On completion of the earthworks, the geo-technical testing authority will be required to provide a report setting out the inspections, sampling and testing it has carried out, and the locations and results thereof. The geotechnical authority is required to express an opinion that the works, so far as it has been able to determine, comply with the requirements of the general specification and drawings.

Basic Relevant Australian Standards

- AS 1289: Methods of Testing Soils for Engineering Purposes
- AS 3798: Guidelines on Earthworks for Commercial and Residential Developments
- AS 1726: Geotechnical site investigations
- AS 2870: Residential Slabs and footings

The Contractor is to meet all requirements in relation to the general civil works as specified in the Specification.

The Owner will provide information and additional geotechnical testing, reports and supervision pertaining to the application. This will include:

- Pre-treatment soils analysis and design protocol
- A protocol for cementitious additive application
- Post application performance testing (CBR, UCS, Deflection, Permeability and Final Deflection Survey)
- Supervision

1.3 Definitions

For the purpose of this specification, the definitions below apply.

1.3.1 Cohesion less soils - poorly graded sand and gravel), which are mixtures, generally with less than 5% fines (i.e. finer than 75 non-plastic and which do not exhibit a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1.

1.3.2 Cohesive soils - those materials which have a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1.

1.3.3 Collapsing soil - a soil that may suffer a significant decrease in volume under load or when it becomes nearly saturated. Such soils may have existed in this metastable state for long periods.

1.3.4 Dispersive soil - a soil whose clay component loses its structure on contact with water, forming particles of colloidal or near-colloidal size. AS 1289 C8.1, C8.2 and C8.3 are used to assess dispersion.

1.3.5 Foundation - the earth material immediately underlying and supporting any engineering structure; thus, the foundation for a fill or building is the stripped surface and a fill itself can be a foundation for a building.

1.3.6 Pavement materials - generally granular and often manufactured from hard rock sources such as crushed rock. Except where specifically referenced, pavement materials will be considered as fill within the context of this general specification.

1.3.7 Reactive soils - clay soils, for which a change in moisture content may result in a sufficient change in volume to affect the engineering performance of any structure in contact with this soil.

1.3.8 Relative compaction - for cohesion less soils, the density index determined in accordance with AS 1289.E6.1; and for cohesive soils, the dry density ratio determined in accordance with AS 1289.5.4.1, or the Hilf density ratio determined in accordance with AS 1289.5.7.1.

1.3.9 Rockfill - fill composed almost exclusively of fragments of broken rock. It generally consists of a large portion of gravel and larger sized fragments. Such fill may contain large open voids.

1.3.10 Structural fill - any fill which will be (or may be), required to support structures or pavements, or for which engineering properties are to be controlled. In this case this may also include soils which have been stabilised with cementitious additives such as cement and enzyme.

1.3.11 Subgrade - the earth material on which it is proposed to construct a pavement. Generally taken as being to a depth of 300 mm below the level from which the formal pavement is constructed, but may be deeper in areas where deep subgrade improvement have been carried out.

1.3.13 Topsoil - a superficial soil containing some organic matter, usually darker than the underlying soils.

1.4 Designation of Personnel For the purpose of this specification, the following terms are relevant:

- The owner sometimes called the proprietor or the principal
- The designer
- The superintendent sometimes called the engineer or the architect
- The constructor sometimes called the contractor or the builder
- The geo-technical testing authority

SECTION 2 - Investigation, Planning and Design

The investigation, planning and design for projects involving earthworks require the designer to give consideration to those factors which may affect the works. The contractor should be aware of requirements associated with approvals, inspections, adjoining properties, regulations, preservation items, areas affected by construction activities, drainage, erosion and saltation protection, requirements for sloping ground, stability of slopes, zoning of fills, soft or compressible fills, reactive soils, low density soils, existing filled ground, use of suitable water for moisture content control, trench excavation, optimum moisture content, minimising surcharging on slopes and adjacent trenches, quantities of fill (this may also include additives), physical separation of dissimilar materials, geotextiles, vibration, contamination and retaining walls as further discussed with AS3798, Section 2.

Soil stabilisation using Enzyme and Cement has proven most effective in subgrade support using existing soils and rock. By combining Enzyme and Cement with existing material, that contains a mixture of 50% Crushed (Well Graded) Basalt, 50% On-Site CLAY with 3% Cement & 1% Enzyme to provide a low reactive capping layer and solid base. The cost effectiveness in site preparation is most apparent in improved support characteristics.

The Enzyme product and process is further detailed in the following sections.

SECTION 3 - Details for the Enzyme Stabilisation

3.1 General

This Section includes details for the design and construction of stabilised earthworks.

3.2 Investigation and Planning

Investigations for the planning of earthwork contract for the project and generally covering:

- condition of the site(s) including:
    - present uses, i.e. buildings and vegetation; and
    - evidence of past uses, i.e. demolition, filling and vegetation;
- foundation and sub-grade materials;
- special areas due to groundwater, seepage, rock, reactive and collapsing soils;
- available fill materials and, where applicable, details of the overburden;
- suitability of the fill materials (see Item IV), for the intended purposes;
- availability of suitable pavement materials, where applicable;
- quantity and quality of the available water; and
- suitability of water for the placement of the fill;
- the quality assurance requirements for the project

3.3 Design and Specification

The functional requirements of the design are generally documented in the specification and civil works drawings to be provided by the Civil Consultant.

This documentation should be sufficiently complete to allow the Contractor to unambiguously carry out the works, and for the superintendent (and the geo-technical testing authority, as necessary) to be able to interpret the design and administer the contract. Such documentation will typically include, or have consciously excluded, the following, as well as any other matters which may be of particular importance to the particular project:

a. Adequate specification and drawings to allow the proper pricing, planning, execution and supervision of the works. Plans, sections and elevations should clearly show areas of earthworks, identifying requiring specific treatments. Particularly on larger projects, the specification and drawings shall adequately define the following:

    I. The areas in which spoil may be dumped or stockpiled

    II. Restrictions on clearing and stripping

    III. Drainage requirements during and after construction

    IV. Criteria for selection of materials for placement in various parts of the fill and for material to be excluded from fill. Material descriptions should be clear, unambiguous and in accordance with AS 1726

    V. Criteria for standard of surface trim of completed earthworks

    VI. Details of tests, including minimum frequency, to be carried out for testing to ensure the fill complies with the specified criteria. The scope of the commission is given to the geo-technical testing authority (see Clause 1.4)

    VII. Either the methods to be used for construction or the requirements to be met by test in the finished project. It is generally unwise to mix performance and method specifications. Where a performance specification is adopted, restrictions on methods should be limited to those absolutely necessary, for example, to limit the risk of damage to nearby structures

b. Site investigation information, including that specified in Clause 4.2(b), together with details of, and provision for, access to any further relevant information for the purpose of design or construction planning. Selective provision of available site investigation data can give rise to serious problems, either engineering or legal or both, and should not be done not be done without due consideration of the issues involved.

c. Any other relevant information in the possession of the engineer.

3.3.1 Enzyme Applications Parameters

Equipment needed:

Enzyme is applied with the same equipment normally used to build a road.

1. Capable equipment operators
2. Motor graders with rippers
3. Stabilising mixing machine
4. 16 tonne or heavier pad foot and/or steel drum roller (with vibrator if available) further water proofing may be assisted by the use of a pneumatic (rubber) multi-wheel roller
5. Water truck with pressure spray bar
6. Other additives are applied as per manufacturers specification

3.3.2 Recommended Pre -Treatment Soils Analysis

It is necessary that the soil, or soil mixture to be used in the construction of the road be analysed to ensure the application design will meet optimum results.

a) Maximum density /optimum moisture comparison. This analysis will determine the amount of water needed to achieve best compaction.

Analysis method: AS1289.5.1.1 Methods of testing soils for engineering purposes Method 5.1.1: Soil compaction and density tests – Determination of the dry density/moisture content relation of a soil using standard compactive effort. (Also see Tongi study and use as a guideline for this analysis).

b) For 18-28% of material passing a 0.0475 sieve PI to be within 6% to 18%. Gradation to be within the envelope as shown on a table.

c) Gradation

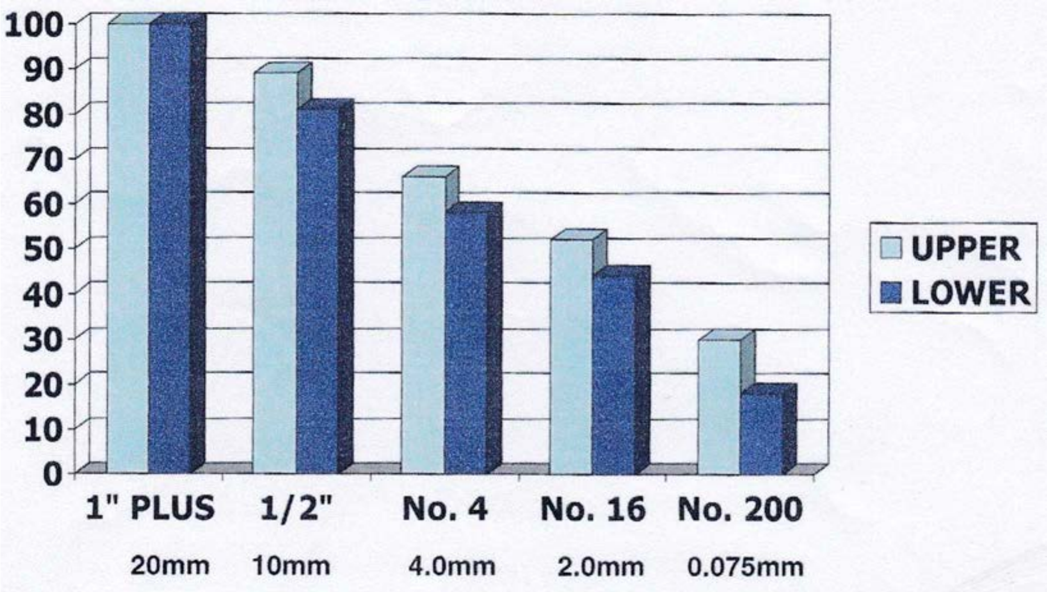

Figure 1- Recommended gradation schedule

3.3.3 Procedure to be Followed

Enzyme stabilisation will prove less than effective if the following minimum procedures are not followed:

a) Ensure a soils analysis is undertaken on the subject soils and proposed additives before treatment begins (see Clause 8);

b) During initial preparation it may be necessary to add further plain water to bring the soil close to optimum moisture level, for best compaction or aerate and allow to dry. Proper engineering supervision is essential;

c) Add the appropriate quantity of Enzyme additive to the water truck AFTER the truck is filled with water; the quantity of enzyme depends on the in-situ soil type and its condition. The recommended tests proposed in Clause 8 will facilitate the designer to determine such optimised amounts of enzymes.

d) After the soil/gravel and any other cementitious additives is mixed the Enzyme treated water is dispensed into the material and thoroughly mixed using a purpose built roto-mill. In most cases adequate mixing can be achieved using a single pass;

e) The mixed material should then be spread and shaped before compaction by rolling in maximum layers of 250mm. For fill depths refer to engineering plans;

f) The rollers must make enough passes to ensure adequate compaction is taking place. A vibrating pad foot roller is most effective for this application. On the final passes, when the tyre tracks no longer show, the vibrator should be turned off. This prevents excessive surface cracking caused by rapid drying. The top surface should be rolled until it shows a uniform sealed appearance. The final stages of rolling should be performed by a smooth drum roller followed by a pneumatic (rubber) roller to assist drainage and prevent ponding of water on the surface.

g) Ideal curing time for a 250mm pavement depth would normally be 72 hours. Light traffic may be permitted, as soon tyre tracks are no longer visible at the top surface. Light rain or high humidity will increase curing time. Application of Enzyme may not be undertaken during rains unless otherwise approved by the superintendent.

3.3.4 Post Application Performance Tests

Cementitious additive performance will be assessed through:

a) CBR or similar load bearing tests. This will gauge the increase in load bearing effectiveness of ENZYME in comparison to the normal untreated soil;

   Test method: AS1289.6.1.1 Methods of testing soils for engineering purposes method 6.1.1: Soil strength and consolidation tests- Determination of the California Bearing Ratio of a Soil – Standard laboratory method for a remoulded specimen. **With Enzyme this test has to be modified to allow the samples to cure before submersing in water. (72 hours is suggested);**

b) Permeability – the addition of Enzyme reduces moisture penetration affecting the structural design of the road. Test method: AS1289.6.7.2 falling head or similar;

c) Standard UCS and tensile strength will also be used to further evaluate the effectiveness and advantages of using Enzyme;

d) To ensure adequate performance consideration should be given to undertaking a deflection survey across the site in a grid pattern.

3.4 Construction Records

Adequate records need to be kept during construction, including conditions encountered, works as executed, testing and any alterations to the specification and drawings. As a minimum, these records should show the following:

a) The areas in which fill is placed;

b) Levels after stripping;

c) Location of any trees or large shrubs that may have been removed;

d) Materials exposed after stripping and the criteria upon which the decision to cease stripping was made;

e) Levels after completion of the filling;

f) Types of fill material in various zones;

g) Location and level of each compliance test, together with test results. Where a test is a retest of an area which was previously rejected, this should be stated;

h) Action taken where testing indicated that the specified criteria had not been met. Any areas in which the fill material or compaction is to be of a lesser standard or a greater standard than elsewhere on the site should be clearly identified.

For larger projects, of which this project is considered, daily diaries and detailed drawings of works, as executed, should be maintained by the geotechnical testing authority in summarizing the works as executed.

Typical site records are:

1. a weekly geotechnical report, generally appropriate for larger projects such as this one;
2. a geotechnical site visit record; and
3. an earthworks summary report.

NOTE: Typical examples are given in Appendix C of AS3798 and contain only relevant technical information relating to the work as executed. It is likely that records of other aspects of the works, such as weather conditions, work hours, breakdown and standby times, instructions issued conversations between parties, visitors to the site and the like may need to be kept by the superintendent, the constructor or other parties, for the purpose of contract administration.

NOTE: Refer also to section 3.3.3 above.

4.0 Materials

4.1 General

The earthworks for most projects, for which this Specification is intended, will involve cut and fill operations using on-site and imported materials.

In some areas, materials may be encountered which are unsuitable for use as fill, or which may require particular attention in the specification, placement and control, if they are to be used. This Section provides guidelines regarding material acceptance and control. Clauses 4.2 and 4.3 refer to fill for earthworks. Clause 4.4 refers to pavement materials.

4.2 Unsuitable Materials

Some materials are unsuitable for forming structural fill and should be either removed to spoil or used in non-critical areas. However, a design may include a provision for the use of some of these materials in structural fill.

Unsuitable materials may include:

a) organic soils, such as many topsoils, severely root-affected subsoils and peat;
b) materials contaminated through past site usage which may contain toxic substances or soluble compounds harmful to water supply or agriculture;
   NOTE: Disposal of such materials will generally require special consideration, and often will be subject to control by regulatory authorities.
c) materials containing substances which can be dissolved or leached out in the presence of moisture (e.g. gypsum), or which undergo volume change or loss of strength when disturbed and exposed to moisture (e.g. some shales and Sandstones), unless these matters are specifically addressed in the design;
d) silts, or materials that have the deleterious engineering properties of silt;
e) other materials with properties that are unsuitable for the forming of structural fill; and
f) fill which contains wood, metal, plastic, boulders or other deleterious material.

4.3 Suitable Materials

Most naturally occurring soils, with the exceptions specified in Clause 4.2, are capable of being compacted to form a homogeneous mass capable of supporting commercial and residential developments and associated infrastructure. Similarly, weathered rock which can be ripped and broken down by compaction will be generally suitable for use as structural fill in such developments so to can cementitious stabilised materials.

However, the applicability of some materials will depend, among other things, upon their in situ condition at the time of the work, the intended end use of the fill, and upon the economics of winning and placement to the specification requirements.

Special consideration may be required for:

a) clays of high plasticity which may be reactive and need to be selectively placed within the fill and under strict moisture and density control;
b) material which, after compaction, contains large particles and may lead to difficulties in the excavation of trenches for footings or services or driving of piles or drilling of piers, if this is necessary;
c) over wet materials, as may be encountered in low-lying areas, which may be difficult to satisfactorily dry out within an economical time for use in the project;
d) single-sized or gap-graded gravels or rock fill which will not break down upon compaction, leaving voids into which finer material may subsequently migrate;
e) saline, chemically aggressive or polluted soils;
f) carbonate soils where acid disposal may occur;
g) will be material that has a P.I of between 6 and 20 and an even graduation of particle sizes from 20mm minus.

4.4 Pavement Materials

Whilst these specifications have generally been prepared for main roads, highways and freeways, their adoption for other pavements is common. In many circumstances applicable to this Specification.

Similarly, in many circumstances locally occurring gravels or ripped rock may be suitable for part of the pavement.

The choice of pavement materials adopted will be the responsibility of the pavement design engineer (see 1.4.(b)), and will be dependent on such issues as the design loading, the subgrade conditions, availability and type of wearing course.

5.0 Compaction Criteria

5.1 General

Where it is required to reduce the potential for swelling, reactive clays should be placed close to their equilibrium moisture content (not a soil property, but dependent on the soil and environment). In temperate climates, the equilibrium moisture content is often close to the optimum moisture content (standard compaction). In arid and semi-arid environments, the equilibrium moisture content may be considerably drier than in temperate climates. Material in borrow areas at or about the depth of seasonal influence is often close to the equilibrium moisture content and therefore the potential for problems may be minimized by placing material directly from cut to fill.

5.2 Compaction of Soils

Minimum relative compaction values for different applications of various projects are given in Table 5.2. These values are for a specification of the 'no value to be less than' acceptance criteria.

<u>Minimum Compaction Levels</u>

a) Commercial - fills to support minor loadings, including floor loadings of up to 20 kPa and isolated pad or strip footings to 120 kPa, 98 std

b) Pavements
   a. Fill to support pavements 95 std
   b. Subgrade (to a depth of 0.3 m) 98 std
   c. Sub-base courses 95 mod
   d. Base course
      - Heavily loaded 98 mod
      - Other 95 mod

Where necessary to achieve the required density or moisture content or both, adjust the moisture content of the fill before compaction. Ensure the moisture distribution is uniform, and avoid saturation at the specified density.

Required moisture content should be within 3% of optimum, (but not above). Adjust the moisture content of fill during compaction within the range of 85 - 100% of the optimum moisture content determined by AS 1289.5.1.1 or AS 1289.5.2.1 as appropriate, in order to achieve the required density.

As a field guide to assessing whether a clayey soil is near its Optimum Moisture Content (OMC) for Standard Compaction (AS 1289 5.1.1), the following test is useful. A representative handful of material proposed for use as backfill is squeezed in the hand. Suitable material should be wet enough so that it binds together with no more than slight crumbling when the hand is opened, and not so wet that it is at all plastic or slippery, nor exudes water when the material is well shaken in the hand. Clayey material, at about standard OMC should be able to be rolled into a worm, approximately 2 mm in diameter, but when an attempt is made to bend the worm, it should not bend but should break.

When compacted against a firm surface, the material of correct moisture content should not surge ahead of the roller or other equipment and should not rebound excessively after wheel loading. It should readily bind together under the rolling action.

5.3 Coarse Material

Where ripped rock or coarse material is used for filling, the after-compaction quantity of material coarser than 37.5 mm may exceed 20%. With such material, the test procedures for in situ determination of dry density ratio specified in the relevant parts of AS 1289 are not applicable and special consideration should be given to alternative methods of testing for compaction. In such circumstances, it is common to adopt a method specification which may include test rolling (see Clause 5.4).

5.4 Test Rolling

The method specification for placement of coarse granular material should include test rolling, to assist in evaluating the stability of fill materials being placed.

Areas upon which fills are to be constructed, and all layers of fill, should be compacted so as to be capable of withstanding test rolling without excessive deflection, using any of the following:

a) Steel wheeled roller - used without vibration and which has a minimum applied load intensity of 4 t/m width of the wheels or drum being considered.

b) Pneumatic tyred roller - not less than 3 t per tyre with tyres inflated to 550 kPa.

Highway truck - with rear axle or axles loaded to no less than 8 t each with tyres inflated to 550 kPa.

Fill layers should be test rolled immediately following completion of compaction. If further test rolling is required at some later date, the surface should be moisture conditioned, as required, and given not less than four passes of the testing roller before test rolling resumes.

Any areas where excessive deflection is detected by test rolling should be rectified and re-presented for test rolling. Where unstable areas exceed 20% of the area being test rolled, the whole of the area should be ripped, re-compacted and re-presented for test rolling.

5.5 Other Materials

Waste materials such as demolition rubble are extremely variable and should only be accepted as structural fill after due consideration by the Designer, preferably in conjunction with field trials. The specification for the supply, placement and compaction of such fill should then be clearly stated.

5.6 Trenches

Trenching infill for service installation, or like works, is common in commercial developments. It is important that rapid lateral changes in the engineering properties of the ground in such areas should not occur. Compaction of backfill to trenches to a comparable condition to that of the surrounding ground, therefore, is important and should be clearly specified in terms of relative compaction and should be controlled. The practice of flooding sands to achieve compaction of backfill is insufficient and should only be used in conjunction with other compaction methods.

6.0 Construction

6.1 Site Preparation

6.1.1 General

This Section covers specific activities which are likely to form part of these earthworks and are presented in the approximate order of works.

6.1.2 Fencing

Fencing should be installed if required by the Head Contract, before earthworks commence, to define the limits of the work, to restrict construction plant to the site or for public protection.

6.1.3 Drainage, erosion and sedimentation control

Earthworks should avoid the siltation or erosion of adjoining lands, streams or watercourses. Drainage, erosion and sedimentation control should be installed before the natural surface is disturbed. Sedimentation basins, stream diversion or other works may be appropriate in some environments or topography. Careful planning is required for these works. Erosion and sedimentation control may be aided by minimizing the area of disturbance and by the progressive re-vegetation or development of the site.

Provision for temporary drainage where water may tend to accumulate, shall be made by the Contractor. Care shall be taken to guard against scour on any part of the construction. All temporary provisions for drainage, unless otherwise directed to be retained for use as catch or shoulder drains, shall be restored to the satisfaction of the Superintendant before pavement materials are placed. The cost of temporary drainage shall be the responsibility of the Contractor. The location of each drainage line shall be determined by the Superintendant or Geotechnical Consultant.

6.1.4 Site clearing

The site should be cleared (to the minimum extent required for the work) of all trees, stumps and other materials unsuitable for incorporation in the works. The roots of all trees and debris, such as old foundations, buried pipelines and the like, should be removed to sufficient depth to prevent inconveniences during subsequent excavation or foundation works. Resulting excavations should be backfilled and compacted to the same standard as that required for subsequent filling operations. Disposal of cleared combustible material may have to be off-site, if clean air or bushfire regulations prevent on-site burning.

6.1.5 Stripping

The area on which the fill is to be placed and the area from which the cut is to be removed should be stripped of all vegetation and of such soils as may be unsuitable to support the proposed loadings or for incorporation in fills subject to density, moisture or other specified controls. Topsoil may need to be stripped as unsuitable material or as required for subsequent revegetation. Special care is needed to ensure that materials which will inhibit or prevent the satisfactory placement of subsequent fill layers are not allowed to remain in the foundations of fills. Geotechnical assessment of the depth and quality of topsoil or vegetal cover of the underlying soils and of the quality and depth of the proposed fill may obviate the need for such stripping in some circumstances. All stripped materials should be deposited in temporary stockpiles or permanent dumps in locations available for subsequent re-use if required, and where there is no possibility of the material being unintentionally covered by, or incorporated in, the earthworks.

6.1.6 Slope preparation

Where a fill abuts sloping ground, benches should be cut in the ground. It is unlikely that slopes flatter than an 8:1 (horizontal to vertical) gradient will require benching. The benches should be shaped to provide free drainage. The boundary of cut-and-fill areas requires special consideration. All topsoil and other compressible materials should be stripped prior to benching into the natural material of the cut zone. The depth of bench should be not less than 100 mm, but generally be of the order of 300 mm. However, it may vary depending upon the natural slope of the ground, the nature and proposed end use of the fill and the equipment being used.

6.1.7 Foundation preparation

Wherever practicable, the ground surface exposed after stripping should be shaped to assist drainage and be compacted to the same requirements as for the overlying layers of fill, preferably with equipment to be used in subsequent filling operations.

The surface exposed upon completion of excavation works may also require preparation prior to fill placement proceeding. This will typically be the case whenever subsequent fill is to be placed, which is the case for pavement construction or base material in this project. In such circumstances, it will be necessary to loosen the exposed excavation surface by tining to a depth of at least 200 mm, and to then moisture-condition and compact this loosened material. The depth to which tining is carried out should not exceed that which can be compacted. The degree of compaction achieved should be consistent with that required for subsequent filling operations.

In ground where it is impracticable to achieve compaction of the existing or stripped surface, design advice may be required. In such cases, a working platform generally of granular material, end-dumped and spread in sufficient depth to allow the passage of earthmoving equipment with minimal surface deflection, may provide a suitable foundation for subsequent filling. Localized springs or seepages in the foundation area, detected during site investigation for the work, should be noted and allowed for in the design. If such problems are not detected until the works are in progress, they should be investigated so that measures such as subsoil or rock rubble drains may be designed for incorporation in the works.

6.2 Fill Construction

6.2.1 General

Planning for fill construction should include, but not be limited to:

a) the quantity and quality of the fill material;

b) the expected rate of output of the earthmoving, delivery and spreading equipment;

c) the compaction specification to be met; and

d) the availability and effectiveness of particular items or types of compaction equipment.

The number of passes of a particular roller required to compact a layer of specified thickness at a given moisture content (or within a specified moisture range), can only be established in the field.

6.2.2 Placing fill

The quality of fill material and the control tests to be used as the acceptance criteria should be specified in the documentation (see Clause 3.3). Fill material should be placed in near-horizontal layers of uniform thickness, deposited systematically across the fill area. The thickness of each layer should be appropriate to the equipment to be used and test procedures to be adopted.

This will vary according to the material being placed and the equipment being used. It may be necessary to excavate or ‘box’ into the existing surface at the edge of fills to provide a suitable junction with the existing surface to avoid feathered edges. The method of excavation, transport and depositing of fill material should ensure that the fill is placed in a mixture as uniform as practicable. Such uniformity will assist in providing consistent relative compaction from the chosen plant and work practices and in avoiding material variations which may affect the long-term performance of the fill.

Each fill layer thickness should be such that the bottom of each layer is compacted to the specified relative compaction and can be tested by the specified test methods. Whilst compaction may be achieved in deeper layers by using heavier equipment or increasing the number of passes, the relative economy of various options may need to be examined, if a particular layer thickness is not specified.

Before any loose layer of fill is compacted, the material and its moisture condition should be as uniform as practicable throughout its depth. The maximum particle size of any rocks or other lumps within the layer, after compaction, should not exceed 75mm. If there is a delay in the placement of subsequent fill layers, previously accepted layers should conform with the specification before further fill is placed. If these layers have wetted up or dried out, they may inhibit compaction or cause heaving of subsequent layers. In some instances, drying of the fill may be deleterious, especially with reactive soils.

The standard of surface trim of the completed earthworks should be specified in the documentation (see Clause 3.3).

6.2.3 Fill moisture control

Limits on the moisture condition of fill material during compaction are specified, and should be such that they allow the required degree of compaction to be achieved. If the moisture content of the fill falls below the specified minimum, water should be added either on the fill or in the cut/borrow area before it is transported to the fill area. Water applied on the fill should be finely sprayed and uniformly blended throughout the full depth of uncompacted material. If the moisture content of the uncompacted fill is non-uniform, the material should be mixed to provide a consistent moisture distribution. Care is needed to ensure that mixing or blending does not produce segregation of the fill material. If the moisture content of material is above the specified maximum, drying of the material may be accelerated by aeration or by blending with drier materials (without oven-drying). If the moisture content is such that it exceeds optimum at the specified density, it may be difficult, if not impossible, to achieve the specified compaction. Control of moisture content should be applied not only to the upper layer of uncompacted material, but also to the material of the previously compacted layer. This surface material should be brought to within the specified moisture range before it is covered by a new layer.

If rain is threatening or the site is to be left unattended, the upper surfaces of fills should be crowned and if possible, sealed with rubber-tyred or smooth-wheeled plant and graded to prevent ponding.

6.2.4 Fill compaction

Each 250mm layer of fill should be compacted as a systematic construction operation, using plant that is specifically assigned to the compaction task and which tracks progressively across the surface of the fill. Construction and earthmoving plant may be routed to assist in this regard. Selection of the compaction equipment requires careful consideration of the job specification requirements.

The plant should be capable of compacting all of the fill area, including its edges and junctions with the natural ground. Fill batter faces should be compacted as a separate operation or alternatively, overfilled and cut back. The trimmed and compacted batter face should have a roughened surface to reduce run-off velocities, if required. Where density testing shows the relative compaction of the fill to be below the specified level, all material represented by the test, or tests, should be further compacted to exceed the minimum compaction requirements, as confirmed by further testing, or be reworked. Additional moisture blending or drying out may be required to facilitate re-compaction.

The surfaces of all fill layers should be shaped to provide drainage and to prevent ponding which will cause deterioration of previously compacted fill layers.

6.2.5 Surface heaving

Surface heaving results from the compaction of materials approaching saturation and inhibits further compaction. The development of surface heaving on fills may be avoided by the following:

a) Ensuring that the moisture content of materials during placement avoids over optimum conditions at the specified density;

b) Providing drainage on the surface of fills and preventing the ponding of water on fill layers.

c) Selecting appropriate earthmoving and compaction equipment.

6.2.6 Fill against structures

Fill, adjacent to structures, such as pipes, culverts, abutments, retaining walls or other structural components, may need to take into account the following:

a) The strength or age of cast in situ concrete before filling can commence.

b) The filter zone to be provided adjacent to weep holes or other subsoil drainage systems.

c) The quality of fill. Sand, natural gravel or quarry products may be specified to facilitate compaction in confined areas, to minimize differential settlement which might otherwise overload the structure or to divert seepage to subsoil or other foundation drainage systems.

d) The type and method of compaction compared with normal fill construction. Fill should be brought up equally on each side of pipes and culverts, to avoid unbalanced loading. The first layers of fill over the top of structures will require careful placement. The design should specify the depth of fill to be placed over pipes or culverts, or special conditions which might apply to other structures. In some cases, internal propping may be required if normal compaction is to be used immediately above or adjacent to structures.

7.0 Methods of Testing

7.1 General

This Section describes the procedures to be followed when carrying out acceptance testing of field compaction.

However, measurement of relative compaction in general is not sufficient to assess compliance and should be used in conjunction with visual inspection and test rolling. Strength or other tests such as unconfined compressive strength (UCS), California Bearing Ratio (CBR) and Permeability will need to be undertaken to provide a measurement of the performance of the compacted fill material properties.

7.2 Field Density

Methods for the determination of field dry density are as follows:

a) Direct

The methods are as specified in AS 1289.5.3.1, AS 1289.5.3.2, AS 1289.5.8.1 and AS 1289.E3.5.

NOTE: Although the method specified in AS 1289.5.8.1 relies upon correlation of recorded density count against standard blocks (see AS 1289.E8.4), provided calibration has been carried out as specified, it is, for the purpose of this specification, a direct method.

b) Indirect

These methods provide an empirical measure of achieved density by measurement of another engineering property, principally shear strength may be used to further validate density however the method of direct testing will govern acceptance.

7.3 Establishment of a Reference Density for Calculation of Relative Compaction

To permit relative compaction to be calculated, it is necessary to establish a laboratory reference density. Procedures for establishing such reference densities have been developed empirically over many years and standardized with test procedures of AS1289.51.1, AS1289.5.2.1, AS 1289.5.7.1 and AS1289.E5.1.

7.4 Sample Selection for Reference Density

For routine ‘compaction’ testing, the sample for determination of the laboratory reference density (see Clause 7.3), should comprise either the material recovered from the field density determination, (see AS 1289.5.3.1), or from that volume of material considered in the field density.

For cement-modified (including ENZYME) stabilised materials may alter with time. The laboratory compaction should be carried out on material which has been mixed and compacted by purpose built machinery on site, however density tested and re-compacted in the laboratory as soon as practical however before significant curing has occurred.

For granular materials including pavement base and sub-base materials which have been manufactured from a hard rock source under controlled conditions consideration may be given to providing an assigned value as further discussed within AS3798 Section 7.4 and the procedures of AS 1289.5.4.2.

8.0 Supervision, Inspection and Testing

8.1 General

To assess whether the quality of materials and workmanship provided on a project are consistent with the design requirements, the earthworks for a project will require inspection and testing at regular and appropriate intervals as set out in this section having regard to the nature of the work, its required function and the specification. Good supervision will require inspection measures such as test rolling, and should not rely upon test results alone. Such inspections should be carried out by personnel experienced and knowledgeable in earthworks.

8.2 Testing

Given the scale of the project variable or difficult conditions may be expected and it is not envisaged to relax the test frequencies specified herein, in some cases more frequent testing may be required. These testing frequencies relate to acceptance on a ‘not one to fail’ basis.

In order to obtain an optimised performance of the stabilized road, it is recommended to estimate the performance of the stabilized soil through a comprehensive test plan in the laboratory prior to the field application. This is mainly due to the performance of the stabilized soil (i.e. treated road pavement) can be governed by the in-situ soil type and its condition. Figure 2 shows the recommended laboratory tests which could be conducted in the application of enzymes to stabilize pavements. The proposed tests will facilitate to determine the suitability of in-situ soil in stabilizing the pavement, as well as to obtain the optimised amounts of enzymes which can result the expected road performance. The recommended standard based on American Society for Testing and Materials (ASTM) are showed in Fig. 2 for each test. It is to be noted that oven-drying is not allowed in any of the tests prescribed in this test plan. The soil needs to be air-dried, or lime could be used as a drying agent prior to testing. Should the natural soils be over-saturated, then 3% lime mixture is suggested to add into the soil, and allow drying for 3 days, until the natural soils are fully dried. This procedure can also be used in the field to obtain the desired result.

As noted in Fig. 2, the proposed tests can be conducted in 3 stages. At stage 1, initial tests are proposed to obtain the description and physical (& chemical) properties of raw soils (possibly in-situ/natural soil). These tests include; gradation tests, mineralogy tests, chemical tests, Atterberg tests, compaction tests and permeability tests. The results from these tests will facilitate the user to ascertain whether the field soil would satisfy Clause 3.3.2 and 4.3. Having obtained the description and properties of the raw soils, samples are prepared at maximum dry density and optimum moisture content and leave them curing for 72 hours before mechanical testing (stage 2 in Fig. 2). The tests in stage 2 are similar to what were proposed in the Clause 3.3.4 for assessing the post-performance of the stabilized road. Further, every mechanical test can be repeated at 4 days and 7 days after curing to characterise the time dependant strength gain of stabilized soils. Such mechanical tests will be helpful to assess whether the stabilized material is effective to perform as a pavement material in accordance to relevant road standards (such as Austroads, 2010). In addition to the tests noted in stage 2, a permeability test is also recommended on stabilized samples to determine whether the stabilization has improved the permeability of the mix. If the material is showed to be not suitable (i.e. violating Clause 3.3.2), the strength of stabilized mix could be improved with the addition of cement. The proposed series of mechanical tests on the stabilized mix with cement and enzymes will be able to ascertain the suitability of in-situ soil to utilize as a pavement material.

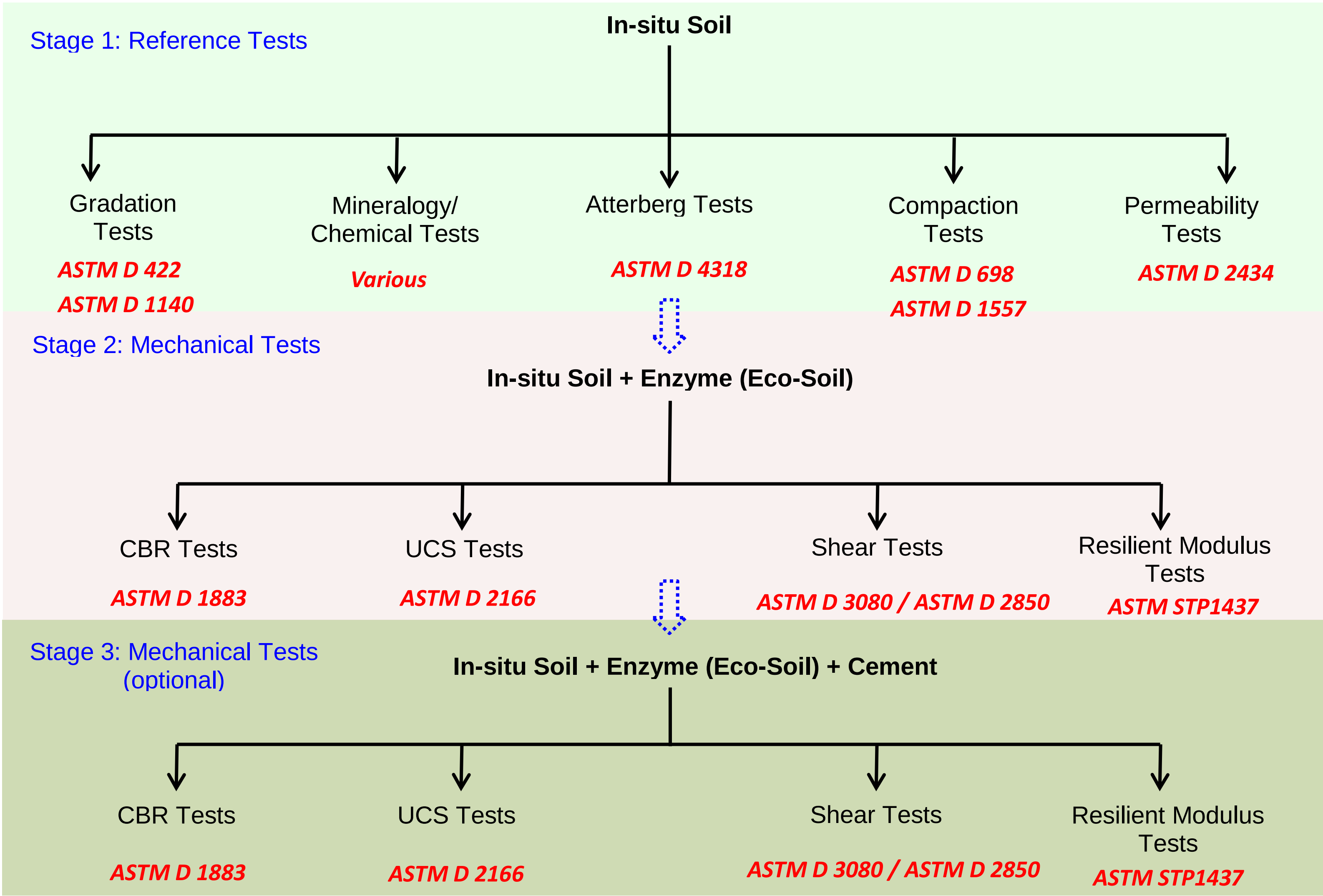

Figure 2 Geotechnical testing protocol for CPEAP

For projects requiring more than just a few tests to check compliance, the testing should essentially be carried out in a number of randomly chosen locations and at the frequencies given in the following section.

8.3 Frequency of Field Density Tests & Unconfined Compressive Strengts

Type 1 Large-scale operations (e.g. subdivisions, large industrial lots, road embankments - greater than 1500 m^2)

Not less than:

a) 1 test per layer or 250 mm thickness per material type per 2500 m^2; or

b) 1 test per 500 m^3 distributed reasonably evenly throughout full depth and area; or

c) 3 tests per visit; whichever requires the most tests.

Confined operations: 1 test per 2 layers per 50 m^2.

To ensure the strength of Enzyme and cementitious modified materials (clays mixed with local gravels, cement and enzyme) are achieving desired strengths in the order of 0.5MPa to 1.5MPa (at 7 days), it is recommended that a minimum of two moulded samples of these materials be re-compacted in the laboratory for the purpose of obtaining unconfined compressive strength (UCS). Two moulded samples should be compacted in the laboratory and allowed to cure for 7 days.

Curing the moulded samples have been allowed to cure one sample should have its unconfined compressive strength (UCS) determined, after 4 hours soaking under water. UCS samples should be taken at the same frequency as that for field density testing.

Both values of UCS and density ratio should be reported for each test site. UCS samples are to be moulded at their field moisture content as sampled using 100% standard compaction in a ‘A” type mould.

For further correlation of soil strength California Bearing Ratio’s (CBR’s) should be undertaken on cementitious modified materials for each second day’s production or every 2,500m3 whichever is lesser. Desired CBR values of cementitious modified materials should be in excess of 15%.

To ensure that the cementitious materials maintain a desired permeability of less than 5 x 10-8 m/s however preferably less than 5 x 10-9 m/s permeability testing should be undertaken on cementitious modified materials for every fourth day’s production or every 5,000m^3 whichever is lesser.

Please note this document has been compiled with the assistance of Frank Tostovrsnik, Managing Director, Site Geotechnical.

Prof Brian O'Donnell FIE Aust, IntEng., CPEng

Group CEO and Managing Director

Centre for Pavement Excellence Asia-Pacific Limited

in association Dr Dilan Robert

Lecturer in Civil Engineering

Civil Engineering Department,

School of Engineering, RMIT University.

Certified Stabilised Pavement Design in accordance with Centre of Pavement of Excellence Asia Pacific Protocols controlled document

Dated ....

Certified Stabilised Pavement Construction in accordance with Centre of Pavement Excellence Asia Pacific Protocols controlled document

Dated ....