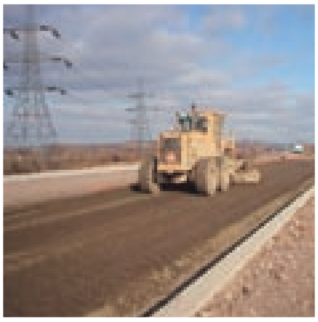

TECHNICAL DATA SHEET

STABILISED SOILS

As subbase or base for roads and other pavements

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The British In-situ Concrete Paving Association

Benefits of Soil Stabilisation

Soil stabilisation is a process whereby unsuitable materials can be treated by the addition of stabiliser to produce a valuable construction resource. The use in this way of site-won materials has both economic and environmental benefits:

- Elimination of lorry movements for disposal of site material.
- Reduced lorry movements for importation of construction material.
- Reduced noise and nuisance to local residents as well as less wear and tear on the local road network.
- No tipping charges or landfill tax.
- Landfill capacity is maintained.
- Valuable non-renewable aggregate resources are not wasted.

Further sustainable and economic benefits can be obtained by designers who appreciate that strengthening the lower layers of a pavement allows for possible economies in the upper layers. The thickness of overlying blacktop and concrete can often be reduced while still maintaining the overall pavement stiffness obtained by more traditional, less sustainable and expensive specifications.

Stabilised soils as subbase or base for roads and other pavements

Introduction

Lime stabilisation of **cohesive** soils for capping layers is a widespread and well-proven process [1][2]. By employing techniques that further enhance the strength of the soil, the process can be extended to produce pavement subbase and base layers. This can be carried out by firstly treating the soil with quicklime, leaving it to mellow and then treating it with either cement, pulverized fuel ash (pfa) or ground granulated blastfurnace slag (ggbs). This is termed a two-stage mixing operation.

In the case of **non-cohesive** soils, treatment can be carried out using cement alone or by a combination of quicklime or cement with either ggbs or pfa.

The treatment of non-cohesive soils and granular materials for pavement layers, particularly with cement, is well documented and covered fully elsewhere [3]. However there is less information covering the treatment of cohesive soils. This data sheet provides guidance on the treatment of such soils to provide:

- A subbase whatever the traffic level [4].
- A combined subbase and base for lightly-trafficked situations.

History

Two-stage stabilisation of cohesive soils using quicklime in combination with cement was pioneered in the UK by the British Airports Authority during the early 1980s [5]. It continues to be common practice for runways, taxiways and aprons at many BAA airports. As a result, the use of the two-stage system spread into the general construction industry where the process has been used for warehouses, motorway service stations, car parks and retail and leisure developments.

Triggered by work at Purfleet [6] and the Tingewick bypass in Bucks [7] in the 1990s, the process of treating cohesive soils has also been used for major highway subbases including the A130 DBFO contract in Essex [8], the Crick bypass in Northants [9] and the A27 Polegate bypass in Sussex [10].

Composition of mixtures

Typical examples of mixture proportions for cohesive soils are shown below. These are expressed as a percentage of the dry mass. The examples are intended to be indicative only for subbase or base applications and proportions will vary according to the soil being treated and the method of mixing.

Mix	Soil (%)	Quicklime (%)	Pfa (%)	Ggbs or cement (%)
1	90 - 96	1.5 - 4	-	4 - 8
2	87 - 93	2 - 4	6 - 10	-

NOTE: In view of the practicalities of the construction process with cohesive soils, UK experience to date supports the use of total stabilizer contents of around 8% to ensure a structurally sound and durable layer.

Specification guidance for treated cohesive soils

Requirements for subbase and base applications include:

- Long term structural performance.
- Trafficability.
- Resistance to frost.
- Volume stability.

Guidance on satisfying these requirements is given below. It is stressed that it is only guidance and it will vary according to the exact requirements on any particular contract and should be adjusted as appropriate.

- Performance can be specified by compressive strength. A level of 0.5 to 1.5 MPa has been found to be realistic and has been specified for test specimens.
- If preferred, stiffness measured with the NAT (Nottingham Asphalt Tester), can be used and specified. Target NAT stiffnesses in the range 1000 to 2000 MPa are normally achievable. For pavement design purposes, however, even if the measured NAT value were higher, a design stiffness of 500 MPa would be appropriate for treated cohesive soils or other fine-grained materials [11].
- CBR (California Bearing Ratio) is an additional although less robust alternative to specifying compressive strength or stiffness. If used, ultimate soaked CBR values in the region of 50% should be expected.
- The strength specified for trafficability will vary according to the age when trafficking will start and the degree of protection afforded by any overlying layers. Unless direct trafficking is heavy, the above performance recommendations should minimize wear during other site operations, although the recommendation is to overlay with the next layer as soon as possible to obtain the best protection.
- Experience in France with both cement and lime/pfa or lime/ggbs combinations, indicates that stabilised layers can be trafficked or overlain immediately without using a curing period. This can be ascertained in the laboratory at mixture design stage by determining the IBI (immediate bearing index) [12}. This is a CBR test without surcharge determined immediately after specimen manufacture using 2.5 kg Proctor compaction for cohesive mixtures and 4.5 kg Proctor compaction for non-cohesive mixtures. The ability to take traffic immediately can be assumed provided the layer thickness is appropriate for the ground conditions and the stabilised mixture achieves the IBI values below. (Note that the indicated values may be conservative)

Soil before treatment	IBI values
Soil with > 35% passing 63 microns and plasticity index > 12	10
Soil with > 35% passing 63 microns and plasticity index < 12	15
Soil with 12-35% passing 63 microns	25
Soil with < 12% passing 63 micron	35
Natural sands and gravel sand mixtures or similar	50

- Compressive strength levels for frost resistance will vary according to local conditions (climate, water table, drainage etc), the properties of the mixture and the thickness and timing of placement of the overlying cover. It is recommended that the overlying construction is placed before the first frosts. If specific frost resistance tests are not carried out and the layer is to be left unprotected over winter (not recommended), a compressive strength of at least 2 MPa should be achieved before the anticipated first frosts.
- Resistance to immersion in water to check volume stability should be carried out using the immersion test in BS 1924 [13]. The mixture will be regarded as suitable for use as a subbase or base provided immersed specimens do not lose significant compressive strength compared with non-immersed specimens (a maximum 20% loss is typically specified although 40% may be more appropriate depending on application, the nature of the soil and for less demanding situations). The test also monitors swelling and should be used for soils of known sulfate/sulfide potential (such soils are listed in reference 2).
- For mixtures based on fine-grained soils, the manufacture of specimens using the moisture condition value (MCV) apparatus has been found very appropriate. Such specimens can be used for compressive strength determination, NAT stiffness determination, and for volumetric swell monitoring [14].
- Age of testing of specimens may be 7, 14 or 28 days for cement or combinations including cement, and at least 28 days or longer for non-cement combinations unless 40˚C curing is employed, when 7 or 14 days should be appropriate.

Site investigation

Investigation should be carried out by a competent geologist or soils engineer and should concentrate on obtaining the best picture of the ground conditions at the depths relevant for stabilisation, particularly moisture content, plasticity, and if relevant, grading. From this it will be possible to group materials into classes for detailed testing in the laboratory as described below.

The presence of, and just as important, the potential for the soil to contain [2], sulfates, sulfides and other sulfur compounds needs establishing because of the risk of expansion and disruption. It is important to note that such materials do not tend to be uniformly dispersed within a soil but are often found in concentrated pockets. However, such is the nature of earthworks excavation and deposition that sulfate, sulfide and sulfur-bearing materials from cuts are likely to be mixed with non-contaminated material, thus diluting their effect.

Attention will also need to be paid to organic matter since it may interfere, although often only temporarily, with the hydration, setting and hardening of the mixture.

As far as possible, it is important to test material in the laboratory that is indicative of what will result after earthworks operations.

Mixture design

The object of the laboratory testing is to determine the type and quantity of stabilisers that are required to produce the desired properties. The properties of each stabiliser should be fully understood.

Stabiliser properties

- Quicklime reduces moisture content and plasticity, and also modifies the structure of cohesive soils. It is the material that best aids pulverization. It also activates ggbs and pfa. The full potential of quicklime is only realized with cohesive soils if full slaking of the quicklime occurs at the time of addition and the mixture is left to mellow for at least 24 hours. Full slaking requires the water content of the mixture to be wetter than Proctor optimum moisture content (OMC) or less than the equivalent MCV. In this way, a high pH environment is produced during mellowing. This aids breakdown of the clay structure and dissolution of silica and alumina from the clay for subsequent reaction with the lime [www.britishlime.org].
- Cement is the fastest acting of all the stabilisers, but compaction of the final mix must take place within two hours of its addition.
- Ggbs is a hydraulic binder that is activated by lime. It is slower to gain strength than cement but provides a longer period, at least six hours in normal temperatures, for construction and compaction operations. At 28 days it may produce greater strengths than cement, but early strength development is more temperature dependent than for cement. Care must be taken when using this material during the colder times of the year [www.ukcsma.co.uk].
- Pfa is a pozzolanic material that reacts with lime. As with the lime/ggbs combination, care must be exercised with a lime/pfa combination in the colder times of the year [www.UKQAA.org.uk].
- In the case of sulfate/sulfide bearing soils, UK research [15] indicates that the lime/ggbs combination has advantages over most other combinations but testing must include immersion and swell testing. American experience with lime-only treatment [16] has found that extended mellowing periods of 72 hours or more at high moisture levels have been beneficial.

Laboratory procedures

- Mixtures should be prepared in a manner that reflects the construction process.
- Where the construction method involves two-stage mixing of cohesive soils, mixtures should be stored between stages in a sealed condition for the anticipated/necessary mellowing period at a target MCV of 10.
- The mixtures (including stabilisers) for the manufacture of the strength specimens should be made at water contents corresponding to OMC and wetter than OMC, say 1.2 x OMC of the mixture. For mixtures made from cohesive materials the OMC should be determined in accordance with the Proctor method given in BS 1924 [13]. (For mixtures made from non-cohesive materials, the OMC should be determined by either the vibrating hammer or the modified Proctor methods of BS 1924.) The OMC should be determined in the laboratory at a time after mixing that relates to the likely time of final compaction in the field.

- As an alternative to water content for cohesive mixtures, it has been found convenient to use water contents at final mixing corresponding to moisture condition values (MCV) of 12 and 8, where generally a value of 12 relates to OMC and a value of 8 to the wettest condition compatible with satisfactory placement, compaction and trafficking.
- Mixing should continue until the mixed material is uniform. In addition, cohesive mixtures should be mixed so that the degree of pulverization prior to final compaction, measured in accordance with BS 1924 [13], is in excess of 30%.
- The specimens should be tested for performance in accordance with the specified requirements, including immersion testing over the above range of water contents or MCVs. The mixture proportions for the works, including moisture content, can then be selected.

Construction

Production of the mixture may be carried out in situ or ex situ. Non-cohesive materials and silty or low plasticity soils can usually be mixed in situ with a rotavator or ex situ in a pugmill or other suitable mixer. Cohesive soils are more difficult to mix in a pugmill and are generally processed in situ.

The following steps are required for in-situ construction using lime at the first stage followed by another stabiliser at the second stage:

- To avoid final level problems, it is recommended that the site is prepared to the level required after stabilisation, using a roller and number of passes similar to that proposed by the stabilisation contractor.
- Spread quicklime over the soil at the specified rate.
- Rotavate the lime into the soil to achieve thorough mixing. Adjust the water content to achieve a target MCV of 10 and not more than 11 for cohesive mixtures.
- Lightly compact the layer to seal the top surface and leave to mellow for at least 24 hours.
- After mellowing re-mix to achieve the necessary pulverization. More than one pass may be required to achieve this. Lightly roll after the re-mixing.
- Spread the cement, ggbs or pfa at the required rate and thoroughly mix into the soil layer. Check that the moisture content is close to OMC and not more than MCV 12 for cohesive mixtures, The moisture content should be sufficient to achieve full hydration of the stabiliser, the required degree of compaction and low air voids to minimize subsequent ingress of ground water. Check the degree of pulverization if not measured earlier.
- Fully compact within the time limits for the stabiliser used and trim to level.
- Seal with a curing membrane or place the next layer.

For ex-situ production, it may be possible for stabilisers to be introduced and mixed simultaneously. It is also possible to use a pugmill to mix the second stabiliser with cohesive material that has already been treated with lime using the in-situ method.

Control testing

During construction, the following aspects should be monitored:

- The depth of the processed layer at all stages
- Stabiliser addition
- Water addition or MCV at all stages
- Pulverization
- Degree of compaction
- Strength.

Site tests to measure surface stiffness can also be performed.

References

1. THE HIGHWAYS AGENCY. Manual of Contract Documents for Highway Works. Volume 1 *Specification of Highway Works.* The Stationary Office, Norwich, England.
2. THE HIGHWAYS AGENCY. Design Manual for Roads and Bridges. Vol. 4 Geotechnics and Drainage. Section 1 Earthworks. *Treatment of fill and capping material using either lime or cement or both.* Part 6. HA 74/00, 2000.
3. KENNEDY, J & HOPKINS, M. *Cement-bound materials for pavements.* Crowthorne, British Cement Association, BCA Publication 46.048, 2000.
4. TRANSPORT RESEARCH LABORATORY. *Stabilised sub-bases in road foundations: structural assessment and benefits.* Crowthorne, TRL Report 248, 1997.
5. HEATH, DC. *The application of lime and cement soil stabilisation at BAA Airports.* Proceedings Institution of Civil Engineers Transportation, 1992, 95, February 11- 49 Paper 9817.
6. KENNEDY, J. *In-situ stabilisation using ground granulated blast furnace slag. Report of a full scale trial carried out in Essex, 30.06.94* John Kennedy, Marlow, 1995.
7. HIGGINS, DD & KENNEDY, J. *Lime + ground granulated blast furnace slag stabilisation of boulder clay on the A421 Tingewick Bypass,* 3rd European Symposium on the Performance and Durability of Bituminous Materials and Hydraulic Stabilised Composites. Leeds, UK 1999.
8. COAKLEY, H. *Case study – stabilisation on the A130.* Britpave seminar, October 2000.
9. BICZYSKO, S. *Maximising the potential for stabilised materials on the Crick Bypass – Case study.* British Lime Association lime stabilisation seminars, 2003.
10. WALSH, ID. *An innovative solution for the A27. Stabilised subbase as aggregates replacement at the Polegate Bypass – Case study.* British Lime Association lime stabilization seminars, 2003.
11. TRANSPORT RESEARCH LABORATORY. *Enabling the use of secondary aggregates and binders in pavement foundations.* TRL Report 408, 1999.
12. BS EN 13286-47. Unbound and hydraulically bound mixtures – Part 47: Test method for the determination of California bearing ratio, immediate bearing ratio and linear swelling.
13. BS 1924: Part 2: 1990. *Stabilised materials for civil engineering purposes. Part 2. Methods of test for cement stabilised and lime stabilised materials.* BSI, Chiswick, London.
14. BS EN 13286-49. Unbound and hydraulically bound mixtures – Part 49: Accelerated swelling test for soil treated by lime and/or hydraulic binder.
15. HIGGINS et al. *Soil stabilisation using lime activated ground granulated blast furnace slag.* Proceedings sixth CANMET/ACI International Conference, Bangkok, Thailand,1998.
16. AUSTIN WHITE LIME, CHEMICAL LIME, TEXAS LIME. *Guidelines for stabilization of soils containing sulfates.* Technical Memorandum, Texas, USA, www.lime.org/sulfate.pdf, August 2000.





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