ENVIRONMENTAL & DURABILITY CONSIDERATIONS OF LIME/CEMENTSTABILISED MATERIAL

1. INTRODUCTION

The treatment of soils with lime, cement and or with lime and cement, is now a well-established technique within the civil engineering industry in the UK. Well over 2 million cubic metres of soil are treated each year to improve their strength and generally make them suitable for construction purposes. Modification and or Stabilisation not only gives financial benefits but also has huge environmental advantages. Construction sites, which are lime and or cement stabilised, have less material taken to tip, fewer lorry movements on and off the projects and less new material import overall.

It is recognised, however, that mixing lime or cement with the site soils during the construction may have some environmental impact on the site during the undertaking of the process, but these are limited compared to overall benefits that can be achieved by using such a process.

2. LIME MODIFICATION/STABILISATION - HOW IT WORKS

When lime is mixed with cohesive soils several reactions take place. Firstly, the lime hydrates as it meets the moisture in the soil. During this hydration process, water is chemically bonded in the reaction and heat is generated. It will, therefore, be noticed that the soil dries quickly, and wisps of water vapour may be noticed as the slight rise in temperature causes loss by evaporation. The chemical reaction that takes place during this time is part of the 'lime cycle' and can be shown as:

CaO +H2O= Ca(OH)2+ Heat

It can be seen from this equation that only water vapour will be liberated during the hydration of the lime due to the heat of hydration.

Once the lime is absorbed within the soil a rapid physio-chemical reaction takes place, which changes the soil properties. Plasticity decreases and workability improves which allows the soil to be compacted to a high standard. This makes it very suitable for civil engineering applications and produces a highly impermeable and durable material once compaction is complete.

Over the longer-term, a pozzolanic reaction takes place between the lime and the soil that forms hydrates of silica and alumina. These are first produced as gels, and later as crystals. They form within the voids of the soil locking the structure together, increasing its strength and reducing permeability. This is a similar reaction to that which occurs in cement although it occurs much more slowly.

Generally, the amount of Lime required to initiate this process is between 1 and 3% of the dry weight of the soil. This will raise the alkalinity of the lime soil mixture, which will generally attain a pH of between 10 and 12.5 required for the cementing process.

2.1. PROPERTIES OF THE LIME/SOIL MIXTURE

Perry et al (1995) confirmed that the treated soil has completely different plasticity characteristics to the original un-stabilised material, and this can be reflected in the way in which the moisture condition valve (MCV) changes after the lime is added. The soil breaks down into a more friable material which is easier to handle and can be compacted to a high standard.The effect of lime on the clay soil also causes a drop-in density and a slight increase in permeability. Littleton (1994) carried out several permeability tests on natural soils and lime modified material by varying both the lime and moisture contents. He concluded that although the soil became more permeable after the addition of lime, it was still classified as clay, and practically impermeable.

2.2. THE LONG-TERM REACTIONS WITHIN A LIME TREATED SOIL

The reactions that take place within a cohesive soil treated with Lime are varied and complex. Sherwood (1993) found that the highly alkaline environment promotes the dissolution of the clay, particularly at the edges of the clay plates, permitting the formation of calcium silicates and aluminates at these sites. These cementitious products are broadly similar in composition to those of cement paste. Most clays found in temperate regions are sufficiently reactive for significant strength to develop, although this reaction is very temperature dependent. As long as the alkalinity remains high and unreacted clay is available the pozzolanic reaction will continue and strength will increase.

Biczysko (1996) studied a stabilised road formation 14 years after initial construction. This indicated a significant increase in strength over the untreated soil and a continuing gain in strength over the 14 years it had been in use. pH testing confirmed that the initial value had fallen from in excess of 12 to a figure of 10.9. This occurs as the lime is used up in the pozzolanic reaction and is also due to carbonation from the reaction with carbon dioxide in the air. Sherwood (1993) states that a pH of at least 8.3 must be maintained to ensure the integrity of the treated material.

2.3. ENVIRONMENTAL PERFORMANCE

When a site is being developed it is essential that this is done in such a way that there is no harm to the environment and that there is no long-term liability from any construction processes that are used.

The controlled introduction of Quicklime (calcium oxide) into a soil during the lime stabilisation process is not an operation that is generally harmful to the environment. Lime stabilisation does raise the pH of the soil during the process, but as has already been established the pH must remain high in a modified / stabilised product to ensure the long-term integrity of the mix as a whole.

The Environmental Protection Act 1990: Part IIA Contaminated Land, defines a contaminated site as one that has a contaminant, a pathway for that contaminant and a receptor that can be affected by the contaminant. If any one of these elements are missing, then by definition, the site cannot be contaminated. The contaminant also must be a substance that can cause significant harm to the receptor or presents a significant possibility of causing harm to that receptor. In addition, the pollutant must be capable of the pollution of controlled waters or to be likely of polluting those waters.

If water were able to pass freely through lime stabilised soil it is possible that some lime may be leached out which could affect animal or plant life. It has already been demonstrated, Littleton (1994), that this is not possible, as the treated soil is impermeable. The source, pathway, receptor linkage is not present in the case of lime stabilised soil and therefore the potential to cause harm or pollute controlled waters is not possible.

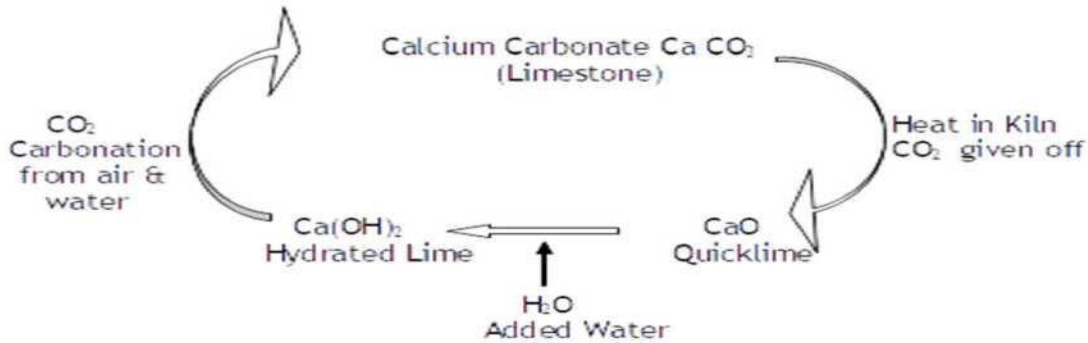
Gettings (1999) records the detailed monitoring whilst constructing the second runway at Manchester airport. Large quantities of lime stabilised soil were used in the construction of the embankment for the diverted river Bollin and sampling during construction and consolidation was carried out in conjunction with the Environment Agency.

Gettings reports that the results from the monitoring programme indicated that the water quality of both outfall and water courses remained unchanged through the modification and subsequent consolidation process.

Biczysko (1996) demonstrated that the pH of the Lime-treated material falls with time, which is a result of the continuing pozzolanic action taking place within the material. Littleton (1994) has also demonstrated that the permeability of this material decreases with time due to the formation of cementitious products within the pore spaces of the material. This means that the likelihood of leachate emanating from the Lime stabilised material reduces with time.

It is possible that a lime or cement stabilised site may be redeveloped in the long-term and that the treated material will need to be removed from site. It is likely that by the time redevelopment takes place the pH of the soil will have reduced to a figure below 10 that should not pose problems for disposal to a landfill site.

As stabilised material essentially retains the original properties of the soil, it easy to handle with modern earth moving equipment. It has the added advantage that once exposed to the atmosphere, carbonation of the lime products occurs causing calcium carbonate (limestone) to form. This conversion will take place within a few days once the Lime-treated material is exposed to the atmosphere and the pH will fall to that of calcium carbonate (8.3). The chemical cycle involving the use of lime in soils can be represented as follows.



2.4 DURABILITY

The durability of a Lime stabilised fill in terms of its actual ability to withstand the potential of wetting and drying or physical water movement, is driven by the quality of the clay fill selected especially in the lower construction. If a selected fill has a low clay content, high silt content and or high granular content then a Lime process alone will not create enough binding and pozzolanic reaction, thereby allowing the placed fill to minimise the ingress or movement of moisture/water. Any Lime stabilised fill being placed within a flood plain must have a high clay content and sufficient Lime addition so as to ensure the full pozzolanic reaction and cementation of the fills placed.

If a low clay content fill is to be considered, then additional binders would need to be added to ensure the full cementation of the placed fill, this being in lieu of any pozzolanic reaction between the Lime & Clay. Additional binders such as PFA and GGBS in conjunction with OPC should be considered or a straight OPC mix, to form a fully cemented fill, though an autogenous mix is likely to be preferable to a rigid cemented product where long-term movement is likely.

3. CEMENT STABILISATION – HOW IT WORKS

When cement is mixed with granular, sandy, or silty soils a pure cementitious action occurs, primarily it's a weak concrete. Unlike lime, cement does not have the same drying / hydrating effect on the treated soils, and in wet conditions more cement and curing time may be required, to counter act raised moisture contents.

As well as considering moisture it's also necessary to consider the particle size of the materials being stabilised, as small particle size and or single size particles, can significantly increase the overall surface area of the materials being treated (at a micro level), all these surfaces and or voids need to be fully bonded, to allow the resultant materials take the shear and loads expected. In such circumstances binder quantities may need to be increased to generate sufficient paste and laboratory results should be fully considered as they may not necessarily truly reflect what may occur in field, lab samples are restrained by their mould when under test, where as in the field no such restraint is present, and silty/sandy materials must fully rely on the cementitious bonding alone, to hold the stabilised materials together, under permanent and most importantly temporary traffic loads.

Like concrete, Cement stabilised materials must be given time to cure, to reach their expected design strength, which like concrete is still considered to be 28 days in terms of ultimate testing, though generally it would be considered that a stabilised layer will reach sufficient strength (60 – 80% of final strength) to allow further works to continue after 5 – 7 days, with an initial set in a constructed layer (200 – 300mm), generally occurring in approximately 24 - 48 hours.

Some form of curing medium (stone layer, bitumen spray, curing compound etc.) should always be considered especially in the summer to ensure that no cemented layer rapidly dries out.

A fully cemented and properly cured fill / pavement layer, will continue to gain strength beyond 28 days.

3.1 . GENERAL PERFORMANCE GUIDANCE

The specifications which are generally applied to hydraulically bound materials (including stabilised soils) in the UK, are as detailed in the specification for hydraulically bound materials as specified in the “Specification for Highway Works” series 600 and 800:

Series 600 covers stabilised capping is based upon British Standards (BS) for stabilised soils.

Series 800 is based upon European harmonised standards (BS ENs) and covers aggregate based hydraulically bound mixtures and stabilised soils for subbase and base applications.

Guidance can also be found in HA 74/007 and Highways Design HD 25

3.2. ENVIRONMENTAL PERFORMANCE

In terms of affecting their surroundings, it is not considered that hydraulically bound materials / layers have an impact on the surrounding environment, where soil stabilisation has been carried out and water courses present, they have not been affected (ref: BritPave, 2006). The process has been regularly adopted to treat contaminated sites (known as solidification) where cells are buried at depth.

It must also be noted that hydraulically bound materials are not a satisfactory growing medium; the bound matrix is densely compacted which impedes root penetration and reduces permeability and nutrientavailability necessary to support plant growth. Therefore, hydraulically bound materials may not be suitable in close proximity to trees, i.e. within the ‘Precautionary Area’ (NJUG 10).

This guidance is simply based upon the mechanical properties of the material.

The use of hydraulically bound materials may actually be considered advantageous in certain areas where roots are problematic (exploiting trenches and damaged pipes as pathways of least resistance). In such circumstances the hydraulically bound materials may serve as a root barrier, protecting the underground services.

4. GENERAL CONCLUSIONS (LIME/ CEMENT - MODIFICATION & STABILISATION)

Lime/Cement modification & stabilisation is a highly cost-effective way of treating unacceptable site materials to make them fit for construction use and or add significant value in the overall pavement design and construction process.

Environmental benefits are gained by minimising the arisings that are taken to a tip and also by reducing the need for importing new materials. The transport requirements and resulting local disruption are also minimised. By increasing the strength of site won materials within a pavement construction, can also significantly reduce the need and amount of the expensive imported materials required in a pavement, such as Type 1 and Asphalt etc.

To utilise a Lime only process within a flood plain area, there should be careful selection of the cohesive clay fill that is to be used within any wet zone, so as to ensure a full pozzolanic/cementitious reaction occurs.

Research and practical experience demonstrates that the inherent properties of both Lime & Cement modified/stabilised fills can create a stable and highly impermeable matrix, that can eliminate the risk of contamination and minimises the potential for leaching, whilst providing a highly durable and valuable product construction product.

It must also be noted though, that whilst a fully mixed and initially set, Lime or Cement modified/stabilised product presents little risk to the environment, the loose powders themselves can present problems and need to be handled appropriately.

Procedures need to be in place in regard to the receiving, transferring, transporting and incorporation of all binders, to ensure the minimum of dust and or spillage occurs during the construction process, as it is these materials that may cause issues if not correctly managed. Storage areas should be cleaned and cleared regularly, and any spillages dealt with by clearing and incorporating, such powders, into suitable soils and or stockpiles.

As a general rule Lime and or Cemented products do not provide an ideal growing medium and therefore may not be suitable for final incorporation into an agricultural area without either being at a substantial depth below the growing zone and or without further treatment to negate/reverse the original processes. In some situations, it may only be viable to remove the modified/stabilised materials to reach agreement and approval of the agricultural land owner. Such arisings would normally be classified as inert waste, but may also retain a substantial value in further construction use.

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