Soil Modification & Ground Stabilisation

Principles, Methods and Applications

Introduction

FURLONG Ground Stabilisation recognise that soil modification and ground stabilisation are crucial techniques in the construction industry, particularly for road and airport projects in the UK since the 1970s. FURLONG Ground Stabilisation aims to share insights into soil treatment and ground improvement, providing an overview of methods, objectives, suitability, and practical considerations.

Applications of Soil Treatment

Soil treatment using lime and cement is widely applied in road and pavement construction by Furlong Ground Stabilisation. It also serves various other purposes:

- Creating temporary access and haul roads for construction sites, including wind farms and cross-country pipelines.
- Adoptable road capping and subbase replacement.
- Industrial building floor slabs.

Improving Unsuitable Soils

Furlong Ground Stabilisation utilise Soil treatment binders to enhance soils that are soft, wet, and possess low shear strength or bearing capacity. Once treated, these soils become suitable as sub-base material for road and pavement construction and may be retained and utilised on-site rather than being removed.

Soil Treatment in the House Building Sector

The house building sector has adopted soil treatment and ground stabilisation technology. Marginal load-bearing soils can be treated and used as platforms for housing development, allowing for shallower foundations.

Objectives of Soil Treatment

The main objectives of soil treatment are:

1. To enable the soil to be handled and placed, achieving maximum compaction with minimal air voids (95% compaction required).
2. To achieve a volumetrically stable treated soil.
3. To realise developments free from differential settlement.

Suitability Assessment for Domestic Applications

The suitability of hydraulically treated soils for domestic building is established through:

1. A review of available treating agents.
2. Site investigation techniques specific to the technology.
3. Appropriate soil chemical analysis for ground treatment.

Verification testing ensures that the treatment is competent, stable, and durable for the design life of the development, including:

1. Laboratory evaluation tests.
2. Site control tests during construction.

Every project is unique, and there is no universal approach suitable for all situations.

Lime Chemistry and Treatment

The lime used in soil treatment by Furlong Ground Stabilisation, is produced by burning chalk or limestone ($CaCO_3$) at high temperature, driving off carbon dioxide (CO_2) and leaving calcium oxide (CaO), known as quick lime. This granular product is ground to varying fineness grades. When quick lime is exposed to water, it undergoes a hydration process, forming calcium hydroxide ($Ca(OH)_2$), or hydrated lime, which appears as a fine powder.

An exothermic and alkaline reaction occurs when quick lime reacts with soil moisture, playing an essential role in soil treatment. Quick lime should not be confused with agricultural lime, which is ground calcium carbonate. If quick lime remains exposed during treatment, it can revert to chalk or limestone through carbonation, turning from an active to an inert state.

Guidance on lime treatment is available from the British Lime Association (www.britishlime.org) and Furlong Ground Stabilisation website (www.furlonggroundstabilisation.co.uk)

Lime Treatment Effects

Adding quick lime to wet soil rapidly dries it and produces slaked lime. The highly exothermic reaction and water combination significantly reduce the soil's moisture content. This reaction also increases soil alkalinity (pH). When sufficient quick lime is added to clayey soil, raising the pH to 12–13, clay minerals undergo a physical transformation known as flocculation or cation exchange, making the soil less clay-like and more friable.

This rapid change in cohesive soils is termed soil modification. Quick lime dries and modifies clay soils, changing their properties and characteristics.

Modification and Stabilisation of Soils

Modification of clay soils results in several improvements:

1. Increase in optimum moisture content (OMC), enabling full compaction at higher moisture levels.
2. Increase in the plastic limit.
3. Enhanced handling characteristics.
4. Greater interparticle attraction, leading to increased shear strength and improved bearing capacity.
5. Reduced susceptibility to shrinkage and swelling.
6. Lower coefficient of compressibility, resulting in reduced settlement and heave.

Drying and modification occur rapidly, usually within 24 hours, triggering a further chemical reaction—stabilisation—which is permanent.

Pozzolanic Reactions and Stabilisation

Clays consist mainly of silica and alumina. When lime is added to raise the pH, silica and alumina dissolve and react with lime to form calcium silicates and aluminates, essentially cement. The clayey soil reacts hydraulically with lime, resulting in strength development and increased resistance to water, frost, and loading. Stabilisation, with correct design and construction, is a permanent process, beginning alongside modification and causing significant strength increases that can continue for years.

Proper curing is essential to maximise cementing potential, typically achieved by sealing the surface with bituminous emulsion.

Cement Treatment Effects

Construction Methods

Soil treatment using lime and cement is carried out mainly by Furlong Ground Stabilisation mobile machinery directly onsite

- **In Situ:** Treatment occurs directly at the site.
- **Ex Situ:** Treatment occurs alongside the area or at a stockpile

Equipment such as combined spreaders and mixers, tractor-mounted mixers, and tractor-drawn spreaders are utilised for efficient application.

Guidance and Specification

Highways England provides guidance and specifications for soil treatment and ground stabilisation in IAN 73 (draft HD 25) and SHW Series 600. The aim is to produce a capping layer with necessary strength and durability for the pavement's design life, typically 40 years. Stabilisation is verified through California bearing ratio (CBR) testing, requiring a soaked CBR value of at least 15% and strict limits on swell and expansion for highway use.

Guidance for stabilised capping is detailed in HA 74, emphasising the involvement of experienced engineering geologists or geotechnical engineers. Treated soils are also permitted for sub-base, with structural design covered in IAN 73 and specification in SHW Series 800, referencing BS EN 14227 for hydraulically bound mixtures.

Performance Controls for Sub-base

Highways England's requirements for treated soil for sub-base include:

1. Testing for sulfates and sulfides, with a maximum limit of 0.25% Total Potential Sulfate (TPS).
2. Strength after immersion in water testing, requiring specimen strength to be at least 80% of the non-immersed specimen.
3. Testing strength specimens on the field mixture.
4. In situ density testing on the compacted layer.
5. Surface stiffness testing on the finished layer.

Performance requirements for sub-base are more rigorous than for capping. Industry guidance is provided by Britpave, British Lime Association, Concrete Centre, Cementitious Slag Makers Association, and UK Quality Ash Association.

Requirements for the Soil Mixture

During construction, the mixture must meet specific requirements:

1. Moisture content.
2. Pulverisation (particle size) after mixing.
3. Immediate bearing capacity.
4. Moisture Content Value (MCV).
5. Workability period (time available between mixing and final compaction).

Field mixing and compaction tests determine the strength and durability of the constructed layer.

Sulfates and Sulfides

Past issues with soils containing high sulfate or sulfide levels are now better understood. To minimise performance problems, the following steps are recommended:

1. Thorough desktop analysis to identify potential for sulfates and sulfides.
2. Extensive site investigation to assess occurrence and degree.
3. Laboratory testing with appropriate treating agents.

Swelling and expansion issues can occur with sulfate levels as low as 0.25%. Choosing the right treating agent is essential to minimise risks.

Construction Recommendations

Lime and cement, as well as ggbs and coal fly ash, have been used for over 30 years in the UK to produce stabilised capping layers for highways. The process, described in HA 74, involves two-stage mixing for lime: initial mixing, followed by a maturing period of 24 to 72 hours.

Lime improvement is a more recent development for highway earthworks, involving a one-stage mixing process to dry unsuitable soils for optimum compaction.

1. Raise the MCV from less than 8 (very wet) to the range 8–12.
2. Produce dry soil suitable for excavation and placement.
3. Enable appropriate compaction to achieve good density and minimal air voids.

Preparation for Soil Treatment and Ground Stabilisation

Preparation depends on whether treatment occurs at source, in a dedicated mixing area, or at the point of use. Furlong Ground Stabilisation Test and Record the potential density after treatment and compaction must be established to determine lime spread rate and treatment depth.

- **Quick Lime Spreading:** Spreaders with flotation tyres are used for wet, low-bearing soils.
- **Mixing and Pulverisation:** Binding agents are mixed with clays using rotovators, often requiring at least two passes to optimise drying.
- **Grading and Levelling:** Grading ensures proper water run-off, and treated soil is placed in layers via scraper or dozer.
- **Compaction and Finishing:** Selecting suitable compaction equipment (rollers and whacker plates) ensures required compaction levels and produces a sealed, well-closed surface.

Environmental and Health & Safety Considerations

Furlong Ground Stabilisation understand Lime and cement are strong alkalis, necessitating adequate personal protection equipment for operatives. Measures must be taken to minimise airborne dust and protect health and the environment, including:

1. Proper maintenance and operation of dust filters on spreaders during filling.
2. Use of rubber skirts at discharge points on spreaders.
3. Ceasing work during windy conditions.
4. Applying water spray to dampen exposed treating agents.
5. Preventing plant from driving over spread treating agents.
6. Prompt mixing-in of the treating agent.

Skin contact with cement and lime must be avoided, as burns can occur in the presence of water. Binder suppliers are responsible for providing safety data sheets, and advice is available from the Health and Safety at Work etc Act 1974. Once mixed, leachate or run-off is unlikely due to rapid chemical consumption within treated soil. Studies show quicklime migration through clay soils is negligible. Although lime and cement inhibit growth when added to soils, the pH can be restored by removing imported granular material, Pulverising stabilised layers, testing pH, and adding fertilisers like nitrogen and other regenerative minerals. Furlong Ground Stabilisation specialise in the regenerative element of the stabilisation process once works are decommissioned.

Sustainability

The primary advantage of soil treatment is the use of indigenous soils, resulting in:

1. Minimised off-site disposal.
2. Reduced haulage of unsuitable material and replacement with suitable material.
3. Limited construction trafficking.
4. Reduced lorry movements through local road networks.
5. Lower energy consumption.
6. Significantly reduced carbon footprint compared to conventional road construction practices.