

FURLONG Ground Stabilisation

Lime Stabilisation – Saving Lime, Time and Carbon

Introduction

Lime stabilisation is widely used to improve the engineering properties of soil. The process involves adding lime, typically quicklime (calcium oxide) or hydrated lime (calcium hydroxide), which reacts with the soil to improve strength, workability and durability. Furlong Ground Stabilisation uses lime stabilisation across a range of applications, including road construction and foundation works.

Furlong Ground Stabilisation has undertaken research and trials to assess whether lime content can be reduced while maintaining effective stabilisation and soil modification performance.

Key control parameters:

- Compaction
- Moisture
- Mellowing

Compaction Methodology and Moisture Condition

The first objective was to identify a compaction method that would provide adequate short-term stiffness while meeting long-term durability requirements. The specification required low air voids, below 5%, in stabilised cohesive fills.

Using the modified Proctor method with a 4.5 kg rammer was considered because it can produce a higher compacted Maximum Dry Density (MDD). However, achieving low air voids requires the material to be at, or wetter than, Optimum Moisture Content (OMC) when compared with the 2.5 kg rammer OMC. This corresponds to a maximum Moisture Condition Value (MCV) of 12, which is commonly adopted in UK specifications.

By contrast, achieving high relative compaction with the 4.5 kg rammer would require a drier mixture. This conflicts with UK best practice and would make the low-air-voids requirement harder to meet.

Laboratory trials compared moisture conditions and compaction regimes to assess their effects on compaction, air voids, swell and soil strength over time. The 2.5 kg rammer samples were prepared at:

- MCV 10, equivalent to OMC +2–3%
- MCV 12, equivalent to OMC +1%
- MCV 13, equivalent to OMC

4.5 kg rammer samples were prepared at MCV 10, equivalent to OMC +7–8%, and MCV 12, equivalent to OMC +5–6%. Results showed comparable remoulded densities for both rammer sizes, with no significant difference in California Bearing Ratio (CBR) performance or swell over time.

Mellowing Period Trials

The trials involved adding lime to the material, allowing it to mellow for 0, 2, 6, 12 or 24 hours, then compacting the samples and soaking them in water for 28 days. After each mellowing period, the following properties were tested:

- Pulverisation
- Remoulded density
- Air voids at compaction
- California Bearing Ratio (CBR)
- Linear swell

Samples with longer mellowing periods were harder to remould to achieve low air voids. The results showed that a 2-hour mellowing period produced the lowest linear swell while still achieving suitable strength and the required pulverisation.

The shortest practical mellowing period was therefore adopted.

Following lime spreading, mixing and compaction, this typically resulted in a 1–2 hour mellowing period. Pulverisation and MCV tests immediately before compaction confirmed compliance with the requirements, including at the lowest lime content trialled.

Specification Context

The specification required two passes of the stabilising mixer to achieve pulverisation, followed by a 24–72 hour period for the lime to react with the soil. This mellowing period is intended to support material breakdown, allow lime to coat the particles and reduce the risk of untreated material.

Excessive mellowing can be counterproductive. It may increase clod porosity and, in turn, increase durability risk if water enters the treated material. The existing minimum mellowing requirement has been in place for many years and was influenced by the stabilisation plant efficiency and lime reactivity available at the time.

Long mellowing periods can also disrupt earthworks sequencing, particularly where multiple fill layers are being placed. A shorter mellowing period enables layers to be completed within the same shift and avoids leaving areas unavailable while mellowing takes place.

Programme Benefits

Because bulk earthworks filling requires treatment across multiple layers, improving productivity was essential to meeting programme requirements. Given the high reactivity of modern lime products and the efficiency of current stabilisation plant, reducing mellowing time was a key target.

Durability Validation for Lower Lime Content

Laboratory stabilisation trials were undertaken to determine whether reduced lime content could still deliver suitable stabilised fill performance, while reducing lime demand, cost and the carbon impact associated with imported lime.

Experience from similar schemes indicated that 1.5% lime could provide the required performance. To demonstrate long-term durability, a one-year test period was selected to compare lower-lime mixtures with mixtures containing higher binder contents.

Full immersion in water for one year was considered conservative and more onerous than typical field conditions, providing a robust basis for assessing durability and performance. Retention of strength, measured by California Bearing Ratio (CBR) over time, was used to assess the risk of localised softening if water enters the earthworks during service.

The specification required stabilisation, rather than short-term improvement, using either a minimum of 2.5% quicklime or the Initial Consumption of Lime (ICL) value.

ICL is reached when the pH rises above 12.4, at which point the material is considered stabilised. To justify reducing lime content, an alternative method was needed to demonstrate long-term stabilisation performance.

BS EN 16907-4:2018, clause 3.20, defines stabilisation as follows:

“Soil stabilisation – operation consisting in obtaining a homogeneous mixture with binder(s), and optionally with water, which properly compacted significantly changes (generally in the medium or long term) the characteristics of the soil in a way that renders it stable, particularly with respect to the action of water and frost.”

To demonstrate compliance with this definition, the trials had to prove both long-term durability and successful pulverisation. Performance was compared at 1.5% and 3% quicklime addition. A 1.5% lime addition is common in French high-speed rail practice and was considered the lowest practical spread rate achievable.

pH and Permeability Findings

Mixture pH was measured at different lime contents. The 1.5% lime addition produced an average pH of 11.5, compared with more than 12.4 for the 3% lime addition. Despite the lower pH and lime content being below the ICL threshold, the trials showed that stabilisation was still achieved.

After identifying the optimum moisture condition for achieving low air voids, mixture durability was further validated through permeability testing. Samples were tested untreated and with 1.5% and 3% lime additions. The 1.5% and 3% results were comparable, both showing a two-order-of-magnitude reduction in permeability compared with the untreated material, from 10^{-8} m/s to 10^{-10} m/s. This provided further evidence of long-term durability and confirmed that 1.5% lime addition can provide a durable stabilised solution.

Site Trials

A 300 mm layer thickness was targeted to improve output. This thickness also allows direct testing using a nuclear density gauge, aligning field compliance control with the approach proposed for the works.

The trials showed that lime stabilisation can achieve comparable durability and performance with a 1.5% lime addition. This represents a 40% reduction from the UK standard minimum practice of 2.5%. The key findings are grouped below.

Key Findings

- **Lower lime contents can still achieve stabilisation.** Long-term stabilisation was achieved at lower lime contents than previously specified. Although the lower lime content raised pH to around 11.5 rather than the 12.4 required for ICL, alternative verification methods demonstrated long-term durability that meets the standard.
- **Moisture condition is critical.** If the mix is too dry, it may draw in available water and lose strength. The target condition should be just wet of optimum before compaction, equivalent to approximately MCV 10–12 for the MMG used in these trials.
- **Higher lime contents increased water demand.** Increased lime addition was counterproductive because it dried the material more rapidly and resulted in air voids above the specification requirement.
- **Shorter mellowing periods are appropriate.** A mellowing period of less than 2 hours is suitable for modern mixing plant and lime sources. It also reduces the risk of increased porosity within treated clods associated with longer mellowing periods.
- **Effective pulverisation remains important.** Pulverising the material before lime mixing and compaction helps ensure thorough lime distribution.

- **Low air voids should be prioritised.** Achieving low air voids at the correct moisture condition, typically MCV 10–12 for lime-stabilised soils, is preferable to pursuing higher relative compaction in isolation.
- **Site control procedures must account for changing material properties.** Changes in moisture content, MDD and particle density over time after lime addition informed improvements to site control, testing and monitoring procedures.
 - Samples were taken immediately after mixing, and soaked CBR specimens moulded on site so that the moisture condition reflected the in-situ material.
 - Initial wet weights for disturbed moisture-content samples were recorded on site using a portable balance to avoid moisture loss during transport to the laboratory.
 - Nuclear density gauges were correlated specifically for moisture-content readings as well as density, reducing moisture measurement issues.
 - Samples used to determine reference OMC/MDD in the laboratory were taken from the mixed material and tested immediately on receipt to avoid changes in MDD or particle density over time.

Conclusion

Careful material selection, effective pulverisation and controlled moisture conditioning enabled shorter mellowing periods and supported the use of lower lime contents. Long-term durability testing confirmed that 1.5% lime addition can provide a durable stabilised solution where the correct moisture and compaction controls are applied.

These findings represent a significant development in lime stabilisation practice. They provide a basis for reducing lime demand, cost and carbon impact, while maintaining performance, and are expected to inform future project specifications and wider industry practice.

With appropriate design, testing and site control, Furlong Ground Stabilisation can use lime stabilisation to support more sustainable and resilient infrastructure delivery.