

International Society for  
Soil Mechanics and  
Geotechnical Engineering

Time Capsule



## Lime Stabilisation

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### Introduction

Although lime stabilisation of clay soils had been practiced for decades, and the obvious beneficial effects of dehydration, clay modification and stabilisation (or solidification) were widely observed and reported, the exact nature of the alteration of the clay chemistry, or more importantly the physico-chemical properties, remained poorly understood towards the end of the last century (Rogers *et al.*, 1996). If the wealth of empirical evidence was to be relied upon for assurance of long-term physical properties (e.g., in road foundations), for the treatment of contaminated ground and for deep stabilisation (e.g., of slopes and foundations), then the fundamental knowledge base needed to be strengthened and rigorous research on the applications was necessary to support, or contradict, the many ambitious claims made in the literature. This time capsule describes the foundational studies.

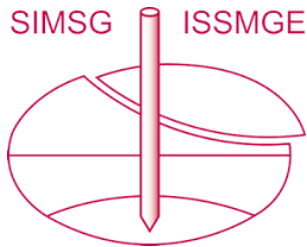
### Fundamental Lime-Clay Reactions

The time-dependent effects of mineral structural chemistry on the lime–clay reaction were established for two clays representing the extremes of structural negative charge development (English China Clay and Wyoming Bentonite) by Boardman *et al.* (2001a). Changes in the physico-chemistry of clay samples (solution pH, conductivity, and analysis of eight elements in solution) were monitored for different percentage lime additions over different time periods. Geotechnical characterisation included undrained shear strength and Atterberg limit testing. Pozzolanic reactions occurred due to the dissolution of aluminium and silicon from the respective minerals, yet the solidification mechanisms were found to be different for the two minerals and these were characterised in detail. Successful solidification could be monitored using simple conductivity measurements without the need for extensive and complex elemental analysis.

More specifically, for English China Clay (a pure form of kaolinite) short-term flocculation is dependent on pH and long-term strength is dominated by the production of calcium aluminate hydrate (CAH), whereas for Wyoming bentonite, strength is dominated by short-term flocculation that is only enhanced by high pH, and long-term strength is a function of the production of calcium silicate hydrate (CSH). These CAH and CSH reactions were further studied by Boardman *et al.* (2004) to determine the effects of metal contamination, using lead and iron in the form of additions of  $Pb^{2+}$  or  $Fe^{3+}$  ions. It was found that these contaminants strongly affect the initiation and development of the lime–clay reactions, both during short-term modification and during the longer-term solidification, and that the effects are clay mineral-dependent. The most profound effects were observed in clay minerals with pH-dependent charge (typical of clays commonly found in the UK), where both flocculation and mineral dissolution were substantially altered.

### Lime Modification and Stabilisation of Clay Soils for Surface Applications

Lime modification can transform unworkable wet clay soils and impossible-to-traffic site conditions into materials that don't obstruct site works. Much empirical engineering evidence proved this, but scientific determinations of the quantities of lime to add to different clay



types was lacking. The fundamental principles were reported by Rogers and Glendinning (1996), while the scientific justification for the quantities of lime required for different clay mineralogies was reported by Rogers and Glendinning (2000). However, lime-clay mixing has applications far beyond construction expediency (Rogers *et al.*, 1997), being used originally by the Romans for road-building and extensively for unsurfaced roads in the US, for example. It was adopted in the UK as a method of improving subgrade soils as capping layers beneath more competent structural materials in road foundations, supported by techniques for monitoring the properties of lime-treated clay *in situ* (Boardman *et al.*, 2001b) and measurements of the two primary performance characteristics for roads: resilient elastic modulus and resistance to permanent deformation (Rogers *et al.*, 2006).

### Deep Stabilisation of Clay Soils using Lime Piles

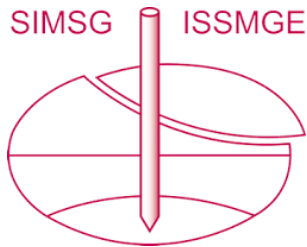
Lime treatment of clays clearly had potential for deep stabilisation and its reported efficacy (e.g., in stabilising slopes) was accompanied by wide-ranging claims of pervasive changes in the ground. Unpicking this evidence and researching the true mechanisms of lime pile stabilisation of failing slopes formed the focus of an extensive programme of research (Rogers and Glendinning, 1993, 1994, 1997a&b). Glendinning and Rogers (1996) summarised these mechanisms as:

- the immediate creation of large negative pore water pressures due to the hydration of quicklime (hence halting slope movements),
- overconsolidation of softened and weakened clay in shear zones,
- dehydration and cracking of the clay surrounding the lime pile,
- increased strength of the clay due to 'lime migration', and subsequent lime stabilisation reactions, aided by penetration of dissolved ions from the lime pile into the cracks radiating from the pile, and
- crystallisation of the hydrated lime in the pile itself.

The primary mechanism – stabilisation of the clay *in situ* via ion migration – became the focus of subsequent research (Rogers *et al.*, 2000; Barker *et al.*, 2006, 2007). While chemical gradients and hydraulic gradients come into play here, the question of assisted ion migration overtook the field of study; the focus turned to the various mechanisms of ion and water movement caused by electro-kinetics (e.g., Barker *et al.*, 2004; Liaki *et al.*, 2008, 2010; Jones *et al.*, 2017).

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