UNITED KINGDOM QUALITY ASH ASSOCIATION

Technical Datasheet

6.5

Fly Ash and Lime Stabilised Clays Preventing Sulfate Heave

(Recommendations in this datasheet are given in good faith and are presented for consideration and adoption by the responsible engineer concerned)

Introduction

Lime-stabilisation is a cost-effective and environmentally sustainable technique to enhance soil properties, particularly for highway construction purposes. While there have been many successful lime stabilised contracts over the years, the process can also cause heave of the stabilised material in some sulfate-bearing clays. For a number of years it has been known that Ground Granulated Blastfurnace Slag (GGBS) can prevent these problems in certain ground conditions. As fly ash, also known as Pulverised Fuel Ash (PFA) in the UK, is used in the manufacture of sulfate resisting concrete mixes and had been used in the USA to prevent sulfate heave issues in stabilised soils, the UKQAA proposed to the University of Dundee[i] that research into this area may be useful. This was to look at the efficacy of fly ash at preventing sulfate heave and was supported by a number of materials producers and users. This Technical Datasheet summarises the findings of that work.

The project

A wide range of test materials were used in the research project including;

- Five clays, containing different levels of Total Potential Sulfate (TPS), sourced from different locations in the UK, of which three clays had a high Total Potential Sulfate content as follows;
  - Oxford clay, 1.8% TPS
  - Lias clay, 1.5% TPS
  - Kimmeridge clay 1.0% TPS
- A typical highway works soft-burnt CL90 quicklime (CaO) conforming to BS EN459-1,
- Seven fly ashes of varying fineness, loss-on-ignition and storage history from a number of differing power stations within the UK and,
- A sample of ground granulated blast furnace slag (GGBS) was used as a benchmark.

Figure 1 - Weald Clay Quarry

Accelerated volumetric swelling tests (in accordance with BS EN 13286-49) were carried out on the sulfate-bearing clays, stabilised with different percentages of lime (at 3, 4.5 and 6%) and fly ash (at 6, 12, 18 and 24%) or GGBS (at 3, 6 and 9%) and compacted to optimum moisture content and maximum dry density. This test procedure is considered to be more sensitive than the linear swelling test method BS EN 13286-47 method and is believed to give better discrimination of effective solutions to sulfate swelling.

Many differing tests were carried out to determine the mechanisms by which the fly ash was reducing the swelling, including the key engineering and durability properties, scanning electron microscope analysis, etc. This datasheet is only a summary of the findings, as the full project resulted in a comprehensive report.

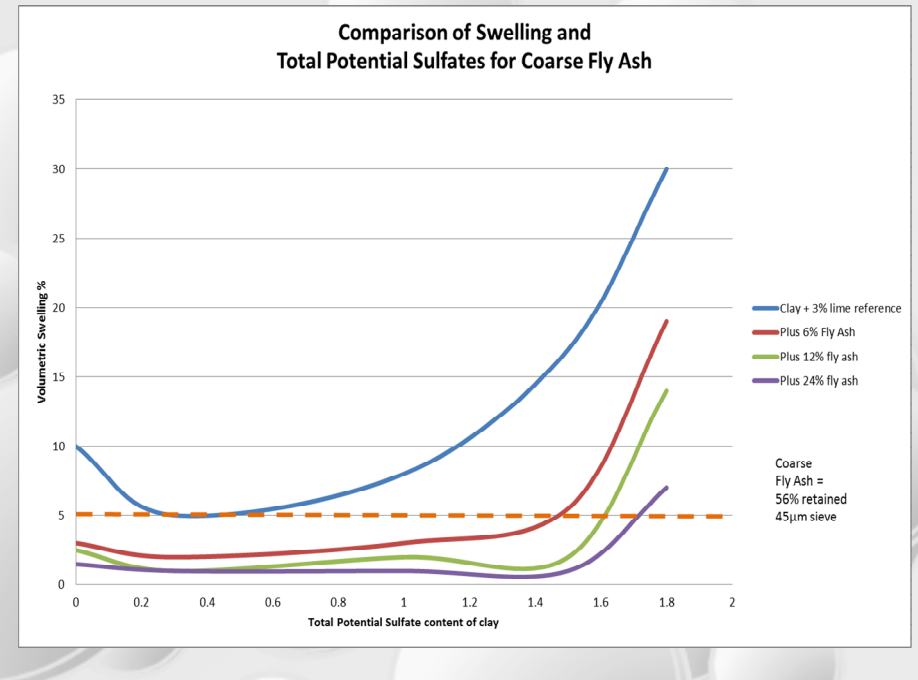

Figure 2 - Coarse fly ash is particularly effective at reducing swelling

The findings

Fly ash was found to be effective in reducing sulfate swelling of lime-stabilised clays below the accepted 5% limit, by volume. The degree of reduction was essentially proportional to the quantity and coarseness of the fly ash added, with around 12-18% being the optimum as shown in Figure 2. The reduction in swelling is related to the coarseness of the ash, with coarse fly ash (~56% retained 45µm sieve) being significantly more effective than fine ash (~10% retained on a 45µm sieve), as shown in Figure 2.

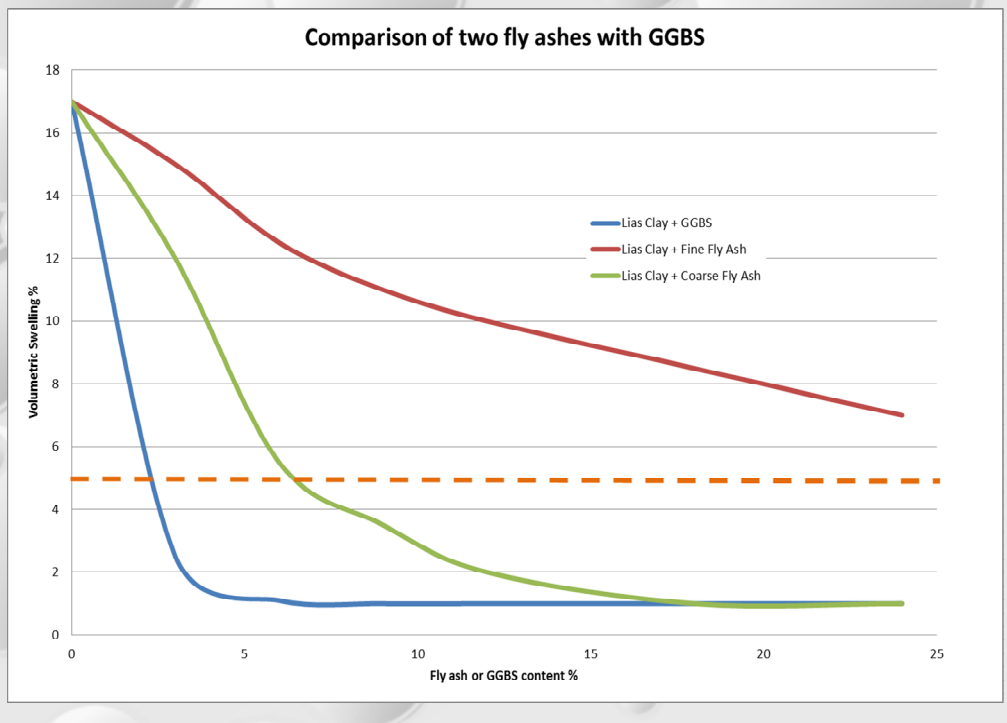

Figure 3 - The differences between GGBS and coarse and fine fly ashes

Extending the mellowing period prior to compaction was found to reduce swelling, but there was little benefit when this was increased beyond 1 day. The effects of exposure temperature and the simultaneous addition of fly ash to soil with lime (one step technology) were minor with regard to the occurrence of swelling. The work examining the underlying mechanisms indicates that ettringite formed in all combinations irrespective of the fly ash used. It, therefore, appears that the beneficial effect of fly ash was due to increased soil porosity, which can 'accommodate' ettringite expansion, hence why coarser fly ashes will perform more efficiently. There is also a contribution through enhanced soil strength due to pozzolanic reaction.

The lime-stabilised soils containing fly ash gave improved properties (compressive, tensile and shear strengths, immediate bearing index, permeability, frost heave etc.) compared to combinations without fly ash. Overall, the results indicated that fly ash can be used effectively to minimise swelling in sulfate-bearing lime-stabilised clays, while meeting or improving other properties relevant to the application.

It should be noted, as recommended in Britpave Soil Stabilisation publications, that where Total Potential Sulfate concentrations in clays of greater than 1.0% are found, that lime stabilisation should be carried out with extreme caution.

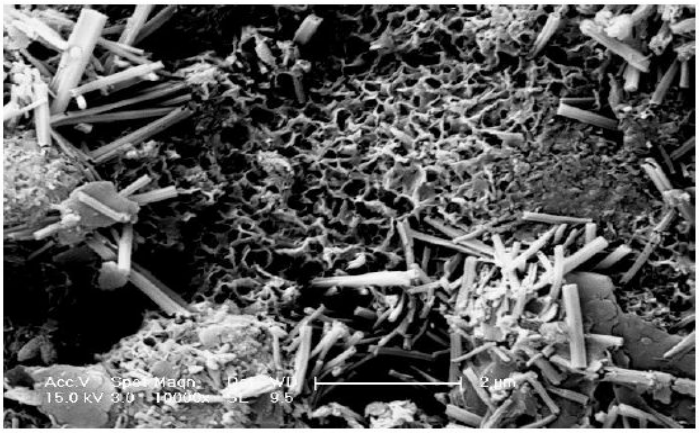

Figure 4 - Lias Clay with 3% lime & 18% fly ash after 10 days of accelerated curing

A summary of the findings

The following conclusions were drawn from the project;

1. Fly ash was effective at reducing the sulfate heave in lime treated clays. The proportions of fly ash required were greater than required for GGBS.
2. Coarse fly ash was more effective at preventing swelling than fine fly ash. Coarse ash in not generally so effective in concrete, but was found to give the best performance in lime stabilised clays. Finer fly ashes may not be effective in the clays being treated containg higher TPS values.
3. Longer mellowing times reduced the swelling potential. However, in practice, extended mellowing is rarely possible due to time restrictions on modern construction sites.
4. Fly ashes with higher levels of sulfate were less effective at preventing sulfate heave. Fly ash containing less than 1% by mass of sulfate (as SO_3) is preferable.
5. Blending lime and fly ash with the clay at the same time was no different than using a two stage process. Considerable time savings are possible using this single pass approach.

6. The permeability and frost heave characteristics of lime stabilised clay and fly ash mixes remained within the recommended limit values.

Recommendations

The following are considered essential when assessing any potential contract;

1. The procedures described in Britpave Technical Datasheet BP/16, 'Stabilisation of Sulfate-Bearing Soils' shall be followed. Where the Total Potential Sulfates (TPS) of clay are greater than 1.0%, extreme caution shall be taken in order to avoid the risk of swelling.

2. Representative samples of the clay, lime and fly ash shall be obtained. These should be used to assess the effectiveness of any given fly ash/clay/lime combination in the prevention of sulfate swelling using extensive laboratory testing.

3. Volumetric Swelling tests according to BS EN 13286-49 should be carried out, in preference to linear swelling.

4. Finer fly ashes may not be able to prevent swelling at higher TPS levels, whereas coarser ashes may be effective. Therefore it is important that the same type/source of fly ash and lime as used in any laboratory evaluation is used in the field.

5. Fly ash should as a minimum comply with BS EN13055-2.

   Note: There are other standards which may be appropriate for compliance purposes.

Bibliography

The following papers and standards have been published which give more details of the research test methods as follows;

1. McCarthy MJ, Csetenyi LJ, Sachdeva A, and Dhir RK: Controlling swelling in lime-stabilised sulfate-bearing soils using fly ash, Ground Engineering, in press
2. McCarthy MJ, Csetenyi LJ, Sachdeva A, and MR Jones: Role of Fly Ash in the Mitigation of Swelling in Lime Stabilised Sulfate-Bearing Soils, World of Coal Ash, Lexington, Kentucky, May 2009. See http://www.flyash.info/2009/106-mccarthy2009.pdf to download this paper.
3. BS EN 13286-49, 2004, Unbound and hydraulically bound mixtures – Part 49, Accelerated swelling tests for soil treated by lime and/or hydraulic binders, London, BSI.
4. BS EN13055-2 BS EN 13055-2:2004, Lightweight aggregates. Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications, London, BSI.
5. BS EN 459-1:2001, Building lime. Definitions, specifications and conformity criteria, London, BSI.
6. BS EN 13286-47:2004, Unbound and hydraulically bound mixtures. Test method for the determination of California bearing ratio, immediate bearing index and linear swelling, London, BSI.

If you require more information, lists of contractors, etc on the stabilisation of soils, visit the Britpave dedicated Soils Stabilisation task group web site at http://www.soilstabilisation.org.uk/.

Also http://www.hydraulicallyboundmixtures.info/ has information on HBMs and soil treatment.

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