Industry Voices

Treatment of clay shrinkage via non disruptive expansive geopolymer injection.

In collaboration with:

Treatment of clay shrinkage via non disruptive expansive geopolymer injection.

Geobear was originally founded in the 1980s in Finland, known then as URETEK. Since that time the proprietary URETEK geopolymer injection solutions developed by the company have gone on to be used successfully on over 200,000 projects across the globe. The geopolymers are multi chemical component systems which are mixed at the point of injection into the ground. The chemical reaction between these components creates an expansive geopolymer which compacts and densifies granular materials and strengths clay soils by filling existing and newly created micro fractures. The geopolymer injection design varies according to the desired objective, whether this is filling voids, lifting sunken slabs, and building or increasing bearing capacity and reducing settlements.

This article focusses on the use expansive geopolymers to mitigate the impact of subsidence and heave caused by shrinkable clay soils.

The current situation:

According to the British Geological Survey website[1] *"Shrink–swell is the volume change that occurs because of changes in the moisture content of clay-rich soils. Swelling pressures can cause heave, or lifting of structures, whilst shrinkage can cause settlement or subsidence, which may be differential.*

This shrink–swell behaviour is the most damaging geohazard in Britain today, costing the economy £540 million following a drought in 1991. Heat waves in 2003 and 2006 led to peaks in subsidence claims. More recently, the Association of British Insurers (ABI) reported that over 10,000 households made claims worth a total of £64 million during July to September in 2018 (ABI, 2018). The ABI stated that the 350 per cent increase in the value of claims during July to September 2018 was the highest quarterly jump since records started more than 25 years ago."

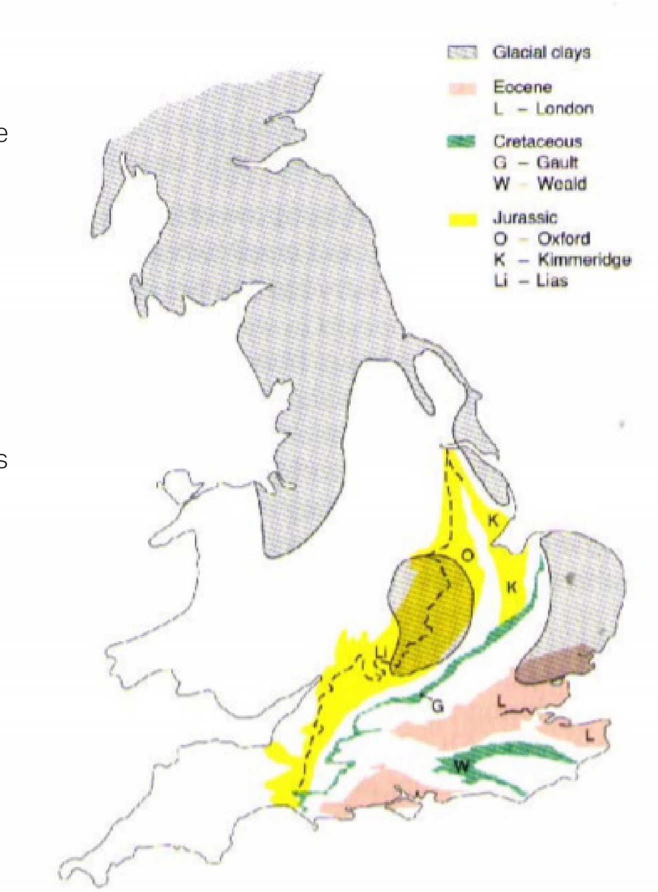
[1] *https://www.bgs.ac.uk/geology-projects/shallow-geohazards/clay-shrink-swell/*

What causes clay shrinkage and swelling?

Water molecules are adsorbed in layers onto the surfaces of the clay minerals which form clay soils. The maximum amount of water which can be adsorbed is a function of the specific surface area of the minerals. As the specific surface area increases more water can be adsorbed and volume will increase. There are three principal clay minerals, listed in increasing specific surface area in meters sq. per gram of soil[2].

- Kaolinite - 10 to 20
- Illite - 65 to 100
- Montmorillonite - Up to 850

Therefore, it is the relative proportions of these clay minerals in clay soils which determines the magnitude for volumetric change due to changes in moisture content.



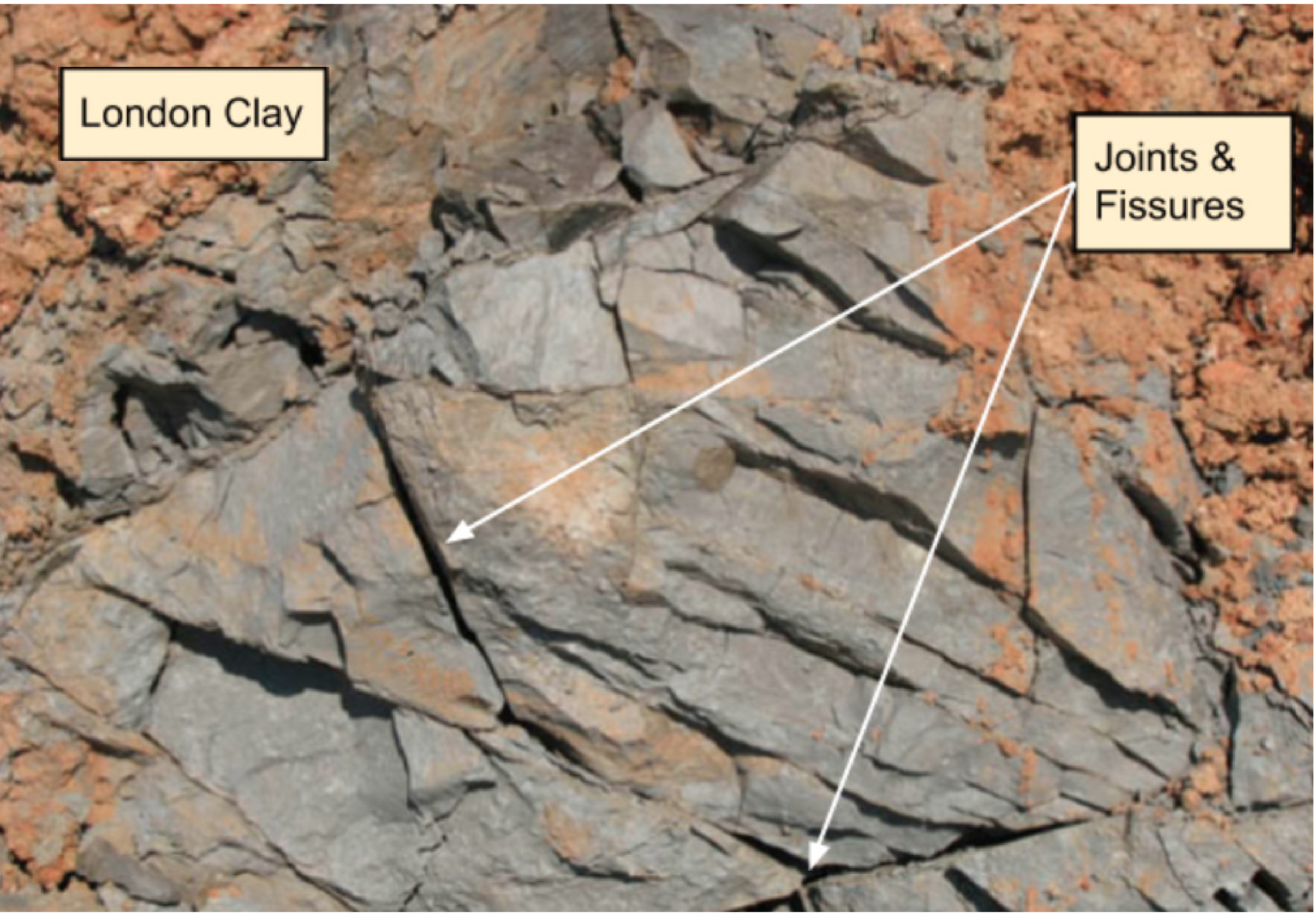
Volume change potential:

Liquid and plastic limit tests[3] were developed to characterise the behaviour of clay soils and these are referred to as Atterberg Limit tests. These tests are key to determining likely clay shrinkage and swelling potential and are indicative of the relative proportions of the principal clay minerals in a soil.

The National House Building Council (NHBC) uses the modified plasticity index[4] to assess volume change potential and has developed detailed guidance for building near trees on potentially expansive soils, see Table.

Modified Plasticity Index	Volume Change Potential
40% and greater	High
20% to less than 40%	Medium
10% to less than 20%	Low

[2] *Knappett, J and Craig, R.F. (2020) Craig's Soil Mechanics.9th Edition. CRC Press. London*
[3] *The liquid limit (LL) is the moisture content of a clay at which liquid behaviour is observed, the plastic limit (PL) is moisture content at which the clay deforms plastically.*
[4] *The modified plasticity index is the difference between the LL and PL, multiplied by the % of particles <426μm.*



Fissured Clays

All the clays in the United Kingdom which have a high or medium volume change potential are overconsolidated fissured clays, which were formed millions of years ago in ancient sedimentary basins. The process of diagenesis and consolidation from very loosely compacted clay particles under water into mud-rock, created natural lines of weakness called joints and fissures in these formations. These discontinuities are very tight at depth but open under stress relief and weathering which turns the mud-rock into clays near the surface. The spacing of fissures, joints and discontinuities is site specific, but is often less than 50mm in the top 10m of the above listed formations. A picture of an outcrop of London Clay is presented below with clear fissures, joints and discontinuities present.

Fissured clays include the following formations:
- London Clay
- Gault Clay
- Weald Clay
- Oxford Clay
- Lias Clay

The distribution of these formations across the UK has been mapped by the British Geological Survey.

What is the significance of fissures to clay shrinkage?

Natural fissures and joints play a key role in the seasonal moisture content variation observed in clay soils and the consequential volumetric change which can occur. This is because they provide the pathway for water movement, intact clays with no fissures or joints have a very low permeability typically 1×10^{-10} m/s or 3 mm/year, which means water moves through clay extremely slowly. For this reason, 'puddled clay' was used to build the UK canal network in the 1700's and we use 'compacted clay' for landfill lining systems to prevent leachate from escaping.

The presence of fissures and joints greatly increases the bulk permeability of a clay as water moves through the fissures and not the intact clay. The permeability of fissured and desiccated clays is given in Knappett & Craig (2020) to range between 1x 10^{-2} m/s and 1x 10^{-7} m/s, which is several orders of magnitude higher than intact clay. This increase in permeability is entirely due to nature of the fissures and joints present.

The fissures allow water to be lost quickly from clay soil in the summer which causes shrinkage and conversely replenished quickly in the winter as the clay rehydrates and it swells back to its original volume. If foundations of buildings are cast in the zone of soil subject to these seasonal changes structural damage to foundations can occur. The presence of trees increases the depth to which seasonal changes in moisture content can occur due to evapotranspiration. The finest roots and root hairs take moisture from the soil, pass to main tap root system and then finally to the leaves via the trunk and branches. The trees are acting like a groundwater pumping system, reducing soil moisture contents below normal levels to significant depths. A key observation is that the roots will tend to grow along lines of least resistance which in most desiccated clays are the natural fissures and joints.

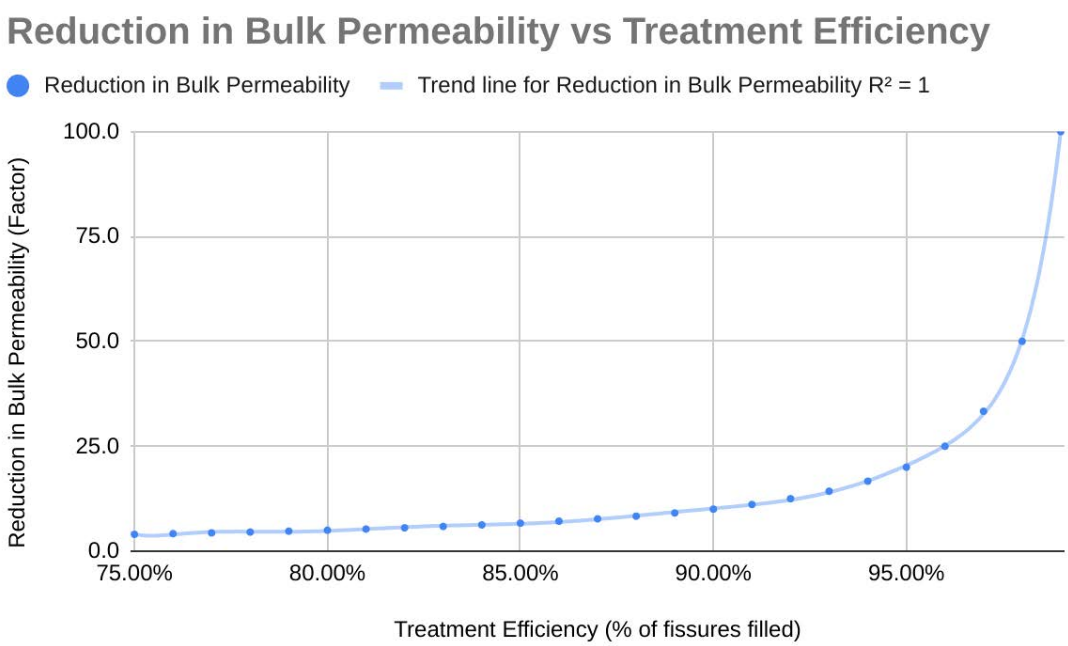
Expansive Geopolymer Injection Solution

The primary objective of the treatment is to fill the fissures in the shrinkable clay with low permeability expansive geopolymer.

By doing so the bulk permeability of the fissured clay will typically be reduced by a factor of 50 according to Buzzi et al (2010)[5]. The reduction in bulk permeability achievable by filling the fissures in clay with a low permeability geopolymer is shown in the graph below.

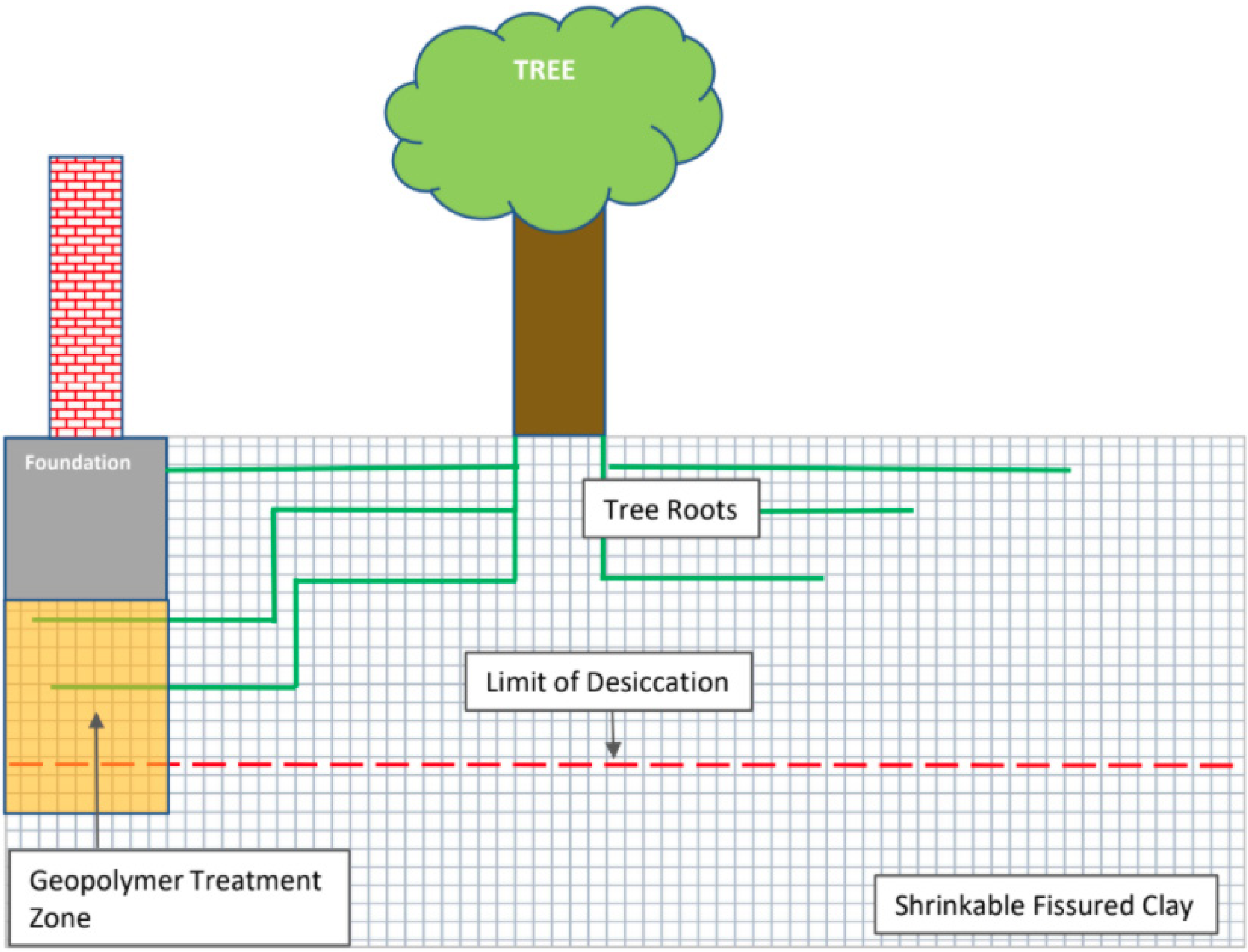
By filling in the fissures with strong, durable and low permeability material the rate of moisture content change will be dramatically reduced, such that any ongoing subsidence will stop. In addition, as the mechanism by which moisture content changes occur is greatly inhibited any subsequent seasonal movement due to increased rainfall will also be reduced to acceptable limits.

In addition, filling the fissures which contain roots will prevent moisture being removed by the tree in the treatment zone, as the geopolymer is effectively impermeable.



[5] *Buzzi O, Fityus S and Sloan S. (2010) Use of expanding geopolymer resin to remediate expansive soil foundations. Can. Geo. J.47.*

Geopolymer injection is specifically targeted below the structural foundations which are suffering from subsidence, see below. The injections are made through small diameter (12-14 mm) steel tubes which are placed into drilled holes. The depth of treatment reflects the depth zone of desiccation and the presence of tree rootlets. This would essentially be the same depth as a traditional foundation underpinning solution, but with far less disruption.



During the injection process the soil-structure interaction is monitored using laser level to an accuracy of +/- 0.5mm. A small positive reaction on the structure is required to confirm all the fissures have been filled with the expansive geopolymer.

Long term monitoring of treated properties has confirmed that any residual seasonal movements are well within acceptable structural limits.

Conclusion

In summary, expansive geopolymer injection provides an effective and non-disruptive solution to subsidence in buildings as a result of clay shrinkage, which is often exacerbated by the presence of trees. The treatment solution described will most often not require the removal of trees which is seen as an environmental benefit. Geopolymer injections can be carried out quickly whilst the building remains occupied which is of great benefit to end users.

Attaining a BBA Certificate facilitates the use of these and other innovative products while ensuring that they meet the required standards, providing reassurance to specifiers, contractors and architects that the products are fit-for-purpose.

Meet the Authors...

Morteza Aboutalebi

A chartered engineer with Post-Doc Research Fellowship from the University of Greenwich, London, and PhD in Civil Engineering (Structures). Morteza is a Fellow member of Institute of Materials, Minerals and Mining (IOMMM) and a member of the Institute of Civil Engineering (ICE). He is the Principal Structural Engineer in the BBA's Technical Excellence department.

Andy Lee

A chartered engineer and geologist with BSc in Geological Geophysics and MSc in Foundation Engineering. Andy is a member of Institute of Materials, Minerals and Mining (IOMMM) and Fellow of the Geological Society and has over 30 years practical hands on ground engineering experience. He is Geobear Global VP Engineering.

Find out more here:
https://www.bbacerts.co.uk

Watford Office
British Board of Agrément,
Bucknalls Lane,
Watford,
Hertfordshire
WD25 9BA

Liverpool Office
British Board of Agrément
Avenue HQ, 2nd Floor
No. 4 St Pauls Square
Liverpool
L3 9SJ