Ground Stabilisation Magazine Article: The Permeation Game

By Steve Henn, Managing Director at Oxford Hydrotechnics

Safe excavation without adjacent ground loss or undue water ingress has been an issue since the advent of construction within the ground.

With the outlawing of the use of disposable workforces, alternative means of construction were sought to allow safe excavation, without causing undue death!

Dewatering, contiguous / secant piling, sheet piling,jet grouting and permeation grouting aresome of the techniques that have been developed over many years and each have their rightful place within the toolbox of below ground construction.

There are various pros and cons to each technique; not limited to the cost, working space and environmental considerations for each process. But I'll concentrate on a specific form of permeation grouting adopted and developed by Oxford Hydrotechnics.

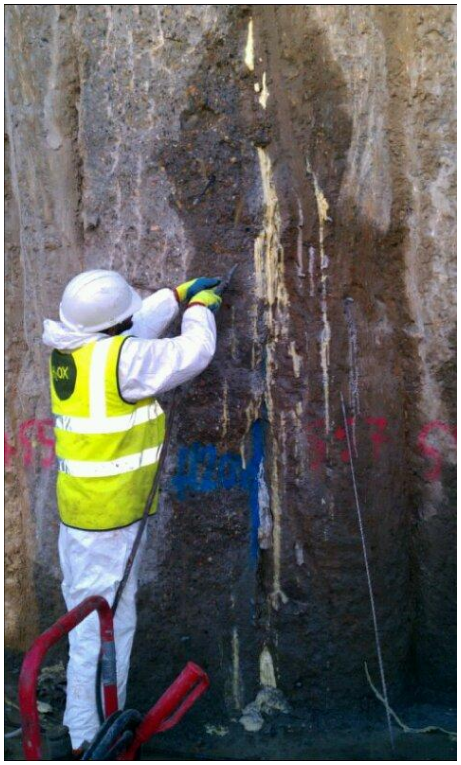
Polyurethane resins have been in existence for over 75years and their uses include:injection moulding to form seating on aircraft, dashboard and bumper components of cars, soles of shoes, high performance adhesives, carpet underlay and synthetic fibres including Batman's favourite: Spandex (obviously I'm talking about the 1960's Batman; whereas the modern day version probably uses Kevlar and some kind of polycotton mix)!

The use of injected liquid polyurethane resins as a means of controlling water ingress didn't really begin until the 1970's.

Since its formation over 20years ago, Oxford Hydrotechnics has gained a well-respected reputation for solving groundwater ingress issues using resin injection techniques. The approach has always been to look at all the issues associated with a particular problem and try to devise an engineered solution.

Typically polyurethane resins are used to seal active water ingress through defective structures, by injection into leaking joints and cracks; includingjoints within secant piled walls, diaphragm walls, car parks, tunnels etc. Some of the projects worked on include the Channel Tunnel Rail Link, Docklands Light Railway and the Jubilee Line extension.

On the whole, the resins used by Oxford Hydrotechnics are single component hydrophobic polyurethanes that react with moisture, foam and expand to fill the defects and prevent water ingress. Their hydrophobic nature, means that once cured the resins do not change their properties and water cannot pass through them.



Resin Injection to Seal Joints within a Secant Piled Wall

Leading on from injection into actual leaking locations, Oxford Hydrotechnics were called in to address issues within large diameter precast concrete shafts on a drainage project on the East Coast of England. The issue being that the client had sunk several shafts and was about to pipe jack out through the side of them, but needed to break open an 'eye' in the shaft wall to commence jacking. The soils outside the shaft at that particular level were running sands; several metres below groundwater level and I'm sure that you are all aware of the problems of running sands; like trying to excavate through soup! The slightest drilled hole in the shaft wall resulted in the ingress of water and ground at a substantial rate and the project was halted, whilst the client attempted to dewater the ground outside using deep wellpoint pumping.

The approach adopted by Oxford Hydrotechnics, was to draw up a grillage pattern on the wall of the shaft, drill through the shaft wall and insert horizontally, 14mm diameter, 1.5m long steel injection lances. A low viscosity polyurethane resin was then used in a systematic series of overlapping injection and retractions within the soils from within the shaft. The viscosity of the resin was such that it would permeate the pores within the sands as a liquid, react with the groundwater, foam and expand; further permeating the sands and then cure to form a solid mass. By establishing the correct centres for the lance insertions and the volume of resin injected at each location, the soils were successfully stabilised to allow breaking out of the shaft eye and initial excavation by hand.

Excavation of Previously Injected Soils

This technique was used extensively on projects, to great effect. However the economic downturn in 2008, drastically reduced the number of similar projects, leading us to seek alternative uses for the system.

One such use was the injection of soils beneath party walls, to allow installation of underpinning. Initial trials showed that modifications of the resins were required, to improve the cohesiveness of the treated soils. There were issues with the treated soils falling into excavations due to the aggressive nature of excavation and trimming up and the fact that the cured resin itself was quite friable. From discussions with resin formulators, a new product was developed; Stabila P200 Soil, which addressed all the issues and this has now been used on many projects with great success.

Injection lances are driven into the soils to be treated and the resins are mixed and pumped using pneumatic single piston pumps. Pumping pressure is set to zero initially and gradually increased until the pump starts to move the resin through the soils. The pressure is not increased beyond this level. Once the pre-determined volume of resin has been injected the lance is retracted or removed and reinstalled at the next location and the process is repeated until all areas have been treated.

Stabilised Soils between Secant Pile and an existing buried concrete wall

The advantages of the system over other grouting techniques are as follows:

- No need to de-water in advance or during the injection works.
- Small kit for injection, allowing access into very tight areas; through doorways, down stairs etc.
- A two man team is usually sufficient to carry out the works.
- The resin arrives in a 20kg drum with a 2kg catalyst, so easy enough to transport by hand.
- The resin is injected in low viscosity liquid form, allowing it to penetrate into pores inaccessible to conventional cementitious grouts. There is no aggregate or filler within the resin, so no possibility of segregation.
- The resin reacts quickly. Reaction time can be adjusted by altering the volume of catalyst added to the resin. Typically in ground stabilisation works, the resin reacts within a few minutes and is fully cured to allow safe excavation the next day.
- The resin can be mined through using hand tools, so it is particularly suited to injection beneath party walls, where subsequent development of neighbours properties will be unaffected by any presence of cured resin within the ground.
- The resin cannot fail to react in contact with moisture (even atmospheric) and will not ‘bleed’ or permeate further than required. Typically a 3kg injected volume of resin will produce a bulb of injected soils of approximately 500mm diameter within sands and gravels.
- Low pressures used during injection, preventing the possibility of hydro-fracture of soils and damage to adjoining structures. Injection pressures are often established at a level where the injection pump just starts to move the resin into the ground.
- The foaming action of the resin significantly reduces the volume and weight of injected product. A typical assumed foaming factor of 4 times the injected volume is often used in calculations and

in 40% voided soils, this equates to 100litres or 110kg of resin injected per m3 of soil. The equivalent in cementitious grout would be approximately 400litres or 830Kg.
- Minimal environmental impact; the water is locally displaced rather than removed.
- With regards to the important question of trespass beneath the party wall, the resin cannot permeate more than approximately 300mm from the injection lance, due to the volume injected, the reaction time and the fact that it will always react with moisture. It does not displace ground, it merely fills the pores within it; effectively 'glueing' the soil particles together. It is actually improving the soil conditions beneath the party wall and compared to other means of temporary soil support it is far less disruptive and aggressive.
- There is very little vibration during installation of the lances. Depending on depth and the soils, they can often be driven in by hand.
- It can be very cost effective, in that excavation can usually commence the day after treatment.

Before I start gabbling on about how I pour the resin over my cornflakes each morning and how it is the greatest thing since sliced Hovis (other breads are available), I'll highlight some of the limitations:

- The soils must be permeable. Usually fine sands and upwards is sufficient for the resin to permeate, but we would always need to see a suitable soil analysis before promoting this as the solution. Site trials can be arranged if the soils are borderline or other site testing may be necessary; such as permeability tests.
- The depth of installation of the injection lances is usually limited to approximately 2metres; using hand tools and air hammer (CP9's and the like). Beyond that depth, a drilling rig may be required and the associated cost and disruption escalates. It is often advantageous to excavate down to the groundwater level and construct the underpins in 2m lifts to allow a staged treatment.
- Soils can vary within a very short distance and permeation results can also vary accordingly. Localised re-treatment may be required during excavation.
- Treating one wall within a property does not reduce water ingress from elsewhere on the site. Often a sump and pumping regime is still required to dewater the general excavation within a site, unless the treatment is continuous around the entire perimeter. Even then, the treatment would need to continue down to an impermeable layer such as London Clay, to completely isolate the site from the surrounding groundwater.
- The system can be expensive if a large volume of soil is to be treated; although this can be outweighed by the advantages above.

In summary, this system is often a quick, cost effective means of providing temporary support to allow safe excavation; minimising the possibility of ground loss and water ingress in the treated locations. Whilst it is not suitable in every situation, it is an invaluable solution to many of the problems encountered during excavation in waterborne granular soils.

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