KELLER

Geotechnique

Grouting Solutions
Piling Solutions
Ground Anchorages
Soil Nailing
Fondedile
Environmental Solutions

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Geotechnique

Introduction

Keller Geotechnique is a leading Ground Engineering specialist in various grouting techniques, restricted access piling, ground anchoring, soil nailing and environmental solutions.

This combination of operational capability, together with a highly experienced and comprehensive in-house geotechnical design team, gives the company the ability to undertake wide ranging projects, which may vary from single solution situations to those where a multi-discipline geotechnical approach is required.

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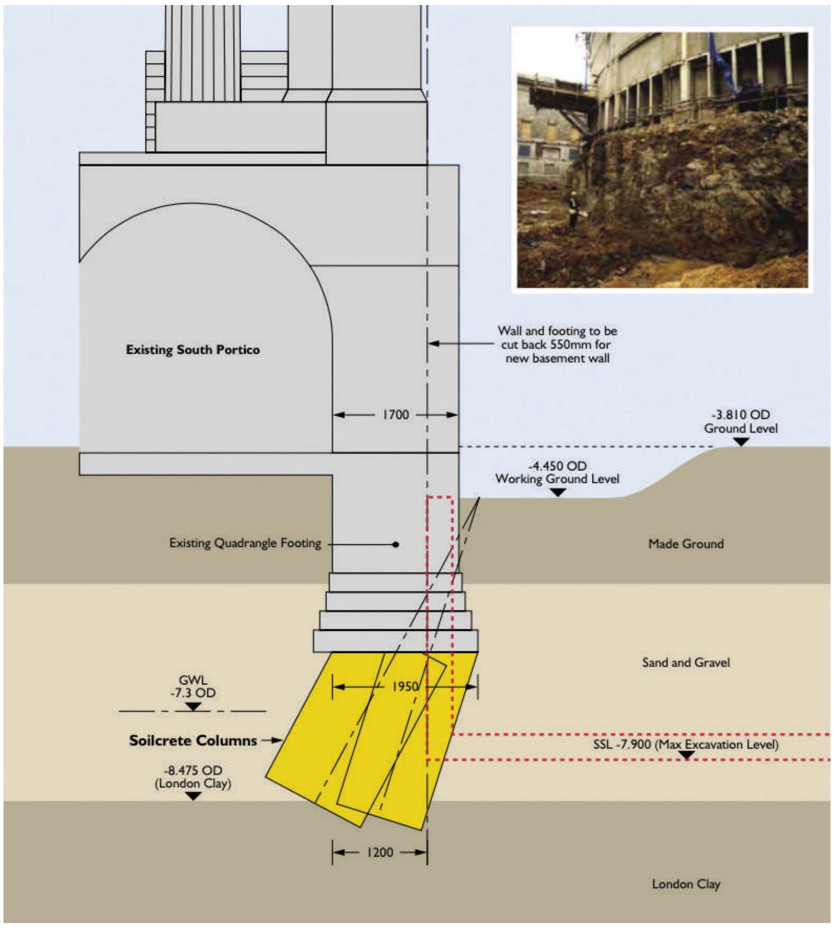
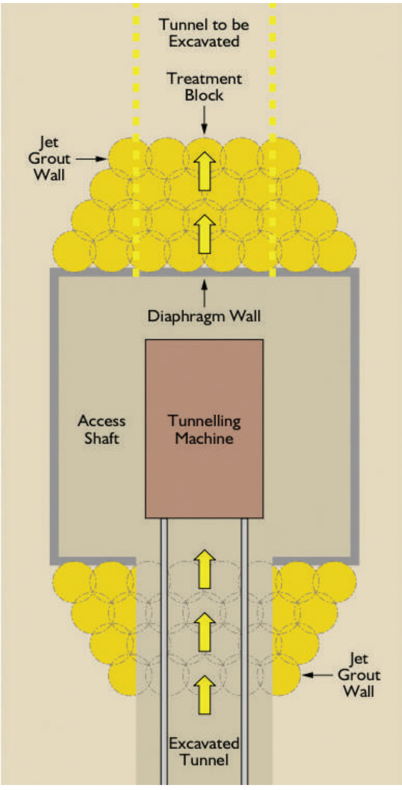
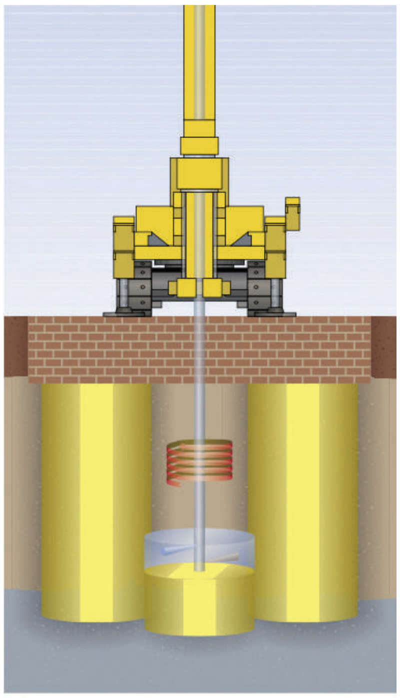
Grouting Solutions

Jet Grouting







Process

Jet grouting is a procedure for the insitu construction of solidified ground of pre-determined shape, size and depth, to a designed characteristic (strength, permeability, flexibility). This solidified ground is known as Soilcrete.

Advantages

• A more predictable degree of soil improvement.
• A high level of permeability control.
• Geometric flexibility.
• Improved cost forecasting over alternative processes.
• Minimal vibration and noise.
• Ability to operate in headroom as low as 3.0m.
• Minimum site disturbance and limited working space required.
• Only environmentally acceptable grouts are used in the process.
• Installation beneath foundations from outside building.
• Encapsulation of obstructions including services.

Soil types

Wide range: gravels to clays above and below groundwater level.

Method

Soil is loosened by the jetting action of high pressure water often sheathed in a cone of air. The loosened soil is partially removed to the surface via air-lift pressure as the remaining soil is simultaneously mixed with grout.

Product

A homogeneous Soilcrete mass with the following typical characteristics:

Quality Control

• Site monitoring of lift speeds, rotation, depth and the pressures and flow rates of grout, water and air.
• Trial columns where appropriate.
• Grout mix quality control tests.
• Insitu sampling where appropriate.
• Measurement of the specific gravity of the grout waste slurry.

Grout types

Environmentally acceptable and durable cement-based or cement/bentonite grouts are used.

Excavation showing reading room supported on Soilcrete columns which extend down from masonry footings into water-bearing granular soils and London Clay.

Compensation Grouting

Process
Compensation Grouting is a process used to control or reverse the settlement of structures. It consists of the injection of material into the soil between the foundation to be controlled and the process causing the settlement. The material injected is forced into fractures thereby causing an expansion to take place counteracting the settlement that occurs or producing a controlled heave of the foundation.

Soil types
Because the process requires that the soil is fractured and not permeated, Compensation Grouting may be used in most soil types ranging from gravels to clays or weak rocks.

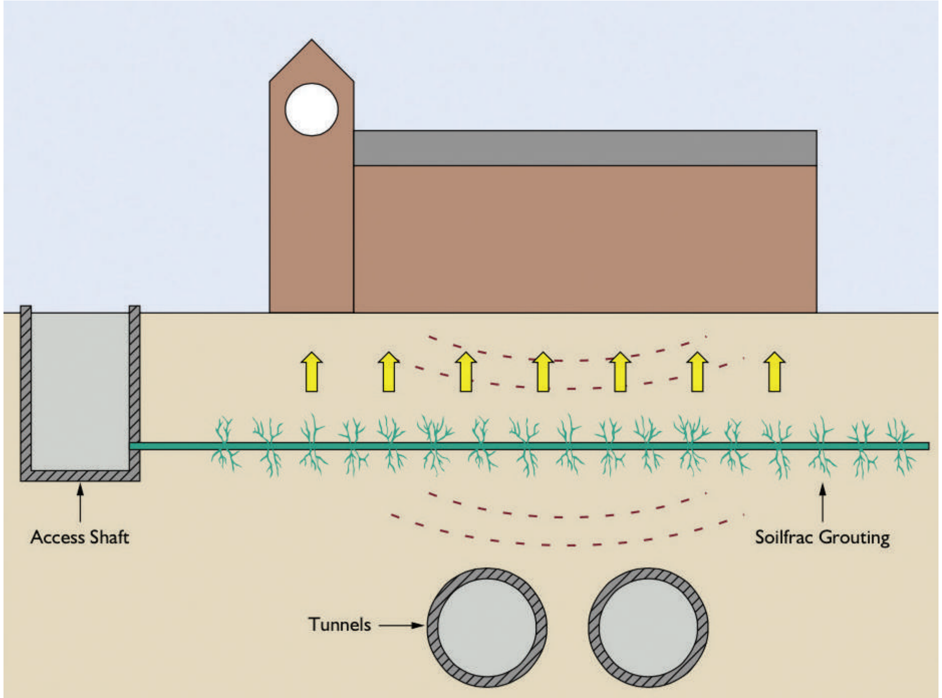
Advantages
The control of settlement is carried out from outside the building and hence there is no disruption to the occupants. The process can be repeated allowing continuing settlement to be controlled. Control can be very selective inducing very small level changes of varying amounts over the space of several metres.

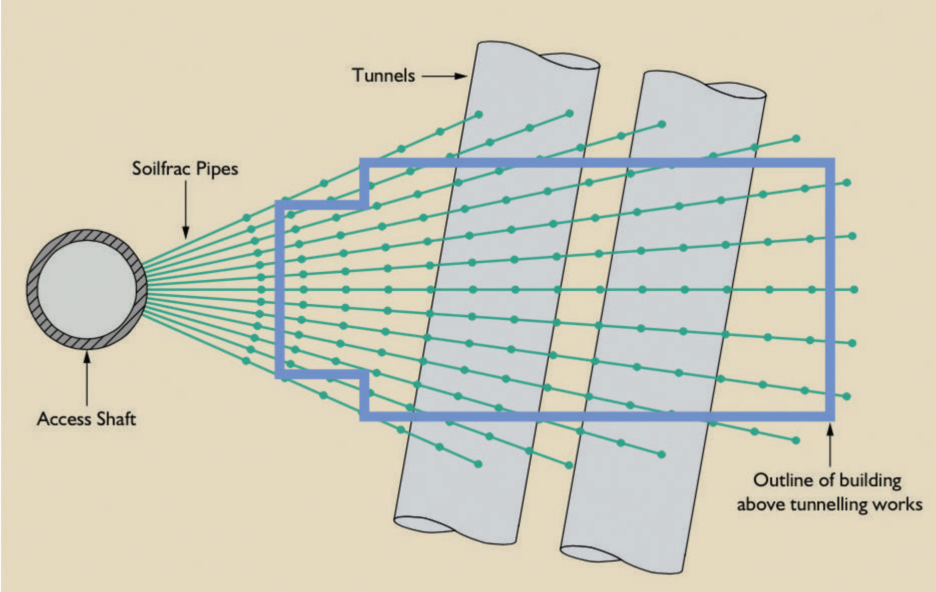
Grout types
As the intention is to open fractures, generally cement-based grouts are used which are environmentally acceptable and durable.

Method
The Compensation Grouting process involves:
• Installing grout injection tubes to a pre-determined pattern.
• Monitoring movements by either precise levelling or the use of special settlement systems.
• Injection of grout through sleeves with careful process control to induce compensating movements.

Product
Protection of buildings and other structures from damaging movements caused by sub-surface processes.

Quality Control
All stages monitored from installation of tubes to actual injection.
Grout mix, injection pressure, volume and pump rate carefully designed and computer monitored.
Computer monitoring of movements.
Full documentation for every stage.





Drilling within a shaft for installation of Compensation Grouting pipes.

Compensation Grouting module and control centre.

Compaction Grouting

Process
Compaction grouting is the injection of very stiff, low slump (25-75mm) mortar-type grout under relatively high pressures to displace and compact soils in place.

Soil types
Most effective in cohesionless soils but can also be effective in finer grained soils where disturbance has occurred.

Advantages
• Controlled and accurate placement.
• Predictable degree of improvement.
• High production rates.
• Grouting programme sequenced to site operations.
• Cost-effective; can be implemented when monitored settlement exceeds a pre-determined value.
• Re-compacts soils within vicinity of the problem rather than waiting for settlement to reach adjacent structure foundations.
• All grout pipes can generally be installed outside building.
• No harmful vibrations to nearby structures/utilities.
• Minimum disruption.

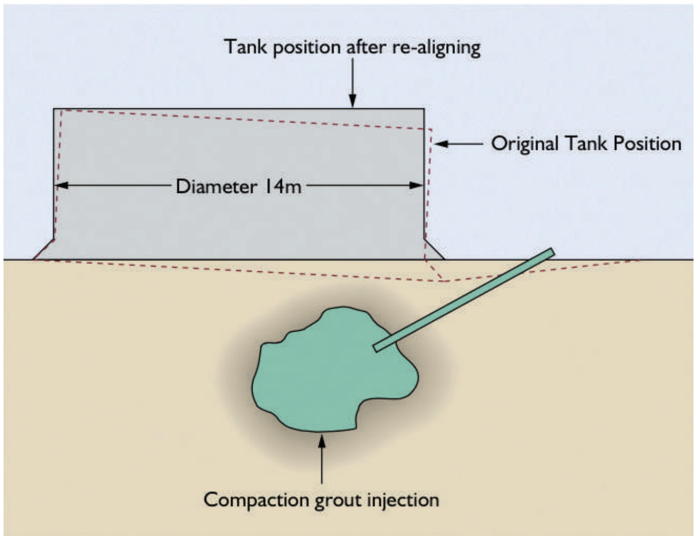
Grout types
Normally low slump sand-cement grouts are used with additives.

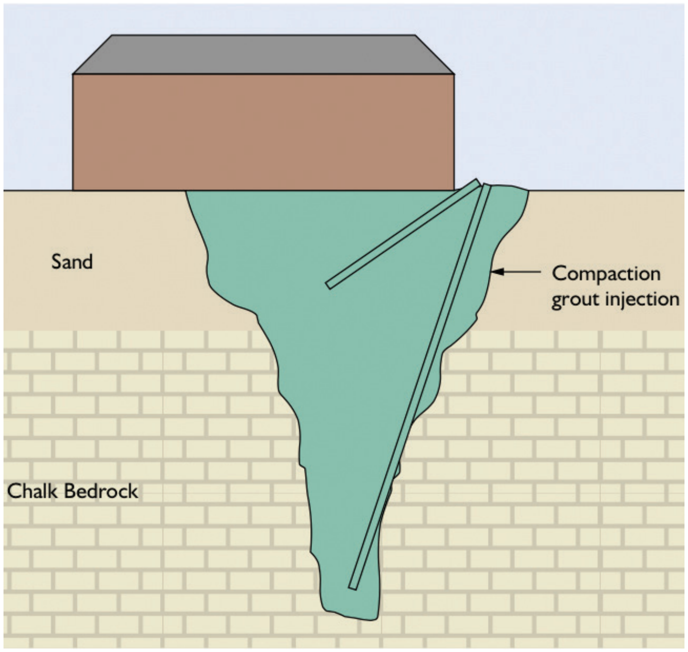
Method
Grout pipes are installed in a pre-determined design pattern (vertically or angled) to the required depth. Grout is pumped until one or a combination of the following criteria is met:
• Refusal at maximum pressure is achieved.
• A pre-determined maximum grout volume is reached.
• Ground or structure heave is observed.

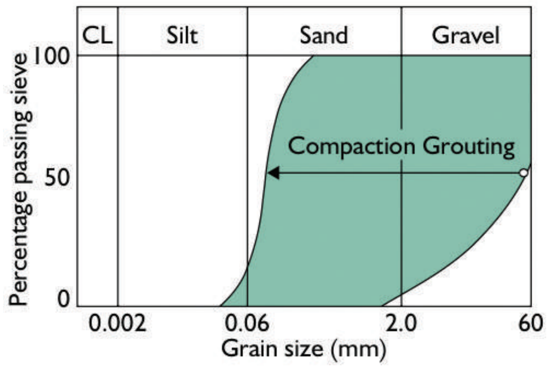
Product
Homogeneous grout bulb or series of linked bulbs, formed near grout pipe tip as grout pipe is extracted; displacement strengthens and re-compacts adjacent soils.

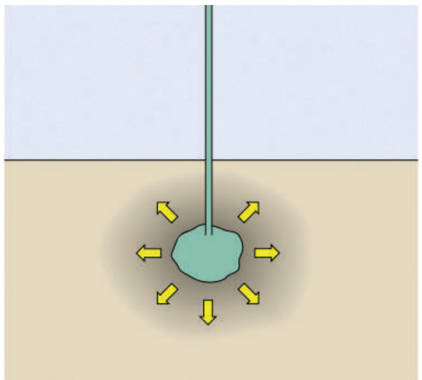
Quality control
During construction:
• Pressure and grout volume monitoring.
• Monitoring of ground movement.
• Grout tests.

Post-treatment
• Settlement monitoring.
• CPT (Dynamic Cone Testing).
• SPT (Standard Penetration Testing).









Permeation Grouting

Process
Permeation grouting is the injection of a fluid grout into granular, fissured or fractured ground to produce a solidified mass to carry increased load and/or fill voids and fissures to control water flow.

Soil types
Sands, gravels and coarser open materials, fissured, jointed and fractured rock.

Advantages
• Controlled and accurate placement.
• Pre-determined size, shape, depth of treatment area.
• Flexibility to increase scope of treatment, both in time and location.
• Economical costs.
• Significant and predictable degrees of improvement.
• Non-vibratory.
• Limited work space required.

Grout types
Cement-based:
• OPC/SRC.
• Cement/Bentonite.
• Cement/Sand.
• Cement/PFA/GSBFS.
• Microfine Cement.

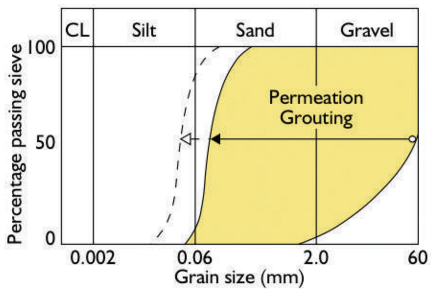
Chemical based:
• Sodium Silicates.
• Polyurethanes.
• Resins.

Method
Ranging from hand lancing and 'end-of-casing' methods, ascending and descending stage grouting to tubes-ŕ-manchette (TAM) methods wherein sleeved port TAM pipes are installed in a pre-determined pattern horizontally, inclined or vertically.

Permeation of the ground is by injection through discreet ports at specified designed intervals, rates and pressures to fully treat the target area. Re-injection via adjacent or previously injected ports is possible.

Product
Consolidated and strengthened soil and/or rock mass. Zone of reduced permeability for water control.

Quality Control
• Setting and gel time checks.
• Viscosity, density and bleed.
• Flow rate pressure vs. time.
• Volume per injection location.
• Pre and post treatment water permeability tests.
• Grout sample strength.
• Inspection pits and borehole samples.
• SPT, CPT and pressuremeter.



Bulk Infill Grouting

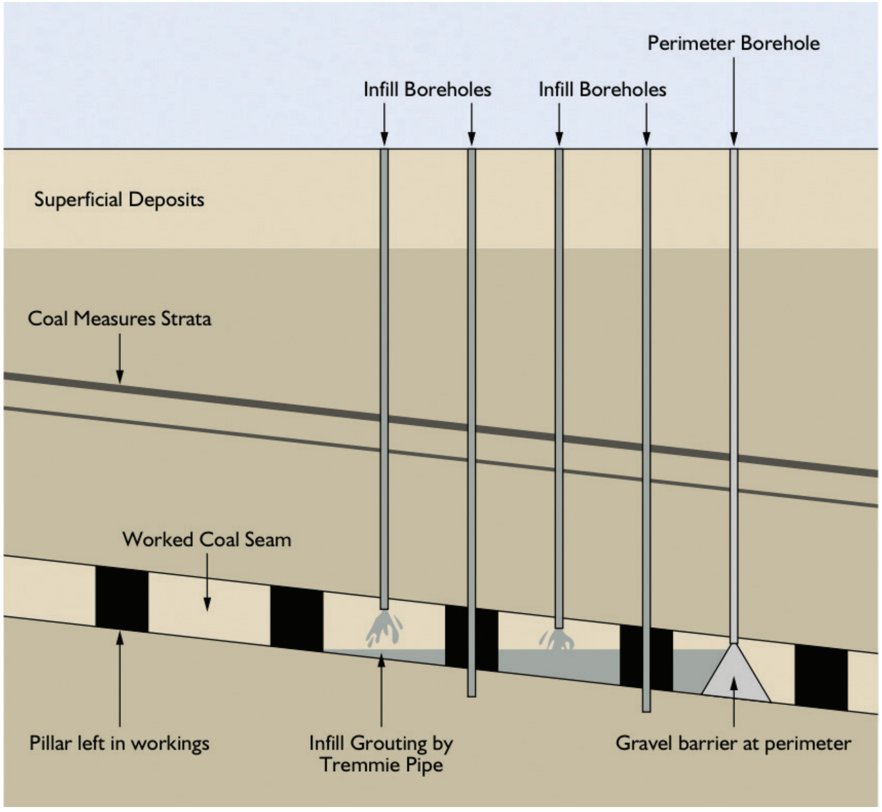
Process
With the wide variety of coal mining methods and extraction patterns developed in Britain now in various states of deterioration or collapse, careful consideration needs to be given to the most appropriate method of treatment. Consolidation grouting is generally the preferred approach. The key to success in grouting such sites is a detailed understanding of the mining and geological conditions, and the experience to interpret the available information.

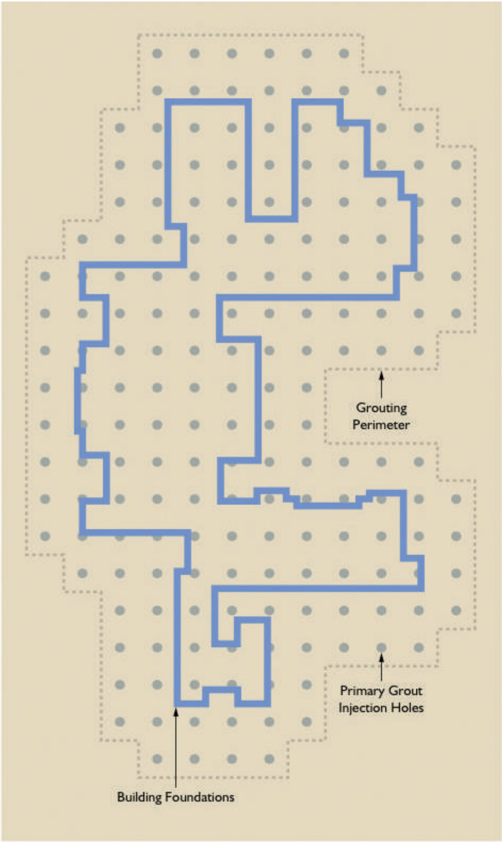
Applications
The workings may be single or multi-seam, horizontal or inclined. In their present state they may be open or collapsed, dry or waterlogged, or underlying unconsolidated deposits or fractured rock strata as a result of partial subsidence. There might also be old mine shafts present that are often now hidden. They could be empty, backfilled completely from the bottom, or the infill may be supported on a natural construction or platform at a shallower depth.

Each condition requires a particular approach to the method of grouting. Keller Geotechnique offer a full grouting design and construct service to meet all these variations.

Grout Types
Bulk filling generally uses a cement/PFA mix to suit site conditions with compressive strengths in the order of 1.0 N/mm2. The mixes may include Sand and Bentonite etc. as required. Gravel is introduced to fill major voids and/or to form containment barriers.

Method
Bulk infill grouting is normally carried out from primary grout injection holes on a square grid with secondary and tertiary holes as required.





Piling Solutions

Restricted Access Piling & Minipiles

In restricted access situations, where heavy conventional equipment cannot be used, we provide a choice of piling systems such as cased auger, continuous fight auger (CFA), drilled rock socket or driven. With a number of these methods, and using our bespoke equipment, piles can now be constructed to carry very high working loads to give an efficient and cost effective foundation solution. We specialise in dealing with difficult ground conditions in poor access and limited space situations.

A number of our mini rigs are able to enter buildings via a normal service entrance or a standard doorway.

To give quiet and fume free indoor working conditions, many of our hydraulically powered rigs can be run by an externally situated diesel engined powerpack whilst others are electric and can use a suitable in-house supply or suitably located generator.

Scope

- Piles in soft soils, obstructed ground and rock.
- Bearing piles and piled retaining walls.
- Diameters from 100mm to 600mm.
- Axial capacities up to 2000kN, according to ground conditions.
- Headroom as low as 2.0m.
- Rubber Tracked rigs for sensitive surfaces.

Applications

- Sites with noise and/or vibration restrictions.
- Areas where weight or surcharge limits apply.
- Restricted access and/or headroom sites.
- Operating retail stores and factories.
- Archaeologically sensitive sites.
- Underpinning sensitive buildings and structures from within.

(See also Pali Radice).

Bored Pile Walls

Keller Geotechnique designs and builds bored pile retaining walls which can be constructed using either CFA, cased auger or rock drill piling techniques according to ground conditions. We build contiguous, secant or king post pile schemes and these can be made using either our full-size rigs or restricted access rigs - the latter giving us the capability of working in areas where using conventional large plant is not possible.

We offer a range of solutions and can combine techniques and schemes on major projects to provide the most effective solution both technically and in terms of cost. Where walls require anchorages to enable a prop-free working area (within a basement for instance) we can carry out the piling and anchoring work as a combined package.

Our in-house design capability gives us a direct and speedy way forward in establishing the optimum solution in terms of practicality and cost.

Contiguous Pile Walls

Where ground water or loss of fines are not a consideration, contiguous bored piled walls offer a robust and economic ground support solution which can be constructed with a minimum of land take. Walls can be designed to work entirely in cantilever or to have additional support by means of ground anchorages for reasons of economy and efficiency. Pile diameters for our schemes range from 300mm to 750mm, retained heights may typically be up to 8 metres and we can use CFA, cased auger or rock drilling techniques as dictated by ground conditions and site constraints.

Secant Pile Walls

Secant pile walls comprise a series of interlocking (secanted) piles to form an essentially watertight wall. This system will be used where dry basement structures are to be built in water bearing ground and where maximum of floor space is to be released. The technique is frequently used (as are contiguous pile walls) on confined city sites as part of the 'top down' construction method of building basements and superstructures where the ground and below ground floors give structural support to the walls in both temporary and permanent build stages.


SONS ARMS
PULLED BEERS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Ground Anchorages

Working to BS8081, BS En1537 or other applicable standards, we design, construct and test temporary and permanent ground anchorages. We also provide an anchorage load monitoring, re-stressing and maintenance/decommissioning facility. Anchorages can be installed in 'normal' and restricted access situations or in over-water environments.

We have tracked drilling rigs for typical working conditions and excavator mounted drills for 'over the edge' or high slope working where traditional equipment does not have the reach.

Scope

• Permanent and temporary ground anchorages, rock bolts and dowels.
• Fully removable strand temporary anchorages.
• Anchor systems including mono bar, multi-strand and multi stage.
• Passive tension pile anchorages.

Applications

• Lateral support for sheet pile, bored pile and king post walls.
• Base slab anti-flotation systems.
• Stabilisation of rock faces and fixing of rockfall netting.

Temporary

Temporary Works involving ground retention can be simplified and your costs reduced through the use of Keller's advanced temporary or fully removable Anchorage solutions. Clear internal working spaces can be created for deep excavations on civil engineering projects such as cofferdams, cut and cover tunnels - producing valuable savings in programme and budget. Costly, intrusive propping systems for deep urban basements etc, that hinder construction progress, can also be avoided through the adoption of high capacity fully removable SBMA's or temporary ground anchorages.
Keller Geotechnique provides a full design and construct service for a complete range of ground anchorage and nailing solutions, helping you to develop the most cost-effective and technically efficient temporary works solution. Systems available include:

Temporary Anchorages
This type of anchorage is generally de-stressed following its working life. The tendon incorporates a single layer of corrosion protection and designed to remain within the ground following redundancy.

Fully Removable SBMA Anchorages
The Keller Removable Anchorage system is the only anchorage system in the market place that allows for the removal of the entire anchor tendon. Removable anchorages can be de-stressed and the full length of strand removed.
Removal is undertaken when the final support is in position, all that is left within the ground at depth are small saddles and plastic components together with the grout column. Material which would pose no problem for a future neighbouring foundation activity.

Drilled Tie Bars & Anchor Piles Where conditions suit and the anchorages are not required to conform to the permanent requirements of BS8081:1981 and EN1537:2000, Keller Geotechnique can offer a tension bar system utilizing either fully threaded, high yield steel or self-drilling hollow bar systems.

Permanent

Increases in capacity along with advances in corrosion protection systems have enabled ground anchorages to be used for an ever increasing variety of permanent retention functions.

They are frequently used in new ports and harbour developments, road schemes, dam refurbishments and for the tensile support of new sports stadium structures.

With the introduction of Keller's SBMA system, high capacity anchorages have never been more cost effective.

Single Bore Multiple Anchor System

Single Bore Multiple Anchor System
The Keller SBMA system involves the installation of a multiple of unit anchorages in a single borehole. The encapsulations of the unit anchorages are located at staggered depths in the borehole and transfer the load from each unit anchorage in a controlled manner to a discreet length of the borehole. The system ensures a uniform mode of load transfer to the ground over the entire fixed length and a gross increase in efficiency in the mobilisation of ground strength. It also allows the utilisation of an almost unlimited fixed length over which the load may be transferred.
Keller's award winning SBMA anchorages can increase the ultimate load capacity by 200 to 300% of conventional anchorage load transfer techniques.
Suitable for installation in most ground conditions, the SBMA system has particular advantages in clays, mixed cohesive and granular soils and weak rocks where conventional anchors only achieve a limited capacity. Indeed, utilising SBMA technology, load carrying capacity can safely be achieved in varying geological strata encountered within the same borehole (each unit anchor being individually designed).
No other anchoring system can offer this versatility.


SEATRAX
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VOS PRELUDE


BYRNE BROS.


JLG LIFT
JLG LIFT
H21TX ACCESSRENTALS

Soil Nails

Soil Nailing provides a cost effective and efficient solution to many slope stability and earth retention problems.

Employed extensively on highway/ motorway widening schemes, the system is also frequently used by developers to create more usable space on sloping sites etc. Adaptable to difficult access sites and quick to install, Soil Nailing is a technique that works by reinforcing and strengthening existing ground. Each Soil Nail consists of a reinforcing bar that is generally made of steel (with full corrosion protection for permanent works) or alternatively can comprise reinforcement in the form of GRP or carbon fibre bars. Keller also installs self- drilling hollow bar Soil Nails where conditions allow.

Installed from the top down, the slope or required excavation, is supported by the Soil Nails being put into tension as the ground deforms laterally around them.

Facing systems are generally required to protect the face of the cutting. These can comprise sprayed concrete or geo-mesh fabrics as required.

Keller also offers a full hydroseeding service to provide a vegetated face along with a range of structural reinforced soil facings such as Timbacrib and Geolock walls. Unlike Ground Anchorages, Soil Nails are generally passive inclusions and are not post-tensioned; however, testing, to prove the bond capacity at the soil/grout interface, is an essential part of the Soil Nail design process. Testing works are carried out prior to or during the nailing works using sacrificial nails and should consist of the testing of the active and passive zone of the soil nailed block. This data is then used to confirm and/or finalise the assumptions made in the proposed design. The testing of production nails is not recommended as this can affect their working properties.

With available development land becoming ever more costly, gaining usable space on steeply sloping sites is paramount, Soil Nailing can offer the following benefits:

- Using top down construction methods, with each subsequent row of nails providing both temporary and long term support, the need for costly temporary works is avoided.
- Elimination of the need for expensive stone backfill imported to site.
- Existing structures and embankments can be stabilised without rebuilding, saving costs and maintaining serviceability, for example, existing railway embankments.
- Trees, vegetation or architectural features can often remain unaffected by soil nails, as the nails can be sited to pass around or between obstacles.

Typical applications for Soil Nailing:

- Stabilising steep cuttings to maximise development space.
- The stabilising of existing over-steep embankments.
- Soil Nailing through existing concrete or masonry structures such as failing retaining walls and bridge abutments to provide long term stability without demolition and rebuild costs.
- Temporary support can be provided to excavations without the need for bulky and intrusive scaffold type temporary works solutions.

Fondedile SpA of Italy became renowned in the 1950's for introducing a mini pile system to underpin and preserve historic buildings and other important structures. Their specialist technique, with its ability to drill through masonry and concrete is known as the Pali Radice system. This was first introduced into the UK market in 1962 and was eventually added to Keller Geotechnique's repertoire of specialist capabilities on the purchase of Fondedile Ltd. from Sir Robert McAlpine in 2005. This acquisition augmented the restricted access activities of Keller Geotechnique to give a further specialist design and construct facility. Fondedile techniques are particularly appropriate in major city scenarios where limited workspace and sensitive methods of piling are needed.

Fondedile Multibell Anchors

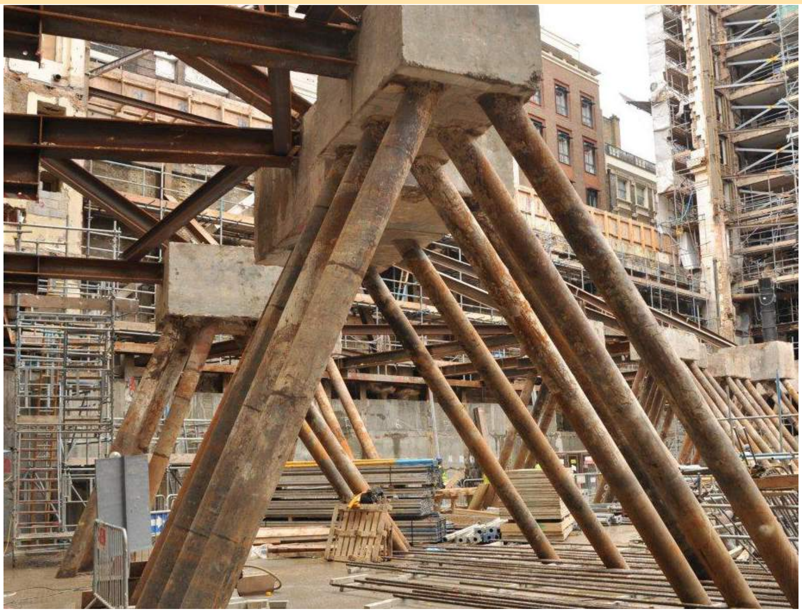
The key advantage of the Fondedile multibell anchor for use in cohesive strata is the ability to form high capacity anchors (up to 700KN SWL) as short as 12m in length, minimising infringement into third party property. This is a particular valuable application in providing prop free deep excavations in city centre locations.

Straight shafted anchors relying upon skin friction developed in the surrounding soil, whilst satisfactory in granular materials (sands, gravels etc.) may not be able to develop economic load capacities in clay and other cohesive soils owing to their relatively low shear strengths or other anchor length limitations.
A high capacity reliable anchorage in clay can be obtained by engaging its shear strength via expansions ('bells') formed along the shaft of the anchor fixed length.
The belling tool, a Fondedile innovation, provides a system which can satisfactorily meet all the requirements of reliable anchorage. This proprietary system is called the Fondedile Multibell Anchor. It conforms to all aspects of design and construction demanded by BS 8081 : 1989 – Ground Anchorages – for a Type D anchorage.
Multibell anchors are formed by, first, forming a pilot hole in the clay using a rotary casing and augering drilling technique to the required depth and inclination. The belling tool is then introduced into the hole and rotated while the spoil cut by the blades is brought to the surface by a direct circulation of flushing water. The belling tool consists of a number of hinged blades which open gradually to form a series of quadrilaterals equal to the number of bells required: thus all the bells are formed in one operation either by hydraulic or mechanical means.When the undereaming operation is completed, the tool is extracted from the hole. A cementitious grout is pumped to the toe of the borehole via a tremmie tube until the drilling water is flushed out and the hole is filled with fresh grout.The double or single corrosion protected tendon (either multi-strand or prestressing grade monobar) is then inserted and kept centralised.
The number of bells which can be formed in one anchor normally varies between 2 and 6 in two bell modules.

The following is a guide line of the approximate safe working capacities of permanent Multibell Anchors which are dependent on clay strength and the under-ream dimensions.

Number of Bells	Safe Working Capacity Range KN
2 Bell Anchors	150 to 300
4 Bell Anchors	250 to 450
6 Bell Anchors	400 to 700

These typical capacities are based on a geotechnical factor of safety of 3 which is applied to permanent anchorages and typically 2.5 for temporary anchorages.



Pali Radice

Since its inception Pali Radice- (literally "Root Pile") has been extensively employed throughout the world as an underpinning system for strengthening existing foundations which are settling or are required to support increased loads.

When used for underpinning, the piles are formed through the structure thereby achieving a direct connection between the foundation and a competent subsoil strata, providing the structure with "roots" and hence giving the piles their name.

The equipment and techniques employed have been designed to minimise vibration and to operate with minimal noise. They can be employed in areas of restricted access and have the ability to bore through virtually any obstruction. In addition to underpinning, the systems are cost effective for new foundations on sites where geological formations or physical obstructions render other systems unsuitable.

Scope

- Minimal vibration - ensuring no damage to fragile structures or foundations
- Minimal noise - allowing undisrupted work in any environment.
- Employed in areas of restricted access (limited headroom of only 2.2m)
- Cost effective for new foundations in difficult geological environments
- Piles can be installed only 250mm from an existing structure.
- Can drill through reinforced concrete, RSJ's, timber and other artificial obstructions
- Complete package including building works where required.

Applications

- Underpinning to existing structures
- Tubular reinforced piled retaining walls
- Pali Radice reticulated walls
- Contiguous piled walls - 220mm & 600mm diameter
- Stabilisation of bridge structures, quay walls, embankments and listed structures
- Stabilisation of embankments & cuttings
- Stabilisation of listed structures
- Upgrading of existing structure and building foundations.
- Supplementary support for upward or outward extension of existing buildings.

Environmental Solutions

Slurry Walls

Keller installs cut-off walls to prevent the lateral passage of leachates and ground water.

These containment systems range from slurry cut-off walls to soil mix structures, each designed to reduce permeability to specified requirements, typically 10-9m/sec. Keller cut-off walls are constructed to exacting standards using purpose designed mixes to provide known strength and maximum durability. Keller can install slurry walls to depths in excess of 25 metres using modified excavators.

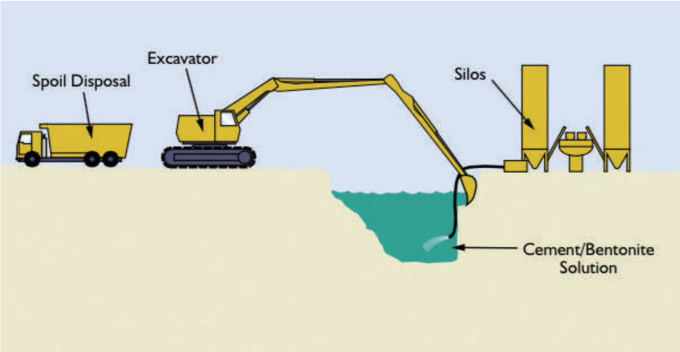
Active Barriers

Keller also constructs slurry wall containment systems with 'active barriers' or treatment gates.

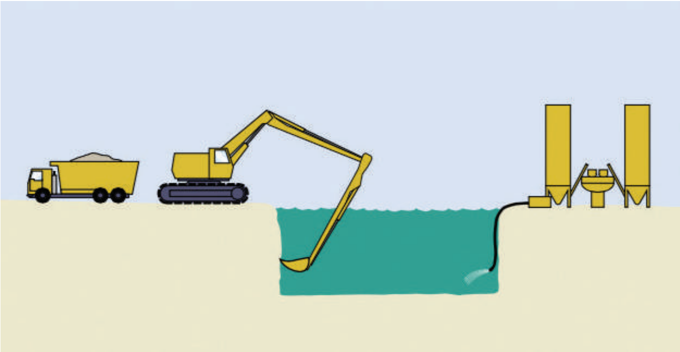
These use the cut-off walls and the ground's natural hydraulic gradient to funnel the leachate through a treatment system or gate, incorporated within the cut-off wall. The principal benefit of this system is that whilst providing protection against lateral spread, the 'contained' mobile pollution is naturally depleted over time through hydraulic flow.

The 'gates' also control upstream and contained ground water levels without the need for a sealing/capping layer. Once treated the discharge is generally passed to a foul water sewer for disposal.

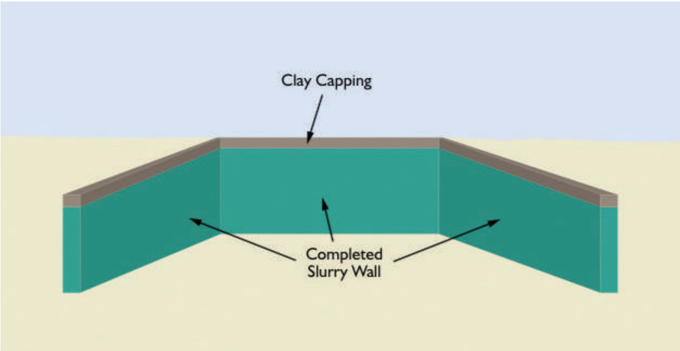
Slurry Wall Construction Sequence



1st Stage.



2nd Stage.



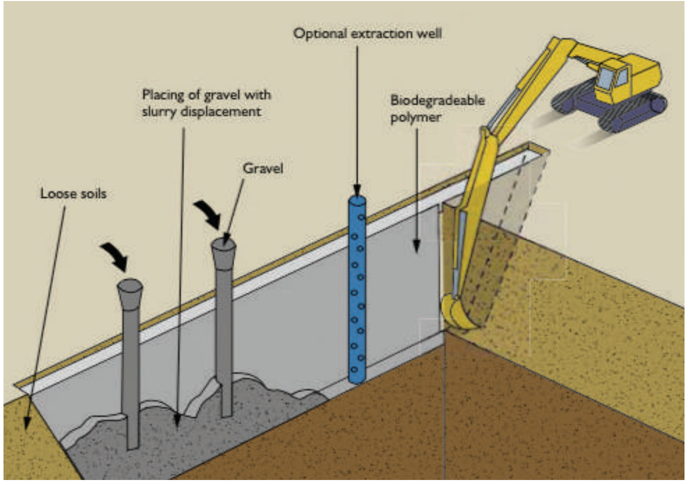
Completed Slurry Walls.

Membranes

The passage of landfill gases such as Methane and Carbon Dioxide, along with vapours produced by hydrocarbons and other VOC's, can be controlled using insitu cement/bentonite slurry wall barriers and venting systems.

For purposes of gas control, Keller normally incorporates HDPE membranes within their slurry walls. The membrane acting as the primary gas barrier with the slurry wall being used to provide a high level of secondary protection, whilst at the same time containing any residual contamination or leachate flow. The HDPE liners used are usually supplied in panels, which are lowered into the bentonite/ cement slurry using specially weighted frames. The panels are connected using proprietary interlock systems.

Alternatively, where gas or vapour control is required without a slurry wall, Keller can install deep columns or gravel trenches as the venting medium. In unstable soils, these would be constructed using bio-degradable muds as temporary support and can also incorporate 'barriers' in the form of HDPE liners. Collection pipes can be laid within the trenches to channel the gas to ventilation stacks.



Gravel trench being constructed using temporary support provided by bio polymer muds.

Case Studies

Crossrail C300/C410 Compensation Grouting

Crossrail is currently the largest and most ambitious project in Europe. Works started in May 2009 over 40 construction sites throughout London.

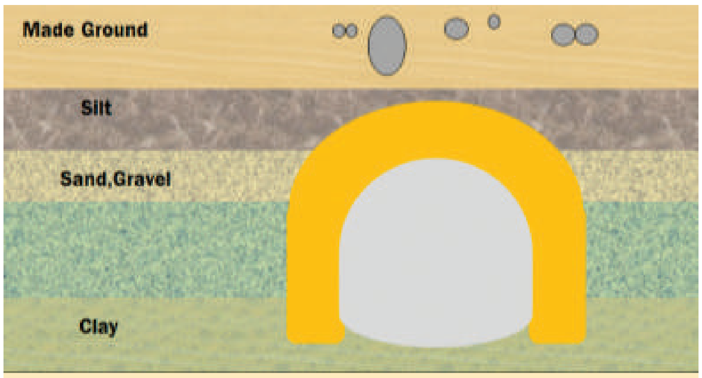
It involves the construction of 42km of twin underground railway tunnels and 10 new stations. The line commences in Maidenhead and runs beneath London from Paddington to East London.

Keller carried out the Compensation grouting works between the tunnel crown and structures above to mitigate settlements at a number of locations because the large diameter platform tunnel and cross passage excavations were being formed underneath high value areas of London's West End.

The grouting for the Western Running Tunnel and Caverns (C300/ C410) required the installation of over 45000m of 75mm diameter steel tubes Tubes á Manchettes (TaM) pipes from within a number of shafts located in open space around the West End.

The TaM pipes cover an approximate area of 50,000m^2 in the Bond Street and Tottenham Court Road stations. From these TaM pipes the grout is injected in stages to arrest settlement as the tunnelling machines pass. Compensation Grouting was pioneered by Keller, initially in Germany and has now been used on underground projects on five continents.

Victoria Station Upgrade Project



Diagrammatic section through the jet grouted zone (in yellow) and tunnel (in pale grey).

The ground treatment is made up of overlapping jet grout columns. The jet grouting technique allows relatively small diameter boreholes to be drilled between the numerous services and structure and then form a much larger column to treat the ground below.

Keller undertook Europe's largest ever Jet Grouting Project to upgrade one of London's busiest underground stations. The scheme also involves the use of Building Information Modelling (BIM) as a system for plotting services, tunnels, buildings so the grouting could avoid a myriad of services beneath the site.

At Victoria, various tube lines meet and the scheme involves the construction of new ticket halls and links to modernise the existing station. Much of these new structures are to be constructed in water bearing Terrace Gravels with a high risk of collapse. Stabilising the Terrace Gravels by Jet Grouting was necessary as the site is surrounded by numerous fragile listed buildings and one of London's important theatres. The target was to provide a block of jet grouted soil as a 2m thick annulus of ground treatment around the proposed tunnels by installing overlapping jet grout columns from 1.4m to 2.0m in diameter to depths up to 14m.

Accurate orientation of each column was achieved by reading prisms mounted on the drill mast. Column diameter was monitored by thermal degradation, a technique used by Keller in Austria. All of this information was entered into the Building Information Module (BIM) allowing complicated geometries to be modelled around underground services and structures.

A target strength of 1 to 10N/mm^2 and permeability of $<1x10^{-7}$m/s was required to facilitate the future tunnelling works. To date all of the new shafts and tunnels have been constructed without any significant loss of ground, settlement of structures and damage to the vital services.

Tottenham High Road bridge reconstruction

Tottenham High Road Bridge is a Victorian Network Rail structure which crosses the A10 in North London. For proposed deck reconstruction the abutments will be subjected to increased loading and solutions involving conventional vertical piling near to the toe were ruled out due to the presence of extensive buried services within the pavements.

Keller Geotechnique designed a solution with raking Pali Radice underpinning micro piles and permanent anchors installed in limited headroom.

The Fondedile 'root pile' system was required to safely resist the additional deck loading and 8No pairs of raking 220/190mm diameter Pali Radice mini piles were installed in pairs at some 750mm centres. These were rotary bored directly through and permanently bonded to each of the existing 4m deep abutment walls and the mass concrete footing foundations. The mini piles were installed at rakes of 10° and 20° to support the vertical loadings. Ground Anchors were designed and installed to resist the given horizontal loading in groups between the existing columns. The anchors have a safe working capacities varying from 230kN to 250kN installed to lengths from 26.5m to 31.5m, founded in the London Clay, measured from the abutment face.

Ground Anchorages were tested to 150% SWL and locked off at 110% SWL. The existing bridge which remained in service was monitored throughout.

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Keller Geotechnique is a leading specialist in various grouting techniques, restricted access piling, dry soil mixing, ground anchoring, soil nailing and various environmental solutions for treatment /clean-up and encapsulation systems for contaminated soil and ground water.

This combination of operational capabilities, together with a highly experienced and comprehensive in-house geotechnical design team, gives the company the ability to undertake wide ranging projects. These can vary from ‘single solution’ situations to those where a multi-discipline geotechnical approach is required.

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