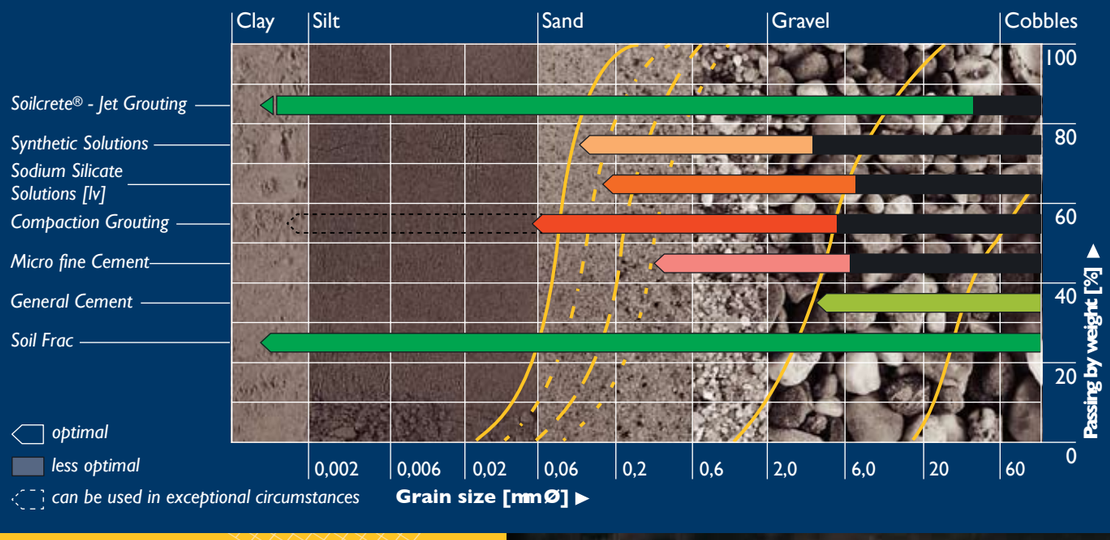
KELLER
GROUND ENGINEERING

Specialist Grouting

KELLER GROUND ENGINEERING

Keller Ground Engineering has sixty years grouting experience. Whether a common application or one that draws upon our unparalleled experience and creativity throughout Australia, New Zealand and the South Pacific we assist engineers, contractors and owners with identifying and implementing the right solution from outline concept to detailed design and execution for any situation.

LIMITS FOR GROUTING TECHNIQUES:



GROUTING SOLUTIONS

KELLER MEETS YOUR ENGINEERING NEEDS

GROUND MODIFICATION SOLUTIONS

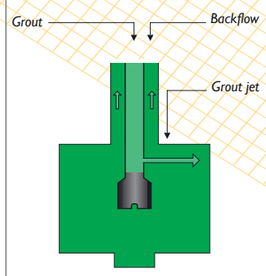
APPLICATIONS	SOILFRAC®	SOILCRETE®	PERMEATION	COMPACTION	INFILL
Ground Water Control		◆	◆		
Underpinning	◆	◆	◆	◆	
Settlement Control	◆	◆	◆	◆	
Ground Strengthening/ Consolidation	◆	◆	◆	◆	◆
Settlement Reversal	◆			◆	
Void Grouting			◆		◆
Dam Grouting		◆	◆		
Excavation Support		◆	◆		
Leachate Control		◆	◆		
Mine & Shaft Infilling	◆				◆
Pile Base & Shaft Grouting	◆		◆		
Piping Failure Control		◆	◆		
Sealing Slabs		◆			
Solution Features				◆	◆
Swallow Holes				◆	◆
Shaft Bases		◆	◆		
Tunnelling Support	◆	◆	◆		
Underslab Grouting			◆	◆	◆
Liquefaction Prevention	◆			◆	
Ground Compaction	◆		◆	◆	
Foundation Support	◆	◆	◆	◆	◆

SOILCRETE® JET GROUTING

THE PROCESS

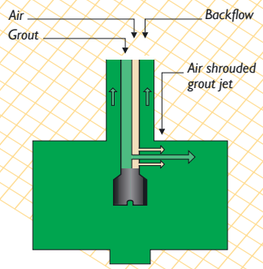
Jet Grouting is a Ground Modification System used to create insitu, cemented formations of soil. Using high velocity (>100m/s) cutting jets of water or cement suspension (grout) the system erodes and insitu mixes the soil to form the soil grout composite material.

Soilcrete® Jet Grouting can be carried out using three different systems. The choice of method is determined by the soil conditions, the required geometry, the required Soilcrete® parameters and the application.



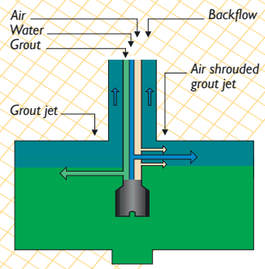
Single System:

Single System operates with a grout jet for simultaneous cutting and mixing of the soil. The Single System is used for small to medium sized Soilcrete® columns in low density soils.



Double System:

The Double System uses a compressed air shroud around the jet nozzle to increase the erosion capability of the jet. The Double System is used in dense soils, installing panel walls, underpinning and mass treatment.



Triple System:

Typically used for underpinning and in sensitive or highly variable soils, the Triple system erodes the soil with an air shrouded water jet and simultaneously injects grout into the eroded soil through an additional nozzle.

SUPER JET

Keller Ground Engineering hold the exclusive licence for the Super Jet system. Developed in Japan and operated by Keller companies in North America, Europe and the Pacific, Super Jet takes advantage of tool efficiencies and increased energy to deliver columns up to 5.0m in diameter. The benefits of Super Jet are technical supremacy, reduced program periods and costs.

Excavated 5.0m Super Jet Column.

Super Jet monitor and nozzle.

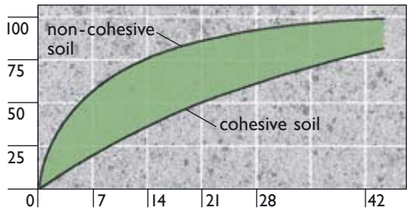
THE PROPERTIES

The compressive strength of Soilcrete® is a function of the cement content of the grout and grading of the portion of soil within the Soilcrete® mass.

The permeability and strength of the Soilcrete® can be controlled by the addition of additives to the grout mix.

Type of Soil	Silt or Clay	Sand	Gravel
UCS (MPa)	≤5	≤10	≤20

▼ Compressive strength in % of the final strength



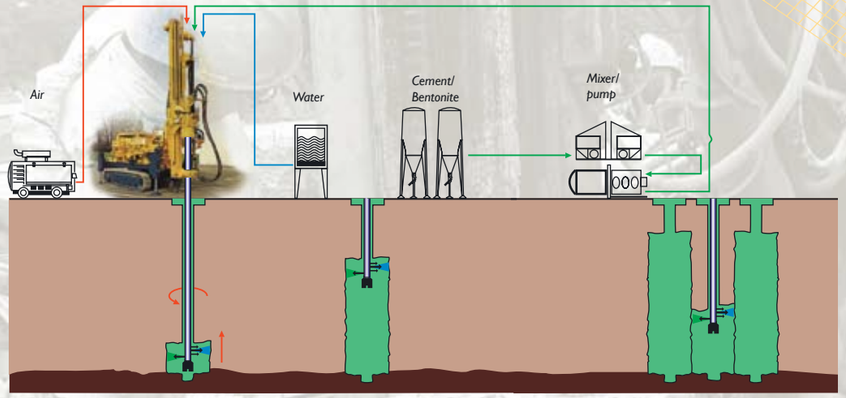
Development of Soilcrete® Strength with time

SOILCRETE® JET GROUTING

CONSTRUCTION SEQUENCE

Soilcrete® Jet Grouting equipment consists of a high pressure pumping unit, cement mixing equipment, storage silo and stores containers.

The grout mixing and pumping unit is connected to the drill rig with high pressure hoses and control cables allowing remote location of the plant. The jetting process can be performed using a wide range of drilling rigs with mast heights varying from 2.5m to 35.0m. The boreholes are normally contained in shallow trenches used to direct the flow of the excess soil-water-cement spoil to tanks or settling ponds.



1. Drilling

Drill rods fitted with jet nozzles are bored to the final depth using grout to stabilize the hole. Jetting commences at the base of the hole.

2. Grouting

Turbulence caused by the jet results in the uniform mixing of grout and soil. Excess water, soil and grout returns to the surface through the space between the drill rod and borehole wall.

3. Continuation

Additional columns can be added fresh on fresh or fresh on firm. Sequence depends upon the jetting system as well as the technical requirements of the structure being treated.

DESIGN AND QUALITY CONTROL

Soilcrete® Jet Grouting can be designed to mix or almost fully replace a soil with grout. For the common application of underpinning, excavation support and groundwater cut-off the design consists of developing a continuous Soilcrete® mass to resist over turning and sliding whilst maintaining the integrity of supported structures or utilities.

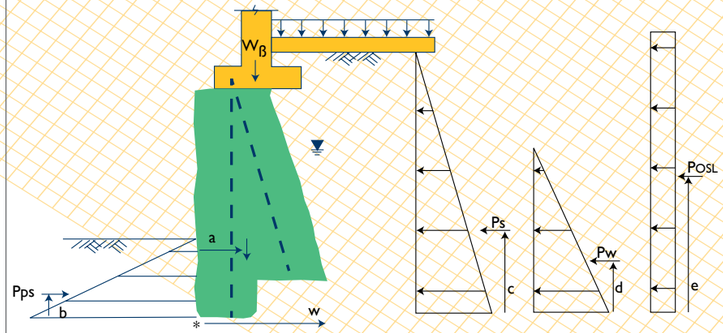
For retaining structures design checks are made for the competency of the soils below the base for bearing and settlement together with an evaluation of the internal shear and bending stresses in the Soilcrete®. The strength of the Soilcrete® is a function of the insitu soils and strength variations are to be expected, for this reason a factor of safety of 2.5 to 3.0 is typically applied for an average allowable strength.

The size of the Soilcrete® mass to be created is dictated by the application, a variety of geometries can be achieved. The width or diameter of each panel or column is determined during the design stage. Reliable descriptions of the soil composition and strength or density allows this assessment to be made with confidence.

Left: Soilcrete® underpinned Heritage Building, Manly NSW
Top: Intimate bond between Soilcrete® and Foundation.
Middle: Double or Triple Rods provide separate flows of grout, air and water.
Bottom: Jet grout pump.

SOILCRETE® JET GROUTING

DESIGN AND QUALITY CONTROL



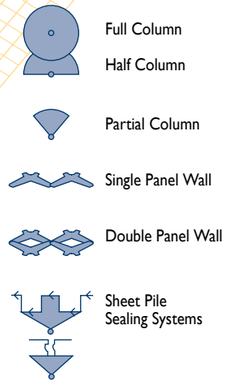
$$F = (W_\beta + W_{SC}) \tan \S + w \bullet Ca$$

$$\text{FS overturning}^* = \frac{(W_\beta + W_{SC})\, a + Pps \bullet b}{(Ps \bullet c) + (Pw \bullet d) + (Posl \bullet e)} \geq 1.5 \qquad \text{FS sliding} = \frac{Pps + F}{Ps + Pw + Posl} \geq 1.5$$

Legend

a,b,c,d,e	Moment arms	Posl	Surcharge force
Ca	Base soil adhesion	Pps	Passive force
§	Base soil friction angle	Pw	Hydraulic force
F	Friction force	W_β	Weight of structure footing load
FS	Factor of safety	W_{SC}	Weight of Soilcrete®
Ps	At-rest or active soil force	W_{SL}	Surcharge load

SOILCRETE® GEOMETRICS



Full Column
Half Column
Partial Column
Single Panel Wall
Double Panel Wall
Sheet Pile Sealing Systems

QUALITY ASSURANCE

Critical aspects of a successful Soilcrete® jet grouting program are quality assurance and quality control. These ensure that sub-surface soils are consistent with design assumptions and that design parameters are met or exceeded.

Typically projects commence with a test section to verify the design geometry and to confirm the quality and strength characteristics of the Soilcrete® material. During the Jet Grouting process a series of inspection items are monitored and documented, these include:

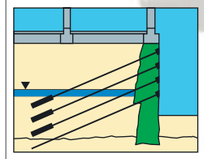
Drilling:	Location, angle, depth;
Batching:	Preparation of grout for consistency in material content and physical and chemical properties;
Jetting:	Checking of drill parameters (lift speed, rotation rate) and injection parameters (pressure and flow of all inputs);
Documentation:	Construction times and correlation to any sampling;
Sampling & Testing:	Retrieval of representative samples for external testing.

Right: SuperJet Grouting to provide tunnel support at RNA Showgrounds, Brisbane

SOILCRETE® JET GROUTING

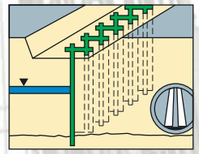
APPLICATIONS

In contrast to conventional grouting Soilcrete® Jet Grouting may be used for stabilization and sealing of all kinds of soil ranging from loose granular sediments to clay. This applies for homogenous soil formations and variable soil layers. Weak rock formations have also been treated with Soilcrete® Jet Grouting.



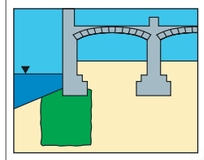
Underpinning

Underpinning by means of low deformation gravity walls, sometimes also used as a ground water seepage barrier, may be safely constructed even from confined working areas. Can be used in conjunction with ground anchors.



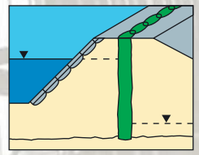
Panel Walls

Soilcrete® panel walls to cut off ground water are used below roads and buildings, for crossing pipelines and to subdivide building pits into different excavation sections. According to the sealing requirements single or multiple panels may be constructed.



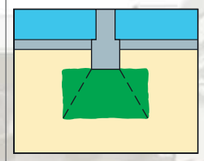
Foundation Restoration

Historic buildings may be endangered in the event of settlements occurring. Soilcrete® provides a safe foundation with the maximum structural protection.



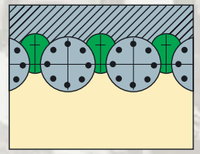
Column Walls

In the event of higher mechanical strain by shear force, danger of undermining or of a high impermeability requirements, cut off walls of intersecting Soilcrete® columns may be constructed.



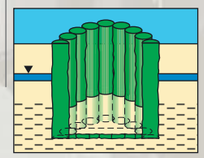
Foundation Improvement

Changes in use or modifications of buildings often require an enlargement or alternation of the foundation. Soilcrete® is an economical and flexible solution for this task.



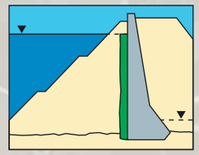
Joint Sealing

For sealing of joints between piles, sheet piles or other construction parts in the ground, Soilcrete® is ideal.



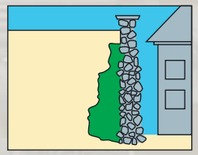
Shaft Supports

Shafts with intersecting Soilcrete® columns are constructed if a vibration free installation is required and/or the shafts enter into ground water bearing strata.



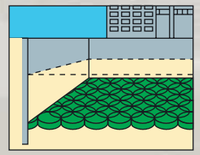
Dam Sealing

Soilcrete® may be used to repair dam cores or enlarge cut-off walls in or below dams.



Earth Pressure Relief

Structures exposed to earth pressures, such as historical walls, abutments, steep slopes protections or quay walls may be relieved by the addition of or connection to a backup Soilcrete® body.



Sealing Slabs

Soilcrete® sealing slabs are constructed by means of overlapping columns within an uplift proof depth. The sealing slabs may be connected to any kind of vertical sealing systems.

Top: Self Drilling jet grout monitor
Middle: Drill head and mast configuration
Bottom: Joint sealing between piles

COMPACTION GROUTING

THE PROCESS

When compaction grout is injected into loose soils, homogeneous grout bulbs are formed that displace, densify and thus strengthen the surrounding soil. Originally developed as a remedial measure for building settlement control the technique has evolved to treat a wide range of sub-surface conditions including rubble and poorly placed fill, loosened or collapsible soils, sinkholes and liquefiable soils.

The grout mix must have specific characteristics; a very low mobility (low slump) mixture that is 'pumpable' but upon installation, exhibits an internal friction enabling it to remain intact and displace the surrounding soil without fracturing it

Compaction grout improves ground conditions by displacement of soil particles.

A high viscosity (low mobility) aggregate grout is pumped into the ground in stages to displace and densify the surrounding soils. By sequencing the grout injections from primary to secondary and tertiary locations this densification process can be performed to achieve the required improvement.

Above: Low mobility compaction grout.
Left: Controlled underpinning of shallow foundations.

DESIGN

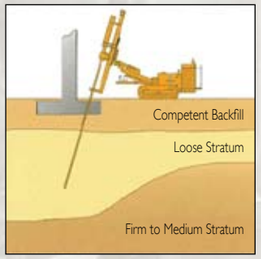
A number of aspects must be considered for compaction grouting to work best:

- The insitu vertical stress in the treatment zone must be sufficient to enable the grout to displace horizontally and hence avoid uncontrolled heave.
- In saturated soils a pore water pressure increase will occur as a result of ground displacement, for effective densification this must dissipate.
- Soils that loose strength during remolding should be avoided
- Greater displacement will occur in weaker soil strata, exhumed grout bulbs confirm that compaction grouting focuses improvement where it is needed most.

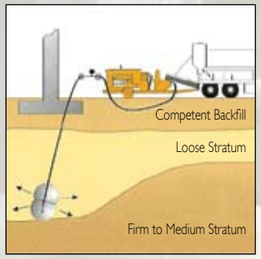
Quality control includes procedural inspection and documentation of work activity, testing to ensure proper mix design and verification works.

COMPACTION GROUTING

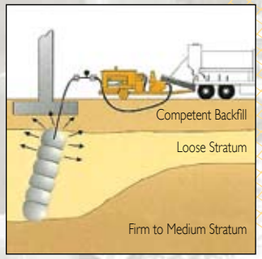
CONSTRUCTION SEQUENCE



Installation Of Grout Pipe:
- Drill or Drive Casing
- Record Ground Information from Casing Installation



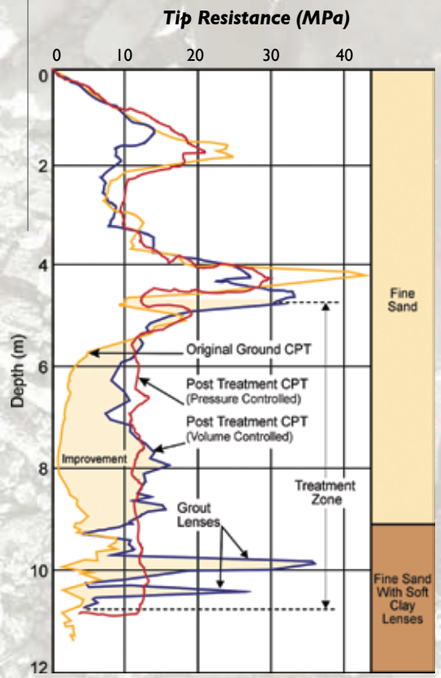
Initiation of Grouting:
- Typically a bottom up process
- Grout quality important
- Slow uniform stage injection



Continuation of Grouting:
- On-site batching of grout can aid control
- Sequencing of plan injection points very important
- Usually injection is pressure or volume limited

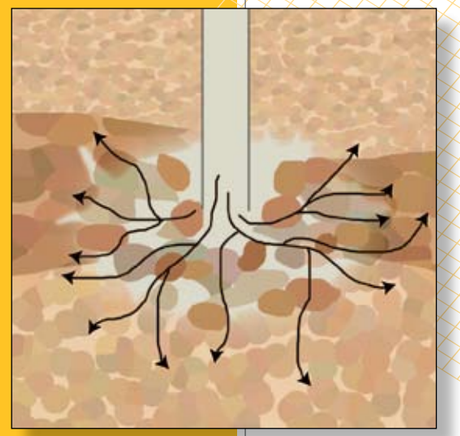
ADVANTAGES OF COMPACTION GROUTING

- ***Pinpoint treatment***
- ***Speed of Installation***
- ***Non Hazardous***
- ***No waste disposal***
- ***Can be performed in very restricted access***
- ***No need to connect to existing foundations***
- ***Economic alternative to removal & replacement or piling***
- ***Volume and pressure control options***



Left: Cone Penetrometer Test results, such as the ones illustrated left for volume cut-off and pressure cut-off, show the degree of improvement achieved by compaction grouting.
Right Top: Grout tubes
Right Centre: Steel point on driving shoe
Right Bottom: Driving grout pipes

PERMEATION GROUTING



Permeation of cement or chemical grout through granular soil.

THE PROCESS

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

Grout Materials include:

- General Cement
- Micro-fine Cement
- Sodium Silicate Solutions

Cement Grouts are often applied with admixtures or additives to improve grout stability, viscosity or durability. Common Admixtures include: bentonite, sand, plasticiser and PFA.

DESIGN

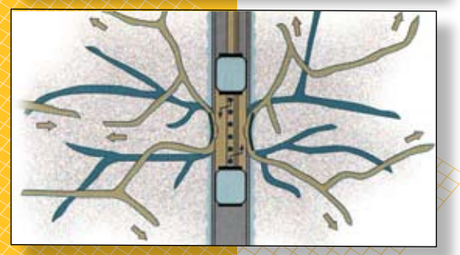
- Dependent upon the preferred grout viscosity and particle size.
- Generally limited to soils containing sand and gravel size particles only.

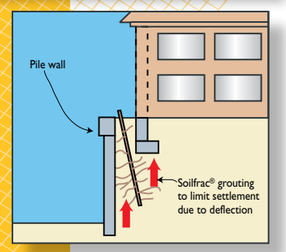
CONSTRUCTION SEQUENCE

Grout can be injected into the soil by a variety of methods:

- Hand Driven lances or spears.
- Drilled casings with grout injected through the end of the hollow casing.
- Tube-à-manchette (TAM), a series of pipes with regular spaces rubber sleeve covered injection holes.

SOILFRAC® COMPENSATION GROUTING





Top: Grout fractures emanating from TAM pipe in clay
Middle: TAM pipe and Soilfrac® injection
Bottom: Typical application to mitigate potential for settlement damage due to adjacent piling and excavation.

THE PROCESS

Soilfrac® Compensation Grouting is a process used to control or reverse the settlement of structures. It uses similar equipment and grout materials as permeation grouting to induce fractures in the soil thereby causing an expansion to take place counteracting settlement and producing controlled heave of the foundation. The system can be applied in all soil types.

CONSTRUCTION SEQUENCE

Soilfrac® is an observational process involving the installation of grout injection tubes (TAM) in a pre-determined pattern, careful injection of grout through sleeves to fracture the soil and the monitoring of ground or building movements to feed back into the grouting regime.

ADVANTAGES OF SOILFRAC® COMPENSATION GROUTING

- Method is usually performed from outside the building without disruption.
- Repeatable process allows settlement to be controlled on an ongoing basis.
- Cost effective.

ROCK GROUTING

THE PROCESS

Rock Grouting is normally performed in fissured rock masses to reduce the flow of water along the joints and discontinuities in the rock.

- Grout is typically injected in isolated stages from boreholes drilled using rotary percussive drills.
- Reduction in permeability is a function of the grouting material, the rock and grout design.
- Rock Grouting is typically performed with General Purpose, Ultra-fine or Micro-fine Cements.

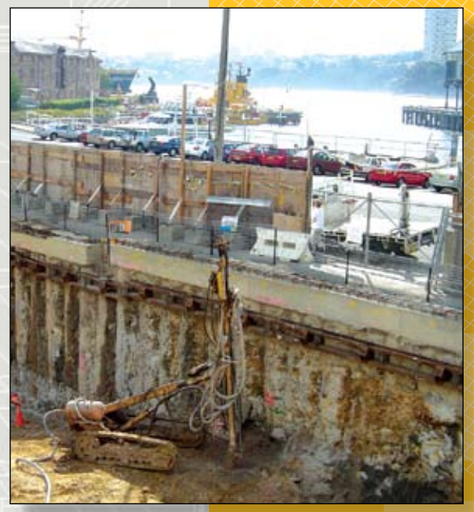
DESIGN AND QUALITY CONTROL

- Injection pressure and volume is recorded during the injection.
- Periodic water testing (lugeon test) is performed to demonstrate the achieved reduction in permeability.

Electronic monitoring and recording of grout injections can be used to provide significant cost savings through ongoing observational design of the grouting.

CONSTRUCTION SEQUENCE

- Drill and Grouting is progressed in either 'Down stage' or 'Up Stage' manner.
- Grout viscosity varied during each stage injection to ensure effective grout penetration.
- Holes are drill and grouted in a split spacing method with a primary, secondary, tertiary, etc approach.



Rock grouting in Hawkesbury sandstone, Sydney NSW.

MINE INFILL GROUTING

THE PROCESS

Coal and mineral extraction has taken place for the past two centuries using a variety of methods. With exhausted workings in various states of collapse careful consideration needs to be given to the most appropriate method of treatment.

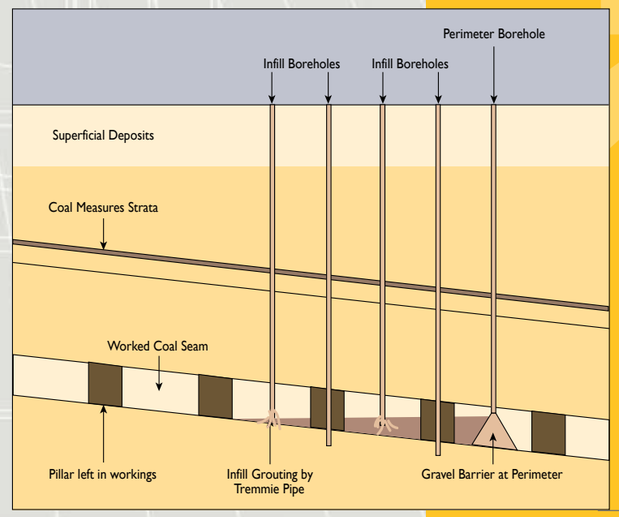
- Consolidation and Void fill grouting is the preferred method when access to the seam is not possible.

CONSTRUCTION SEQUENCE

- A perimeter barrier is installed to prevent grout migration
- Grout is pumped through tremmie pipes placed in pre-drilled holes.
- Temporary casing is used to support the drill hole in unstable ground

DESIGN & QUALITY CONTROL

- Keller Ground Engineering offer a full remediation design and construct service to meet all the needs of the project.
- Works performed in accordance with established practice developed from extensive international experience of similar projects.



KELLER
GROUND ENGINEERING

Keller Ground Engineering Pty Ltd

BRISBANE
MELBOURNE
SYDNEY
PERTH

Enquiries to:
PO Box 7974, Baulkham Hills NSW 1755
Level 1, 4 Burbank Place
Baulkham Hills NSW 2153 Australia
t: (02) 8866 1155
f: (02) 8866 1151
e: info@kellerge.com.au
w: www.kellerge.com.au