What is Grouting?

- Grouting is the injection of pumpable materials into a soil or rock formation to change the physical characteristics of the formation.

Why Grouting?

- Increased soil strength and rigidity
- Reduced ground movement
- Predictable degree of improvement

Where Could it Be Used?

- **Grouting Can Prevent:**
  - Collapse of granular soils
  - Settlement under adjacent foundations
  - Utilities damage
**Grouting Design Steps**

- Identify underground construction problem
- Establish objectives of grouting program
- Perform special geotechnical study
- Develop initial grouting program
- Develop performance prediction
- Compare with other solutions
- Refine design and prepare specifications

**Grouting Selection Considerations**

**Important Geotechnical Parameters**
- Site specific requirement
- Soil type
- Soil groutability
- Porosity
- Permeability
- Microstratigraphy
- Groundwater

**Groutable Soils**

**Chemical Grouting**

- Structural chemical grouting is the permeation of sands with fluid grouts to produce sandstone like masses to carry loads.
- Water control chemical grouting is the permeation of sands with fluid grouts to completely fill void to control water flow.
### Permeation Grouting Applications
- For lagging operation
- Support of footing
- Grouted tunnel support
- Pit excavation below water
- Grouted cut-off wall
- Grouted pipeline support

### What Chemical Grouts Used?
- Sodium Silicates (GELOC-4)
- Acrylates (AC-400)
- Acrylamides (AM-9, discontinued)
- Polyurethanes (TACCS)
- MC-Silicates

### Define Grout Pipe Layout Plan
- Fan Array Below Footing
- Parallel Array from Surface
- Fan Array from Pit
- Fan Array from Successive Heading
Develop Injection Staging & Sequencing plan

How to Control Grouting
- Grout hole location and geometry
- Injection rates and pressures
- Grout properties: liquid, transition, set

injection process measurements (QC)
- What to measure During Injection?
  - Total grout volume at each grout port
  - Injection flow rate vs. time
  - Injection pressure vs. time
  - Microseismic (acoustic) emissions
  - Laboratory injection tests

Flow Rate – Pressure Ratio / Time

Fracture
No Closer
Closer

Time
Post-Injection Evaluation Tests (QA)

- Is performed to establish the location and boundaries of the grout, and the properties of the grouted soil.
  - Core sampling
  - Inspection pits
  - Pressuremeter Testing (PMT)
  - Standard Penetration Testing (SPT)
  - Reinjection testing
  - Radar profiling
  - Seismic velocity (shear wave) profiling

Compaction Grouting (Displacement)

- Injection under relatively high pressure
- Very stiff, "zero slump" mortar grout
  - to displace
  - compact soils in place

Compaction Grout Materials

- Silty sand
- Cement (Fly-ash)
- Additives (fluidifiers, accelerators)
- Water (up to a maximum of 3" slump)

Compaction Grouting Applications

- Arrest foundation settlements
- Control soft-ground tunnel settlements
- Provide pre-construction site improvement
- Lift and level slabs and foundations
- Rectify sinkhole problems
Compaction Grouting Design Steps

- Define geotechnical - structure interaction problem
- Locate compatible soil zones
- Define degree of improvement needed
- Estimate required grout volume displacement
- Plan grout locations and sequence (Test program needed?)

Procedures

- Special "chop" mixing - 1 to 30 yd³ per hour
- Force feed piston pumps - to 1000 psi
- "Easy flow" hoses. Friction holds pipes in ground
- Create "grout bulbs" or "piers" to density adjacent ground and arch loads onto piers

Quality Assurance

- Review pressure/grout volume records
- Review ground and surface displacement records
- Cone Penetrometer Test (CPT)
- Dilatometer Test (DMT)
- Pressuremeter Test (PMT)

RECOMMENDED READING


What is Jet Grouting

- Jet Grouting is Ground Modification system, and is an erosion / replacement system that create an engineered, in situ soil / cement product known as Soilcrete®

Effectiveness of Jet Grouting

- Soil Type
  - Widest range of soil types
- Performed
  - Around subsurface obstructions
  - In confined spaces
- Effective valuable tool
  - for soft soil stabilization
  - Underpinning
  - excavation of unstable soil
  - Excavation support
  - Control of underground fluids

Jet Grouting Systems

- Single Fluid System
- Double Fluid System
- Triple Fluid System

Jet Grout Process

- Drilling
- Jet Grouting Starts
- Soilcrete Column Under Construction
- Repetition of The Process
**Soilcrete Plan Geometrics**

- Full Column
- Half Column
- Partial Column

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**Soil Erodibility Scale**

Jet Grouting is an erosion based system, soil erodability plays a major role in predicting geometry quality and production.

The geometry & physical properties of the Soilcrete are engineered, the degree of improvement can be readily predicted.

- **Highly Erodable**
  - Cobbly Soils
  - Gravelly Soils
  - Clean Sands
  - Loose Silty Sands
  - Dense Silty Sands
  - Dense Clayey Sands
  - Low Plasticity Silts
  - Low Plasticity Clays
  - Low Plasticity Clays (Stiff)
  - Dense Clays
  - High Plasticity Clays

- **Difficult to Erode**
  - Highly Erodable
  - Low Plasticity Clays (Soft)

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**Typical Soilcrete Strengths**

- **Sands & Gravel**
- **Silty & Silty Sands**
- **Clays**
- **Organic Silts & Peats**

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**Design Considerations for Underpinning**

- Bearing capacity of the system
- Settlement control
- Strength capacity of the system
- Design consideration for subsurface support
- What are the excavation and surface loading requirements and geometry of the excavation?
- Are there any critical ground failures or internal bearing capacity?
- What are the groundwater levels and any expected reduction?
## Advantages of Jet Grouting

- Nearly all soil types groutable
- Specific in situ replacement possible
- Treatment to specific subsurface locations
- Only inert components
- Limited working space required
- Any cross-section of soilcrete possible
- Maintenance free
- Safest method of construction
- Ability to work around buried active utilities
- The most effective means of direct underpinning of structures and utilities
- Much faster than alternative methods

## Quality Control/Quality Assurance (QC/QA)

- Sampling of waste materials-conservative relative assessment of in situ characteristics
- Core samples
- Daily report forms-parameters and procedures of treatment

## RECOMMENDED READING


- Slurry Grouting is the intrusion under pressure of flowable particulate grouts into open cracks and voids and expanded fractures.
**Slurry Grout Applications**

- Rock foundation treatment for dams
- Rock cut-off curtains
- Pressure injected anchors
- Stabilization of gravels and shot rock

**Slurry Grout Materials**

- Cement
- Clay (Bentonite)
- Sand
- Additives
- Microfine Cement
- Fly ash
- Lime
- Water

**Ratios Groutability**

For Sand: $N = \frac{W}{D}$
- $N > 24$: Grouting consistently possible
- $N < 1$: Grouting not possible

For Rock: $N = \frac{W}{D}$
- $N > 2$: Grouting consistently possible
- $N < 1$: Grouting not possible

Additional guidelines relating to particular grout types and particle size are:

Types I and II Portland cement are suitable for soils coarser than 0.09 mm.
Type III Portland cement is suitable for soils coarser than 0.05 mm.

**Microfine Cement is ...**

- Finely ground slag/portland cement that is mixed with a dispersant and large quantities of water for permeation of fine sand and finely cracked rock.
Microfine Cement

Pumping Cement Grouts
- Steady pressure
- Variable water/cement ratios
- Circulating vs. one-way grout hose systems
- Measuring quantities and pressures: microcomputers
- Uplift

Slurry Grout Split-Spacing techniques
- Single curtain
- Multiple curtain
- Blanket grouting

Slurry Grout Quality Control
- Conventional
- Electronic monitoring
- Microcomputer and analysis
RECOMMENDED READING

- Welsh, J.P., (1984), "Innovation Cement Grouting", American Concrete Institute, Detroit, MI, 9 papers, 178 pgs.

Soilfrac (SM) Grouting

- Soilfrac Grouting is the injection and hydrofracturing with grout slurry of the soil between the foundation to be controlled and the process causing the settlement. Grout slurry is forced into fractures, thereby causing an expansion to take place counteracting the settlement that occurs or producing a controlled heave of the settlement that occurs or producing a controlled heave of the foundation. Multiple injections and multiple levels of fractures create a complementary reinforcement zone.

Soil Types

- Because the process requires only that the soil is fractured, Soilfrac may be used in most low permeability soil types ranging from weak rock to clays.

Application

- Typical applications of the Soilfrac process are:
  - Reduction or reversal of differential settlement
  - Reduction or reversal of total settlement
  - Prevention of the settlement of buildings as tunneling is carried out
The Soilfrac Process Involves

- Installing grout injection tubes to a predetermined pattern
- Monitoring movements by either precise leveling or the use of special settlement systems
- Injection of grout into sleeves with careful process control to induce compensation movements

Design of Soilfrac Systems

- Selection and positioning of monitoring systems
- Position of injection tubes
- Initial injection (conditioning)
- Injection during construction to control settlements
- Injection post construction

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 continued control of settlement (if required)
- Control can be very selective including level changes of varying amounts at specific locations

Method of Working-Soilfrac

- Sink Shaft
- Install sleeved pipes
- Condition grout
- Inject grout as necessary
- Reinjection unlimited, without redrilling
**Quality Control**

- All stages monitored from installation of tubes to actual injection
- Grout mix, injection pressure, volume and pump rate carefully designed and monitored
- Computer monitoring (real time) of structure movements
- Full documentation for every stage

**Monitoring System**

- Precise levelling/surveying
- Water level system
- Electro level

**RECOMMENDED READING**