MULTIURETHANES
Suppliers of grouting materials, equipment and engineering support services

TECHNICAL INFORMATION

Grouting Narrow Fissures

INFLUENCE OF APERTURE DIMENSIONS ON CEMENT GROUTING OPERATIONS

Although grouting research programs have achieved penetration of cementitious grout into very thin fissures, for practical purposes under typical field conditions the minimum fissure widths for successful grouting with ordinary Portland cement-based grout have been established by Houlsby (1990) after many years of grouting experience as follows:

- 500 microns without special care
- 400 microns with extra care using high-quality grout
- a little finer under very experienced supervision

The suitability of various cement grouting materials for penetrating narrow fissures may be evaluated by using the following formula:

$$\text{GROUTING RATIO (GR)} = \frac{\text{fissure width}}{d_{95}\ \text{(grout)}}$$

Satisfactory grouting results can be consistently obtained with stable cementitious grout mixes for site conditions where GR $>$ 5. For site conditions where GR $<$ 5, it becomes increasingly difficult to obtain satisfactory grouting results.

The penetrability of cement grouts are enhanced through the use of stable, balanced grout formulations with dispersion admixtures. Cement grouts that are balanced to eliminate excessive bleeding will produce grouts with homogeneous rheology properties. The use of superplasticizers as dispersion agents will eliminate flocculation of cement particles and thereby facilitate grout injection.

The influence of narrow apertures on cement grouting operations has been identified on many rock grouting projects where it was not possible to achieve significant grout penetration using ordinary Portland cement due to the relatively coarse cement particle size. By switching to microfine cement with relatively small particle size, the grout consumption was dramatically increased even at the same W:C ratios and at lower injection pressures.

SELECTION OF CEMENT PRODUCTS FOR GROUTING NARROW FISSURES

For reasons of low cost and local availability, ordinary Portland cement is always preferred for the major component of any cementitious grouting program, provided that fissure widths are greater than 400 microns.

For a nominal extra cost, high early strength cements will provide enhanced penetration relative to ordinary Portland cement when grouting fissure widths are greater than 200 microns, due to signicantly reduced d_{95} cement particle diameters.

For grouting fine fissures in rock or concrete structures, the use of **microfine** cement facilitates grout penetration relative to conventional cements due to its finer particle size.

Grout penetration into narrow fissures can be facilitated by selecting grouting materials manufactured with smaller particle diameter to accommodate narrow aperture conditions as shown on the following table:

Cement Product	d_{95} (grout)	Practical Range
ordinary Portland cement	80 - 100 microns	$>$400 microns
high early strength cement	40 - 60 microns	$>$200 microns
microfine cement	10 - 12 microns	$>$ 50 microns

IMPROVED GROUT PENETRATION

Research has shown that penetration of grouting fluids into fine fissures is proportional to the cube power (w^3) of the fissure width (Lombardi, 1985; Witherspoon, 1986).

As a result of this relationship, penetration of fine fissures may be significantly enhanced, at various water:cement ratios, by selecting finer cements in accordance with site conditions.

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Underground drill hole showing the result of intersecting water-bearing fractures at a depth of 500 feet below surface; water pressure testing established that rock fissures were very narrow, thus justifying the use of microfine cement grout

INFORMATION DERIVED FROM WATER PRESSURE TESTING

Especially in deep mine grouting operations where water flows usually occur under high hydrostatic pressures, the use of water pressure testing can be instrumental in quantifying the hydraulic conductivity of the area to be grouted.

By measuring the water flow rates at various dynamic water pressures, the static water pressure under no flow conditions and knowing the length of the borehole, it is possible to calculate the hydraulic conductivity of the rock formation. With this information, an appropriate cement material can be selected, balanced grouting formulations can be established and target volumes of grout consumption can be assessed.

Water pressure testing can also be useful in establishing the effectiveness of grouting operations by measuring the reductions in hydraulic conductivity that have been achieved by previous grouting activities.

This mine shaft grouting operation utilized a colloidal grout mixer for preparing high-quality ordinary Portland and microfine cement grouts, in conjunction with a grout agitator tank and a low-pressure, high-volume diaphragm pump suited for site conditions; actual grouting pressures within the shaft were higher than pump pressures due to the effect of gravity.

USING APPROPRIATE SIZE GROUTING EQUIPMENT

Many rock grouting operations, especially those that involve narrow fissures, can be most easily grouted by using relatively small grout mixers and pumps. A common mistake of many mine grouting operations is attempting to use cement grouting equipment that is too large or too high in output volume and pressure for a specific application.

Selecting appropriate sizes of grouting equipment provides for safer working conditions and results in overall higher standards of cement grouting performance.

Call the technical specialists at **MULTIURETHANES** for detailed equipment recommendations for specific cement grouting applications.

Grouting equipment is available for purchase or rental from **MULTIURETHANES** to suit a wide range of cement grouting requirements.