MULTIURETHANES
Suppliers of grouting materials, equipment and engineering support services

GROUTS - SEALING THE FUTURE

Author

Peter White, P.Eng.
Grouting Specialist

Abstract

Grouts are heavily relied upon in the trenchless technology industry. From filling voids to soil stabilization and sealing off ground water inflow, grouts are used alone or in combination with other trenchless techniques to ensure success in the challenging underground world.

Introduction

Within the trenchless technology industry, grouts are defined as fluids which can be injected into place and which will cure in a predetermined manner into a solid, inert material. The list of grouting materials used in the trenchless technology industry is lengthy and includes the following generic types of materials:

- Cements
- Sodium Silicates
- Acrylamides
- Acrylates
- Polyurethanes
- Epoxies

Cost of Grouting Materials

Cement grouts are the least expensive type of grout costing $1 to $2 per litre of mixed grout. A number of performance-enhancing additives extend the range of potential grouting applications for Portland cements. Cement grouts are typically used in sliplining and void filling applications, but can also be applied in many other grouting situations.

Sodium silicates are an inexpensive, non-toxic type of grout costing $2 to $3 per litre of mixed grout. Sodium silicates are also combined with cement grouts to obtain quick-setting grouts and are also used independently with special chemical hardeners for soil stabilization projects.

Acrylamides are an inexpensive grout costing $3 to $4 per litre of mixed grout. Acrylamides are the most common form of grout used for in-line sewer pipe joint sealing.

Acrylates are non-toxic grouts costing $4 to $5 per litre of mixed grout. Acrylates are less toxic than acrylamides but are similar in viscosity and performance. Acrylate grouts have the potential to displace acrylamides for some trenchless applications.

Polyurethane grouts cost as low as $5 to $6 per litre of cured grout for gels and as high as $10 per litre for foams. Polyurethane gels are used for sealing leaking joints and cracks in man-accessible sewers and in-line sewer pipes. Some polyurethane foams have been approved for potable water repair applications.

Epoxy grouts cost $20 - 30 per litre of cured grout. Epoxies are used for spot repairs to damaged sewer pipe and for coatings of man-accessible sewers.

Overall Cost of Grouting Operations

The cost of grouting materials, as summarized above, is only one aspect of selecting the most suitable product for a specific application. Where material performance and durability considerations are paramount, the cost of more expensive materials may be justified.

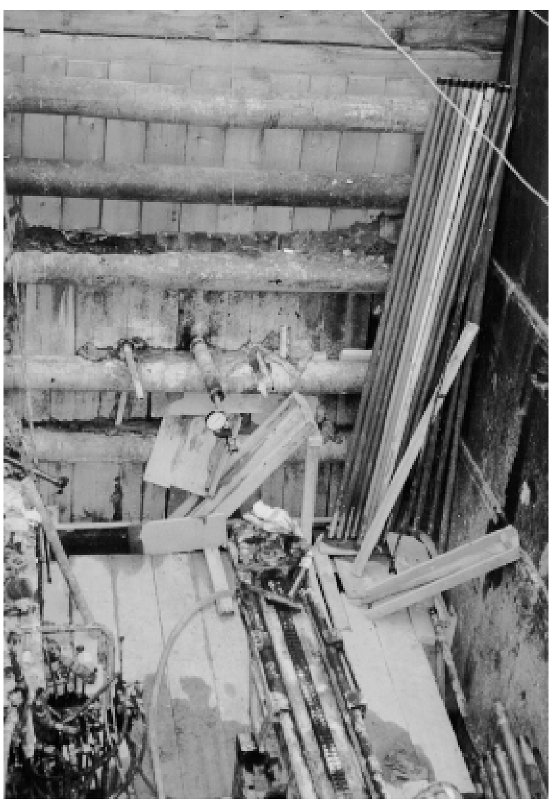
The capital and operating costs of grouting equipment, and the labour costs involved in grouting operations are typically significant factors in determining the feasibility of using various grouting materials.

Small grouting applications, such as in-line spot repairs, are less sensitive to material costs, since the equipment and labour costs are significantly higher than the material cost. Large grouting applications, such as void filling or soil stabilization, are more sensitive to material costs and allow more opportunity for the creative utilization of alternate grouting materials with the objective of reducing overall project costs.

Not withstanding the competitive choices between repair and replacement technologies, there are also many choices which warrant careful consideration by utility owners, consultants and contractors within the area of grouting materials and technologies.

Cambridge, ON
Soil Consolidation Using Sodium Silicate

Prior to installing a new watermain beneath highway 401 in fine water-bearing soils, it was decided to pre-grout the area to reduce the potential for ground settlement beneath the highway. Although microfine cements were originally specified, it was ultimately decided to use sodium silicate grout due to the very fine nature of the soil. Drilling and grouting were undertaken using horizontal holes installed from the pipe jacking pit.



Grouting Chemistry

All grouting materials are two-part or three-part chemical systems which are mixed prior to being injected if the reaction time is slow, or are mixed in place at the time of injection if the reaction time is fast. Grouting materials which are pumped through long delivery hoses are mixed in place regardless of the reaction time involved.

All grouts rely upon chemical reactions to be transformed from fluids into solids. The reaction chemistry is usually dependent upon the correct proportioning of the system ingredients and upon the temperatures involved.

When the proportioning of various ingredients is outside the allowable range for a given product, a poor quality product will be created with poor operating characteristics and performance.

Many products which perform satisfactorily under laboratory or ideal conditions are not tolerant of typical site conditions, such as improper proportioning or mixing, low tolerance for moisture or wet conditions, or an inability to cure properly at low temperatures. To further complicate matters, many products are not given adequate technical support by manufacturers and distributors and depend too much on the resources of the applicator.

Two major factors - moisture and temperature - associated with the trenchless technology industry have a significant impact on grout chemistry and grout performance. Grout materials which perform well in damp Toronto sewers in the summer probably will not perform as well in wet Timmins sewers in the fall. To some degree, manufacturers and applicators can compensate for grout chemistry in various ways. The bottom line is that some form of chemical or technical compensation is required if optimum grout performance is to be obtained under a wide range of site conditions.

Many otherwise excellent grouting materials are moisture-sensitive, which inhibits their utilization in most site conditions. Similarly, the reaction time for all chemical reactions doubles for every 10°C drop in temperature, so that applicators must compensate by technique or by different material proportioning in order to maintain uniform quality of grouted installations.

While all grouts rely upon chemical reactions to form solid insitu materials, the nature of the chemical reactions differ widely between the different types of grouts. When comparing competing grouting technologies, a basic knowledge of the chemistry involved is helpful in anticipating and overcoming problems in the field.

Fluid Dynamics

One of the principal characterisitics of grouts is the material rheology, which is determined by viscosity and cohesion of grout components and/or of the mixed fluid, and which determines the injectability of grouts for different applications. The fluidity of grouts ranges from watery fluids to pasty gels, any of which can be pumped by utilizing the appropriate equipment.

The viscosity of grouting materials can vary as a result of changes in temperatures, dilution ratios and the chemical reaction which causes the grout to cure. Even before curing occurs, grouting materials may enter a transition state where sufficient cohesion is developed that grouting can not be continued within the available pressure limitations of pumps and hoses.

Suspension grouts, such as cement-based grouts, are susceptible to line blockages due to pressure filtration unless appropriate modifying additives are used. Solution grouts are susceptible to crystallization if allowed to sit for prolonged periods or if exposed to cold temperatures.

All grouting techniques associated with trenchless applications are dependent upon materials being pumped, portion-controlled and mixed under various site conditions, to which some materials are more forgiving than others. To a large extent, the fluid dynamics of grouting materials is a major determining factor in the selection of grouts for specific applications.

Cured Grout Properties

One of the most challenging tasks to be addressed by the trenchless industry is to establish the required (or desired) properties for cured grouts in various applications. Another challenge is for people to understand the significance of various properties and to determine how these properties are affected under the range of site conditions which are encountered within the industry.

Sodium silicate, for example, is typically used only for temporary requirements since it is widely known that cured sodium silicate grout deteriorates over time. Cement grouts can achieve satisfactory compressive strengths, but are easily cracked if subjected to movement and will deteriorate in aggressive environments.

Hydrophobic polyurethane grouts are stable over time, but hydrophilic polyurethane grouts are susceptable to wet/dry cycles and freezing conditions. Also, the adhesion and elongation of various polyurethanes varies widely depending on the chemical composition of the material.

Waterloo, ON
Sewer Repairs Using Cement Grout

Man-accesible sewers in soft, sandy soils can be affected by water infiltration and soil migration through leaking joints. The upper photo shows typical sewer repairs in progress by pumping cement grout around the exterior of the pipe.

The photo below shows typical grout preparation equipment in use on such projects, including X-Y strip chart recorders, electronic flow meters and a colloidal grout mixer.

Baddeck, NS
Repair of Leaking Manholes

As shown in the photo above, the contractor encountered problems with groundwater infiltration through joints in the precast segments of several manholes. The repair procedure commenced with drilling injection holes mid-way through the wall of the precast segments to intersect the leaking joint.

The photo below shows the results of grouting with a hydrophilic polyurethane gel using a special grouting manifold to regulate water and resin ratios. The technician has complete flow control of both resin and water independently of the truck-mounted pumping equipment.

Epoxy grouts, if properly mixed and applied, are very durable materials. In trenchless applications, however, epoxy products are installed under very difficult conditions, so it is no surprise when problems arise with the application of these products.

Product Safety

In general, insufficient priority is given to the safety aspects of grouting materials, whether to the environment, or regarding occupational hygiene pertaining to application personnel. We have heard too many horror stories from the industry. Also, we have been exposed to too few organizations where product safety was given a high priority. The steel mills in Hamilton and the TTC are recognized as leaders in setting high standards for product safety and occupational hygiene when it comes to the selection and use of grouting materials on their project sites.

Selection of Grouting Materials

Within the trenchless technology industry, the selection of grouting materials depends on many factors, not all of which are well understood by industry participants. For the most part, applicators are obliged to utilize grouting materials based on their experience and from word-of-mouth advice from others in the industry.

The evolution of grouting materials selection for trenchless technology applications is driven primarily by a variety of commercial interests "pushing" proprietary products, with limited amounts of coordinated research focused on the needs of the industry. Opportunities exist for the innovative use of existing materials through improved and modified application techniques, as well as the use of new materials being developed and transferred from other industries.

The following sections of this paper summarizes the status and the potential for various grouting materials with applications within the trenchless technology industry.

Ordinary Cement Grouts

Cement grout technology has developed far beyond mixing "water-and-cement". A wide assortment of performance-enhancing additives is available to facilitate the use of cement grouts under a wide range of conditions.

Small doses of bentonite improve grout yield, reduce bleeding and improve performance when grouting under pressure. Superplasticizer reduces viscosity and cohesion and facilitates grout penetrability into fine fissures and soils. Very small doses of welan gum significantly reduces problems associated with pressure filtration. The use of thixotropic admixtures prevents washout when grouting in water-filled or water-flowing areas. Sodium silicate can be used to accelerate the gelation of cement grouts, even to the point where flash-setting can be created if required by difficult inflow conditions. Grout retarders and accelerators are available for use when long delivery lines are involved or when lines must remain filled and pumping restarted at a later time.

Four positive attributes concerning cement-based grouts are that they are inexpensive, commercially available everywhere, less toxic than most other grouts, and easily cleaned in the event of spillage.

Microfine Cement Grouts

For soil stabilization applications, microfine cements are less expensive and less toxic than chemical grouts. The essential difference between microfine and ordinary cement is that the maximum particle size is up to 10 times less in diameter, which facilitates penetration into fine soils. In many cases, microfine cements are used where ordinary cements will not penetrate and where only chemical grouts could formerly be employed. The wide spread use of chemical grouts for soil stabilization has diminished considerably in the past 10 years as a result of microfine cements becoming available.

Cement Foam Grouts

Cement foam grouts are frequently used for sliplining applications where buoyancy concerns prohibit the use of ordinary cement grouts and where grouts must be pumped for long distances at low pressure without collapsing the slipliner pipe. Specialized equipment and techniques are required to prepare and place cement foam grouts, but several manufacturers now supply competitive products for these applications.

Sodium Silicate Grouts

Low-viscosity sodium silicate grouts were widely used for soil stabilization and still are applied on a few occasions where low soil permeability prohibits the use of microfine cements. As indicated above, sodium silicate is used in conjunction with cement grouts to accelerate the curing of cement grouts and to create flash-setting grouts when water inflow conditions are encountered.

Alexandria, ON
Repair of Leaking Manholes

As shown in the photo above, personnel are repairing a leaking joint where a PVC sewer pipe entered a manhole. At the beginning of the job, ground water was streaming through the leaking joint and projecting into the centre of the manhole. Three small wooden shims were used to temporarily stop the majority of the water infiltration until grout holes could be drilled and grouted.

The photo below shows the completed repair with no further infiltration through the joint. The collars of the grout holes can be seen at the 12 and 3 o'clock positions around the PVC pipe. In this application, a hydrophilic polyurethane gel was used to seal the leaking joint.

Victoria, BC
Greater Victoria Water District

GVWD had a number of valve chambers where water infiltrated between the water supply piping and the cast-in-place concrete wall. The chambers flooded to groundwater level unless drainage pumps were left running day-and-night.

As shown in the photo above, groundwater was actively infiltrating through 3/8”drill holes and plastic packers installed for the polyurethane grouting operation. The holes were drilled to intercept the pipe/concrete joint and did not penetrate through the wall of the chamber.

The photo below shows the joint successfully sealed using a flexible, hydrophobic, polyurethane foam grout. In this case, the desired result was achieved using a small quantity of grout installed with hand-operated grouting equipment.

Acrylamide Grouts

Acrylamides are widely used for in-line grouting of sewer pipes. Acrylamides are relative low in cost and function quite satisfactorily from a technical perspective. In recent years, however, acrylamides have increasingly come under attack from various regulatory agencies due to toxicity considerations. Acrylamides will continue to be used for many years, until other products have been proven to be cost-effective equivalents.

Acrylate Grouts

Acrylate resins are relatively new grouting materials which have comparable performance characteristics as acrylamides, at a slightly higher cost, but without the potential environmental disadvantages. The trenchless technology industry will experience an increasing number of applications of acrylate resins in the next few years as concerns about the safety of acrylamide continue to mount and acrylate resins become more readily available.

Polyurethane Gel Grouts

Polyurethane gels are fast-acting, hydrophilic grouts which are mixed at high ratios with water (6-8 times more water than resin) to produce a flexible gel. The reaction time from mixing to cured product is typically about 30-40 seconds.

Older generation polyurethane gels are based on TDI (toluene-diisocyanate - a possible carcinogen) and may contain up to 20% acetone. Newer generation materials are based on MDI and are solvent-free (100% solids).

Polyurethane gel grouts are typically used for sealing leaking manholes and for in-line sewer pipe joint repair. These **hydrophilic** products will shrink if allowed to dry out and are not recommended where freeze-thaw cycles are encountered or where rebar is encountered in structural concretes.

Flexible Polyurethane Foam Grouts

Older generation flexible polyurethane foam grouts are based on TDI (toluene-diisocyanate - a possible carcinogen) and may contain up to 10% acetone. These **hydrophilic** grouts are mixed at high ratios with water (up to equal volumes of water and resin) to provide a flexible foam product. These products will shrink if allowed to dry out and are not recommended where freeze-thaw cycles are encountered.

Newer generation flexible polyurethane foam grouts are based on MDI and are solvent-free (100% solids). These **hydrophobic** grouts are activated at low ratios with water (1-2% of resin volume). When cured, these flexible grouts will **not** shrink if allowed to dry out and will tolerate freeze-thaw cycles.

Flexible polyurethane foams are typically used in man-accessible sewers for sealing leaking cracks and construction joints, particularly where a non-shrink, microcellular gasket is required. Some flexible **hydrophobic** grouts have been approved for use in potable water applications.

Rigid Polyurethane Foam Grouts

Rigid polyurethane foam grouts are based on MDI and are solvent-free (100% solids). These **hydrophobic** grouts are activated at low ratios with water (1-2% of resin volume). When cured, these rigid grouts will **not** shrink if allowed to dry out and will tolerate freeze-thaw cycles.

Rigid polyurethane foam grouts are used in repairs of high pressure water inflow situations where site conditions are beyond the performance limitations of flexible materials.

Epoxy Injection Grouts

Epoxy injection resins are used when it is required to make a structural repair, rather than just a crack sealing repair to prevent water inflow. Epoxy resins can be used to repair concrete pipe and structures, as well as pipes made of other materials.

Due to the relatively high cost of epoxy resins and the slow curing times involved, these materials are seldom used for sewer crack repairs unless site conditions require a structural bond to be reestablished on both sides of the crack.

Epoxy Gel Grouts

Epoxy gel grouts are commonly used to make spot repairs within broken or damaged sewer pipe which has deteriorated to such an extent that sealing with polyurethane grouts is not a viable alternative and where isolated sections of damaged pipe do not warrant replacement or relining by other methods.

Epoxy repair materials are also used in man-accessible situations to repair damaged concrete and to resist the effects of aggressive sewer environments.

Mississauga, ON
Hanlon Feedermain Tunnel Project

A 10 foot diameter tunnel boring machine was stopped after the roof of the tunnel collapsed on top of the TBM. The cavity was estimated to measure about 10 feet high and 10 feet wide and was located directly on top of the TBM. After considering various options, the contractor decided to use rigid polyurethane foam grouts to create a low-density, light-weight grout for void filling.

The grouting work was completed in one shift using high-volume, low-pressure grout pumps and special manifolds to trigger the foaming reaction before injecting the polyurethane into the cavity. Plastic injection pipes were pre-installed to discharge the foaming polyurethane near the top of the cavity.

The foaming polyurethane cascaded into the void under atmospheric pressure only, to ensure that a low density end product was achieved.

COMPANY OVERVIEW

WHO WE ARE

Since 1988, **MULTIURETHANES** has become a leading supplier of injection materials, equipment and accessories used for the repair and/or waterproofing of concrete structures in municipal and heavy utility applications. In mining and tunneling applications, our products and services are used for soil consolidation, water cut-off and grouting of rock fissures.

THIS DOCUMENT

This technical paper provides a detailed explanation of grouting applications undertaken with products and services supplied by **MULTIURETHANES**. Additional technical information on specific grouting materials and techniques is available from **MULTIURETHANES**. For additional information, call to obtain one of our ENGINEERING REFERENCE MANUALS.

WE'RE HERE TO HELP

Specialist advice for your grouting projects is available from **MULTIURETHANES**. We encourage you to consider our specialists part of your engineering team, providing technical assistance to ensure that your grouting projects are both cost effective and successful. For groups interested in learning more about grouting operations, **MULTIURETHANES** offers technical seminars on various grouting topics.

ON-SITE EXPERTISE

Where possible, **MULTIURETHANES** provides on-site technical assessments to determine project requirements and recommend appropriate grouting materials, equipment and techniques for specific site conditions. Specialists from **MULTIURETHANES** are available to provide training to those with limited grouting experience.

CALL TOLL FREE

1-800-663-6633

VISIT OUR WEBSITE

www.multiurethanes.com

ACTIVITIES

- Pressure Grouting
- Cement Grouting
- Soil Stabilization
- Water Cut-Off
- Sewer Rehabilitation
- Concrete Restoration
- Crack Injection
- Waterproofing

APPLICATIONS

- Potable Water Tanks
- Municipal Services
- Underground Utilities
- Hydro Dams
- Mines and Tunnels
- Geotechnical

PRODUCTS AND SERVICES

- Polyurethane Resins
- Acrylate Resins
- Microfine Cement
- Sleeve Pipes
- Grouting Equipment
- Hydrotite Waterstop
- Multi-Paste Sealant
- Injectable Tubing
- Quality Control
- Engineering Services

Canada
5245 Creekbank Road
Mississauga, Ontario L4W 1N3
Tel: (905) 564-7650
Fax: (905) 564-7998
Toll Free: 1-800-663-6633
email: info@multiurethanes.com

USA
PO Box 127
Buffalo, NY 14207
Tel: (716) 842-0066
Fax: (716) 842-0055
Toll Free: 1-800-663-6633
email: usa@multiurethanes.com