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INTRODUCTION TO THE FIELDS OF GEOFLUIDS

The transfer of very large localized loads through drilled or bored piles has become common place today in almost any ground conditions thanks to a large part to improved drilling fluid materials and practice. From a 6 inch diameter micro-pile to a 9 feet diameter caisson or 15 feet square load bearing element, a variety of fluids are responding to specific soil conditions, skin friction optimization, chemical environment or any other particularity.

Mass transit, depressed highways or railroads, underground parking garages, complex waste water works and other utilities require sophisticated excavation support systems, particularly below the ground water table. A combination of traditional foundation and cutoff wall construction techniques has caused the development of very performing construction techniques, derived from the slurry trenching technology: reinforced concrete diaphragm walls, soldier beam tremie concrete slurry wall, pre-cast concrete panels installed in self-hardening slurry, steel sheet piling or soldier beam and lagging prefab panels placed in IMPERMIX®.

Barriers, cutoff walls, slurry trenches are a main tool in containing migrating contaminated plumes. Typically, watertightness and compatibility are the main properties. Mineral slurries either from just clays or self-hardening provide the main characteristics. Non-trenching techniques such as deep soil mixing and jet grouting also form barriers, using properly formulated self-hardening slurries or grouts.

Passive permeable and reactive barriers are more and more common and a departure from the traditional waterproof barrier. The so-called "funnel and gate" system combines the impervious barrier (funnel) with the pervious passive and reactive barrier (gate) through which the ground water flow is concentrated.

Modern tunneling has become very mechanized. Soft-ground tunneling often uses machines that are either of the earth pressure balance type (EPB) or the slurry shield type. A few manufacturers make hybrid machines that combine both characteristics. EPB machines eventually require soil conditioners to fight unfavorable soil conditions. Slurry shield machines require a face support fluid

capable of being continuously recycled through a solids separation plant while maintaining its properties within a narrow band.

The drastic reduction in public disturbance by implementing trenchless techniques in the various urban utility works has caused a dramatic evolution in the vast array of technologies. Microtunneling is an evolution of the older pipe jacking and auger boring. In all such techniques, proper lubrication is essential for uneventful drives and reduced jacking forces. When a service pipe is placed inside the jacked pipe, the annulus created need to be backfilled. Cellular concrete has been the common practice. Liquid backfilling with self-hardening slurry has proven a cost effective and more flexible construction method.

Our company welcomes challenges that gives us a chance to build on our experience and advance construction technology such as when the Big Dig program in Boston required the jacking of huge pre-cast concrete roadway tunnels through frozen ground, the C09B4 Joint Venture desired a sidewall antifreeze lubricant capable of hanging vertically while being easily pumpable: the result was FREEZLUBE™.

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HEAVY CONSTRUCTION

DEEP FOUNDATIONS

This covers all forms of drilled shafts or multi shaped barrettes or load bearing elements for picking concentrated loads. These construction processes involve excavation under slurry; the selection of slurry type is governed by ground conditions and ground water presence and elevation.

Although practitioners may have specific habits, a mineral slurry is typically preferred in coarse granular soils and a polymer slurry offers more advantages in cohesive soils such as clays or silts. Heavy molecular weight anionic polymers are flocculants and cannot be combined with clay which limits their use to low permeability soils.

WONDERMUD™, PREMIX™ and PREMIX XXL™ are used as pure polymer slurry eventually with pH regulators and chelating agents if mixed or in presence of brackish or salt water. POLYBLEND-B™ and PREMIUM™ are compatible with mineral slurries and offer the most efficient and flexible mud formulation: behaving as a mineral slurry with respect to filter cake formation and as a polymer slurry with respect to the inability to suspend sand with the ability of the slurry to clean itself by segregation. If polymer is the only possibility but mud weight is an issue or gel strength is, our 3D GUM™ is a thixotropic biodegradable polymer that is an expensive bentonite replacement. When excavating through jet grouted or soil mixed soils, high pH and calcium may be detrimental to conventional mud systems either clay or polymer based. Our KC polymer is a biodegradable polymer that is not affected by Portland cement (Xanthan gum will gel in presence of Ca++ions). SEAPOLY™ is an expensive biopolymer that performs beautifully without any additive when seawater is the only make up water available. When excavating in fine sand where heavy molecular weight

polymers have proven traitorous, a pure polymer slurry consisting of 80% POLYBLEND-B™ and 20% MICROPLUG™ has proven reliable to provide stability and filtrate control. This is particularly helpful on small jobs where the use of bentonite is burdensome. When bentonite slurry is used, filtrate control can be provided by addition of our very low molecular weight ANIONIZER™ polymer that has little impact on viscosity. When pure polymer slurry loss cannot be controlled by addition of MICROPLUG™ or its coarser partner PLUG, an option is to gel the bottom of the mud column where the loss is occurring and allowing the gel to permeate and seal the open formation and resume excavation shortly after. This localized investment in GELLAR™ may save a lot more in regular polymer slurry not lost and in preventing hole instability.

SUPPORT OF EXCAVATION

Perimetral diaphragm walls or slurry walls generally act as support of excavation during the excavation phase in conjunction with ground anchors or tiebacks and as foundation bearing walls as part of the permanent foundation system. Typical slurry walls consist of reinforced concrete or soldier pile tremie concrete (SPTC walls). Diaphragm walls are most often linear in underground structures with the exception of circular walls used for tunnel access shafts or pumping stations. Other types of slurry wall may be cost effective: pre-cast concrete panels set in a self-hardening slurry. Similarly, steel sheeting and pre-fabricated soldier beam and lagging wall panels can be lowered in self-hardening slurry for temporary supports of excavation or integrated into the design final condition at a fraction of the cost of concrete slurry walls.

The slurry technology for tremied or pumped concrete slurry walls is identical to that of drilled shafts, with the caveat that rectangular excavations are intrinsically less stable than circular ones and risk evaluation is most stringent. The same products listed in the previous paragraph apply. Chemical additives are often required to correct the mixing water or counteract the effects of excavation such as fines build up or cement contamination. pHBUFF™, LESAP™, HEXAM™ are chemical regulators, while AQUAFIX™ is a dispersing polymer that reduces the gel build up of a mineral slurry and reduces viscosity while allowing sand to settle at the bottom for an easy cleanup.

Self-hardening slurries are quite different since instead of being displaced by the final product, they are part of it. While used as a trenching fluid, they must provide similar characteristics as mineral slurries over a proper period while in a cured condition they must satisfy specific physical properties. IMPERMIX® offers a wide range of formulations that will be detailed in a dedicated page.

Except for internally braced excavations or auto-stable circular or ellipsoidal slurry walls, a linear support of excavation is generally held by anchorages, and most often soil anchors. A number of installation practices exist. The quickest and most performing technique is the open-hole method drilled with an appropriate polymer slurry such as WONDER MUD™, PREMIX™ or PREMIX XXL™.

Whether in sandy soils or in clay, the grout-soil interface is the cleanest possible, especially if the primary grouting is performed through the rods on the way out and the anchorage pushed in the grout filled hole. As of 1987, we have stopped recommending drilling for anchors with bentonite slurry and polymer slurry has been satisfactory almost 100% of the times.

LIGHT WEIGHT BACKFILLS

When excavations take place in low specific weight material or above very compressible layers, conventional backfilling with dirt or stone does not apply. Ultra lightweight backfill such as cellular grouts or synthetic foams are often used in dry excavations; fly ash flow-fills are economical, quite heavier and also must be placed in the dry. An IMPERMIX slurry can be used to excavate in the wet below the water table, at any depth and be left in place to constitute the backfill with a weight around 70 pcf and total cohesion. This is particularly interesting for backfilling behind steel sheet piling cofferdams since ground pressure behind the sheets can be largely reduced depending on the thickness of the backfill.

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ENVIRONMENTAL REMEDIATION

Geofluids are instrumental in many aspects of cleaning up the environment: all sorts of small diameter holes are drilled for soil investigations, monitoring wells, venting or injection wells. The choice of drilling fluid is governed by the chemistry of the contaminants and the science being implemented; our range of synthetic, semi-synthetic and natural polymers offers a great selection. Some states used to allow monitoring wells drilled only with bentonite slurry: talk about icing on the cake! Bad engineering.

Extraction of contaminated groundwater over the long term is more economically done with horizontal wells or leachate extraction trenches than with numerous wells requiring energy and maintenance: depending on soil conditions, one of POLYBLEND-B™, PREMIUM™, as blends or PREMIX™, TALGUAR™, 3D GUM™ or SEAPOLY™ as pure polymer slurry will be selected. A new application is venting methane out of capped sanitary landfills using a French drain concept consisting in trenching down to the aquifer and backfiling with coarse gravel after placing a synthetic liner on the outside face with well casings placed at intervals and rising to vent 12 feet above ground surface. Trenching with slurry in unsaturated soils can be tricky and requires serious thought in selecting the geofluid.

We have developed a trenching method using a discontinuous gel mass as the trench support fluid instead of a liquid-phase slurry. This has the benefit of minimizing losses in very open soils and allowing the filter sand or iron filings sand mixes backfill to be placed in the trench without saturating with slurry and remaining dry until ground water saturation occurs. The gel mass is created with PLUG, swollen ahead of time in storage tanks.

Barriers containing migrating plumes of contaminated ground water are of many kinds but generally trenched from 4 to 36 inches wide. The end product must be engineered to provide long term compatibility with the contaminants. The one step construction concept of self-hardening slurry is at home in HAZ MAT where simplicity and worker safety are maximized. With almost universal compatibility with industrial contaminants, IMPERMIX® is the ideal self-hardening slurry that provides ease of preparation, use in the fresh state, very low hydraulic conductivity and substantial strength. These characteristics extend to non-trenched barriers such as the thin vibrated beam wall, jet grouted barriers and Deep Soil Mixed walls. See IMPERMIX® dedicated page for more details.

The passive ground water treatment known as Funnel and Gate requires the use of watertight barrier technology (self-hardening slurry) for the funnel and pervious barrier technology (bio-polymer slurry) for the gate (TALGUAR™, PREMIUM™). The occurrence of such projects is increasing since they offer treatment instead of strict containment.

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TUNNELING

With ever increasing urbanization of humanity, the need to take advantage of the underground space at the same time as the air space has lead to a significant increase in tunneling work under major cities, around the world. Mass transit either for rail transport or automobiles provides major relief of surface congestions: the just completed Central Atery/3rd Harbor Tunnel Boston project is a good example of tunneling by cut and cover and drill and blast. Control of surface runoff water that needs to be treated before being released to the natural streams has created a considerable amount of tunneling work for C.S.O. projects. More population means larger sewers and extensive work is being performed to modernize our wastewater conveyance systems.

Tunneling today can be traditional drill and blast or by tunneling boring machines but always highly mechanized. In soft ground tunneling, when NATM is not desirable or practical, different types of shielded machines are used. Earth Pressure Balance (EPB) machines use the restrained excavated materials to support the bore's face, Slurry Shield machines use liquid earth support to stabilize the face. Some machines are hybrids of the two systems. EPB machines eventually require soil conditioners to help in the control of the spoil extraction process. Slurry shields are more complex and require a comprehensive slurry management program, all spoils being removed by slurry lines to the surface through a solids separation plant and recirculation of the slurry whose characteristics must remain in tight control while being able to face unanticipated ground conditions.

Tunnels that are lined, always require some form of contact grouting. Judicious grout selection can make this work much easier. Unlined tunnels that receive a

service pipe of a smaller diameter which requires to fill the space in between, can be economically flooded with engineered self-hardening slurries that will set slowly without excessive heat, and form a permanent utility encasement of sufficient strength but nevertheless easily re-excavated if necessary in the future.

Access shaft to tunnels call on a wide variety of construction techniques generally making use of a plurality of geofluids. Slurry walls, secant piles either drilled or auger cast, jet grout columns, deep soil mixed columns, steel sheet piles driven or placed in slurry, ground freezing. We have products that assist all these activities.

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TRENCHLESS TECHNOLOGY

WONDER MUD®, PUSHLUBE™: Trenchless Technology has seen a tremendous progress over the last 20years, not only in this country but in many much less developed countries were urbanization is more acute that in our spacious land. This is a multi-disciplinary industry and we have followed certain sectors with more interest than others. A main area of interest is the various forms of pipe jacking: auger boring, microtunneling with non-man-entry machines, mini-tunneling with slurry shield or Earth Pressure Balance (EPB) shield. Aside from boring a clean hole on target without undermining the ground, the second concern is controlling the friction forces along the jacked pipe not to run short of jacking capacity before the end of the drive. Our experience with mineral muds and polymer slurries has helped many contractors staying out of trouble or getting out of trouble. We formulate lubricating slurries on a case by case basis, generally combining a clay with a polymer and chemical additives according to soil, ground water and type of pipe used. WONDER MUD® and bentonite is the basic formulation for granular soils. The primary criterion is as low a filtrate loss possible to confine the slurry within the annulus. In swelling shale, a concentrated polymer cream like PUSHLUBE™ will prevent the shale from absorbing water, hence from swelling. The same PUSHLUBE™ has been used successfully in relining work of old gas lines with swaged HDPE pipe.

GEOGREASE™:

When the ground is very coarse and loose gravels may bridge and bind and eventually damage the pipes at a joint, especially clay or mortar resin types, a more pasty lubricant is recommended and GEOGREASE™ formulations may be used. Depending on the drive lengths, larger diameter lubrication plumbing may be in order to limit internal pumping pressures.

SLOWGROUT®:
When engineers contemplate shallow drives and consider the potential for secondary settlements as a result of the delayed decompression of the annulus, they specify a post drive grouting phase which is typically ineffective and expensive. As a compromise, we have developed a low filtrate loss lubricating slurry that is a highly retarded self-hardening slurry that fills the annulus and ultimately sets into a solid of sufficient strength to match the surrounding ground. SLOWGROUT® has been accepted by Owners as an enhanced quality assurance benefit.

IMPERMIX®:
In many instances, the jacked pipe is only a protective casing for the product pipe or duct bank. The space between the two must be filled with a volumetrically stable, low-hydration-heat grout. ***Cellular concrete*** or more specifically ***foam grout*** is an option but with some limitations regarding placement length, diameter limitation and cost. A successful solution for self-performing contractors is to flood the annular space with our IMPERMIX® self-hardening slurry through bulkheads at each end of the drive with risers to the surface. The mixer on the surface is the only equipment required, the mixer centrifugal pump dispensing the backfill slurry in the line, from the lower end. Typically, a 2,000 LF drive is not a length limitation, this covers almost all jacked pipe drives. Given IMPERMIX's long setting time, the work can be carried out over a number of days, without or with interruptions. The cost per CY in place is a fraction of any other method. The end product is a durable firm non-shrink, chemically stable, homogenous lightweight grout encasement.

THERMGROUT™:
In the electric power transmission business, the amount of power that can be transmitted through an underground cable varies with the ability of the heat generated according to Joule's law
to dissipate into the ground. A factor called ***thermal resistivity*** defines the characteristics of a solid to transfer radiant heat energy. The higher the material's density, the lower the thermal resistivity coefficient. Formulating a highly sanded grout capable of being placed perfectly in a fairly small annular space over a very long distance without detrimental hydration heat susceptible of damaging the plastic ducts was the challenge. Eventually, we formulated a 130 pcf grout (16% moisture) showing a thermal resistivity of 53 C-cm/watt fully saturated and 92 C-cm/sec in near dry conditions, which are exceptionally good numbers while the placement is rendered easy by very long setting times, good plasticity and no measurable heat of hydration. Although the project for which this in house research was cancelled, a new product with a good value is now available to the power-transmission Industry. Welcome to THERMGROUT™. A similar application for THERMGROUT™ is the backfilling of loops in ***geothermal wells***, a most energy efficient way of heating and cooling homes and small commercial buildings.

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A deepening of the navigation channel in the Chelsea River in East Boston caused the WMRA to rquire a new siphon and to procure the installation of an 1,100 feet long 48"ductile iron pressure water pipe inside a 72" Permaloc® casing jacked by Microtunneling between slurry wall shafts with a floor 90 feet below ground surface. The alignment started and finished in a silty till while under the river bed a thick gravel layer could put the river in communication with the bore.
After difficulties of all kinds the contractor faced the prospect of having to breakthrough the reception shaft slurry wall without a seal, the precise location of the break through being too vague to have one installed. The problem was the 85 feet of head from the Chelsea River having access to the bore annular space representing the risk of channeling and flooding the reception shaft. Being called in by the contractor, we proposed and implemented a solution that created and maintained an active filter cake plug, 100 feet back from the reception shaft. The self-hardening slurry was a modified IMPERMIX® tuned not to set for 4 days; while the rest of the pipe was lubricated with a WONDER MUD®/bentonite mix, the grout was pumped through the lubrication express line to the head. Constant slow pumping provided counter pressure and the resulting cake formed an effective packer. As seen in the picture, the annulus did not allow any water in during and after breakthrough. The process was continued until the machine was out of the shaft and the Permaloc® pipe pushed to its final location at which point the gap between pipe and concrete wall was plugged with hydraulic cement. This "first" was successful thanks to the practice of the Observation Method, where soil conditions, grout formulations, equipment selection and controls are evaluated in real time by an experienced practitioner. Incidentally, the space between the water pipe and the Permaloc® pipe was eventually filled with an

IMPERMIX® formulation from the launch shaft in a single phase.

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