W H I T E P A P E R

Ultrafine Pozzolanic Cementitious Grout

PERFORMANCE GENIUS x 2

EXECUTIVE SUMMARY

SITUATION

Standard Cementitious Grouts have two main limitations: One, the inability to effectively penetrate rock microfractures or dense, silty sand soils, and two, poor performance due to the deleterious curing problems inherent in standard concrete.

PROBLEM 1

Microfractures allow water in or through, and, in the case of underground waste confinement facilities, radionuclides and other toxins out. If the rock fractures are too small, effective penetration and seal is not possible using a standard cementitious grout. As for necessary performance, standard cementitious grouts are simply unacceptable for many applications in terms of hydraulic permeation resistance, compressive strength, and effective lifespan.

PROBLEM 2

Massive structures need to be fixed into stable soil. If weak soils needs to be stabilized, permeation grouting can often be the answer…unless the soil is too dense for Ordinary Portland Cement (OPC) grouts to permeate to the proper depth and saturation point.

SOLUTION

Inject an ultrafine, pozzolanically-charged cementitious grout.

RESULT

Mines, storage caverns, and transportation tunnels remain dry behind a protective grout curtain. Tunnels are efficiently driven without fighting costly water infiltration. Earthen dam cores and critical embankments are solidified. Concrete dams and the surrounding bedrock aprons are sealed tight. Weak soils are strengthened to carry heavy structural loads and mitigate liquefaction. Transuranic wastes are sealed away for tens of thousands of years.

US GROUT

ANCIENT TECHNOLOGY:

A cementitious grout super-charged with natural pumice pozzolan successfully overcomes the degradation and durability concerns of non-pozzolanic grouts.

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MODERN TECHNOLOGY:

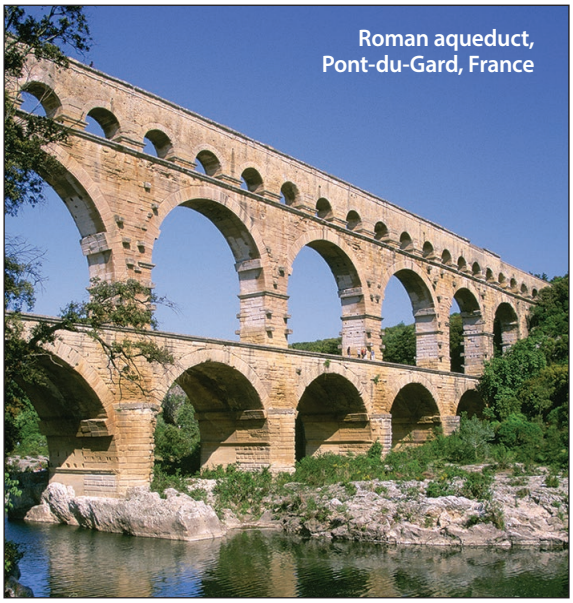
Processed to an ultrafine grade, grout will flow where other cementitious grouts can't: successfully penetrating microfractures as small as 3 microns for several meters.

WHEN YOU HAVE THE resources of the United States government, and a product suitable to meet a critical energy need is not available, you simply tap one of your genius national laboratories to develop that product. That was the case with the U.S. Department of Energy.

Deep under the New Mexican desert, 2,154 feet below the surface located in a salt bed approximately 2,000 feet thick, the U.S. Department of Energy carved out the Waste Isolation Pilot Plant (WIPP)—a multi-chambered repository designed as a final resting place for transuranic waste generated by the nation's nuclear energy activities.

The weight of the overlying rock subjects the underground storage chamber openings to closure force. This force, equal in all directions, is roughly one pound per square inch per foot of depth. Stress redistribution around the openings results in microfracturing of the salt, which ultimately extends into the enclosing salt as much as a meter and a half. This microfractured rock salt, called the "Disturbed Rock Zone," would allow brine and radionuclides to bypass any seal placed in the tunnels.

An ultrafine cement-based grout was required to effectively seal these extremely small fractures (often as small as 6 microns). To enter such tiny fractures, the grout particles had to be even smaller than the fracture width. Commercially available microfine grouts were analyzed by Sandia National Laboratories (the scientific advisor for the Waste Isolation Pilot Plant) and found to be unsuitable. Sandia then proceeded to develop a new grout which, after extensive laboratory development and testing, was successfully tested underground at the WIPP. The permeability of the DRZ was lowered as much as 1,000 times, and the grout was then approved for use at the WIPP.



Roman aqueduct, Pont-du-Gard, France

Pumice has long been recognized as the original natural pozzolan.

Naturally calcined pumice pozzolan

Sandia National Laboratories obtained two patents on this grout and transferred the process, under license, to U.S.Grout, LLC, to make the ultrafine pozzolanic grout available worldwide.

Genius Times Two

The result of a unique combination of ultrafine particle technology, natural pumice pozzolan, and Portland Cement, the chart-topping performance and indefinite lifespan of this ultrafine pozzolanic grout rests on two critical points: The ultrafine particle size (average of 3μ) and the pozzolanic reaction that occurs between the amorphous aluminum silicate (pumice) and Portland cement.

The result is a non-hazardous cementitious grout that has effective application for sealing microfractures in rock, "squeeze" cementing in the petroleum industry, repairing concrete structures, improving the bearing capacity of weak soils and limiting the migration of contaminants in environmental remediation.

Practical Proof from the Romans

Pumice is the natural, sustainable pozzolan the Romans so successfully used in their millennia-defying concrete mixtures. They produced a strong, densified, essentially impermeable concrete resistant to chemical attack, and the evidences of the effectiveness of that pozzolanic charge still stand today—aqueducts, temples, stadiums, cisterns—some 2000 years later. Modern science has detailed the pozzolanic process by which pumice acts to overcome the deleterious effects that take place as standard concrete cures…the same damaging effects that plague the performance of cementitious grouts.

Modern Scientific Analysis

In a nutshell, studies show that only about 75% of the cement powder is converted to Calcium Silicate Hydrate (CSH), the binder that glues concrete together. Most of the remaining 25% is converted to Calcium Hydroxide (CH), a by-product of the hydration reaction between water and cement—a by-product that has a tendency to create a host of problems that have an adverse effect on long-term performance. Adding a high-purity, ultrafine natural pumice pozzolan to the grout formulation mitigates or completely eliminates the CH problem. In fact, the pumice pozzolan turns the CH into additional CSH, densifying the concrete and making it nearly impermeable. And, as Sandia National Labratories discovered, the pozzolanic effect is greatly enhanced by the increased surface area of the ultrafine pumice particles.

Sandia also sought and received testing support and a confirming peer review of their formulation and research findings from the Canadian Atomic Energy Commission.

Ultrafine Particle Technology

The process to refine the Portland cement, the pozzolanic pumice, and the super plasticizer down to an ultrafine size resulted in one of the two US Patents issued for the grout. Such an ultrafine particle size is crucial to the ability of the grout to deeply penetrate and effectively seal microfractures and pass through and completely grout silty sandy soils. US Grout Ultrafine contains particles of which approximately 90% are less than 8µ in diameter, with average particle size approximately 3µ in diameter. (Sizes determined by the Micro Meretics company, using their sedigraph.) Standard OPC grouts have an average particle size of 15µ.

Standard OPC grouts simply cannot penetrate microfractures or dense soils.

The Wrong Grout Can't Be "Made Right"

The fact is, it is particle size and rheology, not viscosity, that determines a grout's ability to penetrate extremely small openings. Tweaking the viscosity of a standard cementitious grout to amp injectability results in lower compressive strength and water bleed-off during crystallization, perforating the grout seal with porous, interconnected wormholes and resulting in an undesirable density matrix. Those problems compound the already inherent deleterious effects of standard cementitious grout mix designs.

A Superior Grout

Ask an engineer to list the characteristics of a superior grout, and you would probably hear the following: resistance to chemical attack, wide range of water-to-cement ratios, little or no bleed, generous injectability window, adjustable rheology and set time, impressive strength, extremely low hydraulic conductivity, volume stability, negligible contraction cracking from heat of hydration. Many would also add things like a ready-to-mix-and-pump product, the availability of custom blends, a stable, competitively-priced supply, stringent quality-controlled manufacturing to insure uniformity, expert technical support, an international distribution network, and a safe-to-use, non-hazardous product.

The US Grout Ultrafine and Microfine products deliver all of the above. Proven in successful use in projects around the world—including the DOE WIPP site and the

Microfractures in the rock at the Waste Isolation Pilot Plant repository successfully filled with US Grout Ultrafine

Strategic Petroleum Reserve, an intake tunnel beneath Lake Mead, an extension of the Hollywood Metro Tunnel—US Grout products are effective and safe to use.

Specifically, US Grout Ultrafine:

- has successfully penetrated microfractures as small as 6 microns up to distances of several meters.
- can pass through and completely grout silty sand with a hydraulic conductivity as low as 5 x 10-2 centimeters/second. (The hydraulic conductivity of the grouted mass was reduced to 1 x 10-7 centimeters/second.)
- is densely welded by pozzolanic action: there is essentially no permeability. Average diameter of disconnected grout pores is one micron (evidenced by mercury porosimetry and extremely low hydraulic conductivity). Grout continues to gain strength and density for years. Grout able to self-mend fractures during curing.
- is volume stable at less than 0.1% shrinkage.

Expert Support

Avanti International (www.avantigrout.com) provides the customer service, objective professional advice, material estimates, and the caliber of world-class technical support that comes only from 35 years of geotechnical experience.

—by Brian Jeppsen, VP R&D at US Grout, LLC of Malad City, Idaho.