Pressure Grouting of Concrete Pavements

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A brief overview of current practice in concrete pavement jacking and in grout subsealing of concrete pavements is presented. One of the major causes of concrete pavement failure is the loss of support caused by the pumping action beneath the pavement. Early detection of this condition and prompt filling of the voids created will prevent early deterioration of the pavement. Topics discussed are materials and their necessary physical properties, equipment requirements, and methods and the current state of the art.

The preservation and extension of the useful life of concrete pavements is becoming of great importance today. Although little understood or used, the techniques of cement grout subsealing and concrete pavement jacking offer proven help to achieve longer life and better rideability of concrete pavements.

One of the major causes of pavement failure is the loss of support caused by the pumping action of the pavement. Early detection of this condition and prompt filling of the voids created will stop premature deterioration of the pavement.

When pavement and bridge-approach settlements occur, they can be raised back to their correct grade by the addition of pumped grout to the void caused by the pumping action of the pavement. The process may be repeated until the pavement has been brought to its correct grade. In order to estimate the quantity of grout required to jack a pavement settlement to grade, the approximate volume of the visible settlement must be computed and then 20–25 percent added for voids under the pavement. The same procedure is used for bridge-approach panels; 50–60 percent is added for the large voids that generally occur. Additional adjustments must be made for any other voids such as inadequate backfill at culverts.

The original jacking slurries were simply a silty loam soil that was pumped under the pavement. It was soon discovered that these early mud slurries were not very satisfactory. It took many days for the water to drain out or evaporate from the slurries, and they were constantly subject to erosion by water. Some additional stability was given to these mud grouts by the addition of small percentages of cement, but the problems still persisted. Attempts were then made to do the jacking by using better-controlled materials such as sand-and-cement grouts. These grouts presented additional problems in that the angularity of the particles generally found in most sands made it difficult for it to flow into narrow spaces, and the sand frequently went out of suspension under pressure. Bentonite and other materials were added in an attempt to keep the sand in suspension; the result was lower grout strength. Cement-and-pozzolan slurries have a definite advantage over other materials, and their use is highly recommended.

The history of pozzolanic materials dates back to the days of ancient Rome, but the use of these materials in grout slurries is a fairly recent development. The family of pozzolans includes natural
pozzolans such as volcanic ash, diatomaceous earth, and artificial pozzolans (fly ash) produced by the combustion of coal. These materials are classified under ASTM C618. The use and performance of these materials in grout slurries is not to be confused with their use as a cement replacement in structural concrete.

Several properties of pozzolans are responsible for improved pavement-jacking characteristics. These include particle size and shape, gradation, and pozzolanic activity.

The fineness of the pozzolan particles and their predominantly spherical shape enable grout-incorporating pozzolans to be more easily pumped than those that contain only cement or cement and sand or other mineral fillers (Figures 1 and 2). The spherical shape results in a ball-bearing effect, which enhances the flow properties of the grout. Partial replacement of either cement or sand by using pozzolans improves permeability and injection penetration by keeping the grout in suspension and thus reducing sedimentation.

During the jacking process, as the pavement is being lifted new voids are obviously being created that must be promptly filled in order to maintain a uniform hydraulic pressure on all parts of the slab. In addition, permanent support is required to protect the pavement from excessive flexure and breaking. The pozzolanic grouts have the unique ability to fulfill these needs.

Although pozzolan particles are mainly the size of silt, they also contain a small but effective amount of clay-sized particles. These clay-sized particles provide sufficient grading to reduce segregation during pumping and injection; less voids and increased durability result.

The pozzolanic characteristics of these materials in combination with lime produce a stable cementitious material. Since the hydration of cement produces lime, additional cementation results when pozzolans are mixed with cement. This reaction produces a more-effective bond than that developed between sand and cements in weak cement grouts.

The sole purpose of the grout is to transfer the vehicular wheel loads from the rigid pavement to the underlying base or subgrade. The engineering properties that the grout must possess are incompressibility, nonsolubility, and nonerodibility. The grout must be confined in situ and cannot be displaced laterally after it has lost fluidity. It does not require flexural strength. The actual in-place yield of these grouts will be as much as 10 percent greater than that of other grouts when dry volume is compared, because of the fine particle size. This creates an additional economy in their use.

MIX DESIGN

A typical mix design for pavement jacking is as follows: one part (by volume) of portland cement type 1 or type 2, three parts (by volume) of pozzolan (natural or artificial), and water to achieve the required fluidity. Type 3 (high early) cement may be specified if there is a need for early strength.

Because of variations in pozzolans from differing sources, the contractor should be required to supply test reports from a laboratory that has competency in this field that show chemical and physical properties of the material suggested for use as well as compressive-strength tests (one-day, three-day, seven-day), flow-cone times, shrinkage and expansion observed, and time of initial set.

The pozzolans should meet the requirements of ASTM C618. Should the material not meet these requirements, the contractor may be allowed through testing to show that the proposed pozzolan will meet or exceed the qualities needed for the project.

Some of the western (class-C) ashes are sufficiently reactive that reduction or elimination of the cement component may be considered.

The consistency of these slurries is not measurable by using conventional slump-cone testing techniques. Water content is determined by the flow-cone method (U.S. Army Corps of Engineers, CRD-C 79-77), and for pavement-jacking slurries it should
be in the range of 16-26 s. A very fluid mix (flow-cone range 9-15 s) may be used for the first few minutes of the jacking operation if needed to penetrate very dense materials and permit pumping of the jacking slurry. These ranges will allow for differing field conditions, and the flow-cone tests should be made twice a day. Even with high water content, this material will show little or no bleed water. The purpose of slab jacking is to replace low subgrade support for the overlying rigid pavement. The strength required is limited to that of the minimum subgrade strength that underlies the pavement.

The determination of initial set time of the grout in the laboratory tests is useful in comparing various grouts. Cement-and-pozzolan grouts at normal temperatures will lose their fluidity within approximately 20 min after placement. Since they are virtually always in a totally confined environment, they are therefore capable of supporting substantial loads long before the set time of one and one-half to two hours that would be indicated by the generally accepted testing methods. Reapplication of vehicular traffic immediately after the completion of jacking has shown no pumping or displacement of the in situ grout.

Various additives may be specified to achieve required goals. Laboratory tests show widely differing reactions from the same additive when it is combined with pozzolans from different sources, and various brands of similar admixtures will react differently when combined with the same pozzolan. Each must be tested and evaluated in the laboratory prior to final approval by the contracting agency. They may consist of water-reducing agents, fluidifiers, superplasticizers, expanding agents to offset the shrinkage sometimes found with volcanic ashes, calcium chloride to accelerate set, etc.

**EQUIPMENT**

As a minimum, the following equipment will be needed:

1. A grout plant that has the ability to accurately measure and batch the dry materials and water. The dry materials should be packaged in uniform-volume sacks or measured by weight if they are in bulk. Water should be metered or weighed. To achieve a true colloidal mix that will stay in suspension and resist dilution by free water, it is necessary to use a high-speed colloidal mixer that operates in a range of 800-2000 rpm. Placement of the grout is done by a positive-displacement cement-injection pump.

2. A skimmer that has a pressure pump and adequate capacity for the day's production.

3. An air compressor and rock drills or a mechanical hole-drilling device capable of drilling holes of the required number and diameter (usually 2 in).

4. Necessary hoses, valving, and valve manifolds to control pressure and volume; pressure gauges and gauge protectors; expanding packers for the grout injection; wood plugs; hose-washing tools; drill steel and bits; material transport and handling equipment; and service trucks.

5. Traffic-control equipment as required.

**TECHNIQUES**

Hole-drilling patterns for pavement jacking should be determined in the field by the contractor based on conditions such as location of joints, cracks, and subgrade conditions. Extra holes may be required during the progress of the jacking to apply additional pressure in a particular area. Because the hole drilling is determined by the contractor, it should not be a paid item and will be considered incidental to the jacking. Holes may be washed by using water or blown by using air to create a small cavity from which the grout slurry can then spread. The injection holes should be drilled through treated base so this material may be lifted with the pavement.

The jacking is then begun by the injection of the grout slurry. Pressure should be observed and will be of the order of 75-200 psi. In some conditions, pressures as high as 300 psi may be required for short periods. When the pavement structure is bonded to the subgrade, grade pressure increases to 600 psi may be tolerated. Pressures this high or higher cannot be sustained without damage to the pavement. At bridge-approach panels, care must be exercised to prevent lifting the slab off the seat.

String lines with blocks should be continually monitored for pavement movement. Vertical offsets between panels and lanes should not be tolerated nor should overjacking. Final grade on jointed pavements and bridge-approach panels should be 0.03 ft plus or minus from the string line and on continuously reinforced pavements it should be 0.02 ft plus or minus from the string line. In field conditions most of the work can usually be brought to within the thickness of the string. Any lesser tolerances will exhibit poor riding qualities.

On occasion, difficult situations may arise that need special consideration. In the case of bridge panels that are down 5 in or more, the tolerances should be increased to 0.04 ft. This is because a panel so far down is usually wedged or bound. Sawing full depth at the joints will generally relieve this problem, in which case extra payment or a bid item for sawing should be set up.

Cracks in the pavement that emanate from the drill holes are an indication of overpressure and poor grouting techniques. Consideration should be given to the imposition of penalties in the event of this occurrence.

Some small quantities of grout will be wasted on the pavement from the insertion and removal of packers and leaks at panel joints and along the edge joints. Uncontrolled flow and waste that go into the ditches should not be paid for.

**WORK BY OTHERS**

Work done by others may include asphalt shoulder adjustments, removal of overlays, joint and spall repairs, etc., or they may be included as separate bid items in the contract.

**MEASUREMENT AND PAYMENT**

A single unit of measurement (cubic feet [dry measure] of grout placed into or under the pavement structure) can be used, or it may be expanded into items that cover mobilization and traffic control. The basic grout item will include all labor, materials, and equipment; incidental items; additives; hole drilling; etc. This will simplify field management of the project. To bid this work on a square-yard basis is not advisable, since the contractor will then hedge the bid because of unknown grout volume.

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