Report and Review of a Major Slabjacking Case History

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A review is presented of a major case history of lifting and leveling portland cement concrete highway slabs by injection of a fluid cement/pozzolan material between the subgrade and the slab. The paper includes history and background data as well as current practices, advantages, disadvantages, and specific procedures. Grout materials, mixtures, equipment, and lifting controls are discussed.

U.S. Interstate highways constructed under the 1956 Federal-Aid Highway Act are aging to the extent that general maintenance is no longer acceptable for their serviceability. Major innovative rehabilitation methods are required to restore the wearing surfaces, and, in many cases, the stability of the subgrades. The intent of this paper is to illustrate what is being done with the problem of substrate stability. Although not as visually evident as the resurfacing, it will play a major role in the longevity of the overlayment.

For many years it has been standard practice to relevel highway settlements and dips by merely adjusting the thickness of the resurfacing material, only to have it prematurely spall and break up. A soft substrate or voids below the original slabs perpetuate the problem under the loading and unloading effect of traffic. This condition, known as pumping, can be effectively eliminated by a system known as slabjacking *(1)*.

The modern-day process of slabjacking evolved mainly from work that was performed during the past 50 years under the term "mudjacking." While technically both terms are synonymous, the main reasons for the change in terminology are as follows: In the mid-1920s a machine was invented for the specific purpose of mixing soil-cement in a slurry and pumping it to fill voids. By over-pumping, pressure was applied, resulting in the lifting of a structural element. The manufacturer named this machine the Mudjack. Because of its widespread use over many years, the entire process adopted the term of mudjacking. Slabjacking more correctly describes the effect of the process on the component. As the technology improved, mudjacking was no longer limited to the use of soil-cements alone, as the following discussion will demonstrate.

In June of 1981 the Wyoming State Highway Department solicited bids for Statewide Slabjacking Project SMP-7892. It was to involve the lifting and re-leveling of concrete bridge approach slabs, highway dips caused by improper compaction over underground structures, and filling of voided areas behind sloped concrete paving around bridge abutments. There were more than 167 separate locations listed, from Green River to Gillette, Wyoming, on state and Interstate highways 373, 80, 25, and 90.

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PROJECT DESCRIPTION

The work was to consist of raising concrete pavement slabs by drilling 2-in. (50-mm) diameter holes and pumping grout into the holes under sufficient pressure to bring the slabs to the line grades established by the engineer. This differs from a similar process known as slab undersealing where lifting of the slab is not a consideration. The slabjacking process requires additional operator expertise, time, and materials. The operator must work with the structural capacity of the slab so that it is raised without cracking or breaking.

Some advantages of the slabjacking process are:

1. By lifting the slab or structural member close to its original elevation, the stresses that have built up are relieved, thereby restoring its structural integrity.
2. The lifting process allows grout to travel and seek out additional voids that might otherwise be missed, resulting in a more stabile component.
3. It requires less overlayment, or restores the ride over a section that is not scheduled for resurfacing.

Equipment Specifications

The contractor was to furnish a grout plant, which consisted of an injection pump and a high-speed colloidal mixer. The colloidal mixer had to operate at a minimum speed of 1,200 RPM and was to have a rotor operating in close proximity to a stator. This creates a high shearing action and subsequent pressure to make a homogeneous grout mixture. A water meter or scale was required to record the day's water consumption.

Materials Specifications

The standard mix design for slabjacking on project SMP-7892 was to meet minimum and maximum cone effluent efflux times of 10 to 15 sec (Corps of Engineer's CRD-C 611-80), and attain a minimum 7-day strength of 300 psi (2.1 MPa) proportioned as follows:

1 part (by volume) portland cement type I or II, AASHTO M85
3 parts (by volume) pozzolan (fly ash) type C, ASTM C618
2.25 parts (by volume) water

The Wyoming State Highway Department has had experience with several alternative grout designs. including soil-cements, hot asphalts, neat-cements, and so forth, and considered these before choosing the design listed. Reasons for their choice for this project were fivefold:

1. Assured uniformity of materials,
2. Proven ability during underesealing operations to taper out and fill minute voids,

3. Non-shrink characteristics of the design,
4. Strength considerations,
5. The economics and availability of the materials *(2)*.

Grout Holes

The contractor spaced the holes according to the particular site and the manner in which the slab was raised or tilted, but generally on a 4 ft (1.22 m) grid pattern. The holes were 2 in. (51 mm) in diameter and drilled by a pneumatic percussion method. Upon completion of grouting, each hole was cleaned and patched with a non-shrink 4,000 psi (28 MPa) grout.

Method of Measurement

The quantity of slabjacking completed was to be measured by the cubic foot (m^3) of dry material only—portland cement and pozzolan—used in slabjacking.

Basis of Payment

The accepted quantity of dry material used for slabjacking was paid for at an in place per ft^3 (m^3) unit price. The project was estimated at 21,900 ft^3 (620 m^3). The total project, however, required 24,600 ft^3 (697 m^3) because of site and change orders required by the state.

DISCUSSION OF THE PROJECT

Before project No. SMP-7892 was initiated, to this author's knowledge, the combination of portland cement and pozzolan was used extensively for undersealing of concrete pavements but never for the lifting and releveling of slabs which had experienced settlements of 4 in. (102 mm) or more. The fact that the grout mix was to meet a maximum standard cone effluent efflux test of 15 sec meant working with a material that is fluid and subject to excessive flow. There were containment problems at adjacent slab edges, where the concrete slab met the outside bituminous pavement shoulder, and where there was no access to tamp a containment bank.

Control of grout flow and hydrostatic pressures on underground adjacent structures can become an important application consideration. For this reason correspondence and discussions took place between the highway department engineering staff and the contractors before bid opening. The highway department decided to maintain their original specifications.

While the contractor's operating technicians on this project had more than 45 combined years of experience using other slabjacking materials, the use of cement and pozzolan/fly ash required approximately one week of frustrating experience before they became proficient at controlling grout losses around bridge abutments, escape points, and so on. The art of controlling slab lifts also required some experimentation with flow rates, grout consistency, and pressures that were different from anything with which they were familiar.

However, once they learned the characteristics of the material they found that grout loss cutoff and slab lifting could be accomplished with as much accuracy as with any material previously used. The crews reported some of the following observations:

1. The dust from the combined materials causes skin burning and rashes if the slurry is allowed to make contact with the skin.
2. By prepacking known escape points with the dry materials very little if any grout loss was experienced.
3. Hydrostatic pressures against underground structures were less, due to the fast set time of this material resulting in less wait time between lifts when filling large voids against or near them.
4. This grout design often needed some additional material to accomplish the same results as other materials due to greater underslab coverage and because some previous subgrade materials absorbed the grout.

Slabjacking Operations

The project was awarded to the bidder having the lowest cubic foot (m^3) unit cost, with a notice to proceed being issued July 16, 1981. The contractor began work September 5, 1981, shut down for the winter months between mid-November 1981, and April 1982, and completed the project by August 1982. Slabjacking operations were terminated when the ground was frozen or the ambient temperature fell below 40°F (4.4°C).

The contractor pumped in a pattern and with amounts required to raise the pavement to within 0.03 ft (9 mm) from a stringline or established grade. After a slab was raised to its desired elevation, every hole was pumped one more time to ensure that all voids were filled and that the slab had total support. Slabs were not allowed to be raised more than 0.25 in. (6 mm) while pumping in any one hole, nor was any part of a slab allowed to lead another part of an adjacent slab in order to avoid cracking.

Equipment Assessment

The contractor chose to modify and use equipment that would facilitate the bulk handling of materials as opposed to the standard method of using bags (Figure 1). This required the following major equipment list:

1. A modified Daffin concrete mobile used as a volumetrically calibrated batch plant. It had a loaded capacity of 324 ft^3 (9.17 m^3) of bulk materials with a 300-gal (1136-L) water tank, all mounted on a tandem truck.
2. A custom-built pumping trailer consisting of a 7 ft^3 (0.20 m^3) agitating tank, a high-speed colloidal mixing unit, and a 6-in. (152-mm) cavity advancing Moyno pump.
3. Two auger feed bulk tankers, used to tender the concrete mobile with pozzolan and cement materials.

FIGURE 1 Grout plant set up for bulk handling of materials.

4. A truck-mounted auxiliary 1,000-gal (3.785-L) water tank.
5. A 175 ft^3/min (4.95 m^3/min) compressor.
6. Several 60-lb (27-kg) sinker drills with drill steels and bits.
7. Required traffic control equipment including two trailer-mounted sequentially lighted chevrons.

With current technological advances, it would be inappropriate to indicate that this equipment is the only way to set up for this type of operation. However, this project covered four highway districts involving seven different district construction engineers and the consensus was that this equipment best fulfilled requirements for the project specifications.

PROJECT REVIEW

Due to temperature constraints the project was performed over three seasons, fall of 1981 and spring and summer of 1982. As a result one weather-related factor surfaced. The contractor's operating technicians learned at the start of the project that the set time of the designed mix was directly affected by temperature. For example, as the ambient temperature rose to 80°F (27°C) or more, a grout mix with an initial efflux of 10 sec would set hard in approximately 5 min. However, when the ambient temperature dropped to 50°F (10°C) or less, the same grout mix would begin to stiffen slowly at 20 min or more. This directly affected the slabjacking process in several ways.

High temperature and quick set have the desired characteristic of a fast cutoff, which limits the grout loss at slab edges or other areas of escape. It became apparent on this project that the operating engineer could begin pumping at the lowest point in the slab, and by the time the grout spread out and began oozing from escape points it would set and cut itself off. This happened when the initial fluid mix of the material was pumped at rates of up to 5 ft^3 (0.14 m^3) per min.

In many cases this allowed the operator to lift an entire slab near to its required elevation from one or two holes. Complete support coverage was indicated by the escape of grout at adjacent holes and edges. Subsequently, the operator merely pumped the surrounding holes with minimum grout takes, resulting in less lifting stress to the slab than pumping hole to hole and lifting at different points. This was evidenced by the fact that less cracking or breaking of slabs occurred than on previous occasions when the contractor had used soil-cement materials.

The set time of some of the material was retarded by chemical additives. In the interest of limiting grout losses, however, the district engineers soon asked the contractor not to use them.

The problems encountered with the fast-setting grout were frustrating but not insurmountable. The operators' experience and expertise are always significant contributing factors in the success of a slabjacking project. If there was to be a delay in the grouting application the operators learned how to anticipate the material's flash set time. The material was discharged into waste areas before the hoses and equipment were locked up. For grout consistency changes a circulating process was accomplished in two ways:

1. When slabjacking in close proximity to the grout plant and pump, one hose was used for proper grout delivery into the holes or recirculating back into the agitating tank for additional mixing.
2. When working with longer pumping distances, a tee was inserted at the injection point with a return line. The grouting technician always kept a portion of the grout flowing back to the grout plant to keep the return line from locking up. For this reason the operators on this project preferred to use, and were much more efficient with, the one line system.

Cooler temperatures and longer set times resulted in delays because of containment and grout-control problems. These were overcome in two ways:

1. The grouting technician moved around the slab using more drilled holes for lifting and filling purposes.
2. Water in the grout mix was reduced resulting in cone test effluxes above specification (18 to 21 sec) to reduce its flowing characteristics. This resulted in cooler temperature jelling set times of approximately 5 min.

Typical grouting operations are shown in Figure 2.

Safety

The most dangerous aspect of this project was that the grouting technicians were working close to high-speed traffic (Figure 3). Despite repeated attempts by the traffic controllers to slow traffic to the posted 40 mph (64 km/hr) the speed of a passing vehicle in the adjacent lane averaged 57 mph (92 km/hr). This meant that the grouting technicians and engineers had to be alert at all times, especially when working a row of holes along the center dividing line. Semitrailer trucks passing at high speeds would cause a rush of air followed by a suction effect that threatened to pull workers under the truck unless they were

FIGURE 2 Typical grouting operations.

FIGURE 3 Wide loads and high-speed trucks are a constant safety hazard.

secured by tie lines attached to the grouting equipment or were holding securely to the grout injection nozzle.

Due to the many varied locations of this project, it was not feasible to consider installing median barriers for protection; therefore, requesting a patrol car to work with the traffic controllers became the most effective way of holding speeds to a minimum.

CONCLUSIONS

Despite the problems encountered using a cement, pozzolan/fly ash material for slabjacking, and the contractor's initial concerns about controlling lifts with a fluid, these materials should be considered for future uses for the following reasons:

1. The material shows uniformity.
2. Shrinkage is lessened.
3. The material exhibits greater strength than other slabjacking materials.
4. The material can be used to seek out small voids and penetrate some yielding subgrade materials.
5. It provides more support while lifting or tilting slabs, resulting in less cracking or breaking.
6. The fast set time of the grout mix can be a major asset to the slabjacking process although it requires experienced operators.
7. A maximum cone efflux test of 21 sec is required to perform slabjacking with these materials in cool temperatures.

REFERENCES

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