WISCONSIN DEPARTMENT OF TRANSPORTATION

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BRIEF

Jetting and Flooding of Granular Backfill Materials

Granular backfill materials on highway projects are often compacted by mechanical methods. This requires the contractor to place backfill material into loose lifts of varying thickness and use compaction equipment to reduce air voids and increase material density until the required compaction is achieved. Under the appropriate conditions, alternative methods to traditional compaction are hydraulic jetting or flooding. Jetting inserts a probe into the backfill layer and emits a high pressure jet of water, saturating the material from the bottom-up. Flooding, or compaction by drainage, completely saturates an area and material from the top of the fill downward. Slurry flooding involves a mixer "pouring" a slurry mix of granular backfill material and water as the fill layer and allowing it to drain. All three hydraulic methods use residual suction upon drainage to increase the effective stress and move grains into a more compact arrangement.

What is the problem?

Compaction operations discussed in Section 207 of WisDOT Standard Specifications are difficult near or around bridge abutments and sewer lines or utility repairs. There are two critical problems around these structures: poor drainage leading to erosion and inadequate compaction due to confined spaces. The use of jetting or flooding could provide an alternative that may be faster and more economical than traditional methods of mechanically compacting backfill materials. However, methodologies, materials and performance must be properly understood and specified before jetting and flooding compaction methods are adopted.

Research objective

The objective of this study is to provide WisDOT with needed data and analysis to help evaluate the use of jetting and flooding. Necessary specifications for implementing compaction by jetting and flooding will be provided if these methods have proven to be effective.

Methodology

After a thorough literature review, researchers conducted laboratory and field tests.

Laboratory tests: The laboratory tests include standard tests to determine particle size distribution, particle shape, specific gravity, minimum and maximum void ratio, and Proctor compaction curves of representative backfill materials. Hydraulic jetting and flooding compaction methods were also tested in a liquefaction tank and in large plastic containers.

Field tests: Drainage flooding and slurry flooding compaction methods were investigated in the field at the Highway 51 project site in DeForest. Jetting compaction method was investigated in the field at the Greenfield Avenue project site, west of Milwaukee.

A nuclear density gauge, soil stiffness gauge, and dynamic cone penetrometer (DCP) were used to assess the quality of compaction in the field.

Jetting Operation (a)

Slurry Flooding (b)

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Results

- Laboratory tests discovered a number of things that control the performance of jetting in compaction operations. They include: spacing of jetting events, flow rate, layer thickness, drainage capacity of the system, and the rate of insertion and removal of the instrument. Jetting has been implemented successfully in the field, even under poor drainage conditions, by recreating flooded deposition conditions. Jetting introduces water between grains, possibly creating a viscous mixture with low shear strength after jetting materials with low drainage capacity, such as silty sand. Effectiveness of jetting depends on the energy with which water drains through the layer. High pressure jetting is slightly more effective than low.
- Laboratory results of flooding indicate limited potential to improve compaction. The increase in effective stress, produced by seepage force and residual matric suction following drainage, is not great enough to break the in situ particle contacts and move the grains into a more compact arrangement. However, uniform and rounded particles tended to form more compact soil structures upon deposition than angular particles, which exhibited greater interlocking.
- Flooding field tests indicated that backfill reached a greater density near the surface, and adjacent to the abutment wall, than backfill compacted by traditional methods utilizing the steel drum vibratory roller. However, dynamic cone penetration measurements show that backfill compacted by flooding beneath the surface exhibited very low shear strength and had to be dug out and recompacted by traditional means. The sandy backfill used is a well-graded sand that has relatively low conductivity when compacted to a dense condition, making the specified backfill at Highway 51 a less than ideal candidate for compaction by drainage flooding.
- Slurry flooding created compacted lifts of uniform quality with shear strength greater than the shear strength and dry density of compacted lifts next to an abutment using traditional compaction equipment. Engineers and contractors should ensure the soil used to create the slurry is well graded (to obtain high dry density values), has minimum to low percentage of fines (to allow free drainage) and has spherical particles to allow easy flow ability.

Recommendations

Current standards for granular backfill limit the fines passing the No. 4 sieve in Granular Grade 1 and Granular Grade 2 and structural backfill to no greater than 8 and 15 percent passing by weight No. 200 sieve, respectively. The percent of fines for jetting and flooding backfill should be as close to zero as possible to ensure adequate drainage. Finer natural sands are more prone to settlements and pore pressure buildup, resulting in erosion and premature damage to approach pavements and bridge structures.

Flooding compaction is suitable for use in open country where traditional equipment is not available. Only a laborer, a water source and an instrument to fan spray the water are needed to perform flooding and induce drainage compaction. Jetting exerts much greater energy on the soil, and under appropriate drainage conditions, can produce dense soil structures. As similar labor and equipment is needed for jetting as flooding, it is the more effective and practical method. Slurry flooding is promising with its simplicity, uniform compaction system and improved shear strength next to abutments.

WisDOT is evaluating material specifications and will evaluate different combinations of material and compaction methods to establish improved standards and best practices for specific projects and sites.

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