1. **Cover**

Wisconsin Highway Research Program

Evaluating the Methodology and Performance of Jetting and Flooding Granular Backfill Materials

Wisconsin Highway Research Program
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University of Wisconsin-Madison

March 3, 2010

2. Summary Page

Project Title:	Evaluating the Methodology and Performance of Jetting and Flooding Granular Backfill Materials
Proposing Agency:	University of Wisconsin-Madison Office of Research and Sponsored Programs 750 University Avenue Madison, WI 53706
Person Submitting the Proposal:	Dante Fratta, Associate Professor
Proposal Written By:	Dante Fratta, Associate Professor
Proposal Date:	March 3, 2010
Principal Investigator:	Dante Fratta, Ph.D., P.E. Associate Professor Geological Engineering Program Civil and Environmental Engineering University of Wisconsin-Madison 1415 Engineering Drive Madison, WI 53706 Tel: 608-265-5644 e-mail: fratta@wisc.edu
Administrative Officer:	Tamara C. Kuhn Martin Research Administrator 2630F Engineering Hall 1415 Engineering Drive Madison, WI 53706 Tel: 608/265-0504 E-mail: tckuhn@engr.wisc.edu
Proposed Contract Period:	36 months
Total Contract Amount:	$74,000
Indirect Cost Portion at:	15 **%**

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4. Research Plan

4.1 Problem Statement

The use of backfill jetting or flooding could provide an alternative that may be faster and more economical than the traditional method of placing and compacting coarse-grained materials (e.g., granular materials) by mechanical means. That is, the use of backfill jetting or flooding could save both contractors, departments of transportation, and taxpayers' time and money in the construction of structural fill behind bridge abutments, next to utility trenching operations, and in local repairs of roads and embankments. However, before the use of backfill jetting or flooding is adopted; methodologies, materials and expected performance must be properly understood and specified. The assessment of the techniques, the specification of the required materials, and the laboratory and in situ evaluation of the performance are the problems that this proposal will address.

4.2 Research Objectives

The research objectives of this proposal are:

- (Phase I) To review both engineering and academic literature and evaluate best practices in jetting and flooding techniques for the construction of structural backfills.
- (Phase I) To compile commonly used coarse-grained materials (e.g., granular materials) properties for the construction of backfills jetting and flooding.
- (Phase I) To compile and assess the performance of constructed backfills using jetting or flooding.
- (Phases II-III) To evaluate in the laboratory and in the field most promising jetting and flooding techniques using fill materials commonly found in the Wisconsin construction market and allowed in the WisDOT Standard Specifications.
- (Phases II-III) To measure the quality and the engineering performance of structural backfills constructed using jetting and flooding techniques.
- (Phase IV) To develop proposed specifications for the implementation of jetting and flooding compaction techniques for Wisconsin.

The testing objectives will be addressed using a suite of testing procedures, including: nuclear density gauge (to measure the quality of the backfills), dynamic cone penetrometer, nondestructive propagation techniques (e.g., elastic wave propagation and time domain reflectometry) to estimate the engineering performance of the fills, and the vibration monitoring, Soil Stiffness Gauge (SGG) and Compactor Inspector™ to assess fill performance during compaction operations. All these instruments and techniques are available to the research team in the Geotechnical Engineering Laboratory at the University of Wisconsin Madison.

4.3 Background and Significance of the Problem

> *"… the placement technique is the single most important factor controlling the geotechnical behavior of a given type of sand when placed as a hydraulic fill."*
> (Lee et al. 1999)

Traditionally, the Wisconsin Department of Transportation (WisDOT) has used mechanical methods to compact granular materials in structural backfills. Examples include abutment backfills and utility trenches (White et al. 2005; Maifield and Herbst 2009). In particular, the WisDOT Standard Specifications (i.e., Section 209 Granular Backfill and Section 210 Structure Backfill) requires contractors using mechanical compaction methods to place coarse grained soils in maximum loose lifts of 30 cm (12-inches) and then decreasing the void ratio of the material by applying compaction energy the until the fill material reaches required density levels. The required coarse grained material (i.e., granular material) is defined in Section 207 of the WisDOT Standard Specifications.

The compaction of backfill materials is difficult due to the confined areas found in abutments and utility trenches in construction operations. For this reason, it takes significant time and resources to complete the work correctly. Furthermore, the use of small and light compactors typically fail to achieve proper compaction levels causing large differential settlements (e.g., bumps at the bridge approach) and reducing strength and stiffness of the structural system and

reducing the driving quality and safety of the pavement surface (White et al. 2005). Alternatively, as stated in WisDOT specifications, jetted compaction and flooded compaction methods under the appropriate conditions, and the approval of the engineer in charge, could be used as alternative to construction operations to improve the placement and compaction of fills. These alternative methods have the potential to reduce the contractor's time and achieve an equivalent densely compacted granular material. However, the placement and final quality of the operations must still be studied to fully implement these techniques in the construction of bridge abutments. For example, the jetting and flooding technique has been used in the construction large embankment and fills for geotechnical and structural systems in airports and harbors (Whitman 1970; Shen and Lee 1994; Lee et al. 1999). Many of these structures have had significant problems related to large settlement and dynamic liquefaction. These problems and other associated to the use of backfill jetting and flooding must be addressed before the methodology can be properly used in the construction and repairs of roadways.

Description of the Alternative Filling and Compaction Techniques

The use of alternative flooding and compaction techniques (namely jetting and flooded compaction) has the potential to increase efficiency of construction operations without sacrificing performance. However, to implement these techniques to the Wisconsin road construction market, an in-depth study is required. The proposed techniques are described below (Whitman 1970; Shen and Lee 1994; Lee et al. 1999; Iowa Department of Transportation 2009; Melbourne Retail Water Agencies 2008):

- In the *Jetting* process, metal pipe that introduces water under pressure saturates the granular material from the bottom of the fill. After the saturation process is completed, the water is drained quickly creating suction in the soil, increasing the effective stress, deforming the soil and reducing its void ratio (i.e., compacting the soil). In this process, the contactor adjusts the location and number of pipes to reach the required conditions. The greatest problem in the methodology is that pressure pipes may leave zone of loose soils that are not compacted during draining.

- During the flooding process, the saturation of the soil to be compacted starts form the top of the fill and moves to the bottom. When saturation is completed, the water is then rapidly drained forcing seepage and capillary forces to compact the granular soil. The contractor controls the amount and rate of draining to reach the required level of compactions.

Both methods require the water to be confined within the granular materials being compacted, and allowed to quickly drain out of the system under controlled conditions. These parameters along with location and pressure of the pressure pipes, the characteristics of the materials (e.g., grain size distribution, particle shape and angularity of the material composing the fill) and size of the fill (both area and depth) control the quality of the operations and therefore the final performance of the fill.

During this study the research team will:

- Perform an exhaustive literature search review to evaluate past experiences on the use of these techniques in construction operations, document the required specifications for fill materials, and establish bench mark for successful performances.
- Using the information collected during the data gathering tasks of the project, the research team will develop laboratory and field testing and monitoring programs to evaluate the performance of jetted compaction and flooded compaction in bridge abutment backfills and utility trenches.
- Using the support of WisDOT officials, the research team will identify sites where the use of backfill jetting and flooding techniques can be applied and tested. The research team will use nuclear density gauge, dynamic cone penetrometer, nondestructive propagation techniques (e.g., elastic wave propagation and time domain reflectometry), Soil Stiffness Gauge (SGG) and Compactor Inspector™ to assess the quality and the expected performance of the backfill jetting and flooding techniques.
- Finally, the research team will compare compaction operation using traditional mechanical methods vs. the alternative water compaction methods studied in this proposal.

4.4 Proposed Work Plan

This proposed research work will be divided into four main phases: Literature review and development of laboratory and field testing work plans; Implementation of the work plan in the laboratory (including testing of controlling parameters and performance evaluation of the jetting and flooding methodology); Implementation of work plan in a field study of the jetting and the flooding compaction methods; and Development of proposed specifications for WisDOT compaction jetting and flooding methods.

The first phase includes a thorough literature search of similar-type backfill compaction studies that have been completed by other Department of Transportation, by compaction manufacturing equipment companies or by research groups around the country. This detailed literature survey search will include gathering other background data/studies that would have applicability of alternative backfilling techniques. Based on the review of current practice, the UW-Madison research team will make recommendations related to the feasibility of applying these technologies to WisDOT practice and will proposed work plans for evaluating these compaction technologies in the laboratory and the field.

The literature review, recommendations, and experimental plan will be presented in a meeting with Technical Oversight Committee (TOC) and will be formally submitted in a written report to the TOC. After evaluation of the report, the TOC to will decide whether there is a need for the continuation of the research study. The recommendations will include a decision whether these technologies may show promise to improving backfilling and compaction operations. The remaining phases of the research project will be completed if the TOC consider that the techniques show promise. If the TOC evaluates that the benefits are limited, the study may be terminated at this time.

As part of phase one, the research team will proposed a work plan for laboratory and field testing of the techniques. If the TOC recommends the continuation of the project, the second phase of the research study will include implementing the work plan developed for the

laboratory work to further define the controlling parameters of the jetting and flooding compacting techniques. These parameters will include at least:

- Soil parameters: initial density, moisture content, grain size distribution, permeability, drain capacity, water quantity and final density and moisture content
- Jetting: pressure and number of pipes
- Performance: reduction in void ratio, strength gain, stiffness gain

To perform these tests, we plan to use a 70 cm high, 30 cm diameter Plexiglass column that will allow controlling all testing parameters including: initial density, moisture content, grain size distribution, drain capacity, and water quantity; and evaluate final density and moisture content of the granular material. Obtained results will be presented WisDOT officials and TOC members for review and decision on the continuation of the work.

The third phase of the research project will involve implementing the work plan for performing a field study of the jetting compaction method and the flooding compaction method. The research team will work with the WisDOT officials, TOC members and a contractor to locate suitable projects for testing. The granular soil characteristics (compaction properties –i.e., Proctor tests, grain size distribution, maximum and minimum void ratios) of the material to be used for testing will be determined by the research team.

The final compaction properties will be established from nuclear density gauge (NDG), dynamic cone penetrometer (DCP), nondestructive propagation techniques (e.g., elastic wave propagation and time domain reflectometry), Soil Stiffness Gauge (SGG) and Compactor Inspector™ before and after the application of jetting and flooding compaction techniques. The details of the optimum methodologies should be investigated (the range optimum methodologies will be constrained with the laboratory testing).

As part of phase three, the research team will also develop a field measurement program and monitor the long term performance (settlement) of the granular fill for at least one complete Winter season (i.e., a complete freeze/thaw season). This monitoring system will include

repeating the following tests: nuclear density gauge (NDG), dynamic cone penetrometer (DCP), nondestructive propagation techniques (e.g., elastic wave propagation and time domain reflectometry), and Soil Stiffness Gauge (SGG).

In the fourth phase of proposed study, the research team will develop a set of specifications that will be used by WisDOT officials in the implementation of compaction jetting and compaction flooding techniques in Wisconsin. Results from this study will provide the WisDOT with the data, analyses, and information to determine if these methods are effective for their application in Wisconsin. Necessary specifications for implementing the use of compaction jetting and compaction flooding will also be provided.

4.5 Reporting and Presentations

The proposed project will be performed in a period of time no longer than 36 months. Before the completion of the project, all data, findings, analyses and recommendations will be presented in an oral presentation and documented in a final report approved by WisDOT officials and TOC members.

An electronic copy of the draft final report will be submitted to the TOC and WisDOT officials after month 33 of the project. These three months will allow accommodating a thorough review for the draft final report, the scheduling of the final presentation, and incorporation of review comments in the final report. The research team will deliver 36 paper copies of the final report, along with an electronic version.

5. References

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Melbourne Retail Water Agencies (2008). "Backfill Specification". MRWA Specification No. 04-03.1. 27 pages.

Shen, C. K.; Lee, K. M. (1994). "Hydraulic Fill Performance in Hong Kong". Report from Hong Kong Government, Geo Report Series, Geo Report No. 40. URL: http://www.cedd.gov.hk/eng/publications/geo_reports/doc/er40.pdf. 200 pages

White, D., Sritharan, S., Suleiman, M., Mekkawy, M. and Chetlur, S. (2005). "Identification of the Best Practices for Design, Construction, and Repair of Bridge". Iowa Department of Transportation CTRE Project 02-118. 379 pages.

Whitman, R. V. (1970). "Hydraulic Fills to Support Structural Loads". Journal of the Soil Mechanics and Foundations Division, Vol. 96, No. 1, pp. 23-47.

6. Time Requirements and Schedule

Phase I Schedule

1 Year (12 months)			
Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**
Literature review	Polling of Large DOTs		
	Assessment of past experiences	Analyses of Collected Data	Preparation of Proposed recommendations
		Preparation of Work Plans for Phases II and III	
			Submission of Phase I Report

Phases II through IV Schedule (if approved)

Phase Number	2 Year (12 months)				3 Year (12 months)			
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
II	Laboratory testing and evaluation							
III			Field testing and evaluation				Evaluation after Freeze	

							/Thaw	
III					Development of Specifications			
								Final Report

7. Budget

The total cost of the proposed project is $74,000. Phase I will be for 12 months at a cost of $34,000. If approved, Phase II thought IV will be completed in 24 months at a cost of $40,000. The research team understands that the award of Phase I of the project does not guarantee the award of Phases II through IV.