Evaluation and Analysis of Current Compaction Methods for FDOT Pipe Trench Backfills in Areas of High Water Tables

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<u>Executive Summary</u>

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This research project was undertaken to examine the practicality and adequacy of the FDOT specifications regarding compaction methods for pipe trench backfills under high water table. Given the difficulty to determine density and to attain desired degree of compaction under high water table areas, typical in South Florida, it was alleged that the specification is difficult to follow. The main objective of this research project was to evaluate the variations in soil conditions, as determined by the Standard Penetration Test (SPT) *N*-values, as a result of varying methods of compaction. In this summary report, we highlight the major findings of the field tests conducted in simulated trenches.

Survey of Current Practices

A questionnaire survey was mailed along with a cover letter to all Departments of Transportation of the 49 (except Florida) states in the US and the Canadian states. We received 26 responses back from the US DOT's and 4 from Canadian states. The Florida DOT was left out of this survey as it was the state being investigated and information was going to be gathered by various means in the course of the study. This information is summarized in the following paragraph. Survey results revealed that most of the northern and western states in the US and the Canadian states, in general, do not experience the problem addressed in this research project. It was also noticed that the departmental specifications in most of the states, that responded to the survey, do not specifically address this issue. Most common methods to circumvent the problem of high water table were cited as dewatering and use of coarse backfill material, such as gravel or crushed stone. French draining method was also mentioned as an alternative technique for avoiding this problem.

Study of completed and current FDOT projects

Site visits were helpful in developing a better understanding about the nature and extent of the problem under investigation. Three site-visits were made in Miami. All three were ongoing projects. Two of them involved installation of french draining and the other involved utility pipe laying and

backfilling. In addition, several recently completed projects in the Dade County were visited. These observations and discussions with the local FDOT officials and consulting engineers helped the investigators greatly in designing and constructing the test fixture for controlled analysis of compaction methods. The study of completed and current projects was focused on:

(1) the difficulty in following specifications,
(2) the field procedures used by the contractors in reality, and
(3) the problems of measuring the degree of compaction under high water table.

A set of elevation readings was taken from the sites of three completed projects near Milam Dairy Road and the NW 37th Avenue (Douglas Road) in February, 1997. A second set of elevation readings was taken from the sites of three completed projects near Milam Dairy Road and the NW 37th Avenue (Douglas Road) in July, 1997. Initial observations suggested no significant change in elevation, indicating the fact that settlement did not occur. Background information on the projects visited - both ongoing and completed - are gathered and included in the report.

Field tests of selected conditions

In the first phase of the project, three field tests were performed. The investigators were fortunate to have a site ideal for testing the conditions stipulated in the project proposal. The three conditions investigated were:

(1) Backfilling in the dry condition, above water,
(2) Backfilling under water table, according to the specifications, hand-tamping with a 2x4 as specified; and
(3) Backfilling under water table, without tamping.

Subsequently, Standard Penetration Test (SPT) *N*-values were obtained for all three conditions. In the second phase, two additional field conditions with dewatering were tested. According to the FDOT specifications dewatering should be done during pipe installation and backfilling under certain conditions. As such, this should be considered as one of the "control" conditions and be compared with the situations where dewatering was not done. Another condition, with dewatering involved but with no compaction, was tested. In summary, the research team:

(1) carried out field investigation on a simulated trench with constant dewatering during pipe installation and backfilling with periodic compaction according to FDOT specifications, and
(2) carried out field investigation on a simulated trench with constant dewatering during pipe installation and backfilling by dumping (no compaction).

Standard Penetration Test (SPT) *N*-values for both conditions were obtained, as before.

Analysis of Field Test Results

For each of the five field conditions, as noted above and briefly described below, readings were obtained at seven locations. Average (mean) and standard deviations of these seven SPT *N*- values are included in the report.

Field Conditions:

A: Control dry - excavate trench, place and bed typical (24-inch dia.) pipe segments, backfill and compact under ideal dry conditions in strict accordance with FDOT specifications (FDOT specifications 1996, section 125-8.3 - Requirements for Pipe Culverts and Storm Sewers).
B: Dump soil, no compaction, no dewatering.
C: Dump soil, compact per FDOT specifications, no dewatering.
D: Control wet, dewatered with pump, compact per FDOT specifications
E: Dewatered with pump, dump soil, no compaction.

Several observations can be made from the results obtained. As expected, highest *N*-values were obtained for the control dry condition (field condition *A*). Under this condition, density (100 percent of the maximum density as determined by *AASHTO T 99, Method C*) was obtained at 6-in. lifts for the material beneath pipe haunches, at 6-in. lifts for material along sides of pipe to 1-ft. above pipe, and at 1-ft. lifts up to finished surface.

The next best set of *N*-values was obtained for the control wet condition (field condition *D*). Although, at 1-2 ft. depth the *N*-value of condition *D* is slightly higher than the corresponding value of condition *A*. This was expected as under this condition a dewatering pump was used and the backfilling material was compacted in lifts in accordance with the FDOT specifications. The trench was excavated in an area where the ground water level was about 6-in. (actual measurement indicated 0.8-ft. or 9.6-in.) above the top of the pipe. Dewatering of the trench was continued after the pipe segments were placed and bedded. Backfilling and compaction was done in strict accordance with the FDOT specifications. Due to limitations of dewatering procedure the first backfilled lift was placed to "springline" (horizontal centroidal axis) of the pipe since the bottom of the trench could not be completely dewatered. This first lift and subsequent lifts were compacted according to section 125-8.3, FDOT 1996 specifications. After backfilling and compaction, installation was allowed to stabilize for water table to return to its original level. *N*-values were obtained at seven locations as before.

In field condition *B*, a trench was excavated as in field condition *A*, in an area where the natural water table was approximately 6-in. above the pipe once it was installed. The trench was dewatered long enough to place and bed the pipe segments. The open trench with the bedded pipe was let to sit overnight to allow ground water table to rise and stabilize at its natural level at about 6-in. above the pipe. Backfilling was done as is normally done in the field (by dumping the backfill material with no tamping) under wet conditions where dewatering is impractical. Backfill was placed to 1. 5-ft. to 2.0- ft. above top of pipe, compacting to 100% of *AASHTO T-99*. Backfilling was continued in 1-ft. lifts compacted to 100% of T-99.

In field condition *C*, the trench was excavated as in *B*, placing and bedding the pipe segments in the wet. Backfill material was compacted by hand-tamping in accordance with the FDOT specifications for backfilling under wet conditions (Section 125-8.3.3). It was evident from the SPT values, that the result did not noticeably improve from condition *B* to condition *C*.

In condition *E*, the trench was excavated very much like in condition *D*. Dewatering was continued after the pipe segments had been placed and bedded. Lifts of backfill material were dumped without compacting or tamping. The third lift was backfilled to about 12-in. above pipe (about 6-in. above water table). Dewatering was stopped and the fourth lift was backfilled to about 2-ft. above pipe (about 1.5-ft. above water table). The fourth lift and the subsequent lifts were compacted to 100% of T-99 according to FDOT specifications. The *N*-values obtained from field condition E were not significantly different from the values obtained for either conditions *B* or *C*. The average *N*-value (as well as the individual *N*-values at each of the seven locations) at the depth of 4-6 ft. for condition E, was found to be very low as compared to other conditions. This may have been caused by the pre-existing subsurface soil condition at this location.

It can be concluded that, dewatering without compaction (condition *E*) yielded similar results as compacting (by hand-tamping) with no dewatering (condition *C*). Both condition *C* and *E* gave *N*-values very close to that of condition *B*, in which neither dewatering nor compaction were done. This finding raises questions about the justification of the provision of hand-tamping as required by the FDOT specifications.

On the other hand, both dewatering and compacting done simultaneously showed a significant improvement in the density as indicated by the *N*-values obtained for condition *D*.

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Chapter 1 - Introduction

Due to Florida's abundance of low lying regions, the Florida Department of Transportation (FDOT) is continually faced with the situation of placing and backfilling utility pipes and culverts in high water table areas. The problem that arises from this situation is the uncertainty associated with the compactive integrity of the backfill placed at or below the water table, if the trench is not dewatered. In response to this problem, Florida International University (FIU), in conjunction with FDOT, as the sponsor, has undertaken this research study.

1.1 Problem Statement

The FDOT specifications on backfilling is contained in section 125-8 (FDOT Standard Specifications for Road and Bridge Construction 1996). Requirements for pipe culverts and storm sewers are covered in subsection 125-8.3. By the time this report was being finalized, the 1999 edition of the FDOT specifications had already been published. The changes are pointed out in the last part of this section. According to the 1996 specifications, upon which this study is based, backfilling of pipe trenches should be done in three stages, as quoted below:

> "First Stage: The material beneath the haunches of the pipe and above any bedding required in 125-4.4.1 (FDOT Specifications, 1996) shall be placed in six-inch layers (compacted thickness) and compacted with mechanical tampers suitable for this purpose.
>
> "Second Stage: The material along the sides of the pipe and to a point of at least one foot above the top of the pipe shall be placed in six-inch layers (compacted thickness) and compacted with appropriate equipment. The width of compaction to be done under this stage shall be the width

of the portion of the trench having approximately vertical sides or, when no portion of the trench has approximately vertical sides, compaction shall extend a distance equal to two times the outside diameter of the pipe on either side of the pipe.

"Third Stage: The material in the trench above the second stage up to the bottom of the subgrade or the finished surface of the embankment, as appropriate, shall be placed in layers not to exceed one foot in thickness and compacted with appropriate equipment."

Density requirements are stated in 125-8.3.2. as follows:

"For non-flexible culvert construction, all backfill shall be compacted to a density of at least 100 percent of the maximum density as determined by AASHTO T99, Method C." (FDOT Specifications, p. 125, 1996.)

The difficulty associated with following this specification while backfilling is to be done under high water table is recognized in the specifications. In subsection 125-8.3.3, entitled, "Backfill under Wet Conditions" the following is stated:

"Where wet conditions are such that dewatering by normal pumping methods would not be effective, the procedure outlined below may be used when specifically authorized by the Engineer in writing and noted in the job diary. In such specifically authorized cases the backfill material used below the elevation at which mechanical tampers would be effective shall be of the A-3 soil classification. After the pipe is bedded properly, the A-3 material shall be placed, and rammed and compacted under the pipe haunches by the use of timbers or hand tampers, and hand-tamping continued during the placing of the backfill until the backfill reaches an elevation such that its moisture content will permit the use of mechanical tampers. When the backfill has reached such elevation, normally acceptable backfill material may be used and compaction shall be obtained by the use of mechanical tampers. The mechanical tamping shall be done in such manner and to such extent as to transfer the compacting force into the previously hand-tamped fill." (FDOT specifications, p. 126, 1996.)

As noted earlier, at the time this investigation was coming to its conclusion, the 1999 edition of the FDOT specifications came out. The corresponding section "Backfill under Wet Conditions" in the 1999 edition is numbered 125-8.3.4 and is stated as follows:

"Where wet conditions are such that dewatering by normal pumping methods would not be effective, the procedure outlined below may be used when specifically authorized by the

Engineer in writing. The Department will pay for any select material which is not available from the grading as Unforeseeable Work. The Department will not pay for select material that might be used by the Contractor for his own convenience instead of dewatering.

"The Department will permit the use of granular material below the elevation at which mechanical tampers would be effective, but only material classified as A-3. Place and compact the material using timbers or hand tampers until the backfill reaches an elevation such that it's moisture content will permit the use of mechanical tampers. When the backfill has reached such elevation, use normally acceptable backfill material. Compact the material using mechanical tampers in such manner and to such extent as to transfer the compacting force into the material previously tamped by hand.

"The Department will permit the use of coarse aggregate below the elevation at which mechanical tampers would be effective. Use coarse aggregate as specified in Section 901 fro Aggregate Size Number 89, 8, 78, 7, 68, 6, or 57. Place the coarse aggregate such that it will be stable and firm. Fully wrap the aggregate with a layer of Type D-4 filter fabric, as specified on Roadway and Traffic Design Standard, Index No. 199. Do not place coarse aggregate within 1.2 m of the ends of the trench or ditch. Use normally accepted backfill material at the ends." (FDOT specifications, p. 125-126, 1999.)

Except for minor changes in wording, this provision in the specifications is not much different from the previous 1996 edition. The last paragraph, however, is a new addition. It is clearly stated in this new paragraph that under certain condition use of coarse aggregate is allowed. For obvious reasons density should not be a concern when coarse aggregates are used as backfill.

The provision of hand-tamping - and the degree of compaction achieved by such tamping - is the central research question in this investigation. Specifically, the investigators sought answers to the following questions:

1. Does hand-tamping under water increase density?
2. Does dewatering help increase density significantly?
3. How can the compactive integrity of the backfill material under water (with or without tamping) be assessed?
4. How can one determine the acceptability of the assessed compactive integrity of

the backfill material?

5. What are the conditions of completed project sites?

6. Based on the research findings, should the specifications be revised? If so, what should be the change?

1.2 Scope and Objectives

In order to obtain specific answers to the research questions posed above the investigators proposed a detailed research plan that was subsequently consulted with, and approved by, the FDOT officials. The investigation process was constituted of: (a) literature search and information gathering; (b) Inspection of ongoing and completed projects; and (c) experimental field study. In the following the scopes of each of these tasks are outlined.

(a) Literature Search - A search for existing literature, published materials, and research findings on this topic.

(b) Inspection of projects - Field inspection of selected backfilling projects, both completed and ongoing, mainly under FDOT Districts 4 and 6. In particular, the investigators attempted to determine the extent and magnitude of construction difficulty in ongoing projects, and visible settlement in completed projects.

(c) Field Study - Selected field conditions were simulated in a site. Backfilling under both dry and wet conditions, with or without tamping, and with or without dewatering, with a total of five different field conditions, were simulated in order to determine the differences in soil compaction.

The major objectives of this research study are:

1. To determine the extent and nature of the problem caused by backfilling operations under water table.

2. To determine the extent and nature of the problem in achieving satisfactory compaction of the backfill material under water table.

- To recommend revisions in the current FDOT specifications in light of the findings of this research study.
- To suggest future directions of research regarding backfilling operations under water table.

1.3 Organization of the Report

In this chapter the scope and the objectives of the research project are outlined. The problem has been defined and the research questions are laid out.

The remainder of the report is organized as follows:

In Chapter 2, results of the literature search are reported and relevant materials that were found using the library and Internet resources are discussed. Next, a report on the investigation carried out on a few selected ongoing projects and some completed projects is included in Chapter 3. In Chapter 4, the experimental field study is introduced. Descriptions of the five field conditions studied and the results of investigation are reported in this chapter. Analysis and interpretation of the results are presented in Chapter 5. Suggestions for further study are included and lessons learned are discussed in Chapter 6. In the last chapter (Chapter 7) conclusions of the study are highlighted and recommendations for future actions by FDOT and potential researchers are outlined.

Chapter 2 - Literature Search and Questionnaire Survey

2.1 Literature Search

An extensive literature search using the library resources available at Florida International University was conducted. Both conventional and electronic means were utilized. The search did not yield much published material directly related to the topic of this research study. A number of articles indirectly related to the topic, however, were found. The sources of the reference articles and information obtained are presented below.

ASCE (American Society of Civil Engineers) journals of transportation and geotechnical engineering were throughly searched for any related articles. An article on consolidation settlement was obtained in the ASCE *Journal of Geotechnical Engineering* entitled, "Limitations of Conventional Analysis of Consolidation Settlement." (Duncan, J.M., Vol. 119, No. 9, September, 1993, p. 1333-1359.) In the ASCE *Journal of Transportation Engineering*, an article on concrete pipe entitled, "Buried concrete pipe trench installation analysis" (Selig, E.T., and Packard D.L., Vol. 113, No. 5, September 1987, p. 485-501) was found. A paper entitled, "Underground Pipeline Materials, design and construction" in the Proceedings of the 1995 ASCE *International Conference on Advances in Underground Pipeline Engineering* (Jeyapalan, J.K., et al. Proceedings of the 2nd International Conference on Advances in Underground Pipeline Engineering - 1995, ASCE, p.25-41) was located. The following articles were found in *Geotechnique,* a journal of geotechnical engineering:

- "Time Drawdown Behavior of Construction Dewatering Systems in Fine Soils," (Powrie, W. and

Preene, M., Vol. 44, No. 1, 1994, p. 83-100),

- "Horizontal Drainage during Consolidation," (Al-Tabbaa, A. and Wood, D.M., Vol. 41, No. 4, 1991, p. 571-585),
- "Pipe Penetration in Cohesive Soil," (Murff, J.D., Vol. 39, No. 2, 1989, p. 213-229), and
- "Lateral Displacement of Shallow Buried Pipelines Due to Adjacent Deep Trench Excavation," (Croft, J.E., Menzies, B.K., Tarzi, A.I., Vol 27, No. 2, 1977, p. 161-179).

Information was also gathered on some of the common testing methods used for analyzing degree of compaction. See *Appendix-A* for a brief discussion on compaction principles, test methods, and techniques to determine bearing capacity of soils.

The following articles were found on the Internet. These articles are related to the cone penetration test (CPT). Although, CPT was not used in this investigation, a list of available materials on the Internet, is included here.

- "Uncertainties in cone penetration testing," by Post, M.L., CPT'95 Paper A39, http://130.237.60.125/aom/SGF/CPT95/Contrib/a39.htm
- "Settlement analysis of granular soils based on cone penetration tests," by Rainer, K., Massarsch Royal Institute of Technology (KTH), Stockholm, Sweden, CPT'95 Paper A11, http://130.237.60.125/aom/SGF/CPT95/Contrib/a11.htm
- "Recommended standard for cone penetration tests," (established by the Swedish Geotechnical Society, June 15, 1992), Swedish Geotechnical Society, SGF Report 1:93 E, http://130.237.60.125/aom/SGF/other/SGF1_93E.htm
- Evaluation of soil properties by CPT (Cone Penetration Test), by Eskel, U., Mets, M., and Talviste, P., CPT'95 Paper A26, http://130.237.60.125/aom/SGF/CPT95/Contrib/a26.htm
- "Evaluation of trench backfill compaction using CPT (Cone Penetration Test) - A case study," by Islam, M.S., Hashmi, Q.S.E., and Helfrich, S.C., CPT'95 Paper A46, http://130.237.60.125/aom/SGF/CPT95/Contrib/a46.htm

In addition to the above, the investigators were able to retrieve a research report entitled "Synthesis of Recent Trench Backfilling Studies" sponsored by the Minnesota Department of Transportation (Mn/DOT) (1972). This was a follow-up study of an earlier investigation entitled, "Backfilling Trench Excavation" completed in 1971. In this study utility trenches were dug, backfilled and monitored for settlement. Variables, including soil, type of compaction equipment and density were investigated. Data obtained from this study were re-analyzed in the 1972 study. Compaction procedures were recommended for limiting settlement to given tolerable amounts for various soil types. The study lists compaction techniques and provides settlement prediction limits to be designed for. A compaction specification has been included in the specifications for the installation of watermains and sanitary and storm sewers which has been published by the Minnesota League of Municipalities in 1975 and revised again in 1979 (Research Review, 1983). Although this was a very comprehensive study in regards to the variables mentioned, the effect of high water table on compaction was not investigated in this study.

2.2 Questionnaire Survey

A simple questionnaire survey was prepared (see *Appendix-B*) along with a cover letter. The questionnaires were mailed out to 49 US states (excepting Florida as it was the state under investigation) and 10 Canadian provinces. Responses were received from 29 (58%) US States and 4 (40%) Canadian provinces, as discussed below. Of the total 33 responses received, 21(64%) stated they have previously experienced the problem in some form or another in the past.

An analysis of the survey responses indicates that there are mainly three different methods or techniques employed to address the problem. They are:

1. Dewatering, using pumps during laying of pipe segments and during backfilling until the desired density in the backfill material is obtained.
2. French drains, where appropriate. The technique consists of a sloping trench lined with soil-filter

fabric and filled with gravel. For more effective drainage and/or longer runs, perforated drain pipe segments are used along the bottom.

3. Backfilling with granular material. When granular material (coarse aggregate, such as No. 57 stone) of a specified grade is used under water table, density requirement does not have to be met for obvious reasons.

Many states employ combinations of these techniques. For example: Texas uses dewatering and French drains. Maryland and New Jersey specify dewatering, in addition to the use of granular backfill to provide a suitable foundation for the underground pipelines. Of the states that responded, Washington, New Jersey, and North Carolina, had the most experience with this high water table problem.

The following is a summary of the responses provided by the individual states. The responding states are listed in alphabetical order, with the US states preceding the Canadian provinces.

Alabama: This state has some, although limited, experience with this problem. The problem is not addressed in their departmental specifications. It is usually resolved by lowering the water table using pits, trenches, and/or well points in conjunction with granular, highly permeable backfill.

Arkansas: This State has experienced the problem. Selected pipe backfill material (granular) or gravel/crushed stone is used as backfill. It is not addressed in their specifications.

California: The problem has been experienced in California. It is dealt with as follows:

(1) For minor amounts of water, sump pumps are used to dewater the pipe trench.
(2) For larger amounts, dewatering wells have been used to lower the water table within the project area.
(3) If adequate compaction is unattainable due to groundwater, concrete backfill is considered.

The issue is addressed in the Caltrans (California Department of Transportation) specifications. These specifications (see *Appendix-C*) give only general discussion to tell the contractor that the situation must be taken care of, without much specific "how-to."

The methods to be used to control and remove water at excavations where seal courses are not shown on the plans shall be the option of the contractor and may include, but are not limited to, well point systems, pumping sumps, cofferdams, or concrete seal courses. At locations where concrete seal courses are shown on the plans and the Engineer determines that a seal course shall be used, control and removal of water shall be accomplished by the use of a cofferdam.

Care shall be taken during excavation to prevent disturbing the foundation. If ground water is encountered during excavation and a concrete seal course is not to be used, dewatering shall be commenced and shall proceed in advance of or concurrently with further excavation. The foundation shall be free of water at the time pipes are placed, and water control shall continue as necessary to prevent damage to the work.

Connecticut: Problem is encountered but not significant. The contractor is required to construct the pipeline "in the dry" including backfill and compaction. This should be done before pumping is discontinued. Inspection staff has the option to replace native material with the compacted gravel fill as deemed appropriate.

In the specifications, ground water is not specifically addressed. Contractors are required to provide pumping, if needed, as per specifications. The line item is usually included in the unit bid price for trench excavation.

Hawaii: When problem is experienced, bed course material is replaced with coarse aggregate size #57 or #67 (AASHTO M43 designation.) Not addressed in departmental specifications.

Indiana: Not a significant problem. Usually solved by dewatering the trench and using granular material as backfill. All the soil surrounding the storm sewer should be compacted to at least 95% of the maximum dry density. The soil in the bottom of the excavation, any bedding material, and any backfill material, should be tested to insure compliance with the density criteria. Groundwater levels must be lowered in the excavations prior to pipe installation and sump pumps and well points are recommended. (See *Appendix-D.*)

Maryland: Problem experienced in wetland areas and Eastern Shore region east of the Chesapeake Bay. In dealing with this problem, they normally dewater the trench during construction, place a bed of stone (typically, #57 stone) cradling the utility or culvert pipe and backfill with excavated material on select material if necessary. Not addressed in the specifications.

Minnesota: Wide trenches are almost always done in the dry by pumping out the water. Often, the trench problems come from an isolated job where the contractor or the utility company does not have the proper size compaction equipment to do the job, or they get in and out before an inspector can catch the substandard work. Another problem involves not wanting to use large compaction equipment over a pipe for fear of damage. Lean mix concrete backfill could be an option in such cases. Fill placement "in the wet" is mostly done when building new roadways or embankments over a swamp. From these cases, a massive granular backfill may be pushed into the water with no requirements for compaction.

Missouri: Missouri has two major river systems within its boundaries, the Missouri and the Mississippi. The flood plains of these rivers and the "boothill" area of Missouri are comparable with the low-lying regions of Florida. Few problems were encountered. Occasionally, standing water and foundation problems result from the lack of drainage or the presence of a highly organic soil within the excavation. Foundation problems for box culverts must be addressed when encountered by dewatering and/or undergrading. (See *Appendix-E.*)

Nevada: The problem has been experienced. Dewatering using pumps is employed to solve the problem. Any saturated material found is re-excavated before backfilling. The problem is addressed in the specification (See *Appendix-F*).

New Jersey: The problem has been encountered in a few localized areas. It is treated on a case by case basis using submersible pumps to dewater. Crushed stone (3/8") or pea gravel is normally used for bedding and backfill. The problem is not addressed in their specifications.

New York: This state has experienced the problem. Standard specifications require dewatering. For "crossover carrier pipe," the preferred installation method when operating below the water table or in softground is to employ an "earth pressure balance" or comparable system in order to prevent flowing soil or ground loss and pavement distress. Department specifications do address this issue (See *Appendix-G.*)

North Carolina: The problem has been encountered mostly in the eastern or coastal plain region of the state. Typically the method used is dependent on the source and/or flow rate of the water. Well point or sheet pile and pump system are often utilized, however, some sites may warrant undercut and bedding/backfill operations to be performed in the wet utilizing crushed stone or gravel. The problem is addressed in the departmental specifications (See *Appendix-H*). Pipe installation shall be made on "uniformly firm bedding." Where pipe installation encounters extremely wet conditions, the method for site conditioning will be determined by the Engineer (NCDOT).

Ohio: The problem is experienced. Open graded granular material is used as backfill with 35% air voids. The granular material shall meet the gradations of No.57 or 67 sieves. (See *Appendix-I.*) These specifications mainly address the different types of material to be used as backfill. When allowed, the granular material can be used below the bottom of the pipe. This material shall be placed in layers not to exceed 305mm (12inch) loose depth and vibrated, tamped or compacted to approximately 85% of the original thickness.

Pennsylvania: The problem is not encountered in this state, but specifications were sent for our information (See *Appendix-J*). These specifications deal mainly with flowable backfill material.

Texas: The problem has been experienced. The techniques involving, dewatering with pumps, well point installation, French drains, deep wells and bailing are all utilized to mitigate this problem. Their specifications address the issue of dewatering (See *Appendix-K*.)

Vermont: The high water table problem is rarely encountered, but they frequently encounter problems originating from soft and unstable foundations. Granular backfill is used in these situations. If the foundation is very soft and yielding, excavating up to 2 feet below grade and backfilling with 1-1/2" stone is usually done. Granular backfill is to be compacted to 90% t-99.

Washington: (Response received from South West region office.) This State provided a detailed account of their experience with our problem. They begin their work at the low point of the pipeline to provide a point of discharge. Dewatering using trash pumps with 3" intakes were found adequate in their applications. They recommend use of a flat bit bucket in lieu of the one with teeth, to minimize the amount of residual loose material at the bottom of the excavation, prior to backfilling. The foundation material should consist of 4"-8" quarried rock with a maximum of 20% passing the 1" screen placed in a 1' minimum lift. Compaction of the foundation material should be sufficient to embed the stone into the native soils and provide a uniform yielding surface. If native soils are observed at the surface of the foundation material after compaction the cause is generally due to inadequate foundation depth and/or excessive compactive effort.

A high water table in fine sand can lead to two conditions that can affect production: (1) Infiltration and contamination of bedding and other backfill materials; and (2) Excess accumulation of solids at the discharge end of the suction pump. The following suggestions will reduce these potential impacts. Use of portable shoring (coffin box) will expedite trench excavation and reduce exposure provided existing utilities and structures in the surroundings do not restrict their use; and installation of well points in the trench will lower the water table in the immediate area.

Where excavation and backfilling are intended using native sandy soils in high water table locations, high moisture contents (20% +) can exist, depending on the gradation of the native sand. If the application requires permanent and immediate restoration, for example, at road crossings etc., the saturated sand may not be sufficiently stable to provide a firm unyielding base for surfacing materials to be placed. Typically with oversaturated sandy soils the PCF (pounds per cubic foot) necessary to achieve 95% of maximum density can be attained; however, the structural stability is normally unacceptable (pumping) due to the excess water displacing solids. When moisture contents can not be controlled and pumping of the sand backfill is evident there are two possible methods to ensure a stable backfill is constructed:

1) If saturated native material exist, provide a temporary stockpile several days prior to the time of backfilling to allow the excess moisture to drain. Moisture contents less than 10% are desired. If this is not possible and permanent restoration is essential the saturated excavation may have to be wasted and select suitable backfill imported to ensure that work is completed and structurally sound.
2) When the work does not require permanent and immediate completion of overlying embankments or surfacing, the saturated backfill can be placed and compacted as is, allowed to drain and compaction verified by potholing at various depths and locations to confirm that minimum density values are achieved. They have successfully utilized this process on several projects.

Except for requirements to dewater excavations and backfill lift thickness and density requirements their specifications do not direct the method or manner in how to accomplish the work (See *Appendix-L*).

West Virginia: Not a significant problem in this state due to terrain and type of soils commonly encountered. A granular backfill is used with vibratory compactors. A flowable fill (slurry) that displaces water and cures like a *tremie pour* is used. The issue is not addressed in their specifications.

Saskatchewan: They have experienced the problem in mushy areas, but it is not addressed in their specifications. Installation under these mushy conditions is conducted by first excavating at least 2' of material, and then backfilling with a well graded granular backfill. The top 6" is then compacted until firm, (no density specified). The pipe or culvert is then placed.

Victoria BC: The problem has been experienced. During installation, the trench is dewatered and the native soil is replaced with granular material beneath the culvert. In some cases, granular material may need to be enveloped with geosynthetic. They do not address this problem in their departmental specs.

2.3 Conclusions

As can be seen from the response summary, a significant number of states do not have the problem categorically addressed in their specifications. Of the specifications obtained as a result of this survey, California, Ohio and Indiana provide best guidelines on the installation procedure in unfavorable water conditions. As the survey results indicate, most of the states do not encounter the problem of backfilling under high water table, due to the nature of their geographic terrain.

In their specifications, Caltrans (California Department of Transportation) attempts to make the contractors aware of the situation by saying that the problem, if encountered, must be taken care of, without much specifics on how to deal with the problem. The methods to be used to control and remove water at excavation where "seal courses" are not shown on the plans shall be the option of the contractor and may include, but are not limited to, well point systems, pumping sumps, cofferdams, or concrete seal courses (*Appendix-C*). At locations where concrete seal courses are shown on the plans, and the engineer determines that a seal course shall be used, control and removal of water shall be accomplished by the use of a cofferdam. Care should be taken during excavation to prevent disturbing the foundation. If ground water is encountered during excavation and a concrete seal course is not to be used, dewatering shall be commenced and shall proceed in advance of or concurrently with further excavation. The foundation shall be free of water at the time pipes are placed, and water control shall continue as necessary to prevent damage to the work.

The relevant specifications of Ohio Department of Transportation (ODOT) address mainly the different types of material to be used as backfill. Open graded material with 35% air voids is used as backfill when pumping operations do not cause severe ground water problems. When allowed, the granular material can be used below the bottom of the pipe. This material shall be placed in layers not to exceed 305mm (12 in.) loose depth and vibrated, tamped or compacted to approximately 85% of the original thickness. The lift thicknesses may be adjusted by the engineer to obtain the required compaction, fill all the voids, achieve the proper seating of the backfill material and achieve the stability of the backfill material and the pipe.

According to the Indiana Department of Transportation, all the soil surrounding the storm sewer should be compacted to at least 95% of the maximum dry density. The soil in the bottom of the excavation, any bedding material, and any backfill material, should be tested to insure compliance with this density criterion. Groundwater levels must be lowered in the excavations prior to pipe installation and sump pumps and well points are recommended.

2.4 Summary

A questionnaire survey was mailed along with a cover letter to all Departments of Transportation of the 49 (except Florida) states in the US and the Canadian states. We received 26 responses back from the US DOT's and 4 from Canadian provinces. Survey results revealed that most of the northern and western states in the US and the Canadian provinces, in general, do not experience the problem being addressed in this research project. It was also noticed that the departmental specifications do not specifically address this issue. Most common methods to circumvent the problem of high water table were cited as dewatering and use of coarse backfill material, such as gravel or crushed stone. French draining method was also mentioned as an alternative technique for avoiding this problem.

Chapter 3 - Inspection of Ongoing and Completed Projects

3.1 Background

Before the work on this project had formally begun, a preliminary survey among the FDOT Districts was conducted during the Summer of 1996 by Dr. Sastry Putcha, Project Manager of this research study. See *Appendix-M* for a sample of this survey. In the survey, respondents were asked to provide information on:

a. the completed projects where backfill was placed in the wet and settlement has occurred, and
b. the current projects (during Summer of 1996) where pipe trench backfill was being placed and compacted in the wet.

Out of 15 responses received, 7 were obtained as answers to part ***a.*** These were:

1. SR 953, Le Jeune Road, from SR 25 to NW 104 St., Districts-4 and 6.
2. Two projects in Tampa and one in Pinellas, District-7.
3. Three projects on SR-35 and one on SR-64, District-1.
4. University Drive (2 jobs), Broward Boulevard, Dixie Highway (3 jobs), and AIA at Hollywood Boulevard, District-4.
5. SR-76 (Kanner Hwy, Stuart), SR-60 (West of $# Pl.), and Port St. Lucie Blvd, District-4.
6. Dunn Avenue, Jacksonville, District-2.
7. Savor Blvd, SR 436 Orlando (2 projects), Nova Rd (Daytona), District-5.

In response to part ***b***, several projects were mentioned as listed below:

1. SR 836/Le Jeune (very near completion), District-6.

2. Milam Diary Rd (72nd Ave.), District-6.

3. Bird Road from SW 87th to 117th Ave, District-6.

4. MacArthur Cswy Bridge, SR A1A, District-6.

5. Quail Roost Drive, SR 994 at US 1, District-6.

6. SR 824, Pembroke Rd. from SR 7 to I-95, Districts-4 and 6.

7. US 41 Nebraska, and Hillsborough Ave, District-1.

8. South Skyway Bridge, SR 776-Englewood, and CR777-Englewood, District - not mentioned.

9. I-95 & SR 528, SR 551 Goldenwood Road, Nova Road SR 5A, and SR 15/600, District-5.

10. SR 2 (Baker Co), SR 2 (Columbia Co), and I-75 (Columbia Co.), District-2.

11. US-1 (Stuart), Warfield Blvd ((Indiantown), SR-70 (Fort Pierce), and SR-60 (Western Indian River Co.), District-4.

12. Pembroke Rd (US 441 to I-95), Hillsboro Blvd (US 441 to Powerline Rd.), and Las Olas Blvd. (16th to Intracoastal WW), District-4.

13. SR-45 Venice, SR-72 Sarasota (two projects), and SR-70 Omeco, District-1.

14. East Bay Drive, Clearwater, Blind Pass, St. Pete, and Plant City, District-7.

None of the respondents indicated any significant settlement problems in the completed projects. The investigators visited some of the project sites, (as mentioned later in section 3.3 of this chapter) and observed no visible sign of settlement.

The investigating team selected two ongoing sites as described and discussed below. These sites were observed during and after backfilling.

3.2 Ongoing Projects

Douglas Road (NW 37 Avenue) in Carol City of North Miami - The investigating team along with Dr. Putcha visited this site in July 1996. The project was under construction at that time. We observed pipe segments were being laid under water and backfilling was being done by dumping backfill materials at several sections of the road. Casual interviews with the project engineers and managers on-site revealed no major problem due to high water table. The project was subsequently completed near the end of 1996. The Principal Investigator made another visit on February 14, 1997. No settlement-related problem was observed. Elevation measurements were taken at a couple of sections where pipe segments were laid. Later, on July 3, 1997 elevations were measured again at the same sections. Differences in elevation that can be attributed to settlement of the backfill material due to inadequate compaction, were not detected.

Milam Dairy (NW 72nd Avenue) and NW 43rd Street - Similar investigations at this project site were carried out as described above. This project involved laying out of French drains. *Figure-1* shows a typical view of construction at this site. The trenches were backfilled using conventional procedure as in the Douglas Road project mentioned earlier. It was also completed in December 1996. The results were similar. No significant difference in elevation during the time period between February and July of 1997 has occurred.

3.3 Completed Projects

During the summer of 1998, the Principal Investigator, along with Mr. Acka Darici of FDOT Districts 4 and 6 Materials Office inspected the following completed project sites. The sites are located in the Dade county. All of these projects were completed using conventional backfilling procedure and the investigators did not notice any settlement-related problem in any

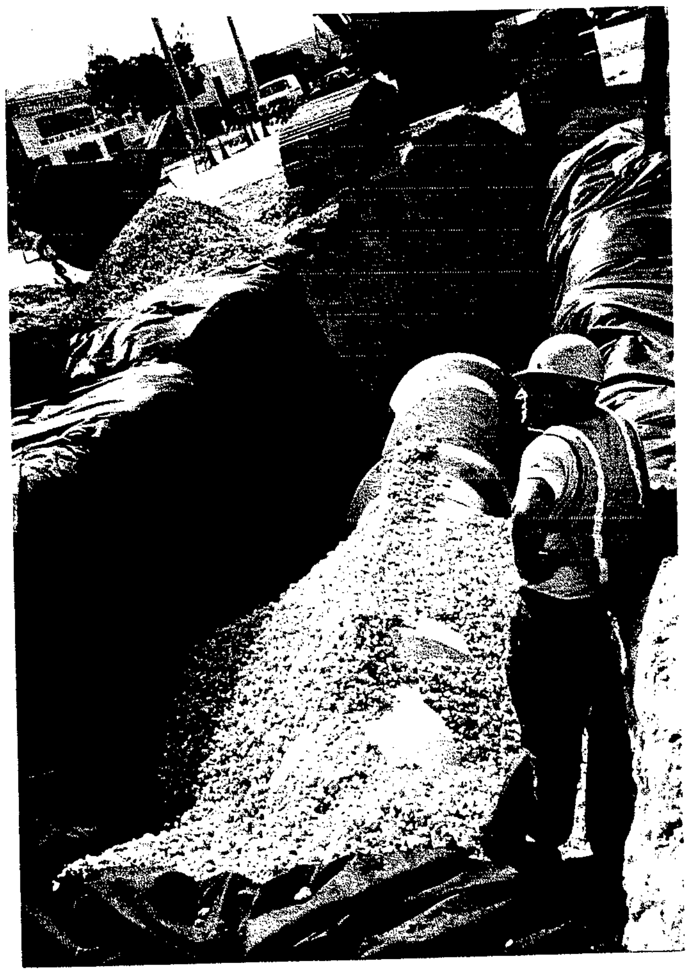


Figure-1. Milam Dairy and the North West 43rd Street Project in Miami

of these sites. These included:

1. US-1 improvement-project at Homestead - a two-year project ended in early 1997, No. 57 stones were used as backfill material. Filter fabric was used.

2. Flagler St. and 72nd Avenue - began in the late 1994 and ended in the middle of 1996. Excavated soil was used as the backfill. Backfilling was done under water without dewatering.

3. On Palmetto Expressway (SR 826) near Florida International University (University Park campus) - Three years-old project recently completed. Excavated soil was used as the backfill material.

4. Douglas Road (NW 37th Avenue) and Palmetto Expressway (SR 826) - project completed a year ago. A3 material was used as backfill material.

5. Milam Dairy Rd (NW 72nd Avenue) and NW 25th to 62nd Streets - project completed a year ago. French draining was the type of construction.

3.4 Summary

Site-visits were helpful in developing a better understanding of the nature and extent of the problem under investigation. Two ongoing project-sites were investigated in Miami. One of them involved installation of French draining and the other involved utility pipe laying and backfilling. The study of the completed and current projects was focused on:

(1) difficulty in following specifications,

(2) field procedures used by the contractors in reality,

(3) problems of measuring the degree of compaction under high water table, and

(4) occurrence of pavement-settlement due to lack of compaction.

A set of initial elevation measurements were taken from the sites of two recently completed projects near Milam Dairy Road and Douglas Road in February '97. In addition, a site visit was made in March by the principal investigator at the US-1 Improvement Project near

Homestead, where crushed-stone was being used as the backfill material. *Figure-2* shows a section under construction. A second set of elevation readings were taken from the project-sites at Milam Dairy Road and Douglas Road in July '97. Observations suggested no significant change in elevation indicating the fact that settlement did not occur.

It was observed that the specifications were not followed word to word. Often variations were made. Most of the variations were of the following types:

1) no tamping and no dewatering,

2) tamping without dewatering, or

3) dewatering without tamping.

To these investigators the issue was, however, the eventual quality of the roadway or pavement. Elevation measurements do not suggest any settlement that can be attributed to lack of adequate compaction of the underlying backfill. Among the completed projects, visited by the investigators, no settlement-related problem was observed.

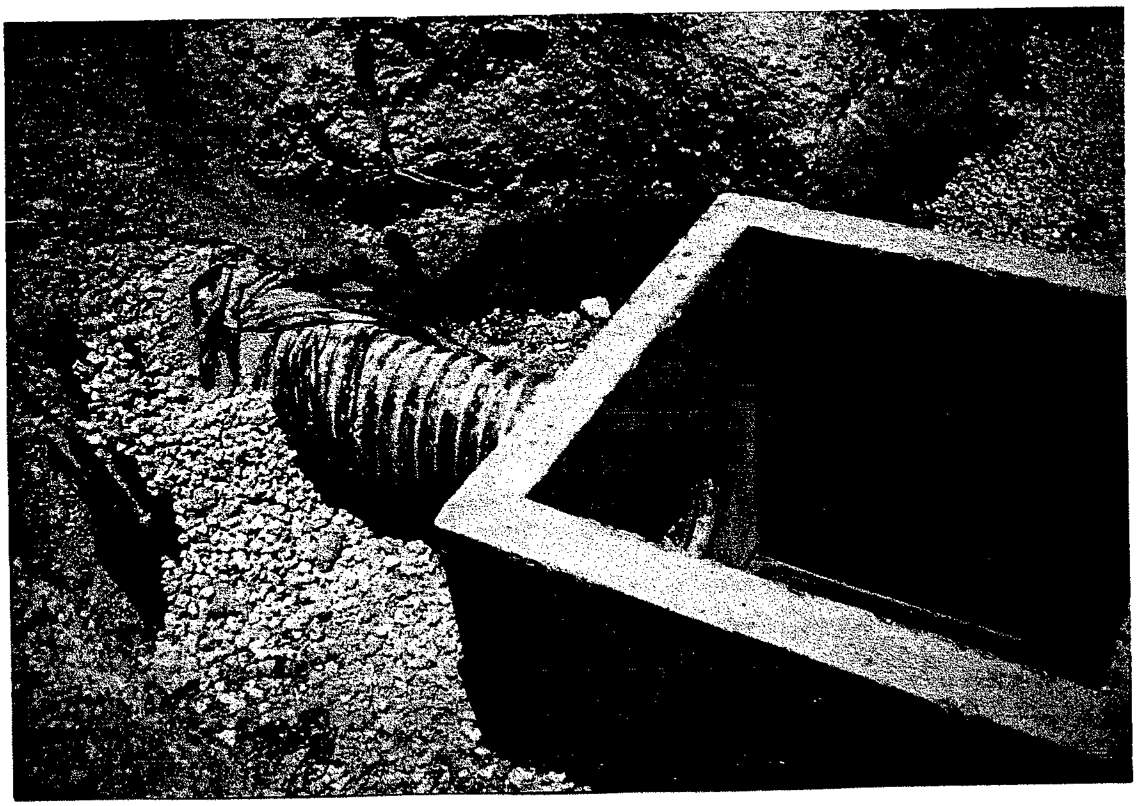


Figure-2. U.S.-1 Improvement Project in Homestead

Chapter 4 - Experimental Study and Results

A major portion of this research project involved field experimental study. The investigators were very fortunate to have a developer-builder company willing to participate and cooperate in this research study. The company let the investigators use a corner of their development site to dig trenches and lay pipes for the purpose of this project. The soil type was fine sand with some amount of silt. Five field conditions were tested. A detailed explanation of the plan and procedure follows.

4.1 Study Plan

Five different settings were designed to simulate five field conditions. They are:

Field Test Condition *A* - Control dry.

Field Test Condition *B* - Dump Soil, No Compaction.

Field Test Condition *C* - Dump Soil, Compact per FDOT specifications, no dewatering.

Field Test Condition *D* - Control wet, Compact per FDOT specifications, Dewatered with pump.

Field Test Condition *E* - Dump Soil, No Compaction, Dewatered with pump.

These conditions are described in detail in the following section. In all of these conditions, three 8-ft. long segments of 24-in. diameter precast concrete pipe were used. A thin layer of #57 rock was placed at the bottom of the pipe trench for each field condition in order to properly bed and align the three pipe segments. The thin bedding layer was placed in the wet for all field conditions except condition *A*, which was the control dry condition. The dimensions of the trenches are shown in the plan view of *Figure-3*. *Figure-3* also shows the seven locations for density and subsequent penetration tests. A nuclear density meter, as shown in *Figure-4*, was used to measure on-site density at every test location in order to make sure that the desired level of compaction was achieved. *Figure-5* shows the vibro-compactor used to attain compaction.

Standard Penetration Tests (SPT) were subsequently conducted and the resulting *N*-values were used to compare density of backfills of the five field test conditions.

4.2 Methodology

The field test conditions are listed in order in which they were conducted.

Field Test Condition *A* - Control dry. This condition involved backfilling in the dry condition, above water table. This was to be considered as the control condition. The site for this condition was selected at an elevated ground in order to avoid the presence of water table. *Figure-6* shows pipe segments in place and the trench being backfilled. The sequence of operations involved are: excavate trench, place and bed typical (24-inch dia.) pipe segments (3 segments, each 8-ft long were used), backfill and compact under ideal conditions in strict accordance with FDOT specifications (section 125-8.3 - Requirements for Pipe Culverts and Storm Sewers - For Non-Flexible Culvert Construction) as described below:

First Stage: Material beneath pipe haunches; 6" lifts-100% T-99.
Second Stage: Material along sides of pipe to at least 1' above pipe; 6" lifts-100% T-99.
Third Stage: Above second stage up to bottom of the subgrade or finished surface of embankment; 12" lifts-100% T-99.

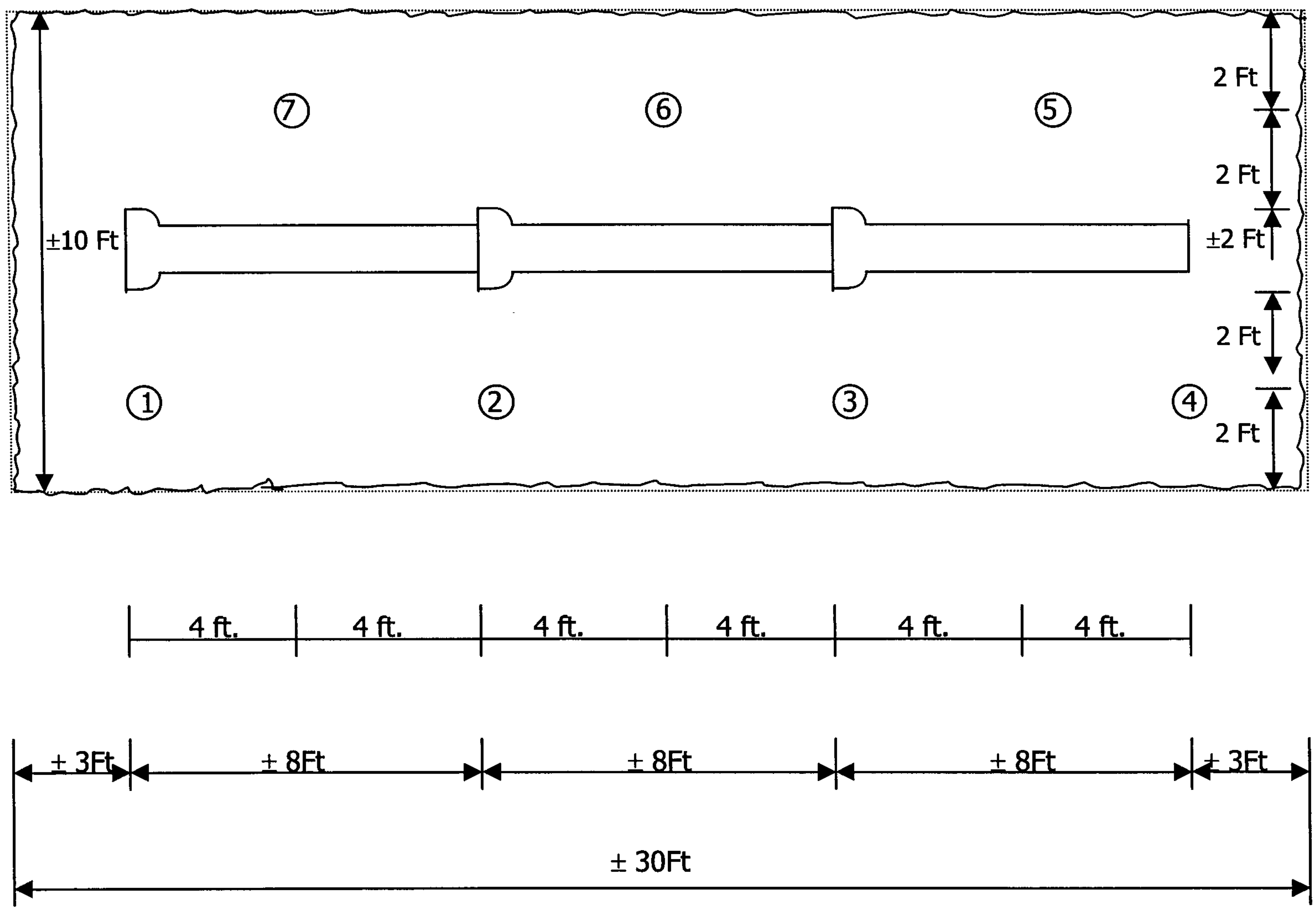


Figure-3. Plan View Showing Dimensions of the Trench

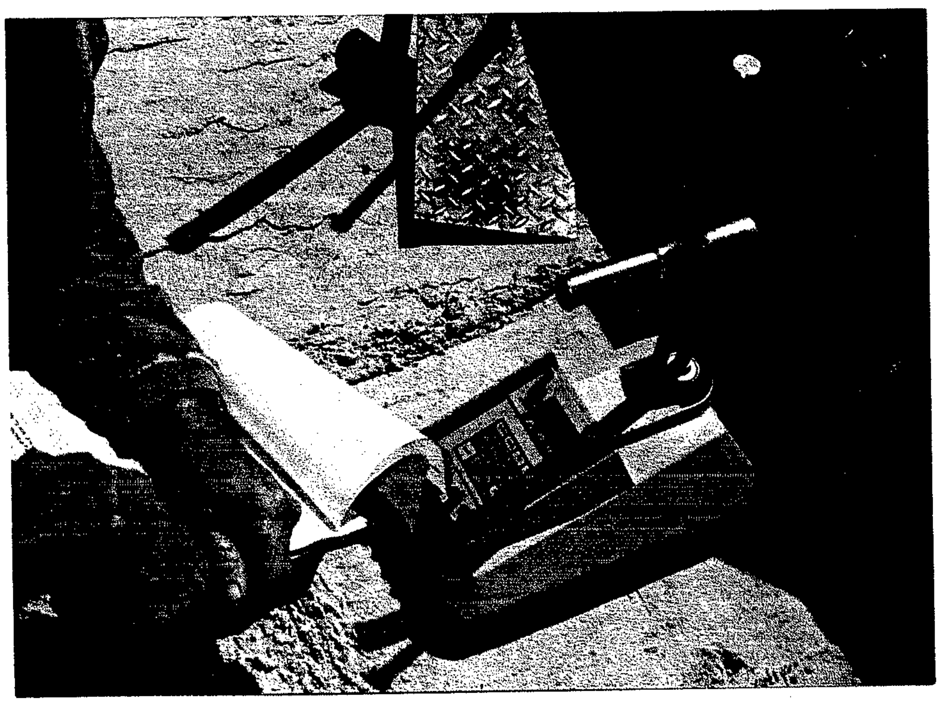


Figure-4. Nuclear Density Meter

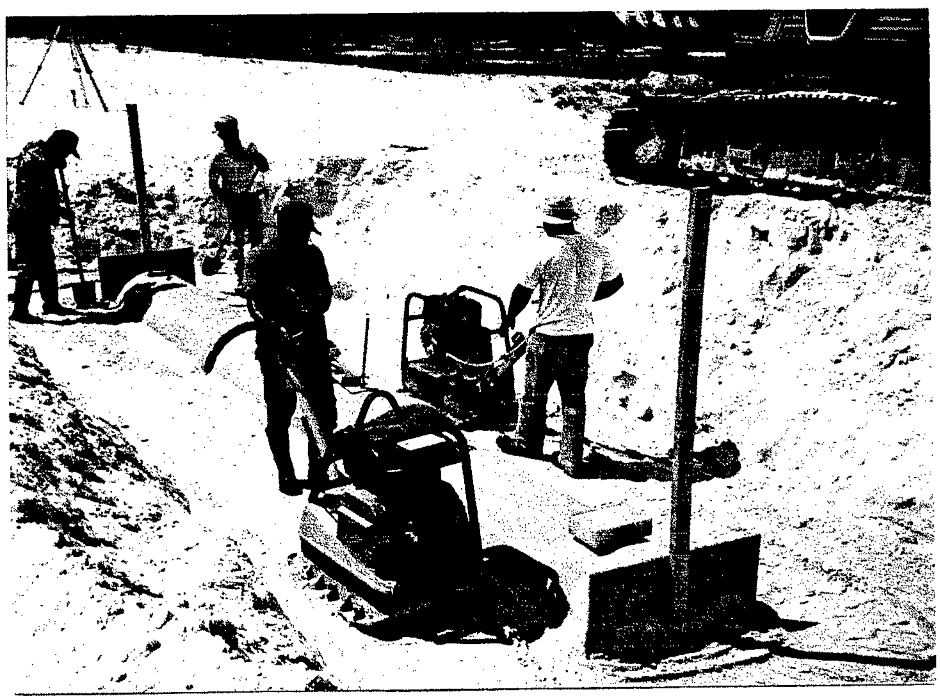


Figure-5. Use of Vibro-Compactor

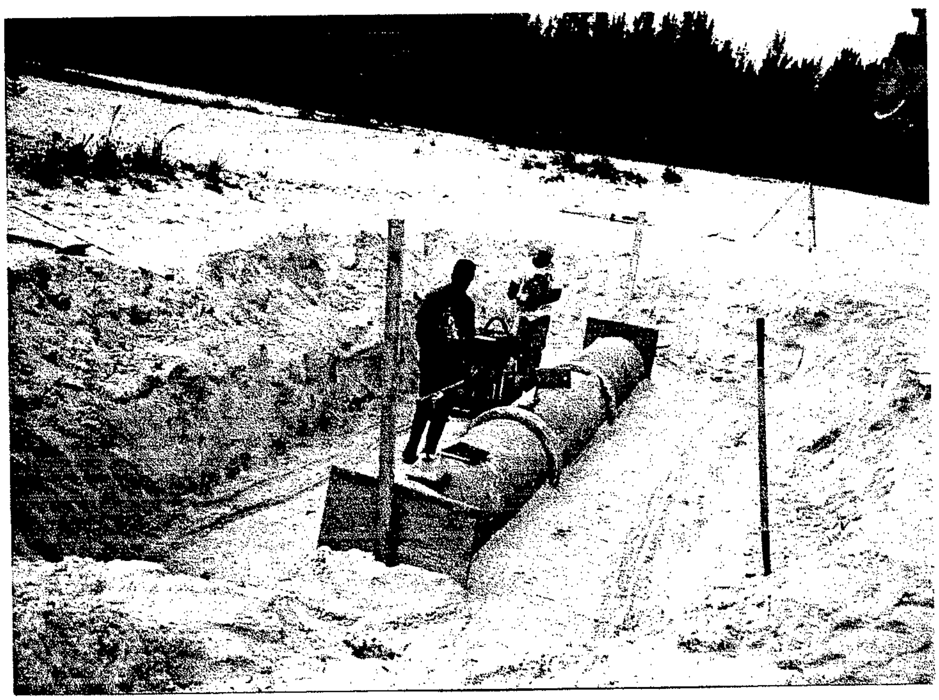


Figure-6. Pipe Sections and Backfilling

Figure-7 shows a typical section of the trench with an illustration of lifts in relation to the stages of compaction.

Field Test Condition *B* - Dump Soil, No Compaction: This simulated field condition involved backfilling under water table, without any compaction. The operations involved are described below in sequence.

Excavate a trench, as in Field Test Condition *A*, in an area where the natural water table is approximately 6-in. above the pipe once it is installed. Dewater trench long enough to place and bed pipe lengths as in Condition *A*. Subsequently let the open trench with bedded pipe sit overnight to allow ground water table to rise and stabilize at its natural level at 6-in. above the pipe. The next morning, backfill pipe as is normally done (no hand-tamping) in the field under wet conditions where dewatering is impractical by placing backfill to 1.5-ft. to 2-ft. above top of pipe, compacting to 100% of T-99. Continue backfilling in 1-ft. lifts compacted to 100% T-99. *Figure-8* shows this condition.

Field Test Condition *C* - Dump Soil, Compact per FDOT specifications, no dewatering: This field condition involved backfilling under water table, hand-tamping with a 2x4, as specified. The trench was excavated as in the Field Test Condition *B*, placing and bedding pipe in the wet. Backfilling was done in accordance with FDOT procedures (FDOT specifications 125-8.3.3) for backfilling under wet condition where dewatering was not practical or possible. This field test is illustrated in *Figure-9*.

Field Test Condition *D* - Control wet, Compact per FDOT specifications, Dewatered with pump: The trench was excavated as in Field Test Condition B, in an area where the ground water level was approximately 6-in. above the pipe. Dewatering was continued after pipe segments

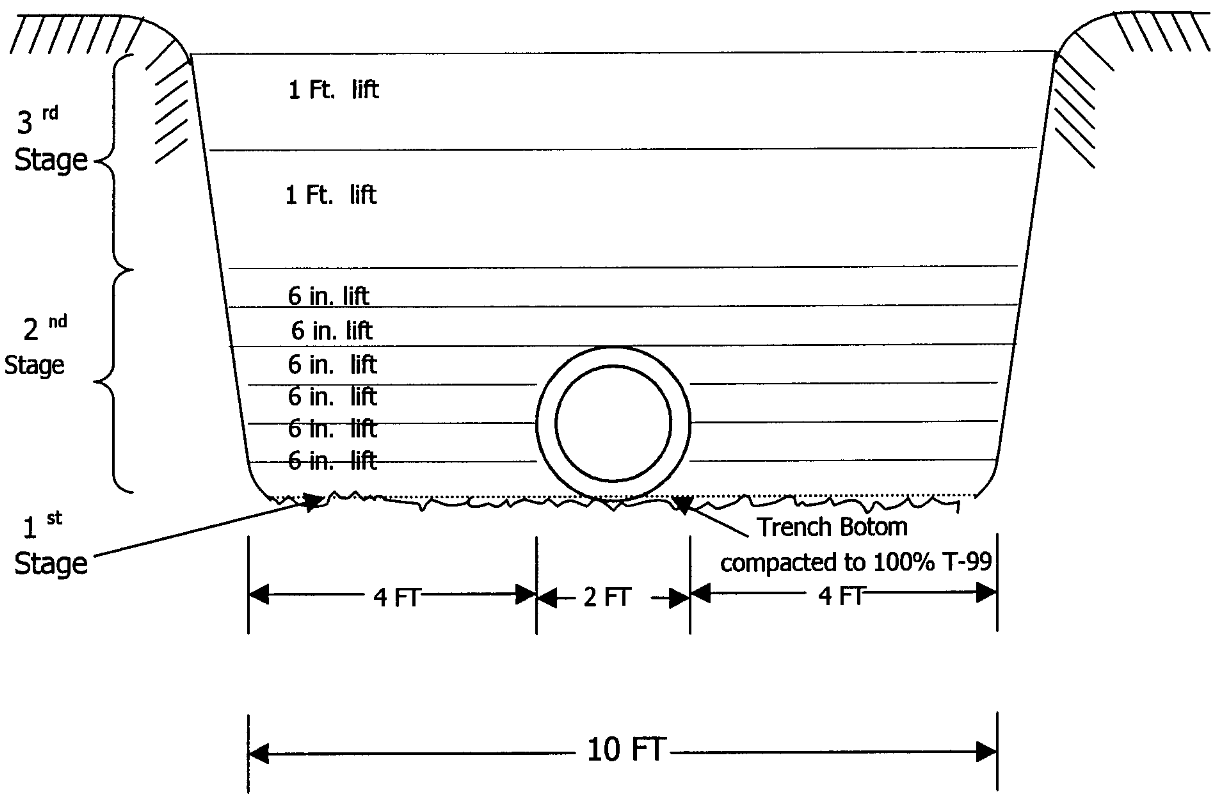


Figure-7. Section Illustrating Field Condition *A*

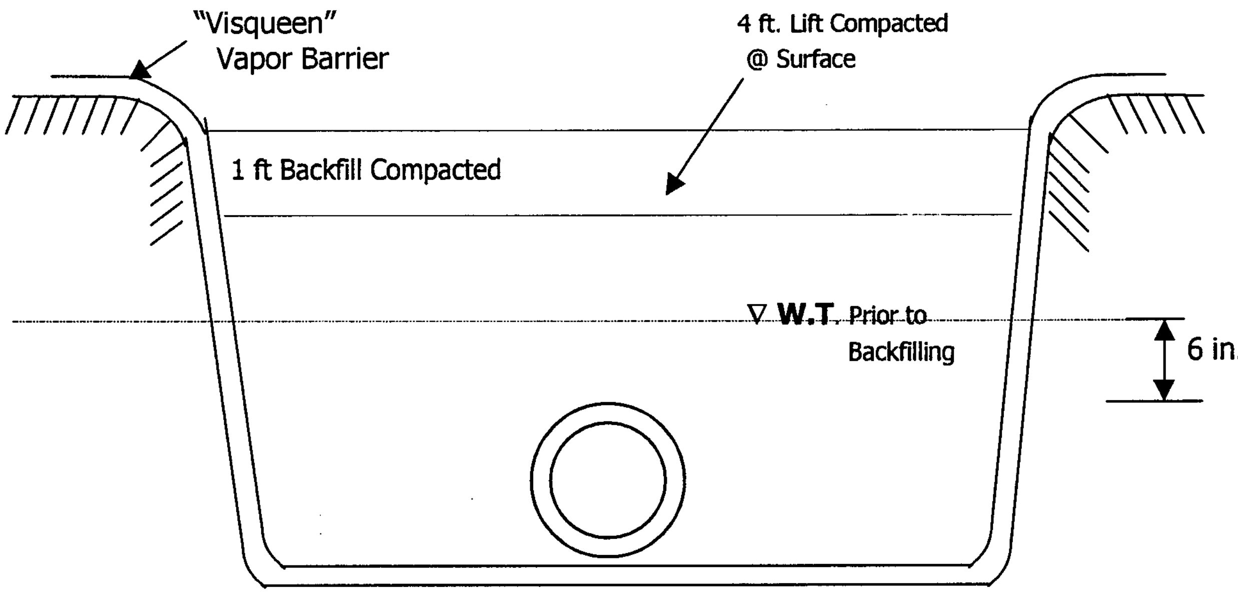


Figure-8. Section Illustrating Field Condition *B*

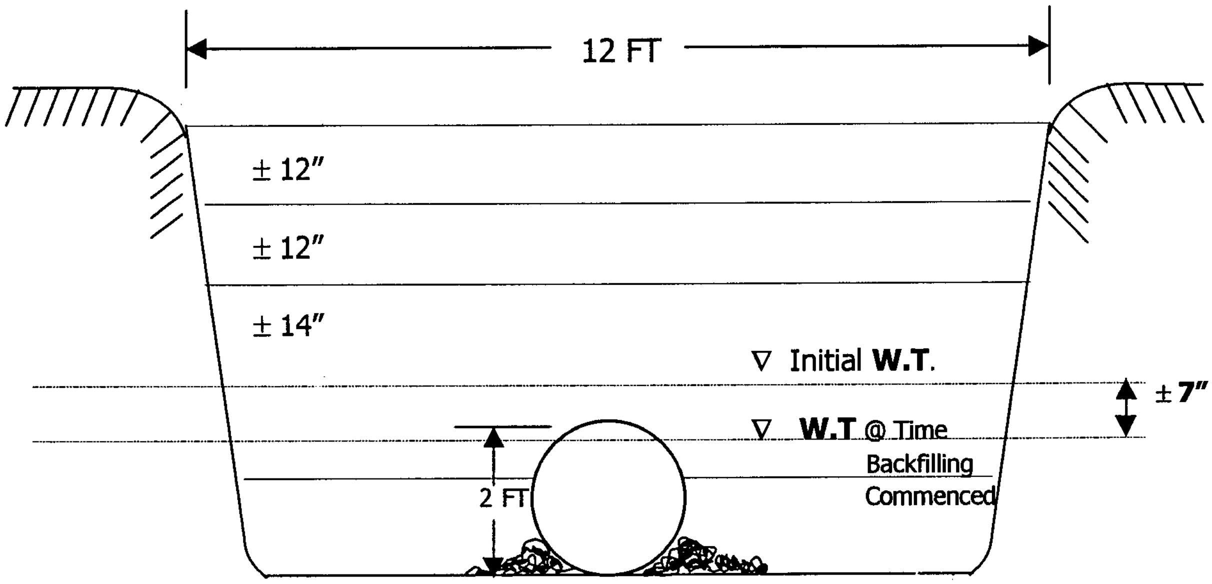


Figure-9. Section Illustrating Field Condition *C*

were placed and bedded. Backfilling and compaction were done in strict accordance with FDOT procedures. Due to limitations of dewatering procedure (pump and sump at each end of pipe), first backfilled lift had to be placed to "springline" (horizontal centroidal axis) of pipe since bottom of the trench could not be completely dewatered. This first lift and subsequent lifts were compacted in accordance with section 125-8.3, FDOT specifications. After backfilling and compaction, installation was allowed to stabilize by letting water table to return to its original level. Subsequently, SPT values were obtained as before. See *Figure-10* for an illustration of this field test condition.

Field Test Condition *E* - Dump Soil, No Compaction, Dewatered with pump: The trench was excavated as in Condition *D*, dewatering was continued after the pipe segments have been placed and bedded. First lift was backfilled to springline. East pump was shut down and sump was backfilled. The first lift was not compacted and the second lift was backfilled to top of the pipe. Again, no compaction was done and the third lift was backfilled to approximately 12-in. above pipe, which was about 6-in. above the water table. After backfilling the third lift the other pump was shut down, sump backfilled, and the fourth lift was backfilled to approximately 2-ft. above pipe. The fourth lift, which was 1.5-ft. above the water table, as well as the subsequent lifts were compacted to 100% of T-99 as per FDOT specifications. SPT values were obtained as before.

Selected photographs taken during the testing of Field conditions *B* through *E* are included in *Appendix-N*.

4.3 Results - Standard Penetration Test (SPT) *N*-Values

SPT values as recorded in the boring logs are shown in *Appendix-O*. These values are shown for all seven locations under each of the five field test conditions. The *N*-values thus obtained are also summarized in the tables of *Appendix-P*.

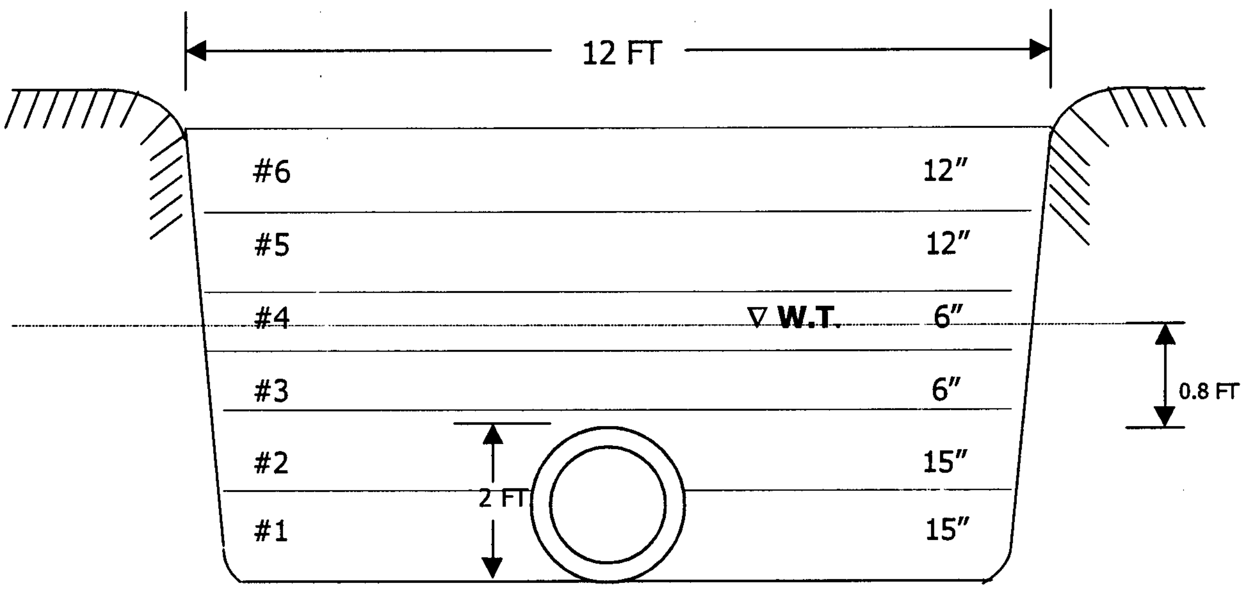


Figure-10. Section Illustrating Field Conditions *D* and *E*

Chapter 5 - Analysis and Interpretation of Results

The main objective of this research study was to evaluate the variations in soil conditions - determined by the SPT values - as a consequence of varying methods of compaction. In this chapter, we highlight the major findings of the five field tests conducted in simulated trenches.

5.1 Field Tests of Selected Conditions

In the first phase of the project, three field tests were performed. The investigators were fortunate to have a site ideal for testing the conditions stipulated in the project proposal. The three conditions investigated during the first phase were:

(1) Backfilling in the dry condition, above water,

(2) Backfilling under water table, according to the specifications, hand-tamping with a 2x4 as specified; and

(3) Backfilling under water table, without tamping.

Subsequently, Standard Penetration Test (SPT) *N*-values were obtained for all three conditions. In the second phase, two additional field conditions with dewatering were tested. According to the FDOT specifications, dewatering should be done during pipe installation and backfilling under certain conditions. As such, this should be considered as one of the "control" conditions and be compared with the situations where dewatering is not done. Another condition, with dewatering involved but with no compaction, was tested.

In summary, during the second phase, the research team:

(1) carried out field investigation on a simulated trench with constant dewatering during pipe installation and backfilling with periodic compaction according to FDOT specifications.

(2) carried out field investigation on a simulated trench with constant dewatering during pipe installation and backfilling by dumping (no compaction).

Standard Penetration Test (SPT) *N*-values for both conditions were obtained as in the three conditions of the first phase.

5.2 Analysis of Field Test Results

For each of the five field conditions, as noted above and described in Chapter 4, SPT *N*-values were obtained at seven locations. Average (mean) and standard deviations of these seven values are reported in *Table-1* and *Figure-11*.

5.3 Interpretation of Results

Several observations can be made from the results obtained. As expected, highest SPT values were obtained for the control dry condition (field condition *A*). Under this condition, density (100 percent of the maximum density as determined by *AASHTO T 99, Method C*) was obtained at 6-in. lifts for the material beneath pipe haunches, at 6-in. lifts for material along sides of pipe to 1-ft. above pipe, and at 1-ft. lifts up to finished surface.

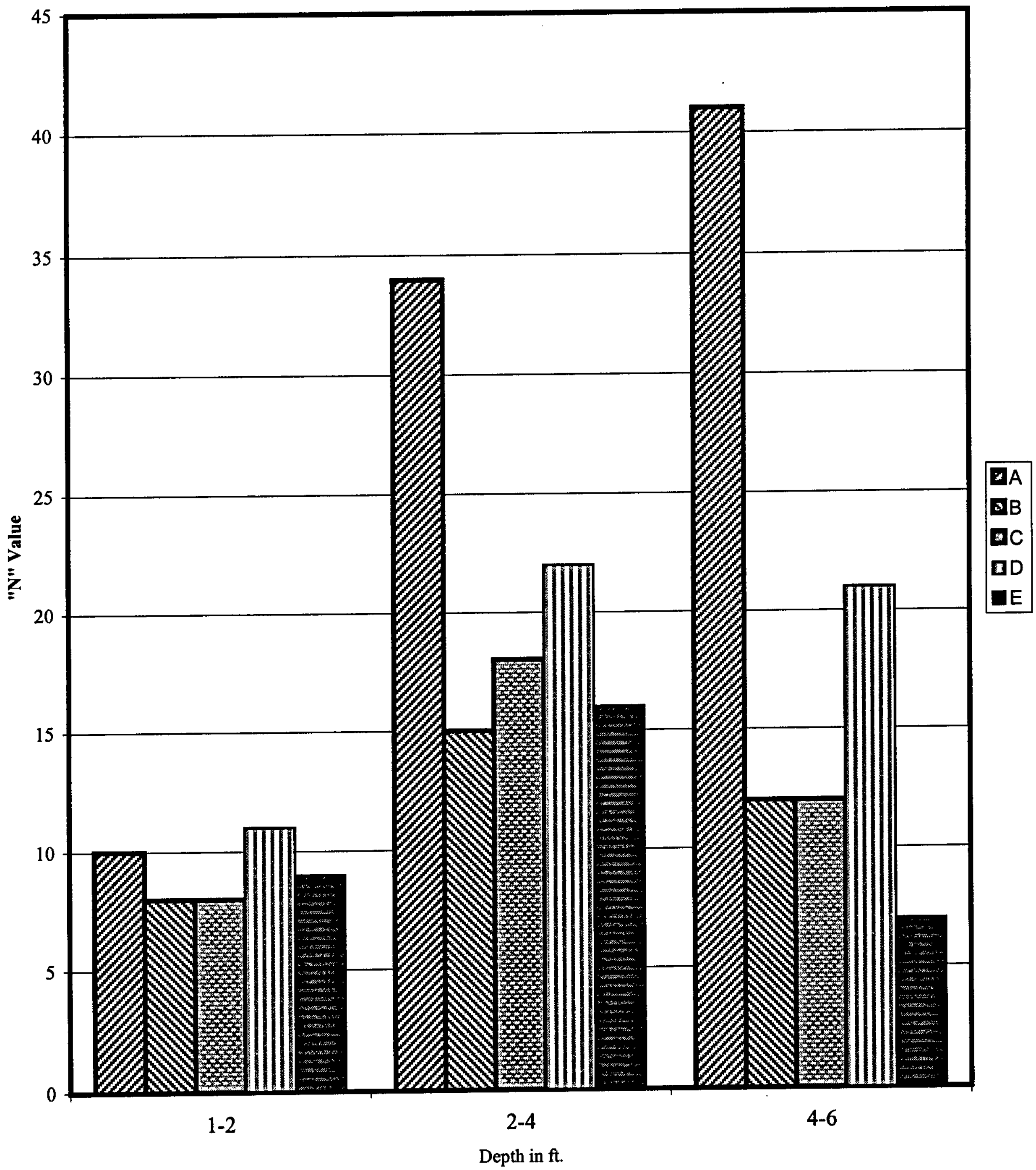
The next best set of SPT values were obtained for the control wet condition (field condition *D*). Although, at 1-2 ft. depth the SPT value under condition *D* is slightly higher than the corresponding value of condition *A*. This was, however, expected as under this condition a dewatering pump was used and backfilling material was compacted in lifts in accordance with FDOT specifications. The trench was excavated in an area where the ground water level was

Table-1. Average SPT *N*-Values

Field Conditions	Control Dry A	Dump Soil No Compaction B	Dump Soil Compact per DOT C	Control Wet Compact per DOT Dewatered w/pump D	Dump Soil No Compaction Dewatered w/pump E
Depth in ft.					
1-2	**10** *1.345*	**8** *1.902*	**8** *1.133*	**11** *2.000*	**9** *0.787*
2-4	**34** *3.047*	**15** *3.155*	**18** *1.718*	**22** *2.360*	**16** *2.690*
4-6	**41** *6.347*	**12** *2.516*	**12** *1.272*	**21** *7.033*	**7** *1.988*

Note: The number in bold in each cell is the "average" and the number in italics is the "*standard deviation*"

Figure-11. Bar Graph of Average SPT *N*-Values



about 6-in. (actual measurement indicated 0.8-ft. or 9.6-in.) above the top of pipe. Dewatering of the trench was continued after pipe was placed and bedded. Backfilling and compaction were done in strict accordance with FDOT specifications. Due to limitations of the dewatering procedure the first backfilled lift was placed to "springline" of pipe since bottom of the trench could not be completely dewatered. This first lift and subsequent lifts were compacted according to section 125-8.3, FDOT specifications. After backfilling and compaction, the installation was allowed to stabilize for the water table to return to its original level. SPT values were obtained at seven locations as before.

In field condition *B*, a trench was excavated as in field condition *A*, in an area where the natural water table was approximately 6-in. above the pipe once it was installed. The trench was dewatered long enough to place and bed pipe segments. The open trench with bedded pipe was let to sit overnight to allow the ground water table to rise and stabilize at its natural level at about 6-in. above the pipe. Backfilling was done as normally done in the field (by dumping the backfill material with no tamping) under wet conditions where dewatering was impractical. Backfill was placed to 1. 5-ft. to 2.0- ft. above top of pipe, compacting to 100% of *AASHTO T-99*. Backfilling was continued in 1-ft. lifts compacted to 100% of T-99.

In field condition *C*, the trench was excavated as in *B*, placing and bedding the pipe in the wet. Backfill material was compacted by hand-tamping in accordance with FDOT specifications for backfilling under wet conditions (Section 125-8.3.3). It was evident from the SPT values, that the result did not improve much from condition *B* to condition *C*.

In condition *E*, the trench was excavated very much like in condition *D*. Dewatering was continued after pipe segments had been placed and bedded. Lifts of backfill material were dumped without compacting or tamping. The third lift was backfilled to about 12-in. above pipe (about 6-in. above water table). Dewatering was stopped and the fourth lift was backfilled to about 2-ft. above pipe (about 1.5-ft. above water table). The fourth lift and the subsequent lifts were compacted to 100% of T-99 according to FDOT specifications. The SPT values obtained from field condition *E* were not significantly different from the values obtained for either conditions *B* or *C*. The average SPT value (as well as the individual SPT values at each of the seven locations) at the depth of 4-6 ft. for the condition *E*, was found to be very low as compared to other conditions. This may have been caused by the pre-existing subsurface soil condition at this location.

In conclusion, it can be said that, dewatering without compacting (condition *E*) yielded similar results as compacting with no dewatering (condition *C*). Both conditions *C* and *E* gave SPT values very close to that of condition *B*, in which neither dewatering nor compaction were done.

On the other hand, both dewatering and compacting done simultaneously showed a significant improvement in the SPT *N*-values obtained for condition *D*.

Chapter 6 - Suggestions for Further Investigations

6.1 Lessons Learned

The results of this research study, as detailed in Chapters 4 and 5, point out the difficulty of measuring density and achieving desired compaction under high water table. This study was undertaken as a recognition of the fact that existing specifications are difficult to follow. Dewatering, although suggested in the specifications, is not always practical and provision is made in the specs to allow the FDOT engineer-in-charge for waiving this requirement. An example of such a request for waiving this requirement is shown in *Appendix-Q*. The new 1999 edition of the FDOT specifications allows use of certain types of coarse aggregates as backfill material under specific circumstances. It was observed that, ramming of backfill material under water as specified, was not always followed. We found out, from both observations of recently completed projects, and from the results of experimental test conditions, that these deviations do not necessarily make the backfilled facility unusable or its performance unsuitable. This observation raises the question of whether the existing specs should be relaxed. The issue is further discussed in the final chapter of this report.

6.2 Suggestions for Future Research

In the following, a number of areas for further investigation are pointed out. Lessons learned from this project can serve well in formulating future research studies as outlined below.

6.2.1 Long-Term Field Study on Actual Roadway Under Traffic

While several valuable and useful findings came out of this research study, the scope of the project was limited by various constraints, time being one of them. Actual project sites, preferably ongoing at the time of project commencement, can be selected for conducting a pilot study aimed at finding out the effects of vehicular traffic on the backfill material, where backfilling is going to be done under water using conventional methods. The test sites should be observed for a period of two to three years to study the long-term effects. In addition to controllable variables such as, compaction techniques and type of backfill materials, effects of uncontrollable factors such as volume of traffic, and weather-pattern can be investigated under such a scheme.

6.2.2 Flowable Fill as Alternative Backfill Material

Flowable backfill is one of the alternatives to backfill the trench after placing the pipe. In flowable backfill, a concrete-like mixture containing cement, water, sand, and fly ash is first poured in to cover the pipe before the trench is backfilled with spoils (http://www.masterbuilders.com/press/7.htm). The term Controlled Low Strength Materials (CLSM) has been established by the American Concrete Institute (ACI) for what is commonly known as flowable fill, backfill, trenchfill, controlled density fill (CDF), flowable mortar, flowable grout, cellular concrete and foamed concrete (ACI 229R-94 Report - by ACI Committee 229). Flowable fill is a fluid, low strength material alternative for project owners, and contractors to meet a project's backfill needs. A slurry-like material with the consistency of pancake batter, flowable fill is self-leveling, can be placed in one lift with minimal labor and no vibration or tamping, and reaches 95% or more compaction within a few hours of placement.

Section 121 of the FDOT Supplemental Specifications addresses flowable fill (*Appendix - R*). Construction requirements are detailed in subsection 121-5. In addition, DOT specifications from the states of Pennsylvania and Indiana were obtained and are included in this report as

Appendix -S and *Appendix -T* respectively. Pennsylvania specifications address the issue of pipe bedding and backfill and utility trench backfill respectively. A crucial step in flowable backfill is to prepare the right mixture. The flowable fill mixture normally contains four components, cement, water, sand, and fly ash. The right percentage of each of these components will produce a mixture with favorable structural and heat transfer characteristics. Four types of mix designs for flowable fills are specified in Table 1 of Pennsylvania specifications.

If flowable material is to be used in areas where water table is high, dewatering to some extent would be necessary in order to pour the material into the trench. Sufficient time must also be allowed for the material to harden before the water table can be allowed to rise to its natural level. As a result, it may not be an inexpensive alternative of backfilling. Its advantages - both tangible and intangible - should, however, be considered. Although flowable fill costs more per cubic yard ($40.00 to $45.00 per cubic yard depending on strength, location of delivery, etc. according to a quote by Tarmac Florida, Inc. *Appendix -U*) than most soil or granular backfill materials, its many advantages result in lower in-place costs. A list of the following fifteen reasons to use flowable fill was found in the website, http://www.Alby.com/ready/flow15.htm.

1. Readily available - Ready mixed concrete producers, using locally available materials, can produce flowable fill to meet most project specifications.
2. Easy to deliver - Ready mix trucks can deliver specified quantities of flowable fill to the jobsite whenever the material is needed.
3. Easy to place - Depending on the type and location of void to be filled, flowable fill can be placed by chute, pump, conveyor, or bucket. Because flowable fill is self-leveling, it needs little or no spreading or compacting. This speeds up construction and reduces labor costs.
4. Versatile - Flowable fill mix designs can be adjusted to meet project needs - structural or excavational.
5. Strong and durable - Load-carrying capacities of flowable fill typically are higher than those of

compacted soil or granular fill. Flowable fill is also less permeable, thus more resistant to erosion. Structural fills can be designed to achieve 28-day strengths of 1200 psi.

6. Can be excavated - Flowable fill having compressive strengths of 50-100 psi is easily excavated with conventional digging equipment yet is strong enough for most backfill needs.

7. Requires less inspection - During placement, soil backfill must be tested after each lift for sufficient compaction. Flowable fill self-compacts consistently and doesn't need expensive field testing.

8. Allows fast return to traffic - The quick placement of flowable fill minimizes downtime for pavement repairs.

9. Won't settle - Flowable fill does not form voids during placement and won't settle or rut under loading.

10. Reduces excavating - Because flowable fill needs no compaction, it allows for narrower trenches. Conventional fill materials must be compacted - excavators have to widen trenches to accommodate the compaction equipment.

11. Improves safety - Workers can place flowable fill in a trench without entering the trench, reducing their exposure to possible cave-ins.

12. Allows all-weather construction - Flowable fill will displace any standing water left in a trench from rain or melting snow, reducing the need for dewatering pumps.

13. Reduces equipment needs - Unlike conventional fill materials, flowable fill can be placed without loaders, rollers, or tampers.

14. Requires no storage - Storing fill on site is not necessary with flowable fill, there is also no leftwover fill to haul away.

15. Makes use of waste by-product - Fly ash is by-product of power plants that burn coal to generate electricity. Flowable fill containing fly ash benefits the environment by making use of this industrial waste material.

For more information on flowable fill, please visit the websites listed below:

http://www.igshpa.okstate.edu/Publications/source/1995/9508/aug.95.htm

http://www.irmca.com/ff_basic.htm

http://www.irmca.com/ff_res.htm

http://www.irmca.com/ff_spec.htm

Chapter 7 - Conclusions and Recommendations

7.1 Limitations of the Study

Before summarizing the conclusions of the study and presenting its recommendations, we feel that it is very important that the scope of the project including its limitations be clearly pointed out. First of all, the five simulated field conditions should be considered as idealized models. Conditions that most likely would prevail in the field will be different in many respects, such as soil conditions, weather conditions, degree of compaction, lift heights, etc. Secondly, vehicular movement was not considered as a variable in this study. Moving loads over a period of time are expected to have some impact on the condition of backfill. Thirdly, it should be noted that SPT *N*-values can only give an indirect measure of degree of compaction, and hence, density. Thus, *N*-values were used only for comparative purposes, not as standards. Finally, the numbers of tests were limited by budgetary constraints. For obtaining statistically significant results, each field condition should have been tested at least three times.

Despite the limitations outlined above, we strongly feel that the findings of this investigation added significant value to the existing body of knowledge on this subject and can be useful for developing improved scopes of future research ideas.

7.2 Conclusions

The major findings of this research study are listed below:

- Condition of the underlying backfill improves when both dewatering and compaction are done. The SPT *N*-values, when neither dewatering nor hand-tamping was done, were observed to be significantly lower in comparison to dewatering /compaction results.

- Hand-tamping without dewatering, does not improve the density of soil when compared to backfilling without dewatering or hand-tamping. This finding raises the question: Should the provision of hand-tamping under water, as stated in the FDOT specifications Section 125-8.3.4, be revisited?
- Dewatering, without simultaneous compaction, does not result in a significant improvement of the density of the backfill. This process of backfilling is not prescribed or suggested in the FDOT specifications, but perhaps, it is practiced anyway. On the basis of this finding, we recommend that this practice be discontinued. If dewatering is to be done, soil should be compacted following due procedure.

7.3 Recommendations

We recommend another thorough look at the relevant sections of the FDOT specifications in order to come up with specific revisions based on the findings of this study. Although, we were able to answer the research questions as outlined earlier in this report, we do not suggest any changes in these specifications without further investigation. To the main question "how effective is hand-tamping without dewatering," we do have an answer: We found out that it was not noticeably effective.

Consequently, the choices are -

(1) Make the provision of dewatering mandatory, or

(2) Make the provision of hand-tamping optional.

Choice (2) can be accepted only if it can be determined that the resulting backfill, when done under the water table, will have sufficient bearing strength and will not settle under structural-load or vehicular traffic. Perhaps some attempt at compaction verification utilizing the

SPT may be contemplated, especially if SPT results could be “calibrated” to specific project conditions. From our observations of existing backfilled roadways that were allegedly completed without dewatering and hand-tamping, we did not find any noticeable settlement-related problems. Given the fact that dewatering may not be practical under some situations (such as flooding of neighboring areas), choice (2) should be further investigated.

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2. "Settlement analysis of granular soils based on cone penetration tests," by Rainer, K., Massarsch Royal Institute of Technology (KTH), Stockholm, Sweden, CPT'95 Paper A11, http://130.237.60.125/aom/SGF/CPT95/Contrib/a11.htm
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16. http://www.irmca.com/ff_spec.htm

Appendix-A: Principles of Compaction

PRINCIPLES OF COMPACTION

Compaction increases the strength characteristics of soils, thereby increasing the bearing capacity of foundations constructed over them. Compaction also decreases the amount of undesirable settlement of structures and increases the stability of slopes of embankments.

Compaction, in general, is the densification of soil by removal of air, which requires mechanical energy. The degree of compaction of a soil is measured in terms of its dry unit weight. When water is added to the soil during compaction, it acts as a softening agent on the soil particles. The soil particles slip over each other and move into a densely packed position. The dry unit weight after compaction first increases as the moisture content increases. At zero moisture content, the moist unit weight is equal to the dry unit weight. When the moisture content is gradually increased and the same compactive effort is used for compaction, the weight of the soil solids in a unit volume gradually increases. Beyond a certain moisture content, any increase in the moisture content tends to reduce the dry unit weight. This is because the water takes up the spaces that would have been occupied by the solid particles. The moisture content at which the maximum dry unit weight is attained is generally referred to as the optimum moisture content.

The laboratory test used to obtain the maximum dry unit weight of compaction and the optimum moisture content is called the Proctor compaction test. In this test, the soil is compacted in a mold that has a volume of 1/30 cu ft. The diameter of the mold is 4 in. During the test, the mold is attached to a base plate at the bottom and to an extension at the top. The soil is mixed with varying amounts of water and then compacted in three equal layers by a hammer that delivers 25 blows to each layer. The hammer weighs 5.5lb and has a drop of 12in. For each test, the moisture content of the compacted soil and its dry unit weight is determined in the laboratory.

The values of the dry unit weight thus determined can be plotted against the corresponding moisture contents to obtain the maximum dry unit weight and the optimum moisture content for the soil.

With the development of heavy rollers and their use in field compaction, the standard Proctor test was modified to better represent field conditions. This is referred to as the modified Proctor test. The same mold is used to conduct the test as in the standard proctor, but the soils compacted in 5 layers by a hammer that weighs 10 lb. The number of hammer blows per layer is kept at 25. Because it increases the compactive effort, the Modified Proctor test results in an increase of the maximum dry unit weight of the soil. The increase of the maximum dry unit weight is accompanied by a decrease of the optimum moisture content.

In most specifications for earth work, the contractor is specified to achieve a compacted field dry unit weight of 90% to 100% of the maximum dry unit weight determined in the laboratory by either the Standard or Modified Proctor test.

The standard procedures for determining the field unit weight of compaction include

1. **Sand cone method.**
2. **Rubber balloon method.**
3. **Nuclear method.**

Following is a brief description of these methods:

Sand Cone Method: The sand cone consists of a glass or plastic jar with a metal cone attached at its top. The jar is filled with very uniform dry Ottawa sand. The weight of the jar, the cone, and the sand filling the jar is determined. In the field, a small hole is excavated in the area where the soil has been compacted. If the weight of the moist soil excavated from the hole is determined and the moisture content of the excavated soil is known, the dry unit weight of the soil can be determined by calculation. After excavation of the hole, the cone with the sand filled jar attached to it is inverted and placed over the hole. Sand is allowed to flow out of the jar to fill the hole and cone. After that, the weight of the jar, the cone, and the remaining sand in the jar is determined. Using mathematical equations, the dry unit weight of compaction made in the field can be determined.

Rubber balloon method: The procedure for the rubber balloon method is similar to that for the sand cone method; a test hole is made and the moist weight of soil removed from the hole and its moisture content are determined. However, the volume of the hole is determined by introducing into it a rubber balloon filled with water from a calibrated vessel, from which the volume can be read directly, and the dry unit weight is again determined by calculation.

Nuclear method: Nuclear density meters are now often used for determining the compacted dry unit weight of soil. The density meters operate either in drilled holes or from the ground surface. The instrument measures the weight of wet soil per unit volume and also the weight of water present in a unit volume of soil. The dry unit weight of compacted soil can be determined by subtracting the weight of water from the moist unit weight of soil.

Measurement of Bearing Capacity

The allowable bearing capacity of a sand depends primarily on the relative density, stress history, the position of the water table relative to foundation level and the size of the foundation. Of secondary importance are particle shape and grading. Both the magnitude of settlement and the value of the shear strength parameter are strongly dependent on relative density.

Standard Penetration Test:

The standard penetration test, is used to assess the insitu relative density of a sand deposit. The test is performed using a split barrel sampler, 50mm external diameter, 35mm internal diameter and about 650mm in length, connected to the end of boring rods. The sampler is driven into the sand at the bottom of a cased borehole by means of a 65kg hammer falling freely through a height of 760mm onto the top of the boring rods. The borehole must be cleaned out to the required depth, care being taken to ensure that the material to be tested is not disturbed. Initially the sampler is driven 150mm into the sand to seat the sampler and to by-pass any disturbed sand at the bottom of the borehole. The number of blows required to drive the sampler a further 300mm is then recorded, this number is called the standard penetration resistance(N). The number of blows required for each 75mm of penetration(including the initial drive) should be recorded separately. If 50 blows are reached before a penetration of 300mm, no further blows should be applied but the actual penetration should be recorded. At the conclusion of a test the sampler is withdrawn and the sand extracted. Tests are normally carried out at intervals of between 0.75 m and 1.50 m to a depth at least equal to the width(B) of the foundation. If the test is carried out in gravely soils the driving shoe is replaced by a solid 60 degree cone. There is evidence that slightly higher results are obtained in the same material when the normal driving shoe is replaced by the 60 degree cone.

When testing below the water table, care must be taken to avoid entry of water through the bottom of the borehole as this would tend to loosen the sand due to upward seepage pressure. Water should be added as necessary to maintain the water table level in the borehole(or at the level required to balance any excess pore water pressure). When the test is carried out in very fine sand or silty sand below the water table the measured N value, if greater than 15, should be corrected for the increased resistance due to negative excess pore water pressure set up during driving and unable to dissipate immediately. The corrected value is given by: $N' = 15 + 1/2(N-15)$.

The relative density of a sand can be described in general terms, on the basis of standard penetration resistance as follows:

N-Value	Classification
0-4	Very Loose
4-10	Loose
10-30	Medium dense
30-50	Dense
>50	Very ~~loose~~ dense

Dutch Cone penetration test: This method covers the determination of end bearing and side friction, the components of penetration resistance which are developed through the steady slope penetration of a pointed rod into soil. A cylindrical cone with a cross section of 100mm2 and an apex angle of 60 degrees is pushed 80 mm vertically into the ground at a constant rate of penetration of 10 to 20mm/s when obtaining resistance data. During penetration, measurements are made of the cone resistance and the side friction against the cylindrical shaft just above the tip. The resistance of the cone at any depth is called the cone penetration resistance. This method includes the use of both cone and friction cone penetrometers, of both the mechanical and electrical types. Mechanical penetrometers operate incrementally, using a telescoping penetrometers tip, resulting in no movement of the push rods during the measurement of the resistance components. The design constraints for penetrometers preclude a complete separation of the end bearing and side friction components. Electric penetrometers are advanced continuously and permits separate measurement of both components. Differences in shape and method of advance between cone penetrometer tips may result in significant differences in one or both resistant components.

Every report of a cone or friction cone sounding shall include a graph of the variation of cone resistance (in units of tones plus square foot or one hundred KPa) with depth in feet or meters. Successive cone resistance test values from the mechanical cone and friction cone penetrometers, usually determined at equal increments of depth and plotted at the depth corresponding to the depth of the measurement, maybe connected with straight lines as an approximation for a continuous graph.

Appendix-B: Sample Cover Letter and Survey

Florida International University

October 4, 1996

Mr. Larry Scofield
Transportation Engineer Supervisor
Arizona Department of Transportation
7755 S. Research Park Dr. - Suite # 106
Tempe, AZ 85284

Due to Florida's abundance of low lying regions, the Florida Department of Transportation (FDOT) is continually faced with the situation of placing and backfilling utility pipes and culverts in high water table areas. The problem that arises from this situation is the uncertainty associated with the compactive integrity of the backfill placed at or below the water table. In response to this problem, Florida International University (FIU), in conjunction with the FDOT, is conducting research to study this common occurrence. As a part of this effort, the researchers are sending out the following questionnaire to the various state and provincial highway agencies throughout the United States and Canada. Your timely participation is vital to the success of this study, and the researchers would like to thank you in advance for your time and effort in responding to this survey.

Sincerely,

Irtishad Ahmad, Ph.D., P.E.
Associate Professor

Department of Construction Management • College of Engineering and Design
VH 230, University Park, Miami, Florida 33199 • (305) 348-3172 • FAX (305) 348-2766

FIU/FDOT SURVEY
[Backfilling utility pipes under high water table]

Are you aware of, or have you experienced this problem? Yes/No

If yes, what methods or alternatives were used?
(attach additional pages if necessary.)

Is this problem addressed in your departmental specifications? Yes/No

If yes, please send a copy of the sections of your specifications relating to this problem situation.

We will greatly appreciate any other documentation and/or information on this topic. The researchers would again like to thank you for your cooperation. If you have any additional comments regarding this study, please attach them with your response. Please send your response to the address given below.

Irtishad Ahmad, PhD, PE
Associate Professor
Department of Construction Management
Florida International University
Miami, FL 33199
E-mail: ahmad@eng.fiu.edu

Appendix-C: Specifications from California

After completion of the substructure, the cofferdams with all sheeting and bracing shall be removed at least to 0.6-m below the level of the streambed, by the Contractor at the Contractor's expense, and the removal shall be performed in a manner that will not disturb or mar the finished concrete or masonry.

19-3.04 Water Control and Foundation Treatment.—The methods to be used to control and remove water at excavations where seal courses are not shown on the plans shall be at the option of the Contractor and may include, but are not limited to, well point systems, pumping sumps, cofferdams, or concrete seal courses. If the Contractor elects to use a concrete seal course at those locations, the provisions of the fourth paragraph and the first 2 sentences of the fifth paragraph of Section 51-1.10, "Concrete Deposited Under Water," shall not apply for spread footings and the entire Section 51-1.10 shall not apply to pile footings. The successful performance of the seals, if used, shall be solely the responsibility of the Contractor.

At locations where concrete seal courses are shown on the plans, and the Engineer determines that a seal course shall be used, control and removal of water shall be accomplished by the use of a cofferdam, a concrete seal course placed in accordance with the requirements of Section 51-1.10, "Concrete Deposited Under Water," and dewatering pumps.

When no piles are used and footing concrete, culverts or other structures are to rest on an excavated surface other than rock, the following shall apply:

Care shall be taken during excavation to prevent disturbing the foundation. If ground water is encountered during excavation and a concrete seal course is not to be used, dewatering shall be commenced and shall proceed in advance of or concurrently with further excavation. The foundation shall be free of water at the time footing concrete or pipes are placed, and water control shall continue as necessary to prevent damage to the work.

If suitable foundation material has been disturbed by the Contractor's operations, has been damaged by water or has been removed for the Contractor's convenience in dewatering the foundation, the foundation shall be restored by the Contractor, at the Contractor's expense, to a condition at least equal to the undisturbed foundation as determined by the Engineer. For culverts, the material used to replace the damaged or removed foundation material shall be Class 2 aggregate base, conforming to the provisions in Section 26, "Aggregate Bases," and shall be compacted as required for structure backfill, unless the Engineer determines that a different type of material is required to provide the equivalent bearing capacity.

When undisturbed original material at the planned grade of the excavation is determined by the Engineer to be unsuitable material, as defined in Section 19-2.02, "Unsuitable Material," the Engineer will direct corrective work and the cost of the corrective work, other than structure excavation and backfill within the limits described in Section 19-3.07, "Measurement," will be paid for as extra work as provided in Section 4-1.03D.

When footing concrete or masonry is to rest upon rock, the rock shall be fully uncovered and the surface thereof shall be removed to a depth sufficient to expose sound rock. The rock shall be roughly leveled or cut in steps, and shall be roughened. Seams in the rock shall be grouted under pressure or treated as the Engineer may direct and the cost thereof will be paid for as extra work as provided in Section 4-1.03D.

When excavating for culverts, other than arch culverts, and solid rock or other unyielding material is encountered at the planned elevation of the bottom of the culvert, the material shall be removed below the bottom of the culvert to a depth of 0.05- of the height of embankment over the top of culvert, but in no case less than 0.3-m nor more than 1.5 m. The resulting trench below the bottom of the culvert shall be backfilled with structure backfill material in accordance with the provisions in Section 19-3.06, "Structure Backfill." The excavation and backfill below the planned elevation of the bottom of the culvert will be paid for as extra work as provided in Section 4-1.03D.

When footings are to be supported on piles, excavations shall be completed to the bottom of the footings before any piles are drilled or driven therein. When swell or subsidence results from driving piles, the Contractor shall, at the Contractor's expense, excavate, or backfill with suitable material, the footing area to the grade of the bottom of the footing as shown on the plans. If material under footings is such that it would mix into the concrete during footing placement or would not support the mass of the fluid concrete, the Contractor shall, at the Contractor's expense, replace the material with suitable material, install soffit forms or otherwise provide a suitable platform on which to cast the footing.

19-3.05 Inspection.—In order to determine the character of the foundation material, the Contractor shall, if directed by the Engineer, dig test pits and make test borings and foundation bearing tests, and the cost thereof will be paid for as extra work as provided in Section 4-1.03D.

Whenever any structure excavation is completed substantially to grade, the Contractor shall notify the Engineer who will make an inspection of the foundation. No concrete or masonry shall be placed until the foundation has been approved by the Engineer.

19-3.06 Structure Backfill.—Backfill material shall be placed in uniform layers and shall be brought up uniformly on all sides of the structure or facility. The thickness of each layer of backfill shall not exceed 0.2-m before compaction except that when compaction is done by ponding and jetting, the thickness shall not exceed 1.2 m.

Compaction equipment or methods which may cause excessive displacement or may damage structures, shall not be used.

Structure backfill shall not be placed until the structure footings or other portions of the structure or facility have been inspected by the Engineer and approved for backfilling. No backfill material shall be deposited against the back of concrete abutments, concrete retaining walls, or the outside walls of cast-in-place concrete structures until the concrete has developed a strength of not less than 17 MPa in compression, or until the concrete has been in place for 28 days, whichever occurs first.

Backfill at the inside of bridge wingwalls and abutments shall be placed before curbs or sidewalks are constructed over the backfill and before railings on the wingwalls are constructed.

Compaction of structure backfill by ponding and jetting will be permitted when, as determined by the Engineer, the backfill material is of such character that it will be self-draining when compacted and that foundation materials will not soften or be otherwise damaged by the applied water and no damage from hydrostatic pressure will result to the

Appendix-D: Specifications from Indiana

All the soil surrounding the stormsewer should be compacted to at least 95% of the maximum dry density as determined in accordance with Section 203.24 of the Indiana Department of Transportation Standard Specifications. The soil in the bottom of the excavating, any bedding material, and the "B-Borrow" for structure backfill, should be tested to insure compliance with this density criteria. Where water is encountered the "B-Borrow" shall be placed in accordance with Section 211.03 of the Standard Specifications.

EXCAVATIONS

Excavations which may be required for utilities or sewers will generally be in both cohesive and non-cohesive materials. Excavations which occur in non-cohesive materials will require cut slopes adequate to prevent cave-ins or subsidence, or sheeting for safe construction operation. The method used will probably be dictated by final design and field conditions at the time of construction. These soils can likely be excavated with temporary side slopes of 2H:IV or flatter if the soil is wet. It should be noted that Indiana Occupational Safety and Health Administration (IOSHA) regulations will not allow unprotected open cuts deeper than 5 feet (1.5 m). Therefore, trenches deeper than 5 feet (1.5 m) will require adequate sheeting, shoring, flattened slopes or a "Safety box". If sheeting or boxes are required, they should be used in a manner as not to disturb the embedment materials within two pipe diameters on each side of the pipe. Excavated material should not be stored immediately adjacent to the top of the cut.

The Contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope or bench the sides of the excavations as necessary. All work should comply with applicable local, state and federal regulations including the current OSHA Excavation and Trench Safety Standards. Construction site safety generally is the sole responsibility of the Contractor, who shall also be responsible for the means, methods and sequencing of construction operation.

In no case should slope inclination or excavation depth, including utility trench excavation depth exceed those specified in local, state and federal safety regulations. Specifically, the current OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926 should be followed. We understand these regulations are being strictly enforced and if they are not closely followed, the owner and contractor could be liable for substantial penalties.

The Contractor's responsible person, as defined in 29 CFR Part 1926 should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. If an excavation, including a trench is extended to a depth of more than twenty (20) feet (6.1 m), it will be necessary to have the side slopes designed by a professional engineer registered in the state of Indiana. The Contractor's "responsible person" should also establish a minimum lateral distance from the crest of the slope or excavation for all spoil piles and vehicles. Likewise, the contractor's "responsible person" should establish protective measures for exposed slope faces.

If material is stored or equipment is operated near an excavation, stronger shoring must be used to resist the extra pressure due to the superimposed loads. Care should always be exercised when excavating near existing buildings, roadways or utilities to avoid undermining. In no case should excavations extend below the level of adjacent existing foundations unless underpinning or other support for the foundations is planned.

2/2

Dewatering

At several of the boring locations, water levels were observed above the proposed storm sewer invert elevations. In the cohesive soils where excavations extend to a depth of less than 1 m above the groundwater level, water can likely be removed from excavations by means of sump pumps and pits. However, where excavations extend below the water level in granular soils, the water level should be maintained below the sewer trench excavation bottom. This will reduce the risk of "piping" (loss of soil fines) or "heaving" (trench bottom instability) which can cause a quick condition in the latter case. Groundwater control in the near surface soils can likely be achieved through the use of shallow well points and/or the use of localized dewatering such as a sump pump system. The sump could consist of installing 200- to 250-mm diameter slotted casings in the relatively permeable granular soils, surrounding the casing with a filtered granular material and installing a submersible pump to control the groundwater level, prior to making the excavation. It should be noted that any dewatering program should consider the potential for damage to existing structures in the vicinity. In addition, appropriate site drainage is recommended prior to commencing any excavation.

Appendix-E Specifications from Missouri

Missouri Department of Transportation

MoDOT

Joe Mickes, chief engineer

105 West Capitol Avenue
P.O. Box 270
Jefferson City, MO 65102
(573) 751-2551
Fax (573) 751-6555

October 24, 1996

Dr. Irtishad Ahmad, Ph.D., P.E.
Associate Professor
Florida International University
Department of Construction Management
College of Engineering and Design
VH 230, University Park
Miami, Florida 33199

Dr. Ahmad,

Your questionnaire has been referred to me for reply. Missouri has two major river systems within its boundaries, the Missouri and the Mississippi. The flood plains of these rivers and the "bootheel" area of our state may be the most typical regions that would be most comparable with the low lying regions of Florida.

We have few incidents when pipes and culverts must be placed at or below the water table. Occasionally, standing water and foundation problems result from the lack of drainage or the presence of a highly organic soil within the excavation. Foundation problems for box culverts must be addressed when encountered by dewatering and/or undergrading.

I am attaching copies of the portion of our General Construction Manual and specifications that address this situation. If I can be of any further assistance, please call me at (573) 751-7600 or you can fax me at (573)526-5640.

Sincerely,

Jerome B. Hirtz, P.E.
Field Liaison Engineer, Construction

construction engineer, the district design engineer who will prepare a new contract for the abatement.

When an Abestos abatement contract is completed the Division of Materials and Research shall be advised as soon as possible of the completed work in order to finalize the abatement records.

202 **STABILIZATION OF FOUNDATIONS FOR CONCRETE BOX CULVERTS.** The bottom slab of concrete box-type structures should be placed on reasonably dry foundation material of sufficient uniformity to prevent differential settlement of the structure. The foundation need be only sufficiently stable that the foundation material does not become mixed with concrete as the bottom slab is being placed.

202.1 It is the contractor's responsibility to provide a satisfactory foundation at the contractor's own expense except when foundation material at grade is inherently unsound. Inherently unsound material is material which, even if properly drained, would prevent satisfactory installation of reinforcing steel and placement of concrete.

202.2 If the foundation consists of material which can be stabilized by draining, it is the contractor's responsibility to provide drainage at the contractor's expense. In some cases involving sandy materials and high groundwater table, contractors have elected to install well point drainage systems at their expense. This is one way of providing a suitable foundation but is at the contractor's option.

202.3 Sometimes the contractor elects to undergrade a few inches and backfill with granular material at the contractor's expense to provide an easily maintained base on which to construct the culvert. This is a satisfactory procedure. Payment should not be authorized for removal or replacement of material in this situation, or when the foundation is unsuitable due to improper methods of construction.

202.4 Some material may have a high organic content or may be a soil which will not permit satisfactory construction of the bottom slab even when properly drained. When this situation exists authorization may be given to remove and replace material, with payment to be made in accordance with Sec 206.6.3 of the Standard Specifications. Payment for stabilizing foundations should be authorized only after the contractor has provided adequate drainage to establish that the material is unsuitable. Undergrading must be authorized by documentation record. If the contingent item of granular backfill is involved, an approved change order is required before payment can be made. Payment is allowed for the actual delivered material cost only.

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be the existing ground line, or

the lower limits of the roadway excavation, whichever is lower. Class 3 Excavation under embankments and in channel changes will be measured from the original ground surface unless otherwise designated on the plans. For box culverts without bottom slabs, measurement will be made as above except no material below plan flow line will be included which is outside of the area bounded by vertical planes 18 inches each side of and parallel with the neat lines of the walls or footings.

206.5.2.1 Final measurement will not be made of Class 3 Excavation for box culverts with a span of 8 feet or less, pipe culverts, sewers, and miscellaneous small structures unless there is an authorized change from plan location resulting in a different quantity or there is an authorized change averaging more than 6 inches in the foundation elevation. When Class C excavation material, as defined in Sec 203, is encountered and no pay item for Class 3 Excavation in Rock is included in the contract, payment will be made at $65.00 per cubic yard. If a revision is made or an appreciable error is found in the contract quantity, the revision or correction will be computed and added to or deducted from the contract quantity. Measurement of Class 3 Excavation will be made for authorized excavation necessary to locate existing utilities requiring reconstruction work.

206.5.3 Where concrete in footings or walls is cast against the vertical faces of the excavation, the neat lines of the concrete footings will be considered the limits of excavation for that depth in which the concrete is in contact with the excavation, and no measurement will be made of any excavation or overbreak beyond the neat footing lines.

206.5.4 The volume of porous backfill will be computed to the nearest cubic yard at each structure from dimensions on the plans. Any porous backfill material placed outside the neat lines shown on the plans shall be placed at the contractor's expense. Final measurement of the porous backfill will not be made except for authorized changes during construction, or where appreciable errors are found in the contract quantity. The revision or correction will be computed and added to or deducted from the contract quantity.

206.6 Basis of Payment.

206.6.1 Payment for additional Class 1 and Class 2 Excavation required to carry footings a maximum of 8 feet below elevations shown on the plans will be made at 125 percent of the contract unit price for that additional excavation within the limits of Class 1, and at 150 percent of the contract unit price for that additional excavation within the limits of Class 2 Excavation. Additional excavation required to carry footings a depth of more than 8 feet below plan elevations will be considered changes in the work, and will be paid for as provided in Sec 104.3.

206.6.2 Payment for drilling test holes for foundation tests will be made at the rate of $6.00 per foot of hole drilled.

206.6.3 Payment will not be made for removal or replacement of foundation material which became unsuitable because of improper methods of construction by the contractor. Payment for removal of inherently unsound material for foundation stabilization will be made at the contract unit price for excavation for structures. No payment will be made for any costs involved in replacing the volume below grade, except that the contractor will be reimbursed for the delivered material cost if a granular type material is specified by the engineer.

206.6.3.1 When Class C Excavation material is unexpectedly encountered for retaining walls with spread footings, payment will be made at five times the rate for Class 1 Excavation. Increased payment will be made only in cases where the presence of Class C Excavation material was not identified in information available under Sec 102.5 pertaining to soundings for the spread footings.

206.6.4 No direct payment will be made for placing porous backfill at weepholes, as required by Sec 206.4.10, or for backfilling the structure.

206.6.5 The accepted quantities of excavation for structures and porous backfill will be paid for at the unit price for each of the pay items included in the contract.

Appendix-F: Specifications from Nevada

SECTION 206

STRUCTURE EXCAVATION

DESCRIPTION

206.01.01 General. This work shall consist of the removal of all material of whatever nature encountered for the construction of foundations for bridges, retaining walls, headwalls for culverts, and other structures; the excavation of trenches for pipe and box culverts, cut-off walls for slope paving and concrete aprons, footings for riprap, and other excavation specifically designated on the plans, in these specifications, or in the special provisions as structure excavation, including the work of disposing of surplus material and cleaning up the sites. Structure excavation shall include dewatering and the furnishing of all equipment and the construction or installation of all cofferdams, cribs, and other facilities which may be necessary to perform the excavations and the subsequent removal of such facilities except where they are required or permitted by the plans or specifications to remain in place. it shall also include all the necessary clearing and grubbing within the proposed structure area and removing old structures or parts thereof as required if the proposal does not include separate bid items for such work.

For specific requirements pertaining to the excavation involved in the installation of pipe culverts and underground piping, attention is directed to those sections of these specifications governing such work.

When shoring, cribbing, or cofferdams are to be used, the Contractor shall be responsible for designing and constructing such shoring, cribbing, or cofferdams. The shoring, cribbing, or cofferdam shall be safe and adequate to provide the necessary rigidity and support the loads imposed.

Design calculations along with detailed drawings of the shoring, cribbing, or cofferdam shall be furnished by the Contractor to the Engineer for approval in accordance with subsection 105.02, "Plans and Working Drawings," of these specifications. If such plans are not satisfactory to the Engineer, the Contractor shall make such changes in them as may be required. Construction of such shoring, cribbing, or cofferdam shall not begin until the Engineer has reviewed and approved the drawings.

206.01.02 Classification. Classification of structure excavation will not be made on the basis of materials or conditions encountered. Classification of excavation, if made, will be on the basis of the material removed between certain elevations, and such classification as shown on the plans or set forth in the special provisions shall not be changed regardless of the material encountered.

CONSTRUCTION

206.03.01 General. The Contractor shall notify the Engineer a sufficient time in advance of the beginning of excavation for structures so that elevations and measurements may be taken of the existing ground before it is disturbed and of existing substructure units within the limits of excavation for structures before they are removed. Any material excavated or removed before these measurements have been taken will not be paid for.

The excavated area shall conform to the outlines of the footings, as shown on the plans, and shall be of sufficient size to permit placing of the full width and length of the footings shown. The elevation of the bottoms of footings as shown on the plans shall be considered as approximate only, and the Engineer may order, in writing, such changes in dimensions or elevation of footings as may be necessary to secure a satisfactory foundation.

Unless otherwise permitted by the Engineer, foundations for culvert pipe and structures shall be compacted to not less than ninety (90) percent of the maximum density as determined by Test Method No. Nev. T101. Test Methods No. Nev. T102 or T103 may be used to determine the in-place density. Test method to be determined by the Engineer.

All rock or other hard foundation material shall be freed from all loose material, cleaned and cut to a firm surface, either level, stepped, or serrated, as may be permitted by the Engineer. All seams and crevices shall be cleaned out and filled with concrete mortar or grout.

Where masonry is to rest on material other than rock or boulders, special care must be given not to destroy its bearing value.

Should the Contractor remove foundation excavation below grade, he shall backfill to the required elevation at his own expense with backfill or with foundation fill in a manner satisfactory to the Engineer.

Wet pits shall be unwatered for inspection and for construction of foundations unless otherwise provided.

Excavated material which is suitable for backfilling shall be so utilized or used in embankments, in a manner satisfactory to the Engineer. Surplus or unsuitable material shall be disposed of so as to cause no obstruction to flow of streams; or otherwise impair the efficiency or appearance of the structure. It shall be disposed of in such manner as to prevent damage to property or the creation of unsightly conditions, and shall not be placed where it will interfere with the operation of drains or impair the roadway ditches, etc.

206.03.02 Inspection. After each excavation is completed, the Contractor shall notify the Engineer, and no masonry shall be placed until the Engineer has approved the depth of excavation and the character of the foundation material.

METHOD OF MEASUREMENT

206.04.01 Measurement. The quantity of structure excavation measured for payment will be the number of cubic yards calculated and shown on the plans, plus or minus quantities covered by approved changes. The Engineer or the Contractor may request recalculation if a possible error is suspected in the quantities shown on the plans. If the Contractor requests recalculation of quantities, such request shall be in writing. When quantities are recalculated, the quantities derived therefrom will be the quantities used for payment. All calculations will be made according to the dimensions shown on the plans. Only those quantities complete and in place will be measured for payment.

The yardage of water or any other liquid will not be included in the measurement for payment, except that the yardage of mud, muck, or similar semi-solid matter not resulting from construction operations and which cannot be pumped or drained away shall be included.

All measurements will be made in accordance with subsection 109.01, "Measurement of Quantities."

BASIS OF PAYMENT

206.05.01 Payment. The accepted quantity of structure excavation measured as provided in subsection 206.04.01, "Measurement," will be paid for at the contract unit price bid per cubic yard, which payment will be full compensation for clearing, grubbing, cofferdams, cribs, sheeting, shoring, bracing, pumping, unwatering, and disposing of all materials, as well as any other additional work which may be required to comply with safety regulations, including, but not limited to, additional sloping outside the designated pay limits.

No compensation will be made for the removal and disposal of material which may come into an excavation from outside the designated limits or for the removal and disposal of swell material resulting from the driving of piles in an excavation.

When an item for structure excavation does not appear in the proposal, structure excavation will be considered as incidental to the installation of the structure and compensation shall be considered as being included in the contract prices for other items of work.

All payments will be made in accordance with subsection 109.02, "Scope of Payment."

Payment will be made under:

Pay Item	Pay Unit
Structure Excavation	Cubic Yard

Appendix-G: Specifications from New York

and slope work is completed in the vicinity of each installation. Any installation rendered inoperative due to damage by construction equipment after partial or full payment, shall be immediately repaired or the full amount of such payment shall be deducted from other monies due the Contractor under the contract.

203-5.06 Cleaning Culverts and Closed Drainage Systems. The unit price bid per linear meter shall include the cost of all labor, materials, and equipment necessary to satisfactorily perform the work.

Payment, for cleaning culverts and/or closed drainage systems will be made only for those facilities designated on the plans or by the Engineer. Only one payment for each facility will be made regardless of the number of times it is cleaned. The cleaning of drainage structures and manholes shall be paid for under their respective item.

203-5.07 Cleaning Drainage Structures and Manholes. The unit price bid for each shall include the cost of all labor, materials and equipment necessary to satisfactorily perform the work. Payment for cleaning drainage structures and manholes will be made only for those facilities designated on the plans or by the Engineer. Only one payment for each facility will be made regardless of the number of times it is cleaned.

Payment will be made under:

Item No.	Item	Pay Unit
203.01 M	Unclassified Excavation and Embankment	Cubic Meter
203.02 M	Unclassified Excavation and Disposal	Cubic Meter
203.03 M	Embankment In Place	Cubic Meter
203.05 M	Select Borrow	Cubic Meter
203.06 M	Select Fill	Cubic Meter
203.07 M	Select Granular Fill	Cubic Meter
203.0801 M	Select Granular Fill, Slope Protection - Type A	Cubic Meter
203.0802 M	Select Granular Fill, Slope Protection - Type B	Cubic Meter
203.10 M	Surface Settlement Gages	Each
203.11 M	Subsurface Settlement Gages	Each
203.12 M	Settlement Stakes	Each
203.13 M	Piezometers	Each
203.1601 M	Applying Water	P.D.D.
203.1770 M	Cleaning Culverts with Span of 1300 Millimeters or Less	Meter
203.1780 M	Cleaning Culverts with Span of More Than 1300 Millimeters	Meter
203.18 M	Cleaning Closed Drainage Systems	Meter
203.19 M	Cleaning Drainage Structures and Manholes	Each
203.20 M	Select Granular Subgrade	Cubic Meter
203.21 M	Select Structure Fill	Cubic Meter

Sections 204 and 205 (VACANT)

SECTION 206 - TRENCH, CULVERT AND STRUCTURE EXCAVATION

206-1 DESCRIPTION

206-1.01 General. This work shall consist of the excavation of all materials and backfill or disposal of excavated material required for trenches, culverts, structures, conduit and direct burial cable not otherwise provided for in other sections of these specifications. All such excavation shall be unclassified excavation as defined in §203-1.01.

206-1.02 Trench and Culvert Excavation. The work specified under this item shall include the excavation for and backfill of all culverts, pipe lines, and other minor structures including but not limited to leaching basins, catch basins, field inlets, manholes and drop inlets.

206-1.03 Structure Excavation. The work specified under this item shall include the excavation for all bridge foundations, walls and other major structures.

206-1.04 Conduit Excavation and Backfill. The work specified under this item shall include the excavation and necessary backfill required for conduits and direct burial cables.

206-2 MATERIALS. (Not Specified).

206-3 CONSTRUCTION DETAILS

206-3.01 General. The appropriate construction details specified for "Excavation and Embankment" in §203-3.01 through and including §201-3.12, §203-3.15, and the requirements of "Legal Relations and Responsibility to Public" in §107 shall apply to the work specified in this section.

The excavation shall be dewatered when necessary and kept free from water, snow and ice during construction.

Special care shall be taken not to disturb the bottom of the excavation and not to remove the material at final grade until just before the structure is placed.

The Contractor shall be responsible at all times for the carrying out of all excavation operations in a safe and prudent manner so that the workers, the public, and adjacent public and private property will be protected from unreasonable hazard. All applicable local, State and/or Federal requirements shall be observed and necessary permits acquired by the Contractor.

The Contractor shall comply with §107-05 E, Guarding and Protection, when trenches are left open overnight and on non-work days.

Sheeting shall be used in conformance with §107-05, Safety and Health Requirements, to protect employees and to satisfactorily complete the work without causing subsidence and to prevent damage to adjacent ground and structures. These requirements are minimum standards and may have to be increased depending on the hazard or as directed by the Engineer.

Instead of using sheeting, the Contractor may, with written approval from the Regional Director, open the excavation with the sides sloped to a stable slope not steeper than that allowed by the Title 29 Code of Federal Regulations, Part 1926, Safety and Health Regulations for Construction (OSHA). Taking this option, however, does not relieve the Contractor of responsibilities as stated in this subsection. Where the Contractor is permitted to do this, the materials used and method of construction outside the payment lines shall be the same as those required for adjacent zones within the payment lines.

When excavation is required for the installation of conduit or direct burial cable, the Contractor shall notify the Engineer upon completion of the excavation. No conduit or cable shall be placed in the excavation until the Engineer has approved the depth and cross-section.

206.3.02 Replacement of Pavement Structure Courses. When the Contractor, in placing conduits, direct burial cable or utilities, excavates into the pavement, subgrade, subbase, or shoulder courses, such courses must be replaced in kind, character and condition, to maintain a uniform road section.

206-3.03 Disposal of Excavated Material. The provisions of Subsection 203-3.06 and/or 203-3.07 shall apply to all material excavated under this section which is not used as backfill.

206-4 METHOD OF MEASUREMENT

206-4.01 General. The quantity of excavation shall be the number of cubic meters of material computed from payment lines shown on the plans or the appropriate standard sheets, except where revised payment lines are established by the Engineer prior to performing the work. Work performed beyond any designated payment line will not be included in the computation of quantities for the item involved.

206-4.02 Trench and Culvert Excavation. Unless otherwise shown or indicated on the contract plans, payment lines for excavation of pipe and culvert lines, and minor structures will be determined as follows:

A. Bottom Payment Line. The elevation of the bottom payment line shall be the invert elevation of the pipe, conduit, or culvert. For pipes, conduits, or culverts of nominal horizontal dimensions of 300 to 3700 mm, the width of the excavations at the bottom payment line shall be the nominal inside horizontal dimension of the pipe, conduit, or culvert plus 1.2 m, or three (3) times the nominal inside horizontal dimension, whichever is less; for pipes with a nominal horizontal dimension greater than 3700 mm the width will be as shown on the appropriate standard sheets or in the contract documents. For concrete pipe, twice the minimum wall thickness shall be added to the preceding.

B. Top Payment Line. Except when otherwise provided in the contract, the payment line in a cut section shall be the surface at the centerline of the pipe, culvert or conduit after the completion of general excavation and prior to excavation to place material paid for under another item of the contract; except that, when an undercut is made for unstable conditions, the payment line will be at the top of the undercut backfill. The payment line in fill section shall be the ground surface prior to commencing work on the contract.

C. Side Payment Lines. The side payment lines of the excavation shall be vertical to the bottom of payment line, regardless of whether sheeting is or is not required or used.

For utility lines, exclusive of conduit and cable lines, of less than 300 mm diameter, the excavation width shall be the actual bottom width necessary, as determined by the Engineer, to properly perform the installation work required, or 1 m, whichever is less.

D. Payment Lines for Minor Structures. Payment lines for minor structures shall be vertical from the bottom of the footing and shall extend out 0.6 m from the perimeter of the structure footing. The top payment line shall be the same as for (B) above.

206-4.03 Conduit Excavation and Backfill. The quantity of conduit and/or cable excavation and backfill for payment shall be the number of linear meters measured along the center of the conduit and/or cable placed, in accordance with the methods stated below.

Wherever a pair or group of conduits and/or cables are physically connected together, they shall be considered as a single conduit and/or cable.

Method of Measurement

A. Wherever conduit and/or cable in the same trench are physically separated laterally by 150 mm or more between centerlines, as shown on the plans or as directed by the Engineer, the linear meter measurement shall be made along the center of each conduit and/or cable.

B. Wherever a pair or group of conduits and/or cable in the same trench are physically separated laterally by less than 150 mm between centerlines of adjacent conduit and/or cable, as shown on the plans or as directed by the Engineer, the linear meter measurement for those conduits and/or cable shall be made along the center of that pair of group of conduit and/or cable.

206-5 BASIS OF PAYMENT

206-5.01 Trench, Culvert and Structure Excavation. The unit price bid for this work shall include the cost of labor, materials and equipment required to satisfactorily complete the work, including the costs of excavation, backfill (except select backfill paid for separately), disposal of excavated material, presplitting rock excavations where required, and keeping the site dewatered when necessary and free from earth, water, ice and snow during construction.

The cost for necessary guarding and protection required to protect the public from open trenches shall be included in the bid price for Trench, Culvert and Structure Excavation. Progress payments will be made after the excavation has been completed, and prior to the completion of other work included under this item, including but not limited to pumping, fencing and backfilling. Payment will be made, at the unit price bid, for 75% of the quantity excavated within the prescribed payment lines. The balance of the quantity excavated will be paid for upon proper completion of backfill placement.

206-5.02 Sheeting or Cofferdams. Payment for Sheeting or Cofferdams required by the plans, specifications, Title 29 Code of Federal Regulations, Part 1926, Safety and Health Regulations for Construction (OSHA) or ordered by the Engineer in writing will be made in accordance with the appropriate item.

Where cofferdams are specified for structure excavation, the work required to keep the site free from earth, water, ice and snow during construction shall be included in the item for cofferdams.

206-5.03 Replacement of Pavement Structure Courses. With exception of the Conduit Excavation and Backfill item, the work of replacing pavement, subcourses and shoulder courses shall be paid for and performed under the provisions of their respective items and subsections.

206-5.04 Conduit Excavation and Backfill. The unit price bid per linear meter for this work shall include the cost of furnishing all labor, materials and equipment necessary to excavate and backfill the trench and to replace any pavement, shoulder, and sidewalk courses, subcourses, curbs, drives, lawns and other top surfaces as required to complete the work.

Payment will be made under:

Item No.	Item	Pay Unit
206.01 M	Structure Excavation	Cubic Meter
206.02 M	Trench and Culvert Excavation	Cubic Meter
206.03 M	Conduit Excavation and Backfill	Meter

SECTION 207 - GEOTEXTILE

207-1 DESCRIPTION. The work shall consist of furnishing and installing approved Geotextile at the locations and in the manner shown on the plans or as directed by the Engineer, in writing, prior to performing the work.

207-2 MATERIALS

207-2.01 General. The Geotextiles shall be the type appropriate for the intended use as shown on the plan and as shown on the Approved List issued by Department's Materials Bureau.

207-2.02 Basis of Acceptance. The Geotextiles which are on the Approved List issued by the Department's Materials Bureau shall be accepted on the basis of the brand name labeled on the Geotextile or the Geotextile container and verification of the Geotextile by a Departmental Geotechnical Engineer.

Approval of a Geotextile not on the Approved List may be obtained by submitting a 17 m^2 square sample of the Geotextile to the Department's Geotechnical Engineering Bureau for evaluation and acceptance (minimum of four months). Acceptance of the Geotextile will be made in accordance with procedural directives of the Geotechnical Engineering Bureau.

207-2.03 Quality Assurance. When the state elects to sample, one ten square meter sample will be obtained for quality assurance testing. This testing will only affect a product's standing on the Approved List. Payment for this sample will be made at the unit bid price.

207-3 CONSTRUCTION DETAILS.

207-3.01 General. The Geotextiles shall be protected from exposure to sunlight during transport and storage. After placement, the Geotextile shall not be left uncovered for more than two (2) weeks.

Part 131

ACCOMMODATION OF UTILITIES WITHIN STATE HIGHWAY RIGHT-OF-WAY

Statutory Authority: Highway Law §§10, 30, 52, 103, 230, 249, 250; Transportation Law §14, 14b; General Obligations Law §11-102

The next adjoining poles shall also be guyed. Braces may be used instead of guys. Special precautions shall be taken on curves and where lines cross. There shall be no guying from trees without permission from the owner. Guys are considered fixed objects subject to clear zone restrictions.

131.19 Underground Work. Underground work shall be in accordance with the nationally recognized standards, and as prescribed below. Regional Offices may impose more stringent conditions in a permit based upon prevalent weather and traffic conditions.

(a) Installation.

(1) Pavement crossings for underground utilities shall be accomplished by jacking, driving, drilling, boring, or tunneling. "Open cut" installation will be approved by the Department only upon a clear demonstration of necessity or other conditions which warrant such a procedure. Subsurface rock formations, excessive presence of boulders, excessive and damaging skin friction during jacking operations or insufficient rights-of-way limits to allow jacking, driving or tunneling may constitute a necessity. Where an ongoing construction contract requires pavement removal and/or construction of new pavement, the Department may consider approving an "open cut."

(2) The edge of the excavation (nearest the pavement) used for driving or jacking shall not be less than 10 feet, measured laterally from the curb, or edge of shoulder at shoulder break, whichever provides more clearance. When the highway configuration or other circumstances preclude the minimum offset, the Department may consider approving an alternate configuration and offset.

(b) Crossover Carrier Pipes.

(1) Crossover carrier pipes shall be designed to withstand all applied and/or superimposed loadings resulting from the roadway section, traffic, potential pipe settlements, and installation procedures. Certain soil and/or site conditions may require encasement. Where a cathodic system is designed to be installed for the crossover carrier pipe, the design of any casing shall be so as not to diminish the desired level of protection.

(2) Crossover carrier pipe design shall be site specific, based on field investigation. The design shall address all potential applied loads, installation methods, and loads induced during installation. The preferred installation method when operating below the water table or in soft ground shall employ an earth pressure balance or comparable system in order to prevent flowing soil or ground loss and pavement distress.

(3) Design of a crossover carrier pipe section shall include consideration of, but not be limited to the following:

(i) Increased pipe wall thickness for the distance within the pavement plus possible additional distance to allow for future highway widening.

(ii) Adequate wrapping, coating or other treatment to protect against corrosion.

(iii) Protective jacket adequate to ensure the integrity of the anti-corrosion material under installation and service conditions.

(c) Longitudinal Carrier Pipes, including utility service connections, shall be installed outside the area of live load influence, unless there is no practical alternative.

(d) Temporary pavement repairs with cold patch or other acceptable bituminous patching shall be placed as soon as backfill is made. It shall be maintained flush with the pavement surface until the backfill has been properly compacted, and permanent restoration of the pavement surface completed.

(e) Existing underground facilities shall be maintained and protected by and at the expense of the permit applicant in compliance with Industrial Code Rule 53 (12 NYCRR Part 53).

(f) Sheeting. Where excavation is within the pavement area or when the depth of excavation is greater than the distance from the edge of pavement to the edge of trench, sheeting may be required.

(g) Backfill. Backfill material shall be of a quality and type acceptable to the Department and shall be compacted sufficiently to preclude future settlement of the excavated area. The backfill material shall be of a quality so as not to block or intercept the drainage of the subgrade. Excavations for service connections shall be backfilled within two days.

(1) Within Roadway. Within the roadbed limit of a cut section or within the embankment section, the excavation shall be backfilled using approved layer thicknesses of material acceptable to the Department, to the top of the subgrade. Material shall be compacted to an acceptable density with approved equipment.

(2) Outside Roadway. The backfill for excavated areas shall be compacted to an approved density with acceptable material and upper surface maintained level with the original surface. The surface shall be treated, if required, in order to leave the surface in essentially the same condition as it was prior to the excavation. All surplus material and trash shall be removed and disposed of in a lawful and proper manner. The work area shall not be left in an unsightly condition.

(3) Trenchless Installations. All detrimental voids created during the installation of a crossover pipe, regardless of method, shall be filled. Appropriate backfill type and method of placement shall be addressed in the design of the crossing.

(h) Pavement replacement.

(1) Temporary pavement restoration shall consist of a minimum compacted thickness of three inches of asphalt concrete, and approved base material of a depth to provide for permanent pavement. In situations where heavy traffic loads are anticipated or cases where the temporary pavement is required for a protracted period, more substantial pavement and backfill design may be required. The asphalt concrete shall be maintained flush with the existing pavement until permanent restoration of the pavement.

(2) Permanent pavement replacement will be specified in the permit.

(3) On reinforced concrete pavements, the appropriate class of concrete shall be used. Undermined and broken slabs shall be completely replaced. Approved joint dowels and sealer, transverse ties and reinforcing steel shall be used as required.

(4) Asphalt concrete pavement shall be replaced with adequately compacted base material, binder and top course material which is at least equal in quality, mix type and thickness to the pavement which was removed. Existing pavement should be saw cut to provide a clean butt joint between the old and new pavement. An emulsified asphalt tack coat shall be applied to all existing pavement edges prior to placing the new asphalt pavement courses.

(5) Shoulders shall be replaced with material of like quality, thickness and type as the existing shoulder.

(6) Manhole frames, grates and similar appurtenances placed within the roadway shall be approved by the Department and shall be set in a workman-like manner flush with the surface of the roadway.

(i) The Department will not undertake or accept financial responsibility for any remediation or similar activity with respect to the removal of hazardous wastes (6 NYCRR Part 373 and 374) and non-hazardous solid industrial wastes (6 NYCRR Part 360) which under law would not be required at the time but for the accommodation of utility facilities within the right-of-way. Such responsibility and costs shall be solely those of the utility.

131.20 Utility Facilities on Structures. (a) General. Utility facilities may be placed on bridges upon written approval of the Department. The following provisions are applicable to new or replacement installations of usual size, pressure and voltage. The Department will establish requirements for situations beyond the norm and for those not specifically covered by this subsection.

(b) All utility facilities to be installed by State let contract or owner let contract, shall be fully detailed and shown in plan, section and elevation when required. Utilities shall not be placed on an existing structure if their weight would reduce the allowable vehicle loading below the legal limit except in certain instances when approved by the Department.

(c) Location of Utility Facilities on Bridges.

(1) Utility facilities shall not be placed at nor extend below the bottom of the superstructure.

(2) Utility facilities shall not be located where they may be subject to vehicular impacts nor shall they be attached to railing systems which may be subject to vehicular impacts.

(3) Utility facilities shall not be located where they will impair or interfere with roadway drainage.

(4) Utility facilities shall not be supported from the bottom of the concrete structural slab.

(5) Utility facilities should be located so they do not interfere with maintenance and inspection of the structure. Aesthetics is

Appendix-H: Specifications from North Carolina

NORTH CAROLINA

DEPARTMENT OF TRANSPORTATION

RALEIGH

STANDARD SPECIFICATIONS

FOR

ROADS AND STRUCTURES

ENGLISH

JULY 1995

partial lengths are needed or, if damaged sufficiently, the Engineer will reject the joint or section as being unfit for installation and the Contractor shall remove such rejected pipe from the project.

Minor damage to pipe may be repaired by the Contractor when permitted by the Engineer.

300-4 PREPARATION OF PIPE FOUNDATION.

The pipe foundation shall be prepared in accordance with the applicable method shown on the plans and shall be true to line and grade and uniformly firm.

Where necessary, invert grade shall be cambered by an amount sufficient to prevent the development of sag or back slope in the flow line. The amount to camber used will be determined by the Engineer.

Bedding material shall be placed and shaped beneath the pipe where so directed by the Engineer.

The pipe foundation shall be shaped to fit the outside of the pipe for at least 10% of its outside diameter under all pipe culverts.

Where bell and spigot type pipe is used, recesses shall be excavated to receive the pipe bells.

Where the foundation material is found to be of poor supporting value or of rock, the Engineer may make minor adjustment in the location of the pipe to provide a more suitable foundation. Where this is not practical, the foundation shall be conditioned by removing the existing foundation material by undercutting to the depth as directed by the Engineer, within the limits established on the plans, and backfilling with either a suitable local material secured from unclassified excavation or borrow excavation at the nearest accessible location along the project, or foundation conditioning material consisting of crushed stone or gravel or a combination of sand and crushed stone or gravel approved by the Engineer as being suitable for the purpose intended. The selection of the type of backfill material to be used for foundation conditioning will be made by the Engineer.

When necessary, the contractor shall provide for the temporary diversion of water in order to maintain the pipe foundation in a dry condition.

300-5 LAYING PIPE.

(A) Rigid Pipe:

The pipe shall be carefully laid on the prepared foundation, bell or groove end upgrade with the spigot or tongue fully inserted to make a water tight joint and each joint checked for alignment and grade as the work proceeds.

Flexible plastic joint material shall be used. Joint material of other type or design may be used when designated on the plans, by special provisions, or when permitted in writing by the Engineer.

Appendix-I: Specifications from Ohio

W:603class:610may

JUNE 1996

Proposal Note No. 610-95
County_______________
Section _______________

Bedding and Backfill Requirements for All 603 Items and 603, As Per Plan Items

The bedding and backfill material and compaction requirements for all 603 and 603 as per plan items in this contract shall be modified as follows:

603.02 Materials. *Granular materials type 1, 2 , or 3 shall be used as specified in this note when granular materials are required or are permitted as an option under 603. Soils shall meet the requirements of 203.02 and this note.*

Granular material for bedding and backfill shall be sound crushed limestone, crushed gravel, sand, air-cooled blast furnace slag, granulated slag, *open hearth slag from approved sources on file at the laboratory* or recycled portland cement concrete(RPCC).

RPCC may be used without wear testing , sodium soundness testing, or fracture count requirements if the Contractor provides information proving the material met this specification at the time of its original incorporation.

Granular material Type 1 shall meet the gradation of 304.02 *and the physical properties of 304 in 703.04.*

Granular material Type 2 *shall meet the fine aggregate requirements of 703.05 or 703.02; or meet* the following gradation and the physical properties of 304 in 703.04 except the Los Angeles abrasion and fracture requirements shall be waived.

Sieve	Total Percent Passing
19.0 mm (3/4 inch)	100
9.5 mm (3/8 inch)	80-100
4.75 mm (No. 4)	60-100
2.36 mm (No. 8)	45-95
300 Φm (No. 50)	7-45
75 Φm (No. 200)	0-13

Foundry sand may be used if the material meets these requirements and meets the requirements of the Division of Surface Water Policy 400.007 " Beneficial use of Non-Toxic Bottom Ash, Fly Ash and Spent Foundry Sand and Other Exempt Waste," and all other regulations. Ten days prior to using foundry sand on the project, the Contractor shall submit written permission from the OEPA to the Engineer.

Granular material Type 3 shall meet the gradations of No. 57 or 67 *and the physical properties of 304 in 703.04. Type 3 granular materials may be permitted by the Engineer when pumping operations do not control severe ground water problems. When allowed the granular material type 3 shall be used below the bottom of the pipe.* The Type 3 material shall be provided at no additional cost to the Department.

603.04/603.08 Compaction Requirements. The gradation and physical characteristics of all granular materials shall be such that they can be compacted to meet the requirements of this specification and to the satisfaction of the Engineer. All backfill operations shall place the material evenly on each side of the pipe.

A). The soil shall be placed in layers not to exceed 200 mm(8 inch) loose depth. Soil shall be compacted in accordance with 203.09 section (b). When proctor testing is used 96 percent of T-99 is used for acceptance.

B). Granular material Type 1 shall be compacted using mechanical *devices, hand* devices, vibrating plates or other equipment approved by the Engineer. The compaction equipment shall be capable of compacting the material under the haunch of the pipe. The material shall be placed in layers not to exceed 200 mm(8 inch) loose depth.

At the beginning of the work, a test section shall be constructed in accordance with 304.04. The Engineer may require the addition of water to aid the compaction. The average density of this material placed for bedding and backfill shall not be less than 96 percent of the test section. Any material placed for bedding and backfill found less than 92 percent of the test section shall be immediately re-compacted. If density cannot be obtained by re-compaction then a new test section shall be constructed. The location of the testing shall be randomly chosen by the Engineer.

C). Granular material Type 2 shall be compacted by flooding or *a combination of* flooding and compaction. The material shall be placed in layers not to exceed 200 mm(8 inches) loose depth. The material shall be flooded with water to the satisfaction of the Engineer. Satisfactory drainage shall be provided by the use of drainage ditches, pumps or other equipment if the field conditions warrant.

The Engineer may require additional compaction by using mechanical *devices, hand devices*, vibrating plates or other compaction equipment to achieve additional density.

When ordered by the Engineer at the beginning of the work a test section shall be constructed in accordance with 304.04. A combination of flooding and compaction equipment shall be used until a maximum density is achieved. The average density of this material placed for bedding and backfill shall not be less the 96 percent of this test section. Any material placed for bedding and backfill found to be less *than* 92 percent of this test section shall be immediately recompacted. If density cannot be obtained by re-compaction then a new test section shall be constructed. The location of the testing shall be randomly chosen by the Engineer.

The Engineer may permit this material to be compacted without flooding and by compaction equipment if the field conditions warrant.

compaction of mat'l

D). When permitted granular material Type 3 shall be placed in layers not to exceed 305 mm(12 inch) loose depth and *vibrated, tamped or compacted* to *approximately* 85% of the original thickness.

In all of the above compaction requirements the lift thicknesses may be adjusted by the Engineer to obtain the required compaction, fill all the voids, achieve the proper seating of the backfill material and achieve the stability of the backfill material and the pipe.

All of the above work shall be provided at the unit bid price for these items.

Note to Reviewer: Use this note in all projects where 603 or 603 as per plan items are pay items. Call Randy Morris Soils and Drainage Engineer at 614-644-6638

Appendix-J: Specifications from Pennsylvania

SECTION 590 - CRACK CLEANING AND SEALING

590.1 DESCRIPTION — This work is cleaning and sealing of cracks in existing cement concrete pavements having an opening of 1.5 mm and wider.

590.2 MATERIAL —

(a) Joint Sealing Material. Section 705.4(b).

590.3 CONSTRUCTION — Saw or grind cracks to a width of 20 mm wide by 25 mm depth. Immediately after sawing and grinding, flush with water. Do not seal the same day as sawing or grinding. If original crack is between 20 mm and 25 mm wide, saw or grind to a width of 25 mm and a depth of 30 mm.

Immediately prior to placing the sealant, clean the crack by using a compressed air stream of at least 700 kPa measured at the source.

Seal cracks in accordance with the applicable requirements in Section 501.3(n) and as specified herein.

Do not place joint sealant unless the ambient air temperature is 4 °C or greater, and the pavement temperature is 4 °C or greater.

Fill the sealant reservoir to a level of 3 mm to 6 mm below the pavement surface.

590.4 MEASUREMENT AND PAYMENT — Meter

SECTION 600
INCIDENTAL CONSTRUCTION

SECTION 601 — PIPE CULVERTS

601.1 DESCRIPTION — This work is construction or reconstruction and cleaning of pipe culverts, and storm drains; including the direct design, manufacturing and testing of reinforced concrete pipes.

601.2 MATERIAL —

(a) Pipes. Comply with the following:

1. Certification. Section 106.03(b)3.

2. Size and Type of Pipe. As indicated.

3. Reinforced Concrete (RC) Pipe

3.a Round and Elliptical Reinforced Concrete Pipe. Provide RC pipe in accordance with BD-636M, Appendix S of Design Manual 4 and the Pennsylvania Installation Direct Design (PAIDD) computer program. Manufacture and Test in accordance with Pub. 280. Pipes, before installation may have non through wall cracks of less than 80 μm in width and be considered acceptable. Any pipe having both an unloaded surface crack width of 80 μm or greater extending 300 mm or longer, will be rejected.

4. Metal Pipes.

4.a Ductile Iron Pipe. ASTM A 716.

4.b Corrugated Steel Pipe, Metallic Coated. AASHTO M 36/M 36M, Type I and IR; AASHTO M 218; AASHTO M 274; and AASHTO M 289

4.c Corrugated Aluminum Alloy Pipe. AASHTO M 196, Type I and IR.

4.d Coated Corrugated Galvanized Steel Pipe. AASHTO M 245/M 245M, Type I; AASHTO M 246/M 246M; and AASHTO M 218. Fabricate pipes with coatings as follows:

- Grade 250/250 — 250 μm coating on all surfaces.

5. Half-Circle Pipe. Meeting the requirements of the type indicated, except modified to meet the half-circle configuration.

6. Thermoplastic Pipes. Provide cell class of material (actual and minimum), minimum pipe stiffness and the Dimension Ratio, when applicable, if not included in pipe markings.

6.a Group I

6.a.1. Polyethylene

- ASTM F 714, Type S, SDR<21, cell class 335434C, 1200 mm diameter maximum
- ASTM F 714, Type S, SDR=26, cell class 335434C, 525 mm diameter-1200 mm diameter only
- ASTM F 894, Type S, RSC=100, cell class 335434C, 900 mm diameter maximum
- ASTM F 894, Type S, RSC=160, cell class 335434C, 450 mm diameter-1050 mm diameter only

6.a.2. Polyvinyl Chloride

- ASTM F 794, Type S, PS=46, cell class 12454C or 12364C, 1200 mm diameter maximum
- AASHTO M 304, Type S, cell class 12454C, 1200 mm diameter maximum
- AASHTO M 304, Type S, cell class 12364C, 525 mm diameter and 600 mm diameter only
- ASTM F 679, Type S, PS=46, cell class 12364C or 12454C, 900 mm diameter maximum
- AASHTO M 278, Type S, cell class 12454B, 300 mm diameter and 375 mm diameter only

6.b Group II Section 601.2(a)6.a and as follows:

6.b.1. Polyethylene

- ASTM F 894, Type S, RSC=100, cell class 335434C, 1050 mm diameter

6.b.2. Polyvinyl Chloride

- AASHTO M 304, Type S, cell class 12364C, 450 mm diameter and 750 mm diameter-1200 mm diameter

6.c. Group III Section 601.2(a)6.a, 6.5, and as follows:

6.c.1. Polyethylene

- AASHTO M 294, Type S, cell class 325420C, 750 mm diameter maximum

6.c.2. Polyvinyl Chloride

- ASTM M 304, Type S, cell class 12364C, 300 mm diameter and 375 mm diameter

6.d Group IV

6.d.1. Polyethylene

- AASHTO M 294, Type S, cell class 325420C, 900 mm diameter only

6.e Group V

6.e.1. Polythylene

- AASHTO M 294, Type C, cell class 325420C, 900 mm diameter maximum

(b) Other Material.

- Premolded Expansion Joint Filler — Section 705.1
- Mortar — Section 705.7(a)
- Caulking Compound — Section 705.8(a)
- Preformed Pipe Joint Material — Section 705.5(b)
- Cement Concrete for Miscellaneous Drainage — Section 704
- Reinforcement Steel — Sections 709
- Aggregate for Bedding — Section 703.2
- Coarse Aggregate — Section 703.2
- Concrete Curing Compound — Section 711.2(a)
- Curing and Protecting Covers — Section 711.1
- Bituminous Paint — Federal Specification

TT-V-51F. Certify as specified in Section 106.03(b)3.

- Zinc Chromate Primer — Federal Specification TT-P-645. Certify as specified in Section 106.03(b)3.

(c) Grout - Mix one part cement and two parts fine aggregate with the minimum amount of water necessary to obtain grout of the required consistency containing 3% to 7% entrained air. Air entraining cement may be used in place of the plain cement and air entraining admixture. Use materials meeting the following requirements:

- Cement — Section 701
- Fine Aggregate — Type A or C, Section 703.1
- Water — Section 720.1
- Admixtures — Section 711.3

601.3 CONSTRUCTION — As shown on the Standard Drawings and as follows:

(a) General. Provide 150 mm minimum cover from subgrade to pipe barrel. Construct the embankment to 1.2 m above the top of pipe elevation or to subgrade, whichever is less before excavating for the pipe. Hauling will not be permitted over pipe with less than 1.2 m of cover.

Where running water is encountered and cannot be diverted, provide an acceptable temporary pipe or other structure prior to placing embankment, or as otherwise directed.

(b) Trench and Bedding. Excavate trench and construct bedding as shown on the Standard Drawings.

(c) Laying Pipe. Lay pipe as shown on the Standard Drawings prior to constructing base course or pavement. Lay pipe with bells or grooves up grade.

Control the pipe alignment and grade with suitable string lines, with an electronic laser beam system, or by other acceptable methods.

Camber the grade line, if directed, to offset anticipated settlement due to the height of embankment and bedding used.

Lay pipe, except interlocking style and pipe joined with bands, with mortared joints. Before placing succeeding pipe sections, mortar the lower half of the joint, to bring the inner surface of the abutting pipe flush. Before placing mortar, wet the pipe with as much water as it will readily absorb. Fill the outside of bell and spigot pipe joints with mortar, flush with the bell end. Fill tongue-and-groove pipe joints flush with the pipe's outside surface. On the inside of the pipe, fill the lower half of the joint flush with mortar, wipe clean, and finish smoothly. However, for pipes of 600 mm diameter and larger, fill the joints for the entire inside periphery in the same manner. Fill voids for lift holes with mortar after pipe is placed. Backfilling may proceed immediately after joints are mortared if the operation avoids joint damage, maintains pipe in proper alignment and grade, and provides satisfactory curing conditions for mortar. When permitted, either a preformed joint or caulking compound of an acceptable type may be used in place of mortar to join pipe sections.

When pipes are protected by endwalls or connected with drainage structures, place exposed pipe end within cast in place wall or cut off flush with precast structure face and finish with mortar, as directed. Provide satisfactory connections to existing drainage structures.

Coat all aluminum surfaces to be embedded in concrete with one (1) coat of zinc chromate primer, or a coat of bituminous paint. Allow coating to dry completely prior to placement of concrete.

(d) Elongation of Metal Pipes. When indicated, elongate metal pipe vertically 5%, using acceptable shop methods. Elongate coated pipe by acceptable shop methods only. Satisfactorily repair coating damaged by elongation procedures.

(e) Backfilling Trench. After the pipe is laid, backfill the trench as shown on the Standard Drawings. Place material in 100 mm layers; however, 200 mm layers will be permitted when using vibratory compaction equipment. Compact each layer of backfill to the density indicated on the Standard Drawings to a height of 1.2 m above the top of the pipe for the full trench width. Use mechanical tampers or other acceptable compaction equipment that will not damage the pipe. Compact backfill material to the density shown on the Standard Drawing as determined by Standard Proctor Density (SPD). Test in accordance with Section 206.3(b)1. Test the coarse aggregate backfill for reinforced concrete pipe before placing remaining backfill.

(f) Shored or Trench Box Installation. Construct shored or trench box installation when indicated in accordance with Section 107.08.

Construct shored or trench box installation as required for reinforced concrete pipe.

Construct shored or trench box installations for thermoplastic or metal pipe as follows:

- Unless otherwise directed by the Engineer, leave trench sheeting in place to prevent loss of foundation support and backfill materials. When the top of trench sheeting is to be cut off, make the cut 460 mm or more above the crown of the pipe. Leave rangers, whalers and braces in place as required to support the cut off sheeting and trench wall in the vicinity of the pipe zone. Timber sheeting is considered a permanent structural member to be left in place. Treat timber sheeting against biological degradation and decay if placed above the ground water table.

- Do not disturb the installed pipe and its embedment when using movable trench boxes and shields. Do not use movable supports below the top of the pipe backfill pay limit zone unless approved methods for maintaining the integrity and level of compaction of the backfill material are used. Before moving supports, place and compact embedment to sufficient depths to ensure protection of the pipe. As supports are moved, finish placing and compacting the backfill material.

- When use of sheeting or other trench wall supports is permitted by the Engineer below the pipe backfill pay limit zone, ensure that pipe, bedding and backfill materials are not disturbed by support removal. Fill voids left upon removal of supports and compact all material to required densities.

(g) Jacked Pipe. Jack pipe by means of conventional tunneling or boring methods, when indicated. Prior to commencement of this work, submit a complete plan and schedule for pipe installation. Include complete details of sheeting, shoring, and bracing for the protection of facilities above the pipe, as well as materials and equipment pertinent to the jacking operation. Do not proceed with pipe installation until the plan and schedule have been accepted.

Proceed in a manner which will not disturb facilities or cause settlement of the ground above the pipe. Provide free and unobstructed use of facilities above the pipe, without delay or danger to life, equipment, or property.

Install pipe immediately following the heading or tunneling excavation. After completion of the jacking operation fill voids around the pipe with grout placed under pressure. Properly protect the grout for not less than 3 days.

Place joint sealant material on concrete pipe in front of the jacking frame. As directed, replace or repair pipe damaged during the jacking operations. When steel casing pipe is used, butt-weld the joints as installation progresses. Make joints watertight.

If it is determined that the pipe installation is being conducted in an unsatisfactory manner, stop this work and place a bulkhead at the heading until an alternate procedure is proposed and accepted.

(h) Extension of Existing Pipe. When extensions of pipe culverts or drains are indicated or required, remove the existing endwalls, if indicated or directed. Cut the existing pipe to a true edge, as required, to make a satisfactory joint. Join the new pipe to the existing pipe or endwalls, using acceptable collars constructed of Class A Concrete or acceptable metal connecting bands. Clean the existing pipe being extended, as specified in Section 601.3(i). Repair or replace existing pipe damaged during construction.

As an alternate to removing the endwall, if permitted, extend the pipe, using a Concrete Collar for Pipe Extension, as specified in Section 618.

(i) Cleaning Existing Pipes. Clean existing pipe culverts, as indicated and as directed, prior to the start of roadway paving operations. Clean inlets, bridge scuppers and piping, manholes, endwalls, and other drainage appurtenances connected to the pipes, as directed. Clean in an acceptable manner and repair damage resulting from the cleaning operation. Remove any material deposited in inlets during paving operations. Prevent material cleaned from the drainage system from entering streams or other bodies of water, and dispose of this material in a satisfactory manner.

(j) Relaid Pipe. Where indicated, remove and clean existing pipes and have them inspected. If the existing pipes are accepted, transport and relay them, at the indicated locations, in the same manner specified for new pipes.

(k) Removal and Replacement. Remove and replace pipe which is not true to alignment, shows settlement after laying, is broken, or is damaged.

(m) Inspection of Pipes. Prior to final acceptance, inspect installed pipe with total load applied. Inspect all pipes over 750 mm in diameter from inside the pipe. Inspect 450 mm to 750 mm diameter pipes from access points. Provide written documentation of all inspections to the Engineer within 72 hours following each inspection.

1. Concrete Pipes. Inspect concrete pipes for signs of damage including cracks greater than 180 μm in width, spalls, damaged or cracked ends, and visible reinforcement. Submit a plan for repair or replacement in accordance with Section 601.3(k) to the Engineer for approval.

2. Metal Pipes. Inspect metal pipes for damage including rust, cracking of coatings, damaged galvanization or lining, loose bolts, and areas of local buckling. Repair damaged coatings in accordance with AASHTO M 36/M 36M and AASHTO M 245/M 245M. For damage repairs not covered by AASHTO M 36/M 36M or AASHTO M 245/M 245M, buckling, or other major damage develop a repair or replacement plan in accordance with Section 601.3(k) and submit it to the Engineer for approval.

3. Thermoplastic Pipes. Inspect thermoplastic pipes for cracking and joint separation, and perform deflection testing at least 30 days after the embankment is completed. Perform the deflection testing using either electronic deflectometers, calibrated television or video cameras, properly sized "go, no-go" mandrel, direct measurement by extension rulers or tape measures in pipes that permit safe entry, or another acceptable device. Where pipe cannot be physically inspected, perform deflection testing at a minimum. Where deflection is greater than 5% of the unloaded inside diameter of the pipe, or cracking or joint separation is detected, develop a remediation or replacement plan in accordance with Section 601.3(k) and submit it to the Engineer for approval.

(n) Remediation. Remedial action may include but is not limited to removal and replacement or an accepted repair procedure.

601.4 MEASUREMENT AND PAYMENT —

(a) Pipe Culverts and Relaid Pipe Culverts. Meter

Measured to the point of centerline intersection of "T", "Y", and other branches. Includes the pipe, the bedding material, and the backfill as shown on the Standard Drawings. Furnishing personnel and equipment for dewatering operations, inspection of pipes, and all remedial measures will be considered incidental to the pipe items.

When the pipe item for shore/trench box is indicated or required; includes placement and removal or keeping in place of shoring, supports, shield systems and trench boxes in accordance with Section 601.3(f).

(b) Half-Circle Pipe. Meter

Appendix-K: Specifications from Texas

(e) **Dewatering Of Excavation Area.** Structures shall not be constructed or laid in the presence of water unless approved by the Engineer. Setting of precast members, placement of concrete, or pipe placing operations shall be performed on a dry firm bed. This shall be accomplished by removal of water from the surface of the bed by bailing, pumping, wellpoint installation, deep wells, french drains, or any other method approved by the Engineer.

For foundations placed in the presence of water, when approved by the Engineer, pumping or bailing from the interior of any foundation enclosure shall be done in a manner which precludes the possibility of movement of water through or alongside any concrete being placed. No pumping or bailing will be permitted during the placing of structural concrete, or for a period of at least 36 hours thereafter, unless from a suitable sump separated from the concrete work. Pumping or bailing during placement of seal concrete shall be only to the extent necessary to maintain a static head of water within the cofferdam. Pumping or bailing to dewater a sealed cofferdam shall not be started until the seal has aged at least 36 hours.

In the event that the excavation cannot be dewatered to the point where the subgrade is free of mud, or it is difficult to keep the reinforcing steel clean in cast-in-place structures, a special material shall be used in the bottom of the excavation. Such special material shall be a minimum depth of three (3) inches and shall consist of a lean concrete mixture (not less than three (3) sacks of cement per cubic yard), or other material approved by the Engineer.

Appendix-L: Specifications from Washington

FIU/FDOT SURVEY
(Backfilling utility pipes under high water table)

We have had the following exposure to high water table drainage installation:

1) Installation of a tight line storm water system with a foundation topped with 3/4"-0 bedding compacted to 95% of maximum density and backfilled with select backfill (dredge sand) in clay soils.

2) Installation of a perforated storm/ground water drainage system bedded and backfilled with clean drain rock and wrapped with geotextile and remaining backfill completed with native material in fine sand influenced by tides.

3) Installation of a tight line storm water system with a foundation consisting of compacted pit run (6"-8" quarry rock) bedded and backfill with native material in fine sand influenced by tides.

Controlling the water was a key element in each of these designs. In all cases this was accomplished by beginning the work at the low point (outfall) of the system to provide a point of discharge. Pumping using trash pumps with 3" intakes were adequate in these applications.

In clay soils, providing a firm and unyielding foundation which allows compaction of the bedding material to the desired density without softening the underlying soils and subsequently contaminating the backfill materials and a loss of foundation integrity can be achieved. It is recommended that a flat bit bucket be utilized in lieu of one with teeth to minimize the amount of residual loose materials at the bottom of the excavation prior to backfilling. The foundation material should consist of 4-8" quarried rock with a maximum of 20% passing the 1" screen placed in a 1' minimum lift. Compaction of the foundation material should be sufficient to embed the stone into the native soils and provide a uniform unyielding surface. If native soils are observed at the surface of the foundation material after compaction the cause is generally due to inadequate foundation depth and/or excessive compactive effort. Once an unyielding foundation is attained placement and compaction of the bedding materials are simplified providing the water table is maintained at or below the top of the foundation. To reduce material loss and facilitation of compaction it may be desirable to place a layer of geotextile between the foundation and bedding materials.

Where a high water table exist in fine sand the time of exposure (open trench) can be hindered by the problem of flowing sand. This circumstance can lead to two conditions which can affect production: 1) Infiltration and contamination of bedding and other backfill materials. 2) Excess accumulation of solids at the discharge end of the suction pump. The following suggestions will reduce these potential impacts. Use of portable shoring (coffin box) will expedite trench excavation and reduce exposure providing other utilities and structures do not restrict their use; and installation of well points in the trench will lower the water table of the immediate area. A well point consist of a perforated or slotted conduit 12-24" diameter wrapped with geotextile and installed vertically. The well point should be installed to allow the intake of the suction pump to be placed 1-2' below the bottom of the excavation. A sandpoint dewatering system is also effective in high water table situations but is a very time consuming and very expensive method.

Where excavation and backfilling is intended using native sandy soils in high water table locations high moisture contents (20% +) can exist, depending on the gradation of the native sand. If the application requires permanent and immediate restoration i.e.: road crossings etc., the saturated sand may not be sufficiently stable to provide a firm unyielding base for surfacing materials to be placed. Typically with oversaturated sandy soils the PCF (pounds per cubic foot) necessary to achieve 95% of maximum density can be attained; however, the structural stability is normally unacceptable (pumping) due to the excess water displacing solids. When moisture contents can not be controlled and pumping of the sand backfill is evident there are two possible methods to ensure a stable backfill is constructed:

1) If saturated native materials exist, provide a temporary stockpile several days prior to the time of backfilling to allow the excess moisture to drain. Moisture contents less than 10% are desired. If this is not possible and permanent restoration is essential the saturated excavation may have to be wasted and select suitable backfill imported to ensure that work is completed and structurally sound.

2) When the work does not require permanent and immediate completion of overlying embankments or surfacings the saturated backfill can be placed and compacted as is, allowed to drain and compaction verified by potholing at various depths and locations to confirm that minimum density values are achieved. We have successfully utilized this process on several projects.

Except for requirements to dewater excavations and backfill lift thickness and density requirements our specifications do not direct the method or manner in how to accomplish the work. The attached excerpt from the 1994 Standard Specifications for Road, Bridge, and Municipal Construction Section 2-09 " Structure Excavation" pages 2-28 and 2-29 is included for your review.

2-09 STRUCTURE EXCAVATION

2-09.1 Description

Structure excavation consists of excavating and disposing of all natural material or man-made objects that must be removed to make way for bridge foundations, retaining walls, culverts, trenches for pipelines, conduits, and other structures as shown in the Plans.

This work also includes, unless the contract provides otherwise, removing whole or partial structures, grubbing structure sites that would not otherwise be grubbed, building and later removing shoring, cofferdams, or caissons, pumping or draining excavated areas, protecting excavated materials from the weather, and placing and compacting backfill.

2-09.2 Vacant

2-09.3 Construction Requirements

2-09.3(1) General Requirements

All structure excavation, trenching, and shoring shall be performed in strict compliance with Chapter 296-155 WAC as well as all other applicable local, Contracting Agency, and Federal laws and regulations.

2-09.3(1)A Staking, Cross-Sectioning, and Inspecting

The Contractor shall not begin excavating until after the Engineer has set stakes to locate and/or outline the structure and taken cross-sections to determine how much material to remove. The Engineer will occasionally inspect material taken from and material remaining in the excavation.

2-09.3(1)B Depth of Excavation

The Contractor shall excavate foundation pits to the depth the Plans require, or to any revised depth ordered by the Engineer.

2-09.3(1)C Removal of Unstable Base Material

When the material at the bottom of an excavation is not stable enough to support the structure, the Contractor shall excavate below grade and replace the unstable material with gravel backfill.

Gravel backfill shall meet the requirements of Section 9-03.12. It shall be placed in layers not more than 6 inches thick with each layer compacted to 95 percent of the maximum density determined by the Compaction Control Test, Section 2-03.3(14)D.

2-09.3(1)D Disposal of Excavated Material

The Engineer may direct the Contractor to dispose of excavated material in embankments, backfills, or remove it from the site.

All costs for disposing of excavated material within the project limits shall be included in the unit contract price for structure excavation, Class A or B. If, however, the Contractor must load and haul the material to a disposal site, the Contracting Agency will pay as provided in Section 1-04.4 for loading and hauling. The Contracting Agency will not pay for handling at the disposal site. Any such disposal shall meet the requirements of Section 2-03.3(7)C.

If the contract includes structure excavation, Class A or B, including haul, the unit contract price shall include all costs for loading and hauling the material the full required distance.

2-09.3(1)E Backfilling

The backfilling of openings dug for structures shall be a necessary part of and incidental to the excavation. Unless the Engineer directs otherwise, backfill material shall be nonclay material containing no pieces more than 3 inches across, no frozen lumps, and no wood or other foreign material.

Alternative sources. When material from structure excavation is unsuitable for use as backfill, the Engineer may: require the Contractor to use other material covered by the contract if such substitution involves work that does not differ materially from what would otherwise have been required; require the Contractor to substitute selected material in accordance with Section 2-03.3(1); or require the Contractor to obtain material elsewhere. Material obtained elsewhere will be paid for in accordance with Section 1-04.4.

Stockpiling. The Engineer may require the Contractor to selectively remove and stockpile any usable material excavated for a structure. If this material meets the requirements for gravel backfill for walls it may replace gravel as wall or abutment backfill.

If the Contractor stockpiles excavated material for use as backfill, it shall be protected with plastic sheeting or by some other method from contamination and weather damage. If the material becomes too wet or contaminated in the stockpile, the Contractor shall dispose of and replace it with an equal amount of suitable material, all at no expense to the Contracting Agency. All costs for storing, protecting, rehandling, and placing stockpiled material shall be included in the unit contract price for structure excavation, Class A or B.

Compaction. Backfill from structure excavation shall be placed and compacted in keeping with the following requirements:

1. Backfill supporting roadbed, roadway embankments, or structures — placed in horizontal layers no more than 6 inches thick with each layer compacted to 95 percent of the maximum density determined by the Compaction Control Test, Section 2-03.3(14)D.
2. Gravel backfill for drains — placed in horizontal layers no more than 12 inches thick, with each layer compacted by at least three passes of a vibratory compactor approved by the Engineer.
3. All other structure excavation backfill — placed in layers no more than 2 feet thick (loose), with each layer tamped and graded so that final settling will leave the backfill flush with surrounding ground.

Timing. Backfill shall not be placed against any concrete structure until the concrete has attained 90 percent of its design strength and has cured for at least 14 days. However, the Contractor may backfill footings and columns as soon as forms have been removed, so long as the backfill is brought up evenly on all sides.

The Engineer may order the Contractor to use lean concrete in backfilling around piers and in front of abutments and walls. The Contracting Agency will pay for such backfilling as provided in Section 1-04.4.

If water prevents the Contractor from properly placing and compacting backfill, it shall be removed by pumping or other means.

Appendix-M: Sample of Preliminary FDOT Survey

A Survey of FDOT Compaction Methods for Pipe Trench Backfills in Areas of High Water Tables

Due to Florida's abundance of low lying regions, the Florida Department of Transportation (FDOT) continually is faced with the situation of placing and backfilling utility pipes and culverts in high water table areas. The problem that arises from this occurrence is the uncertainty associated with the compactive integrity of the backfill placed at or below the water table. In response to this dilemma, Florida International University (FIU), in conjunction with the FDOT, is conducting research to study this common occurrence. The researchers wish to identify completed FDOT projects wherein pipe trench backfill was known to have been placed in the wet and subsidence or differential settlement has occurred. Additionally, the study is interested in identifying any current projects in which pipe trench backfill is being placed and compacted in the wet. Your participation is vital to the success of this study, and the researchers would like to thank you in advance for your time and effort in responding to this survey.

Respondent Information:

Date: 4/30/96

Name: Gregory S. Lady

Title: District Scheduling Engineer

District: 4

Address: 3400 W. Commercial Blvd. Ft. Lauderdale, FL 33309-3421

Telephone: (954) 777-4390

FAX: (954) 777-4149

Completed Projects Information (where backfill was placed in the wet and settlement has occurred)

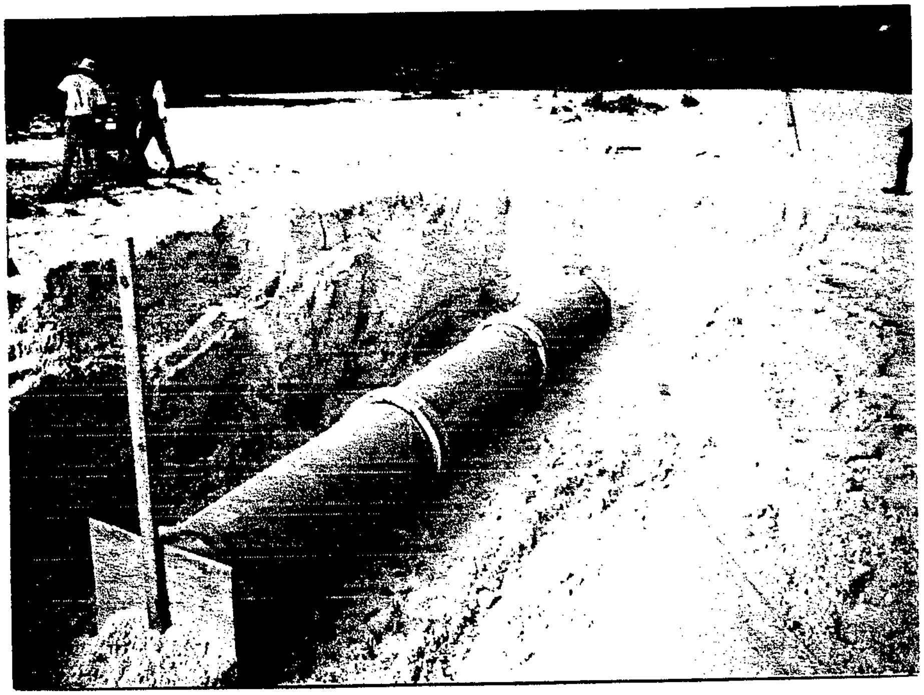
1. Project Title: University Drive (2 jobs)
   Project Location: Stirling Rd to N of Orange
   Project ~~WPI~~ SPN Number: 86220-3538 & -3500
2. Project Title: Dixie Hwy (3 jobs)
   Project Location: So. of Oakland Pk. Blvd to Atlantic Blvd.
   Project ~~WPI~~ SPN Number: 86170-3507, -3509 & -3521
3. Project Title: Broward Blvd.
   Project Location: US 441 to US 1
   Project ~~WPI~~ Number: 86006-?
4. Project Title: A1A
   Project Location: @ Hollywood Blvd.
   Project WPI Number: 86030-? or 86040-?
5. Pines Blvd ~~E~~ of University 86040-3544
   Also Pembroke Rd., Hallandale Rd., Griffin Rd.

Current Projects Information (where pipe trench backfill is being placed and compacted in the wet)

1. Project Title: Pembroke Rd.
   Project Location: US 441 to I-95
   Project ~~WPI~~ SPN Number: 86018-3501
2. Project Title: Las Olas Blvd.
   Project Location: 16th to Intracoastal WW
   Project ~~WPI~~ SPN Number: 86050-3500
3. Project Title: Hillsboro Blvd.
   Project Location: US 441 to Powerline Rd.
   Project ~~WPI~~ SPN Number: 86120-3508
4. Project Title:
   Project Location:
   Project WPI Number:

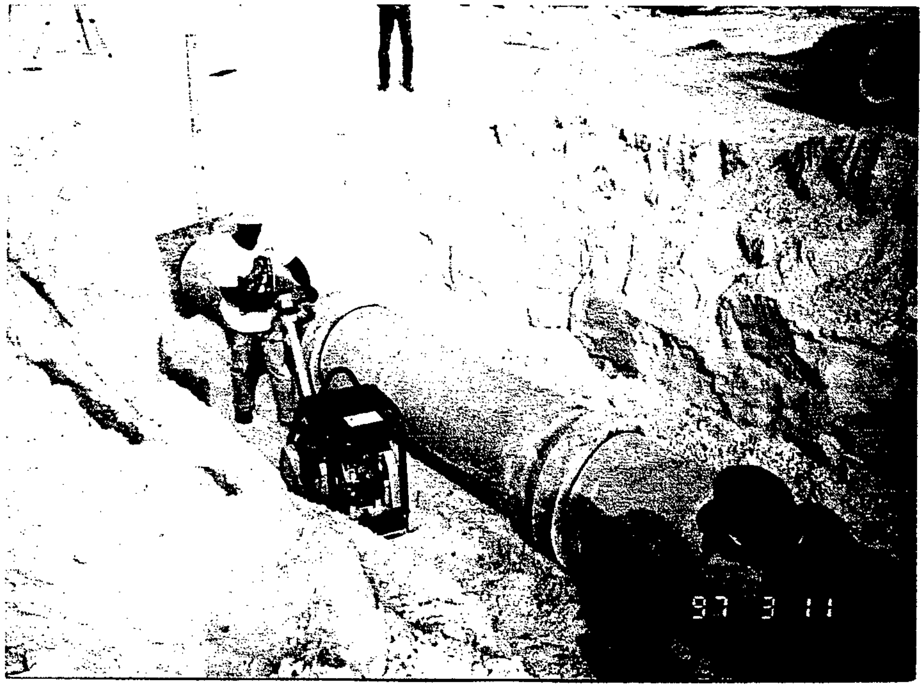
If you know of other completed or current projects not listed above, please include this additional information on a separate page. The researchers again would like to thank you for your cooperation, and if you have any additional comments regarding this study, you are encouraged to attach them to your completed survey.

Appendix-N: Representative Photographs of the Experimental Study



Pipe sections in the trench (Control dry condition)

Backfilling (Control dry condition)



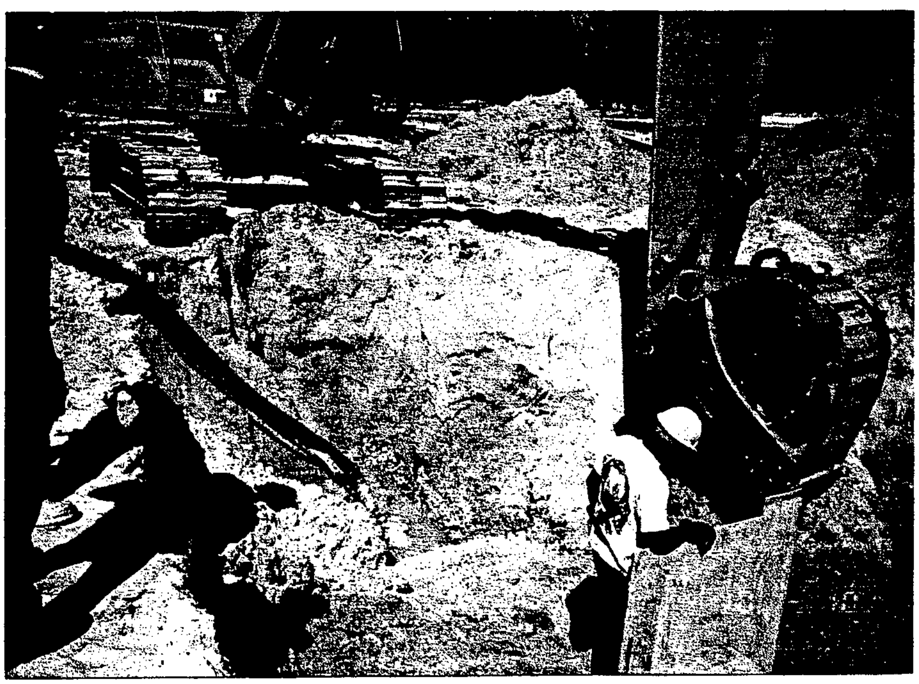
Compacting with the Vibro-Compactor (Control dry condition)

Taking density readings

Excavating

Pipe Segments being laid in the trench

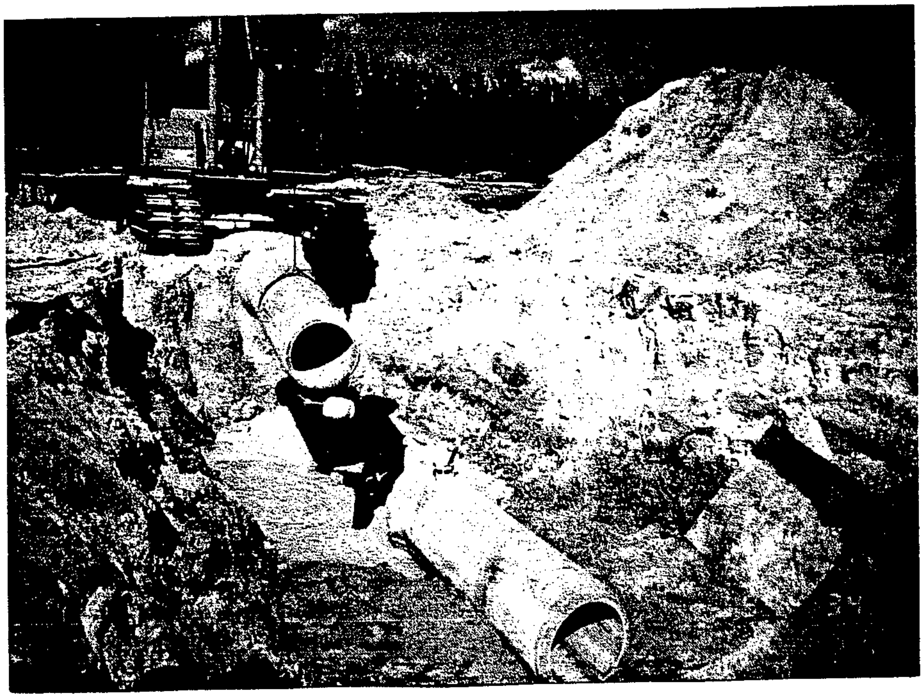
A view of the trench



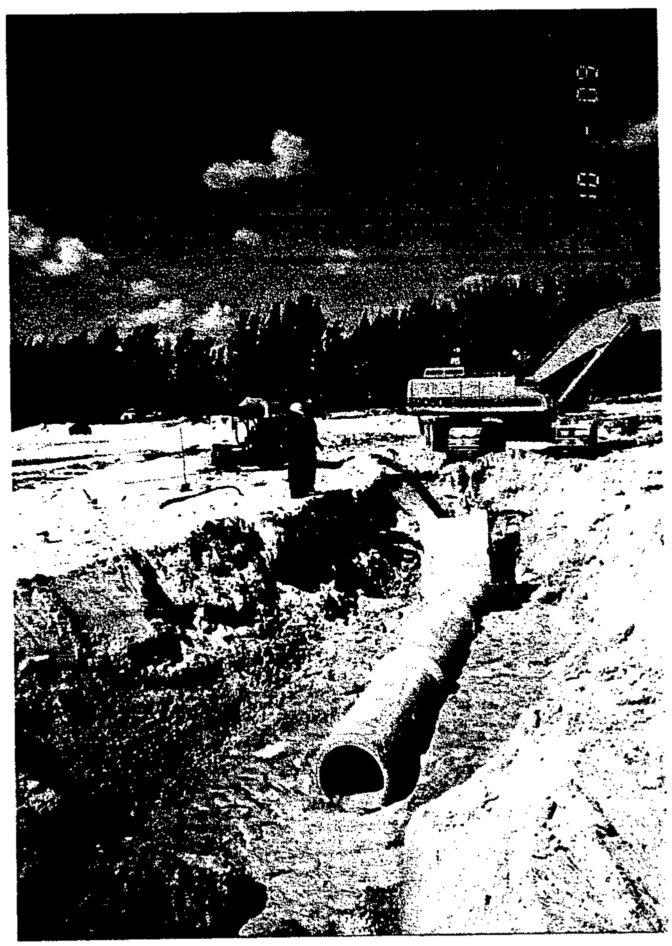
Excavating

Dewatering

Dewatering as pipe sections being laid



Aligning pipe sections



Pipe sections in the trench

Laying pipe sections in the water

Backfilling

Appendix-O: SPT Boring Logs of the Field Tests

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	1		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	4		
1.5	8	12	Light grey fine sand
2.0	11		
2.5	12		No water table
3.0	14		
3.5	20	34	
4.0	23		
4.5	18		
5.0	16		
5.5	17	33	
6.0	17		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	2		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	6	9	Light grey fine sand
2.0	10		
2.5	13		No water table
3.0	17		
3.5	23	40	
4.0	24		
4.5	19		
5.0	18		
5.5	15	33	
6.0	15		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	3		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	6	9	Light grey fine sand
2.0	10		
2.5	13		No water table
3.0	13		
3.5	18	31	
4.0	22		
4.5	18		
5.0	23		
5.5	27	50	
6.0	26		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	4		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	4		
1.5	6	10	Light grey fine sand
2.0	10		
2.5	12		No water table
3.0	15		
3.5	19	34	
4.0	21		
4.5	20		
5.0	20		
5.5	25	45	
6.0	23		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	5		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	7	10	Light grey fine sand
2.0	11		
2.5	13		No water table
3.0	15		
3.5	17	32	
4.0	21		
4.5	17		
5.0	20		
5.5	22	42	
6.0	26		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	6		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	3		
1.5	6	9	Light grey fine sand
2.0	9		
2.5	15		No water table
3.0	14		
3.5	18	32	
4.0	19		
4.5	19		
5.0	21		
5.5	21	42	
6.0	23		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	A	Control dry	
Location	7		
Date	3/29/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	4		
1.5	8	12	Light grey fine sand
2.0	10		
2.5	11		No water table
3.0	13		
3.5	19	32	
4.0	22		
4.5	21		
5.0	26		
5.5	19	45	
6.0	20		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - No compaction	
Location	1		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	6	9	Light grey fine sand
2.0	9		
2.5	7		Water table at 2'-7"
3.0	6		
3.5	7	13	
4.0	7		
4.5	6		
5.0	5		
5.5	6	11	
6.0	7		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - No compaction	
Location	2		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	4	7	Light grey fine sand
2.0	8		
2.5	8		Water table at 2'-6"
3.0	9		
3.5	9	18	
4.0	9		
4.5	5		
5.0	6		
5.5	5	11	
6.0	6		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - no compaction	
Location	3		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	7	10	Light grey fine sand
2.0	11		
2.5	8		Water table at 2'-7"
3.0	7		
3.5	7	14	
4.0	7		
4.5	5		
5.0	5		
5.5	6	11	
6.0	6		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - no compaction	
Location	4		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	7	10	Light grey fine sand
2.0	8		
2.5	6		Water table at 2'-6"
3.0	6		
3.5	4	10	
4.0	6		
4.5	5		
5.0	8		
5.5	8	16	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - no compaction	
Location	5		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	5	8	Light grey fine sand
2.0	7		
2.5	7		Water table at 2'-7"
3.0	6		
3.5	6	12	
4.0	6		
4.5	7		
5.0	7		
5.5	8	15	
6.0	9		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - no compaction	
Location	6		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	7	10	Light grey fine sand
2.0	8		
2.5	9		Water table at 2'-7"
3.0	9		
3.5	8	17	
4.0	7		
4.5	5		
5.0	5		
5.5	6	11	
6.0	7		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	B	Dump soil - no compaction	
Location	7		
Date	4/2/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	2		
1.5	3	5	Light grey fine sand
2.0	8		
2.5	8		Water table at 2'-8"
3.0	10		
3.5	8	18	
4.0	10		
4.5	4		
5.0	4		
5.5	5	9	
6.0	6		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	1		
Date	5/597		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	8		to medium grain sand
2.5	10		
3.0	7		Water table at 3'-9"
3.5	7	14	
4.0	9		
4.5	8		
5.0	7		
5.5	6	13	
6.0	10		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	2		
Date	5/5/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	9		to medium grain sand
2.5	10		
3.0	9		Water table at 3'-8"
3.5	9	18	
4.0	8		
4.5	5		
5.0	4		
5.5	6	10	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	3		
Date	5/5/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	8		to medium grain sand
2.5	9		
3.0	9		Water table at 3'-7.5"
3.5	9	18	
4.0	9		
4.5	5		
5.0	5		
5.5	6	11	
6.0	7		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	4		
Date	5/597		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	8		to medium sand grain
2.5	9		
3.0	8		Water table n/a
3.5	9	17	
4.0	8		
4.5	5		
5.0	6		
5.5	6	12	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	5		
Date	5/5/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	9		to medium grain sand
2.5	9		
3.0	9		Water table at 3'-10"
3.5	10	19	
4.0	9		
4.5	4		
5.0	4		
5.5	6	10	
6.0	10		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	6		
Date	5/5/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	5	8	Light grey fine
2.0	8		to medium grey sand
2.5	9		
3.0	9		Water table at 3'-10"
3.5	10	19	
4.0	9		
4.5	5		
5.0	6		
5.5	7	13	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	C	Dump soil - Compact per DOT	
Location	7		
Date	5/5/97		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	3		
1.5	6	9	Light grey fine
2.0	9		to medium grain sand
2.5	8		
3.0	9		Water table at 3'-8"
3.5	9	18	
4.0	9		
4.5	5		
5.0	6		
5.5	6	12	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	1		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	5		
1.5	7	12	Light grey fine
2.0	8		to medium grey sand
2.5	8		Trace of rock & shell
3.0	9		
3.5	11	20	Water Table at 3'-3.5"
4.0	12		
4.5	7		
5.0	7		
5.5	7	14	
6.0	9		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	2		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	4		
1.5	8	12	Light grey fine
2.0	9		to medium grey sand
2.5	10		Trace of rock & shell
3.0	12		
3.5	13	25	Water Table at 3'-5"
4.0	10		
4.5	10		
5.0	9		
5.5	10	19	
6.0	10		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	3		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	1		
1.0	4		
1.5	6	10	Light grey fine
2.0	10		to medium grey sand
2.5	9		Trace of rock & shell
3.0	11		
3.5	14	25	Water Table at 3'-5"
4.0	12		
4.5	12		
5.0	12		
5.5	15	27	
6.0	15		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	4		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	5		
1.5	8	13	Light grey fine
2.0	12		to medium grey sand
2.5	14		Trace of rock & shell
3.0	12		
3.5	11	23	Water Table at 3'-5.5"
4.0	9		
4.5	9		
5.0	8		
5.5	7	15	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	5		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	4		
1.5	5	9	Light grey fine
2.0	6		to medium grey sand
2.5	8		Trace of rock & shell
3.0	9		
3.5	10	10	Water Table at 3'-5"
4.0	10		
4.5	15		
5.0	13		
5.5	14	27	
6.0	14		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	6		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	5	8	Light grey fine
2.0	6		to medium grey sand
2.5	8		Trace of rock & shell
3.0	10		
3.5	11	21	Water Table at 3'-5"
4.0	15		
4.5	12		
5.0	15		
5.5	16	31	
6.0	16		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	D	Control wet - Compact per DOT	
		Dewatered with pump	
Location	7		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	4		
1.5	6	10	Light grey fine
2.0	9		to medium grey sand
2.5	12		Trace of rock & shell
3.0	15		
3.5	14	29	Water Table at 3'-4.5"
4.0	15		
4.5	15		
5.0	12		
5.5	11	23	
6.0	13		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	1		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	3		
1.5	7	10	Light grey fine
2.0	10		to medium grey sand
2.5	7		Trace of rock & shell
3.0	7		
3.5	6	13	Water Table at 3'-2"
4.0	5		
4.5	3		
5.0	4		
5.5	3	7	
6.0	8		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	2		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	4		
1.5	6	10	Light grey fine
2.0	10		to medium grey sand
2.5	9		Trace of rock & shell
3.0	12		
3.5	8	20	Water Table at 3'-3"
4.0	7		
4.5	4		
5.0	5		
5.5	4	9	
6.0	4		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	3		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	5	8	Light grey fine
2.0	8		to medium grey sand
2.5	9		Trace of rock & shell
3.0	9		
3.5	5	14	Water Table at 3'-3"
4.0	5		
4.5	3		
5.0	3		
5.5	2	5	
6.0	4		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	4		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	3		
1.5	6	9	Light grey fine
2.0	9		to medium grey sand
2.5	9		Trace of rock & shell
3.0	10		
3.5	9	19	Water Table at 3'-6"
4.0	7		
4.5	5		
5.0	4		
5.5	5	9	
6.0	4		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	5		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	3		
1.5	7	10	Light grey fine
2.0	8		to medium grey sand
2.5	9		Trace of rock & shell
3.0	9		
3.5	6	15	Water Table at 3'-6"
4.0	5		
4.5	4		
5.0	3		
5.5	2	5	
6.0	3		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	6		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	3		
1.0	3		
1.5	6	9	Light grey fine
2.0	8		to medium grey sand
2.5	9		Trace of rock & shell
3.0	8		
3.5	7	15	Water Table at 3'-6"
4.0	6		
4.5	5		
5.0	4		
5.5	3	7	
6.0	4		
End of boring at 6'-0" below land surface.			

FIU/FDOT Pipe Trench Backfill Research Project			
	Log of Boring		
Field Condition	E	Dump soil - No compaction	
		Dewatered with pump	
Location	7		
Date	4/9/98		
Depth (ft)	Blows/6 in.	"N" Value	Soil Description
0.5	2		
1.0	3		
1.5	7	10	Light grey fine
2.0	9		to medium grey sand
2.5	8		Trace of rock & shell
3.0	8		
3.5	6	14	Water Table at 3'-5.5"
4.0	5		
4.5	3		
5.0	3		
5.5	2	5	
6.0	5		
End of boring at 6'-0" below land surface.			

Appendix-P: Summary of *N*-Values by Locations of Bore Holes

SPT "N" Value Summary

<u>Location No. 1</u>

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	12	9	8	12	10
2-4	34	13	14	20	13
4-6	33	11	13	14	7

SPT "N" Value Summary

Location No. 2

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	9	7	8	12	10
2-4	40	18	18	25	20
4-6	33	11	10	19	9

SPT "N" Value Summary

Location No. 3

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	9	10	8	10	8
2-4	31	14	18	25	14
4-6	50	11	11	27	4

SPT "N" Value Summary

<u>Location No. 4</u>

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	10	10	8	13	9
2-4	34	10	17	23	19
4-6	45	16	12	15	9

SPT "N" Value Summary

Location No. 5

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	10	8	8	9	10
2-4	32	12	19	19	15
4-6	42	15	10	27	5

SPT "N" Value Summary

Location No. 6

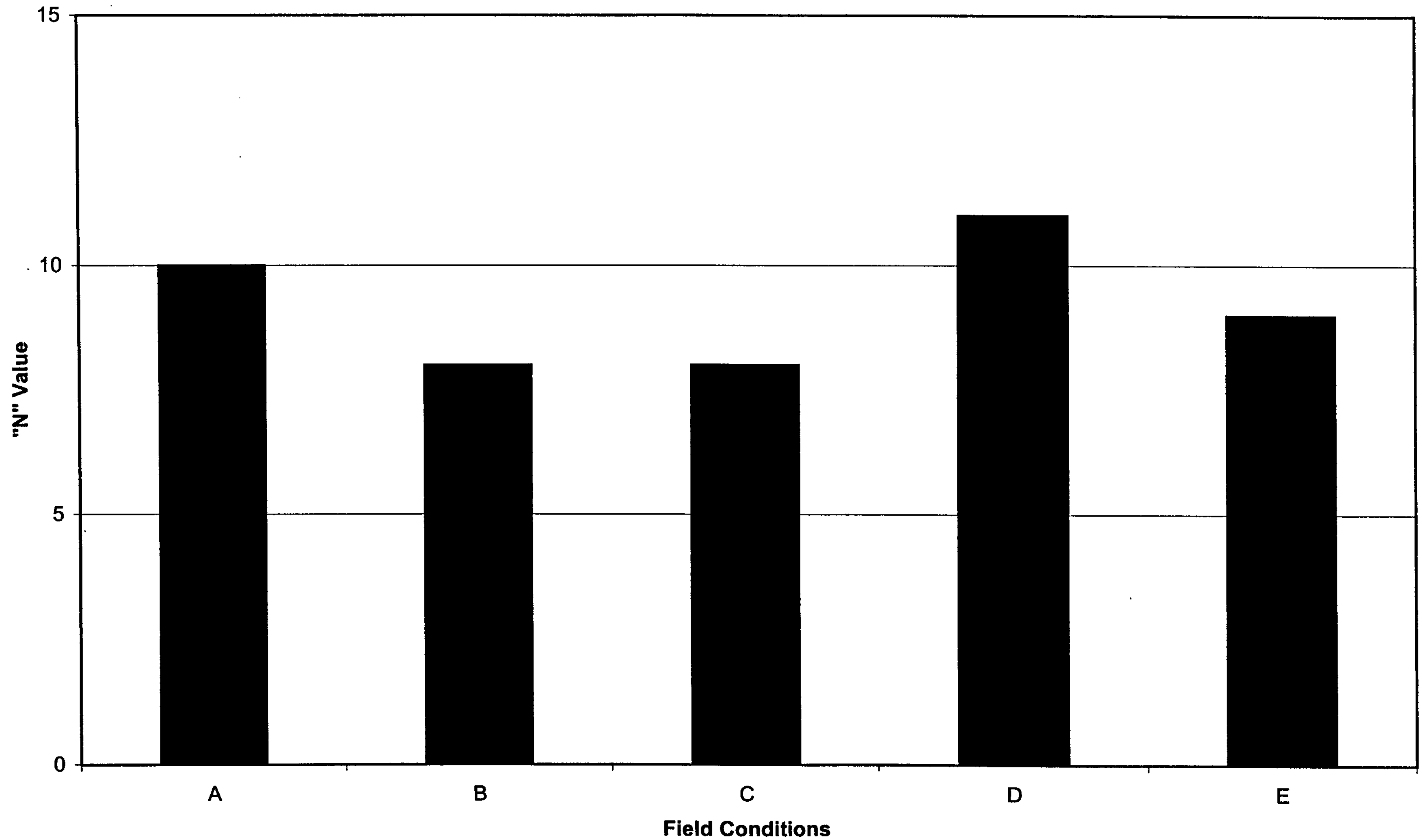
Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	9	10	8	8	9
2-4	32	17	19	21	15
4-6	42	11	13	31	7

SPT "N" Value Summary

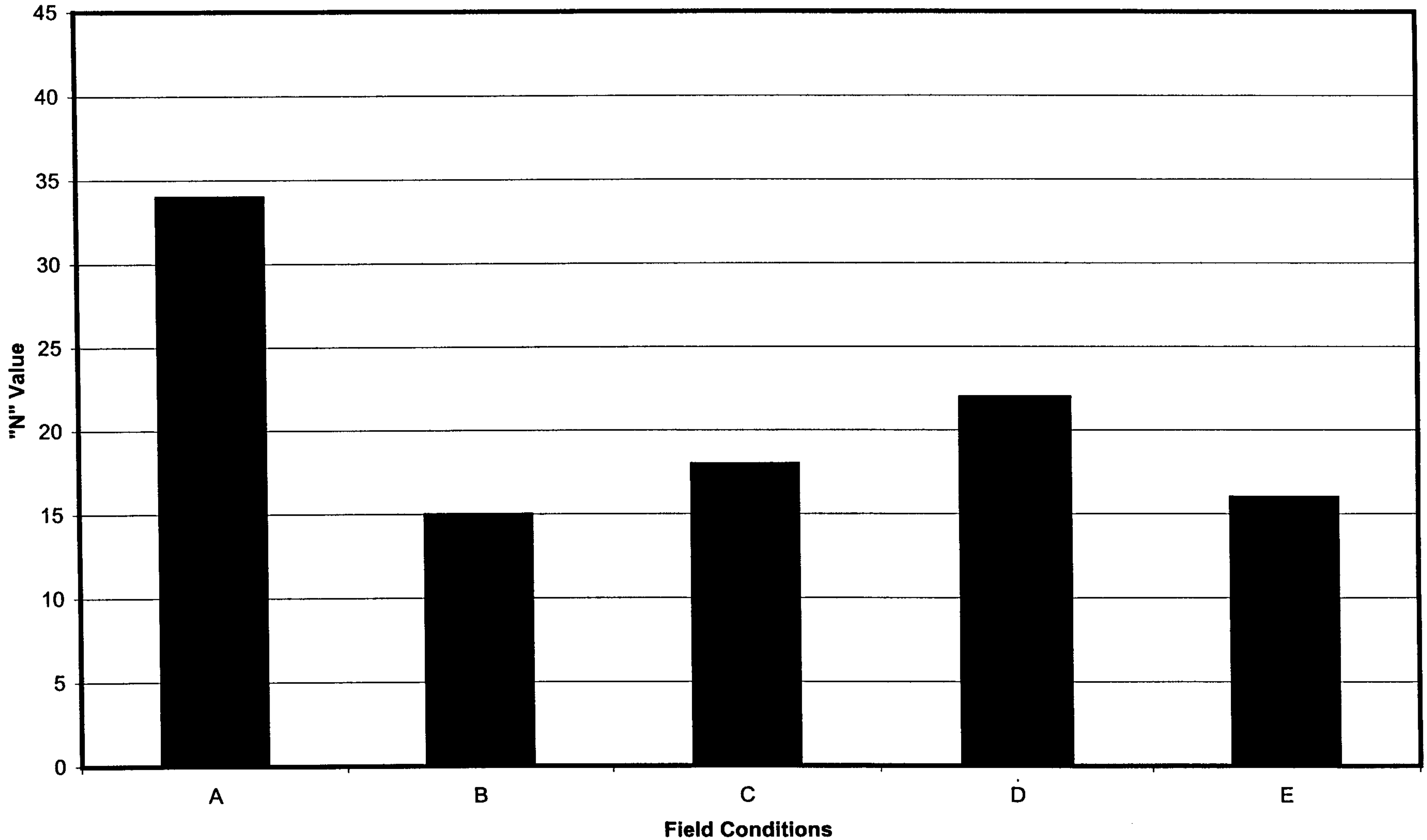
Location No.7

Phase	Control Dry	Dump Soil No Compaction	Dump Soil Compact per DOT	Control Wet Exact per DOT Dewatered w/pump	Dump Soil No Compaction Dewatered w/pump
Depth in ft.	A	B	C	D	E
1-2	12	5	9	13	10
2-4	32	18	18	23	14
4-6	45	9	12	15	5

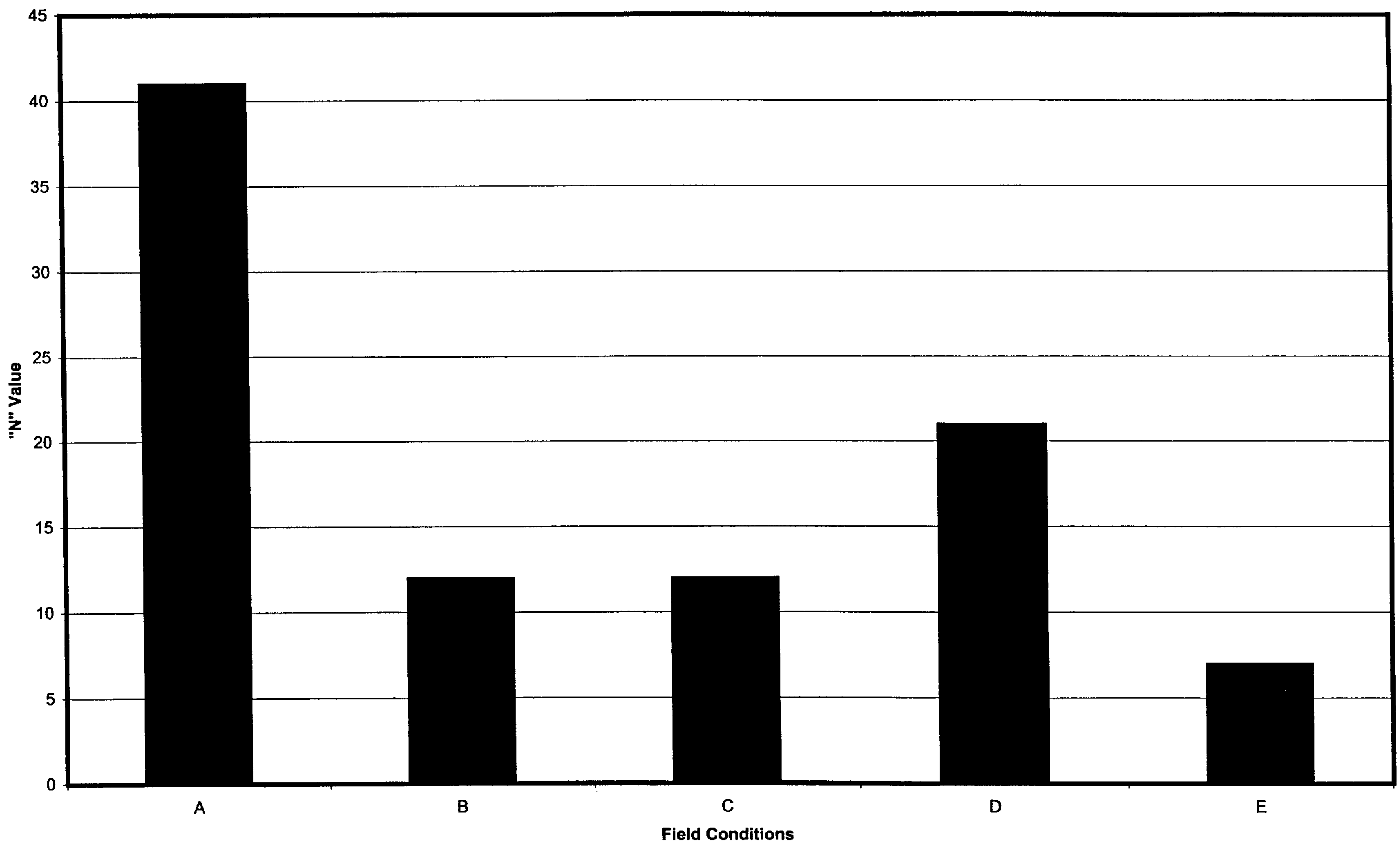
SPT "N" Value Summary (Average) at depth 1-2 ft.



SPT "N" Value Summary (Average) at 2-4 ft.



SPT "N" Value Summary (Average) at 4-6 ft.



Appendix-Q: Example Letter Regarding "Alternative Pipe Backfill Method"

FLORIDA DEPARTMENT OF TRANSPORTATION
LAWTON CHILES
GOVERNOR
FORT PIERCE CONSTRUCTION
3601 Oleander Avenue, Fort Pierce, FL 34982-6594
Telephone: (561) 489-7072; SC 223-7072
FAX: (561) 489-7125; SC 223-7125
THOMAS F. BARRY, JR.
SECRETARY

MEMORANDUM

DATE: April 27, 1998

TO: Lincoln Morgado, P.E., District 4 Materials Engineer
Morteza Alian, P.E., District 4 Drainage Engineer

FROM: James C. Lynch, P.E., Resident Engineer

COPIES: A. Yocca, W. Kyzer, M. Kelly, File, S:\A_PROJ\ST_LUCIE\94010\3505\GENERAL\SR-5.023

SUBJECT: ALTERNATIVE PIPE BACKFILL METHOD

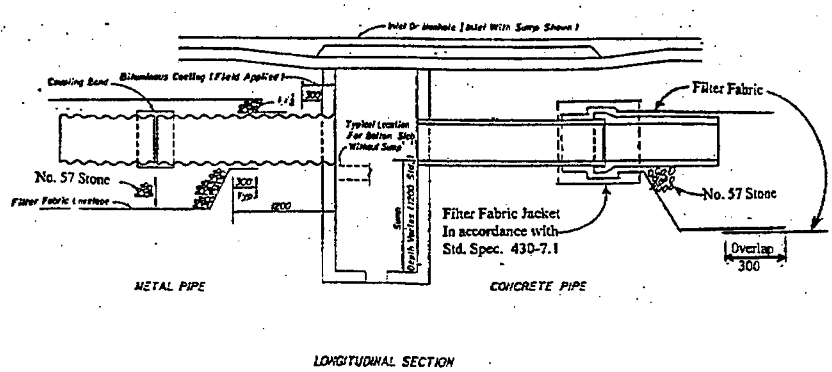
Work Program Item No.:	230356
State Job Number:	94010-3505/ 6505(23035615201 /5601)
Federal Job Number:	4855063P
County:	St. Lucie
Description:	Reconstruction of SR-5 from Georgia Avenue to Ave. B

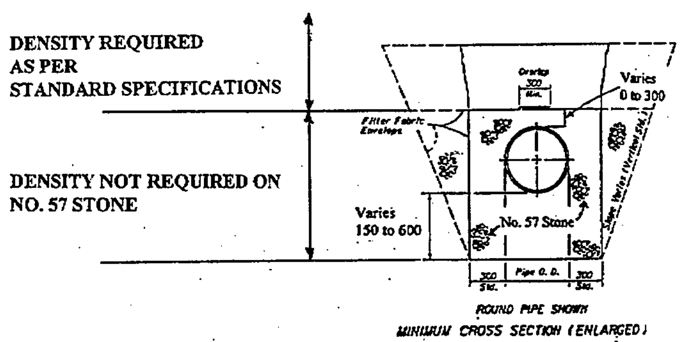
As we discussed on the telephone, the contractor on the subject project has requested permission to back fill the drainage pipe with No. 57 Stone. The proposed method is basically a French Drain without the slotted pipe. There are several advantages to this backfill method.

1. Impacts to the pipe operation due to wet soil conditions are greatly reduced.
2. The contractor does not have to obtain density on the No. 57 Stone for obvious reasons.
3. The contractor should be able to obtain density up to the bottom of the base on a Dailey basis. This will eliminate an over night drop off hazard and the need for barrier wall.
4. This backfill method will speed up drainage operation, and hopefully the overall project.

After our discussions the contractor was given approval to utilize the Alternative Backfill Method as outlined on the attached index drawing (No. 285A) on this project.

If you have any questions please contact this office at SC 223-7072.





GENERAL NOTES

1. This alternative pipe backfill method may be used in leu of method outlined in the Standard Specifications as long as there are no additional costs to the Department.

2. Pipe shall be any of the optional types permitted in section 443 of the specifications unless otherwise restricted in the plans. Dissimilar types of pipe will not be permitted in a continuous run of pipe.

3. Filter fabric shall be Subsurface Drainage type meeting the requirements of Section 985. All filter fabric joints shall lap a minimum of 300 millimeters.

ALTERNATIVE PIPE BACKFILL METHOD

1 of 1 285A

Appendix-R: FDOT Supplemental Specifications on Flowable Fill

102-3.2.4 Flagger: The Contractor shall provide trained flaggers to direct traffic where one-way operation in a single lane is in effect and in other situations as required in 102-3.1. Training of flaggers shall be provided by the Worksite Traffic Supervisor or others as approved by the Department. Department-approved training materials shall be used for this training.

102-3.2.5 Existing Pavement Markings: Where a detour changes the lane use or where normal vehicle paths are altered during construction, all existing pavement markings that will be in conflict with the adjusted vehicle paths shall be removed. Overpainting will not be allowed. The removal may be accomplished by any method that will not materially damage the surface texture of the pavement and which will eliminate the previous marking pattern regardless of weather and light conditions.

All pavement markings that will be in conflict with "next phase of operation" vehicle paths shall be removed as described above, prior to opening to traffic.

102-3.2.6 No Waiver of Liability: The Contractor shall conduct his operations in such a manner that no undue hazard will result due to the requirements of this Article, and the procedures and policies described therein shall in no way act as a waiver of any of the terms of the liability of the Contractor or his surety.

<u>104</u> <u>MOWING</u>. (7-96) (FA 3-5-96) (REV 2-15-96)

SUBARTICLE 104-7.2 (Page 97) is deleted and the following substituted:

The Engineer may direct mowing of areas within the limits of the project. The Contractor shall mow these designated areas within 7 days of receiving such order. Mowing of slopes which are steeper than three horizontal to one vertical will not be required.

<u>110</u> <u>CLEARING AND GRUBBING - BOULDERS</u>. (1-96) (FA 3-31-95) (REV 10-12-94)

SUBARTICLE 110-2.4 (Page 100) is deleted and the following substituted:

Any boulders encountered in the roadway excavation (other than as permitted under the provisions of 120-7.2), or found on the surface of the ground, shall be removed and disposed of by the Contractor in areas provided by him.

<u>121</u> <u>FLOWABLE FILL</u>. (1-97) (FA 12-13-96) (REV 7-25-96)

PAGE 121. The following new Section is added after Section 120:

SECTION 121
FLOWABLE FILL

121-1 Description.

This work shall consist of furnishing and placing Flowable Fill as an alternative to compacted soil as approved by the Engineer. Applications for this material includes, beddings, encasements, closures for tanks, pipes, and general backfill for trenches.

121-2 Materials.

All materials shall meet the requirements of the following Specifications:

Fine Aggregate*	Section 902
Portland Cement (Types I, II, or III)	Section 921
Fly Ash, Slag and other Pozzolanic Materials	Section 929
Air Entraining Admixtures**	Section 924
Water	Section 923

*Any clean fine aggregate with 100% passing a 9.5 mm mesh sieve and not more than 15% passing a 75 μm sieve may be used.

**High air generators or foaming agents may be used in lieu of conventional air entraining admixtures and may be added at jobsite and mixed in accordance with manufacturers recommendation.

121-3 Mix Design.

Flowable Fill is a mixture of portland cement, fly ash, fine aggregate, air entraining admixture and water. Flowable fill contains a low cementitious content for reduced strength development.

The Contractor shall submit mix designs for flowable fill to the Engineer for approval by the District Materials Engineer. The following are suggested mix guides for excavatable and non-excavatable flowable fill:

	Excavatable	Non-Excavatable
Cement Type 1	45-60 kg/m^3	45-90 kg/m^3
Fly Ash	None	90-355 kg/m^3
Water	*	*
Air**	5-35%	5-15%
28 Day Compressive Strength**	Maximum 690 kPa	Minimum 860 kPa
Unit Weight (Wet)**	1440-1760 kg/m^3	1600-2000 kg/m^3

*Mix designs shall produce a consistency that will result in a flowable self-leveling product at time of placement.

**The requirements for percent air, compressive strength and unit weight are for laboratory designs only and are not intended for jobsite acceptance requirements.

Fine Aggregate shall be proportioned to yield 1 m^3.

121-4 Production and Placing.

Flowable fill will be manufactured at plants that qualify as approved sources in accordance with the Standard Operating Procedure for Ready-Mix concrete. Revolution counter requirements are waived.

Flowable fill shall be delivered using concrete construction equipment. Placing flowable fill shall be by chute, pumping or other methods approved by the Engineer. Flowable fill shall be tremied through water.

121-5 Construction Requirements.

When used as backfill for pipe, where flotation or misalignment may occur, correct alignment will be assured by means of straps, soil anchors or other approved means of restraint.

Flowable fill shall be protected from freezing for a period of 36 hours after placement.

The flowable fill shall be placed to the designated fill line without vibration or other means of compaction. Placement shall be avoided during inclement weather, e.g. rain or ambient temperatures below 4°C. The Contractor shall take all necessary precautions to prevent any damages caused by the hydraulic pressure of the fill during placement prior to hardening. Also, necessary means to confine the material within the designated space shall be provided by the Contractor.

121-6 Acceptance.

Acceptance of flowable fill will be based on the following documentation and a minimum temperature of flowable fill at the point of delivery of 10°C.

The concrete plant shall transmit delivery tickets with each load of flowable fill delivered to the worksite. The tickets shall contain information which includes the Project designation, date, time, class and quantity of flowable fill, the actual batch proportions, the free moisture content of aggregates, and the quantity of water withheld. The Contractor shall provide the Engineer with one of the delivery tickets. If available forms do not contain the required information, the Engineer may provide one for use. The fill shall be left undistrubed until the material obtains sufficient strength. Sufficient strength is 240 kPa pentration resistance as measured using a hand held penetrometer in accordance with FM 1-T 197. The penetrometer shall be provided by the Contractor.

121-7 Basis of Payment.

When the item of flowable fill is included in the Contract, payment will be made at the contract unit price per cubic meter. Such price and payment shall include all cost of the mixture, in place and accepted, determined as specified above. No measurement and payment will be made for material placed outside the neat line limits or outside the adjusted limits, or for unused or wasted material.

Payment shall be made under:

Item No. 2121-70 - Flowable Fill - per cubic meter.

<u>125</u> <u>PIPE TRENCH EXCAVATION - PIPE BEDDING</u>. (7-96) (FA 4-11-96) (REV 3-11-96)

SUBARTICLE 125-4.4.3 (Page 123) is deleted and the following substituted:

125-4.4.3 Pipe Bedding: When undercutting is required in order to remove unsuitable material (either hard or soft), the trench shall be backfilled to a point 150 mm above the bottom of the pipe, with suitable granular material which will form a firm bed for the pipe, and the bottom shall be shaped to fit the pipe, to a point 150 mm above the bottom of the pipe.

Appendix-S: Specifications of Pennsylvania on Flowable Fill

I. DESCRIPTION

This work is construction of flowable backfill of the type specified for trenches and structures.

(a) Flowable Backfill, Type A and Type B. Future excavation of the backfill may be necessary such as at utility trenches, pipe trenches, bridge abutments, and around box or arch culverts.

(b) Flowable Backfill, Type C. Excavation of backfills not anticipated, including replacing unsuitable soils below structure foundations, filling abandoned conduits, tunnels and mines, and backfilling around culverts where extra strength is required.

(c) Flowable Backfill, Type D. Construction in areas requiring low density backfill material as in abutments over highly deformable soils, backfilling retaining walls, filling vaults and backfilling on top of buried structures.

II. MATERIAL

(a) Cement. Type I, IP, or II, Section 701. When using Type IP cement, it may be necessary to adjust the quantity of flyash in the design.

(b) Flyash. Type F flyash Section 724 except as follows:

- A maximum Loss on Ignition (LOI) of 12 percent.

The source shall be from Bulletin 15 or other suppliers as approved by the Department.

(c) Fine Aggregate. Type A, B, or C; Section 703.1; except, having a maximum loss of 20% in the Soundness Test, PTM No. 510.

(d) Coarse Aggregate. Type C or better, AASHTO No. 10, Section 703.2.

(e) Bottom Ash. Coal ash having a maximum loss of 20% in the Soundness Test, PTM No. 510, and meeting the following dry sieve gradation requirements:

Sieve Size (PTM No. 117)	% Passing
1/2"	100
#200	0-10

(f) Water. Section 720. 1

(g) Admixtures. Section 711.3. May be used when approved by the Engineer. Air entrainment admixture is not required.

(h) Geotextile, Class 4. Section 735.

(i) Mix Design. Submit a mix design and test results (density and strength) to the Engineer, at least 3 weeks prior to construction. Use Table 1 for the mix design or submit alternate design based on density guidelines and meeting strength requirements of Table 1.

Provide mix designs that meet specific density requirements, where specified. source of material is changed, submit a revised mix design before using :erial. Conduct design mix testing at highest flowability or slump that will be used for the project.

When directed by the Engineer, test design mixes for applications involving exposed metal or thin concrete members in contact with the flowable fill, for corrosion potential as follows:

Resistivity, PTM No. 133, 60 day cure	>2,000 ohm-centimeters
pH of pulverized flowable backfill	5.0 to 9.5
Chlorides of pulverized backfill after cure	<200 ppm
Sulfates of pulverized backfill after cure	<1,000 ppm
Sulfides of pulverized backfill after cure	<200 ppm

(j) Certification. Certify properties of flowable backfill as specified in Section 106.03(b)3.

(k) Forms. Section 1001.2(h)1

III. CONSTRUCTION

(a) General. Furnish indicated type of flowable backfill meeting the requirements of Table 1.

Mix and transport in accordance with Section 704 or by other approved methods. justments to mix in field are permissible provided criteria specified in ..ble 1 are achieved.

(b) Placement. Submit the sequence of operations for review at the pre-construction conference. When required, design form work to sustain lateral fluid pressure equal to total unit weight of unhardened flowable backfill with a minimum 1.3 factor of safety. Construct form work in accordance with Section 1001.3(a).

Prepare supporting surface to receive flowable backfill as specified. Do not place flowable backfill during rain or through flowing water. Remove and replace flowable backfill damaged by rain or flowing water. When excavation cannot be dewatered, place flowable backfill by a tremie procedure, approved by the Engineer.

Break up lumps by remixing or other approved method.

Outlet base drains to avoid intersecting areas where flowable backfill will be placed. Furnish solid base drain outlet pipes in areas intersecting the flowable backfill.

Do not place flowable backfill at a material temperature below 50 F or when the temperature of either the air or the surface on which the flowable backfill is to be placed is 40 F or lower. Maintain the in-place flowable backfill at a temperature of at least 50 F for a minimum of 24 hours or until the next lift is placed.

Do not place additional lifts until surface bleed water dissipates and preceding lift has cured sufficiently to support foot traffic.

1 tect finished surface from frost, erosion and damage at all times with suitable covers of soil, aggregate, concrete, pavement or other material approved by the Engineer.

Some applications may require containing flowable backfill by constructing dikes from the mix using less water to produce a 3" minimum slump, when approved by the Engineer. Dikes will remain as an integral part of completed flowable backfill. Thickening of the mix in other areas is allowable when approved by the Engineer.

1. Structure Backfill. When backfilling, place flowable backfill in lifts to prevent lateral pressures from exceeding resisting capacity of structure. Do not place in excess of 4' Lifts. Protect structure foundation drains from intrusion and contamination by flowable backfill with Class 4 geotextile as a separation membrane. Protect existing structures, drainage facilities, utilities, etc., scheduled to remain within the fill area, from movement, damage, or misalignment during placement of flowable backfill. Repair or replace any damaged items, as directed by the Engineer, at no additional cost to the Department. Provide preformed drain no more than 2" thick between the wall and the flowable fill and provide outlets at no more than 15' through the wall, or as directed by the Engineer.

2. Pipe Bedding and Backfill. Backfill the trench as shown on Flowable Backfill Detail. Place adequate support to provide the minimum required bedding from trench bottom to bottom of pipe and protect pipe from damage, vement, and improper alignment. Protect pipe from intrusion of flowable ckfill. When indicated, place Class 4 geotextile membrane around pipe.

Prevent floating of pipe by placing flowable backfill in lifts or use sandbags or other weights to ballast pipe until lift is set. Place backfill evenly on both sides of the trench to avoid overstressing pipe. Monitor pipe alignment in accordance with Section 601.3(c).

3. Utility Trench Backfill. Provide adequate tie-downs or weights, if required, for utility conduits to prevent floating. Maintain proper alignment of conduits during placement of flowable backfill. Perform all utility work in accordance with permit requirements.

(c) Testing and Acceptance. Section 704.1(g), Section 704.1(d)1, 704.1(d)3 and as follows:

Test flowable backfill for slump, in accordance with PTM No. 600, and for yield, in accordance with PTM No. 613, as part of the quality control plan. Air meters and slump cones as specified in Section 704.1(d)2., are not required.

Test flowable backfill for proper water content using the flow cone or the slump cone. Conduct tests as often as necessary (minimum of every 50 cubic yard) to maintain the correct water content at time of placement and when requested by the Inspector. Test flowable backfill for yield a minimum of one test for every 200 cubic yards of material. Record all test results and submit to the Inspector.

Mold 3" x 6" or 6" x 12" cylinders in accordance with PTM No. 611, except specimens will remain in the mold until just before testing. Test for compressive strength in accordance with PTM No. 604, except use neoprene caps. Have compressive strength tests witnessed by the inspector. Replace material that does not meet the requirements of Table 1.

(, Opening to Traffic. For flowable backfill Type A, Type B, and Type C fill material, do not open to traffic until 1 hour after the surface bleed water has dissipated as indicated by a dry surface and as permitted by the Engineer. Open flowable backfill Type D to traffic when directed by the Engineer.

IV. MEASUREMENT AND PAYMENT

For all pipe installations, flowable backfill and geotextile are incidental to linear foot of pipe payment.

(a) Flowable Backfill - Cubic Yard

For the type indicated, in accordance with the specifications.

(b) Class 4 Geotextile - Square Yard.

TABLE 1				
Properties & Criteria	Type A	Type B	Type C	Type D
ix Design (/cy)				
o Cement (lbs)* o Fly Ash (lbs)* o Bottom Ash (lbs)* or Coarse Agg. or Fine Agg.	100 2000 0	50 300 2600	150-200 300 2600	300-700 100-400 **
FLOW CONE (seconds) ASTM C939	30-60	--	--	30-60****
SLUMP (inches) PTM No. 600	--	7-11	7-11	7-11****
DENSITY (pcf) PTM No. 613	95-110 ***	120-135 ***	125 Min. ***	30-70 or as specified ***
WATER ABSORPTION OF AGGREGATE, PTM NO. 506	--	--	--	20 (max %)
COMPRESSIVE STRENGTH (psi) PTM No. 604				
3 Days (minimum)	25	25	300	40
o 28 Days (range)	50-125	50-125	800 Min	90-400

*Quantities may be varied or alternate designs submitted to adapt mix to meet density and strength requirements or to adapt to specific site conditions.

**Requires the use of suitable lightweight aggregate or air entraining admixture. Provide a mix design that achieves the specified strength and density requirements.

***Approximate Value. Use of air entraining agent may reduce these values.

****As appropriate depending on whether lightweight aggregate or air entraining admixture is used to obtain lightweight properties.

SECTION 601 PIPE CULVERTS

SECTION 601.2(b) Other Material. Add the following after the eighth bullet:

o Flowable Backfill - Special Provision for Flowable Backfill

Geotextile, Class 4 - Section 735

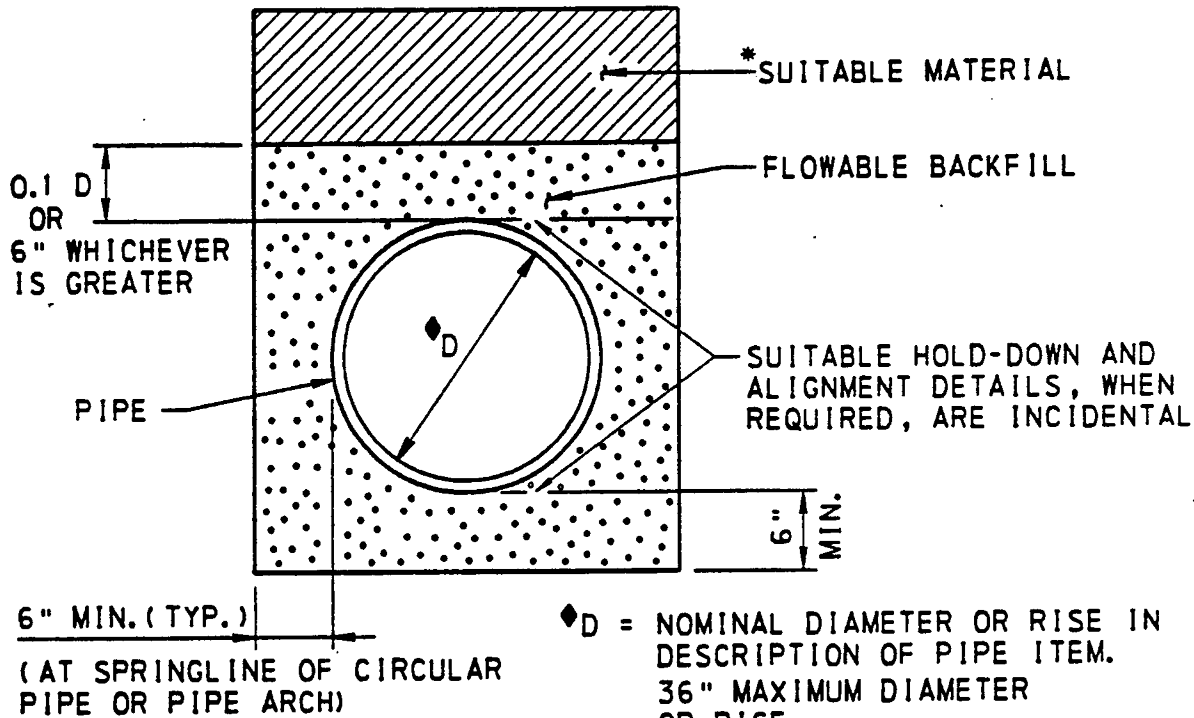
SECTION 601.3(b) Trench and Bedding. Add the following:

When required provide support for pipe as specified in Special Provision for Flowable Backfill.

SECTION 601.3(e) Backfilling Trench. Add the following:

When flowable backfill material is used, backfill the trench in accordance with the attached Flowable Backfill Detail, the Standard Drawings, and the Special Provision for Flowable Backfill.

FLOWABLE BACKFILL DETAIL



♦D = NOMINAL DIAMETER OR RISE IN DESCRIPTION OF PIPE ITEM. 36" MAXIMUM DIAMETER OR RISE.

- REPLACES DETAIL FOR STEPS 6A, 6B, 6C AND 6D ON PAGE 4 OF 4 OF RC-30, SUBSURFACE DRAINS.

- FLOWABLE BACKFILL WILL ENVELOP THE LAST SECTION OF PIPE OR END SECTION, CONSTRUCT DIKE OF FLOWABLE BACKFILL MATERIAL AS SPECIFIED IN SPECIAL PROVISION OR PROVIDE FORMWORK TO CONTAIN FLOWABLE BACKFILL.

- REVISE NOTE 6 ON PAGE 3 OF 4 OF RC-30 AND NOTE 3 ON PAGE 4 OF 4 OF RC-30 AS FOLLOWS: PAYMENT FOR THE BACKFILL ENVELOP (AGGREGATE, BEDDING AND BACKFILL OR FLOWABLE BACKFILL MATERIAL) AND SUITABLE MATERIAL AS INDICATED WILL BE INCIDENTAL TO THE PIPE.

* REFER TO RC-30.

Appendix-T: Specifications of Indiana on Flowable Fill

State of Indiana

Flowable Fill Specification

INDIANA DEPARTMENT OF TRANSPORTATION
INDIANAPOLIS, INDIANA 46204-2249
INTER-DEPARTMENT COMMUNICATION

MEMORANDUM
96-15

May 17, 1996

TO:

District Directors
District Construction Engineers
District Area Engineer
District Materials and Tests Engineers
Project Engineers/supervisors

FROM:

Timothy D. Bertram, Chief
Operations Support Division

RE: Section 213 of Specifications, Flowable Mortar

Attached is the latest complete specifications for flowable mortar. This is the 1995 Specification as revised by the May 1, 1996 Supplemental Specifications and further will be revised by specification revisions effective for lettings on or after September 1, 1996. This revised specification may be used retroactively for all active contracts at the contractor's option without processing any change orders.

TDB:pl

cc: Materials and Tests

Attachment

SECTION 213 - FLOWABLE MORTAR (CONTROLLED LOW STRENGTH MATERIALS)

213.01 Description. This work shall consist of placing flowable mortar to fill trenches for pipe structures, culverts, utility cuts and other work extending under pavement locations, to fill cavities beneath slope walls and other locations in reasonably close conformation with the plans or as directed.

MATERIALS

213.02 Materials. Materials shall be in accordance with the following:

Coarse Aggregate.. 904.02
Concrete Admixtures 912.03
Fine Aggregate (Except Steel Slag)...................... 904.01
Fly Ash 901.02
Portland Cement ....901.01(b)
Water 913.01

If fly ash is used as a filler and not as a pozzolanic material then it shall be in accordance with Section 904.01(a).

213.03 Proportioning. The contractor shall submit a mix design and shall arrange a trial batch demonstration to ensure complete compliance with the requirements listed herein. The mix design shall include a list of all ingredients, the source of all materials, the gradation of all aggregates, the names of all admixtures and dosage rates, and the batch weights. Except for adjustments to compensate for routine moisture fluctuations, minor mix design changes after the trial batch verification shall be documented and justified prior to implementation by the Contractor. A change in the source of materials, addition or deletio of admixtures, or cementitious materials will necessitate a new mix design. However, a new mix design will not be required for a change from one Department approved natural fine aggregate source to another Department approved natural fine aggregate source having the same fine aggregate gradation. The Contractor may be required to provide test data from a laboratory inspected by the Cement and Concrete Reference Laboratory, and approved by the Department, which shows that the proposed mix design is in accordance with the requirements listed herein.

Only the materials listed in 213.02 may be used in the flowable mortar mix designs. The proposed mix design materials and proportions shall be submitted. Final proportioning will be determined based on the approved mix design.

213.04 Mix

(a). Flow. The test for flow shall consist of filling a 3 inch (76 mm) diameter by 6 inch (152 mm) high open-ended cylinder placed on a smooth level surface to the top with the flowable mortar. The cylinder shall be pulled straight up within 5 seconds. The spread of the mortar shall be measured. For good flow in placement, the diameter of the mortar spread shall be at least 8 inches (203 mm). Minor flow adjustments may be made by making minor adjustment in the water or fly ash filler content in the mixture.

(b). Ultimate Penetration Resistance. The ultimate penetration resistance in 28 days or longer shall be not more than 80 000 kPa (11,600 psi) nor less than 24 000 kPa (3,500 psi) in accordance with ASTM C 403.

(c). Mixing Equipment. The mixing equipment shall be in accordance with the applicable requirements of Section 702 or 722, except that in lieu of the calibration requirements of 722.11, the mixer operator shall make delivery in a properly calibrated continuous mixer.

(d). Placement. The mixture shall be discharged from the mixing equipment by a reasonable means into the space to be filled. The flowable mortar shall be brought up uniformly to the fill line as shown on the plans or as directed. Placing of material over the flowable mortar may commence as specified herein or as directed.

The materials shall be mixed, delivered, and discharged within 2 1/2 h.

Voids beneath reinforced concrete bridge approach pavement shall be filled as directed. Holes shall be drilled at locations as directed and in accordance with 612.04. The flowable mortar shall be placed until the bridge approach pavement has uniform support by means of completely filling all voids. During the filling operation, plugs may be required. Plugs shall be installed to confine the mortar as directed. The bridge approach pavement shall not lift off the bridge seat.

(e). Limitations of operations. The flowable mortar shall not be placed on frozen ground. Flowable mortar shall be protected from freezing until the material has stiffened and bleeding water subsided.

The mortar shall not be subject to load nor disturbed by construction activities until an average penetration resistance has been achieved, for a minimum of three readings, of not less than 500 kPa (70 psi) for Portland cement concrete pavement or 10 000 kPa (1500 psi) for bituminous concrete pavement. Penetration resistance shall be determined using ASTM C 403.

213.05 Blank

213.06 Method of Measurement. Flowable mortar will be measured by the cubic meter (cubic Yard) as computed from the neat line limits shown on the plans, or as adjusted. If neat line limits are not shown on the plans, the volume in cubic meter (cubic yards) of flowable mortar furnished and placed will be computed from the nominal volume of each batch and a count of the batches. Unused and wasted flowable mortar will be estimated and deducted. Drilled holes will be measured by the number of holes drilled.

213.07 Basis of Payment. The accepted quantities of flowable mortar will be paid for at the contract unit price per cubic meter (cubic yard) furnished and placed.

Filling voids beneath concrete bridge approach pavement will be paid for at the contract unit price per cubic meter (cubic yard) for flowable mortar. Holes drilled in the pavement will be paid for at the contract unit price per each.

Payment will be made under:

Pay Item Metric Pay Unit Symbol (English Pay Unit Symbol)

Drilled Hole for Flowable Mortar.. EACH
Flowable Mortar.... .... m3 (CYS)

The cost of material placed outside the neat line limits, material placed outside the adjusted limits, and unused or wasted flowable mortar shall be included in the cost of this work.

For more information about Flowable Fill (flowable mortar) e-mail the Indiana Ready Mixed Concrete Association or visit the Indiana Department of Transportation's web site.

Appendix-U: Average Price of Flowable Fill Material

Tarmac

Tarmac America, Inc.
2500 S.W. 2nd Avenue
Ft. Lauderdale, FL 33315
(954) 761-1944
Fax (954) 760-1944

August 21, 1997

State of Florida
Department of Transportation
14200 West S.R. 84
Davie, FL. 33325

Attn: Mr. Leigh Markert

Re: Average Price of Flowable Fill Material

Dear Mr. Markert,

As you requested, the average price of flowable fill material is in a range between $40.00 and $45.00 per cubic yard depending on strength, location of delivery, etc..

If I can be of any further assistance, please do not hesitate to call me.

Sincerely,

Dan Scholz
Quality Assurance Manager
Tarmac Florida, Inc.

cc: J. Conte