Soil Cement Stabilization - Mix Design, Control and Results during Construction

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ABSTRACT

An active two-lane US State Highway located in Northampton County, Virginia, U.S.A., required roadway improvements. Surface features consisted of 2 to 3 inches of asphalt pavement, underlain by a coarse sand base. In order to improve the roadway structure, a soil-cement stabilization was recommended and implemented for the upper 8 inches of the existing roadway structure.

Soil-cement stabilization consisted of pulverizing the existing asphalt and mixing it with existing base materials. The recycled asphalt and base materials were then combined with 4% cement by weight and moisture content was manipulated in order to maintain soils within the optimum moisture content.

In order to design the required cement ratio of the soil-cement mix, several samples of existing asphalt and base were obtained. Standard Proctor tests were performed to determine the maximum dry density and optimum moisture content of these materials when manipulated with varying cement contents. Soil-cement mixes were prepared with varying cement contents ranging from 4% to 6% by weight. The mix design requirement was to establish the cement content necessary to have a minimum unconfined compressive strength of 250 psi (1724 kpa) at 7 days.

This paper presents the soil-cement mix design, field-laboratory procedure and results. The construction sequences and the basic design example of the soil-cement mix are also given in this paper. Lastly, the results of the soil-cement improvements are shown.

1. INTRODUCTION

In general, pavement structure surfaces and/or aggregate bases become deteriorated throughout the years due to vehicular traffic and extensive weathering. This is a normal aging process that occurs during the life expectancy of a roadway. Roadway maintenance programs are typically conducted in a timely manner in order to maintain the integrity of the pavement structure to the required operational standard to assure safety and comfort to users. There are several methods to repair or stabilize pavement structures; one of these methods, known as Full Depth Reclamation - FDR (Utilizing soil cement stabilization means), calls for pulverizing the existing asphalt and mixing it with existing base materials; the recycled asphalt and base materials are then combined with cement to develop a strong compacted base material achievable only within the optimum moisture content. Intensive laboratory work is required to determine the optimum cement content for the resulting recycled mix.

The subject State Route 636 contained a severe pitch in excess of 5% and surface features consisted of 2 to 3 inches of asphalt pavement, underlain by a coarse sand base. The pavement structure was in a fatigued condition and Full Depth Reclamation practices were considered to be advantageous in order to reduce the pitch and provide a
suitable base for the proposed roadway and at the same time improve the pitch of the existing roadway.

A total of eight (8) sample locations were selected for exploration at intervals no greater than 1,320 feet according to the Virginia Department of Transportation (VDOT) requirements. Asphalt and base materials were removed, pulverized and mixed to a maximum depth of 8 inches below the top of pavement.

All samples were subject to extensive, laboratory controlled testing and all data was recorded and analyzed according to VDOT and ASTM standards. The mix design requirement was to establish the cement content necessary to have a minimum unconfined compressive strength of 250 psi (1724 kpa) at 7 days. According to the research, it was found that a cement content of 4% cement by weight was acceptable for the blend of pulverized asphalt and existing base materials.

This paper contains the interpretation and results of our field exploration and soil cement mix design for Route 636 reclamation, located on Cobbs Station Road in Northampton County, Virginia, U.S.A. The owner of the project is VDOT, Hampton Roads District; the reclamation project was conducted by Slurry Pavers Incorporated and the design and field quality control (QC) were performed by ECS Mid-Atlantic, LLC (ECS). The authors of this paper would like to thank Michael J. Galli of ECS for providing input and review of this paper. Works were carried out during the summer of 2010.

2. PROJECT CHARACTERISTICS

The subject roadway reclamation project is located along State Route 636 – Cobbs Station Road in Northampton County, Virginia, U.S.A. The project is located in what is called the Easternshore at the Mid-Atlantic portion of the country (coastal region). The roadway reclamation project consisted of the widening of the existing roadway along a length of approximately 5,000 feet (1,524 meters), and stabilizing the existing pavement cover and base by means of soil cement stabilization. The total thickness of the stabilized portion was approximately 8 inches (0.2 meters).

In order to accomplish soil-cement stabilization using the FDR technique, the existing asphalt was pulverized and mixed with existing base materials. The recycled asphalt and base materials are then combined with a specified amount of Portland Cement and the moisture content is manipulated in the field in order to maintain the soils at levels of optimum moisture content as determined in the soils laboratory by means of the Standard Proctor test. The soil cement material (or reclaimed material) is then roller compacted in one lift of approximately 8 inches with cement, moisture, and aggregate blended at specified levels required to achieve the minimum compressive strength.

3. EXPLORATION PLAN AND RESULTS

3.1 Site Conditions

At the time of the subsurface investigation and design analysis, the existing roadway was active and located within a coastal region; the ground water table was within 2 to 3 feet below the ground surface. The roadway is paralleled by drainage ditches and is surrounded by agricultural facilities.
Photo 1 and 2 depict project site before starting the reclamation works.

3.2 Existing Pavement Structure Conditions

It was observed that the existing roadway consists of 2 to 3 inches of asphalt pavement. Approximately 6 to 8 inches of coarse sand fill material was encountered underlying the asphalt pavement. Laboratory testing determined the actual field moisture content with the added asphalt material is approximately 4%. The underlying coarse sand fill appeared to be well graded and consistent throughout the existing roadway.

The existing roadway had an approximate pitch of 5% and the reclamation process is intended to aid in reducing the existing pitch and fatigued pavement structure. The reclamation process was anticipated to include only the asphalt pavement and base materials; no subgrade soils were anticipated to be included within the mix design. Samplings of the road base are depicted within Photos 3 and 4.

4. SOIL CEMENT MIX DESIGN

4.1 Method Description

Soil samples were extracted from the existing roadway at intervals no greater than 1,320 linear feet (402 meters) within each lane. Sample extraction was controlled in order to ensure the proper depth and ratio of pavement to base soils was consistent with anticipated construction procedures. Bulk samples and asphalt pavements were pulverized and blended within the laboratory using mechanical means to gradations similar to typical blending of the field equipment.
Laboratory testing consisted of full gradation analysis, Standard Proctor testing, molding of cylinders for compressive strength testing; compacted to 97% maximum dry density having cement contents of 4%, 5%, and 6%. Average maximum dry density and optimum moisture content were within 127 pcf and 5.6%, respectively. Density results are depicted within Figure 1.

Figure 1

4.2 Unconfined Compressive Strength Results

A total of 24 cylinder samples were formed using differing cement contents of 4%, 5% and 6% by weight. Samples were prepared to 97% maximum dry density using Standard Proctor compaction test procedures.

Average compressive strengths for soil cement cylinders made from the blended base material with cement contents of 4%, 5% and 6% were 379.5 psi, 448.9 psi and 483.1 psi, respectively. As indicated within Figure 2, soil cement strengths increase progressively as cement content increases. Compressive strength increased in average by approximately 18% from 4% to 5% cement content, and 27% increase from 4% to 6% cement content.

Soil cement cylinders made from samples 1 through 8, taken on the existing roadway, were tested at 7 days and compressive strengths greater than 250 psi were observed for all samples tested.
All soil cement cylinders made from the asphalt blended base material have an observed maximum dry density of approximately 127 pcf and an observed optimum moisture content of approximately 5.6%. These results are similar to those obtained in the lab without cement.

Compressive strength results according to all 8 samples tested are as depicted below within Figure 2; the bolded curve corresponds to the average one used for selecting the cement percentage as explained in next section.

*The bold line depicts the average of soil cement compressive strengths and thinner lines depict the results of each individual sample.

Photo 5 and 6 depict the results of compressive strength testing. Failure planes followed Coulomb type of failure.
4.3 Cement Content Selection

According to VDOT and ASTM requirements, soil cement cylinders taken from FDR procedure must have a compressive strength of 250 psi (1724 kpa) at 7 days. Design cement content was determined based on weight and cement contents were developed at 4%, 5% and 6% accordingly.

The blended soil mix was considered to have a maximum dry density of 127 pcf across the project site. Blending of the mix is depicted within Photos 7 and 8; it was very important to obtain a uniform mix to assure a high quality sample, representative of likely field conditions.

![Photo 7]

![Photo 8]

Based on a thorough analysis of all results and data made available at the time of this study, the following soil cement design parameters were to be applied to the soils specific to the State Route 636 Pavement Rehabilitation. Optimum cement content was recommended to be at least 4% by weight for base materials blended with asphalt pavements encountered on site, in order to obtain a compressive strength of 250 psi (1724 kpa) at 7 days.

5. CONSTRUCTION PRACTICES DURING RECLAMATION

5.1 Construction Reclamation Method

Full Depth Reclamation methods were used in the rehabilitation of the subject roadway with reclamation extending to depths of 8 inches below the top of the existing pavement structure and complete blending of the asphalt pavement with the existing base materials. Some leveling of the roadway occurred after moisture conditioning and the addition of Portland Cement in order to adjust grades and elevations per drainage requirements.

5.2 Quality Control and Results

During the course of construction full time quality control measures were provided and included the verification of cement content, adequate moisture and density via nuclear
gauge testing and minimal sand cones, proper compaction and mixing techniques, and timely mixing and placement of soils.

After a period of 7 days, coring of the rehabilitated base was attempted. Coring of the stabilized mix proved to be unsuccessful because the samples crumbled, likely due to the coring method itself or the resulting stabilized sandy matrix did not have the adequate strength to hold together with the applied pressures of the coring operation. It was not possible to conduct in-situ plate testing to determine the strength of the stabilized soil-cement mix. Due to the inability to obtain quality field specimens after construction to verify in-situ conditions, acceptance was based on density results, adequate means of rehabilitation, and observed stability of the roadway.

6. CONCLUSIONS

Field collection of the soil samples must be strictly maintained to specific proportions, replicating construction conditions, in order to adequately obtain proportioned samples. Additionally, the gradation of asphalt, as pulverized within the lab, must be compared to historical pulverizing of the subject equipment. Best practice for the contractor is to maintain a log of asphalt gradations upon crushing in order to properly determine sufficient pulverizing methods within the laboratory.

The addition of cement should be measured not only by rate of application, but also by means of weight spread over a fixed area. Additional measures to ensure adequate cement content are to collect field samples for additional laboratory testing for Portland Cement content verification.

Soil-cement mix design using traditional mixing and compacting soil laboratory test methods probed to be a reliable procedure to establish the optimum cement percentage for the mix. Standard Proctor test was required to determine maximum dry density and optimum water content. It is recommended for further studies to compare results with Modified Proctor test to verify the ability to core the in-situ material at early ages.

Full Depth Reclamation processes do not allow for compacting soils in multiple lifts; therefore, it is critical that adequate compacting equipment, such as a heavy compaction roller, be used for the compaction of stabilized soils.

Coring of the finished product was not possible on this specific project at 7 days; therefore, acceptance of the subject roadway was based on adequate levels of density and observed stability of the roadway. Based on observations and test procedures utilized on this project, it was determined that field quality control verification for FDR procedures utilizing soil cement means and sandier soils, in lieu of high aggregate content, should be pill-formed during construction for curing within the laboratory and testing at 7 days.

REFERENCES


ASTM D1632 - 07 Standard Practices for Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory