EVALUATION AND FIELD VERIFICATION OF STRENGTH AND STRUCTURAL IMPROVEMENT OF CHEMICALLY STABILIZED SUBGRADE SOIL

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Background

Often subgrade soils exhibit properties, particularly strength and/or volume change properties, that limit their performance as a support element for pavements. Typical problems include shrink-swell, settlement, collapse, erosion or simply insufficient strength. A common approach to subgrade soil support or stability problems involves chemical modification or stabilization (FHWA) with additives such as lime (hydrated or quick), fly ash (Class C from lignite coal), cement kiln dust or Portland cement. Other additives are available, but this group constitutes the major products or by-products used in roadway construction in Oklahoma.

The type and amount of chemical additive is typically selected using standardized procedures (ASTM, ODOT). In cases where the subgrade soil's strength is important in designing pavement thickness and predicting performance, ASTM D4609 test protocol is the best approach for selecting the type and defining the amount of soil additive.

Questions arise with regard to chemically treated subgrade soils about the rate of development and ultimate magnitude of improvement (strength increase or volume change stability) on construction projects. In other words, is the improvement response of field constructed soil layers the same as the laboratory mix design response? Potential differences between laboratory and field improvement responses may be the result of one or more of the following sources:

1. Normal variability of natural soils.
2. Variability (number and lateral extent) of soil types (i.e., assumption that one percentage of additive "fits" all the soils on the project).
3. Variability of field construction process (i.e., components, quality of workmanship).
4. Influence of climate

Typically, once the treated subgrade soil is compacted, the strength or volume change stability improvement is "assumed" to equal the laboratory mix design test results. The pavement is then designed using structural numbers based on historical, and sometimes, limited data reflecting the actual influence of the treated subgrade soil layer on the thickness and performance of the pavement. Often the strength improvement of the treated subgrade soil is simply ignored in the pavement design equation. Limited information is available on the rate of development and comparative magnitude of strength improvement of stabilized subgrade soils.

The "Guide for Mechanistic-Emperical Design of New and Rehabilitated Pavement Structures (MEPDG)" (AASHTO) uses an hierarchical (level) system for selecting or determining design inputs for pavement design. The system is based

"on the philosophy that the level of engineering effort exerted in the pavement design process should be consistent with the relative importance, size, and cost of the design project". The three levels used in the MEPDG procedure are;

1. Level 1 is the most current implementable procedure available, normally involving comprehensive laboratory or field tests.
2. Level 2 requires that inputs are estimated through correlations with other material properties measured in the laboratory or field.
3. Level 3 requires an estimate of the most appropriate design input value of the material property based on experience with little or no testing.

This new or more organized approach to pavement design further highlights the need for a better understanding of the rate of development and comparative magnitude of strength improvement for stabilized subgrade soils, especially for Level 2 and 3 design inputs.

Proposed Research

The purpose of the proposed research is to develop relationships between the rate of development and magnitude of strength improvement for chemically stabilized subgrade soils and pavement design input parameters. These relationships can be used to confirm and/or adjust pavement design input parameters currently recommended in the MEPDG to reflect Oklahoma soils, commonly used chemical additives, and pavement design experience.

The major objectives of the proposed research are:

1. Review existing correlations between chemically treated soils and AASHTO-MEPDG design input parameters.
2. Select roadway construction projects in grading and drainage stages of construction which represent different subgrade soil types and chemical additives used.
3. Collect representative soil samples from construction project locations for classification, quality control, and engineering property testing.
4. Collect representative chemically treated soil samples from construction project locations for engineering property testing.
5. Following compaction and acceptance of the chemically treated project locations conduct time sequenced field (tests) evaluation of strength and stiffness.
6. Using established time rate of development and maximum level of strength gain relationships, compare to previous/existing design input parameters correlations or experience-based lower limits and accept or adjust parameters accordingly.

The Final Report presents the results of the research project.

Laboratory and Field Testing

In order to achieve the objectives of the proposed research, an extensive laboratory and field testing program was undertaken. Five sampling/ monitoring sites were selected, representative soil samples of the local soils were collected for classification testing and soil-additive mix design procedures. During construction of the stabilized subgrades, field mixed samples were collected for strength development with time testing. Following construction of the stabilized subgrades, a series of field tests were conducted with time to measure strength development for the treated soil layer. Results of all the laboratory and field tests were used to evaluate and verify the strength and structural improvement of the treated subgrade soils.

Conclusions

1. UCS and M_R values for field mixed samples are 50 to 90% of the values for laboratory mixed samples. Generally, the higher the PI of the soil the greater the difference between field and laboratory mixed conditions. This is most likely because more of the cations in the cementitious additives being "used" in cation exchange rather than developing pozzalanic reaction products. Although the research was unable to confirm the differences between field and laboratory mixed conditions, the difference could be more or less depending on compaction of the stabilized layer.

2. Measured UCS, M_R, and field parameters such as DCI and PTR indicate that typically 70% or more of the strength and structural improvement occurs in 7 days. The actual rate of improvement is variable and depends on such things as soil type, type, amount, and quality of additive, local construction procedure, and curing environment. The rate of improvement for field mixed and laboratory mixed samples was greater than the rate of improvement of field measured parameters.

3. Cementitious additives such as CKD and FA produce significant increases in strength and structural improvement of stabilized soil layers. For the additives (types and amounts), soils, and construction procedures used in this research project, CKD yielded higher strengths (UCS, M_R) than FA. It's important to remember that these cementitious additives, particularly CKD, have variable characteristics with regard to potential stabilization applications. Research is currently being conducted to characterize the variability limits.
4. AASHTO-MEPDG Level 2 correlations significantly underestimate M_R and E values for the stabilized soils encountered in this research project. If estimates of subgrade strength and corresponding structural improvement of the stabilized subgrade are included in pavement design, then either Level 1 (measured) input parameters or alternate Level 2 correlations should be used.
5. The nuclear moisture density gauge is an effective tool for quality control (QC) of compaction of stabilized soil layers.
6. The stiffness gauge K-values and corresponding calculated E-values did not correlate with accepted or measured long term strength and structural improvement of stabilized soil layers.
7. The portable FWD (PFWD) modulus, E_{vd}, is a simple and quick field test that provides a reasonable measure of long term performance of stabilized soil layers. The major problem is

the number of factors that can influence modulus/stiffness.

8. The Dynamic Cone Pentrometer (DCP) and Dynamic Cone Index (DCI)and corresponding calculated M_R values provide a good measure of long term performance of stabilized soil layers. The DCI has potential as a performance evaluation tool in QC.

9. The PANDA pentrometer tip resistance (PTR) also provides a good measure of long term performance of stabilized soil layers, probably the best of the equipment used. The PTR also has potential as a performance evaluation in QC as it is currently being used in Europe.

<u>Recommendations</u>

Recommendations are separated as potential for practice and as potential topics for additional research.

Practice

1. Consider additive percentage such as those given in OHD L-50 to be minimal guidance especially for higher PI soils (A-6, A-7). One potential approach to address the difference between field mixed and laboratory mixed samples would be to increase the percent additive by 3 to 5% or more.
2. Require more chemical variability data on cementitious stabilizers, similar to qualifying aggregate sources.
3. Until better correlations can be established (AASHTO-MEPDG Level 2) use basic correlation of M_R = 1500 CBR with CBR defined from DCI values measured from stabilized soil layers.
4. Do not consider the stiffness gauge as a viable option for QC or long term performance evaluation

Research

1. Evaluate UCS and M_R values for samples taken from field mixed and compacted layers.
2. Evaluate the influence of pre-treatment with lime on the strength improvement of higher PI soils subsequently stabilized with cementitious additives.
3. Evaluate DCI and PTR for different soil types, additive types, and application rates to develop correlation equations for design and QC.

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