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GUIDELINES FOR SPECIFICATION WRITING FOR DEEP SOIL MIXING

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ABSTRACT: Deep Soil Mixing (DSM) was recently introduced into the United States as a geotechnical and environmental construction method. Primarily, DSM is used for deep foundation improvements. With the onset of this new technology, the need for guidelines for specification writing and the interpretation of testing results arises. This need would include guidelines for specifying construction procedures and equipment, field testing, ASTM standards, implementation of Quality Control plans, mix designs, and interpretation of results. These guidelines are detailed herein.

Guidelines for specifying proper construction procedures and equipment for different soil types will help ensure that the proper results will be attained in the field. By using the proper procedures and equipment, adequate mixing can be obtained to create homogenous columns to depth. Results can then be verified by a variety of field tests.

KEYWORDS: Deep Soil Mixing, Quality Control, performance specifications, ASTM standards, mix design.

INTRODUCTION

DSM Background

Deep Soil Mixing (DSM) dates back o the 1950s when a mixed in-place pile process was being used. From this primitive application, other uses were found on projects throughout the world.

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Refinements in machinery and applications continued to evolve until the Japanese manufacturers mounted multiple shafts on the same leads. This gave the Japanese an economical method of installing retaining walls and temporary support structures in the restricted areas of Japan's cities.

DSM is a soil improvement technique used to improve soil properties without excavation or removal. It is an effective substitute for many current geotechnical soil improvement processes and earth retention systems.

The process utilizes a support crane and leads which guide a series of overlapping mixing paddles and augers. As the ground is penetrated, stabilizing agents or other fluids are fed through the center of each shaft. The auger flights break the soil loose and lift it to the mixing paddles which blend the agents with the soil. Additional mixing paddles continue to mix the soil as the augers advance to greater depths. The augers are then withdrawn leaving a series of overlapping columns which form part of a wall or a treated block of soil.

Currently, DSM has a wide variety of uses. It is used for the formation of seawall, retaining walls, improving bearing capacity, cut-off walls, treating hazardous wastes in-situ and deep soil densification.

Due to the large variety of potential applications and results dependent on site-specific conditions, it is very difficult to formulate one overall specification that would satisfy the requirements of all projects.

ITEMS INCLUDED IN SPECIFICATIONS

The choice in type of specification would be governed by the specific application. If the desire is a specific end product with few restrictions imposed by site conditions, a performance specification may be the best choice. If there are several restrictions imposed on the equipment or method as a result of site conditions or circumstances, a subjective specification may be the better alternative.

A performance specification outlining the final objectives for a specific project would be a preferred choice over a more subjective specification. Due to the relatively recent advances in DSM technology, a performance specification would allow for increased competition, innovations in equipment, and adjustments to actual site conditions. To verify adequacy of individual equipment, the specifications should allow for a submittal process to review expected equipment.

A DSM performance specification should contain minimum guidelines for many tasks. This would include a brief description of construction procedures, basic functions of equipment, acceptable materials, and methods of field verification, applicable ASTM standards, Quality Control plans, mix designs, and methods for interpreting results.

In describing construction procedures, horizontal and vertical alignment, mixing speed, drilling rate, flow rates, drilling sequence, and refusal criteria should be submitted in a contractor's Quality Control plan. Examples of achieving these criteria on other projects are as follows:

Horizontal alignment can be maintained with the use of a rigid template to gauge positioning. A stationary laser can also be used to maintain alignment on applications such as a retaining wall, where the sequence would involve a straight line.

Vertical alignment is most easily maintained through the use of instrumentation mounted on the leads of the machine. This instrumentation would read the pitch and roll in degrees from vertical and alert an operator when out of tolerance. The operator could then make necessary adjustments.

Mixing speed and drilling rate are determined by in-situ soil conditions. An initial range should be discussed in the Quality Control plan. Flow rate would then be determined in order to allow for sufficient additive to match drilling speed to coincide with penetration rate.

Drilling sequence should be such that there are no discontinuities in the pattern. Drilling should advance to a specified depth or continue until refusal has been met. Refusal is determined by a decrease in penetration rate below an acceptable level.

When specifying equipment, there should be allowance for flexibility in the equipment to promote competition. If there are concerns over wall thickness or other items, minimums, maximums or other requirements can be specified.

Performance requirements should be submitted in a contractor's Quality Control plan. This Quality Control program should be a description of the methods used by the contractor to assure proper performance. In addition, it should provide a plan for verification of installation and a reporting system. An example of a generalized outline for a Quality Control program is as follows:

I. Purpose of QC Plan

II. Wall Installation Procedures

1) Equipment to be Used

2) Procedures

3) Injection Control

A) Mix Design

B) Injection Quantities

C) Batching

D) Depth Measurements

4) Location Verification and Assurance

5) Quantity Verification

Appendix – any applicable figures or forms

In order to verify performance, a variety of field tests can be performed. Specific gravity, flow, and depth surveys can all help to control instantaneous events to maintain Quality Control. In-situ sampling can be used to verify in place mixing. These samples can be tested according to applicable ASTM standards such as:

a) C 150 – Specification for Portland Cement.

b) D 806-74 – Cement Content of Soil Cement Mixtures.

c) D 1140-54(71) – Amount of Material in Soils Finer than No. 200 Sieve.

d) D 2113-83(79) – Diamond Core Drilling for Site Investigation.

e) D 2216-80 – Laboratory Determination of Water (Moisture) Content of soil, Rock, and Soil-Aggregrate Mixtures.

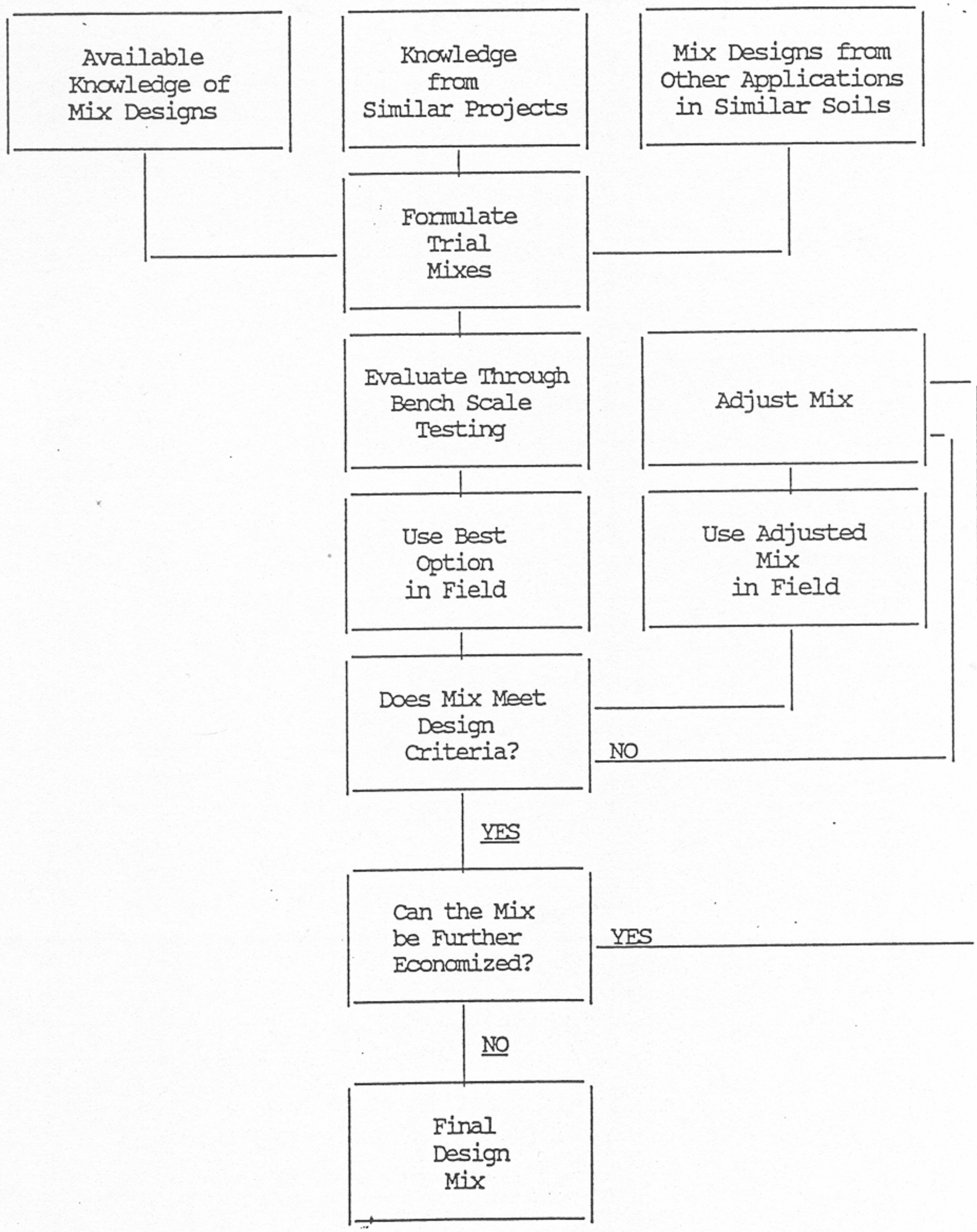
f) D 2901-82(86) – Cement Content of Freshly Mixed Soil-Cement.

g) D 4380-84 – Density of Bentonitic Slurries.

h) D 1633 - Unconfined Compressive Strength of Soil-Cement.

i) Z 1208Z (Proposed) – Test Method for Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeater.

Within the Quality Control plan, a section should provide for the development of a mix design to meet the requirements. The development of this mix design should follow a logic flow diagram similar to the following:


Available Knowledge of Mix Designs
Knowledge from Similar Projects
Mix Designs from Other Applications in Similar Soils
Formulate Trial Mixes
Evaluate Through Bench Scale Testing
Adjust Mix
Use Best Option in Field
Use Adjusted Mix in Field
Does Mix Meet Design Criteria?
NO
YES
Can the Mix be Further Economized?
YES
NO
Final Design Mix

Especially for environmental applications, a preliminary mix design test can be performed to determine an optimum additive rate. This is very useful for applications when reductions in additive rates can be a major source of economy for the owner.

Specific gravity is monitored to verify mix design. The additive, which is most often a cement-based slurry, will reach an ideal specific gravity for the desired mix when additives are mixed in the proper proportions. Instrumentation is available to verify this quickly enough to make adjustments before pumping.

Flow monitoring is achieved with in line floe meters. Magnetic meters tend to be more accurate with abrasive slurries. A digital readout can be set up to read instantaneous flow rate and total flow. When read in conjunction with penetration rate, the flow per foot can be monitored.

Penetration rate and total depth are best measured from the leads. A tracking device can be installed directly on the drill motor housing and track along the leads. This will read out an instantaneous penetration rate and also give a total distance traveled (depth). The alternative would be to visually measure auger stems to determine depth.

Survey control points can be installed to verify overall position of the augers. A template is placed between these points to maintain alignment.

In lieu of a performance specification, with the previous items outlined within a contractor's Quality Control program, a subjective specification would need to discuss these items in detail within the specification. A subjective specification also has a drawback in that, if the contractor performs all of his functions as specified and the desired final product of the application is not achieved, the contractor cannot be held responsible.

The primary responsibility for Quality Control management differs with the contract type. However, good Quality Control is a joint effort between the owner, designer, and contractor.

It is important that all parties involved in a DSM project maintain flexibility and bear in mind that the most important item is an acceptable final product. No matter how many soil samples are taken, the profile of the underlying strata will most likely never be exactly known. Soil samples taken for bench scale testing may not be totally representative of subsurface conditions.

The contractor must be allowed to alter construction procedures and mix designs if necessary to produce the correct final product providing these changes do not exceed restrictions of the project. The design engineer must be allowed complete access to DSM data and be consulted on any variations in procedure.

The owner should be looking for the mix design and/or procedure which will provide the final product the most economically.

On past DSM projects, changes in mix designs to adapt to subsurface conditions encountered has led to more economical and expeditious DSM projects resulting in savings to all parties without compromising quality.

Although DSM is in the earlier stages of development, it is probably too soon to develop new ASTM standards for the technique. However, with the present knowledge, an applicable specification can be developed utilizing the current ASTM standards discussed.