RESEARCH NOTES
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Swedish Research Reports on Soil Stabilization Translated for U.S. Designers

***RESULTS:** The Caltrans' GeoResearch Group (GRG), through the National Deep Mixing (NDM) Program, partnered with the Swedish Geotechnical Institute (SGI) in translating three research reports developed by the Deep Soil Stabilization Research Center in Sweden. This technology transfer assures that European research experience is readily available to U.S. practitioners. The translated reports each address material design issues related to deep mixing of soils. Topics include mechanisms involved in mixing processes and selection of most appropriate binders for stabilization of problematic soils, including organic soils.*

Why We Pursued This Research

Soil stabilization techniques such as "deep soil mixing (DSM)" are increasingly used for construction of highway embankments and other geotechnical systems sited on soft or problematic soils. Broadly, DSM is a ground modification technique where specialized construction equipment is used to mix a cementatious product into the natural soil to create a stronger and stiffer material that meets engineering specifications.

Though relatively costly, DSM design alternatives often provide unique advantages that may outweigh cost considerations and make it the preferred option for a variety of applications. Conditions where DSM is particularly well-suited include: 1) projects requiring accelerated construction where time, or restoration of service, are controlling factors, 2) sites involving contaminated materials where soil removal is extremely expensive, and 3) urban sites where construction vibrations might impact adjacent structures.

DSM techniques were initially developed in the Nordic regions of Europe (Sweden and Finland) and Japan in the 1960's. By the early 1970's, DSM had been adopted by practice in both Europe and Japan and has continued to flourish ever since. DSM was not introduced into U.S. practices until the late 1980's, but it is now becoming increasingly well established. Nevertheless, the U.S. is wise to look to its overseas colleagues in Europe and Japan for research findings and practical lessons gained through their extensive experience in DSM application.

What We Did

The GeoResearch Group (GRG) recently initiated a multi-state pooled-fund research program called the "National Deep Mixing (NDM)" Program to jointly pursue research leading to practical design implementation of DSM techniques in U.S. highway construction. Through a user-needs survey process, the NDM team identified research performed by Deep Soil Stabilization Research Center of the Swedish Geotechnical Institute (SGI) as having significant potential to advance U.S. understanding of key DSM processes. The NDM team reviewed approximately a dozen research titles, and found three to be particularly well-suited to identified needs. The NDM program contracted with SGI to translate these reports, shown in Fig. 1, from Swedish to English. The NDM program then reproduced and distributed over 300 copies of the translated reports to users in Caltrans, other State Departments of Transportation, various research institutes and to the professional community dealing with soil stabilization.

Fig.1 – Translated research reports by SGI & NDM.

The titles of the three translated research reports are:

- Report 6: "Mixing Processes for Ground Improvement by Deep Mixing"
- Report 9: "The Function of Different Binding Agents in Deep Stabilization"
- Report 3: Stabilization of Organic Soils by Cement and Pozzolanic Reactions – Feasibility Study

The reports are quite specialized, as they are targeted toward researchers. Nevertheless, information applicable to routine practice can be gleaned as summarized below.

Report 6 provides a thorough overview of the wide variety of mixing devices and processes used for deep mixing applications as illustrated by the examples in Fig. 2. Emphasis is placed on 'dry mixing' equipment used in Scandinavian countries and a broad range of newer devices employed in 'wet mixing' applications in Japan. This report also surveys mixing mechanisms, operations, and equipment providing insight into what has proven to be a complex process. Another valuable contribution is a summary of the wide range in field-to-lab strength ratio obtained by various investigators.

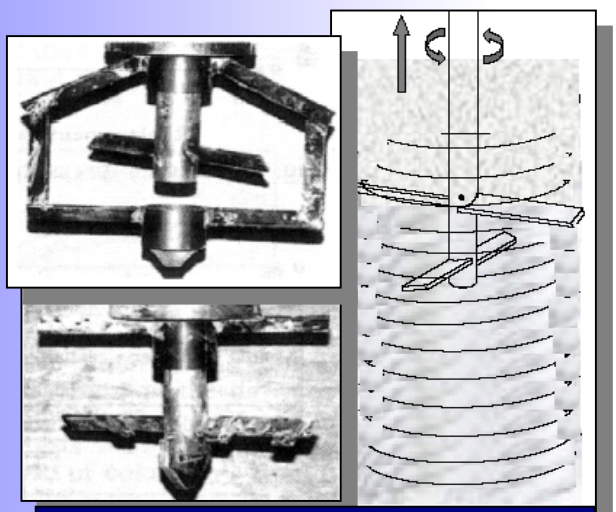

Fig. 2 – Example mixing devices and process.

Report 9 is focused on chemical reactions between binders (cement, lime, industrial by-products) and various soil types. This report provides the background needed to understand why a given binder provides good stabilization effect in some soils while performing poorly in other soils. Special emphasis is placed on "problematic soils" such as organic soils, peat, mud, and soils with high sulfide and saline content. Table 1 summarizes the key findings from this report regarding the relative degree of effectiveness, in terms of strength gain, of alternative binders for a variety of soil types.

Table 1: Relative effect of binding agents for stabilization of different soils

Soil	Lime	Lime-Cement	Cement
Clayey Silt	•	+	++
Silty Clay	+	++	++
Clay	•	+	+
Clay (Quick)	+	+	++
Clay (Saline)	+	+	+
Clay (Sulphide)	-	+	+
Muddy Clay	•	+	+
Clayey Mud	•	•	+
Mud	-	•	+
Peat	-	•	+

Notes: (- no effect or poor effect) (• fairly good effect) (+ good effect) (++ very good effect)

The report also contains recommendations regarding optimum mix ratios for combining cement and lime. This information can be applied to either deep or shallow soil stabilization applications.

Lastly, Report 3 is a feasibility study that investigates the potential for stabilization of highly organic peat soils, and serves as the basis for a future more in-depth investigation of this topic. As Illustrated in Fig. 3, this feasibility study shows that even these most problematic soils can indeed be stabilized provided careful attention is paid to the binder mixture. In particular, the best results for these soils are obtained with cement or a combination of cement with latent hydraulic or pozzolanic additives. The additives are needed since this type of soil is typically deficient in pozzolanic minerals needed to react with the calcium hydroxide in the cement.

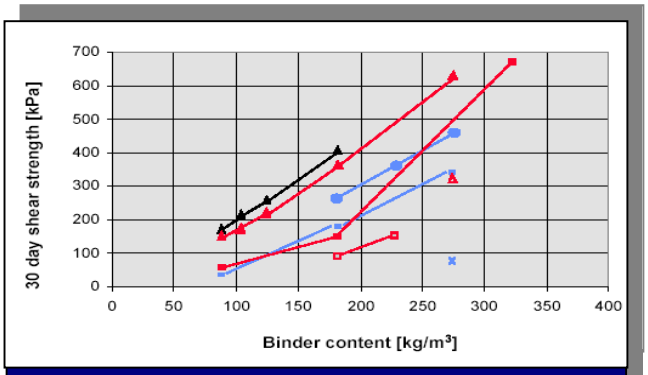

Fig. 3 – Effect of various binders on stabilized peat.

The Researchers Recommend

Deep soil mixing is a promising technology for specialized highway construction applications such as embankments and retaining systems sited in poor soils. A significant body of research and practical experience has been developed overseas that should be used as a resource to guide applications in the U.S. Toward that end, the GRG, through the NDM program and in partnership with SGI, has made three previously inaccessible research reports available to U.S. designers. This translation assures that expensive research is not duplicated, and that key lessons can be implemented in U.S. practice.

Geotechnical designers involved in the stabilization of soils should consider these reports as background reference documents to gain a thorough understanding of mixing processes and equipment, as well as guidance on mix factors that can affect the strength of stabilized soils, including peat. This information is being used in the development of technical design guidelines and field inspection manuals, and also could be used in the development of contract specifications.

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