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Study on the approaches of soil stabilization

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Abstract - *The understanding of soil Geotechnical engineering has a long history of stabilisation. Students, practising, and consulting engineers in the field of geotechnical engineering can access journal articles and textbooks on stabilisation technology. This research paper discusses current trends in stabilisation practise, focusing on stabilisation methods and materials. The introduction and two broad categories of stabilisation are covered in the first section of this review. The second section discusses equipment and methods for stabilisation. To practising engineers, the review briefly describes modernised stabilisation methods and equipment. Readers should consult the cited authors listed in the reference list for more information on the subject.*

***Key Words*: Soil stabilization, Deep Mixing, In–Situ Stabilization, Ex-Situ Stabilization**

1. INTRODUCTION

A site feasibility analysis for geotechnical projects is significantly more advantageous before a project can get off the ground. A site survey is normally undertaken before the design process begins to discover the subsoil features that will be utilised to determine the project's location. The following geotechnical design criteria must be addressed during site selection: design load and function of the structure, kind of foundation to be used, and so on. The carrying capacity of the subsoil, the third consideration, played an important influence in site selection. The options were to adapt the design to meet the site's characteristics, remove and replace the in situ soil, or abandon the site when the soil's carrying capacity became inadequate. As a result of inadequate soil bearing capacity, the number of abandoned sites increased substantially, resulting in land scarcity and increasing demand for natural resources. Liquefaction-prone areas, as well as those with soft clay and organic soils, were all affected. Landslide zones and toxic terrain were among the other areas. Obtaining a building site that matches the design criteria without ground alteration is not achievable in most geotechnical projects, however. The current practise is to adjust the engineering qualities of the native problematic soils in order to meet the design standards. For example, soft clays and organic soils can now be modified to satisfy civil engineering needs. This paper focuses on the soil stabilisation approach, which is one of many soil improvement methods.

To improve soil strength and resistance to water softening, soil stabilisation involves glueing soil particles together, water proofing the particles, or a combination of the two (Sherwood, 1993). Most of the time, technology provides a structural solution to a practical problem. The most basic ways of stabilisation are compaction and drainage (if water drains out of wet soil it becomes stronger). The third option is to improve particle size gradation, which can be further enhanced by adding binders to soils that are weak (Rogers et al, 1996). Stabilization of soil can be accomplished in a variety of methods. All of these approaches fall into one of two basic categories: mechanical or chemical stabilisation (FM 5-410). Soil stabilisation can be accomplished through a physical mechanism like induced vibration or compaction, or by adding additional physical features like barriers and nails. Soil stabilisation is primarily based on chemical reactions between the stabiliser (cementitious material) and the soil minerals (pozzolanic materials) to create the desired effect, which is not the topic of this paper and will not be explored further. Because the foundation of this review is a chemical stabilisation method, the phrase "soil stabilisation" will be used to refer to chemical stabilisation throughout the rest of this paper.Unbound materials can be stabilised with cementitious materials through soil stabilisation (cement, lime, fly ash, bitumen or combination of these). The soil materials that have been stabilised are more durable, have less permeability, and are less compressible than natural soil (Keller bronchure 32-01E).The method can be implemented in one of two ways: (1) in situ stabilisation or (2) ex-situ stabilisation. It's important to remember that stabilisation isn't a magic wand that can improve all soil properties (Ingles and Metcalf, 1972). Which soil properties need to be changed determines whether or not to use technology. Strength, compressibility ,Volume stability, permeability, and durability are the main characteristics of soil that engineers are interested in (Ingles and Metcalf, 1972; Sherwood, 1993; EuroSoilStab, 2002). For a successful stabilisation, laboratory experiments followed by field tests may be required to determine the engineering and environmental features. Although laboratory testing may provide stronger results than field material, they will aid in determining the usefulness of stabilised materials in the field. The laboratory test findings will aid in the selection of binders and quantities (EuroSoilStab, 2002).

2. STABILIZATION METHODS

2.1 In–Situ Stabilization

The method entails applying a stabilising agent to the soil on-site rather than removing the bulk soil. This technology can help with deep foundations, shallow foundations, and contaminated sites by improving soils. The engineering properties of stabilised soil and improved ground must be selected and assessed as part of the design mix planning. The goal is to compute the dimensions of improved ground using appropriate stability and settlement analyses in order to meet the supported structure's functional requirements (Keller Inc.). The technology works by injecting cementitious materials like lime and cement, either wet or dry into soils. The decision to use wet or dry deep mixing methods is influenced by a variety of factors, including in-situ soil conditions, in-situ moisture content, the effectiveness of the binders to be used, and the type of foundation to be built. In situ stabilisation can be classified as either a deep mixing method or a mass stabilisation, depending on the depth of treatment.

2.1.1 Deep Mixing Method

Deep mixing is a technique for stabilising soils at a substantial depth. It's an in situ ground modification technique that involves injecting a wet or dry binder into the ground and mixing it with soft soils (clay, peat, or organic soils) manually or rotational (Porbaha et al, 2005; EuroSoilStab, 2002). Depending on the application, the following patterns (Figure 4) can be created: single, block, panel, and stabilised grid patterns (EuroSoilStab, 2002). It's vital to keep in mind that the goal is to generate a stabilised soil mass that can interact with natural soil rather than a rigid pile capable of carrying the design load on its own. As a result, the stabilised soil's improved strength and stiffness should not hinder the stabilised soil and natural soil from interacting and distributing loads effectively (EuroSoilStab, 2002). As a result, the design load should be split into two sections: natural soil and stabilised soil mass(column).

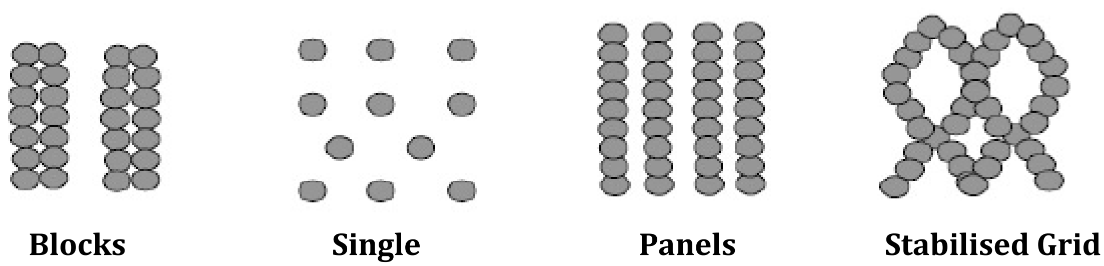

Figure 1: Typical patterns of deep soil mixing (EuroSoilStab, 2002)

Wet Mixing

Wet deep mixing involves turning the binder into a slurry and injecting it into soil through nozzles at the end of the soil auger (Porbaha et al, 2005). (Figure 3). Drilling rod, transverse beams, and a drill end with head make up the mixing tool. Some changes have been made to suit the needs and applications. For example, the Trench cutting Re-mixing deep method (TRD), which was developed in Japan around 1993, is a useful tool for constructing a continuous cutoff wall without the use of an open trench. To create the soil-cement wall, the method uses a crawler-mounted, chainsaw like mixing tool for blend in-situ soil with cementitious binder. It also has a fixed post on which a rotating chain with cutting and scratching teeth rides, as well as injection ports that deliver grout into the treatment zone. Walls with depths of up to 45 metres and widths of 0.5 to 0.9 metres are possible. The permeability of the groundwater barrier wall is between 1×10^{8} and 1×10^{6} cm/s (www.HaywardBaker.com). In 1994, Germany developed the FMI (Massarsch and Topolnicki, 2005) machine, which is similar to TRD. The FMI machine has a special cutting arm (trencher) on which two chain systems rotate cutting blades. The cutting arm is dragged through the soil behind the power unit and can be angled up to 80 degrees (Stocker and Seidel, 2005). The soil is blended with a binder that is delivered as a slurry by injection pipes and outlets installed along the cutting arm, rather than being dug as with TRD (Figure 2).

Figure 2: The FMI and TRD–Trenching machine for construction of deep walls (Massarsch and Topolnicki, 2005; Hayward Baker Inc.)

Figure 3: Parts of wet mixing tool showing injection of slurry into the soil (Porbaha et al, 2005)

Dry Mixing

Dry mixing (DM) is a low-vibration, clean, and quiet process that produces no waste (Hayward Baker Inc). For many years, it has been commonly used in Northern Europe and Japan. In this procedure, dry binders are injected into the soil and completely mixed with damp soil (Figure 4).

Figure 4: Bauer cutter soil mixing (Fiorotto et al, 2005)

Figure 5: Nordic modified dry mixing tool (Larsson, 2005)

During downward penetration, the soil is premixed with a specialised tool until it reaches the desired depth. When the mixing tool is removed, dry binder is injected and mixed with premixed soil, leaving a moist soil mix column behind. This method is known as Lime Cement Column (LCC) in Scandinavian countries, particularly Sweden, whereas Trevimix is used in Italy, and dry jet mixing (DJM) is used in Japan (Bruce et al, 1999; Yasui and Yokozawa, 2005). A track-mounted installation rig and motor drill make up a typical DM machine. Binder is fed into the mixing shaft via compressed air through a hose and out the mixing shaft's outlet into the ground (Figure 5). Powdery binders are injected into soft ground using compressed air without being processed into a slurry. During withdrawal, the blade rotates, creating a cavity in the soil that air and binders fill in. During construction, the most efficient sequence is to use the stabilising machine as much as possible within its operational radius (EuroSoilStab, 2002). This compressed binder is extensively mixed with the local soil, resulting in a cemented column with a diameter of up to 1.5 metres and a depth of up to 40 metres within the ground (EuroSoilStab, 2002). Because penetration-induced vibration can cause soil strength loss in vulnerable soils, it may be necessary to inject some of the binder into the ground during penetration. A wide range of strength can be created by regulating the amount of binder used, from low to high. A high improved ratio can be attained by overlapping mixing or interlocking the column. This approach has a wide range of applications, from embankment stabilisation to slope protection to foundation enhancement and liquefaction reduction (Yasui and Yokozawa, 2005). It should be emphasised that the efficiency of the procedure is determined by the percentage of moisture in the soil. As a result, in sandy strata with less than 30% water content, the approach is useless (Nozu, 2005).

2.2 Ex-Situ Stabilization

The technology entails dislodging soils and/or sediments from their original location and transporting them to a new location for amendment. These can be found in river channel dredging and port dredging. Dredging's major goals can be to alter contaminated sediments to minimise toxicity and mobility, or to preserve or deepen navigation channels enabling ships and boats to pass safely (US EPA, 2004). The sediment can be treated offsite in confined disposal facilities (CDF) before being used or disposed of at a designated site. When planning for ex-situ stabilization, key factors to consider include removal method, mode of transportation, availability of treatment location, disposal site, and demand for reuse (Miller and Miller, 2007; PIANC, 2009). The treatment of sediments in CDF is classified as ex-situ mass stabilization, which can be accomplished in a variety of ways depending on the natural state of the sediments and the amount of water present (Figure 6).

Figure 6: Mass stabilisation with dry soil mixing of soft wet organics was used to manage settlement for storage tanks at Port Everglades, Florida, (Hayward Baker Inc.)

Figure7: Ex-situ for on-site use stabilization (mixing in place of contaminated dredged materials) (Wiki, unpublished document)

Conclusion

Deep soil mixing is a technically sound and cost-effective option for soft and weak subsoils that need to be improved to allow for the intended building. Its applicability has been demonstrated in recent years for a wide range of projects. Other ways are more expensive and time intensive, as well as having stability issues. More flexibility, material and energy savings, and the use of the site's soil qualities are all advantages of deep stabilisation. To achieve the desired performance, an appropriate installation method and binder type can be chosen based on soft ground conditions and project specifications.

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