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Mass Stabilization Technique for Peat Soil – A Review

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ABSTRACT

Peat soil is a representative material of soft soils and classified as highly organic. It is found in all part of the world except in deserts and the arctic regions. Peat is well known to deform and fail under a light surcharge load. An effective method for soil improvement is the mass stabilization. Mass stabilization is a relatively new ground improvement method for soft soil layers such as peat soil. Stabilization is done by mixing an appropriate amount of dry or wet binder throughout the volume of the treated soil layer. Mass stabilization increases peat strength, improve deformation properties and save costs. Various techniques as well as various binders are currently used to strengthen peat. Some of the methods used in laboratory have shown more positive results. Also some binders have proven to be more effective than others to improve load bearing capacity of peat.

Keywords: *Peat; mass stabilization; binder; laboratory tests; curing; strength*

1. INTRODUCTION

Peat soil is a representative material of soft soils and classified as highly organic. In general ,peat is mainly composed of fibrous organic matters, i.e. partly decomposed plants such as leaves and stems. Peat has largely organic residues of plants, incompletely decomposed through lack of oxygen. Therefore, it has been said that peat shows unique geotechnical properties in comparison with those of inorganic soils such as clay and sandy soils which are made up of only soil particles.

Peat is found in all part of the world except in deserts and the arctic regions. The most extensive areas are located in the northern hemisphere. It is estimated that there are about 1 billion acres of peat land in the world or about 4.5% of total land areas [1].

Also, peat is well known to deform and fail under a light surcharge load, and it is characterized with low shear strength, low compressibility, and high water content. Generally any ground that is to be subjected to additional loads which exceed its previous load condition or level, geotechnical requirements for design on that ground are to be established. These requirements include a set of standard laboratory tests and also some foundation design calculations in order to find the allowable bearing capacity.

Usually these laboratory tests including the in-situ tests identify parameters which are essential for foundation design. If these parameters indicate that the in-situ soil is not capable of carrying the design load then there are two alternatives to choose, either the limitation imposed by the in-situ soil properties should be accepted, or use the following techniques enabling the loads to lay on the site [2]:

i. Transfer the load to a more stable soil layer without improving the properties of the in-situ soil.
ii. Improve in-situ soil properties with various techniques of ground improvement.
iii. Remove the soft soil and replace it, fully or partially, with better quality fill.

Sometimes it may be possible to combine different methods to provide a suitable foundation for the imposed loads. In [2], the authors used air curing method to stabilized Peat soil with Ordinary Portland Cement (OPC) as binding agent, and also reinforced with polypropylene fibers as none chemically reactive additive. Hebib, and Farrell [3], provide a technique of surface stabilization combined with stabilized cement columns for foundation loads support. Black et al. [4],in their study used reinforced stone column that not only transfers loads to the lower and stronger layer rather receives lateral support from the weak soil along the way Also, Rahman et al. [5],in their laboratory study, increased the shear strength of untrained plain peat soil by almost 36% using a drainage method.

According to [6], an effective method for soil improvement is the mass stabilization where the whole mass is strengthened to a homogeneous block structure, which behaves like dry crust.

2. MASS STABILIZATION

The progress of the technique for mass stabilization of soft soil materials has been important in Finland since the beginning of 1990's. The first test was made with peat at Veittostensuo in 1993. Since then the technique has spread very quickly specially in the Nordic countries [7].

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Mass stabilization is a relatively new ground improvement method for soft soil layers such as peat soil. Stabilization is done by mixing an appropriate amount of dry or wet binder throughout the volume of the treated soil layer. The binder can consist of a single substance or be a mixture of various substances like cement, lime, fly ash or furnace slag. New binders and binder mixtures using different industrial by-products are being introduced to the market continuously. Mass stabilization may also be combined with another stabilization method known as column stabilization as shown in figure 1[8].

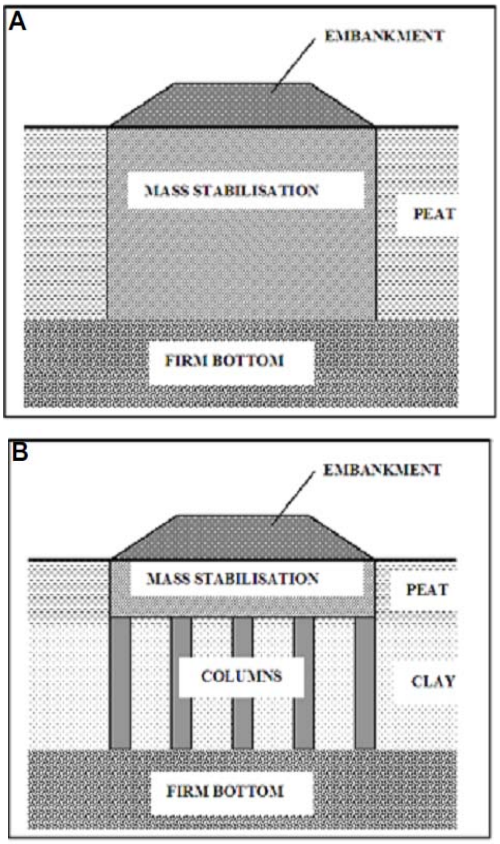
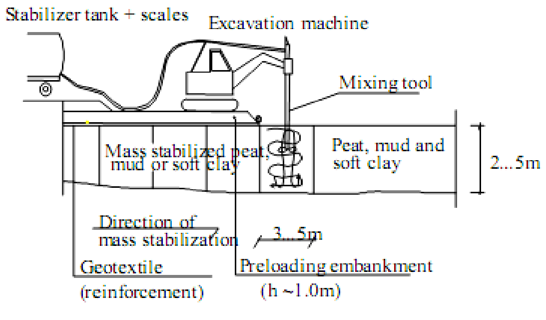
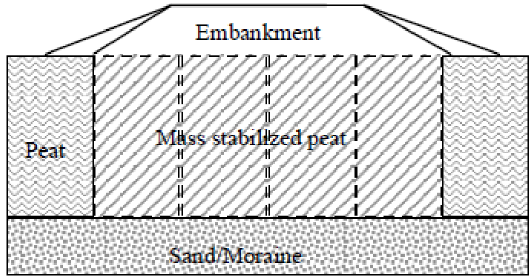


Fig 1.a: Mass stabilization and b) combined mass and column stabilization [8].

Mass stabilization is carried out by a mixing tool installed on an excavator machine as shown in Figure 2a. Mixing is done both in horizontal and vertical directions (see Figure 2a) so that a homogeneous reinforced soil block is formed due to effect of stabilizer (see Figure 2b). Embankments can be founded on mass stabilized soil in the same way as on natural firm soil layers like moraine or gravel [6].



a)



b)

Fig 2: Principle of mass stabilization [6].

The mass stabilization method has many benefits, including:

i. It is a rapid ground improvement method, and can be adapted to varying soil conditions
ii. It is in most cases economically efficient and saves materials and energy
iii. It improves the engineering properties of the soil and can be flexibly linked with other structures and with the surroundings (no harmful settlement differences)
iv. Transfer of the natural soil elsewhere is not needed, so there is less transportation and traffic pollution and no need for disposal sites and offsite transport [8].

3. THE IMPORTANCE OF LABORATORY TEST

Geotechnical properties of stabilized peat depend on physical and chemical properties of natural peat deposit and properties of stabilizer. The most important geotechnical properties of peat that have effect on stabilization are natural water content, humification grade and Ph [6].

To assure the safety and the quality of the final stabilized product, a number of stabilization tests must be carried out in the laboratory beforehand to establish the most suitable stabilizers, to optimize the quantity of stabilizer and to assess strength-deformation properties of the stabilized soil for the actual case. A new laboratory testing procedure has been introduced for

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peat soils so that the actual loading conditions in the field can be simulated in laboratory [6].

About 50-70 % of the total costs in stabilization project is caused by the binder. By careful laboratory work the suitable binder and its optimized quantity [in kg/m^3] is selected and thus considerable savings are reached [8].

4. BINDER TYPES

Binders may be hydraulic or non-hydraulic. A hydraulic binder is self curing in contact with water, while a non-hydraulic binder requires a catalyst to initiate curing. Non-hydraulic binders maybe used to activate latent hydraulic materials to produce reactive blended products. A hydraulic binder will stabilize almost any soil but the mechanical mixing of the binder into the soil must be very precise, otherwise the result will be heterogeneous. Non-hydraulic binders generally react with clay minerals in the soil, which will result in stabilized material with improved geotechnical properties [8].

New binders, produced as by-products of industrial processes, can be used for mass and deep stabilization. In some cases, they can be even more suitable for stabilizing organic soil and peat materials than traditional binders. Binders available as by-products, or by-product based mixtures, are much cheaper on a mass basis than traditional lime-cement binders [8].

Some of the more common binders used are cement, lime, blast furnace slag, ash and FGD, calcium sulphate products, blends of dry binders which are briefly explained in the following sections.

a. Cement

Cement is a hydraulic binder and is not dependent on a reaction with minerals; generally, it may be used to stabilize almost all soil material. There are various types of cement, and in general ordinary Portland cement is used for stabilization purposes. Cement with finer grain size is more reactive. Different additives such as slag, ash or gypsum may be added to other types. Care must be taken to ensure homogeneous mixing, because cement, unlike lime, does not diffuse into the surrounding soil mass [8].

b. Lime

For stabilization purposes, lime is used in two forms: quick lime (CaO) and hydrated lime ($Ca(OH)2$).

Lime stabilization is based on a reaction with minerals in soil or with added mineral materials. Quick lime reacts with the water in the soil and forms hydrated lime. In addition to chemical binding of water, this reaction also releases heat which will contribute to faster reactions and a reduction of water content. During the reaction, ion exchange reactions occur which affect the stabilized soil structure. Long term stabilization reactions, like pozzolanic reactions, may continue for years after completion of stabilization work [8].

c. Blast Furnace Slag

Slag needs to be granulated and ground to be reactive; finer grain size produces more reactive slag. Slag is activated with lime or cement to achieve a faster reaction. Chemically, slag is similar in composition to cement but its quality and reactivity varies. Blast furnace slag may be regarded as a low cost substitute for cement and is normally used as part of a blended product. The long term curing effect (strength development) of slag continues even years after stabilization and in many cases cement-slag mixture is more efficient than cement alone, if results are compared later on[8,9].

d. Ash and FGD

Ash is a fine grained residue from a combustion process. Composition of ash varies depending on the fuel and the burning process. Most common fuels are coal, peat and bio fuels. Fly ash is collected from flue gases with filters.

FGD is the end product of flue gas desulphurization and its composition varies from pure gypsum to almost inert calcium sulphate. Limestone or lime is often used as a sorbent to capture sulphur from the flue gases. Pozzolanic reactivity of ash varies within wide ranges, and therefore should be determined for each product separately. Ashes are as a rule not very reactive by themselves, but may reduce the cost of a blended product. If fly ash is mixed with FGD it may have reduced reactivity [8].

e. Calcium Sulphate Products

Calcium sulphate may be derived from a number of industrial processes as a secondary product. Solubility of gypsum produces Ca- andSO4-ions, which activate for example blast furnace slag and fly ash. In combination with soluble aluminates gypsum reacts to form ettringite. Calcium sulphate products are used as components in blends [8].

5. BLENDS OF DRY BINDERS

The above-mentioned materials maybe blended with each other in different proportions to optimize technical performance and economy with respect to the soil that will be treated. Blends may be factory-produced or mixed at site by the stabilization equipment [8].

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6. BINDERS FOR DIFFERENT SOIL TYPE

The geotechnical and chemical properties of the soil and the choice for the appropriate binder have a significant effect on the results of stabilization. Typical binder quantity values vary from100 kg/m^3 up to 250 kg/m^3.

The most important binder components are cement, lime, blast furnace slag and gypsum. Additionally, fly ash is commonly utilized, most notably for the stabilization of peat. Binder mixes consisting of 2-components are widely used, but 3-component binders are more versatile and can be more effective for many cases [8].

7. STRENGTH OF STABILIZED PEAT

According to [10], in soils with high organic contents, such as mud and peat, the quantity of binder needs to exceed a “threshold”. At a minimum, the quantity of binder added must be sufficient to build up a load-bearing skeleton. That means with the amount of binder below the threshold, the soil would remain unsterilized. Thus, more binder of a given type needs to be added to a porous, watery soil such as peat or mud than to a more densely compacted soil. This is because when sufficient binder is added, neutralization of humid acids within the soil is achieved, thereby increasing the soil PH. Based on laboratory tests of relative strength increase after 28 days of curing on different types of Nordic soils with different binder mixes, the cement-slag admixture was found to be a very good binder for peat with high organic content while it is considered as a good binder for other types of soil as well in many cases. Although when blended with cement in peat, ground granulated blast furnace slag generally produced stabilized soil with lower early age strength if compared to that of peat stabilized with cement only, its strength was expected to increase significantly at later ages. While cracking potential can be minimized with slower rate of strength development of the stabilized soil, high later strength gain in it ensures its durability and fatigue resistance in long term period.

8. ADDED FILLER MATERIALS IN MASS STABILIZATION

To increase the number of solid particles filler, such as fine sand, may be added in soil stabilization. The filler itself does not react but increases the strength of the soil by acting as a "stiffener".

The filler material will be of greatest relevance in the stabilization of peat and mud, as these soils often require large quantities of stabilizers (see next Chapter). Replacing part of the stabilizer within expensive filler can save costs. The filler may also be expected to fill any voids formed during stabilization.

In practice, fillers do differ in effectiveness since no filler is completely inert. Thus, for example, high-silica sand is likely to have a greater effect than limestone filler. However, the effect of fillers of whatever type is considerably less than that of the same quantity of binder [9].

9. STABILIZER QUANTITES

Peat normally requires greater quantities of stabilizer than does clay. This is partly because peat contains fewer solid particles to stabilizes. Since it is the solid particles that provide structure, a greater quantity of stabilizer needs to be added. Moreover, peat has a considerably higher water/soil ratio than clay. The large amount of water in the soil implies larger voids, requiring more stabilizers [9].

10. EFFECTS OF CURING TIME

The effect of curing time differs between different mixes of binder and soil. When using only cement as binder the stabilization reactions will almost totally be finished during the first month. In contrast, the stabilization process of materials containing lime, furnace slag, gypsum or fly ash can continue for several months after mixing. As a result, laboratory tests should be extended for some time, to optimize the binder mixture. the results may show greater applicability for a slow curing binder that produces higher long term effects, but these results may not be observed if tests are discontinued after only one month[8].

11. EFFECT OF DEGREE OF COMPACTION

The bulk density of peat is normally very low, i.e. the ratio of voids to solids is relatively high. The voids are mostly filled with water. The density of peat normally tends to increase on stabilization since some of the water in the soil is replaced by the stabilizer. Since strength of stabilized material generally increases as the voids fraction decreases (other conditions being equal), the effectiveness of stabilization in peat is likely to depend on how well compacted the material becomes. Laboratory mixing tests show large differences in stabilization effectiveness between peat specimens stored under load and specimens stored without load. One reason is that peat often gets very sticky during mixing, making it difficult to compact. Storage under load expels any air pockets and hence higher strength is attained.

In order for the stabilizer to react completely it is also important for the stabilizer to be homogeneously mixed with the soil. In general, stabilization

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effectiveness increases with the homogeneity of the stabilized material [9].

12. CONCLUSIONS

The strength of peat can be considerably improved by stabilization. Mass stabilization is a relatively new ground improvement method for soft soil layers such as peat as a sub foundation soil. The geotechnical and chemical properties of peat and the choice for the appropriate binder have a significant effect on the results of stabilization. Usually as the binder amount is increased in the mixture, the strength or the load bearing capacity of the product is increased as well. Also, it is important for the binders to be homogeneously mixed with the soil.

Peat normally requires greater quantities of stabilizer than does clay, because peat contains fewer solid particles; to increase the number of solid particles a filler, such as fine sand, may be added in soil stabilization. The filler itself does not react but increases the strength of the soil by acting as a "stiffener". The filler material will be of greatest relevance in the stabilization of peat, as this soil often requires large quantities of stabilizers.

The density of peat normally tends to increase on stabilization since some of the water in the soil is replaced by the stabilizer.

The effect of curing time differs between different mixes of binder and soil.

At the end, it is to be noted that mass stabilization is suited for projects where economical reinforcement of wide areas are required.

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