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SOIL STABILIZATION TECHNIQUES

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Abstract

Successful modern soil stabilization techniques are necessary to assure that adequate subgrade stability, especially for the weaker or wetter soils. It is widely recognized that the selection between the cementitious stabilizing agents cement and lime is based on the Plasticity Index (PI) of the primary soil type being improved. Application rate of the selected stabilizing agent is important, both for durability and for cost considerations. The use of bituminous stabilizing agents is somewhat less common, but worthy of consideration. Working with bituminous emulsions requires close attention to application rate. Iowa State University (ISU) studies in the mid-1950s led to Mobil Oil technology developments and introduction of a production foamed bitumen system by Wirtgen in 1996. Cement stabilization offers worldwide availability and ease of application. Bituminous stabilization provides material flexibility and resistance to cracking. Depending upon regional availability, cost for construction is variable.

Keywords:*-soil stabilization technique, lime , plasticity index*

1. INTRODUCTION

1.1 General

The stabilization of naturally-occurring or native soils has been performed for millennia. It was recognized before the Christian era began that certain geographic regions were plagued with surface materials and ambient conditions that made movement of men and materials difficult, if not impossible, over the paths between villages and towns. Mesopotamians and Romans separately discovered that its possible to improve the ability of the pathways to carry traffic by mixing the weak soils with a stabilizing agent like pulverized limestone. This was the first chemical stabilization of weak soils to improve their load-carrying ability.

It was further discovered, through trial and error, that as long as the improved soil bases were protected against the damaging effects of excessive moisture content, they remained stable and capable of carrying increasing traffic volume and heavier loads in the carts and wagons. The use of stone slabs as the wearing surface over these conditioned soil bases was perfected by these technologically-advanced civilizations. In fact, a few sections of roadways built by the Romans are still in remarkably good condition 2000 years following their construction.

Obviously, throughout history, there have been a number of improvements in the technology employed for the material stabilization application. This paper will present an overview of some of the design features of modern soil stabilizers. In addition, additive selection criteria will be reviewed.

1.1 Definitions and Terminology

Asphalt emulsion œ Asphalt emulsion is a mixture of asphalt binder and water that contains a small amount of emulsifying agent to cause the asphalt to become mixed with or suspended in the water. Asphalt emulsion may be either anionic with electro- negatively charged asphalt globules or cationic with electro-positively charged asphalt globules, depending upon the emulsifying agent. Atterberg Limits œ The Atterberg Limits are a basic measure of the nature of a fine- grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state the consistency and behavior of soil is different. Its engineering properties. Thus, the boundary between each state can be defined based on changing the soil's behavior. These limits were created by Albert Atterberg, a Swedish chemist, in the late 1800s. They were later refined by Arthur Casagrande. Bitumen œ Bitumen is a class of black or dark-colored cementitious substances (either natural or manufactured) composed principally of high-molecular weight hydrocarbons, of which asphalts, tars and pitches are typical. Cement œ Portland cement is hydraulic cement made by heating a limestone and clay mixture in a kiln and pulverizing the resulting material. Clay œ Clay is a cohesive soil type composed of very fine material particles; clay is one of the fine-grained soils defined by the Unified Soil Classification System. CQS (Cationic Quick Setting) emulsion œ CQS is a quick-setting cationic slurry emulsion used for a variety of construction applications. CTB (Cement-Treated Base) œ CTB is a mixture of aggregate material and/or granular soils combined with measured amounts of Portland cement and water that hardens after compaction and curing to form a durable paving material. Density œ Density is the measure of the relative weight of any material compared to its occupied volume, expressed in kilograms per cubic meter (pounds per cubic foot). The increasing density is limited only by the degree of solidity that can be achieved in an material by total elimination of voids between the particles in the mass. Fly ash œ Fly ash is fine particulate ash created by the combustion of a solid fuel, such as coal, and discharged as an air born emission, or recovered as a byproduct for various commercial uses. Fly ash is used as a reinforcing agent in the manufacturing of bricks, concrete. There are two major classes of fly ash, C and F. Class F is produced from burning anthracite or bituminous coal; it usually has cementitious properties in addition to pozzolanic properties. Class C is produced by burning sub- bituminous coal and lignite, and is rarely cementitious when mixed with water alone. Foamed Asphalt or Foamed Bitumen œ Foamed asphalt or bitumen is expanded in volume and softened through controlled addition of air and water in an expansion chamber. The foam mixture then distributed (in controlled volume) through spray nozzles into the mixing chamber of a mobile mixer where the bitumen attaches itself to fines in the mix, creating spot —welds“ rather than uniform particle coating. Gravel œ Gravel is a granular material type composed of particles predominantly retained on the 4.75 millimeter (number 4) sieve; gravel is one of the coarse-grained materials identified by the Unified Soil Classification System. Impermeability œ Impermeability is the relative resistance to the passage of air or water into or through a material or pavement layer Calcium hydroxide is used chiefly in mortars, plasters, and cements. LL (liquid Limit) œ The liquid limit of a fine-grained soil is the boundary between the liquid and plastic states of that particular soil, expressed as a moisture content percentage (by weight). PI (Plasticity Index) œ PI is the numerical difference between the liquid limit and the plastic limit of a fine-grained soil. PL (Plastic Limit) œ The plastic limit of a fine-grained soil is the boundary between the plastic and semi-solid states for that particular soil, expressed as a moisture content percentage (by weight). QA (Quality Assurance) œ QA is the activity of providing evidence needed to establish confidence among all concerned, that quality-related activities are being performed effectively. QC (Quality Control) œ QC is a process for maintaining proper standards in construction or manufacturing by employing systems to ensure that products or services are designed and produced to meet or exceed customer requirements. Sand œ Sand is granular material type composed of particles predominantly passing the 4.75 millimeter (number 4) sieve but retained on the 0.075 millimeter (number 200) sieve; sand is one of the coarse-grained materials identified by the Unified Soil Classification System. Soil œ Soil is sediment or other unconsolidated accumulation of solid particles produced by the physical and/or chemical disintegration of rock; soil may or may not contain organic material. SL (Shrinkage Limit) œ The shrinkage limit of a fine-grained soil is the boundary between the semi-solid and solid states for that particular soil, expressed as a moisture content percentage (by weight). Stabilizing additive œ A stabilizing additive is a mechanical, chemical or bituminous additive (or other material) used to maintain or increase the strength and durability, decrease the moisture sensitivity, or otherwise improve the engineering properties of a soil or other material used in construction.

1.2 Objectives

This presentation has been developed to assist attendees to the TAC (Transportation Association of Canada) 2007 Annual Conference understand the state-of-the-industry for modern soil stabilization techniques. A few recent, larger-scale field projects will be discussed. General cost data for the various additives used in soil stabilization will be presented. Explanation of the technology utilized for introduction of the stabilizing agent into in-situ soil will be provided and apictorial record of one of a typical project will be depicted. At the end of the presentation, appropriate references for contemporary technical assistance with this technology will be identified.

2 SOIL STABILIZATION PROCESS

2.1 Stabilization with lime

The use of lime to dry, modify or stabilize soils has been documented in studies as much as 50 years old. Many state agencies developed specifications or procedures for lime stabilization of fine-grained or mixed soils when the United States interstate highway system was being constructed in the 1960s.

In 1999, the National Lime Association commissioned Dr. Dallas Little to evaluate the structural properties of lime and to develop practical lime stabilization MDTP (Mixture Design and Testing Procedure). His work outlined that seven steps may be necessary for mixture design and testing of lime stabilized soils. The seven tests are identified by Dr. Little are as follows:

1. Initial soil evaluation
2. Determination of approximate lime demand
3. Determination of OMC (Optimum Moisture Content) and MDD (Maximum Dry
Density) of lime-treated soil
4. Fabrication of UCS (Unconfined Compressive Strength) specimens
5. Curing and conditioning of ICS specimens
6. Determination of UCS of cured and moisture-

conditioned specimens

7. Determination of change in expansion characteristics of specimens

2.2 Stabilization with cement

2.2.1 CTB (Cement-Treated Base)

According to the PCA (Portland Cement Association), CTB (Cement-Treated Base) has provided economical, long-lasting pavement foundations for over seventy years. These structures have combined soil and/or aggregate with cement and water which is then compacted to high density. The advantages of cement stabilization are several:

1. Cement stabilization increases base material strength and stiffness, which reduces deflections due to traffic loads. This delays surface distress such as fatigue cracking and extends pavement structure life.

2. Cement stabilization provides uniform, strong support, which results in reduced stresses to the sub-grade. Testing indicates a thinner cement-stabilized layer can reduce stresses more effectively than a thicker un-stabilized layer of aggregate. This reduces sub-grade failure, pothole formation and rough pavement surfaces.

3. Cement stabilized bases have greater moisture resistance to keep water out; this maintains higher strength for the structure.

4. Cement stabilization reduces the potential for pumping of subgrade fines.

5. Cement stabilized base spreads loads and reduces sub-grade stress.

2.2.2 CMS (Cement-Modified Soil)

According to the Portland Cement Association, CMS is a soil material that has been treated with a relatively low proportion of Portland cement. The objective of CMS is to mitigate the undesirable properties of materials that are sub-standard in quality or engineering value so that they can be made suitable for construction. The amount of improvement that can be expected is dependent upon the quantity and quality of cement used as well as the type of soil being treated. The engineering properties that can be improved include the following:

1. The soil‘s Plasticity Index can be reduced.

2. The soil‘s CBR (California Bearing Ratio) can be increased.

3. Material shearing strength can be increased.

4. Shrinkage or swelling characteristics for the soil can be decreased.

5. The amount of fine-grained material particles (silt and clay) can be reduced.

2.3 Stabilization with bitumen

2.3.1 Additive selection

Soil stabilization with bitumen can be done with either of two additives. Depends on the project condition the choice is made between using asphalt emulsion and using foamed bitumen as the additive. For example, extremely wet soil conditions might dictate the use of foamed bitumen rather than a standard asphalt emulsion to compensate for the high field moisture content. Emulsion might be chosen for the projects where as high-performance emulsions are readily available.

2.3.2 Use of multiple additives

It is not uncommon for certain materials or project conditions to require that more than a single additive be utilized to achieve the required strength and stability for the new base design. For example, when using foamed bitumen, it is often the practice to also utilize cement or lime to help increase the compressive strength of the base material, or to assist in drying out materials that have field moisture contents greatly exceeding optimum moisture content (OMC).

When more than a single additive is selected, the first additive to be applied may be added in the dry state or as slurry. When added in the bulk state, it is not uncommon for the agent to be spread onto the surface of the material and then either bladed, disked, scarified or otherwise distributed prior to final stabilization. As slurry, it may be applied by a truck distributor, or mixed directly into the soil through an additive system incorporated into the stabilizer‘s mixing chamber.

There are also many projects where the in-situ material field moisture content is not sufficient for proper activation of the chemical reaction of the cement or lime. For these projects, it is necessary to wet the treated soil prior to mixing. Dry spreading of cement or lime in arid regions is often discouraged due to the creation of dust during the process.

2.4 STABILIZATION WITH FLY ASH

2.4.1 Description of work in Iowa

In May 2006 an Iowa contractor was challenged to quickly stabilize a series of tennis courts in the southeastern portion of the state. Iowa is known for fine agricultural soils...loamy, high-organic materials. However, construction projects often encounter material changes from glacial till to sand and many other soil types. Contractors find that the glaciers seem to have deposited material inlayers that, as cuts are made through them, have pockets of different materials within. For this reason, fly ash was chosen as the agent to stabilize these highly variable soil types to produce a stable base for reconstruction of the new tennis courts‘ surfaces.

Type C fly ash was spread by distributor truck at an application rate of (59 pounds per square yard). The fly ash was mixed with the existing subgrade to a depth of 300 millimeters (12 inches); water was used to activate the ash‘s bonding with the in-situ subgrade materials. The stabilized material was then compacted with a pad foot vibratory compactor, and graded to proper profile. A smooth drum vibratory compactor reduced material air void content to about 3 percent. The tennis courts were then capped with about 50 millimeters (2 inches) of reclaimed mix from the original courts.

2.4.2 Site details

A major Texas-based construction firm was contracted to complete soil stabilization on the site of a massive liquid natural gas (LNG) receiving terminal south of Houston on the Texas Gulf Coast. The site contains approximately 348,000 square meters (86 acres), situated between 0.9 to 1.2 meters (3 to 4 feet) below the ground water table elevation. The entire site is situated on a dredge spoil area which includes a variety of materials including fat clay, silt, sand and organic matter from ship channel dredging operations during the past. The contractor was charged to build up the site elevation by up to 4.3 meters (14 feet) plus build levees up to 6.4 meters (21 feet) tall to self- contain the site and protect it from flooding.

Soil from off-site is being trucked in, with 40 to 50 truck loads arriving daily; volume of material being placed varies between 4590 to 5350 cubic meters (6,000 to 7,000 cubic yards) per day. The total amount of soil that needs to be moved for this project is 688,100 cubic meters (900,000 cubic yards).

2.4.3 Construction

Lime is the stabilizing medium for the soil on this project. The contractor needs to truck in more than a dozen 22.7 tonne (25 ton) truck loads each day. Some of the material is being reclaimed from the actual dredge spoil area; other soil is coming in from an offsite borrow pit. Pelletized lime is being used to reduce fugitive dust, to prevent environmental issues. The lime is dumped from the belly-dump haul trucks into windrows and then spread by motor grader, laid at about 5 percent volume. slaking. About 37,850 liters (10,000 gallons) of water are needed for each 22.7 tonne (25 ton) truck load of lime. After slaking is completed, the stabilizers go to work. According to the contractor‗s representative, the soil is mixed back and forth a couple of times"; once the mix is ready, they start compaction with sheepsfoot and smooth drum compactors". Following stabilization, curing time is between two and three days, depending upon ambient condition

3 BENEFITS

3.1Technical Benefits

Treatment with lime (lime stabilisation) and/or cement (cement stabilisation) allows production of a long lasting and stable material comparable to those of graded aggregates. Hard wearing, with a greater stiffness and strength they provided excellent performance within the construction process and have become widely recognised by a strong alternative to typical construction methods.

3.2 Financial Benefits

The recycling and re-use of insitu materials gives significant savings, as it minimises the stripping and removal to landfill of material along with their associated transport costs and also saves on the import of aggregates.In addition to this, the duration of the works are also shorter, giving further savings to the contract program.

3.3 Environmental Benefits

There are significant environmental benefits of soil stabilisation in comparison to traditional construction methods including energy savings by reducing the transport of materials (this also reduces the indirect effects including nuisance to the public), minimising the use of aggregate resources and utilising some binders that are by-products of the energy Indus

CONCLUSION

i. The liquid limit of soil increases when lime, fly ash,lime + fly ash and cement + lime is used as a admixture. When cement is used L.L is first increases then decreases and again increases. When fly ash + cement is used L.L is increases at 2% of their content and then decreases. L.L of soil is minimum for 2% of lime content. At 2% of lime content L.L of soil is 37%.

ii. The plastic limit of soil is regularly increases when lime, cement, lime + fly ash and cement + lime isused as a admixture. When fly ash and fly ash + cement is used as a admixture P.L of soil is first increases then decreases. P.L of soil at 10% of fly ash content is minimum. At 10% of fly ash P.L of soil is 29.58%

iii. P.I. of soil has lesser value at 2% of cement content which is 3.2%. Soil having lesser value of P.I is good for engineering purposes. Hence compared to other combinations 2% of cement content is found to be more suitable.

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