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A Study on Use of Bitumen Emulsion in Gravel Road Construction

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Abstract: The most important part of a road pavement is sub grade soil and its strength. If strength of soil is poor, then stabilization is normally needed. Sub grade is sometimes stabilized or replaced with stronger soil material so as to improve the strength. Such stabilization is also suitable when the available sub grade is made up of weak soil. Increase in sub grade strength may lead to economy in the structural thicknesses of a pavement. Cement, fly ash, lime, fibers etc. are very commonly used for soil stabilization. It is observed that excellent soil strength results by using cationic bitumen emulsion (CMS) with little quantity of cement used as filler. The appropriate mixing conditions for gravelly soil with CMS Bitumen emulsion have been first attempted. This is followed by deciding four particular material conditions to show the variation in dry density and CBR value to achieve the best possible strength properties of gravel soil.

Keywords: Gravel soil, CBR, Bitumen Stabilization, bitumen emulsion

Introduction

Starting from the base, soil is a standout amongst the most abundant construction materials of nature. Just about all kind of construction is based with or upon the soil. Long term performance of pavement structures is altogether affected by the strength and durability of the sub grade soils. In-situ sub-grades frequently don't provide the support required to achieve acceptable performance under the traffic loading with increasing environmental demands. Despite the fact that stabilization is a well-known option for improving soil engineering properties yet the properties determined from stabilization shift broadly because of heterogeneity in soil creation, contrasts in micro and macro structure among soils, heterogeneity of geologic stores, and because of chemical contrasts in concoction interactions between the soil and utilized stabilizers. These properties require the thought of site-specific treatment alternatives which must be accepted through testing of soil-stabilizer mixtures.

Whether the pavement is flexible or rigid, it rests on a soil foundation on an embankment or cutting, normally that is known as sub grade. It may be defined as a compacted layer, generally occurring local soil just beneath the pavement crust, providing a suitable foundation for the pavement. The soil in sub grade is normally stressed to certain minimum level of stresses due to the traffic loads. Sub grade soil should be of good quality and appropriately compacted so as to utilize its full strength to withstand the stresses due to traffic loads for a particular pavement. This leads the economic condition for overall pavement thickness. On the other hand the sub grade soil is characterized for its strength for the purpose of design of any pavement.

Presently every road construction project will use one or both of these stabilization strategies. The most well-known type of mechanical soil stabilization is compaction of the soil, while the addition of cement, lime, bituminous or alternate executors is alluded to as a synthetic or added substance strategy for stabilization of soil. American Association of State Highway and Transportation Officials (AASHTO) classification system is a soil classification system specially designed for the construction of roads and highways used by transportation engineers. The system uses the grain-size distribution and Atterberg limits, such as Liquid Limits and Plasticity Index to classify the soil properties. There are different types of additives available. Not all additives work for all soil types. Generally, an additive may be used to act as a binder, after the effect of moisture, increase the soil density. Following are some most widely used additives: Portland cement, Quicklime or Hydrated Lime, Fly Ash, Calcium Chloride, Bitumen etc. But, mechanical soil stabilization alludes to either compaction or the introduction of sinewy and other non-biodegradable reinforcement of soil. This practice does not oblige compound change of the soil and it is regular to utilize both mechanical and concoction intends to attain detailed stabilization. There are a few routines used to accomplish mechanical stabilization like compaction, combining, soil reinforcement, expansion of graded aggregate materials and mechanical remediation. Any land-based structure depends upon its foundation characteristics.

For that reason, soil is a very critical element influencing the success of a construction project. Soil is the earliest part of the foundation or one of the raw materials used in the whole construction process. Therefore the main thing related to us soil stabilization is nothing but the process of maximizing the CBR strength of soil for a given construction purpose. So many works have been done on cement, lime or fly ash stabilization. But very few works have been found on bitumen soil stabilization.

Objective and scope of work

The main objective of this paper is to study the properties of the gravely soil by adding bitumen emulsion as stabilizing agent and little bit cement as filler. An attempt has been made to use emulsion for improving the strength and geotechnical properties of gravel soil. Very mostly, use of use of bitumen emulsion is environmentally accepted. To achieve the whole project some experimental investigation is needed in laboratory. The experiments which to be conducted are Specific Gravity of the soil sample, Grain size Distribution of soil sample and liquid limit plastic limit test to identify the material and Standard Proctor test to obtain maximum dry density and optimum moisture content of soil sample, CBR test of soil sample mixing with emulsion and cement. So the main objective is to maximize the CBR value by checking some conditions to increase the CBR value of soil sub grade.

LITERATURE SURVEY

Construction of Gravel Roads

For roads with a higher traffic volume, paving the road is more cost effective than spending financial resources on gravel road maintenance in order to keep an acceptable standard regarding dust emission and driving comfort. Newly constructed gravel roads should be built up of two to four layers of gravel material according to specifications in the Swedish National Guidelines. These are, from surface to ground: the gravel wearing course (50-90 mm), the base course (~100 mm), and occasionally the sub-base and protective layer. Limits for variations in grain size distributions for these layers are also specified. Most gravel roads are old and were constructed before this specification existed.

Therefore, the gravel material layer is often thinner than specified and any difference between the gravel wearing course and base course is usually difficult to distinguish (Johansson, 2005). Gravel wearing courses typically consist of graded and compacted 0-16 mm crushed rock material (Vägverket, 2007). The fine material fraction makes up between 8 and 15 percent of the total mass of a well-graded wearing course. Gradations that have less fine material cannot achieve a maximum cohesive effect whereas gradations that have more fine material tend to retain too much moisture, develop ruts, and become soft, instable, and slippery when wet (U.S. Department of Transportation, 2001). Traditionally, certain amounts of clay have been added to wearing courses in order to add cohesion to the aggregate and, thereby, prevent dust emission and ravelling (Thompson and Visser, 2007).

Base course material for gravel roads should be slightly denser and contain more fine material than base course materials for paved roads in order to prevent too rapid drainage and drying of the wearing course (Vägverket, 2007). Gravel demand for road construction, i.e. both paved and gravel roads, represents a large part of the total worldwide demand for gravel material today (Al-Awadhi, 2001). Frequent aggregate supplementation is unsustainable as natural resources are being depleted (Jones and Ventura, 2003). Both naturally found gravel and crushed rock are used as gravel material in Sweden, but crushed rock is used in increasing proportions due to more stringent restrictions regarding usage of naturally found gravel (Johansson, 2005).

Controlling of Dust

A dust suppressant functions either by attracting moisture from the surrounding air, which in turn holds the dust, or by adhering particles together. Salts (chlorides) depend on the former principle whereas most organic suppressants, such as lignosulphonate and vegetable oils, primarily rely on the latter one. The first part of a dust control operation is prewetting and blading. Prewetting brings the gravel material to near optimum moisture content, which assists in blading to remove ruts, corrugations, potholes, and loose gravel. It also reduces the surface tension, which allows for maximum penetration of the dust suppressant and ensures a uniform application of the dust suppressant over the whole treated area (Armstrong, 1987). Where liquid products are used, the amount of water used for prewetting should be reduced compared to the amount used for the application of solid products to avoid exceeding an optimum moisture level (Monlux and Mitchell, 2007). The best time to apply dust suppressants is early spring when the moisture content of the road surfaces is high (Monlux and Mitchell, 2007).

Dust suppressants are usually applied topically. Procedures where the product is mixed-in with the aggregate are probably more effective, but the lower application rate and shorter preparation time for topical applications warrant their use (Rushing and Tingle, 2007). The maintenance crew normally allows traffic to flow during the entire dust control operation, which presents additional challenges to the work process (Powers, 2007). Compaction, other than from regular vehicular traffic, is generally not performed, since there are no indications that this has any long-term performance benefits (Monlux and Mitchell, 2007). When road deteriorations eventually develop, the maintenance crew must reblade the road surface and possibly apply supplementary dust suppressant material.

PROPERTIES OF BITUMEN

The properties of Bitumen can be defined in terms analogous to the Modulus of Elasticity of solid materials. In case of solids, Modulus of Elasticity E is defined by Hooke's law Bitumen is a Visco-elastic material. At high temperatures it behaves like a liquid & hence liquid flow properties like Viscosity are exhibited.

Figure 1: A sample bitumen material constructed road

However, at low temperatures bitumen behaves like a solid and hence solid properties like stress & strain become relevant. Similarly, for shorter loading time bitumen behaves like a solid whereas for longer loading times bitumen behaves like a liquid. The properties that bitumen exhibits in the intermediate temperature range and loading time are of great relevance as this range is very long and bitumen is handled in this temperature range most of the times. Due to the visco-elastic nature of bitumen, there is always a phase lag in stress & strain in case of repetitive loadings. For purely elastic material the phase lag is 00 and for purely viscous material the phase lag is 900 . In case of bitumen since it is neither a liquid nor a solid at most temperatures hence the phase lag is always between 00 to 900 . The above theory is extremely useful in studying fatigue characteristics, properties of creep & also tensile strength of bitumen.

LABORATORY TESTING & DISCUSSION

Laboratory testing was conducted to characterize the materials used in the CR 172 and 118 stabilization construction. This chapter describes the testing conducted on each of the materials, and the results obtained.

Summary of Laboratory

This section details the laboratory testing and data analysis conducted on material samples. The laboratory testing included the following:

- Soil classification
- Gradation
- In-situ moisture content
- Maximum density and optimum moisture content of Class 5 material
- Resilient modulus of stabilized Class 5 material

Samples of unbound aggregates, soils, and the stabilized layer were obtained in the field, as described in the previous chapter on field testing. This chapter discusses the results of the laboratory testing conducted on the samples obtained from the field and emulsion samples obtained from the manufacturer.

Classification

Each of the soils sampled were tested for compliance with the Mn/DOT requirements for Class 5 material, based on its gradation. The gravel samples obtained from both sites met the requirements.

In-situ Moisture Content

The in-situ moisture content of each soil layer was measured in the laboratory after extrusion from the shelby tubes.

Proctor Density of Class 5 Aggregate

Samples of Mn/DOT Class 5 aggregate were obtained during the initial construction phase – placement of seven and nine inches of new gravel on CR 118 and CR 172, respectively. These samples were taken to the laboratory for maximum theoretical density testing.

Resilient Modulus

Some of the Class 5 material samples from the gravel operations at the project locations was used in resilient modulus testing in the laboratory. The resilient modulus test was conducted according to AASHTO TP-46, and was used to test unbound materials obtained from the project locations, as well as material that had been stabilized and compacted to the same density as in the field. The resilient modulus testing occurred over several stages. The first stage was to prepare samples using Class 5 material obtained from the field and emulsion obtained from the manufacturer. Samples were prepared using 4x8 inch cylinder molds and compacted to densities ranging from 128 to 138 lbs/cf, with 4 percent moisture content. A total of six samples were compacted for each of County Roads 172 and 118 in Blue Earth County. Two samples were produced at each emulsion content, at 5.5, 6.5, and 7.5 percent. The prepared samples were then allowed to cure, uncovered, for a period of between two and three weeks before testing.

Figure 2: Emulsion sample in triaxial cell.

MATERIALS AND EXPERIMENTAL DESIGN

Field-based testing is time-consuming, costly but also difficult to fully control due to varying parameters such as weather conditions and traffic. Road-based studies often require long test periods, especially for establishing general models, which means an associated risk of test sections requiring maintenance activities before the test program is completed. Dust emission might also vary naturally over different sections of the road due to differences in topography, geometry, level of groundwater table, ambient vegetation, fine material content, etc. Laboratory experiments are generally the fastest, simplest, and cheapest way to study road material properties. Most parameters can be controlled, e.g. precipitation, moisture content, curing period, temperature, load, and wear. Furthermore, some laboratory investigations simply aim to make chemical or physical analyses of material collected at a test site. However, the influence of traffic and climate is difficult to realistically simulate in a laboratory. Nonetheless, laboratory tests are valuable as complement to field-based studies.

Quantitative methods for analyses of residual concentrations

Gravel wearing course samples of 150 mm x 150 mm x the total depth of the gravel wearing course, were collected for residual quantification of dust suppressant concentration. Some of the test sections constructed to study the efficiency of different dust suppressants were also used in this study. All test sections treated with chloride and lignosulphonate were used. Samples were taken in the middle of each test section, from the same wheel track. The section middle was marked with a post placed beside the road (Fig. 2) For the second sampling, the sample was taken approximately 0.5 m behind the first sample spot and the third sampling a further 0.5 m behind and so on. In this manner, the risk of analysing replaced material was kept at a minimum, while there was a good chance that all samples were similar regarding dust suppressant distribution and environmental conditions.

To evaluate the importance of sampling at approximately the same site and also study the uniformity of the chloride distribution based on a liquid or solid salt application, gravel wearing course samples were collected from five different spots within each test section: the right wheel track 200 m in front of the section middle post, the right and left wheel track as well as in the middle of the road at the section middle post, and the right wheel track 200 m after the post (Fig. 2). The samples were collected about ten days after dust suppressant application on four sections treated with solid calcium chloride, solid magnesium chloride, a calcium chloride solution, and a magnesium chloride solution, respectively.

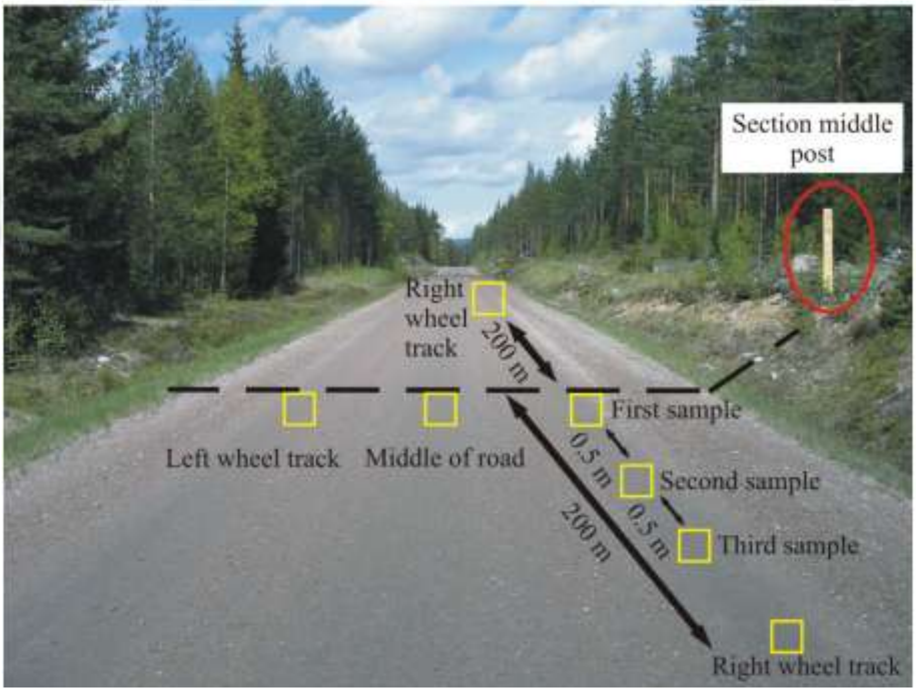

Figure 3: Sampling procedure. Sample squares are 150 x 150 mm.

Sample preparation, i.e. dissolving and purifying residual lignosulphonate and chloride, respectively, from the gravel matrix, before quantification, is shown in Figure 3. To a sample of 50 g gravel wearing course material, containing residual dust suppressant, 50 mL deionised water was added. To avoid incorporation of the largest grains, which would add substantially to the total weight, the 50 g sample had to be hand-picked. The water-soaked samples were then placed in an ultrasonic water bath for 10 minutes to dissolve the residuals. A standard filter paper (125 mm in diameter, Schleicher & Schuell, No. 311611) was folded and inserted into a funnel. The solution, taken from the ultrasonic bath, was decanted into the funnel and placed on top of a clean glass beaker. To avoid eventual background contamination from very fine soil particles which could have passed through the filter paper pores during filtration, each lignosulphonate containing sample was filtered once more with a 0.45 µm PTFE-membrane coupled to a 5 mL syringe with a Luer-connection. Each chloride containing filtrate was centrifuged with the same purpose. Two 1.5 mL samples of the chloride filtrate were put into Eppendorph tubes which were centrifuged at 10,000 rpm (or 13,000 times the G-force) for 10 minutes to sediment fine particles.

CONCLUSIONS

This paper presents the basis for a new design method for the thickness of a bituminous stabilized layer constructed on an existing aggregate surfaced roadway. The method requires the input of properties and thicknesses of existing layers, and then uses layered elastic theory to predict the deflections at the surface after a stabilized layer is placed. Due to the inherently variable nature of fine- and coarse-grained soils, the results of these correlations may not be the most appropriate for the use intended. This method of improving aggregate-surfaced roadways has several benefits, including the following:

- Improvement in ride quality, surface roughness, and safety
- Virtual elimination of dust problems
- Reduction in the loss of aggregate
- Reduction of maintenance and regrading costs
- Relatively inexpensive method of upgrading a gravel roadway
- Conservation of future maintenance and construction funds as well as natural resources due to dramatically decreased regrading and reshaping needs.

There are some possible disadvantages to improving a roadway with this method, including the unintended result of providing a better driving surface – higher speeds. Many aggregatesurfaced roadways are not designed geometrically for higher speeds, and the potential for a false sense of security exists, by driving on a smoother, harder surface. Another potential disadvantage is the possibility for rutting in the surface and the adverse effects of snow plows on the seal coats at the surface which are important to maintaining the integrity of the bituminous stabilized layer.

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