Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 16 Issue 4 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

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By Md Ibtesam Hossain & Md Wasim Ather
Ahsanullah University of Science & Technology

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GJRE-E Classification: FOR Code: 290804

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Abstract- The main objective of this research is to provide a solution to the rapid plastic deformation of flexible pavements due to moisture effect and heavy loading thus increasing the service life of flexible pavements. It is a common phenomena in Bangladesh that pavements undergo critical damage due to uncontrolled traffic flow, heavy loading and weather effect. Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and humidity. Most parts of the country receives at least 2000mm of rainfall per year (weatheronline.co.uk)and the major parts of the country is comprised of sand and silty clay soil which tend to collapse when soaked and thus inducing damage to the sub-base layer of the pavements. The solution requires stabilization of sub-grade soil of flexible pavement using Portland Cement. The method considers three different percentage of cement content by weight (10%, 12% and 14%) with constant water-solid ratio(0.156) and finally recommends 10% cement content to be the optimum selection for stabilization.

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I. Introduction

Pavements in Bangladesh are generally constructed with unbound coarse aggregated sub-grade layer. As a result, when saturated and under heavy traffic load, gradation of the unbound aggregate breaks and weakens the sub-base layers of the pavement. Saturation can also reduce the dry modulus of both the asphalt layer (30% or more) and the base and sub-base modulus (50% or more). As water is one of the principle cause of premature pavement failure, the service life of pavements have become much shorter which leads to greater degree of road accidents and maintenance cost. This is where stabilization comes into play. According to TRL Overseas road note 31 (1993), stabilization can enhance the properties and pavements in following ways: 1) A considerable amount of their strength is retained when they are saturated. 2) Surface deflection is reduced. 3) Erosion resistance is increased. 4) The stabilized layer cannot be contaminated by other materials in other layers. 5) The effective elastic module of granular layers, constructed above stabilized layer, are increased.

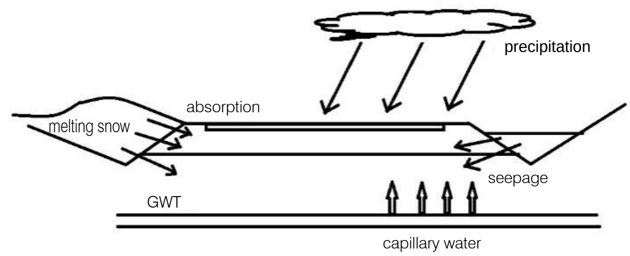


Fig. 1: Main Sources of Water in Pavement

The research evaluated Portland Cement and Lime as stabilizer. This two stabilizer is selected as they are economically available in Bangladesh. But, before choosing any of them, particle size distribution and atterberg limit test is required and commonly used to gain a preliminary assessment of the type of stabilizing agent needed for specific soil type. Also, climate have significant effect on the choice of stabilizer. As for Bangladesh, the moisture content of pavement materials is very high and so it is important to ensure that the wet strength of the stabilizer is adequate. In this condition, cementitious binder is usually preferred although asphalt and asphalt/cement is also considerable. On the other hand, Lime is suitable for cohesive soils, particularly when used as an initial agent to dry out the materials. Lime can also work with silty soils if pozzolan is added to promote cementing reaction. Lime stabilization requires clay content greater than 25-30% but in most part of the country clay content is not adequate enough for lime stabilization. Though lime stabilization with pozzolan can be done for low clay content (e.g. 7% caly content) soil, the research chose cement stabilization for the following reason: Most commonly used pozzolan is fly ash, a finely divided residue that results from the combustion of pulverized coal in power plant boilers, which is transported from the combustion chamber by exhaust gases but in Bangladesh, fly ash is not economically available and only used in cement industries and as a result, cement stabilization stands above from other stabilizations in

Author α: Completed B.Sc. in Civil Engineering from Ahsanullah University of science and Technology.
e-mail: ibtesam.hossain@gmail.com
Auhtor σ: Completed B.Sc. in Civil Engineering from Ahsanullah University of science and Technology.

this country. Cement stabilization refers to stabilize soil with Portland cement and the primary reaction is with the water available in the soil which leads to the formation of cementitious material. These reactions occur almost independent of the nature of the soil and for this reason, Portland cement can be used to stabilize a wide variety of materials.

The research begins with soil classification. It involves:

1) *Grain Size Analysis:* It is done to determine the percentage of different grain sizes contained within soil. The mechanical or sieve analysis along with hydrometer analysis is done to get the distribution of particles.

Equipment used: Balance, Set of sieves, Cleaning brush, Hydrometer, Sedimentation cylinder, control cylinder, thermometer, beaker, timing device.

2) *Atterberg Limit Test:* This test is done for determining the Liquid Limit (LL) and Plastic Limit (PL) of the sample soil. The liquid Limit (LL) is arbitrarily defined as water content, in percent, where soil is put up on a standard cup and cut by a groove of standard dimensions. Soil will flow together at the base of the groove at a distance of 13mm (1/2 inch) when subjected to 25 shocks from the cup being dropped 10mm from a standard LL apparatus operated at 2 shocks per second. The plastic Limit (PL) is the water content, in percent, when soil can no longer be deformed by rolling into 3.2mm (1/8 inch) diameter threads without crumbling.

Equipment used: Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage, Eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilled water, drying oven set at 105°C.

Liquid Limit (LL) = 36%

$$PI = 0.73(LL-20) = 11.68$$

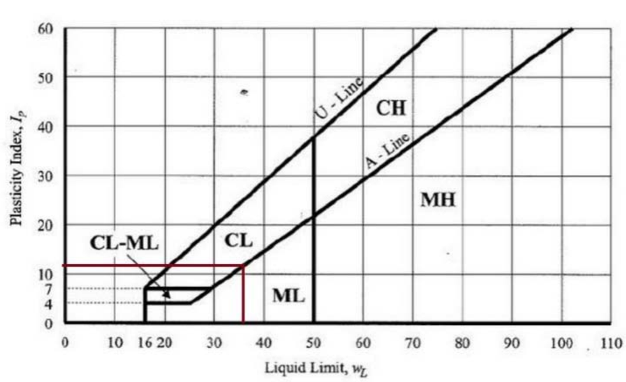


Fig. 2: Plasticity Chart

From the figure it can be said that it is type CL-ML.

Sieve #200 passing = 5% < 50%; so the soil is coarse grained soil.

#4 passing = 91.93% > 50%; so the soil is sandy.

Amount of sand = 91.93%

Amount of gravel = (100-91.93)% = 8.07%

Finally, the soil type is SC-SM and it is silty, clayey sand. (as amount of gravel is <15%)

Cement stabilization is ideally suited for well graded aggregated soil which has required amount of fines to effectively fill the available void space. General guidelines for cement stabilization are that the Plasticity Index (PI) should be less than 30 for sandy materials. A more specific general guideline based on the fines content is given in the equation below which defines the upper limit of PI for selecting soil for cement stabilization

$$PI \leq 20 + \frac{50 - (\%\text{ smaller than } 0.075\text{mm})}{4}$$

$PI \leq 20 + (50-5)/4$

$PI \leq 31.25$; so the soil can be cement stabilized as we got PI = 11.68

II. Sample Preparation

Soil is dried and sieved (to remove large lumps, stones, leaves and other impurities) before it is mixed with cement and compressed into blocks. Once soil has been dried and sifted it is mixed thoroughly with cement of three different percentage of 10%, 12% and 14% by weight. After mixing, water is added little at a time keeping the water solid ratio of 0.156 for proper workability with optimum moisture content. The prepared mixed is then placed into the mould. Mould was placed on a firm , level surface. The mixture was placed in three layers of approximately equal volume and each layer was rod with 25 uniform strokes of tamping rod over the cross section of the mould.. For layers 2 and 3, the rod shall penetrate into 25mm into the underlying layer. Any left voids was closed by lightly tapping on the sides of the mould with the rod. After the top layer has been ridded, the surface was struck off with trowel and covered with saran wrap to prevent evaporation. Then the specimens were stored undisturbed for 24 hours in such a way as to prevent moisture loss and to maintain within a temperature range of 15°C to 27°C. Finally, specimens were removed from mould between 20 and 48 hours and transferred carefully to the place of curing and testing. Each block was set on edges and spaced far enough apart. The blocks were sprinkled with fine water spray three times a day and during the first 4 days of curing, blocks were covered with plastic because the slower the blocks dry, the stronger they will be.

Fig. 1: Soil Cement Mixing and Moulding

Fig. 2: Final Sample of Soil-Cement Block

The samples were taken and tested for compressive strength in 7^{th} 14^{th} and 28^{th} days. Blocks were carefully placed within the machine without shock and load is implied with a constant rate within a range of 0.140 MPa to 0.350 MPa per second until failure occurs. Sub-Section example is given below:

Table 1: Summary of Soil-Cement Block Stabilized with 10% Cement Content

Time (days)	Area (square inch)	Load (lb)	Stress (psi)
7	4	634	159
14	4	745	186
28	4	900	225

Table 2: Summary of Soil-Cement Block Stabilized with 12% Cement Content

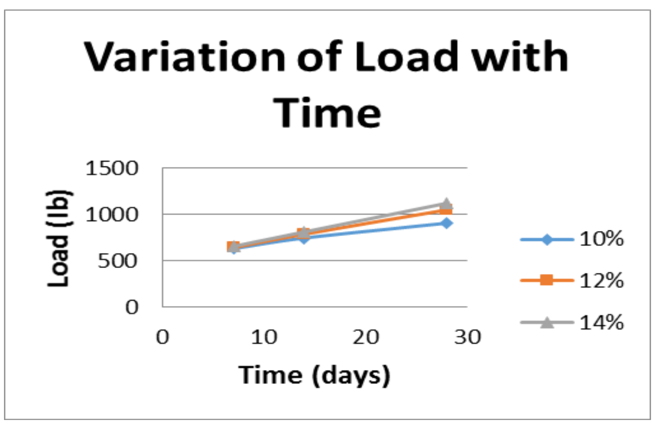
Time (days)	Area (square inch)	Load (lb)	Stress (psi)
7	4	639	160
14	4	784	196
28	4	1047	262

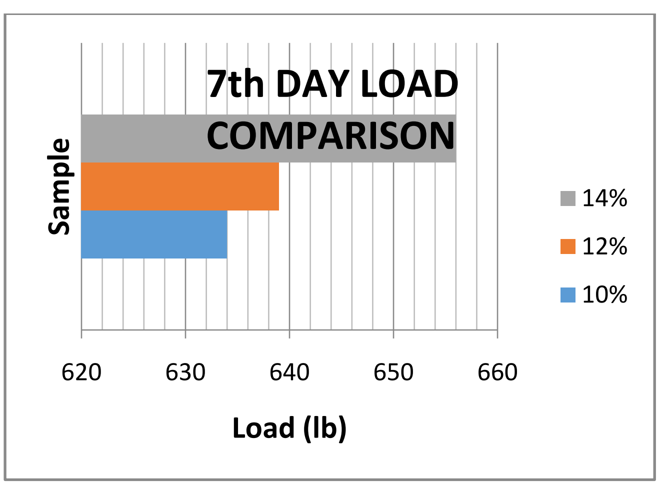
Table 3: Summary of Soil-Cement Block Stabilized with 14% Cement Content

Time (days)	Area(square inch)	Load (lb)	Stress (psi)
7	4	656	164
14	4	812	203
28	4	1119	280

Table 4: Analyze of Load Properties of Soil-Cement Block Stabilized with 10, 12 & 14% Cement Content

Time (days)	Load (lb)		
	Cement Content 10%	Cement Content 12%	Cement Content 14%
7	634	639	656
14	745	784	812
28	900	1047	1119





III. Conclusion

Load bearing capacity of different percentage of cement content in soil-cement is evaluated in this research. Three different percentage 10% 12% and 14% by weight is selected for testing. As the research goal was to find a solution to plastic deformation and shortened service life of flexible pavements, stabilized sub-grade layer provides increased load bearing capacity thus minimizing the damage taken. Generally, the load bearing capacity of Bangladesh varies from 300-500 lb. After stabilizing, the experiment shows that the 7 days load (634 lb) of minimum cement content (10%) is greater than the capacity of conventional practice. Also, the overall maintenance need has been found to be 70,913.82 million taka for the year 2012-2013, 20099.14 million taka for the year 2013-2014, 13322.68 million taka for the year 2014-2015 and 11470.38 million taka for the year 2015-2016 and 10358.24 million taka for the year 2016-2017 (Ministry of communication, Roads and Highways Department, Bangladesh). A large amount of money from a tight budget is spent on the maintenance and thus the author recommends using stabilization to lessen or even mitigate the current crisis. Stabilization with 10% cement content by weight is recommended as it will be cost effective and satisfies general load carrying capacity. Stabilization requires a more detailed and sophisticated verification protocol for which a structured mixture design protocol is included. The mixture design protocol for each stabilizer includes an initial approximation of the appropriate stabilizer content either based on an empirical database or a screening test. This is followed by strength testing where the critical conditions expected in the field are simulated in the laboratory. Since it is normally beyond the scope of stabilizer selection and testing to mimic moisture and environmental variations over the year, a critical condition is normally simulated by partially saturating the sample. The method and degree of this 'moisture conditioning' process is based on experience and varies among design agencies.

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Global Journal of Researches in Engineering (E) Volume XVI Issue IV Version I Year 2016