

Bitumen-cement Stabilized Layer in Pavement Construction Using Indirect Tensile Strength (ITS) Method

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Abstract: In this study, the objective was to blend and mix Portland cement and bitumen emulsion with soil for enhancing the strength, durability and pertinent properties of the soil. In order to enhance the soil strength and lessen its vulnerability to water, soil stabilization is required to be applied to the soil. In line with this, improved load transfer was added to the pavement foundation by having the cement effect which actually boosts the stiffness and Bitumen emulsion effects which improve resilience and soil permeability of the stabilized layer. The current study is divided into two phases. In the first phase, the optimization of Portland cement and bitumen emulsion was performed as well as conducting a series of Indirect Tensile Strength (ITS). Furthermore, in order to lessen the pavement's thickness and to enhance its bearing capacity, alternative roadway sections were scrutinized through the second phase. The results proved that soil stabilization with cement and bitumen enhances the bearing capacity of pavements in two chief areas. Primarily, there was enhancement in pavement's lifetime and the more efficient construction time is achieved.

Keywords: Bearing capacity, bitumen emulsion, indirect tensile strength, Portland cement, soil stabilization

INTRODUCTION

In pavement constructions, soil material is highly required in the road construction industry. Nonetheless, if the road material does not accord with the requisite standards for filling a section of the road with soil, the material will then be supplied either from other cut sections alongside the road or from a borrow site which has the appropriate material (Amu *et al.*, 2011). Exploring novel materials or employing new technological procedures are inevitable nowadays as there is an ever-growing attempt for surging the profits, reasonably lowering financial and material resources as well as being more economical (Mondschein and Valentin, 2007). Thus in stabilization, the chief aim is in enhancing the material performance by improving its strength, stiffness and durability (Sese *et al.*, 2005). By means of chemical and mechanical processes, geomaterials which are in fact soils and rocks need stabilization in construction and maintenance of transportation facilities. When applying these techniques and processes, the properties of stabilized geomaterials and their mixtures should be appropriate for being use in foundation designs, embankments, shoulders, subgrades, bases, as well as the surface courses (Das, 2003). While the vertical

subgrade pressure is significantly decreased by the stabilized layers existing in a pavement, they simultaneously attract the tensile stresses at the bottom of the stabilized layers. Normally for promoting the marginal aggregates' quality, pavement materials must be stabilized. In providing a wearing surface, subsequently, pavements with stabilized layers need to be overlaid with asphaltic materials (George, 1990). It is necessary to be noted that the appropriate quantity of the stabilizing agent and water in the mixture will be determined by the mix design for ascertaining the strength adequacy and stiffness of the layers in order to support the traffic loads (Freeman *et al.*, 2002).

SOIL STABILIZATION

It has been asserted that roadway pavements failure ahead of time was due to their inappropriate design, containing inferior materials, unsuitable construction, environmental conditions, etc (Kearney and Huffman, 1999). For the purpose of enhancing the soils' engineering properties by mechanical or chemical means or both, soil stabilization will be conducted by adding a stabilizing agent to the natural soil deposit. In this process, the additive agent is typically a manufactured commercial product that enhances both

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the soil quality and the soil layer only if it is added in right amounts. Such products include Portland cement, lime, lime-cement, fly ash, bitumen, alone or accompanied with something else (Olawaju *et al.*, 2011). In order to accomplish the binders' properties and enhance load carrying and for the purpose of stressing the distributing characteristics as well as controlling the soil shrinkage and swell, these agents act as potential binders which bind the soil aggregates together efficiently (Farooq *et al.*, 2011). In addition to being a means of pretreatment earlier than the disposal to landfill or treatment of contaminated land, cement is utilized normally as the binder for stabilizing the impure materials (Conner, 1990). Because of the fact that the major reaction i.e. the hydration does not depend on the soil type, cement stabilization can be employed effectively in a variety of soils (Bromhead, 2005). Parsons and Milburn (2003) depicted that for a number of soil types, there exist more than one stabilization choice which can raise effectiveness in the course of building lasting subgrades.

All the required components for cementation are normally incorporated in the cement at the time of cement stabilization. Although the components' hydration occurs when water is added, calcium silicates hydration makes the strong calcium silicate hydrates that subsequently cements the soil or aggregates the particles together. Subgrade properties can be improved by stabilizing soils with cement at reduced cost by either discarding and substituting material or increasing thickness of the base to result in the reduction of subgrade stress (Prusinski and Bhattacharja, 1999). There is a possibility of using bitumen with diverse aggregates and moist aggregates. To disperse the bitumen perfectly in the mix, optimum moisture content is required. The mix's resilient modulus value will be increased by bitumen stabilization over that of the unbound material (Saleh, 2004). By aiming to open the road to traffic rapidly after construction and for preventing or restricting the base layer raveling, emulsion would be primarily included in the pavement layers as it boosts the layer's water-resisting properties and enhances the cohesion on the surface (Liebenberg and Visser, 2003).

MATERIALS AND METHODS

In this section, soil stabilization is presented using Portland cement and bitumen emulsion including the mix design and testing program to determine the best percentage value for cement and emulsion by means of Indirect Tensile Strength (ITS) test which is divided into four stages. Firstly, by making samples through mixing the variation of bitumen emulsion and Portland cement, optimum water and soil aggregates. Secondly, the samples were compacted and cured. The third stage was the Indirect Tensile Strength (ITS) test and finally

Table 1: Characteristic of the soils

Unified classification	Sand	D60 Equivalent	D30 (mm)	D10 (mm)	CC	CU
SW	NP	74	7	1.2	0.15	1.37 47

Table 2: Bitumen characteristics in using bitumen emulsion

Penetration grade	Flash point	Softening point	Penetration at 25°C	Ductility at 25°C	Solubility in CS ₂ (wt)%
60/70	270	47	60	75	99.5
Test Method	D-92	D-36	D-5	D-113	D-4

Table 3: Bitumen emulsion characteristics

Specification	Bitumen 60-70	Water	Emulsifier	Soap ph	Hydrochloric acid
Percentage by weight	60	36.55	1.5	1.75	0.20

Table 4: Gradation of soil

Sieve size and number	mm	Retain (%)	Pass (%)
1 ½ in	38	2	98
1 in	25	6	92
1/2in	12.5	18	74
No.4	4.75	22	52
No.40	0.425	29	23
No.200	0.075	17	6



Fig. 1: Super pave Gyratory Compactor (SGC)



Fig. 2: Super pave gyratory compactor sample

the results were used to draw graphs and determine the best value of the cement and bitumen emulsion. The materials used in this study included soil, Portland cement and bitumen emulsion. Physical properties test was done to ensure the performance of materials. Results are all displayed in Table 1, 2 and 3.

Aggregate gradation: The percentages of aggregates required for each sieve size were determined according to ASTM D 3515-96 that is demonstrated in Table 4.

Table 5: Weight of Portland cement and water

Cement (%)	*Bitumen emulsion (%)	Weight of sample (gr)	Weight of cement (gr)	Optimum water (%)	Weight of bitumen emulsion (gr)	Weight of water (gr)
0	0 to 6	2500	0	3.9	0 to 150	97.5
1	0 to 6	2500	25	3.9	0 to 150	97.5
2	0 to 6	2500	50	3.9	0 to 150	97.5
3	0 to 6	2500	75	3.9	0 to 150	97.5
4	0 to 6	2500	100	3.9	0 to 150	97.5
5	0 to 6	2500	125	3.9	0 to 150	97.5
6	0 to 6	2500	150	3.9	0 to 150	97.5

* Bitumen emulsion was added at different proportion (0% to 6%) for each percentage of cement



Fig. 3: Indirect tensile strength



Fig. 4: Indirect tensile strength

Mixing procedures: Every sample was constructed in the mould which had 15cm diameter and 6.5 cm height. Moreover, the soil particles of every mould in a mixer were soaked with optimum water, Portland cement and bitumen emulsion. They were compacted with Superpave Gyrotory Compactor (Fig. 1). Samples should be compacted as close to 98% Gmm as possible (Fig. 2). Obtained volumetric properties were considered according to ASTM D1074-02. Samples needed curing for 7 days and 28 days. The compacted samples were kept in moulds at ambient temperature for 24 h. They were covered with plastic bags at the temperature of 20°C for 5 days with relative humidity of 95%. Subsequently, we reserved them before testing in a refrigerator with temperature of 5°C for a day. When curing occurred, the Indirect Tensile Strength of each sample was determined. The percentages and the weight of the material are shown in Table 5.

Indirect Tensile Strength (ITS): Diametrically, we loaded a cylindrical specimen across the circular cross section. A tensile deformation will be resulted from the loading upright to the loading direction resulting in a tensile failure (Fig. 3 and 4). We recorded the ultimate load and the dimensions of the specimen; subsequently, the indirect tensile strength of the material was calculated via the following formula:

$$ITS = \frac{2P}{\pi \times d \times h} \times 10000$$

where,

ITS = Indirect tensile strength, KPa

P = Maximum load, KN

h = The average height of the specimen, cm, mm

d = The diameter of the specimen, cm

ITS-Bitumen Emulsion (7 days): Figure 5 displays the ITS values versus various percentage of the cement and bitumen emulsion varying from 0% to 6% after 7 days. It can be observed that the ITS values will grow if bitumen emulsion increases to almost 4%, while more than 4%, this values decreased for various percentages of bitumen emulsion. Considering the standards of ASTM D4867 which affirm that the acceptable value of ITS is 700 Kpa (100psi), consequently 4% is the best result for cement. Based on the abovementioned explanations, it can be concluded that the value of 4% has the best result for Portland cement and bitumen emulsion in the ITS test.

ITS-bitumen emulsion (28 days): Figure 6 exhibits the ITS values versus various percentage of the cement and bitumen emulsion varying from 0% to 6% after 28 days. Accordingly, by increasing bitumen emulsion to almost 4%, the ITS values increase for all the cement values from 0% to 6%. However, there will be a decrease in the ITS values for a variety of cement values as the bitumen emulsion increases more than 4%. Nonetheless, increasing the cement content to achieve a higher strength will increase the possibility of reflection cracking. Consequently, the pavement designer must seek a balance between

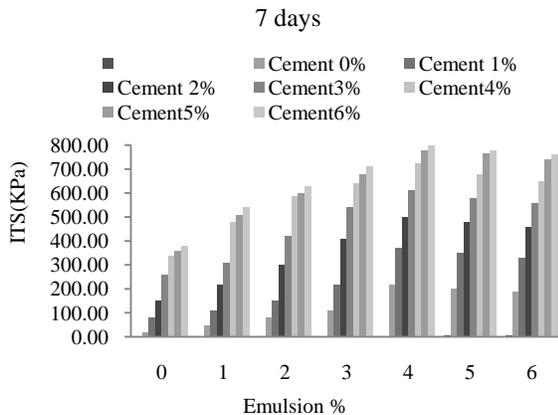


Fig. 5: ITS (7 days)

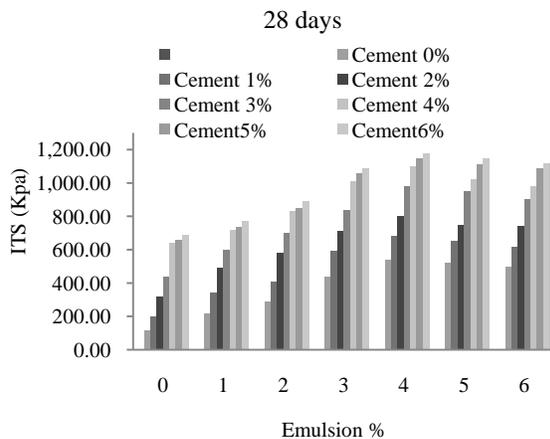


Fig. 6: ITS (28 days)

these two conflicting factors. As a result, 4% has the best result for Portland cement and bitumen emulsion in the ITS test.

DISCUSSION AND CONCLUSION

The stabilization of pavement materials can be regarded as a practically simple process. Furthermore, the poor materials properties can be considerably improved by employing superior construction techniques. It is known that the stabilizer amount needed to be used with a material must be established in the laboratory. Besides, for ascertaining that similar strengths will be obtained in the road, there should be adequate construction supervision and quality control. In this method, cement boosts the resistance and strength while the bitumen emulsion causes resilience in the pavement layer. Most importantly, by increasing the amount of each of the

above mentioned, the other role will be diminished. Therefore, the results of this study revealed that 4% for the bitumen emulsion and cement has the best result in terms of increasing the strength; stiffness, resilience and decrease the soil permeability index according to the ITS test conducted. The results of these tests series which were observed visually and by measurement revealed that the bearing capacity of the pavement was enhanced efficiently by the roles of the cement and bitumen emulsion in mixtures. As opposed to the conventional variant, there was a decline in the entirety roadway layers in the second variant. In effect, such a phenomenon can affect the construction time period.

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REFERENCES

- Amu, O.O., O.F. Bamisaye and I.A. Komolafe, 2011. The suitability and lime stabilization requirement of some lateritic soil samples as pavemen. *Int. J. Pure Appl. Sci. Technol.*, 2(1): 29-46.
- Bromhead, E., 2005. Soil mechanics: Concepts and applications. *Quart. J. Eng. Geol. Hydrogeol.*, 38(4): 401-401.
- Conner, J.R., 1990. Chemical Fixation and Solidification of Hazardous Wastes. Van Nostrand Reinhold, New York.
- Das, B.M., 2003. Chemical and mechanical stabilization. Transportation Research Board.
- Farooq, S.M., M.A. Rouf, S.M.A. Hoque and S.M.A. Ashad, 2011. Effect of lime and curing period on unconfined compressive strength of Gazipur soil, Bangladesh. *Proceeding of 4th Annual Paper Meet and 1st Civil Engineering Congress*. Dhaka, Bangladesh, December 22-24, ISBN: 978-984-33-4363-5.
- Freeman, T.J., D.N. Little, T.D.o.T. Research, T.T. Section and T.T. Institute, 2002. Maintenance Strategies for Pavements with Chemically Stabilized Layers. Texas Transportation Institute, Texas A & M University System. College Station, Tex.
- George, K.P., 1990. Characterization and Structural Design of Cement-treated Base. *Transportation Research Record No. 1288: Geotechnical Engineering*, Transportation Research Board, pp: 78-87.

- Kearney, E.J. and J.E. Huffman, 1999. Full Depth Reclamation Process. Transportation Research Record No. 1684, Transportation Research Board, Washington, DC., pp: 203-209.
- Liebenberg, J.J.E. and A. Visser, 2003. Stabilization and structural design of marginal materials for use in low-volume roads. Proceeding of 8th International Conference on Low-volume Roads. Reno, Nevada, pp: 166-172.
- Mondschein, P. and J. Valentin, 2007. Use of Waste Fillers from Aggregate Production in Road Construction. Financial Support of the Ministry of Education, Youth and Sports of the Czech Republic, Project No. 1M0579, Update, 2, 2.2-3.
- Olarewaju, A., M. Balogun and S. Akinlolu, 2011. Suitability of eggshell stabilized lateritic soil as subgrade material for road construction. *Electron. J. Geotech. Eng. (EJGE)*, ISSN: 1089-3032.
- Parsons, R.L. and J.P. Milburn, 2003. Engineering Performance of Stabilized Soils. Transportation Research Record: Journal of the Transportation Research Board No. 1837, National Research Council, Washington, D.C., pp: 20-29.
- Prusinski, J.R. and S. Bhattacharja, 1999. Effectiveness of Portland cement and lime in stabilizing clay soils. *Transp. Res. Record J. Transp. Res. Board*, 1652(-1): 215-227.
- Saleh, M.F., 2004. New Zealand experience with foam bitumen stabilization. *Transp. Res. Record J. Transp. Res. Board*, 1868(-1): 40-49.
- Sese, J.F., M.J. Oconnell, A.C. De Guzman and J. Rolt, 2005. Stabilized sub-bases for heavily trafficked roads in the Philippines. *J. Eastern Asia Soc. Transp. Stud.*, 6: 1274-1285.