EFFECT OF CATIONIC BITUMEN EMULSION ON SHEAR STRENGTH PARAMETERS OF SOIL

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Abstract

Soil is considered to be most basic construction material that has good shear strength due to the cohesion and internal friction among the soil solid particles. But due to much heavy loads coming from bridges, buildings etc. even soils having good shear strength can fail resulting in subsequent failure of the structures due to differential settlement. Many attempts have been made by numerous scholars in the history to increase the strength of soil by different methods including addition of lime, cement etc. Recent research is being carried to use non-traditional materials like Bitumen Emulsions etc. for improving the properties of soil. Bitumen Emulsions are usually dispersions of minute droplets of bitumen in water i.e. oil in water emulsions and are used to improve the cohesive strength of granular, low cohesion, low plasticity materials. They can also improve the integrity of road base, sub-base or sub-grade materials by resisting the damage caused by water. In this paper, the Direct Shear Test was conducted on soil with varying amount of Cationic Bitumen Emulsion (0%, 2%, 5%, 6% and 7%) to study the effect on Shear Strength parameters of the soil. The maximum shear strength of the soil was observed at 6% Bitumen Emulsion from the laboratory tests performed on the soil i.e. approximately 65% more shear strength by increasing Angle of Internal Friction but reduced Cohesionthan the soil without any Emulsion.

Keywords: *Bitumen Emulsion, Cationic, Shear Strength, Direct Shear Test, Soil Stabilization.*

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1. INTRODUCTION

Soil is the most basic material used in the Civil Engineering since the load form all the structures whether roads, buildings or bridges etc. is eventually taken up by the soil. It is very much difficult for the Geotechnical Engineer to exactly evaluate the various properties of the natural soil deposits and has to rely on soil specimens that are tested in laboratories. The process of improving the soil properties like Shear Strength, Dry Density and Plasticity Index etc. by the mechanical methods or chemical methods is known as Soil Stabilization. In the recent history much development has taken place in the field of Soil Stabilization. Soil Stabilization is essential where there is scarcity of land ortransportation of good soil from borrow pits is not economically feasible. In either case the poor soil needs to be improved by various methods. Lime is one of the most extensively used traditional material for the stabilization of soils but now-a-days many non-traditional methods like addition of bitumen, cement, fly ash etc. and AGSS-ICS (Ionic Stabilization of Clays) are also adopted and extensive research is carried out in this regard. Emulsions are dispersion of small droplets of one liquid in another liquid. Bitumen Emulsion is a two phase system consisting of Bitumen and Water. The Bitumen content can vary from 30% to 70% depending upon the requirements. Bitumen Emulsion is manufactured by shearing the hot bitumen rapidly in water containing emulsifying chemical (emulsifier). Since the density of bitumen is slightly more than water so the sedimentation process is very slow that means even after long storage times emulsions can be regenerated by gentle stirring. Depending upon the type of emulsifier used, the bitumen particles can either get positive or negative charge. Bitumen particles getting negative charge are classified as anionic bitumen emulsion (pH more than 7) and the ones having positive charge are known as cationic bitumen emulsion (pH less than 7). Due care is taken to prevent the mixing of cationic and anionic bitumen emulsion since the electrostatic forces between them can separate the bitumen particles from water resulting in destroying of emulsion. Based on the research done in the field of Soil Stabilization in the past using various materials like fly ash, bagasse ash, crushed glass, coconut coir fiber, lime etc, it was observed that very little research has been done in field of Soil Stabilization by Bitumen Emulsion. Hence an attempt has been made in this paper to study the impact of Bitumen Emulsions on the shear strength of soil.

2. LITERATURE REVIEW

The method to control the soil erosion including fugitive dust was patented by treating the soil with a mixture of polyacrylic acids or polyacrylates, a dibasic acid or acid salt and a wetting agent in water utilizing an aqueous solution of polyacrylate emulsion, sodium citrate an a surfactant, in either diluted or undiluted form (Cargle [1]).There is great difficulty in thorough mixing of different stabilizing agents with the soil to form the homogeneous mass. A trial embankment was constructed successfully by placing the layers of fly ash and expansive soil and operating a “Disc Harrow” (S. Bhuvaneshwari et al. [2]). The fly ash is much used admixture in the soil stabilization as it can cause reduction of 29.57% in the plasticity index of clayey soil and increase of soaked CBR value from 3 to 56% (Dr.

AfafGhaisAbadi Ahmed [3]). Similar studies were also carried out by Vukićević M. et al. [4] that showed the increase in CBR values (appx. 260 to 380%) and reduction in the swell potential of very expansive soils from 8.6% to 3.1% when the expansive soil was mixed with fly ash obtained from thermal power plant "Kolubara".Amit S Kharade et al. [5] have used bagasse ash obtained from sugarcane industry to stabilize the black cotton soil and concluded that significant improvement in the properties (like UCS and CBR values) of black cotton soil was there when 6% bagasse ash was added to the soil. Similarly local soil was stabilized by AshishMurari et al. [6] with the help of bagasse ash and significant reduction in plasticity index was observed. Even some of the research scholars like Patrick KhaoyaBarasa et al. [7] have tried to make collective use of more than one material to stabilize the expansive clays and observed that negligible swelling and maximum value of CBR i.e. 36 had taken place when lime and bagasse ash were combined at the optimum ratio of 4:1. Other materials like Self-Cementing Coal Ash can also increase the CBR value upto 20 times and Unconfined Compression Strength to 12 times the non-treated soil (Scott M. Mackiewicz et al. [8]). Rice Husk Ash and Fly Ash when added in 12% and 25% respectively can strengthen the expansive subgrade soil in terms of UCS and CBR values. Even by the addition of Fly Ash in Clayey Soils permeability can be increased form 1.44×10^{-7} cm/sec to 1.688×10^{-6} cm/sec when mix of clay:63%, sand:27% and flyash:10%(Ravi Kumar Sharma et al. [9]). AmitTiwari et al. [10] have conducted research on stabilization with Fly Ash, Coconut Coir Fiber and Crushed Glass which resulted in optimum combination of 20% Fly Ash, 5% Crushed Glass and 1% Coconut Coir Fiber which resulted in swelling pressure of Black Cotton Soil to $1/10^{th}$. On the similar grounds Gyanen. Takhelmayum et al. [11] tried to find the impact of coarse and fine fly ash on the soil and observed 25% more peak strength with the use of fine fly ash than the coarse fly ash.

3. EXPERIMENTAL SETUP

3.1 Materials

The local soil (shown in Fig-1) was obtained from Amritsar College of Engineering & Technology, 12 km Milestone, Amritsar-Jalandhar G.T Road, Amritsar, Punjab (143001). The properties of the soil are mentioned in Table-1.The details of Cationic Bitumen Emulsionused in the study are mentioned in Table-2.

Table-1: Properties of Soil

Parameter	Value
Bulk Density (γ) g/cc	1.4
Optimum Moisture Content (OMC)	12%
Max. Dry Density (MDD) g/cc	1.94
Specific Gravity (G_s)	2.65
Fines Fraction	0.98
Coarse Fraction	0.02
IS Classification	SW-MI

Table-2: Details of Cationic Bitumen Emulsion

Name of the Company	Shiva Bit
Type	MS
Application	Maintenance
Water Content	50%

Fig-1: Untreated Soil Specimen

3.2 Methodology

The Gradation Test on the collected soil sample was carried out in accordance with IS 2720 (Part 4):1985 [12] to know the details of type of soil. Initially Natural Moisture Content and In-Situ Bulk Density of the soil sample was determined in accordance with IS 2710 (Part 2):1973 [13] and IS 2720 (Part 29):1975 [14] respectively. The Standard Proctor Test was carried out in accordance with IS 2720 (Part 7):1980 [15] to know the Optimum Moisture Content of soil and Maximum Dry Density of soil. After knowing the natural properties of soil, The Direct Shear Test was conducted in accordance with IS 2720 (Part 13):1986 [16] on untreated soil at OMC as well as on mixture of soil and Bitumen Emulsion at different water contents shown in Table-3.Due to presence of presence of 50% water in the emulsion, the quantity of water content is reduced in the mixture with the increasing contents of Bitumen Emulsion.

Table-3: Quantities of Water Content corresponding to different amount of Bitumen emulsions

Bitumen Emulsion	Water Content
0%	12%
2%	11%
5%	10%
6%	9%
7%	8%

Fig-2: Direct Shear Test Apparatus

Fig-3: Soil Sample at failure in Shear Box

4. RESULTS

The results of Shear Stress obtained from different proportions of Bitumen Emulsion at Normal Load of 0.0196, 0.049 and 0.0981N/mm^2 are given in Table-4.

Table-4: Peak Shear Stress (N/mm^2) obtained at different Normal Loads for various Bitumen Emulsion contents

Bitumen Emulsion Content (%)	Normal Load (N/mm^2)		
	0.0196	0.049	0.0981
0	0.2	0.22	0.23
2	0.21	0.24	0.25
5	0.21	0.23	0.24
6	0.18	0.33	0.38
7	0.22	0.25	0.30

The different graphs between Shear Stress and Normal Load are shown in Charts 1 to 5 for Table 4 to determine the values of Effective Cohesion 'c' and Angle of Internal Friction 'φ' from the Equation $\boldsymbol{\tau = c + \sigma\, tan\varphi}$ given by Coulomb (1776) [17] where 'τ' is Shear Strength and 'σ' is Effective Stress (Normal Load per unit area). The angle of line on graph with the horizontal gives the value of 'φ' and y-intercept of graph gives the value of cohesion 'c'.

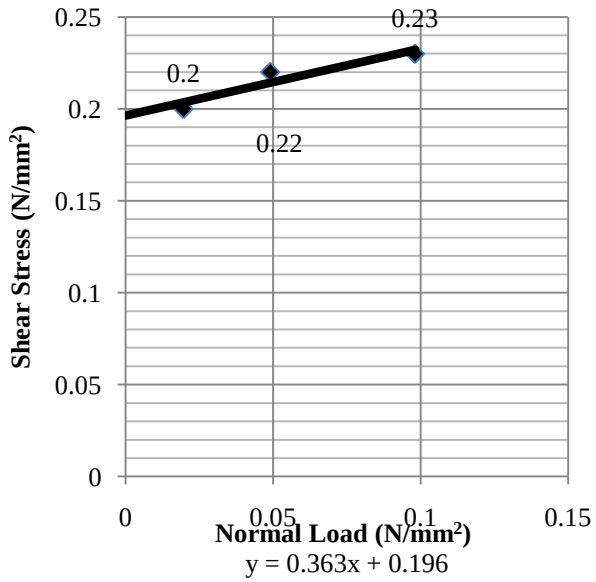


Chart-1: Shear Stress vs Normal Load at 2% Bitumen Emulsion

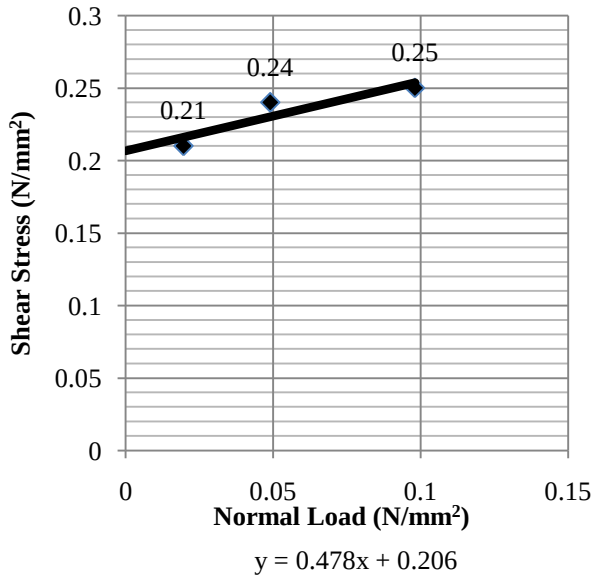
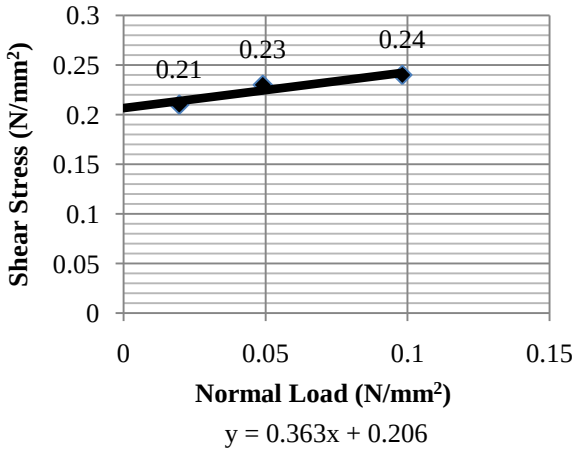
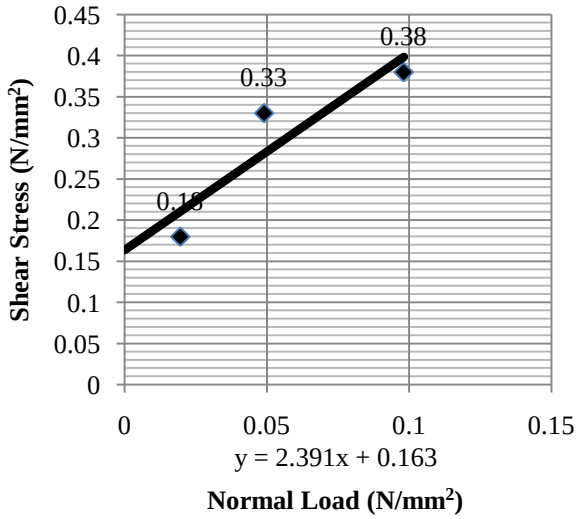


Chart-2: Shear Stress vs Normal Load at 2% Bitumen Emulsion



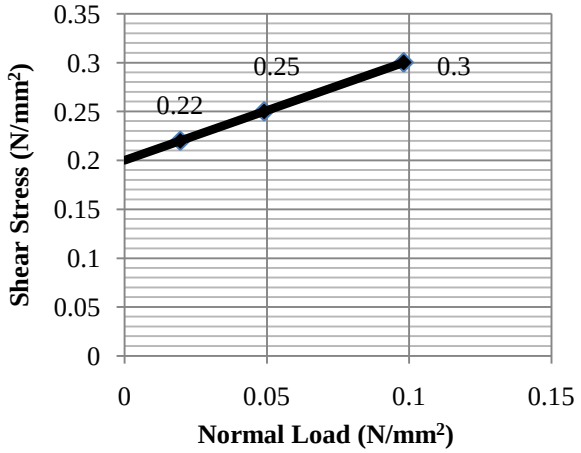
y = 0.363x + 0.206

Chart-3: Shear Stress vs Normal Load at 5% Bitumen Emulsion



y = 2.391x + 0.163

Chart-4: Shear Stress vs Normal Load at 6% Bitumen Emulsion



y = 1.019x + 0.2

Chart-5: Shear Stress vs Normal Load at 7% Bitumen Emulsion

The observations of cohesion 'c' in N/mm^2 and Angle of Internal Friction 'φ' are recorded in Table-5.

Table-5: Values of 'c' and 'φ' corresponding to different contents of Bitumen Emulsion

S.No.	Bitumen Emulsion content	Cohesion Value 'c' (N/mm^2)	Angle of Internal Friction 'φ'
1	0%	0.1964	19.996^o
2	2%	0.2068	25.557^o
3	5%	0.2064	19.996^o
4	6%	0.1638	67.304^o
5	7%	0.2	47.959^o

Charts 6 and 7 show the values of cohesion at different Bitumen Emulsion content and Angle of Internal Friction at different Bitumen Emulsion content respectively.

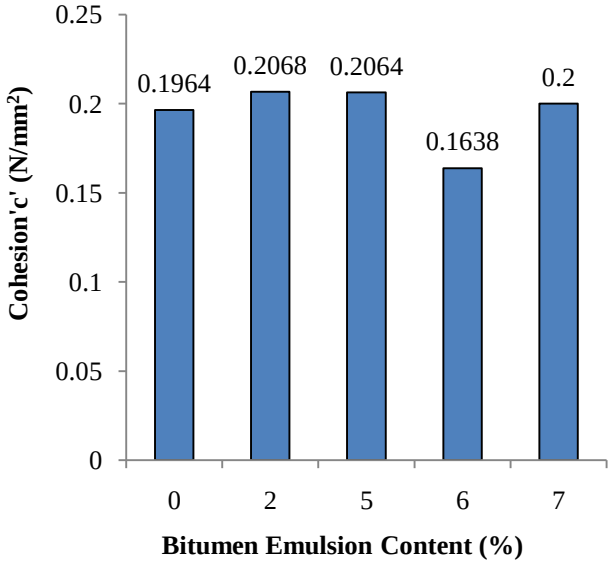


Chart-6: Cohesion 'c' vs Bitumen Emulsion Content graph

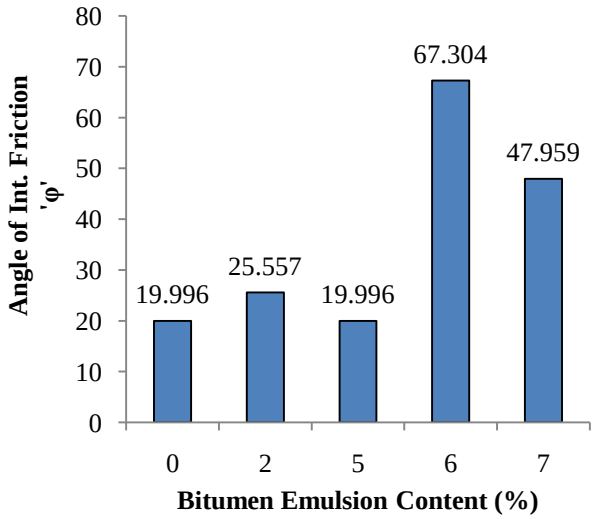


Chart-7: Angle of Internal Friction 'φ' vs Bitumen Emulsion Content graph

5. CONCLUSION

From the experiments carried out on the soil sample to study the effect of Bitumen Emulsion on Shear Strength parameters using Direct Shear Test, the following points are observed:

1. At 6% Bitumen Emulsion, the cohesion between soil particles was reduced to 0.1638 N/mm^2 but at the same time angle of Internal Friction 'φ' was drastically increased to 67.304^o resulting in appx. 65% increase in Shear Strength of soil due to sticking property of Bitumen particles that binds the soil particles resulting in increased friction among soil particles.
2. The Optimum Mix containing 9% Water and 6% ShivaBit Bitumen Emulsion gives the maximum Shear Strength of soil equal to 0.38 N/mm^2.
3. The cost of Bitumen Emulsion is more than various traditional materials used for the Soil Stabilization but it can be used in places having very poor soil due to its Shear Strength enhancing property.

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REFERENCES

[1] Virgil H. Cargle, "Method for Soil Stabilization And Fugitive Dust Control" US Patent No. 4,592,931, June 3, 1986.

[2] S. Bhuvaneshwari, R.G. Robinson, S.R. Gandhi, "Stabilization of Expansive Soils Using Flyash" Flyash Utilization Programme, TIFAC, DST, New Delhi VIII 5.1 to 5.10, 2005

[3] Dr. AfafGhaisAbadi Ahmed, "Flyash Utilization in Soil Stabilization", in Proc. of Int. Conf. on Civil, Biological and Environmental Engineering (CBEE), Istanbul, Turkey, pp. 76 – 78,May2014

[4] Vukićević M., Maraš-Dragojević S., Jocković S., Marjanović M., Pujević V, "Research Results of Fine-Grained Soil Stabilization Using Fly Ash from SerbianElectric Power Plants", in Proc. of Int. Conf. on Soil Mechanics and Geotechnical Engineering, Paris, pp. 3267-3270, 2013

[5] Amit S. Kharade, Vishal V. Suryavanshi, Bhikaji S. Gujar, Rohankit R. Deshmukh, "WASTE PRODUCT 'BAGASSE ASH' FROM SUGAR INDUSTRY CAN BEUSED AS STABILIZING MATERIAL FOR EXPANSIVE SOILS", International Journal of Research in Engineering and Technology, vol. 3, pp. 506-512, March 2014

[6] AshishMurari, Istuti Singh, NamanAgarwal, Ajit Kumar, "Stabilization of Local Soil with Bagasse Ash", SSRG-International Journal of Civil Engineering-EFES, pp. 37-39, April 2015

[7] Patrick KhaoyaBarasa, Dr. Too, Kiptanui Jonah, S. M. Mulei, "Stabilization of Expansive Clay Using Lime andSugarcane Bagasse Ash", International Journal of Science and Research, vol. 4, pp. 2112-2117, April 2015

[8] Scott M. Mackiewicz, E. Glen Ferguson, "Stabilization of Soil with Self-Cementing Coal Ashes", World of Coal Ash (WOCA), Lexington, Kentucky, USA, pp. 1-7, April 2005

[9] Ravi Kumar Sharma, Babita Singh, "MODIFICATION OF CLAYEY SOIL USING FLY ASH", International Journal of Research in Engineering and Technology, vol. 2, pp. 356-361, Oct. 2013

[10] AmitTiwari, H. K. Mahiyar, "Experimental Study on Stablization of Black Cotton Soil by Fly Ash, Coconut Coir Fiber & Crushed Glass", International Journal of Emerging Technology and Advanced Engineering, vol. 4, pp. 330-333, Nov. 2014

[11] Gyanen. Takhelmayum, Savitha.A.L, Krishna Gudi, "Laboratory Study on Soil Stabilization Using Fly ash Mixtures", International Journal of Engineering Science and Innovative Technology, vol. 2, pp. 477-482, Jan. 2013

[12] IS 2720(Part 4):1985 Methods of test for soils: Part 4 "Grain size analysis" May 2010 (second revision)

[13] IS 2720(Part 2):1973 Methods of test for soils: Part 2 "Determination of water content" May 2010 (second revision)

[14] IS 2720(Part 29):1975 Methods of test for soils: Part 29 Determination of dry density" May 2010 of soils in-place, by the core-cutter method (first revision)

[15] IS 2720(Part 7):1980 Methods of test for soils: Part 7 "Determination of water content-" Dec. 2011 dry density relation using light compaction (second revision)

[16] IS 2720(Part 13):1986 Methods of test for soils: Part 13 "Direct shear test" Dec. 2011(second revision)

[17] Dr. K.R. Arora, Soil Mechanics and Foundation Engineering, Delhi, India, Standard Publishers Distributors, pp. 306-356, 2011

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