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Research Paper

BEARING RATIO OF CLAYEY SUBGRADE UNDERLYING COMPACTED FLYASH LAYER AND GEOTEXTILE AT INTERFACE

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This paper presents a laboratory study on California Bearing Ratio (CBR) of flyash overlying a soft clay bed with geotextile at interface. Flyash sample (Class F) has been collected from Titagarh Thermal Power Plant situated near Kolkata. The type of soil collected locally is silty clay. Different thickness ratios (ratio of thickness of flyash to that of clay) has been maintained at 1:2, 1:1 and 2:1. Both Standard Proctor and Modified Proctor compaction tests have been carried out to obtain respective maximum dry density and optimum moisture content. The water contents of clayey soil used in this study are 16%, 22%, 28%, 34% and 40% where 16% is the Optimum Moisture Content (OMC) of the soil corresponding to standard Proctor compaction. Similarly water content of the soil has been kept at 12%, 18%, 24%, 30%, 36% and 42% in case of Modified Proctor energy where 12% is the corresponding optimum moisture content of soil. Improvement of CBR values has been observed with compacted flyash layer placed over the compacted soil with woven geotextile at interface. The bearing ratio increases as the thickness ratio increases and it becomes maximum when the ratio is 2:1. The improvement factor (ratio of CBR of composite matrix to that of original soil) is found to be maximum for highest moulding water content irrespective of thickness ratio, placement of geotextile and compaction energy indicating use of flyash soil composite matrix with geotextile at interface under worse affected condition of high water content. The paper highlights the nature of improvement of clayey soil when compacted flyash layer has been placed on it with different values of thickness ratio and moulding water content and compaction energy where geotextile has been placed at interface.

Keywords: CBR, Flyash layer, Soft clay, Geotextile

INTRODUCTION

A good quality road network reflects a country's social and economic growth. A road capable of carrying higher traffic volume requires a sufficiently strong sub-grade. In case the subgrade soil is of poor quality, the methodology

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that can be adopted to improve subgrade strength is by replacing the top part of the soil with compacted flyash. It is to be noted that in this case the use of flyash plays dual role to minimize today's global disposal problem related to flyash as well as increases the sub-grade strength.

Sahu (2001) investigated the improvement of different types of soils such as silty sand, black cotton soil, silty soils by adding fly ash alone and observed that addition of fly ash increased the CBR values of all the soils. The gain was found to be maximum for silty sand and minimum for black cotton soil with silty soils falling in between. In general higher the plasticity index, lower is the gain in CBR.

Shenbaga *et al.* (2003) studied Geotechnical behaviour of fly ash mixed with randomly oriented fiber inclusions and observed that the fiber inclusions increased the strength of raw fly ash specimens and changed their brittle behaviour into ductile behaviour.

Ghosh and Subbarao (2007) conducted laboratory tests to study the shear strength characteristics of a low lime class F flyash modified with lime alone or in combination with gypsum. Unconfined compressive strength tests were conducted for both unsoaked and soaked specimens cured up to 90 days. After testing they observed from the results that addition of a small percentage of gypsum in the range of 0.5 and 1.0% along with lime content of 4-10% enhanced the shear strength of modified flyash within short curing periods of 7 and 28 days.

Ghosh and Dey (2009) conducted laboratory study on bearing ratio of reinforced flyash overlying soft soil and observed that bearing ratio (CBR) changed with the type of flyash, geotextile reinforcement, position and number of geotextile layer.

Geliga and Ismail (2010) studied the suitability of the local flyash for use in the local construction industry to minimize the amount of waste to be disposed of the environment. They conducted several laboratory tests to study the geotechnical properties of flyash and observed improvement of strength when flyash was mixed with local clay sample.

Bera (2010) studied the effect of pond ash content on engineering properties of fine grained soil through a series of laboratory tests. From the experimental results it was found that with increase in percentage of pond ash while mixing with the fine grained soil, the values of plasticity index of soil pond ash mixture decreased rapidly with increase in percentage of pond ash. It was also observed that the California bearing ratio increased significantly with addition of pond ash with fine grained soil.

Adhana *et al.* (2011) worked on Reinforced Fly Ash Slope using different Geosynthetics. They carried out model tests and numerical study without and with reinforcement along steep slopes made of fly ash resting on soft foundation to check the stability of steep slope. It has been observed from their study that the use of fly ash can be suitable for the construction of infrastructure like embankments, reinforced soil walls and slopes.

Dindorkar and Shrivastava (2012) studied the characteristics of low lime flyash stabilized with lime and gypsum and observed the effect, reasons and advantages for improvement in properties of flyash stabilised with different percentages of lime and gypsum for reduction of solid waste and effective utilisation of flyash.

It appears from the past studies that effect of flyash layer placed on soft clay sub-grade with and without geotextile layer placed at the interface of soil and flyash beds has not been well addressed in available literature for practical use. However it is reported by Ghosh and Dey (2009) that some improvement occurred in case of soft clay sub-grade by placement of compacted flyash layer on it.

Therefore with this in view an attempt has been made to carry out the present study to examine the effect of thickness ratio (ratio of thickness of flyash to that of clay), compaction energy and placement moisture content of clay on CBR of soil-flyash composite matrix with geotextile at the interface.

MATERIALS USED

Three types of materials have been used for the present study-soil, Flyash and Geotextile. Their details are furnished below:

Soil

Locally available soil (silty clay) has been used, in this study-and this has been collected from a marshy land situated at Anandapuri, Barrackpore, and West Bengal, India. The following tables (Tables 1 and 2) present the properties of soil. Samples in triplicate have been tested to arrive

Figure 1: Particle Size Distribution Curve of Soil

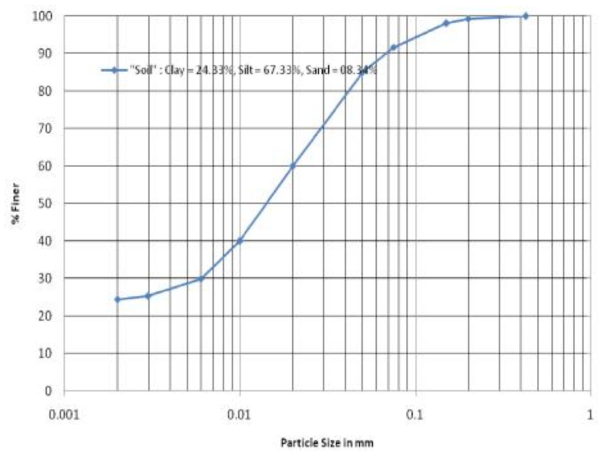


Figure 2: Standrad and Modified Proctor Compaction Curve for Soil

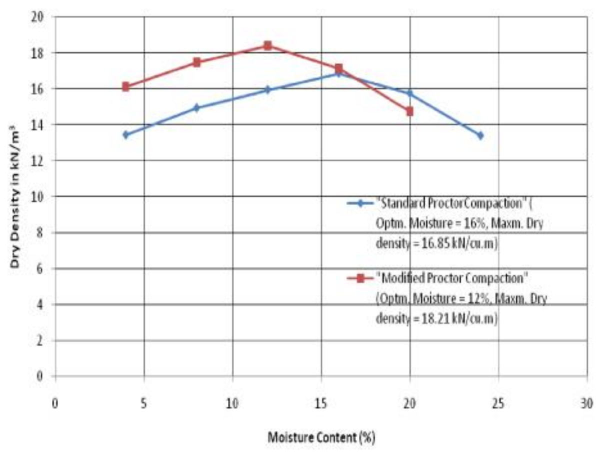


Table 1: Properties of Soil

Sp. Gravity (G)	Grain Size			Atterberg Limits			Compaction			
	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	SL (%)	Standard Proctor Compaction		Modified Proctor Compaction	
							OMC (%)	MDD (kN/m^3)	OMC (%)	MDD (kN/m^3)
2.54	8.34	67.33	24.33	41.2	24.16	18.45	16	16.88	12	18.21

Table 2: Values of Cohesion (kPa) of Compacted Soil at Different Moulding Water Content

Standard Proctor Compaction				Modified Proctor Compaction			
(OMC-6%)	(OMC)	(OMC+6%)	(OMC+12%)	(OMC-6%)	(OMC)	(OMC+6%)	(OMC+12%)
5.52	6.75	2.23	1.12	14.42	19.32	6.29	2.3

at the average value for each property. Figure 1 and 2 furnish grain size distribution, Standard and Modified compaction curves for soil.

Fly Ash

Flyash sample used in the present study has been collected from Titagarh Thermal Power Plant situated in West Bengal, India. Pond ash has been collected for this present investigation. The following tables (Tables 3 and 4) present the properties and composition of flyash. Three samples have been tested to arrive at the average value for each property. Figures 3 and 4 present grain size distribution, Standard and Modified compaction curves for soil.

Geotextile

Commercially available 100% polypropylene high strength fibre woven fabric has been used in the experiment as reinforcement material. Table 5 presents the properties of geotextile.

TEST PROGRAMME

For finding the key factors on bearing ratio of compacted flyash overlying soil with geotextile at interface and for finding the strength of flyash samples, different laboratory tests have been

Figure 3: Particle Size Distribution Curve of Fly Ash

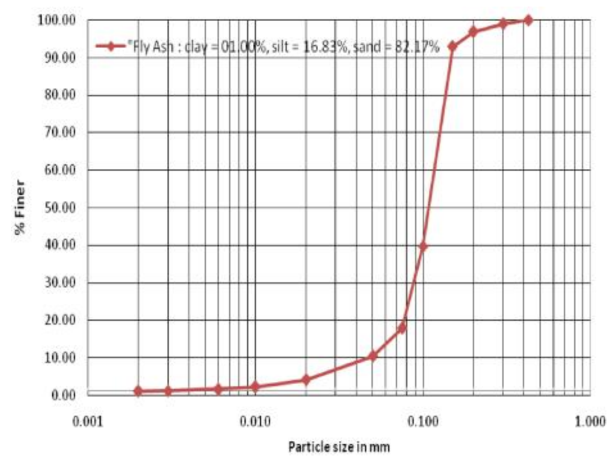


Figure 4: Standard and Modified Proctor Compaction Curves for Fly Ash

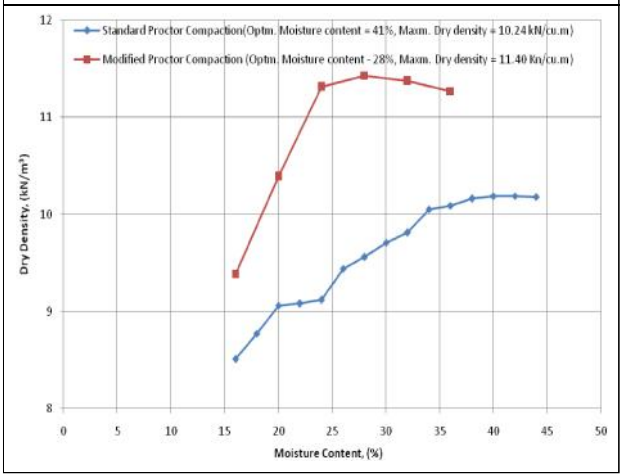


Table 3: Properties of Flyash

Sp. Gravity (G)	Grain Size Analysis			Standard Proctor Compaction Test		Modified Proctor Compaction Test		*C_u	**C_c	Direct Shear Test			
										Standard Proctor Compaction		Modified Proctor Compaction	
										#c (kPa)	##Φ (Deg.)	#c (kPa)	##Φ (Deg.)
	Sand (%)	Silt (%)	Clay (%)	OMC (%)	MDD (kN/m^3)	OMC (%)	MDD (kN/m^3)						
2.11	82.17	16.83	1	41	10.24	28	11.4	2.22	4.54	-	39	-	41

Note: *C_u = Uniformity Coefficient; **C_C = Coefficient of Curvature; #C = Cohesion; ## Φ = Angle of internal friction.

Table 4: Composition of Flyash

Composition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Mn_3O_4	P_2O_5	SO_3	Na_2O	K_2O
Percentage	61.8	22.82	8.4	1.6	1.48	0.9	0.156	0.657	0.357	0.245	1.355

Table 5: Properties of Geotextile

Thickness (mm)	Mass per Unit Area (gsm)	Apparent Opening Size (mm)	Tensile Strength at 5% Strain (kN/m)	Tensile Strength at 10% Strain (kN/m)	CBR Puncture Strength (kN)	CBR Push-Through Displacement (mm)
1.5	450	0.35	35	75	10	25

Table 6: CBR Test Programme of Flyash Soil Composite Matrix with Geotextile at Interface Using Standard Proctor and Modified Proctor Energy

S. No.	Ht. of Flyash (h_f) (mm)	Ht. of Soil (h_s) (mm)	Flyash: Soil (h_f/h_s)	*Moulding Water Content of Soil (%)	
				Standard Proctor Energy	Modified Proctor Energy
1	84	43	2:01	16	12
2	63.5	63.5	1:01	16	12
3	43	84	1:02	16	12
4	84	43	2:01	22	18
5	63.5	63.5	1:01	22	18
6	43	84	1:02	22	18
7	84	43	2:01	28	24
8	63.5	63.5	1:01	28	24
9	43	84	1:02	28	24
10	84	43	2:01	34	30
11	63.5	63.5	1:01	34	30
12	43	84	1:02	34	30
13	84	43	2:01	40	36
14	63.5	63.5	1:01	40	36
15	43	84	1:02	40	36

Note: *Moulding Water Content (MWC) of flyash has been kept same (41%).

conducted according to the test programme presented in Tables 6. The tests have been conducted on fly ash soil matrix with different thickness ratios, such as 2:1, 1:1 and 1:2 and maintaining moisture content of flyash at its optimum (obtained from relevant Proctor compaction tests) and by increasing moisture content of clay from OMC towards its liquid limit. The thickness ratios as mentioned above have been chosen considering the limited dimensions of CBR mould.

Total thirty (30) numbers of tests, 15 numbers with Standard Proctor compaction energy and 15 numbers with modified Proctor compaction energy, have been conducted varying different parameters. Each test has been repeated three times to observe the repeatability. When the results varied within ±0.5%, and average values have been taken for each test.

METHODOLOGY

The following tests were conducted during the present study:

Tests performed on clay are as follows:

- Standard and Modified Proctor compaction test b) CBR test and c) Unconfined Compressive strength (UCS) test.

Tests performed on flyash are as follows:

- CBR Test b) Direct Shear Test

Tests performed on geotextile are as follows:

a) Thickness, b) Mass per unit area, c) Apparent opening size, d) Tensile strength, e) CBR Puncture Strength, f) CBR Push through Displacement.

All the tests mentioned above have been carried out following relevant IS and ASTM codes.

RESULTS

The experimental results, presented in this section, are as follows:

Tables 7 and 8 present the CBR values of soil and flyash individually, at different moulding water contents for standard and modified Proctor compaction energy respectively.

Table 7: Soaked CBR Values (%) of Fly Ash and Soil (for Standard Proctor Compaction Energy)

Type	Depth (mm)	Moulding Water Content (MWC) in %				
		16	22	28	34	40
Soil	127	3.24	1.32	0.39	0.24	-
Flyash	127	-	-	-	-	20.1

Table 8: Soaked CBR Values (%) of Fly Ash and Soil (for Modified Proctor Compaction Energy)

Type	Depth (mm)	Thickness Ratio (Flyash: Soil)	Moulding Water Content (MWC) in %				
			12	18	24	28	30
Soil	127	-	3.87	3.11	0.51	-	0.22
Flyash	127	-	-	-	-	25.93	-

Table 9: Soaked CBR Values (%) of Fly Ash Soil Composite Matrix with Geotextile at Interface (for Standard Proctor Compaction Energy)

Type	Depth of Flyash (mm)	Depth of Soil (mm)	Thickness Ratio (Flyash: Soil)	Moulding Water Content (MWC) in %			
				16	22	28	34
F.A	84	43	2:01	18.01	15.23	10.53	10.53
+	63.5	63.5	1:01	14.09	14.21	6.2	6.2
Soil	43	84	1:02	11.77	4.11	3	3

Table 10: Soaked CBR Values (%) of Fly Ash Soil Composite Matrix with Geotextile at Interface (for Modified Proctor Compaction Energy)

Type	Depth of Flyash (mm)	Depth of Soil (mm)	Thickness Ratio (Flyash: Soil)	Moulding Water Content (MWC)in %				
				12	18	24	30	36
F.A	84	43	2:01	30.71	23.58	13.1	9.03	8.25
+	63.5	63.5	1:01	25.9	12.56	6.13	4.61	2.84
Soil	43	84	1:02	23.48	5.89	2.86	2.01	1.46

Tables 9 and 10 present CBR values of reinforced soil flyash composite matrix with different moulding water contents and thickness ratios for standard and modified Proctor compaction energy respectively.

DISCUSSION

Based on the experimental results presented in this paper an attempt has been made to highlight the effects of bearing ratio of reinforced composite flyash-soil system due to (i) the thickness ratio, (ii) the moulding moisture content of soil, and (iii) compaction energy-standard and modified.

An attempt has also been made to study the improvement of CBR of soil-geotextile-flyash matrix with respect to that of original soil and a term namely “improvement factor” in terms of increase of CBR with respect to that of original soil has been introduced in this respect.

Effect of Thickness Ratio

The variation of CBR with thickness ratio has been plotted in Figure 5 for different moulding water contents. It has been observed from the figure that thickness ratio, defined by ratio of thickness of flyash to that of soil, influences the bearing ratio for both types of compaction energy used in preparing the test samples. From the figure it is inferred that the bearing ratio increases as the thickness ratio of soil-geotextile-flyash matrix increases and it becomes maximum when the ratio is 2:1. Similar trend of variation between thickness ratio and bearing ratio was observed by Ghosh and Dey (2009). This is attributed to the fact that flyash and geotextile are imparting more stiffness to the system. The observations in relation to this aspect shows that the bearing ratio of flyash underlain by clay with geotextile at interface for standard and modified compactions attains a maximum value of 18.01% and 30.71% respectively when the depth of flyash is 84mm (thickness ratio = 2:1). It can therefore be inferred that at this thickness ratio of 2:1 there is an appreciable increase in bearing ratio. It thus implies that if the thickness of flyash is reasonably

Figure 5: Comparison of CBR Values at Different Water Content of Soil

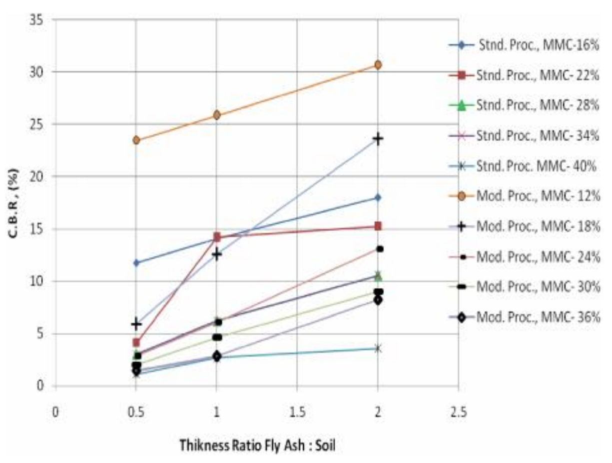
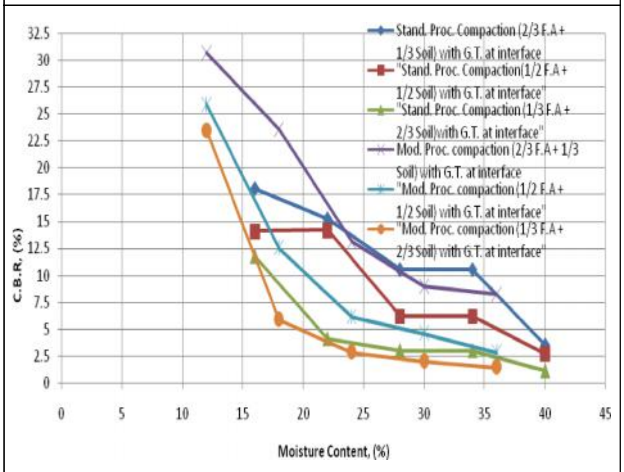


Figure 6: Variation of CBR with Moisture Content



increased in the field with geotextile at interface, the subgrade strength will be appropriate for comparatively lesser pavement thickness leading to a cost effective solution.

Effect of Moulding Water Content of Soil

The effect of moulding water content on bearing ratio has been studied and observed that for flyash underlain by soil with geotextile at interface, the bearing ratio decreases as the moulding water content increases. This is revealed from Tables 9-10 along with Figure 6, which shows the variation of CBR with moulding water content for different values of thickness ratios. It is observed that the bearing ratio is maximum when moulding water content is at about O.M.C. As the moulding water content approaches the liquid limit of soil the bearing ratio decreases noticeably in respect of that corresponding to OMC. The CBR value decreases from 18.01% to 10.53%, for increase in moulding water content from 16% to 34%, for thickness ratio of 2:1 and standard Proctor energy. In case of modified compaction energy the CBR value decreases from 30.71% to 8.25% for the same thickness ratio when the moulding water content changed from 12% to 36%. The observation implies that even at higher moulding water content the soil-geotextile-flyash composite will be helpful to provide an economic solution in pavement construction as at that time also some minimum appreciable CBR value will be possessed by the matrix.

Effect of Compaction Energy

It is observed from Tables 9-10 that CBR of soil-geotextile-flyash matrix increases with increase in compaction energy. It appears that for thickness ratio 2:1 CBR value at OMC increases from 18.01% to 30.71% for increase of compaction energy from standard to modified. This is due to increase of dry density as well as soil strength occurring due to application of more compaction energy. Hence it appears that higher subgrade strength is likely to be achieved with modified compaction energy for the composite matrix.

Improvement Factor

In order to study the improvement of CBR of soil-geotextile-flyash matrix (CBRsgm), with respect to that of original soil (CBRs), an Improvement Factor (IF) has been introduced as ratio of CBR of the composite matrix to that of original soil, expressed as:

$$IF = CBR_{sgm}/CBR_s \qquad ...(1)$$

The variation of improvement factor with thickness ratio for different moulding water contents has been presented in Figures 7-8 presents the variation of improvement factor with ratio of moulding water content (wc) to Liquid Limit (LL) of soil.

It has been observed from Figures 7 and 8, that there is considerable improvement in bearing ratio values for all the tests done by placing flyash over soil with geotextile at interface. The improvement factor is found to be maximum for highest moulding water content used in this study irrespective of thickness ratio and compaction energy. This indicates the effective use of soil-geotextile-flyash matrix under worse affected condition of high water content in the field. It has also been observed that with decrease in thickness of flyash results in reduction of improvement factor.

Figure 7: Variation of Improvement Factor with Thickness Ratio

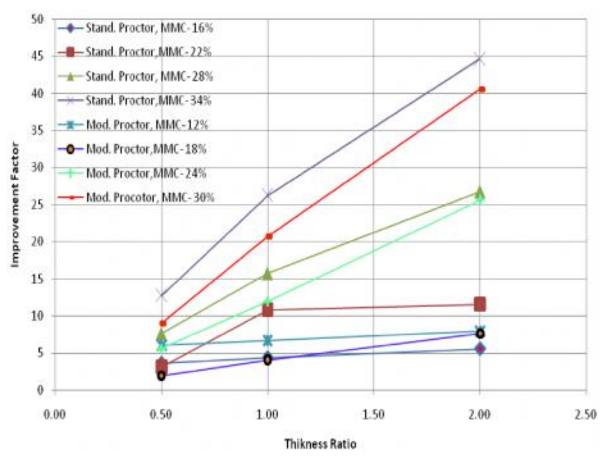
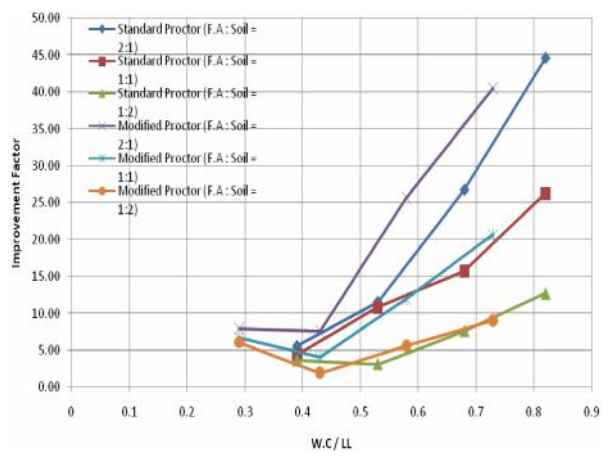


Figure 8: Variation of Improvement Factor with Different WC/LL



CONCLUSION

Based on the results and discussion presented in this paper the following conclusions may be drawn:

- At the thickness ratio of 2:1 there is an appreciable increase in bearing ratio. It thus implies that if the thickness of flyash is reasonably increased in the field with geotextile at interface, the subgrade strength will be appropriate for comparatively lesser pavement thickness leading to a cost effective solution.
- Even at higher moulding water content the soil-geotextile-flyash composite will be helpful to provide an economic solution in pavement construction as at that time also some minimum appreciable CBR value will be possessed by the matrix.
- Higher subgrade strength is likely to occur with modified compaction energy for the composite matrix
- The improvement factor is found to be maximum for highest moulding water content used in this study irrespective of thickness ratio and compaction energy. This indicates the effective use of soil-geotextile-flyash matrix under worse affected condition of high water content in the field. It has also been observed that with decrease in thickness of flyash results in reduction of improvement factor.

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