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NUMERICAL MODELING OF CALIFORNIA BEARING RATIO VALUE OF FIBRE REINFORCED FLY ASH STABILIZED EXPANSIVE SOIL

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ABSTRACT:

Expansive soils causing significant damage to civil engineering structures. It has become a worldwide problem. In United States during 1973, the annual cost of damage was $2.3 billion due to expansive soil movement. A more up-to- date it has reached up to $9 billion annual damages to different structures.

This paper presents experimental study of California bearing ratio values of soil-fly ash mixtures and randomly distributed Nylon fibres. The effect of addition of Nylon Fibres on California bearing ratio values (CBR) is studied. The percentage of HT Nylon 66 Fibres content is considered as 0.25 %, 0.75% and 1.25 % by stabilize soil- fly ash mixtures.

Samples were cured in the laboratory under controlled conditions with optimum moisture content (OMC) and maximum dry density (MDD). The mathematical modelling is done to correlate California bearing ratio values with different parameters. The model is adequately useful to predict the strength.

Adequacy has been tested by conducting different verification experiments on the developed model. It is found that difference of predicted and observed value is lying within 10%.

KEYWORDS: Soil-fly ash, HT Nylon 66 Fibre, California bearing ratio values (CBR), Mathematical modelling

1.0 INTRODUCTION

In India construction of roads demands considerable attention as it contributes the major transportation network. Major issues are being faced by Government agencies maintaining rid able roads both cost wise and time wise, particularly in Central and Western India.

The cause of concern is degradation of pavement surface resting on unsound sub grades comprising of expansive soil stratum containing clay minerals having high affinity for water. Hence, absorbing high amount of water during rainy season accompanied with swelling and shrinking during summer due to moisture loss on account of evaporation. Stabilizing this behaviour of swelling and shrinkage is considered to be essential to reduce volume changes, which could be achieved by altering the plastic content by introducing cementations material.

Fly ash can reduce plasticity of expansive soil as it is a cementation material containing pazzolonic properties. Due to heavier wheel load and heavier traffic level the recent design and construction changes led to the introduction and increased use of stabilized sub grade, sub-base and base courses in flexible pavements.

Reinforcing the soil with HT Nylon 66 fibre is technically as well as economically superior solution to improve the characteristics of sub grade soils. Reinforcing soil increases the stiffness and load carrying capacity by friction between the soil and the fibres.

Hence, reinforcing black cotton soil with fibres is significant in the field of road construction. The random distribution of fibres exhibit advantages while comparing oriented or systematically reinforced soils with fibre reinforced soils. The main advantage of randomly distributed fibres is isotropy and the absence of potential planes in the soils with oriented reinforcement.

This experimental study shows the effectiveness of fly ash and randomly distributed Nylon fibre in providing stable sub grade for the pavement surface. In Mathematical modelling response equations are developed by considering only liner and quadratic effects of % of fibre and fibre length. The MATLAB software is used for appropriate equation formation and coefficient determination.

2.0 LITERATURE REVIEW:

Siva Gowri Prasad S.(2014) showed characteristics of the soil subgrade is very responsive for performance of a pavement. Samples of fly ash are organized with and without Geotextile layers compacted to its MDD and OMC in the CBR mould. Geotextile sheets of same dimensions of CBR mould are placed in distinct preparations of 1st to 4th layers at different locations in the CBR mould.

The CBR value of 4.0% is obtained when the geotextile is placed at all four layers which is an increment of

158.0% compared to the unmodified soil.

Girija K.M. (2013) observed behaviour of randomly distributed fibre with locally available C-Ø soil (SM) and polypropylene fibres with the same aspect ratio (l/d). CBR tests, direct shear tests and unconfined compression tests were conducted on reinforced as well as un-reinforced soil samples to investigate the strength characteristics.

The test results show that the presence of fibres in soil increases the CBR value, UCS and Shear strength of soil. It is found that the optimum fibre content is approximately 0.4% to 0.6% of the dry weight of the soil.

Lakshmi Keshav (2012) studied the effect of fly ash on an expansive soil for flexible pavement design. Decrease in liquid limit, plasticity and swelling index increases CBR value 1.64 times and considerable saving in cost of road construction.

Sridevi G and Sreerama Rao A, 2014 attributed heaving, cracking and the brakeup of road pavement to volume changes in expansive soils due to variation in moisture content. Overall performance of pavement is considered to be function of volume stability, unconfined compression strength and soaked CBR value.

Xu Jiawenaet (2005), have calculated results of the model were in line with the experimental results. The model presented will be helpful for the analysis process and presented numerically controlled electrochemical contour evolution machining process using rotary tool. The modeling method, geometric model and its numerical solution, regarding this process has also been introduced.

K. L. SenthilKumar,R. Sivasubramanian (2011), have performed the experiments on stir- casted A356/SiCp metal matrix composite using electrochemical machining. A multilayer artificial neural network with back-propagation technique was also employed to model the experimental data.

A comparison made between predicted values and experimental values revealed that there was close matching with correlation coefficient of 0.995 and an average prediction error of 6.48%.

3.0 MATERIALS AND METHODS:

3.1 EXPANSIVE SOIL:

Expansive soil is the material which exhibits swell & shrink under alternate wetting and drying situation, the samples exhibiting these volume change characteristics are identified from the field particularly by observing the width, depth and pattern of the cracks at the field.

The samples taken from Shri Shivaji Agriculture College Nagpur Road and Rahatgaon Amravati were then transported to the testing laboratory.

Table 3.1- Results from Series of Conventional Laboratory Tests

Sr. No.	Properties	Unit	Value
1	Specific Gravity, G	-	2.67
2	Grain Size Analysis		
i)	Sand	%	9
ii)	Silt	%	19
iii)	Clay	%	72
3	Atterberg's Consistency Limits		
i)	Liquid Limit, WL	%	72.46
ii)	Plastic Limit, WP	%	32.55
iii)	Plasticity Index, PI	%	39.91
iv)	Shrinkage Limit, SL	%	10.00
4	Compaction Properties		
i)	Maximum Dry Density, MDD	kN/m^3	15.00
ii)	Optimum Moisture Content, OMC	%	27.00
5	Penetration Resistance Strength		
i)	CBR(Soaked)	%	1.70
ii)	CBR(Unsoaked)	%	4.81

3.2 FLY ASH:

Fly Ash is silt –size non cohesive material which has less specific gravity than the normal soils. The samples are taken from the Thermal power station at Koradi, near Nagpur. The fly ash was white in colour and there was a little amount of moisture content. The chemical & Physical properties of Fly Ash used are given in Table 3.2 & 3.3

Table 3.2- Chemical Properties of Fly Ash

Sr. No.	Chemical constituents	Unit	Value
1	Silica	%	40.18
2	Iron oxide	%	6.48
3	Calcium oxide	%	1.23
4	Titanium oxide	%	0.04
5	Potassium oxide	%	0.18
6	Magnesium oxide	%	0.14
7	Phosphorous	%	0.19
8	Sulphur trioxide	%	0.04
9	Disodium oxide	%	0.05
10	Aluminium	%	1.42
11	Manganese	%	0.02
12	Chloride	mg/kg	194

Table 3.3- Physical Properties of Fly Ash

Sr. No.	Physical constituents	Unit	Value
1	Specific Gravity, G		2.00
2	Liquid Limit, WL	%	28.00
3	Plastic Limit, WP	%	Non
4	Maximum Dry Density	kN/	13.24
5	Optimum Moisture Content	%	24.00
6	Color		Grey
7	Gravel		Nil
8	Sand	%	25.00

3.3 HT NYLON 66 FIBRE:

HT Nylon 66 Fibre HT Nylon 66 Fibre is the material which on inclusions increased the strength of the fly ash specimens and changed their brittle behaviour into ductile behaviour. The physical properties of Fibres are given in Table 3.4.

Table 3.4- Physical Properties of Fibre

Properties	Unit	Value
Specific Gravity		1.14
Density	Kg/m^3	1140
Water Absorption	%	1.30
Melting Point	0^0C	260
Elongation	%	15-28
Tensile Strength	MPa	41
Modulus of Elasticity	Pa	445.70

3.4 MIX PROPORTIONS:

Mix Proportions Expansive Soil is taken as 5 to 50% with 5% of increment of fly ash by dry unit weight of the soil. Optimum mix proportion gave highest MDD were used for carrying out further study on influence of HT Nylon-66 fibre on different properties of expansive soil.

Samples were prepared with Expansive soil, Nylon-66 fibre with optimum dose of fly ash and varying percentage of fibre and lengths of fibre. 30% optimum dose of fly ash and Nylon-66 fibre with different percentage of 0.25 to 1.50 with length varying from 6 mm to 24 mm.

4.0 RESULT AND DISCUSSION:

4.1 INTRODUCTION:

Three factors namely Expansive soil, Fly ash, HT Nylon66 are considered for investigation. A preliminary design by using the orthogonal array (OA) was carried out in order to access the relative effect of these three parameters. Three levels of each factor were considered through an L9 orthogonal array method. Table 3.5 shows the parameter and there values used at different levels.

Table 4.1-Factors and their levels

Sr. No.	Parameters	Level1	Level2	Level3
1	Length of Fibre	6mm	12mm	18mm
2	Percentage of Fibre	0.25	0.75	1.25

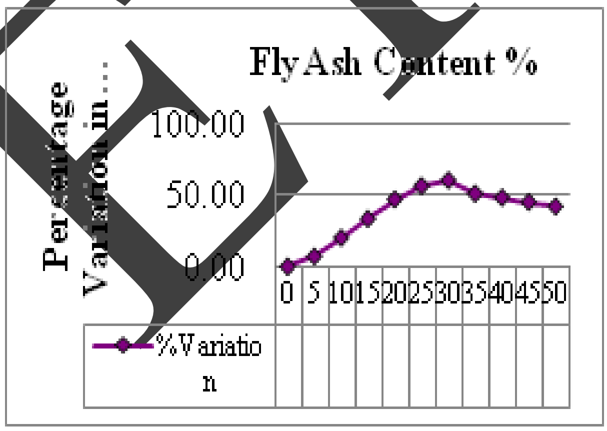

Figure **Error! No text of specified style in document.**.1: Percentage Variation in Strength Characteristics of Expansive Soil in terms of Unsoaked California Bearing Ratio Value with Different % of Fly Ash Content

Table **Error! No text of specified style in document..2**: Variation in Strength Characteristics of Expansive Soil-Fly Ash Mix in terms of Soaked California Bearing Ratio with different % of randomly distributed HT Nylon-66 Fibres

Sr. No.	Designation	Reinforcement in Fly Ash-Expansive Soil Mix		California Bearing Ratio Test Soaked				
		Fibre Length, m	Fibre %	Sample 1	Sample 2	Sample 3	Average	CBR Soaked % Variation
1	OSFB 0.00		0	2.657	2.760	2.322	2.580	0.00
2	OSFB 0.25/6		0.25	2.787	2.840	2.412	2.680	3.88
3	OSFB 0.50/6		0.50	3.066	2.628	3.066	2.920	13.18
4	OSFB 0.75/6		0.75	3.44	3.38	2.93	3.250	25.97
5	OSFB 1.00/6		1.00	3.54	2.97	3.41	3.310	28.29
6	OSFB 1.25/6	6 mm	1.25	3.380	2.82	3.19	3.130	21.32
7	OSFB 0.00		0	2.81	2.32	2.61	2.580	0.00
8	OSFB 0.25/12		0.25	3.56	3.21	3.81	3.526	36.67
9	OSFB 0.50/12		0.50	4.27	3.63	4.07	3.993	54.77
10	OSFB 0.75/12		0.75	4.58	4.72	4.04	4.450	72.48
11	OSFB 1.00/12		1.00	4.48	3.92	4.52	4.310	67.05
12	OSFB 1.25/12	12 mm	1.25	3.87	4.42	4.46	4.520	75.19
13	OSFB 0.00		0	2.81	2.32	2.61	2.580	0.00
14	OSFB 0.25/18		0.25	3.12	2.81	3.34	3.088	19.69
15	OSFB 0.50/18		0.50	3.63	3.08	3.46	3.392	31.45
16	OSFB 0.75/18		0.75	3.91	4.03	3.45	3.795	47.09
17	OSFB 1.00/18		1.00	3.91	3.42	3.95	3.765	45.93
18	OSFB 1.25/18	18 mm	1.25	3.18	3.46	3.98	3.540	37.21
19	OSFB 0.00		0	2.65	2.34	2.73	2.580	0.00
20	OSFB 0.25/24		0.25	2.41	2.7	2.83	2.650	2.71
21	OSFB 0.50/24		0.50	3.01	2.54	2.82	2.790	8.14
22	OSFB 0.75/24		0.75	2.88	3.35	3.17	3.140	21.71
23	OSFB 1.00/24		1.00	2.96	3.41	3.28	3.220	24.81
24	OSFB 1.25/24	24 mm	1.25	2.94	2.88	2.66	2.830	9.69

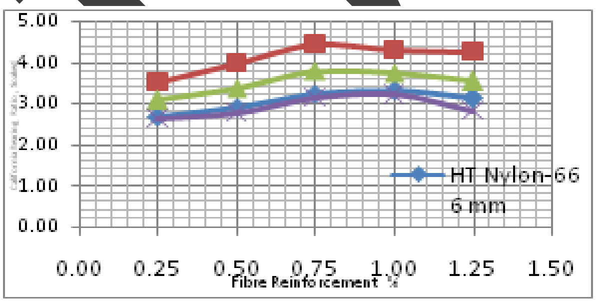

Figure **Error! No text of specified style in document..2**: Improvement in Strength Characteristics of Expansive Soil-Fly Ash Mix in terms of Soaked California Bearing Ratio with Different % of Randomly Distributed HT Nylon-66 Fibres

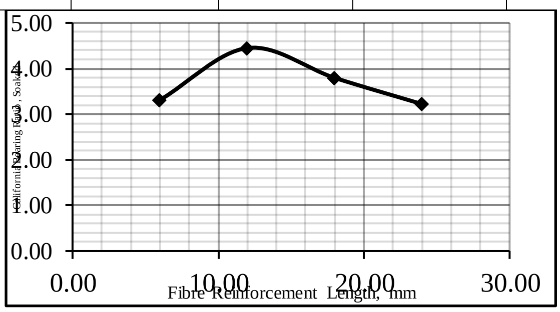

Figure **Error! No text of specified style in document..3**: Improvement in Strength Characteristics of Expansive Soil-Fly Ash Mix in terms of Soaked California Bearing Ratio with different length of Randomly Distributed HT Nylon-66 Fibres

4.2 DEVELOPMENT OF MATHEMATICAL MODELS AND VERIFICATION FOR CALIFORNIA BEARING RATIO OF EXPANSIVE SOIL - FLYASH MIX REINFORCED WITH NYLON FIBRES:

The mathematical models to represent the relationship among strength Characteristics and input parameters have been developed by regression analysis on the basis of L 9 orthogonal array of robust design. The response equation has been developed, considering only liner and quadratic effects of percentage of fibre reinforcement and length of fibres.

The appropriate equation has been decided and coefficients have been determined using MATLAB software.

4.2 Mathematical Model for Average California Bearing Ratio (Soked) of Expansive Soil - Flyash Mix Reinforced with Nylon Fibres

Mathematical Model for California Bearing Ratio (Soked) of Expansive Soil - Flyash Mix Reinforced with Nylon Fibres has been developed for predication of CBR Strength in terms of Fibre percentage and length of fibres.

$$\sigma_{CBR} = -0.6875983 + 0.589866\,X_1 + 3.3182\,X_2 - 0.023\,X_1^2 - 1.8508\,X_2^2$$

Where,

σ_{CBR} = Average California Bearing Ratio (Soked)

X_1= Length of Nylon Fibre in mm

X_2= Nylon Fibre %

Table 4.3: L_9 Orthogonal Array Experimental design Average California Bearing Ratio (CBR)

Expt. No.	Length of Fiber in mm	%age of Nylon Fibre	Average California Bearing Ratio (Soked)			
			Experimental value (Average CBR Soaked)	Model value (Average CBR Soaked)	Difference	Variation in %
1	6	0.25	2.680	2.74	0.06	2.14
2	6	0.75	3.250	3.47	0.22	6.81
3	6	1.25	3.130	3.28	0.15	4.78
4	12	0.25	3.526	3.79	0.27	7.56
5	12	0.75	4.450	4.53	0.08	1.72
6	12	1.25	4.250	4.33	0.08	1.99
7	18	0.25	3.088	3.19	0.10	3.36
8	18	0.75	3.795	3.93	0.13	3.44
9	18	1.25	3.540	3.73	0.19	5.48

From the above equation Average California Bearing Ratio (Soked) has been predicated from the developed model and its reliability is verified with experimental values. These values are tabulated in Table 4.23 and its variation is represented in graphical format in figure.4.41. It is observed that differences between predicted and observed values are within 10%.

Table **Error! No text of specified style in document.**.4: Verification of Experimental and Model Values Average California Bearing Ratio (Soked)

Verification Expt No.	Length of Fibre/Nylon in mm	Percentage of Fly Ash	Experimental value(UC strength)	Model value (UC Strength)	Difference	Variation in %
1	6	0.5	490.99	525.80	-34.82	-7.09
2	12	0.5	544.01	566.45	-22.44	-4.12
3	18	0.5	571.21	589.94	-18.73	-3.28
4	24	0.25	482.08	465.10	16.98	3.52
5	24	0.5	598.41	596.28	2.14	0.36
6	24	0.75	661.51	629.82	31.69	4.79
7	24	1.25	406.77	403.98	2.79	0.69
8	6	1.00	456.55	495.24124	-38.69	-8.47
9	12	1.00	525.48	535.8874	-10.41	-1.98
10	18	1.00	543.564	559.37884	-15.82	-2.91
11	24	1.00	561.65	565.71556	-4.07	-0.72

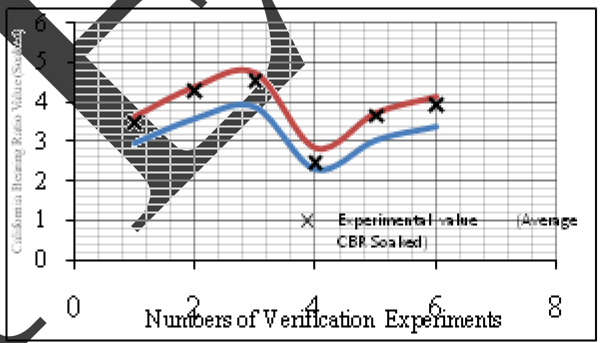

Figure **Error! No text of specified style in document.**.1: Validity of Mathematical Model of California Bearing Ratio Value (Soaked)

5. CONCLUSION:

This research work intended towards an experimental investigation on strength characteristics of expansive soil - flyash mix reinforced with nylon fibres. The experimental investigation carried out composed of tests reflecting Plasticity, Compaction, Compressive Strength, Penetration resistance and swelling characteristics of expansive soil, expansive soil –flyash mix and expansive soil - flyashmix reinforced with nylon fibres. Influence of fly ash content on expansive soil, HT Nylon 66 fibre content on expansive soil –flyash mix is presented and analysed in chapter 4.The results are analysed using mathematical modelling and the response equations are developed.

- Optimum percentage of HT Nylon-66 fibres having significant effect on characteristics of expansive soil fly ash mix is 0.75% of 12 mm length.
- Soaked CBR increased from 1.70 to 2.58 and Unsoaked CBR increased from 4.81 to 7.74 with fly ash content increasing from 0 % to 30%.

- Soaked CBR increased from 2.58 to 4.45 and Unsoaked CBR increased from 7.74 to 13.544 with Nylon Fibres content increasing from 0 % to 0.75 %.
- The developed mathematical model is significant to represent the relationship and useful to predict the values for unconfined compressive strength.
- Adequacy of mathematical modelling is also tested by conducting different verification experiments and it is observed that difference between predicated and observed value of UCS is lying within 10%.

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