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Effective Utilization of Metakaolin and Bagasse Ash as Additives in Soil Stabilization

Gopikumar S[1], Sheela Daniel R[2], Exalin Bibila M[3], Nisha PS[4], Thanga Rathna S[5]
[1,2,3,4,5] Assistant Professor – Department of Civil Engineering, SCAD College of Engineering &Technology, Tirunelveli-627414 , Tamilnadu.

ABSTRACT

The main aim of this study is to improve the engineering properties of clay soil by adding bagasse ash and metakaolin thus making it more stable and also to stabilize the soil. Soil is the foundation material which supports loads from the overlying structure. Soil is the most widely used material in a highway system, either in its natural form or in a processed form. Also, all pavement structures eventually rest on soil foundation. The construction cost can be considerably decreased by selecting local materials including local soils for the construction of the lower layers of the pavement such as the sub-base course. Soil stabilization reduces the permeability and compressibility and increases the bearing capacity and shear strength of the soil. Different dosages of Metakaolin 5% and Bagasse ash 2%, 4%, 6% and 8% were used to stabilize the clay soil. The performance of Bagasse Ash and Metakaolin stabilized soil was evaluated using physical and strength performance tests namely plasticity index, specific gravity, compaction, California bearing ratio (CBR) and Unconfined compressive test.

Key Words: Soil Stabilization, Clay soil, Metakaolin, Bagasse Ash, Unconfined Compressive Strength Test, California Bearing Ratio Test.

Introduction:

Stabilization of clay soil by various admixtures is one of the best alternatives to overcome to the problems associated with clay soils. The swelling potential of the clayey soil mainly depends upon the properties of soil and environmental factors. Some physical factors like initial water content, dry density and type of compaction may also affect the swelling potential of soil. The expansion of expansive soils may be reduced by using marble dust and notice the change in index properties of soil samples with increasing percentage of marble dust Gupta et al 2011. Atterberg, limits, grain size distribution, swell percentage and rate of swell of an expansive soil sample are investigated and the effect of curing on swell percentage and rate of swell of an expansive soil stabilized with waste limestone dust and waste dolomitic marble dust are evaluated Onur et al 2009. Clayey soils posses very low shear strength under wet conditions. Addition of fine marble powder in soil alters the gradation, plasticity character and reduces the permeability Shaukat et al 2011. The optimized proportion of soil: Rice husk ash: Marble dust at 70:10:20 was observed to be effective in Unconfined Compressive Strength test, Compaction tests, Swelling pressure tests, and Durability tests Akshaya and Radhikesh et al 2011. Utilization of Marble Slurry Dust in roads construction is observed to have more strength and stability. Meanwhile Distress progression is slow and would save Rs 1, 50, 00/- per km. in multi lane roads and for high embankment. Misra et al 2009. Free swell index (FSI), swell potential, swelling

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pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied and observed to be competitive with the addition of flyash Phanikumar and Sharma (2004). Polyethylene and Polypropylene Fiber improves the strength properties and dynamic behavior of clayey soils and are used for construction of flexible pavements in low traffic areas Sogan et al 2015. California bearing ratio and compaction of composite containing clay, sand and fly ash showed substantial improvement and the swelling of clay is also reduced after stabilization. Prasad and Sharma 2009. Bentonite, kaoline clay, fly ash and lime are used in soils stabilization and at curing caused a remarkable increase in the strengths Kate et al 2009.

Materials and Methods:

Sample collection:

Clay the naturally available water absorbing soil for the current study was collected from Cheranmahadevi. Metakaolin and Bagasse ash are admixtures used in the study and are collected from sterlite ltd Tuticorin and Dharani sugars Tirunelveli.

Mix proportion:

The experimental investigation was proposed with addition of 5% Metakaolin with stabilized soil and Bagasse Ash added in increasing composition 2% to 10%. The experimentation is carried out for specific gravity, sieve analysis, liquid limit, plastic limit, free swell index, proctor compaction, unconfined compressive strength (stress strain), California bearing ratio (load penetration curve).

Result and Discussion:

Clay particles are always smaller than 0.004 mm and often form colloidal suspensions when immersed in water, but flocculate (clump) and settle quickly in saline water. Metakaolin and Bagasse ash are used as admixture along with clay in the proportion of 5% as constant for metakaolin and increasing from 2 to 10 % for Bagasse ash respectively. Their properties are shown in table 1. The specific gravity of clay soil with the addition of Metakaolin and Bagasse ash are shown in table 2.

Table 1: Physico Chemical Properties of Admixture

S/No	Chemical Properties	Metakaolin % (weight)	Bagasse Ash %(weight)	Physical Properties	Metakaolin	Bagasse Ash
1	Silica (SiO_2)	54.13	62.43	Specific Gravity	2.39 to 2.59	2.09 to 2.69
2	Alumina (Al_2O_3)	38.23	4.38	Physical Form	Powder	Powder
3	Ferric oxide (Fe_2O_3)	4.21	6.98	Color	Off white, Gray to Buff	Gray
4	Potassium oxide (K_2O)	0.52	3.53			
5	Calcium oxide (CaO)	0.39	2.51			
6	Magnesium oxide (MgO)	0.09	0.42			
7	Sulphuric anhydride (SO_3)	0.21	1.48			
8	Sodium oxide (Na_2O)	0.13	0.81			

Table 2: Specific gravity of clay soil and admixtures

S/No	Description	Kg	Metakaolin (Composition)	Bagasse Ash (Composition)	Specific gravity (kg)
1	Weight of Empty Pycnometer, W_1	0.650	5%	2%	2.715
2	Weight of Pycnometer + Soil, W_2	1.393	5%	4%	2.720
3	Weight of Pycnometer + Soil + Water, W_3	1.930	5%	6%	2.736
4	Weight of Pycnometer + Water, W_4	1.462	5%	8%	2.740
Specific Gravity of Soil		2.701			

The specific gravity of clay soil is calculated based on Specific gravity (G) = $\frac{W_2-W_1}{(W_2-W_1)-(W_3-W_4)}$ Presence of admixtures in the clay soil naturally increases the specific gravity of soil. The sieve analysis of clay soil is calculated based on fineness modulus = $\frac{Total\ Cumulative\ Weight}{100}$ Uniformity Coefficient = $\frac{D_{60}}{D_{10}}$ and Coefficient of Curvature = $\frac{D_{30}{}^2}{D_{30}\times D_{10}}$ the corresponding sieve analysis values are shown in table 3.

Table 3: Clay soil sieve analysis

Sl. No	Sieve size	Weight of residue(gm)	Percentage of weight retained	Cumulative % of retained	% of passing
1	2.36mm	0	0	0	100
2	1.18mm	0.418	11.8	11.8	88.2
3	600µ	0.206	20.6	32.4	67.6
4	300µ	0.081	8.1	40.5	59.5
5	150µ	0.467	46.7	87.2	12.8
6	75µ	0.077	7.7	94.9	5.1
7	Pan	0.041	5.1	100	0

The liquid limit is calculated based on flow index = $\frac{w_1-w_2}{log_{10}\frac{N_2}{N_1}}$. The corresponding liquid limit values are shown in table 4.The liquid limit value corresponding to 25 blows was found 36% it is observed that with the addition of bagasse ash and metakaolin, the Liquid limit value decreases.

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Table 4: Liquid limit of clay soil and admixtures

Sl. No	Weigth of clay soil (g)	Weigth of soil with metakaolin	Weigth of soil with bagasse ash	Water added %	No of blows
1.	186	0	0	36	26
2.	186	10	4	36	26
3.	186	10	8	32	26
4.	186	10	12	28	25
5	186	10	16	28	25

The plastic limit of clay soil and admixtures is calculated based on plasticity = $\frac{w_2-w_1}{w_3-w_1} \times 100\%$ and plasticity index = $(w_l - w_p)\%$ the corresponding liquid limit values are shown in table 5.

Table 5: Plastic limit and plasticity index of clay soil and admixtures

S/No	Metakaolin (Composition)	Bagasse Ash (Composition)	Plastic Limit of Clay	Plasticity index of clay soil
1	0	0	0	24
2	5	2	44	19
3	5	4	40	14
4	5	6	33	7
5	5	8	29	3

The increase in percentage of bagasse ash & metakaolin shows higher plastic limit value in the initial stage and observed to be decreasing. Similarly the plasticity index of soil shows decrease in value with higher bagasse addition.

Based on the Index properties of clay soil it is classified as Highly Compressible Clay and is shown in table 6.

Table 6: Index properties of soil with admixture

Sand (%)	Finess (%) (silt+ clay)	Liquid limit (%)	Plastic limit (%)	Plasticity idex	Free swell index (%)	IS Classification
9	91	50	36	44	Very high	CH

Proctor Compaction Test

Table 7: Dry unit weight determination by proctor compaction test

S/No	soil with admixture (%)	Water content (%)	Bulk density g/cm^3	Dry unit weight(g/cc)	Optimum moisture content (%)
1	2	8	1.54	1.680	14
2	4	10	1.64	1.652	14
3	6	12	1.68	1.694	16
4	8	14	1.67	1.619	16
5	10	16	1.65	1.591	8

The diameter, height and weight of mould used for calibration are 15 cm, 11 cm and 5.86 g. From the above test result it is noticed that the maximum dry unit weight of clay soil 1.694 g/cc at Optimum

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moisture content of 16 is observed with 6% of bagasse ash and 5% of metakaolin, further addition in soil admixtures shows decreasing trend.

Unconfined Compressive Strength Test

Table 8: Stress – Strain determination by Unconfined Compressive Strength test

S/No	Soil with admixture (%)	Unconfined Compressive Strength(KN/m²)
1	2	80
2	4	110
3	6	180
4	8	120
5	10	84

The diameter and length of mould used for calibration are 12.5 cm and 4 cm. From the above test result it is noticed that the Unconfined Compressive Strength of clay soil has the highest value of 180 KN/m^3 at 6% of bagasse ash and 5% of metakaolin addition, further addition shows decrease in the strength.

California Bearing Ratio Test

Table 9: Load penetration determination by California Bearing Ratio Test

S/No	Soil with admixture (%)	California Bearing Ratio (%)
1	2	2.02
2	4	3.60
3	6	6.80
4	8	4.55
5	10	4.20

From the above test result it is noticed that the California Bearing Ratio Test of clay soil has the highest value of 6.80 % at 6% of bagasse ash and 5% of metakaolin addition, further addition shows decrease in the strength.

Conclusion:

Addition of bagasse ash and metakaolin with the clay increases its specific gravity, plastic limit but decreases its liquid limit with the increase in bagasse ash. Meanwhile the addition of bagasse ash with the expansive soil reduces the clay content/cohesive property. The reduction in the cohesive property is mainly due to the increase in the stabilizer content. The dry density and the unconfined compressive strength obtained for the clay increases, upto a certain percentage addition of bagasse ash with metakaolin and decreases after reaching the maximum value. The maximum unconfined compressive strength for the clay is 180KN/m^2 when 4% bagasse ash and 5% of metakaolin is added. Thus the waste bagasse ash left unused in the sugarcane industries could be used to stabilize the clay soils effectively.

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