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Experimental Investigation on the Combined Effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Geotechnical Properties of Kuttanad clay

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***Abstract:*-- The construction of engineering structures on fine grained soil is a challenging task and therefore considered as one of the biggest concern in geotechnical engineering. As the methods used conventionally were very uneconomical and time consuming, there is an urgent need for development of new techniques to satisfy the performance and economical criteria, which enhances the geotechnical properties of soil. It is necessary to adopt safer, economically feasible, environmentally sound and cost effective materials to improve geotechnical properties of Kuttanad clay, by utilizing stabilizers such as Metakaolin (Traditional stabilizer), Terrazyme (Non-traditional stabilizer) and Crumb Rubber Powder (By-product stabilizer). From the experimental investigation it is found that 6% of Metakaolin, 200ml/2m3 of Terrazyme and 10% of Crumb Rubber Powder are the optimum values for improving the geotechnical properties of Kuttanad clay after 14 days of curing period. In the present study an attempt is made to investigate the combined effect of optimum values of these three stabilizers on plasticity, shear strength and consolidation characteristics of Kuttanad clay by conducting Atterberg Limits test , Triaxial Compression test and One Dimensional Consolidation test respectively. The test results indicated that Kuttanad clay treated with a combination of 6% of Metakaolin, 200ml/2m3 of Terrazyme and 10% of Crumb Rubber Powder showed improvement in shear strength behaviour, reduced plasticity and consolidation characteristics after 14 days of curing period when compared to untreated Kuttanad clay.**

***Index Terms*:-- Kuttanad clay, Metakaolin, Terrazyme, Crumb Rubber Powder, Atterberg Limits, Triaxial Compression, One Dimensional Consolidation, Traditional, Non-traditional, By-product, Stabilizers, Shear Strength, Plasticity and Geotechnical properties.**

I. INTRODUCTION

In developing countries like India the most important requirement of any project are its cost, durability, time, performance and serviceability criteria. Construction of engineering structures on weak or soft soil is considered as unsafe, unstable and highly risky due differential settlements, poor shear strength, high compressibility and high plasticity characteristics.

Thus soil treatment is necessary by adopting safer, economically feasible, environmentally sound and cost effective materials that can be effectively embraced to improve geotechnical properties of Kuttanad clay by utilizing three different locally available stabilizers such as Metakaolin (Traditional stabilizer), Terrazyme (Non-traditional stabilizer) and Crumb Rubber Powder (By-product stabilizer) thereby enhancing shear strength, reduce plasticity and deformation characteristics of soft problematic clays. An experimental investigation on geotechnical properties of Kuttanad clay were conducted on the soil samples treated with 2%, 4%, 6%, 8% and 10% of Metakaolin, 200ml/1m^3, 200ml/1.5m^3, 200ml/2m^3, 200ml/2.5m^3 and 200ml/3m^3 of Terrazyme and 5%, 10%, 15% and 20% of Crumb Rubber Powder after varied curing periods. From the study it is found that 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder are the optimum values for improving the geotechnical properties of Kuttanad clay after 14 days of curing period. In the present study an attempt is made to investigate the combined effect of optimum values of these three stabilizers on plasticity, shear strength and consolidation characteristics of Kuttanad clay by conducting Atterberg Limits test, Triaxial Compression test and One Dimensional Consolidation test respectively.

II. MATERIALS USED

Kuttanad Clay

In this experimental study, the required quantity of Kuttanad clay was collected from Nedumudi in Upper Kuttanad region, Alappuzha district, Kerala, India. Kuttanad region is well known for its unique agricultural land in Kerala. Kuttanad soil is fine grained soil and it is

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categorised as one of the problematic soils in the world. Representative samples were collected from a depth of 7m to 8m from ground surface. The properties of soil were determined by standard test procedures as per SP: 36 (Part 1) - 1987 and tabulated as per provisions of Indian Standard Code of practice.

Fig. 1. Kuttanad Clay

Metakaolin (MK)

Metakaolin used in this study was acquired from Ashirwad Chemicals, Chennai, India. Metakaolin is a supplementary cementing material manufactured from kaolin. It is neither a by-product of any industrial process nor formed naturally. Metakaolin contains high percentage of aluminosilicates. It is manufactured by the calcination process of Kaolinite clays at a temperature of 550^0C-900^0C. This material is economical, operational and performance based. The most important benefit of Metakaolin is its easiness in handling and mixing. . It is white in colour and amorphous. It had specific gravity of 2.5.

Fig. 2. Metakaolin

Terrazyme (TZ)

Terrazyme used in this study was obtained from Avijeeth Agencies, Anna Nagar East, Chennai, India. Terrazyme is a natural, non-toxic, non-corrosive and non-inflammable liquid, produced by formulating vegetable and fruit extracts. The use of Terrazyme in soil has emerged as one of the renewable technologies for drastically improving soil properties and strength of soil significantly. It is eco friendly and economical in long run. The enzymes have a unique property when added to soil, it increases the wetting and bonding capacity of the soil particles. Enzymes are expected to be very soil specific. Terrazyme is specially formulated to modify the engineering properties of soil. They require dilution in water before application.

Fig. 3. Terrazyme

Crumb Rubber Powder (CRP)

Crumb Rubber Powder used in this study was collected from Dolphin Rubber Industries, Kottayam, Kerala, India. Developing countries like India mainly depend on the transportation sector for their economical growth. Disposal of waste tyres are challenging task due to its long life and non-biodegradable nature of rubber. Various industrial wastes such as Crumb rubber powder a by-product of used automotive tyres that are recycled rubbers retrieved from discarded used truck scrap tyres by crushing and removal of the textiles and metal fibres are effectively used as a soil replacement material which not only solves environmental problems but also provides a new resource for construction industry.

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Fig. 4. Crumb Rubber Powder

III. EXPERIMENTAL INVESTIGATION

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Plasticity Characteristics

- In the present study an attempt has been made to experimentally investigate the combined effect of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder on Plasticity characteristics of Kuttanad clay after 14 days of curing period by conducting Atterberg limits test as per IS: 2720 (Part 5) – 1985. The purpose of the test is to determine the influence of soil samples treated with a combination of three different stabilizers on Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) and the rate of decrease in plasticity characteristics after 14 days of curing period.

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Shear Strength Characteristics

- In the present study an attempt has been made to experimentally investigate the combined effect of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder on Shear strength characteristics of Kuttanad clay after 14 days of curing period by conducting Triaxial Compression test as per IS: 2720 (Part 11) - 1981. The purpose of the test is to determine the influence of soil samples treated with a combination of three different stabilizers on Cohesion(C), Angle of Internal Friction (φ) and Shear strength for different normal stresses of 0.5kg/cm^2, 1kg/cm^2 and 1.5kg/cm^2 and the rate of increase in Shear strength characteristics after 14 days of curing period.

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Consolidation Characteristics

In the present study an attempt has been made to experimentally investigate the combined effect of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder on Consolidation characteristics of Kuttanad clay after 14 days of curing period by conducting One Dimensional Consolidation test as per IS: 2720 (Part 15) – 1986. The purpose of the test is to determine the influence of soil samples treated with a combination of three different stabilizers on Coefficient of Consolidation (C_v), Compression Index (C_c), Coefficient of compressibility (a_v) and Coefficient of Volume Change (m_v) under different applied pressures of 0.5 kg/cm^2, 1 kg/cm^2 and 2 kg/cm^2 and the rate of decrease in Consolidation characteristics after 14 days of curing period.

IV. RESULTS AND DISCUSSION

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Plasticity Characteristics after 14 days of Curing period

The percentage decrement in Atterberg limits for soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder was found to be 34%, 39.3% and 31.5% for Liquid limit, Plastic limit and Plasticity index respectively after 14 days of curing period.

Table I. Combined effect of mk, tz and crp on atterberg limits after 14 days of curing period

Atterberg Limits	**Kuttanad Clay**	**6%MK+200ml/2m^3 TZ+10%CRP**
Liquid Limit (LL) (%)	130	85.8
Plastic Limit (PL) (%)	42	25.5
Plasticity Index (PI) (%)	88	60.3

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Shear Strength Characteristics after 14 days of Curing period

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The percentage increment in shear strength parameters for soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder was found to be 504% for Cohesion, 474% for Angle of internal friction after 14 days of curing period. Similarly the percentage increment in shear strength for soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder was found to be 503%, 505% and 498% for different normal stresses of 0.5kg/cm^2, 1kg/cm^2 and 1.5kg/cm^2 respectively after 14 days of curing period.

Table II. Combined effect of mk, tz and crp on shear strength parameters after 14 days of curing period

Shear Strength Parameters	Kuttanad Clay	6%MK+200ml/2m^3 TZ+10%CRP
C (kN/m^2)	12.5	75.5
φ (^{0})	3	17.2

Table III. Combined Effect Of Mk, Tz And Crp On Shear Strength After 14 Days Of Curing Period

Normal Stress (kg/cm^2)	Shear Strength (kN/m^2)	
	Kuttanad Clay	6%MK+200ml/2m^3 TZ+10%CRP
0.5	15.1	91
1.0	17.7	107
1.5	20.4	122

Combined effect of Metakaolin, Terrazyme and Crumb Rubber Powder on Consolidation Characteristics after 14 days of Curing period

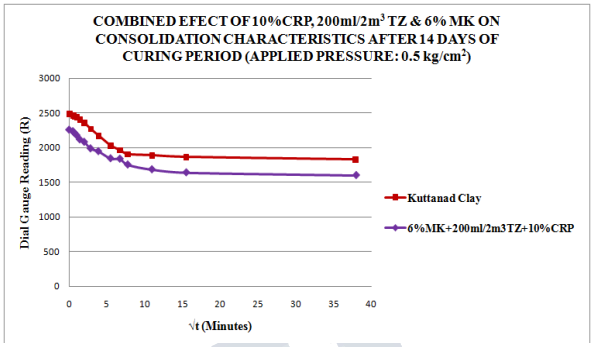

Fig. 5. Combined effect of MK, TZ and CRP on Consolidation characteristics after 14 days of curing period under 0.5 kg/cm^2 applied pressure

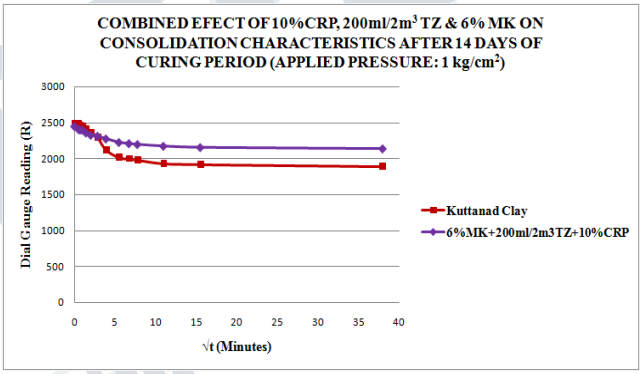

Fig. 6. Combined effect of MK, TZ and CRP on Consolidation characteristics after 14 days of curing period under 1 kg/cm^2 applied pressure

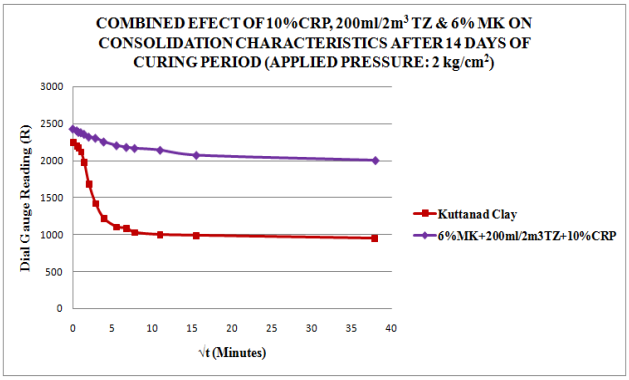

Fig. 7. Combined effect of MK, TZ and CRP on Consolidation characteristics after 14 days of curing period under 2 kg/cm^2 applied pressure

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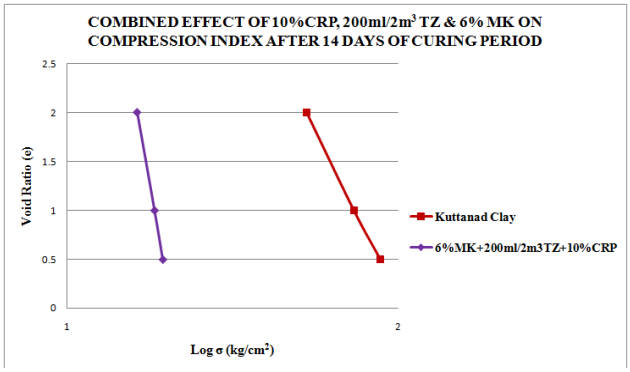

Fig. 8. Combined effect of MK, TZ and CRP on Compression Index after 14 days of curing period

The percentage decrement in Coefficient of Consolidation for soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder was found to be 82.3%, 80.8% and 86.2% under different applied pressures of 0.5kg/cm^2, 1kg/cm^2 and 2kg/cm^2 respectively after 14 days of curing period.

Table IV. Combined Effect Of Mk, Tz And Crp On Coefficient Of Consolidation After 14 Days Of Curing Period

Sample	Applied Pressure (kg/cm^2)	Coefficient of Consolidation (C_v) (cm^2/sec)
Kuttanad Clay	0.5	5.43×10^{-7}
	1.0	6.87×10^{-7}
	2.0	4.25×10^{-6}
6%MK+200ml /2m^{3}TZ+10%CRP	0.5	9.63×10^{-8}
	1.0	1.24×10^{-7}
	2.0	5.92×10^{-7}

Table V. Combined Effect Of Mk, Tz And Crp On Consolidation Parameters After 14 Days Of Curing Period

Consolidation Parameters	Kuttanad Clay	6%MK+200ml /2m^{3}TZ+10%CRP
Compression Index (C_c)	0.661	0.046
Coefficient of Compressibility (a_v) (cm^2/kg)	0.205	0.028
Coefficient of Volume Change (m_v) (cm^2/kg)	0.072	0.013
Degree of Compressibility	Very highly compressible	Very slightly compressible

The percentage decrement in Compression Index, Coefficient of Compressibility and Coefficient of Volume Change for soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder was found to be 93%, 86.3% and 82% respectively after 14 days of curing period.

V. CONCLUSIONS

When compared to untreated Kuttanad clay, soil samples treated with a combination of 6% of Metakaolin, 200ml/2m^3 of Terrazyme and 10% of Crumb Rubber Powder after 14 days of curing period showed:

- Reduction in plasticity characteristics with percentage decrement of 34%, 39.3% and 31.5% for liquid limit, plastic limit and plasticity index respectively.
- Improvement in shear strength characteristics with percentage increment of 504% for cohesion and 474% for angle of internal friction. Similarly percentage increment of 505% for shear strength for a normal stress of 1kg/cm^2.
- Reduction in consolidation characteristics with percentage decrement of 86.2% for coefficient of consolidation under an applied pressure of 2kg/cm^2. Similarly percentage decrement of 93%, 86.3% and 82% for compression index, coefficient of compressibility and coefficient of volume change respectively.

The degree of compressibility for untreated Kuttanad clay was found to be very highly compressible (C_c = 0.661, greater than 0.35) while for soil samples treated with a combination of three different stabilizers reduced to very slightly compressible (C_c = 0.046, lies between 0 - 0.05) after 14 days of curing period.

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REFERENCES

1) Remitha Ann Cherian and Shyla Joseph A, " A Comparative study on the Influence of Traditional, Non-traditional and By-product stabilizers on Geotechnical properties of Kuttanad clay", International Research Journal of Engineering and Technology, Volume 04, Issue 03, pp.2521-2536, March 2017.
2) Leong Sing Wong, Roslan Hashim & Faisal Ali, "Improved Strength and Reduced Permeability of Stabilized Peat: Focus on Application of Kaolin as a Pozzolanic Additive", Construction and Building Materials, Volume 40, pp. 783–792, Science Direct, Elsevier Ltd, December 2013.
3) Zhang Tongwei, Yue Xibing, Deng Yongfeng, Zhang Dingwen & Liu Songyu, "Mechanical Behaviour and Micro-structure of Cement-Stabilised Marine Clay with a Metakaolin Agent", Construction and Building Materials, Volume 73, pp. 51-57, Science Direct, Elsevier Ltd, December 2014.
4) C. Venkatasubramanian & G. Dhinakaran, "Effect of Bio Enzymatic Soil Stabilization on Unconfined Compressive Strength and California Bearing Ratio", Journal of Engineering and Applied Sciences, Volume 6, Issue 5, pp. 295-298, 2011.
5) Joydeep Sen & Jitendra Prasad Singh, "Stabilization of Black Cotton Soil using Bio Enzyme for a Highway Material", International Journal of Innovative Research in Science, Engineering and Technology, Volume 4, Issue 12, December 2015.
   A. U. Ravi Shankar, Harsha Kumar Rai and Ramesha Mithanthaya I., "Bio-enzyme stabilized lateritic soil as a highway material", Journal of Indian Roads Congress, pp. 553, 143-151, 2009.
6) G. Venkatappa Rao & R.K. Dutta, "Compressibility and Strength Behaviour of Sand–Tyre Chip Mixtures", Geotechnical and Geological Engineering, Volume 24, pp.711–724, Springer, 2006.
7) Arin Yilmaz & Nurhayat Degirmenci, "Possibility Of Using Waste Tire Rubber And Fly Ash With Portland Cement As Construction Materials", Waste Management, Volume 29, Issue 5, pp. 1541–1546, Science Direct, Elsevier Ltd, May 2009.
8) B. Sri Vasavi, "Stabilization of Expansive soil using Crumb Rubber Powder and Cement" , International Journal of Innovative Research in Science, Engineering and Technology, Volume 2, Issue 8, January 2016.
9) Ghatge Sandeep Hambirao and Dr.P.G.Rakaraddi , "Soil Stabilization using Waste Shredded Rubber Tyre Chips", IOSR Journal of Mechanical and Civil Engineering, Volume 11, Issue 1, pp. 20-27, February 2014.
10) Shiva Prasad.A, "Study on Effect of Crumb Rubber on Behaviour of Soil", International Journal of Geomatics and Geosciences , Volume 4, No 3, August 2014.
11) Purushotham G. Sarvade, "Geotechnical Properties of Problem Clay Stabilized with Crumb Rubber Powder", Bonfring International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, December 2012.
12) Mahmoud D. Ahmed, "Effect of Metakaolin on the Geotechnical Properties of Expansive Soil", Journal of Engineering, Volume 21, No. 12, December 2015.
13) Venika Saini, "Soil Stabilization by using Terrazyme", International Journal of Advances in Engineering & Technology, Volume 8, Issue 4, pp. 566-573, August 2015.
14) Dr. M T Prathap Kumar, "Compaction and Strength Characteristics of Terra-zyme Stabilized Red Soil", International Journal of Research

Publications in Engineering, Technology and Management, Volume 1, Issue 1, July 2015.

15) H.N. Ramesh and Sagar S, "Effect of drying on the strength properties of terrazyme treated expansive and non-expansive soils", 50th Indian Geotechnical Conference December 2015, Pune, Maharashtra, India.
16) Vijay Rajoria and Suneet Kaur, "A Review on Stabilization of soil using Bio-enzyme", International Journal of Research in Engineering and Technology, Volume 3 Issue 1, January 2014.
17) Puneet Agarwal and Suneet Kaur, "Effect of Bio-enzyme Stabilization on Unconfined Compressive Strength of Expansive soil", International Journal of Research in Engineering and Technology, Volume 3, Issue 5, May 2014.
18) SP: 36 (Part 1)-1987, Compendium of Indian Standards on Soil Engineering: Part-I "Laboratory Testing of Soils For Civil Engineering Purposes", [CED 43: Soil and Foundation Engineering].
19) IS: 2720 (Part 5)-1985, "Determination of Liquid and Plastic Limit", Bureau of Indian Standards, Manak Bhavan, New Delhi.
20) IS: 2720 (Part 11)-1981, "Determination of the Shear Strength parameters of a specimen tested in Unconsolidated Undrained Triaxial Compression without the measurement of Pore Water Pressure", Bureau of Indian Standards, Manak Bhavan, New Delhi.
21) IS: 2720(Part 15)-1986,"Determination of Consolidation Properties", Bureau of Indian Standards, Manak Bhavan, New Delhi.

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