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Use of Acrylic polymer for stabilization of clayey soil

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Abstract— Soft Soils generally referred as clayey soils always remains problematic and usually not suitable for construction purposes because of their poor engineering characteristics. Prehistoric cultures of the Chinese, Romans and Incas exploited various techniques to enhance strength properties of clayey soils. Engineering works based on economy, strength and durability as soil need to provide foundation for structures. Therefore, it needs to provide an economical material to strengthen soil. This paper aims to evaluate the use of waste acrylic polymer in geotechnical applications and to assess the effect of waste acrylic on engineering characteristics of clayey soil. Six different formulations were studied containing different percentages ranging from 0% to 10% of acrylic polymer. The samples were tested for unconfined compressive strength determination after 3, 7 & 14 days of curing period. It was concluded that the addition of acrylic polymers into clayey soil can significantly enhanced the engineering characteristics especially optimum moisture contents, maximum dry density, unconfined compressive strength and California bearing ratio of clayey soil.

Key words— Shear Strength, Acrylic Polymers, Index Properties, Strength Characteristics, soil stabilization

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1 Introduction

The presence of fine particles and high tendency of swelling and shrinkage potential, resulting the clayey soils found to be undesirable for construction purposes. These soils are generally known as expansive soils because of their great changes in volume under variation of water contents [1][2]. Such types of clays are categorized due to very small particle size, large specific surface area and high Cation Exchange Capacity (CEC) [3][4][5]. These soils originate major damages to overlaying structures and hence infrastructure because of higher tendency of volume changes [6][7][8][9][1]. Various researchers reported the stabilization of such types of soils by the addition of different traditional and non-traditional admixtures such as lime, fly ash or cement etc. [4][5] [10-13] and has focused on the eradication of the expansive property of the soil. Soil stabilization is generally referring to enhance its engineering properties such as strength and stiffness. The major objective of stabilization is to remove the voids in the soil and control the void ratio through the addition of a cementitious material or by injecting a substance to fill the voids. Chemical stabilizers are divided into traditional agents and non-traditional agents. Traditional chemical stabilizers such as lime, cement, fly ash or bituminous material have such effects as developing a cementitious bond between the particles or increasing the water resistance of the soil. Recently researchers have found that concentrated liquid agents such as petroleum-based emulsions and polymers can be used as materials for stabilization. These are classified as non-traditional chemical stabilizers [14]. The significant improvement in unconfined compressive strength and California bearing ratio was observed for soil stabilized with flyash [15-17]. The concentration of admixtures like fly ash, lime, cement etc. depends upon the soil type and minerology and range of 15% to 30 % was reported in various studies [18-20]. Cement stabilization increases the compressive, tensile and flexural strength, durability and stiffness properties of soil [21-29]. Cement and lime are extensively used for improvement of strength and engineering characteristics of cohesive soils which has expansive properties like higher potential to swelling and shrinking, higher compressibility index, less strength, etc. [35]. Lime has been proved to be most suitable for improving the clayey soil which has fine fractions in excess of 25%. The reaction of lime with soil results in strength attainment and it arises chiefly from chemical reactions between the lime, clay minerals and amorphous constituent in the soil. Some other admixture which have pozzolanic properties such as bagasse ash, fly ash, rise husk ash, coconut husk ash, etc. have also been extensively employed lime and cement for soil stabilizations [30-36]. California bearing ratio (CBR) values of locally available soil increases when treated with sugarcane bagasse ash [37]. Soil is treated with instead of using only 7% lime by using 4% lime and 3% eggshell powder (ESP) and same soaked California bearing ratio (CBR) value can be found [38]. With addition of eggshell powder (ESP), there was a considerable decrease in Atterberg's Limits, and after 20% the value seems to be almost constant. The optimum moisture content increases and maximum dry density decreases, permeability increases, coefficient of consolidation increases and compression index decreases with increase in percentage of eggshell powder (ESP) [39]. Number of researchers have been studied to evaluate the application of resins/polymers for soil stabilization with different traditional chemical agents. Generally, the studies were carried out on determination of mechanical and physical characteristics of soil stabilized with resins. The curing effects of resins has also been investigated [40-46].

2 Materials

2.1 Soil

Soil was collected from Jahangira District Sawabi, KPK, Pakistan. The soil was than pulverized in laboratory to conduct different tests to obtain various engineering properties like moisture content, grain size distribution, Atterberg's limits, unconfined compressive strength and compaction tests. The results are summarized in table 1

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TABLE 1: PHYSICAL CHARACTERISTICS OF UNTREATED SOIL

Soil Property	Value
Liquid Limit (LL)	54%
Plastic Limit (PL)	25%
Plasticity index (PI)	29%
Percent Passing Sieve No. 200	100%
Unconfined Compressive Strength (UCS)	136 kN/m^2
California bearing ratio (CBR)	2.93%
Optimum Moisture Content (OMC)	24%
Maximum dry density (MDD)	13.5 kN/m^3

2.2 Acrylic Polymer

Acrylic polymers are produced during the manufacturing of plastic goods like acrylic name plates etc. These polymers found in Asian countries where the production of such products is in large scale. Acrylic fibers are also found during the manufacturing of adhesives and paints. The material used in this study was collected from manufacturing unit of name plates from local vicinity.

3 PREPARATION OF TEST SAMPLES AND TESTING PROCEDURE

3.1 Unconfined Compressive Strength (UCS)

ASTM D 2166-00 method was used for sample preparations for unconfined compressive strength testing. For preparation of Soil-Acrylic (SA) mix, the acrylic polymer was mixed with chloroform to prepare the acrylic paste and then added to the soil. The chloroform was evaporated later on. Each sample was sealed in a plastic sheet to make it air tight. Samples were then placed in an oven at 40ºC for the desired curing period. Curing arrangements are shown in Fig. 1b. The treated samples were tested after 3, 7, 14 and 28 days of curing to observe the age effect. Fig.1 illustrated the molds fabricated for samples preparation for unconfined compressive strength, curing of samples and samples before compression tests

3.2 California Bearing Ratio (CBR)

ASTM D 1883-05 procedure was adopted for preparation of test samples for California Bearing Ratio (CBR) test. The test comprises load application to a penetration piston of 50 mm dia. at a rate of 1.3 mm per minute and recording the total load at penetrations ranging from 0.635 mm to 7.67 mm. The samples were kept soaked for 96 hours under controlled temperature

(a) (b) (c)

Fig. 1: (a) Mold for Soil UCS Samples, (b) Curing of UCS Samples, (c) UCS Sample after Curing,

4 RESULTS AND DISCUSSIONS

Fig. 2 depicts the variation in maximum dry density (MDD) with addition of acrylic polymer. It was noted that MDD increases with increasing concentration of acrylic polymer upto the 6% whereas, MDD decreased after 6%. Fig. 3 shows the effect of acrylic polymer on optimum water content. Without addition of acrylic polymer, the optimum moisture contents (OMC) was determined as 36% which was reduced with the addition of acrylic

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polymer. But beyond 6% of acrylic polymer, the OMC starts increasing. This variation may be due the absorbent property of acrylic polymer. The increase in optimum water contents is may be a due to the supplementary water detained with the flocculants clay soil structure and absorption by acrylic resin due to its absorbent properties.

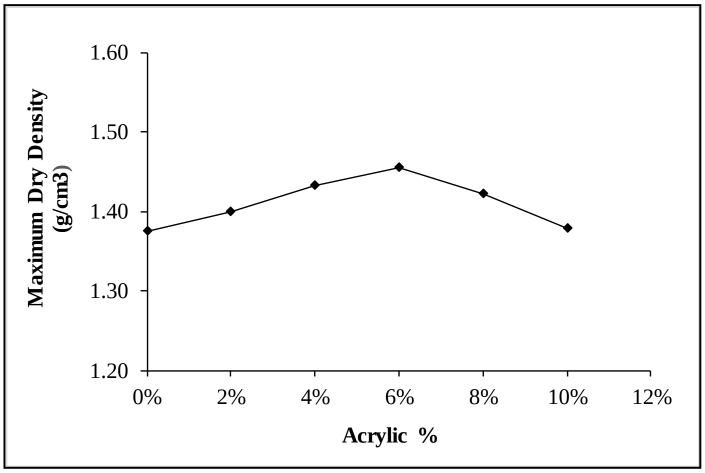

Fig. 2: Effect of Acrylic polymer on maximum dry density (MDD)

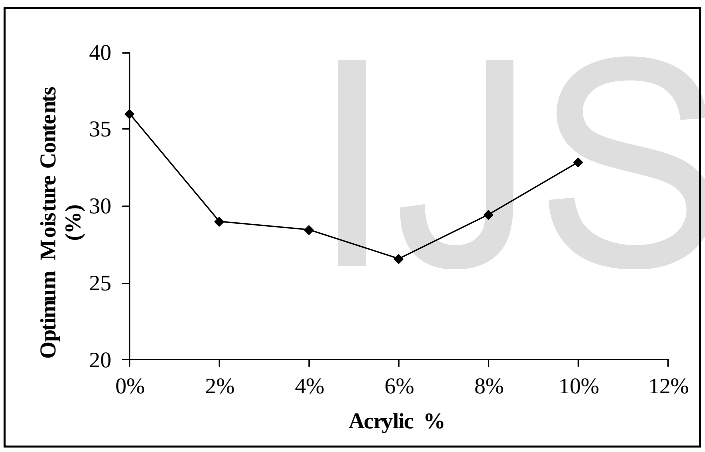

Fig. 3: Effect of Acrylic polymer on optimum moisture contents

Fig. 4 represents the variation in Atterberg's limits of soil with varying concentration of acrylic polymers. It was noted that liquid limit (LL) decreases as the amount of the acrylic polymer increases. Whereas, the plastic limit (PL) increases with increasing the acrylic concentration. The reason for this variation may be due to the hydrophilic nature of acrylic in which water cannot be observed and is free to change its location among the layers of alumina silicate. Green et al. (2001) performed experimental studies on acrylic polymers and presented that chemical composition analysis based on Fourier transform infra-red spectroscopy (FTIR) shows that the acrylic polymer is usually classified to be a polyacrylamide (PAM). The cluster particles are created due to the interaction of acrylic polymers with clay and fine particles in soils [47]. The addition of acrylic polymers results in increase in liquid limit and reduction in plastic limits and hence plasticity index decreased. The effects of acrylic polymer are assumed to be a function of the soil properties such as the type of ions in the soil, texture and clay types among others. Also, acrylic polymer properties like molecular weight, charge, and charge density equally affects the stabilization of the soil [48].

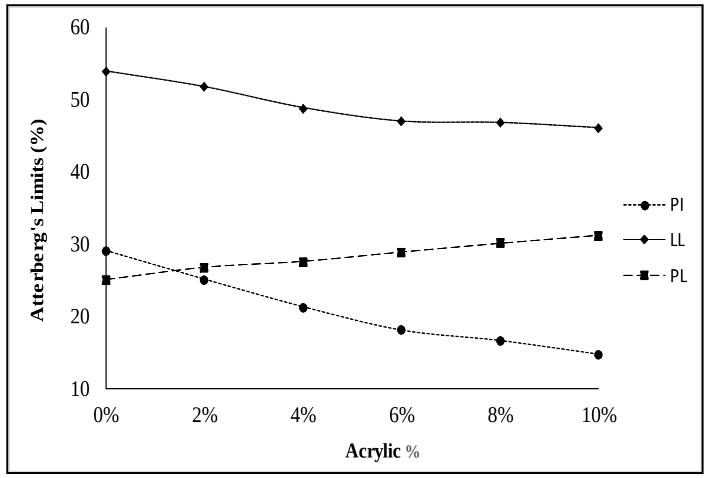

Fig. 4: Effect of Acrylic polymer on Atterberg's Limits

Fig. 5 illustrates the consequence of acrylic polymers on unconfined compressive strength (UCS) of clay after 3, 7 and 14 days curing. It was noted that with increasing the acrylic dosage, the compressive strength increases. After certain dosage of acrylic polymer which is 6%, the UCS decreased, which show the optimum dosage of acrylic to improve UCS of clayey soils. At 6% acrylic, the UCS increased by 57%, 50% and 51% after 3, 7 and 14 days of curing respectively. The early age effect of acrylic is more dominant as compared to later ages. This shows the role of acrylic in enhancing the strength characteristics of the clayey soil. The results are well comparable with the findings reported by Anagnostopoulos et al. (2003) and Estabragh et al. (2011) [14&45]. The effect of acrylic polymers on California bearing ratio (CBR) is shown in Fig. 6. Similar to UCS, the CBR values increases with increasing percentage of acrylic polymer. The optimum content was determined as 8% of acrylic polymers for CBR.

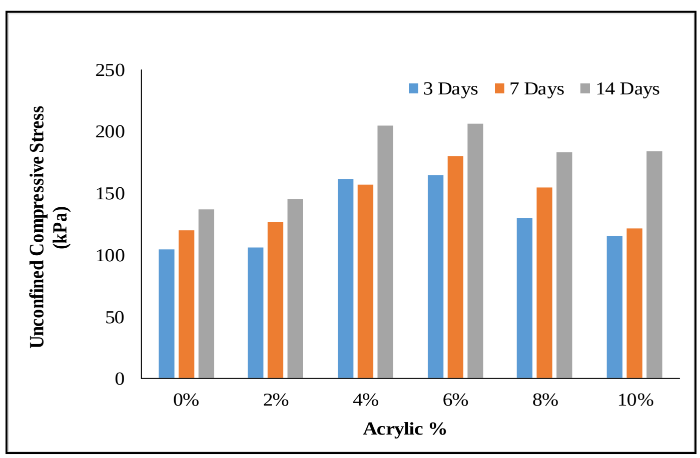

Fig. 5: Variation of unconfined compressive strength with different percentages of Acrylic polymer

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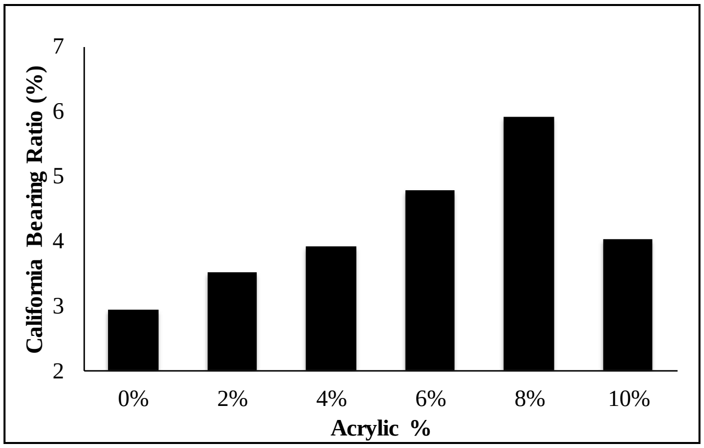

Fig. 6: Effect on California bearing ratio values with different concentration of Acrylic polymer

5 Conclusions:

Based on the current investigation, the following conclusions were made:

- The use of non-traditional chemical agents (acrylic polymers) can significantly enhance the engineering characteristics of soft soil. The soil is reactive with acrylic solution. Optimum percentage of acrylic solution required for stabilization of the soil is 6% by weight of the soil. It can be used as stabilizing agent in conjunction with acrylic is technically and financially feasible as it increases both the strength and durability parameters of soil.
- Compaction effort quickly after mixing acrylic solution is likely to yield maximum strength in the field. The maximum dry density from untreated soil increases to 5.92% with addition of 6% acrylic polymers. Beyond this MDD starts decreasing.
- Unconfined compressive strength increases from untreated soil to 57% (for 3,7 and 14-days curing) with addition of 6% of acrylic polymer, further addition of acrylic polymer causes decrease in compressive strength.
- In California Bearing Ratio test, maximum increment obtained from treated soil was 102% at 6% addition of stabilizer in comparison with untreated soil.
- These non- traditional chemical agents can be used to enhance the strength characteristics of cohesive soils for construction purposes like subgrade and to provide material for erosion resistance where the existing soil is cohesive and limitations such as transport distance of other soils and financial and environmental restrictions make the application of existing soil the preferred option. Durability tests should be conducted to investigate the enduring effects of resins and the environmental effects should be evaluated by considering the possible pollution caused by these agents under actual field conditions.

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