Stabilization of Clays and Clayey Soils using Polycom- A Polyacrylamide Additive

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Abstract. The aim of this study is to assess the benefits of using Polycom- a polymer based additive to improve various performance-related properties of clays and clayey soils. Polycom is a commercially available polymer, which has a wide range of applications related to the improvement of various properties of soils. Generally, the substance is used in road construction as a means of stabilising the soil movement due to changes in moisture content. Studies by the University of Adelaide have indicated that the addition of Polycom to the clay had a significant influence on decreasing the permeability of the respective Compacted Clay Liners (CCL). Three types of soils namely clay of high compressibility and two clayey sand samples are tested in the laboratory by adding Polycom mixed water. Wet application method is used to stabilise the soils in which the dry Polycom powder is mixed with water that is to be applied to the soil to obtain the optimum moisture content. The Polycom reacts with the water such that a highly viscous solution forms. The effect of Polycom on engineering properties of soils is investigated by dry density vs moisture relationship, Unconfined Compressive Strength (UCS), and direct shear tests. Results shows that Clay of high compressibility (CH) showed appreciable improvement in strength in terms of UCS with the stabilizer for different curing periods. The improvement in UCS is about 160% with respect to strength of untreated soil. Similarly for clayey sand (SC), the increase is about 150% and 40% in cohesion and angle of internal friction respectively for 5 days of curing with respect to untreated soil strength.

Keywords: soil stabilization; Polycom; polymer based stabilizer, clayey sand, clay of high compressibility

1. Introduction

Traditional additives such as lime and cement have been used all over the world to stabilise sealed and unsealed roads. Traditional additives have shown to improve soil workability, strength, durability and often lead to a reduction in the design thickness of the structural base layers. They are required in large quantities to be effective and require relatively long curing times. The compaction process also needs to be completed within a limited time period, which leads to significant construction costs. Another disadvantage is that shrinkage cracks associated with cement-stabilised layers which reflect rapidly through asphaltic surfaces. These disadvantages of traditional additives leads to the development of polymeric-based additives. Polymeric based additives demonstrate many added advantages; such as their ability to reduce permeability, increase durability, allow non-time dependence during the mixing stage and provide increased flexibility. The additive used in this study is a synthetic polyacrylamide (PAM) additive called Polycom. Polycom has been used in Australia with positive field results [1]. This paper is focused on laboratory investigation on stabilization of clays and clayey soils by adding Polycom.

1.1 Polycom- polymer based soil stabilizer

Various polymers have been proposed for polymer soil stabilization, including cationic, anionic, and non-ionic polymers. Most chemical stabilizers react with soil in one of two ways: specific chemical reactions occur between soil particles and stabilizer, or the stabilizer provides physical stabilization through the use of binding agents. Polymers fall into the second category. Polymers are essentially binding agents that bind soil particles into a cohesive mass and subsequently improve the physical properties of soil. The interaction between soil and polymer is highly dependent on the properties of the polymer i.e., type and amount of surface charge, polymer configuration, chain length, molecular weight and size as well as the soil properties. Soil properties that influence polymer stabilization are type and percentage of clay content, ionic strength of the soil solution, type of ion in solution and PH value [2, 3].

Polycom is a commercially available Australian-made soil polymer based soil stabilizer, which has a wide range of applicability relating to the improvement of various properties of soils. Polycom stabilizing aid is used to strengthen almost any material commonly found in road construction and earthworks projects. The polymeric additive used in this study is a synthetic soluble anionic PAM [4]. It is produced in a granulated form and was developed in Adelaide, Australia, by Bio-Central Laboratories Ltd. The PAM has a moderate charge density (approx. 18%) and a high-molecular weight between 12 and 15 Mg per mole, which is equivalent to approx. 150,000 monomer units per molecule. Apparent viscosity increases by mixing Polycom with water. The product is a non-toxic water soluble material with a specific gravity of 0.8 and a PH value of 6.9 at 25 °C. Polycom delivers a stronger, more resilient pavement, improving the flexibility and workability of the materials to create a tighter, water resistant surface. Polycom has a pronounced effect on the behavior of the pavement such that maintenance is dramatically reduced which of course reduces life cycle costs.

1.2 Mechanism of stabilization by Polycom

After wet mixing Polycom into an area and then compacted, its action assists the compactive effort improving the natural mechanical interlock between particles which in turn produces tighter compaction of the subject material. This improved compaction means higher density and higher CBR results. Polycom does not ‘cure’ but after drying Polycom leaves behind a polymer bond between the material particles, it is this polymer bond which delivers flexibility to the stabilized pavement.

2. Review of literature

Experimental study was carried out to assess the benefits of using a synthetic Polyacrylamide (PAM) additive to improve various performance-related properties for three types of pavement materials commonly used in the construction of unsealed roads in Australia [4]. The three materials selected for testing were a Silty Gravel, a Clayey Sand and a Clayey Gravel. The addition of PAM was found to increase the unconfined compressive strength and dry density for all soil types. Furthermore, the addition of PAM also changed the failure mode from brittle to ductile, which will naturally increase the fatigue life of the pavement. Improvement in tensile strength of the stabilised samples was also noted. Scanning Electron Microscopy analysis results revealed a decrease in the quantity of loose particles and pore volume, and an increase in contact points between particles for the treated samples, which further verified the mechanical and physical improvements gained by adding PAM to unbound pavement materials

Soils treated with polymeric-based additives have shown to improve various physical characteristics [5,6]. Results reported a significant improvement in strength for granular type soils when treated with three different types of polymers after 28 days of curing. Furthermore, studies revealed that six polymer emulsions (acrylic vinyl acetate copolymer, polyethylene-vinyl acetate copolymer, acrylic copolymer, polymeric proprietary inorganic acrylic copolymer, acrylic vinyl acetate copolymer and acrylic polymer) all yielded an increase in strength and toughness values for a silty sand soil after 7 days of curing, which was similar in magnitude to a typical cement treatment after 28 days [6]. More importantly, the increase in toughness of a pavement layer translates to better flexibility at higher capacity and indicates that this layer would be less susceptible to sudden damage under repetitive axle loading. Polymer binders effectiveness as stabilisers in terms of improving physical, chemical, mechanical and microstructural properties of a silty clayey gravel type soil is studied [7]. Recently conducted studies by the University of Adelaide have indicated that the addition of Polycom to the clay had a significant influence on decreasing the permeability of the respective CCL [8]. Few case studies are presented on the use of Polycom as stabilizer both for sealed and unsealed roads [9, 10].

3. Methodology

Three different soils are used for experimental investigation by adding Polycom water, to find out the changes in the strength of the soil. Classification tests like sieve analysis, Atterberg limits are carried out for the three selected soil samples. Three selected soil samples are classified as clay of high compressibility (CH) and two soil samples of Clayey sand (SC).

Polycom is available in dry powder form. Ploycom water is prepared by mixing 3g of Polycom powder in 5 litres of water. Polycom water is used as substitute for water in compaction and CBR tests. OMC is found for each sample by conducting modified compaction test. Soil sample is now kept in incubator after mixing required amount Polycom water (equal to OMC) for curing. UCC tests are conducted for clay samples and direct shear tests are conducted for Clayey sand (SC) samples. Tests are conducted for different curing periods of 1 day, 3 days and 5 days along with zero curing period or immediate test.

4. Results and Discussion

Results of classification tests carried out for three soil samples are given in table.1.

Table 1 Index properties of three soil samples used for study.

Sample No.	Sample Identification	Modified Proctor Compaction		Atterberg Limits (%)			Particle size Distribution (%)					
								Sand				
		OMC (%)	γ_{dmax} (t/m^3)	Liquid Limit (%)	Plastic Limit	Plasticity Index	Gravel (> 4.75mm)	Coarse (2.0 – 4.75mm)	Medium (0.425 – 2.0mm)	Fine (0.075 – 0.425mm)	Silt& lay<0.075mm)	
1.	Soil sample -1	23	1.6	73	31	42	0	0	0	9	91	CH
2.	Soil sample -2	11.5	1.95	31	18	13	0	20	42	16	22	SC
3.	Soil sample -3	8	2.13	34	16	18	10	8	33	15	34	SC

Table 2. UCS values for Polycom treated clay soil (soil sample-1) for different curing periods

Soil treatment specification	Un-treated	Immediate (without curing)	1 day curing	3 days curing	5 days curing
Unconfined Compressive Strength (UCS), kg/cm^2	6.25	13.5	14.25	16	16.25

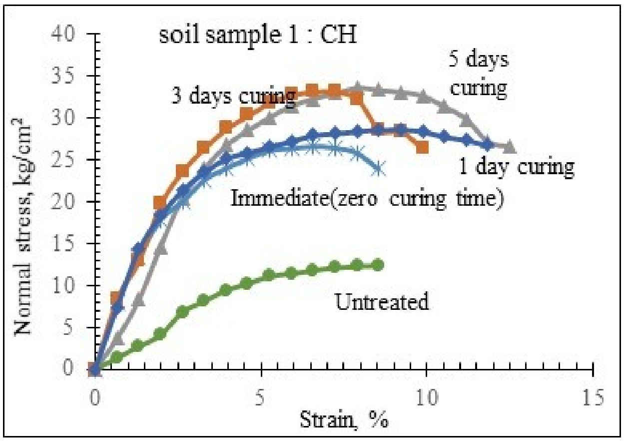

Fig. 1 Comparison of UCS of Polycom treated clay of high compressibility (CH) - soil sample-1 for different curing periods

The variation of UCS of clay for different curing periods with Polycom water is shown in Fig.1. Untreated soil i.e. without addition of Polycom is first tested for its compressive strength. Clay samples are compacted to maximum density after mixing with required amount of Polycom water (equal to OMC). UCS samples are then extracted and kept in desiccator for curing period. UCS increases with increase in curing period as mentioned in Table .2. The increase is about 116 %, 128% and 160% for zero, one day and 5 days curing periods respectively with respect to untreated soil. UCS is almost the same for 3 days and 5 days of curing periods.

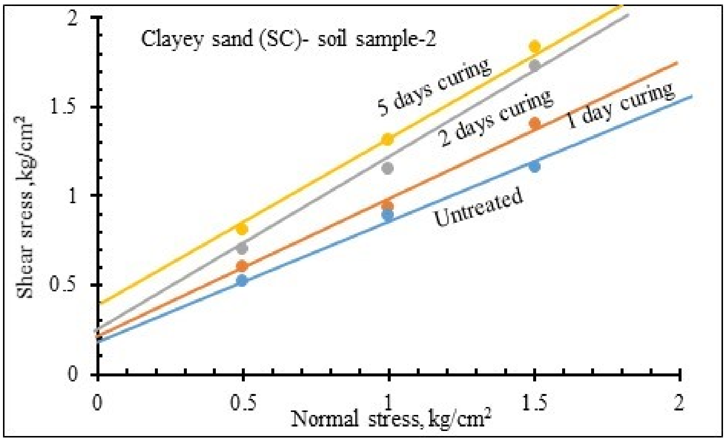

Fig. 2 Shear stress vs normal stress variation of Polycom treated clayey sand (SC) -soil sample-2 for different curing periods

Shear stress versus normal stress variation of Polycom treated clayey sand is depicted in Fig.2. Soil without addition of Polycom has a cohesion, c of 0.18 kg/cm^2 and an angle of internal friction of 37^0. Cohesion of the soil increases with increase in curing period upon addition of Polycom. It increases by about 122% with respect to cohesion of untreated soil sample. The friction angle increases from 37^0 to about 50^0 which indicates a better improvement in overall shear strength of the soil. Table 2 presents the shear strength parameters obtained for Polycom treated clayey sand (soil sample -2). Detailed investigations are required to find the optimum design parameters like curing period, compaction energy, percentage of polycom etc. for maximum benefit.

Table 3. c, ϕ values for Polycom treated clayey sand (soil sample-2) for different curing periods

Soil treatment specification	Untreated	Immediate (without curing)	3 days curing	5 days curing
Cohesion(c), kg/cm^2	0.18	0.2	0.25	0.4
Angle of internal friction, (ϕ)	37^0	43^0	48^0	50^0

Unlike the untreated samples, the effective bonding in Polycom treated samples was significant. It is believed that the polymeric stabiliser was able to bind the granular particles effectively due to the relatively small amount of fines and specific surface area. In other words, Polycom molecular encapsulates the soil particles and upon drying leaving an elastic membrane structure, which acts as a damper sheet that made the application of high compactive effort possible. Also, this bonding increased the contact points between the soil particles, resulting in further increase in frictional resistance force [4]. The Polycom molecules were able to coat most of the clay particles in the Clayey Sandy soil, and increases the cohesion and internal friction forces. This can be attributed to the nature of the soil gradation and fines contents. Clayey Sandy soil consists of adequate proportions of particle sizes that increase inter-particle contact area among large and fine particles and hence, enhancing the bonding action of the Polymer-treated soils [4].

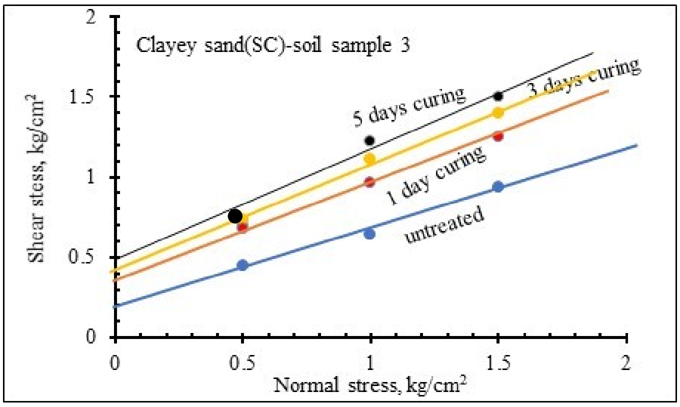

Fig. 3 Shear stress vs normal stress variation of Polycom treated clayey sand (SC) sample - soil sample-3 for different curing periods

Fig .3 depicts the variation direct shear test results of clayey sand (soil sample-3) for different curing periods. Similar variation as depicted in Fig.2 is observed but with little variation in percentage of improvement in both cohesion, c and angle of internal friction, ϕ. Untreated soil possess cohesion of 0.2 kg/cm^2 which increases to 0.35 kg/cm^2, 0.4 kg/cm^2 , 0.5 kg/cm^2 for 1 day, 3 days and 5 days of curing period respectively.

Table 4. c, ϕ values for Polycom treated clayey sand (soil sample- 3) for different curing periods

Soil treatment specification	Untreated	1 day curing	3 days curing	5 days curing
Cohesion(c), kg/cm^2	0.2	0.35	0.4	0.5
Angle of internal friction, (ϕ)	32^0	39^0	43^0	45^0

5. Limitations of the study

Paper presents the results of soil samples treated with Polycom, a polymer based additive. Polymer based additives are better substitution for traditional additives like lime, cement etc. Tests are conducted on limited number of soil samples and the conclusions are drawn based on the results of three soil samples. Detailed investigations are required to confirm and conclude with benefits of using the polymers for soil stabilization.

6. Conclusions

1. Polycom increases the strength of clayey soil to almost double the insitu soil strength with no curing time. Curing period influences the gain in UCS for clayey soils. UCS increases with increase in curing period. Detailed investigation is required to find the optimum curing time to achieve maximum UCS.
2. Both cohesion and angle of internal friction have increased for Polycom treated clayey sand samples. The increase is attributed to Polycom molecular encapsulation around each soil particle and forms a coat on most of the clay particles which facilitates the process of compaction. The increase in cohesion and angle of internal friction is about 150% and 40% respectively.

7. References

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