Effect of Rapid Polymer Treatment on the Liquid Limits of Clay Soils

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Abstract: In this study clay soils in the liquid limit range of 39% to 83% were treated with water soluble polymer (acrylamide) to investigate the effect on the liquid limit. Both field soils (total of 7) and a commercially available soil (kaolinite) were tested in this study. In this investigation 2.25% and 4.5% of polymers (by the weight of solids in the soil) were used to treat the moist field clay soils. The treated field soils and kaolinite were tested for the changes in the liquid limits 24 hours after polymer treatment, considered to be a rapid treatment compared to the other conventional methods. The liquid limits of the soils of the treated soils reduced by 15% to 40% based on the soil and amount of polymer used. Compared to the 2.25% polymer treatment, 4.5% polymer treatment showed greater reduction in the liquid limits of all the soils tested.

1. Introduction:

Clay soils are encountered in all types of surface and underground constructions. Based on the geological formation, the clay soils have highly varying short-term (swelling, strength) and long-term properties (consolidation, fluctuating swelling and strength) that will influence the construction and durability of the long-term stability of the supporting structures. Clay soils cover one-fourth of the surface area of the United States and are found in every state (Jones et al., 1987). Compared to other natural disasters and damages due to clay soils is probably the least publicized natural hazard. The expansive clay soils alone inflict at least $2.3 billion per year in damages to houses, buildings, roads, and pipelines. Also it has been reported that damages from expansive soils are more than twice that which is caused by floods, tornadoes, and earthquakes (Jones et al., 1987).

Clay soils cause problems in certain areas with repeated periods of rainfalls and droughts. Expansion of clays in the presence of moisture is a problem that causes extensive damages to physical infrastructure, such as dams, irrigation canals and roads (Inyang et al., 2007). Wet and dry cycles in clayey soils would cause volumetric changes which may result in considerable damage to the surrounding structures. To overcome the swelling problems caused by expansive soils, many innovative techniques such as stabilization by chemical additives, pre-wetting, squeezing control, overloading, and moisture control have been suggested (Al-Rawas et al., 2005). Stabilization of these problematic soils by employing a suitable additive is one of the preferred techniques of dealing with such soils (Inyang et al., 2007; Vipulanandan et al. 2016).

As such, a variety of additives, which are being employed to stabilize the expansive soils for some time, can broadly be classified into three main categories: cementitious, non-cementitious and chemical additives. Many studies have shown that addition of lime increases optimum water content, shrinkage limit, shear strength, and reduces maximum dry density, swelling potential, liquid limit, and plasticity index of the soil (Bell et al., 1996; Al-Rawas et al., 2005). Although, lime stabilization is well suited for almost any type of expansive soil and is economically available additive, constructability issues and long-term durability issues often make its usage not feasible for all conditions. In addition, effective lime-soil reaction demands elevated temperature that is greater than 40oF. Below this temperature, lime usually remains in a dormant state and does not initiate the reaction (Reddy et al., 2015). A new method of stabilization has been developed using water soluble acrylamide polymer (Mohammed and Vipulanandan 2014, 2016) which was found to be effective, economical and time-saving.

2. Objectives:
Overall object was to investigate rapidly treating CL and CH soils using polymer solutions to reduce the liquid limits of the field clay soils and compare it to commercially available kaolinite clay.

3. Materials and Method:
The moist field soils were treated with 2.25% and 4.5% polymer (based on the weight of solids in the soil). The clays used for the study included kaolinite and field soils. To examine the range of application of the proposed polymer treatment required testing of soils representing a wide range of liquid limit.

Liquid Limit: The liquid limit test on the commercial and field soils were performed using the ASTM D4318-17 before and after treatment.

Polymer: The acrylamide polymer had two solutions, A and B, to polymerize the product. Solution A was acrylamide monomer with triethanolamine (accelerator/promotor) in water and Solution B was ammonium persulfate (initiator/catalyst) in water (Table 1). When 15% polymer solution was used in varying amounts, 15% and 20% by the weight of solids in the soil, it represented polymer addition of 2.25% (Mix C) and 4.5% (Mix D) of polymer addition respectively.

Table 1 Compositions of 15% Polymer Solutions

Polymer Solution	**SOLUTION A (50 g)**			**SOLUTION B (50 g)**		**Remarks**
	Monomer AV 100 (g)	Accelerator AV101 (g)	Water (g)	Initiator AV102 (g)	Water (g)	
15%	15	0.2	34.8	0.5	49.5	Solutions A and B were used separately to treat the soils

<u>15% polymer solution</u>: In this mix solution A was mixed with solution B and the polymer content (monomer) was 15% by weight. The setting time of the polymer was 840 sec (14 min). In order to investigate the effect of this polymer solution, two percentages (based on the weight) were used with respect to the solid content in the soil. When 15% (by weight) of the polymer solution was used to treat the soil it amounted to addition of 2.25% of polymer (by weight) to the soil (Mix C). When 30% (by weight) of the polymer solution was used to treat the soil it amounted to addition of 4.5% of polymer (by weight) to the soil (Mix D). In this study, solution A was first added to the soil and mixed thoroughly. Later, solution B was added and it had higher amount of water compared to solution A, to ensure better mixing (workability) and effective distribution of the additive in the soil.

3.2 Methods of Testing

Mixing polymer with kaolinite clay: Solution A was introduced into the soil and mixed homogeneously using a spatula, for a time period of 15 min to ensure uniform distribution. Later, solution B was poured into the sample and ensured that it is distributed and results in polymerizing the soil. The sample was left for a curing period of 24 hours to ensure effective polymerization and then was used for the proposed methods of testing.

Mixing polymer with field clay:

The field soil samples were broken down into small lumps to ensure uniform distribution of the polymer components when mixed. Solution A and solution B were added with a time lapse of 15 min and a suitable polymerization time was selected to improve the efficiency of mixing and polymerization. After 24 hours of curing the liquid limit tests were performed.

Concentration and Dosage of Polymer

Various combinations of polymer concentration and dosage have been used and the study was narrowed those which proved to treat the problem of this study effectively. The details have been summarized in Table 2.

Table 2 Concentration and dosage of polymer

Mixes	**Concentration (X%) Of polymer solution** (X g of polymer in 100 mL of water)	**Solution Amount (Y%)** (Y g of polymer solution mixed to 100 g of solids)	**Polymer Dosage (Z%)** (Z g of pure polymer added to 100 g of solids)
Mix C	15 %	15	2.25
Mix D	15 %	30	4.5

4. Results and Discussion:

Kaolinite: The liquid limit was 48%, a CL soil.

Field Clay Soils: Total of 7 field clay soils were tested. The Liquid limits varied from 39.7% to 83.1% (Table 3). The natural moisture contents in the soils varied from 17% to 28%.

Polymer Treatment:

After treatment with 2.25% and 4.5% pure polymer dosage to the weight of solids, the liquid limits decreased by 15% to 40% based on the soil and amount of polymer and the results are summarized in Table 4. With 2.25% polymer treatment the liquid limit reduction varied from 15.6 % to 32.4%. With 4.5% polymer treatment the liquid limit reduction varied from 22.5 % to 40.4%. The, kaolinite showed a reduction in liquid limit from 48% to 43% and 41% with dosage of 2.25% and 4.5% polymer respectively.

Table 3 Changes in Liquid Limit (LL) for Polymer Treated Clay Soils

Sample No.	**Polymer Content**						
	0%	**2.25%**			**4.50%**		
	LL	**LL**	**Change in LL**	**% Change**	**LL**	**Change in LL**	**% Change**
1 (CL)	39.7	31	-8.7	21.9%	27	-12.7	32.0%
2 (CL)	46	38.6	-7.4	16.1%	35.4	-10.6	23.0%
3 (CH)	50	42.2	-7.8	15.6%	37.4	-12.6	25.2%
4 (CH)	55.5	46.6	-8.9	16.0%	43	-12.5	22.5%
5 (CH)	61.6	43.5	-18.1	29.4%	40.1	-21.5	34.9%
6 (CH)	71.6	48.4	-23.2	32.4%	42.7	-28.9	40.4.%
7 (CH)	83.1	60.4	-22.7	27.3%	56.2	-26.9	32.4%
Kaolinite	48	43	-5	21.9%	41	-7	21.9%

5. Conclusion:

After 2.25% and 4.5% polymer treatment, the liquid limit (LL) of the clay soils reduced. The following conclusions are advanced:

(1) Polymer treatment was effective 24 hours after treatment and reduced the liquid limits of the field clay soils treated with the natural moisture contents.

(2) Amount of reduction in the liquid limit varied with the initial liquid limit of the clay soils and the amount of polymer used for treatment. With 2.25% polymer treatment the liquid limit reduction varied from 15.6 % to 32.4% for the field clay soils. With 4.5% polymer treatment the liquid limit reduction varied from 22.5 % to 40.4% for the field clay soils.

6. Acknowledgement

The study is being supported by the City of Houston. Sponsors are not responsible for any of findings and conclusions.

7. References

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