

# Effect of Polyacramide as Drilling Fluid in Kuttanadu Soil

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**ABSTRACT:** Proper attention is to be given for borehole stabilisation during cast in- situ piling. Otherwise the concrete shaft of the pile gets affected with collapse of soil in the borehole. Bentonite support fluids are generally used for borehole stabilization. Recently polymer fluids are also used widely as an alternative to Bentonite slurry. This paper deals with the effect of polyacrylamide as borehole fluid on the engineering properties of Kuttanadu soil. The addition of Polyacrylamide in Kuttanadu soil has changed the structure of soil matrix and its geotechnical properties. The unconfined compressive strength of specimens has increased with increment of polymer contents. From the strength aspect of Kuttanadu soils, the optimum polyacrylamide content estimated as 2%.

## I. INTRODUCTION

Soft soils cause deformation and may lead to failure of foundations and structures. The soil in Kuttanadu region, Kerala is very soft and has poor drainage characteristics. It may have poor bearing capacity and large settlements when subject to loads. Pile foundation is most suitable for heavy structures founded on this soil type. During cast-in-situ piling bentonite slurry is the drilling fluid used for borehole stabilisation. The main demerits of this drilling fluid are its slippery nature and sticking to the pile surface can affect its frictional resistance.

Recently use of bentonite slurry is substituted by polyacrylamide. This fluid has some advantages compared to bentonite. It provides a clean working condition near the pile site, helps to the easy movement of man and machinery and the speed of construction can be increased. The mixing up of polyacrylamide with soil near the pile changes its microstructure and engineering behaviour. The presence of polyacrylamid in the soil near the pile can change its load carrying capacity.

This paper describes study conducted to investigate the effect of polyacrylamide in the engineering properties and microstructure of Kuttanadu soil. In order to understand the effect of polyacrylamide on Kuttanadu soil, unconfined compressive strength and consistency limits were determined with and without polyacrylamide. The microstructure of polymer treated Kuttanadu soil samples were analyzed and measured by scanning electronic microscope (SEM). It is concluded that Polymer is dispersed in soil matrix as filler with in the soil particles. From SEM analysis it was noticed that, 0-2 % the polymer covers the voids and cross-link between soil particles.

## II. MATERIALS AND PROPERTIES

The Kuttanadu soil samples were collected from the Kainakari at a depth of 2m and at a groundwater level of about 1.5m below the ground surface. The initial geotechnical properties of these soils were obtained experimentally according to IS specification as shown in table 1.

TABLE 1. PROPERTIES OF SOIL SAMPLE

<i>Properties of soil</i>	<i>value</i>
Specific gravity	2.62
Gravel (%)	5.6
Coarse sand (%)	11.9
Medium sand (%)	19.5
Fine sand (%)	29.4

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Silt (%)	32.93
Clay (%)	0.67
Liquid limit (%)	27.7
Plastic limit (%)	37
Shrinkage limit (%)	18.9
<b>Compaction characteristics</b>	
Optimum moisture content (%)	11.74
Maximum dry density (g/cc)	2.05
CBR value (soaked) (%)	4.05
Plasticity index (%)	18.14

The polymer used in this investigation was polyacrylamide (C<sub>3</sub>H<sub>5</sub>NO)<sub>n</sub> with high molecular weight in granular form. Polyacrylamide is a polymer- synthesised as a simple linear- chain structure. It is not a toxic polymer. This polymer is commercially available, it is environmentally accepted. The polymer is used in a liquid state. The crystalline density and specific gravity are 0.8g/cc, 1.76 respectively[1].

**III. TESTING PROCEDURE**

The amounts of polymer added to the clay soil samples, as a percentage of the dry soil mass, were 0%, 0.5%, 1%, 2%, 3%, 4%, 5% and 6%.

**A. TEST FOR GEOTECHNICAL PROPERTIES OF SOIL**

The engineering properties were determined as per the Indian standards listed below.

1. Atterberg limits
  - a) Liquid Limit (IS:2720,part V)
  - b) Plastic Limit (IS: 2720,part V)
  - c) Shrinkage limit (IS: 2720, part VI)
2. Compaction (IS: 2720, part VII)
3. U C S Test (IS: 2720, part X)

**B. X-RAY DIFFRACTION TEST ON SOIL**

The primary use for X-ray diffraction analysis is the identification of crystalline phases for a large variety of thin film samples. Detailed knowledge about the clay particle is very important for long term environmental sustainability. The XRD analysis was performed to examine the formation of crystalline size of clay minerals in the soil sample as shown in Fig.1.

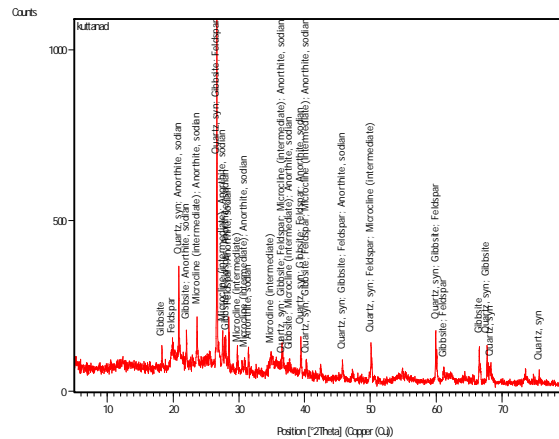


Figure 1. X-ray diffraction of Kuttanadu soil

**C. INFRARED SPECTROSCOPY (IR SPECTROSCOPY)**

IR spectroscopy deals with the infrared region of the electromagnetic spectrum. It covers a range of techniques, mostly based on absorption spectroscopy. As with all spectroscopic techniques, it can be used to identify and study chemicals. For a given sample which may be solid, liquid, or gaseous, the method or technique of infrared spectroscopy uses an instrument called an infrared spectrometer (or spectrophotometer) to produce an infrared spectrum. A basic IR spectrum is essentially a graph of infrared light absorbance (or transmittance) on the vertical axis vs. frequency or wavelength on the horizontal axis. Typical units of frequency used in IR spectra are wave numbers, with the symbol  $\text{cm}^{-1}$ . A common laboratory instrument that uses this technique is a Fourier transform infrared (FTIR) spectrometer.

FTIR (Fourier Transform Infrared Spectroscopy) is a effective analytical tool for screening and profiling polymer samples. Intertek FTIR laboratory testing expertise provides valuable quantitative and qualitative analysis for polymer and plastic materials[2]. FTIR identifies chemical bonds in a molecule by producing an infrared absorption spectrum. The resulting spectra produces a profile of the sample, a distinctive molecular fingerprint that can be used to easily screen and scan samples for many different components. Polymer and Plastics FTIR is an effective analytical instrument for detecting functional groups and characterizing covalent bonding information.

The FTIR pattern of polyacrylamide is given in Fig.2. The FTIR result reveal that the polyacrylamide consisted of functional group such as amide group ( $1680, 1520\text{cm}^{-1}$ ), alkyl – CH group ( $2941 \text{ cm}^{-1}$ ) and stretching –NH group ( $3625 \text{ cm}^{-1}$ ).Amide is the peak point in the graph. Hence we can confirm that the given polymer is polyacrylamide.

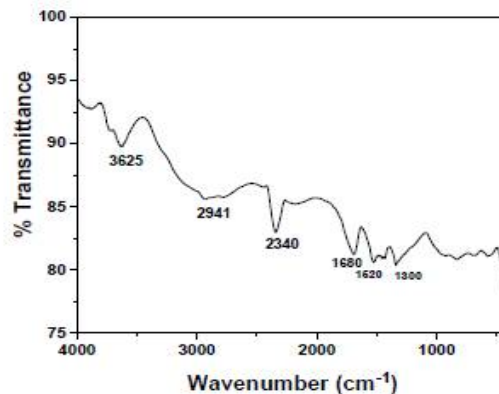


Figure 2. FTIR Pattern of Polyacrylamide

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**IV. RESULTS AND DISCUSSION**

Engineering properties of the soil sample was determined. The same tests were conducted with soil samples with the addition of polymer. Engineering properties like liquid limit, plastic limit shrinkage limit, compaction and compressive strength were determined.

**A. CONSISTENCY LIMITS**

It has been found that adding the polyacrylamide to soil can significantly alter the consistency behaviour of the tested samples due to micro structure change. The variation of liquid limit, plastic limit and shrinkage limit are given in the Fig. 3, 4, 5 &6 respectively.

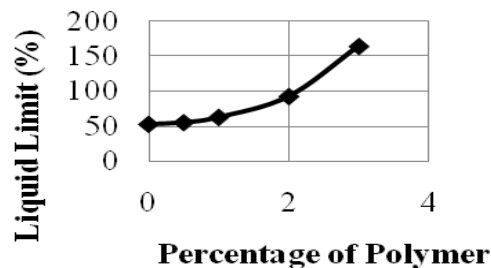


Figure 3. Variation of liquid limit with percentage of polymer

From fig. 3, it is observed that the liquid limit of soil increased with increase of polymer addition into the kuttanadu soil samples. It shows the affinity of drilling fluid to water.

Initially the plastic limit of soil is increasing with percentage of polymer gradually as shown in Fig.4. Up to 1 percentage, plastic limit goes on increasing. And after there is only slight change in the plastic limit and it was difficult to roll in to the thread. It was unable to do the test on soil for percentage more than 2. Samples cannot roll it in to 3mm thread because of the formation of gel and moulding capacity of soil diminishes.

Shrinkage limit of the soil increased with increase in polymer as Fig.5. The test was carried out after air dry and oven dry at 110oC. The polymer content increases the overall shrinkage limit of the soil. Initially there is a steady increase of shrinkage limit. But after 2 percentage, the shrinkage limit increases vigorously. It shows that more water is required for more polymers.

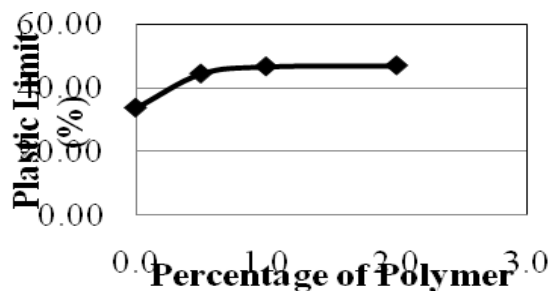


Figure 4. Variation of plastic limit and percentage of polymer

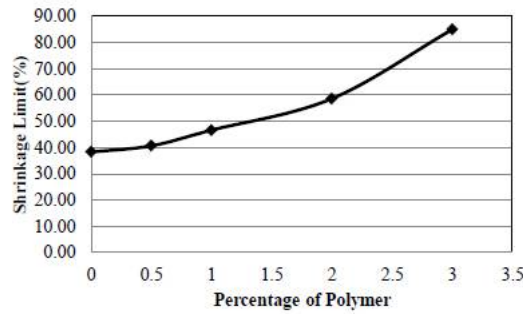


Figure 5. Variation of shrinkage limit with percentage of polymer

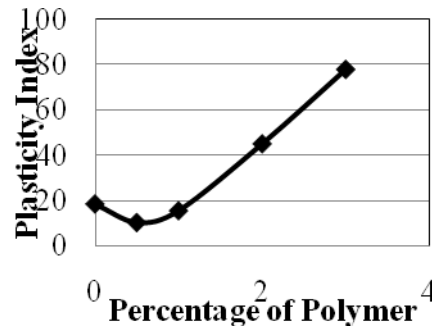


Figure 6. Variation of plasticity index with percentage of polymer

From fig. 6 it is noted that plasticity index of the soil polymer composite is increasing with percentage of polymer. Initially there is a decrease in the plasticity index of the soil. After that the plasticity index is increases with percentage of polymer.

**B. VARIATION OF COMPACTION CHARACTERISTICS WITH PERCENTAGE OF POLYMER**

From the graph, it is clear that maximum density of the soil sample is decreasing with polymer. When polymer is added to the soil sample dry density of the soil is decreasing. This is due to the fact that the polymer occupies the void spaces in the soil and it decreases the net weight of sample due to increased volume.

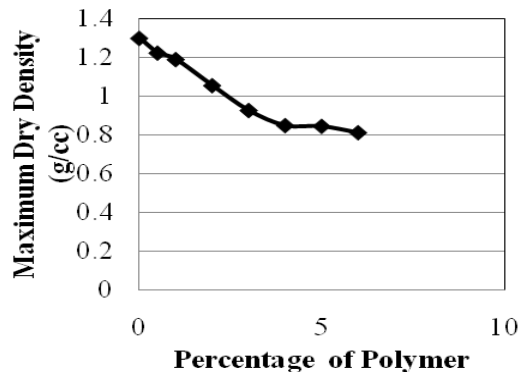


Figure 7. Variation of optimum water content with percentage of polymer

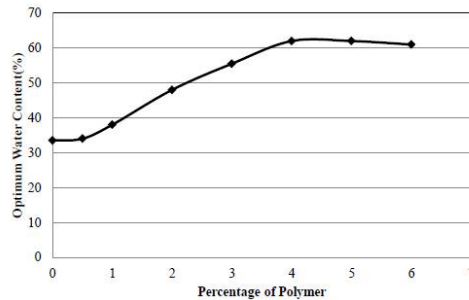


Figure 8. Variation of maximum dry density with percentage of polymer

The graph of optimum moisture content with percentage of polymer shows that the optimum moisture content is increases with polymer content. Up to 4 percentage of polymer, optimum moisture content of the soil sample increases. But after that there is slight decrease in the optimum water content. Polymer has the ability to absorb excess water. Hence the optimum water content of the modified soil is more.

### C. UNCONFINED COMPRESSIVE STRENGTH

In order to understand the effect of polyacrylamide on the stabilization of soil sample, laboratory tests on the unconfined compressive strength is performed. The graph shows that the unconfined compressive strength of clay-polymer composite after 24hours, after 7 days and after 14days. The compressive strength of soil is increasing with polymer. After curing for one day, the strength increases quickly and after seven days of curing strength goes on increasing. But after some point the compressive strength reducing. Compressive strength after 7days and 14dayas also increases.

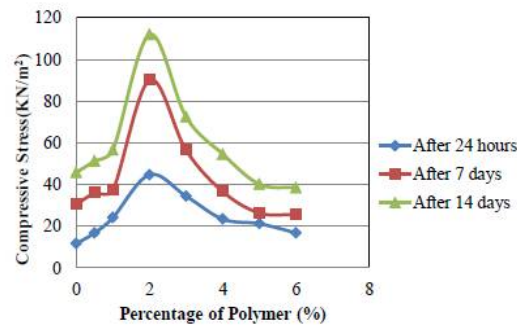


Figure 9. Comparison of compressive strength at various curing time

The results indicated that polyacrylamide- soil stabilizer can significantly increase the unconfined compression strength. The unconfined compression strength increased with the increasing of curing time and the variation mainly occurs in the first 24-hour

### D. SCANNING ELECTRON MICROSCOPY

SEM was also applied to study the behaviour of soil polymer composite. SEM image of modifies clay at a polymer concentration of 0.5%, 1%, 2%, 3%, 4%, 5% and 6% taken as shown in figure 10 to 13 . The polymer bound on the soil and forms a modified soil structure. Polymer and soil forms a good bond between each other. Up to 2 percentage of polymer it improves the strength of the soil. But after 2 percentage of polymer, the polymer soil bond reduced and the polymer forms a film on the soil. This will increases the void spaces and decreases the soil- polymer bonding. Hence the compressive strength of the soil decreases after 2 percentage of polymer.



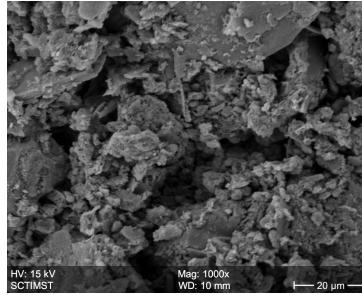


Figure 10. SEM image of clay

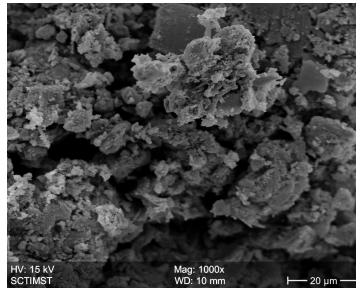


Figure 11. SEM image of clay with 0.5% polymer

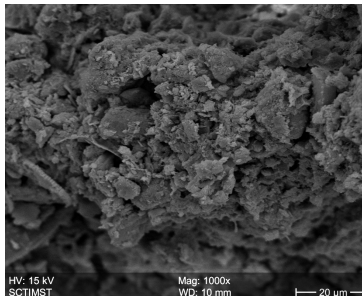


Figure 12. timeSEM image of clay with 1% polymer

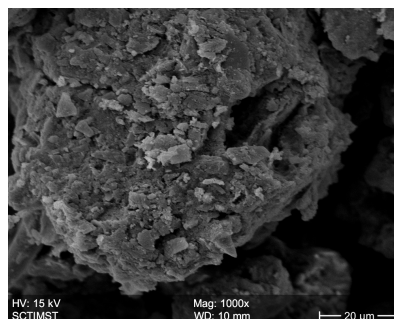


Figure 13. timeSEM image of clay with 2% polymer

## V. CONCLUSION

Liquid limit and plastic limit of the Kuttanadu soil increased with 0-1 % of polyacrylamide addition. Beyond 1 % there was a drastic increase in LL. Shrinkage Limit increased drastically by the addition of Polyacrylamide. The dry

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density and OMC of the soil decreased with Polyacrylamide addition. The unconfined compressive strength significantly increased with curing time.

From SEM analysis it was noticed that, 0-2 % the polymer covers the voids and cross-link between soil particles. After 2 % along with polymer, soil became large size floccules and void size increased. Hence the unconfined compressive strength increased up to 2 % of polymer addition and beyond 2 % there was a sudden decrease in the unconfined compressive strength.

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