# Application of Geopolymer in Stabilization of Soft Clay

**Arun.E, P.D.Arumairaj, S Janaki Raman**

***Abstract—Stabilization of soil has become imperative in the recent past. This study mainly concentrates on the application of geopolymers in stabilization of soft clay. Geopolymers are materials that are covalently bonded which forms amorphous network. Fly ash, metakaolin, ground granulated blast furnace slag, rice husk ash, and few more materials were earlier used for geopolymerization. In this study, ash from Prosopis juliflora was used. Prosopis juliflora is an invasive plant which has created a negative biodiversity that sucks too much of groundwater by deep penetration of their roots. This results in quick ground water depletion. Mass cutting of this plant makes this as a waste material. Geopolymer generally needs an alkali material to be added to it. Sodium hydroxide and Sodium silicate were used as alkali activators. The molar concentration of Sodium hydroxide was varied between 4 M, 8 M and 12 M. 8M gave maximum UCS value. The addition of Prosopis juliflora ash was varied between 5%, 15% and 25%. Addition of 15% ash gave maximum UCS value. The soil was characterized by performing Unconfined Compressive Strength (UCS) test before and after stabilization. The microstructural studies of Prosopis juliflora ash was performed using Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Analysis (EDAX) tests.***

***Index Terms: Geopolymer, Soft clay, Prosopis juliflora, UCS Test, SEM, EDAX***

## 1. INTRODUCTION

Soft clay lacks enough strength to withstand the load from the structure. The strength of this type of soil has to be increased to make use of the soil for any construction. The stabilization of soil can be performed by mechanical, physical, chemical, thermal means. The ground improvement techniques like deep compaction, grouting, preloading, etc., are used widely. In this study, chemical stabilization is chosen. Cement and lime has been used in improving the properties of soil widely. One of the major issue in using cement is that, the amount of $CO_2$ in the atmosphere is increased during manufacturing. The Prosopis juliflora plant is considered as an invasive weed everywhere. The roots of this plant can penetrate deeper into the ground and sucks the water from very deeper layers. Other plants find it difficult to grow alongside it. Geopolymer is an inorganic alumino silicate material formed by polycondensation of silica and alumina. Geopolymers can be synthesized either by alkaline medium or acidic medium. In this study, geopolymer is synthesized by alkaline medium. Geopolymer cements and concretes, geopolymer resins and binders are still in development in the construction industry.

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## 2. MATERIALS

The materials used in this study are as follows:

### 2.1 SOIL:

The soil was collected at a latitude of 11.0182°N and longitude of 76.9360°E. The top soil is removed upto root zone depth. Soil sample was then collected for this study. The soil sample used in this study is categorized as soft clay.

### 2.2 PROSOPIS JULIFLORA ASH:

The barks of prosopis juliflora plant were cut into pieces and burnt into ash. Ash thus collected was used in this study. The micro structural studies were also conducted for ash to know its composition of minerals present. The specific gravity of this ash was found as 2.48.The ash was sieved through 75 micron sieve and the used.

### 2.3 ALKALI ACTIVATORS:

The most commonly used alkali activators are sodium hydroxide with sodium silicate and potassium hydroxide with potassium silicate. In this study, sodium hydroxide with sodium silicate was chosen as alkali activators as they are cheaper than other alkali activators and they maintain higher capacity to detach the silicate and aluminate monomers.

#### *2.3.1 Sodium hydroxide:*

Sodium hydroxide is an inorganic compound with the molecular formula NaOH. It was collected in pellets form and dissolved in water to obtain the required molar concentration. This solution forms a colourless liquid which is denser than water. In this study, the molar concentration of Sodium hydroxide was varied as 4M, 8M and 12M. The molecular weight of Sodium hydroxide is 40 g/mol.


**Fig:1: NaOH and $Na_2SiO_3$ used**


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### *2.3.2 Sodium silicate:*

Sodium silicate is also called as water glass or liquid glass consists of great alkaline nature in it. It was used as a deflocculation agent along with sodium hydroxide. It has excellent adhesive quality as well.

## 3. METHODOLOGY

The soil was tested for its properties like the index properties, engineering properties and strength properties. From the tests conducted, the soil was classified as soft clay soil. Since the strength of the soil was found to be low, the properties of the soil has to be improved. For that geopolymerization process was chosen for stabilizing the soil.

The sodium hydroxide pellets were dissolved in water to obtain the required molar concentration. This alkaline solution was prepared one day before mixing with the soil samples for any test. This was done in order to maintain a constant temperature of the solution during the preparation of samples for all the tests performed.

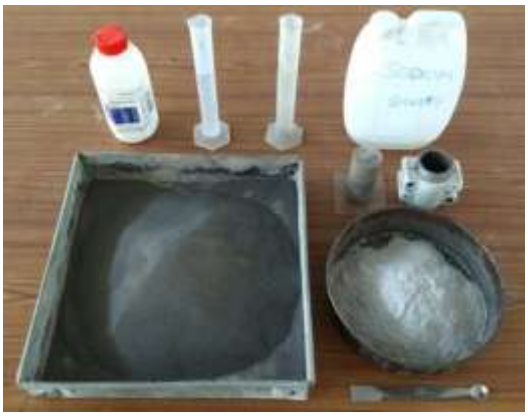


**Fig:2: Preparation of specimen for UCS test**

Unconfined Compressive Strength test was performed before and after stabilization of the soil. The UCS specimens were prepared by mixing Prosopis juliflora ash of 5%, 15% and 25% with the soil by weight. The amount of alkali activators used for UCS test was kept at 20% (10% NaOH & 10% $NA_2Si0_3$) and 10% of water by weight.

**Fig:3: UCS specimen kept for curing**

The index properties and engineering properties of the soil sample were:

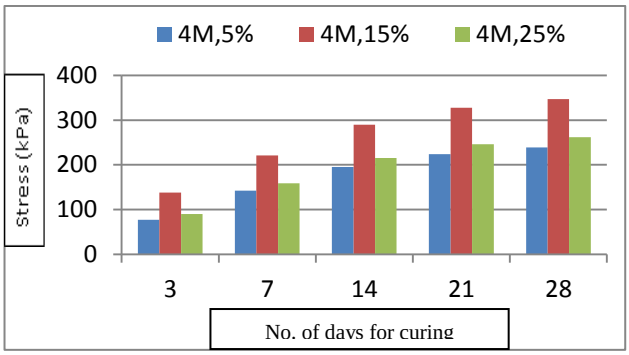
Percentage of clay = 60%
Percentage of sand = 40%
Liquid limit = 53%
Plastic limit = 22%
Specific gravity = 2.58
Differential free swell index = 40%
Unconfined Compressive Strength = 50 kPa

## 4. RESULTS

The test specimens were kept for curing in the range of 3, 7, 14, 21 and 28 days to study the variation in strength.

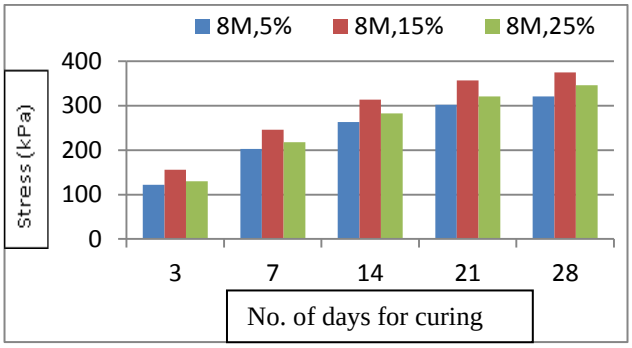
Graph:1 shows the UCS test results with the molar concentration of NaOH at 4M addition of 5%, 15% and 25% of ash

### 4.1 Unconfined Compressive Strength:



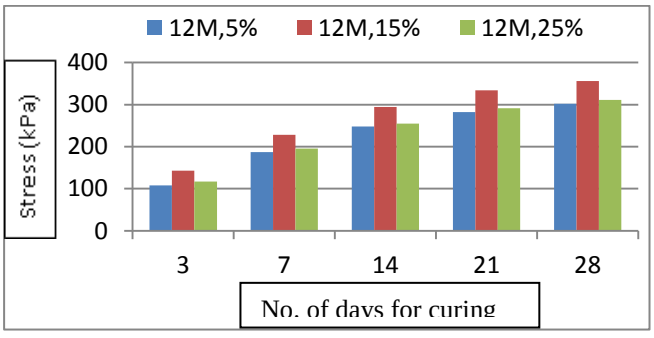

**Graph:1: UCS test results with ash content of 5%, 15% and 25% with 4M of NaOH**

Graph:2 shows the UCS test results with the molar concentration of NaOH at 8M addition of 5%, 15% and 25% of ash




**Graph:2: UCS test results with ash content of 5%, 15% and 25% with 8M of NaOH**

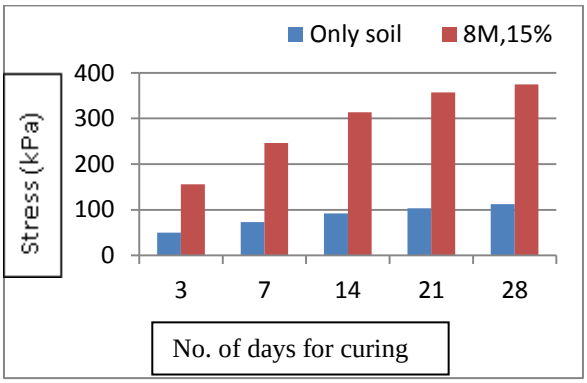
Graph:3 shows the UCS test results with the molar concentration of NaOH at 12M addition of 5%, 15% and 25% of ash




**Graph:3:UCS test results with ash content of 5%, 15% and 25% with 12M of NaOH**

It was seen that the UCS value increased with increase in the number of days for curing.

Graph: 4 shows the UCS test results for unstabilized soil and stabilized soil at molar concentration of NaOH at 8M and addition of 15% of ash.




**Graph:4: Comparison of unstabilized and stabilized soil from UCS test result**

### 4.2 Scanning Electron Microscope (SEM):

It was observed from the results of Scanning Electron Microscope (SEM) analysis that the molecules present in the ash have become very compact which indicates better binding property.

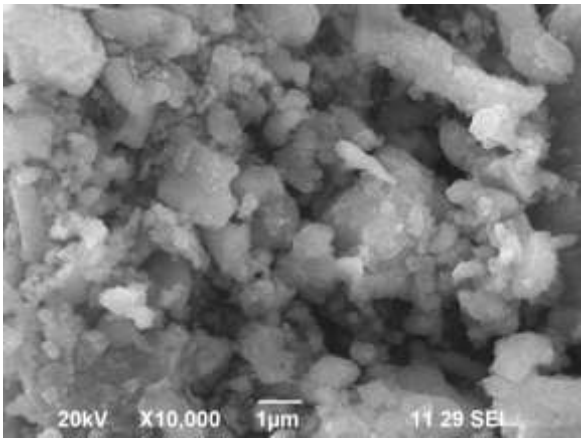



**Fig:4(a):SEM analysis of Prosopis juliflora ash**

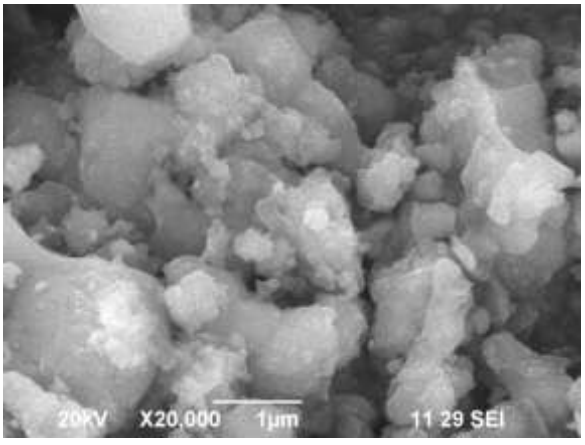



**Fig:4(b):SEM analysis of Prosopis juliflora ash**

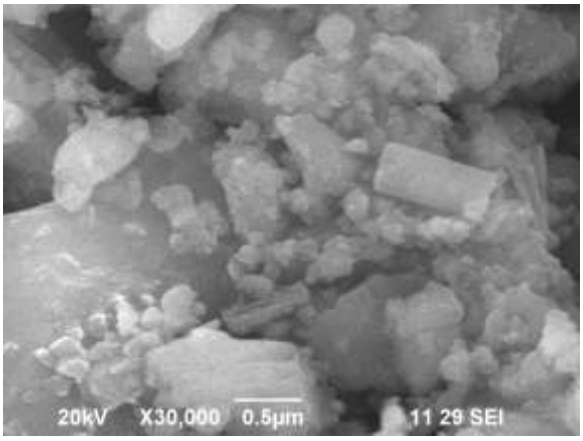



**Fig:4(c):SEM analysis of Prosopis juliflora ash**

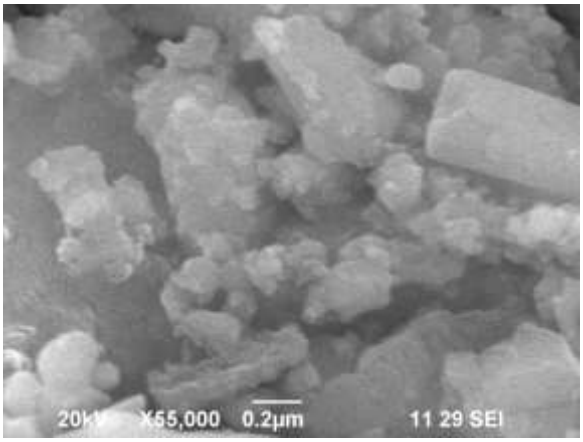



**Fig:4(d):SEM analysis of Prosopis juliflora ash**

### 4.3 Energy Dispersive X-Ray Analysis (EDAX):

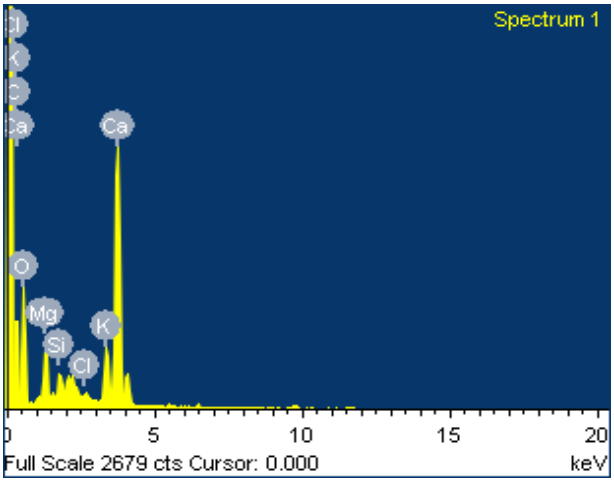



**Fig:5:EDAX test of Prosopis juliflora ash**

From the results of Energy Dispersive X-Ray Analysis (EDAX), it was found that the chemicals such as Silicon dioxide and Calcium carbonate were in large amount.

## 5. CONCLUSIONS

- It is concluded from the UCS test that the optimum proportion of ash is 15%. The UCS value is less at 5% and 25%.
- It is concluded from the UCS test that the optimum molar concentration of NaOH is 8M. The UCS value is less at 4M and 12M molar concentration.
- The UCS strength increases with increase in the number of curing days.
- From UCS test, it is concluded that the rate of increase in strength is maximum from 3 to 7 days of curing. However, there was no considerable amount of increase in strength after 28 days of curing.
- The stabilized soil gives maximum UCS value of 375 kPa at molar concentration of NaOH of 8M and ash content of 15% after 28 days of curing. The unstabilized soil gives maximum UCS value of 112 kPa after 28 days of curing.
- From the Scanning Electron Microscope analysis, it is concluded that the molecules have become compact with the addition of Prosopis juliflora ash.
- From the Energy Dispersive X-Ray Analysis, it is observed that the presence of Silicon dioxide and Calcium carbonate enhances the geopolymerization process.

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