International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 2, pp: (65-73), Month: October 2018 - March 2019, Available at: www.researchpublish.com

# Soft Soil Stabilization with Alkali Activated Sugarcane Bagasse Ash

Jeevan Rana Magar[1], Dr. Indra Prasad Acharya[2]

[1,2]Department of Civil Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal

*Abstract:* **Many civil engineering structures constructed on problematic soils like soft soil, swelling soil etc. faces a risk of failure due to insufficient bearing capacity and excessive settlement. Soft soils are typically replaced by some strong materials like crushed rock, hard soils etc. or treated with other cementing material for better engineering properties. High cost and negative environmental effects of traditional stabilizers like lime and cement etc. and the problem of disposal management of agriculture industrial wastes require the investigation of the potential use of agriculture industrial waste in the stabilization of these problematic soils that replaces the use of the traditional stabilizer in a project partially or completely. In this paper one dimensional compressive behavior (UCS) of the soft soil stabilized with sugarcane bagasse ash, by-products of sugar mill activated by alkali activator (NaOH & $Na_2SiO_3$) has been presented by performing laboratory tests at various proportion of bagasse ash content (15%, 25%, 35% of total solid mass), concentration of alkali (8M, 10M & 12M) and activator/alkali ratio (0.25, 0.45 & 0.65) at different curing periods (7, 14, 28 & 56 days). Test results showed a high reactivity of alkali-activated binder promoting the strength development. UCS tests showed that maximum strength of 0.41 MPa is obtained for AB-25-12-0.25 mixture which is 1.78 times and 78.3% higher than raw soil at 7 days curing. Likewise 0.51 MPa for AB-25-12-0.25 mixture which is 1.89 times and 88.9%, 0.56 MPa for AB-25-12-0.45 mixture which is 1.93 times and 93.1% and 0.59 MPa for AB-25-10-0.65 mixture which is 1.97 times and 96.7% higher than raw soil at 14, 28 and 56 days curing respectively. The optimum bagasse ash content for soil stabilization is found to be 25% of total solids.**

*Keywords:* **Soft soil, sugarcane bagasse ash, alkali activator, stabilization, UCS.**

## 1. INTRODUCTION

The soft soil typically characterized as a soil with low shear strength, high water content, highly compressible and low permeability. The techniques utilized for enhancement of the properties of these soils are known as ground improvement techniques which can be done either by some mechanical method through densification and reinforcement or by a chemical method by adding some admixtures in the soil. Engineering properties of soft soil are generally improved by cement stabilization method.

$CO_2$ emissions from traditional binder because of carbonate decomposition during its production contribute 7% of total artificial $CO_2$ emission (Shahram Pourakbar, 2016). 1kg of carbon dioxide is released into the atmosphere from every 1 kg of cement manufacturing, which increases the greenhouse gas and possesses a serious threat to the global warming (Swain, 2015). The high cost of cement, negative environmental effects of cement stabilized soil resulted in the use of cheap, eco-friendly and sustainable materials for civil engineering application in low-cost infrastructures.

Among various industrial or agricultural waste materials, sugarcane bagasse ash (SBA) which poses serious environmental problem may be the most efficient for soil stabilization. Bagasse ash is produced by burning the bagasse to cogenerate heat and electricity at high efficiency in sugar mills. Bagasse ash has been used extensively as a standalone stabilizer in soil stabilization and as additives in the lime or cement based stabilization to reduce the lime or cement content in concrete production as well as soil stabilization.

(Chavan & Nagakumar, 2014), (Murari, 2015), (Sruthimol & Sindhu, 2015) and (Garg & Veena, 2016) investigated the soil properties using the various proportion of bagasse ash as a standalone stabilizer, they found that the plasticity index, compaction, CBR and UCS of problematic soil is significantly improved. (Hasan, 2016) studied the swelling behavior and strength of expansive soil treated with agricultural waste bagasse ash and hydrated lime at 3:1 ash to the lime ratio for 3, 7 and 28 days curing. Swelling behavior and CBR value of raw soil are significantly improved by the addition of bagasse ash and lime. (Taye, 2015), (Mir, Gupta, & Jha, 2016) and (Pallavi, Gowtham, & Kilbukar, 2016) evaluated the soil behavior using bagasse ash as an additive with cement and they observed soil behavior is improved greatly with bagasse ash content and significantly reduce the optimum cement dosage than cement used as stabilizer alone.

Alkali activation of materials containing silica and alumina has been extensively researched and found that it may be a potential alternative binder to the traditional binders (i.e. cement and lime) in construction. Alkali activation is the chemical reaction between the amorphous aluminosilicate source (precursor) with alkaline (usually Na or K) and alkali earth (Ca) metals. Activation process involves the dissolution of mineral aluminosilicate, thereof the hydrolysis, and condensation of the Al and Si components, resulting in the formation of three-dimensional complex structure, essentially amorphous, aluminosilicate gel (Davidovit, 1991). The aluminosilicate sources are the precursor materials like natural pozzolans (e.g. pyroclastic soils) or artificial pozzolans (e.g. fly ash, silica fume, steel sludge etc.) (Enza Vitale, 2017).

Various researches have been conducted for the production of fly ash-based alkaline activated binders applied in civil engineering application but limited research on the particular application to soil stabilization. (Stephanie, Cristelo, & Amandio, 2010), (Das & Parthi, 2013), (Kumar, 2015), (Mohankumar, 2016) and (Sultana & Srinivas, 2016) examined the physical and mechanical behavior of various types of soil using alkali-activated fly ash, the result revealed that addition of alkali-activated fly ash reduces the plasticity and liquid limit while increases the UCS and CBR value significantly.

Sugarcane bagasse ash may be an interesting source for preparing alkali-activated binders as it is rich in oxides of silica and aluminum as much as that of other fly ash for partial or complete replacement of traditional binders in soft soil stabilization and other civil engineering applications.

## 2. MATERIALS AND METHODS

### 2.1 Materials

#### 2.1.1 Soil:

In the present investigation, soft soil i.e. black cotton soil was collected from the premises of the UN Park at Jwagal, Lalitpur lies on the right bank of Bagmati river at the depth of about five feet. A little amount of soil was immediately sealed in plastic bags to preserve moisture content and prevent contamination with other substances in order to find natural water content. The soil was air dried, pulverized by rubber hammer into small crumbs passing through 2.36 mm and sieved.

#### 2.1.2 Sugarcane Bagasse Ash:

The sugarcane bagasse ash considered for the experimental investigation was collected from Lumbini Sugar Industries Pvt. Ltd., Sunwal Nawalparasi. For the phase pattern analysis of bagasse ash, samples were screened through 2 mm IS sieve and X-Ray Diffraction was carried out at National Academy of Science and Technology (NAST). Bruker D2 Phaser Diffractometer was used for characterization of the crystalline solid sample of bagasse ash.

#### 2.1.3 Alkali Activator Solution:

The alkaline activator solution used was a combination of sodium hydroxide and sodium silicate keeping the silicate to hydroxide ratio constant at 2. The sodium hydroxide in pallets form with a molecular weight of 40 gm/mole, the specific gravity of 2.13 at 20° C and 95-99% purity and sodium silicate having a molecular weight of 284.2 gm/mole and specific gravity of 1.5 were procured from the New Science House Pvt. Ltd., Thapathali Kathmandu.

### 2.2 Methodology

#### 2.2.1 Experimental Setup:

For the evaluation of effect of the ash/soil ratio (by dry mass) on the mechanical strength, three different bagasse ash percentages, regarding the total solids (soil + ash) weight, were used: 15, 25 and 35%, with alkali activator/ash ratios of 0.25, 0.45 and 0.65. Three different concentration of alkali solution were used: 8 Molar, 10 Molar, and 12 Molar in order to evaluate the effect of the alkali concentrations. The nomenclature of the alkaline activated binder treated soil specimens are given in the following way.

AB-SB-M-A/B

Where,

AB- alkali-activated fly ash treated sample; SB-represents the fly ash content in % by weight of total solids, i.e.15 for 15%, 25 for 25% and 35 for 35%; M-designates the activator concentration, i.e. 8 for 8 molar, 10 for 10 molar and 12 for 12 molar and A/B-ratio of alkaline activator by weight of ash.


**Fig. 1 (a) Untested Sample (b) Tested Sample**

### 2.2.2 One-dimensional Compression Tests:

Experimental investigation on the one-dimensional compression behavior of raw samples and alkali activated binder treated sample prepared using Harvard Miniature Apparatus cured for 7, 14, 28 and 56 days has been performed through standard unconfined compressive strength test.

## 3. RESULTS AND DISCUSSION

### 3.1 Material Characterization:

Results of geotechnical characterization of the black cotton soil done as per Indian standard IS 2720 are presented in Table 1. And phase diffraction pattern of bagasse ash is presented in Figure 2.

**Table 1: Geotechnical Properties of Soil**

| S.N. | Properties | Value |
|---|---|---|
| 1 | Coefficient of Uniformity (Cu) | 9.75 |
| 2 | Coefficient of Curvature (Cc) | 1.26 |
| 3 | Specific Gravity (G) | 2.22 |
| 4 | Maximum Dry Density (MDD) (gm/cc) | 0.539 |
| 5 | Optimum Moisture Content (OMC) (%) | 32.82 |
| 6 | Natural Moisture Content (%) | 22.82 |
| 7 | Liquid Limit (%) | 48.90 |
| 8 | Plastic Limit (%) | 29.30 |
| 9 | Classification | CI |
| 10 | Unconfined Compressive Strength (MPa) | 0.27 |

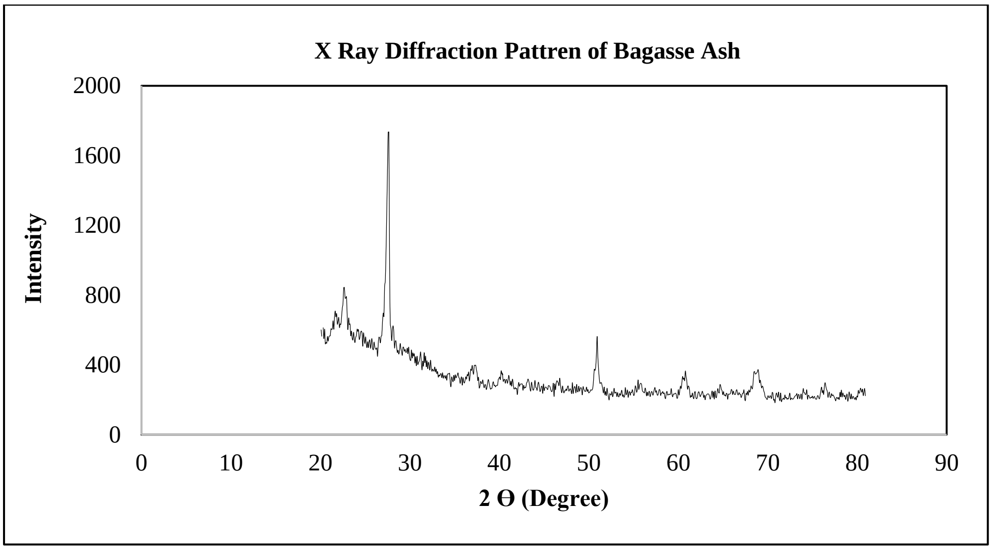


**Fig. 2 X Ray diffraction patterns of sugarcane bagasse ash**

### 3.2 Effect of Curing Time on UCS Values

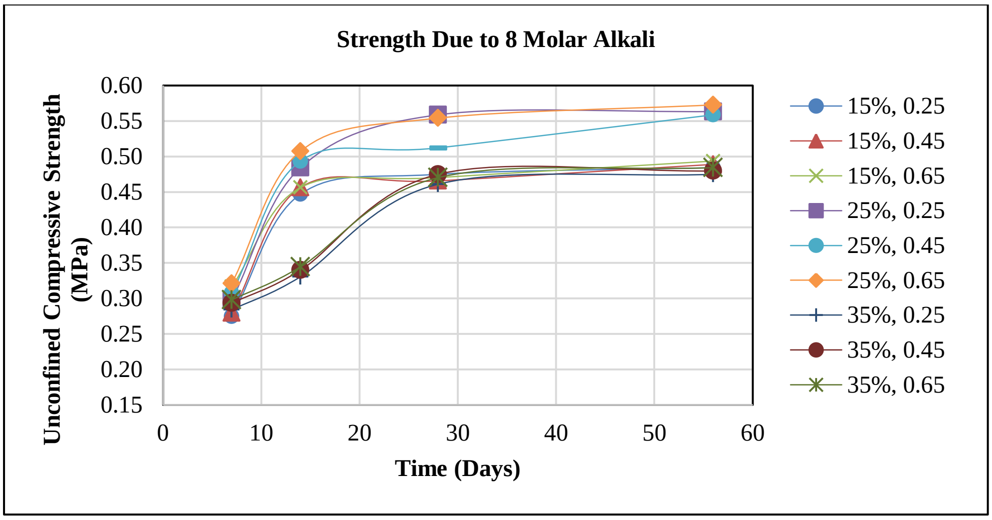


**Fig. 3 UCS (MPa) Result for 8 Molar Alkali Solution**

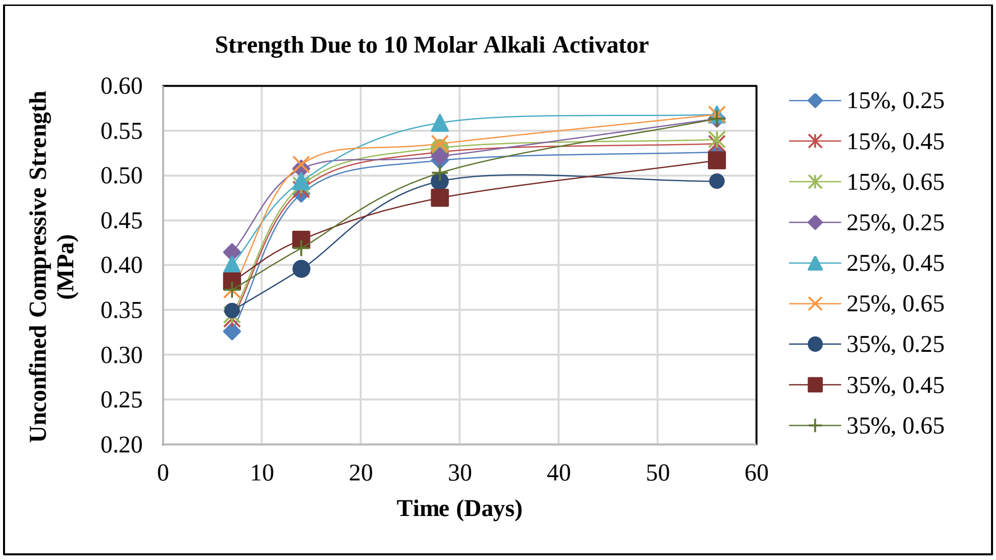


**Fig. 4 UCS (MPa) Result for 10 Molar Alkali Solution**

From the above figures, it is evident that strength increases with the curing time and maximum UCS value of 0.41 MPa is obtained for AB-25-12-0.25 mixture at 7 days curing. Likewise 0.51 MPa for AB-25-12-0.25 mixture at 14 days, 0.56 MPa for AB-25-12-0.45 mixture at 28 days and 0.59 MPa for AB-25-10-0.65 mixture at 56 days of curing respectively.

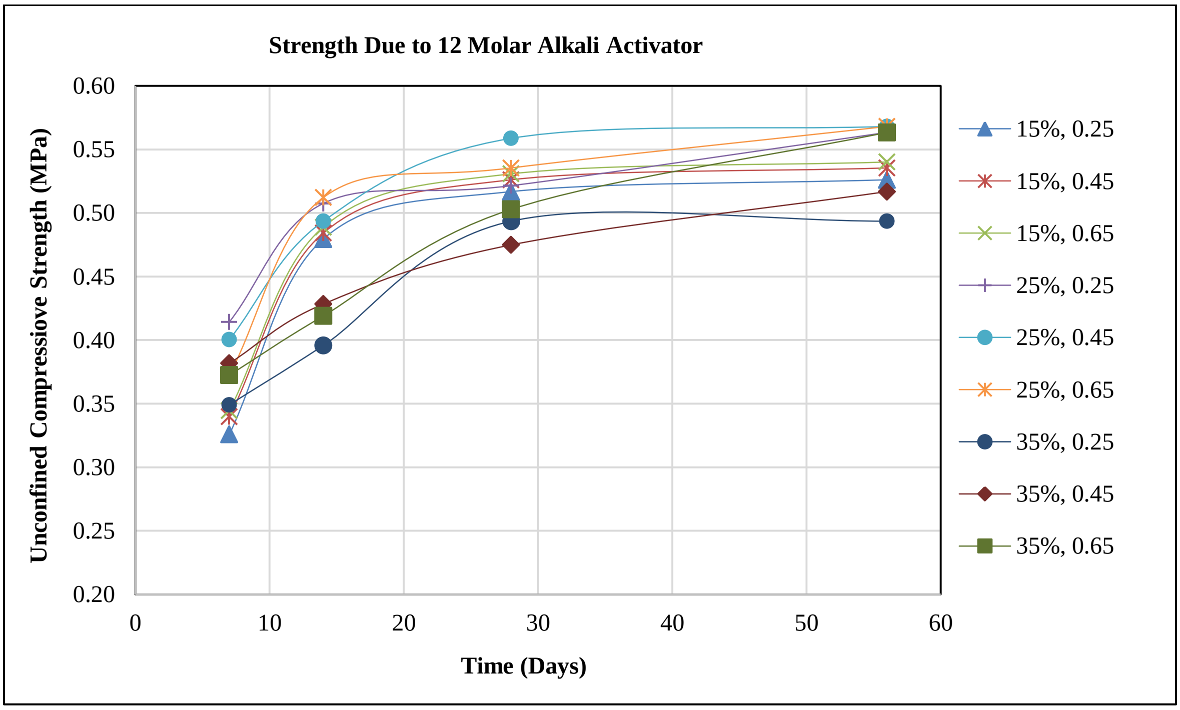


**Fig. 5 UCS (MPa) Result for 12 Molar Alkali Solution**

### 3.3 Effect of Activator Concentration on UCS Values

It can be said that higher concentration results in higher unconfined compressive strength for all curing period but its effect is not so much significant. It is found that in most of the case 12 molar alkali gives higher strength while in some cases 10 molar alkali gives higher strength.

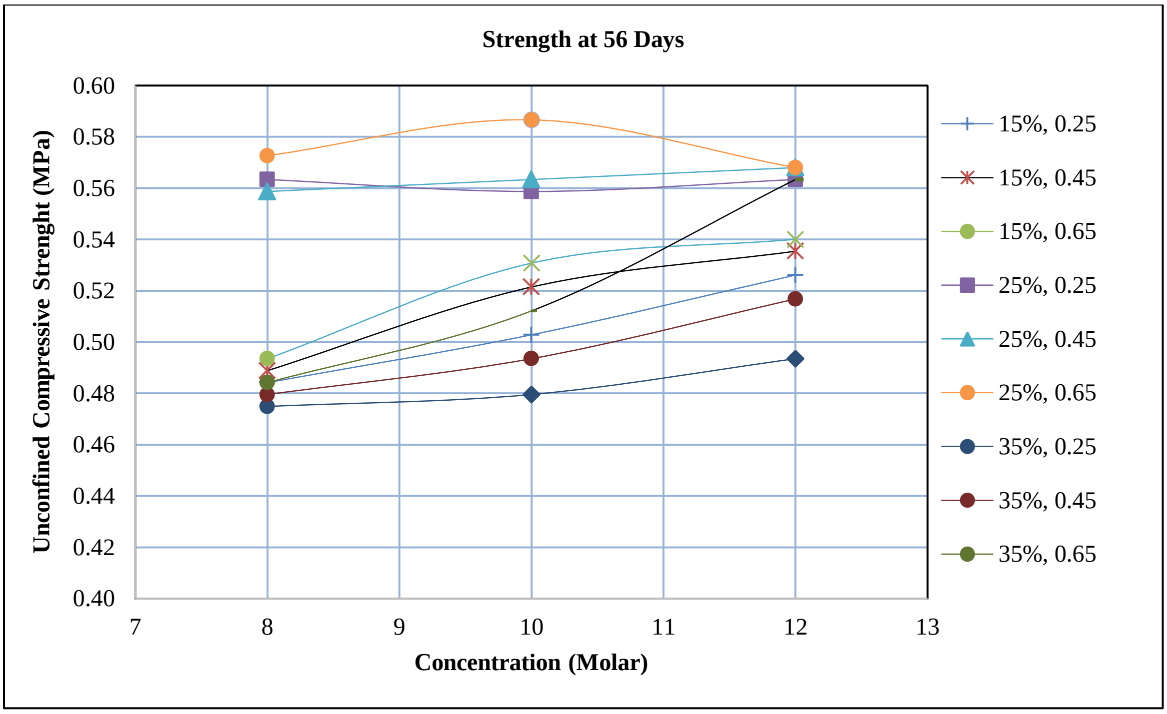


**Fig. 6 UCS (MPa) Result for 56 Days**

### 3.4 Effect of Activator/Bagasse Ratio (A/B) on UCS Values

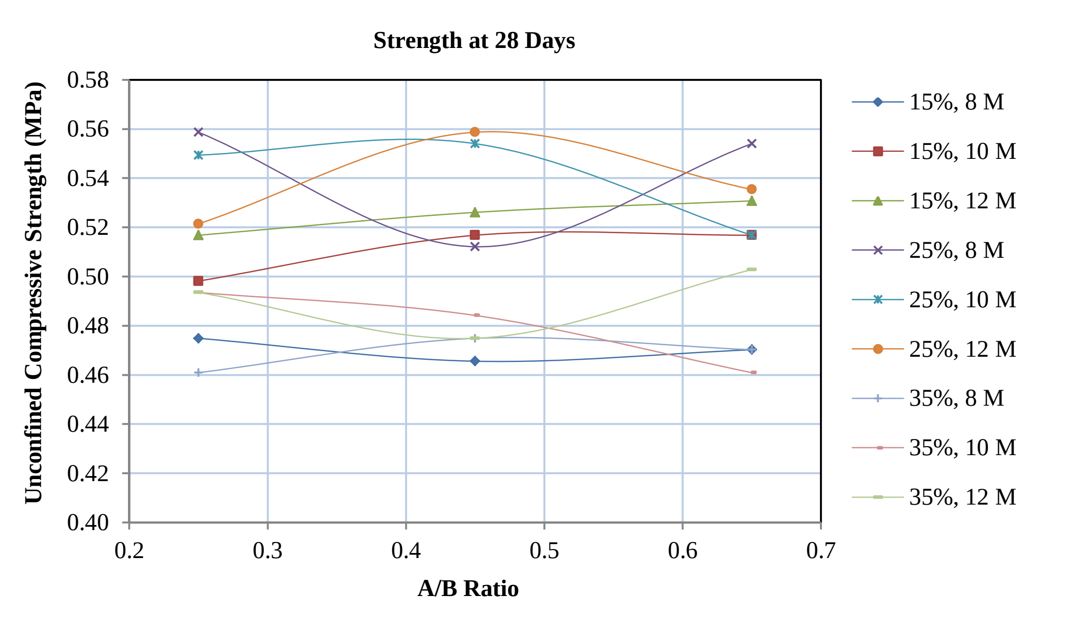


**Fig. 7 UCS (MPa) Result for 28 Days**

Sufficient amount of alkali activator is required for strength development of binder. Higher activator/ash ratio may give the higher strength of the stabilized soil as it is sufficient to make a binder. From the above figure, it shows that 0.45 A/B mixture gives higher strength at 28 days of curing.

### 3.5 Effect of Bagasse Ash Content on UCS Values

Higher ash content may not always increase the strength because higher quantity than required may decrease the strength as higher ash content cause the residual ash in the sample in standalone condition. So there is always the optimum ash content that gives higher strength. Figure 8, 9, 10 and 11 gives the detail of unconfined compressive strength development for various proportions of bagasse ash and alkali solutions and it is found that 25% ash content gives higher strength than 15% and 35%. So, optimum ash content for soft soil (black cotton soil) for this experimental investigation is said to be 25% the total solid mass.

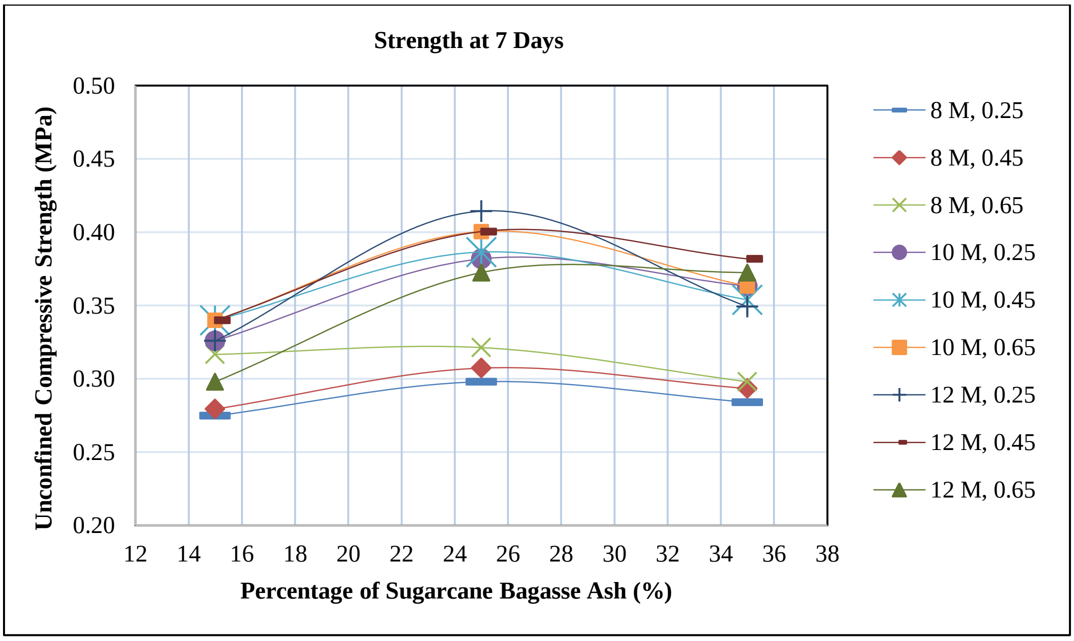


**Fig. 8 UCS (MPa) Result for 7 Days**

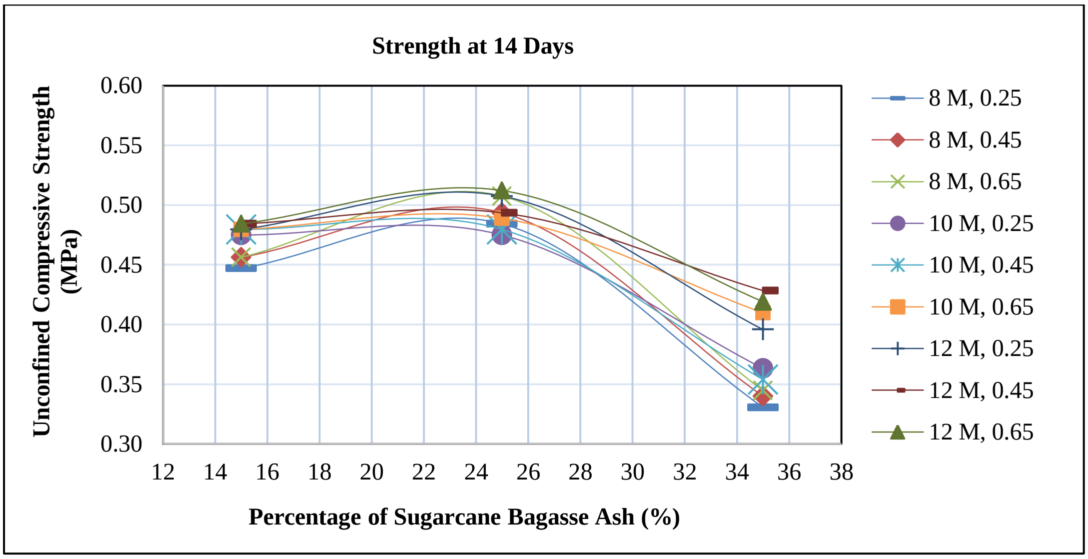


**Fig. 9 UCS (MPa) Result for 14 Days**

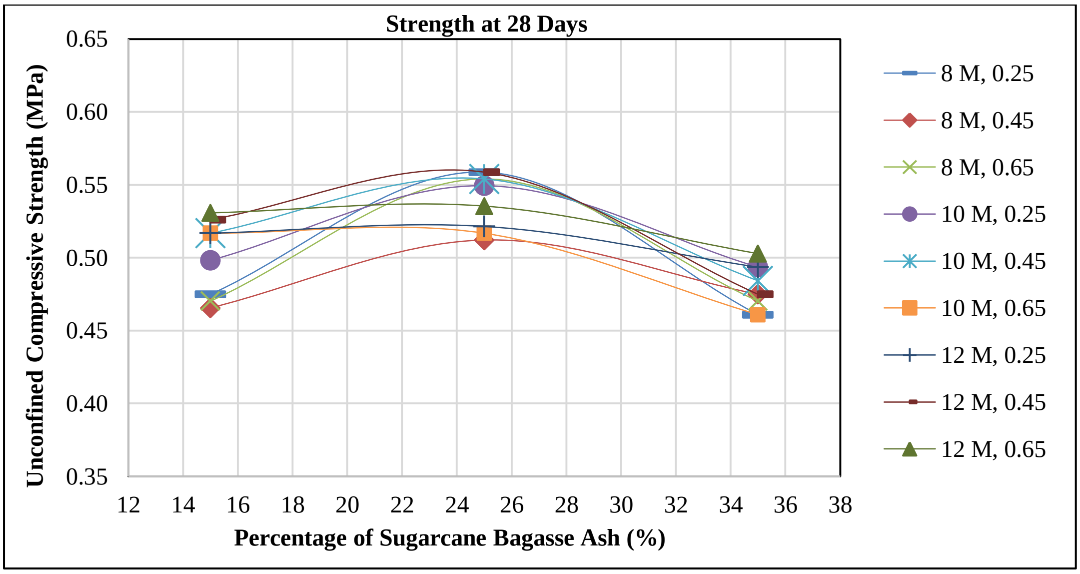


**Fig. 10 UCS (MPa) Result for 28 Days**

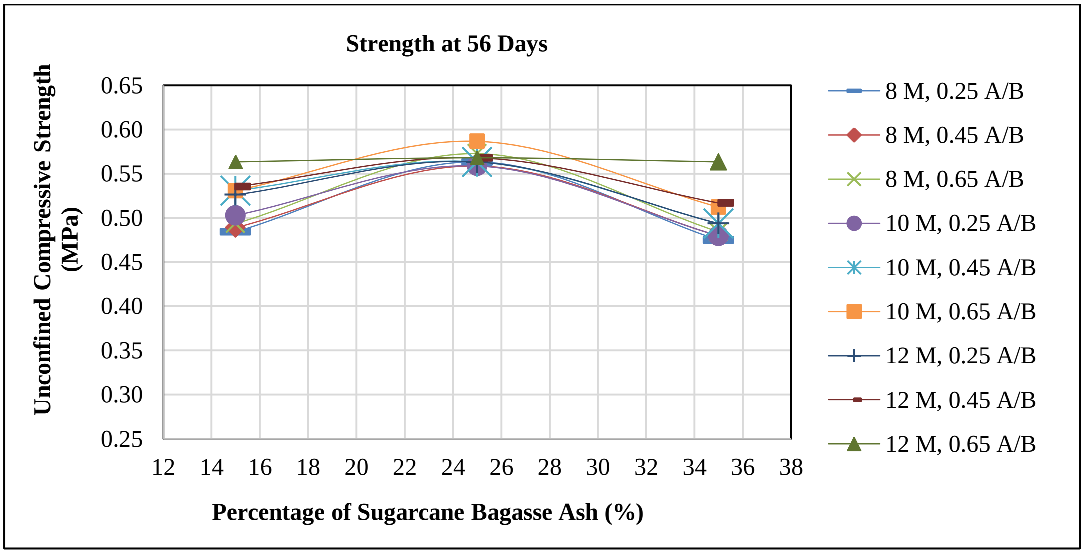


**Fig. 11 UCS (MPa) Result for 56 Days**

## 4. CONCLUSION

Based on the results obtained from the experimental investigation and discussion made the following conclusions can be made:

- The unconfined compressive strength of soil is found to vary with the bagasse ash content, the concentration of alkali activator, alkali/ash ratio and curing periods.
- 25% of bagasse ash is the optimum dosage of the bagasse ash for higher unconfined compressive strength development.
- Maximum 7 days strength attained by AB-25-12-0.25 is 0.41 MPa which is 1.78 times and 78.3% more than raw soil.
- Maximum 14 days strength attained by AB-25-12-0.25 is 0.51 MPa which is 1.89 times and 88.9% more than raw soil.
- Maximum 28 days strength attained by AB-25-12-0.45 is 0.56 MPa which is 1.93 times and 93.1% more than raw soil.
- Maximum 56 days strength attained by AB-25-10-0.65 is 0.59 MPa which is 1.97 times and 96.7% more than raw soil.
- Results showed that it is advantageous to use the bagasse ash for production of alkali-activated binders feasibly.
- Alkali-activated sugarcane bagasse ash can be used effectively as a chemical stabilizer for stabilizing soft soil.

## ACKNOWLEDGMENT

The authors give sincere thanks to Institute of Engineering, Pulchowk Campus for the encouragement and Central Material Testing Laboratory & National Academy of Science and Technology for laboratory testing. Also thanks to Lumbini Sugar Industries Pvt. Ltd. for supply of bagasse ash.

## REFERENCES

[1] Chavan, P., & Nagakumar, M. (2014). Studies on Soil Stabilization by Using Bagasse Ash. *International Journal of Scientific Research Engineering & Technology*, 1-10.

[2] Das, S. K., & Parthi, P. S. (2013). Stabilization of Expensive Soil Using Alkali Activated Fly Ash. *Proceeding of Indian Geotechnical Conference* (pp. 1-4). Roorkee: Researchgate.

[3] Davidovit, J. (1991). Geopolymers: Inorganic Polymeric New Materials. *Journal of Thermal Analysis and Calorimetry*, 37, 1633-1656.

[4] Enza Vitale, G. R. (2017). Mechanical Behaviour of Soil Improved by Alkali Activated Binders. *Enviromnents, MDPI*, 1-10.

[5] Garg, S., & Veena, U. (2016). Analysis of Strength Properties of Sandy Soil Stabilized with Sugarcane Bagasse Ash. *International Journal of Engineering Research & Technology*, 767-769.

[6] Hasan, H. e. (2016). Remediation of Expensive Soils Using Agricultural Waste Bagasse Ash. *International Conference on Transportation Geotechnics* (pp. 1368-1375). Australia: ELSWVIER.

[7] Kumar, A. e. (2015). Stabilization of Lithomargic Soil Using Alkali Activated Fly Ash with GGBS. *International Journal of Constructive Research in Civil Engineering*, 19-23.

[8] Mir, B., Gupta, K., & Jha, J. (2016). Some Studies on the Behavior of Sugarcane Bagasse Ash Admixed with Cement Stabilized Soil. *International Conference on Soil and Environment* (pp. 1-8). Banglore: Researchgate.

[9] Mohankumar, A. e. (2016). Laboratory Studies on Stabilization of Black Cotton Soil with Fly Adh and Geopolymer for Low Volume Roads. *The International Reviewer*, 5-8.

[10] Murari, A. e. (2015). Stabilization of Local Soil with Bagasse Ash. *International Journal of Civil Engineering*, 37-39.

[11] Pallavi, P., Gowtham, B., & Kilbukar, P. (2016). Study of Bagasse Ash and Cement Stabilized Marshy Soil. *International Journal of Innovative Research in Science, Engineering & Technology*, 651-659.

[12] Shahram Pourakbar, B. K. (2016). A Review of alternatives traditional cementitious binders for engineering improvement of soils. *International Journal of Geotechnical Engineering*, 1-11.

[13] Sruthimol, P., & Sindhu, A. (2015). Experimental Study on the Effect of Bagasse Ash on Soft Clayey Soil. *International Journal of Engineering Research & Technology*, 421-423.

[14] Stephanie, G., Cristelo, N., & Amandio, T. (2010). Strength of Bankok Clay Improved by Geopolymer from Palm Fuel Ash. *Preceeding of the Institution of Civil Engineers* (pp. 1-10). Portugal: ICE Proceeding.

[15] Sultana, S. S., & Srinivas, G. (2016). Stabilization of Expansive Soil Using Alkali Activated Fly Ash. *ANVESHANA'S International Journal of of Research in Engineering and Applied Science*, 317-323.

[16] Swain, K. (2015). *Stabilization of Soil Using Geopolymer and Biopolymer*. Rourkela: National Institute of Technology.

[17] Taye, B. (2015). *Stabilization of Expensive Clay Soil with Sugar Cane Molasess and Cement.* Addis Ababa, Ethiopia: Addis Ababa University School of Graduate Studies.