Stabilization of expansive material with biomass bottom ash. CBR behaviour and triaxial test

Cabrera M [1]*, Rosales J[1], Galvín AP[1], Barbudo[1], Agrela F [1]
[1] Area of Construction Engineering, University of Cordoba, Cordoba, Spain

Keywords: soil stabilization; biomass bottom ash; expansive soil; clay soils

***Corresponding author email:** manuel.cabrera@uco.es

Abstract

Clay soils are widely distributed throughout the world and are the origin of extensive damage to civil infrastructure. Soil stabilization is used to increase the load capacity of the soil; mixtures of lime and cement are generally used as binders. In recent years, interest in the recycling of industrial products has increased. A booming industry is power plants using biomass combustion. The management of waste (biomass bottom ash) in these biomass power plants remains a problem.

This paper presents an experimental study in stabilizing expansive soil to determine its bearing capacity and mechanical properties via a triaxial test with the addition of biomass bottom ash. A double objective is obtained, i.e., reduction of the problems of this type of soil and provision of a use for this waste, and a decrease of economic and environmental cost is achieved. Therefore, the use of biomass bottom ash, as a stabilizing agent for expansive soils, to improve the efficiency of the construction process by incorporating this product into a second life cycle is proposed.

1. Introduction

Soil stabilization is the process of the alteration of geotechnical properties to satisfy engineering requirements [1]. Numerous types of stabilizers have been used as soil additives to improve its engineering properties. Many stabilizers, such as lime, cement and fly ash, depend on their physical and chemical reactions with the soil elements in the presence of water [2,3].

Currently, research is being conducted regarding the use of biomass ashes for civil works. In Spain, Andalusia leads the scope of power generation from biomass, with 18 biomass combustion plants and a total installed capacity of 257.48 MW [4, 5]. Biomass ashes are the solid by-products that result from the complete or incomplete combustion of organic matter. The industrial biomass ashes consist of biomass bottom ash (BBA), or slag, and biomass fly ash (BFA). BBA and BFA have been extensively studied, focusing on several applications. BFA has typically been used in agriculture due to its mineral nutrient content, including calcium, potassium and phosphorus [6]. The goal of the present paper is to evaluate the possibility of reusing BBA in soil stabilization according to the technical specifications for road works imposed by Spanish regulation.

To complete this objective, the following parameters were measured to physically and mechanically properties all samples: compactability according to the modified Proctor test, bearing capacity based on the CBR index, plasticity and the triaxial compression test.

Positive results obtained in the present study reveal the possibility of using BBA mixed with clays for certain percentages of dosage. This possibility of BBA valorisation could avoid a large amount of the waste that is currently being sent to landfills, providing economic and environmental incentives.

2. Materials and methods

Five mixes were made with the three types of materials and different replacement ratio. Thereafter, physically properties and mechanical behaviour tests were performed. The mechanical performance and durability were tested (Fig. 1).

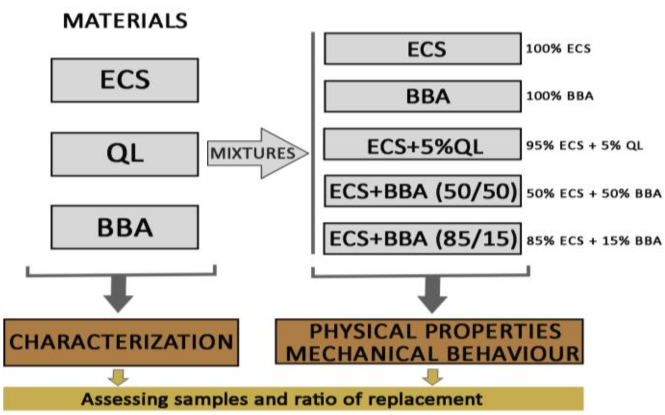

Figure 1: Experimental program

3. Results and discussion

The Modified Proctor compaction test, in accordance with UNE 103-501-94

Table 1. Summary of results

	Strength Parameters (Effective) Φ'	Unsoaked CBR	4-days soaked CBR	% Free-Swelling
ECS	34.6	10.35	2.3	6.74
BBA	43.7	26.99	28.01	0.06
ECS+5% QL	27.5	48.31	5.67	0.02
ECS+BBA (50/50)	40.7	25.84	44.04	0.04
ECS+BBA (85/15)	31.9	47.39	31.75	0.18

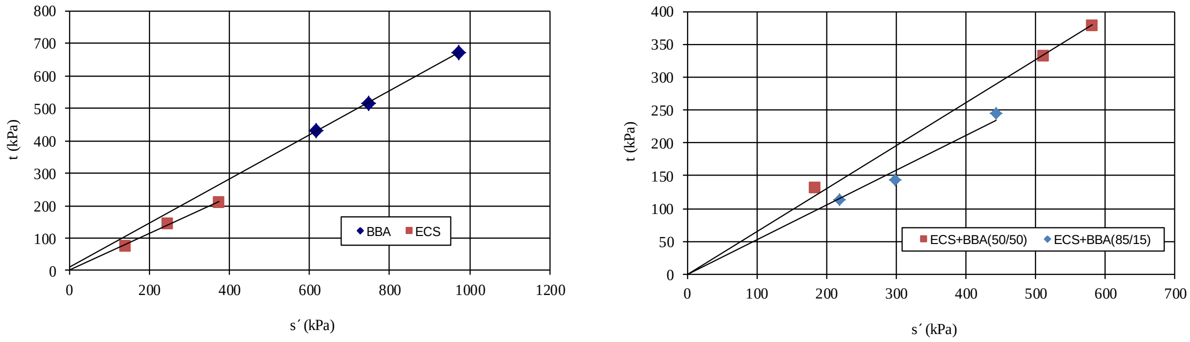

Figure 2: Tests performed with ECS and BBA (Left) and tests performed with ECS + BBA (50/50) and ECS + BBA (85/15) (Right).

All the materials seem to have a non-cohesive behaviour. ECS has a friction angle of 35º (a bit great for its clayish nature) that increases to 41º once mixed with 50% BBA. The mix of 85% ECS with 15% BBA seems to have a similar strength to the original ECS.

From this point of view, the strength of these materials and their combinations can be considered high and sufficient to build any type of embankments.

4. Conclusions

Based on the results obtained, we present the following conclusions:

- When the ECS is mixed with 50% bottom ash from biomass, the free swelling is reduced by 99.5%. The values of this mixture are like those reported for the mix with 5% lime.
- Regarding the values of Mohr-Coulomb failure criteria obtained in the tests, the strength of these materials and their combinations can be considered high and sufficient to build any type of embankments.
- It can be concluded that the use of bottom ash from biomass combustion reduces the expansion of expansive soils with the same percentages as lime, being an economic and environmental benefit of using this industrial by-product.

References

[1] Attoh-Okine, N. O. (1995). Lime treatment of laterite soils and gravels—revisited. Construction and building materials, 9(5), 283-287

[2] Azadegan, O., Jafari, S. H., & Li, J. (2012). Compaction characteristics and mechanical properties of lime/cement treated granular soils. Electron. J. Geotech. Eng, 17, 2275-2284.

[3] Mallela, J., Harold Von Quintus, P. E., Smith, K. L., & Consultants, E. R. E. S. (2004). Consideration of lime-stabilized layers in mechanistic-empirical pavement design. The National Lime Association, 200-208.

[4] Andalusian Energy Agency (AEA) [Agencia Andaluza de la Energía]. La biomasa y el biogás en Andalucía. Consejería de Economía, Innovacion, Ciencia y Empleo. Junta de Andalucía; 2013.

[5] Rosúa, J. M., & Pasadas, M. (2012). Biomass potential in Andalusia, from grapevines, olives, fruit trees and poplar, for providing heating in homes.Renewable and Sustainable Energy Reviews, 16(6), 4190-4195.

[6] Basu, M., Pande, M., Bhadoria, P. B. S., & Mahapatra, S. C. (2009). Potential fly-ash utilization in agriculture: a global review. Progress in Natural Science,19(10), 1173-1186.