USE OF BIOMASS ASH AS A STABILIZATION AGENT FOR EXPANSIVE MARLY SOILS (SE SPAIN)

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INTRODUCTION

In recent years, several biomass power plants have been installed in Southeastern Spain to reuse olive oil industry residues.

Image of widespread Spanish olive grove

This energy production tries to reduce the high costs associated with fossil fuels, but without entering into direct competition to traditional food crops. The waste management in these biomass energy plants is still an issue since there are non-flammable materials which remains after incineration in the form of ashes. In Southeastern Spain there is also a great amount of clayey and marly soils whose volume is very sensitive to changes in climate conditions, making them unsuitable for civil engineering. We propose the use of biomass ash (both fly ash and bottom ash) as a stabilization agent for expansive soils in order to improve the efficiency of construction processes by using locally available materials.

Biomass energy plant for beneficial reuse of olive tree residues

MATERIALS

A sample of marly soil, which is a typical soil in Southern Spain, is used in this study. It was collected in Jaén (Spain). This marly formation can be attributed to the sedimentary sequence of the Guadalquivir basin. It is an expansive soil, since it has a significant amount of smectite, which is one of the most expansive types of clay.

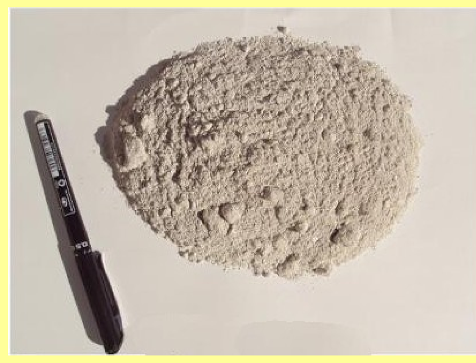
In this study, a non-conventional stabilization agent has been tested in marly soil. Fly ashes from biomass incineration come from biomass power plants where leaves, branches and olive pruning residues are burnt. After incineration, the non-flammable materials involved in the biomass remain in the form of ashes and can be collected. The physical properties of the soil are shown in table I, while the main oxides in the chemical composition of the ashes used in this study are tabulated in table II.

W_L Limit	W_P Limit	Plasticity Index	Free-swell	pH
66	31.4	34.6	12.5	8

TABLE I. Physical properties of marly soil

OXIDES	(%)
CaO	30.4
SiO_2	22.2
K_2O	13.0
MgO	8.1
Al_2O_3	4.5
Fe_2O_3	2.5

TABLE II. Chemical composition of biomass ash



Biomass fly ash from olive residues incineration in SE Spain

METHODOLOGY

The six samples of untreated soil were mixed with fly ash from biomass incineration, in three different proportions: 2%, 4% and 7% wt. Thus a total of 18 specimens were prepared, in addition to the standard sample of clay. Those specimens were later divided in three groups, one of each to be tested in a different curing time. Each of those groups involved six specimens: two of each proportion. The table III shows a scheme of the specimens and curing times.

Laboratory tests consisted on Atterberg Consistency Limits, Free Swell in Oedometer, determination of pH, X-ray Diffraction (XRD) and X-ray Fluorescence (XRF). XRD and XRF led to compare the mineralogy of the treated and untreated soils as well as to be aware of the variations occurred during the process. Recent works carried out by Eren and Filiz (2009), Hossain and Mol (2011) and Rahmat and Ismail (2011) have been taken into account in the interpretation of the test results.

The properties of expansive soil are determined by physico-chemical characteristics of its mineral constituents (Skempton, 1951). Therefore, X-ray diffraction tests were also carried out to observe the differences occurred in the mineral composition of soil and, specially, the changes in position and intensity of reflection of peaks of clay minerals.

GROUP	Marly soil type and biomass ash proportion (%)						Age of tested samples
1	MA - 2%	MD - 2%	MD - 4%	MC - 4%	MB - 7%	MC - 7%	7 days
2	MB - 2%	ME - 2%	MB - 4%	ME - 4%	ME - 7%	MA - 7%	14 days
3	MC - 2%	MF - 2%	MA - 4%	MF - 4%	MF - 7%	MD - 7%	28 days

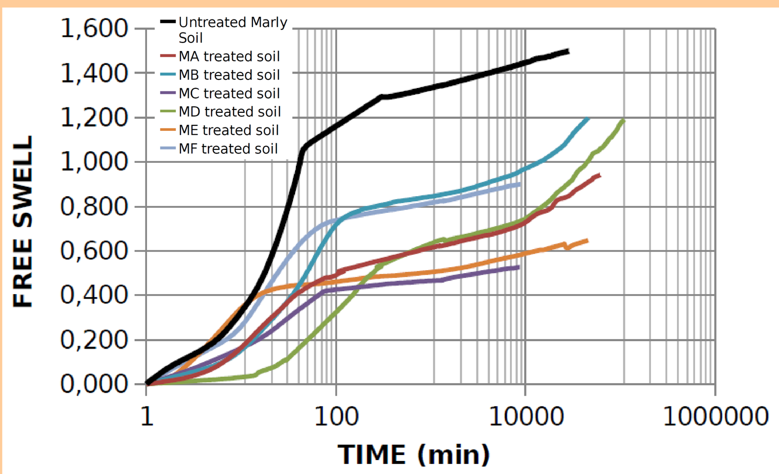
TABLE III. Type of natural soil, proportion of additive in samples and curing time

RESULTS AND DISCUSSION (I): GEOTECHNICS

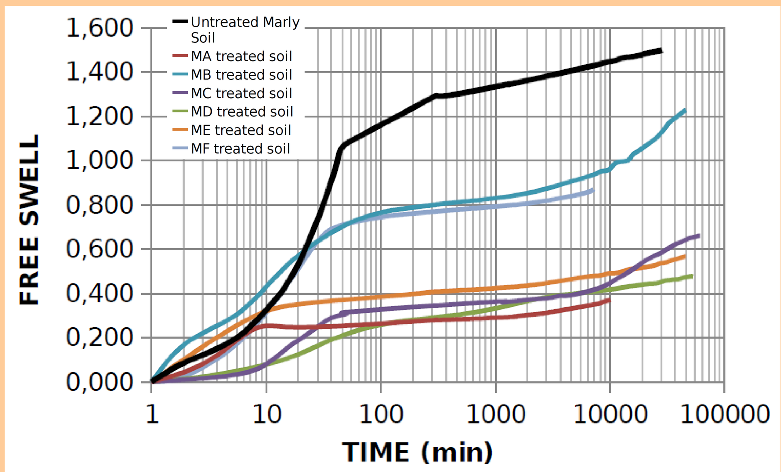
In terms of consistency, the value of the plasticity index (PI) in the sample of untreated soil (34.6) was a high value. After adding biomass fly ash, all the specimens remained plastic, since no Atterberg test provided a PI lower than 25. In terms of comparison among the specimens, there were not significant differences in PI values. At a curing time of 7 days, the most effective proportion of additive seemed to be 7% (the highest proportion tested). However, after 28 days of curing the results became more similar among the specimens, except for the one with the lower concentration of additive (2%), which provided a PI value of 57.5. The table 5 presents the results of the Atterberg tests.

The values of pH measured before and after mixing the marly soil with biomass ashes (2%-4%-7%). The natural pH of the untreated soil was 8. With only 2% biomass ash, the pH of the mixture reached about 10, and increased to about 11 with ash percentage of 4%, and about 12 in certain mixtures with additive percentage of 7%. Regarding the curing time, most of mixtures values of pH remained unchanged over time. The mixtures with 2% of additive provided a pH of 10 (higher than the original value of 8) in six different tests carried out at three different ages. The mixtures with 4% of additive provided a quasipermanent pH value of 11. In the mixtures where the additive percentage was higher (7%) an increase in the pH value was observed, from 11 at 7 and 14 days of curing to 12 in the last measurement at 28 days of age.

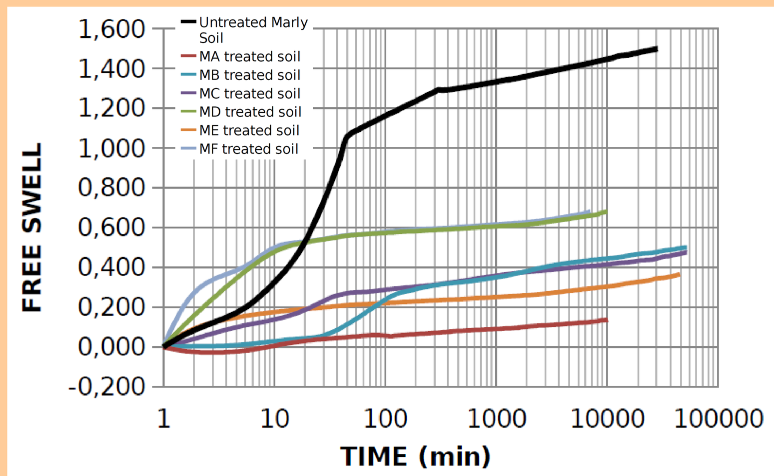
In the table IV the results of the free swell test are presented. Comparing the values with the original untreated soil, a decrease in the value of the swell index can be observed. This is a very significant result, since the free swell test provides a valuable indicator of the capacity of the soil to swell and shrink depending on the climate conditions. Further information will be collected in the XRD studies, in terms of internal structure and mineralogy.



Evolution of Free Swell index value for different control soils treated with biomass ash, 2% wt.



Evolution of Free Swell index value for different control soils treated with biomass ash, 4% wt.

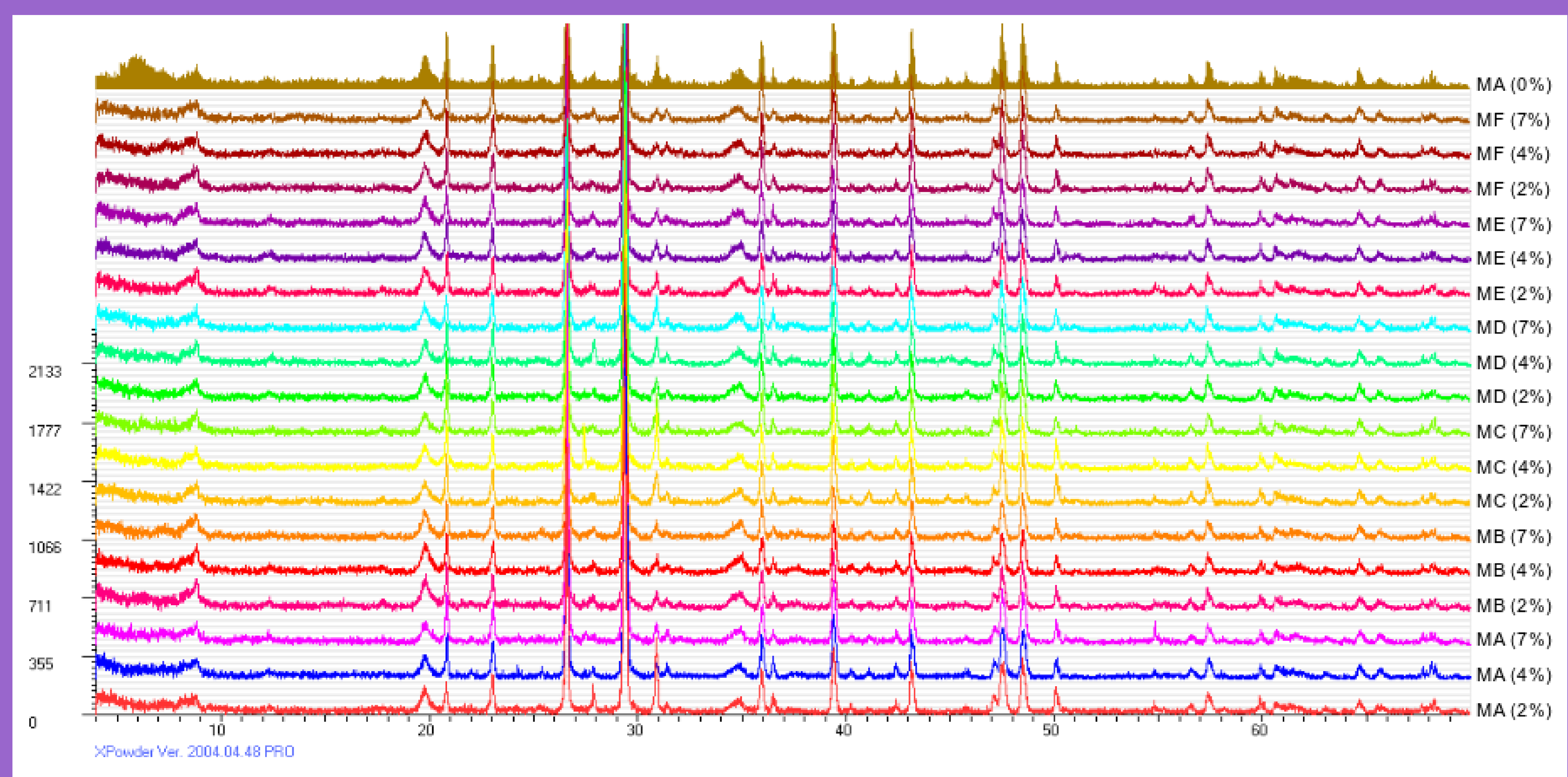


Evolution of Free Swell index value for different control soils treated with biomass ash, 7% wt.

Specimen	Free Swell
Marly soil	12.50
MC (2%)	4.39
MC (2%)	8.18
MA (4%)	1.85
MF (4%)	4.35
MD (7%)	3.41
MF (7%)	3.41

Table IV: Free Swell values after 28 days of curing

RESULTS AND DISCUSSION (II): MINERALOGY (X-ray Diffraction)



XRD Pattern of original marly soil and samples after treatment with 2%, 4% and 7% (wt.) of biomass ash from olive residue

The mineralogy of the samples were studied by X-ray diffraction tests. After the treatment with biomass ash, the results obtained in this study showed a significant reduction in the intensity of reflection of the smectite peak 001, which is the main peak of reflection of smectite and qualitatively characterizes the presence of this expansive phase of clay mineral (Moore and Reynolds, 1997). This reduction of intensity suggests a removal of smectite expansive mineral in the treated samples. Although this is a positive effect, a further study might reveal the formation of mixed-layered clay mineral, which would be a more durable effect and would lead to more stables non-expansive mineral compositions.

The test results showed slight differences among the final values obtained for different samples of marly soil.Despite the fact that, in general, all of the samples tested were significantly improved by the biomass ash addition, it must be said that the final results achieved depend on the kind of marly soil to be stabilized, i.e. its chemical composition and mainly its content of carbonates.

Images of X-Pert Diffractometer used for the XRD Characterization of samples

CONCLUSIONS

This work shows the potential benefit of stabilizing expansive marly soils with fly ash obtained from biomass incineration. This can be inferred from the decrease in the free swell value occurred in all the mixtures tested when they are compared with the original free swell value obtained in the untreated marly soil.

The percentage of additive seems to be an important factor in the final achievement of the soil stabilization. In the tests carried out in this research, the higher percentage of additive in the mixture, the greater decrease in the free swell value.

Atterberg limits tests showed that the plasticity of the original untreated marly soil was not considerably enhanced by the addition of biomass ashes. In fact,regardless the percentage of additive in the mixture and the curing time, the PI obtained in the specimens were not low enough in any mixture to be considered less plastic than the untreated soil.

The pH values of the samples were higher than the pH obtained in the untreated soil. The higher percentage of additive, the higher the pH value. It produced an alkaline environment in the soil which may enable stabilization reactions.

XRD tests showed a reduction in the intensity of reflection of the peaks representing expansive phases of clay mineral, which suggests a possible reduction in the amount of smectite in the soil after mixing with biomass ashes.

The results obtained were slightly different depending on the sample of marly soil selected. Thus further research should be carried out to study how different amounts of carbonate in the sample may affect the final physical properties and strength parameters of the treated soil.

Soil stabilization works "in situ" in Highway A-316, Jaen, Spain
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