Revista Română de Inginerie Civilă, Volumul 10 (2019), Numărul 2

Stabilization of Expansive Soil With Coal slurry and Fly Ash

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Abstract

Due to its great risk on buildings, improving the characteristics of expansive soil is a large concern in the field of civil engineering. On an other hand, valuing of industrial waste has become an urgent need to reduce the damage on both of the public health and the environment. The aim of this study is to evaluate the utility of Coal slurry and fly ash located in Bechar, Algeria on expansive soil stabilization. There is many researches use fly ash as stabilizer, in contrast of coal slurry. In the present work, the mixture of bentonite and sand is stabilized by the coal slurry and fly ash. An experimental program is realized to examine the effects of coal slurry and fly ash on particle-size analysis, the free swell, swell pressure, plastic index and surface area. The soil samples are prepared with three proportions of coal sterile and fly ash (4%, 8% and 12%). The results acquired are very encouraging and they show that the effect of coal slurry and fly ash on the geo-technical properties of expansive soils is very important.

Key words: Expansive soil, Stabilization, coal slurry, fly ash, Swell pressure.

1. Introduction

Expansive soil has the ability to shrink or swell under the change in moisture state [1]. This change causes significant damage to civil engineering structures as buildings and highways [2],[3].The average annual cost of damage to structures due to shrinkage and swelling is estimated about £400 million in the UK, $15 billion in the USA, and many billions of dollars worldwide [4]. Remedy the damage inflicts a substantial extra cost and the soil stabilization is the best approach in this area. Chemical stabilization is the most popular method utilized to enhance the physical and mechanical properties of expansive soil [5]. Stabilization is the procedure of mixing the material with soil to improve this engineering propriety [6].

The industrial waste is the result of modern life where consumer society and economic development requires massive resources processing. It causes hazards in nature due to presence of high toxic substances and needs large space to dump the solid waste [6], [7], [8]. The use of industrial wastes in the field of civil engineering is one of the solutions to reduce their negative effects. On the other hand, the uses of these materials have an economic aspect [7]. Among these wastes, we have the coal waste. Coal has been used as an energy resource for the production of electricity but also an important source of industrial waste. In 2011 China produced 3,520 million tons of coal that represents 49.5% of world coal production. United States product 993 million tons, India 589 MT, European Union 576MT and Australia 416MT [9] .

Bechar town, which located at 980 km of the southwest of the capital of Algeria, since the 1917 until 1975 [10], coal produces large amount of waste during the mining and processing stages. This waste is dumped on to open land which creates a lot of environmental problems [11]. The use of coal leads to the appearance of three types slag heaps:

The slag heaps of the seats: it formed by manual sorting at the seat. The coal in its natural deposit is in the form of a vein (layer), framed by the schist and sandstone, during slaughter operations, the schist and sandstone associated with coal placed near the seat and form the slag heaps of the seat.

- Slag heaps of washing: Once, manual sorting completed at the seats, the selected coal conveyed by wagonnets to wash and separation from the waste rock by flotation in a dense liquid. After that The coal scraped on the surface of the liquid, while the coal slurry deposited at the bottom of and hollowed out by a skip to form the slag heaps of washing. The coal slurry contains a high percent of coal.

- The slag heaps of power plants: by combustion in the power plant plants, the burned coal left fly ash. These stored next to the plant and that is how the slag heaps of power plants have taken birth [12].

Much research has been done on coal waste as an stabilizer of expansive soils. Satyendra (2015) added the fly ash with a percentage of 10%, 20%, 30%, 40%, 50%.

The results show that the liquid limit decreases from 55.2% to 36.3%, the plasticity index decreases from 27.1% to 18.1% and differential Free Swell (DFS) decreases from 52% to 14% [13]. Baviskar and al (2016) use fly ash to stabilize the local expansive soil. They revealed that when fly ash content increased, MDD increased with the corresponding decreased in OMC. The unconfined compression strength value of treated soil increased at 7 days and 28 days of curing when the fly ash increased [14]. Nalbantog (2004), in their research explained that the soil obtain from Degirmenlik, Cyprus gave a swell potential of 19.6% .The fly ash is very effective in reducing the swell potential of Degirmenlik soil. With 15% fly ash treatment the swell potential decreased to 5% ,and with 25% fly ash treatment the swell potential of this soil decreased to 3.7% [15].The researches of Sheng and al (2014)indicated that the rice husk biochar and coal fly ash were able to improve the physical quality and swelling–shrinkage behavior of expansive soils [16].

From the researches precedents, it is noted that no work has been done the effect of coal slurry on expansive soil behavior and limited only on fly ash. For this reason, this research an attempt to study the effect of coal slurry on expansive soils.

In this research, we use the coal slurry containing high residual coal. The odder material use in stabilization of expansive soil is fly ash.

To achieve this work, we used artificial expansive soil consisting of 60% of bentonite and 40% of sand. The artificial soil is mixed with different percentages of coal slurry and fly ash (4%, 8% and 12%). After that, treated and untreated soils were subjected to tests to determine the effect of coal slurry and fly ash on soil expansion.

2. Materials

2.1. Expansive Soil

The soil samples used in this study for current experimental tests was an artificial expansive soil prepared in the laboratory using bentonite and sand. The bentonite and the sand were passed from 400 μm sieve. The mixture was prepared with a dry mass ratio of 60% bentonite and 40% sand. The specific gravity of solids (Gs) was 2.62. The grain size distribution showed that 49 % of particles were in the range of fine-sand, 23% in the range of silt and 32% were clay. The soil prepared has a liquid limit of 115%, plasticity index of 101%.

2.2. Coal slurry

In this study, coal slurry was obtained from the slag heaps of washing. Sterile of coal is relatively lower density than normal soils. The density of this material is 2,2 g / cm^3. A chemical analysis show that coal slurry contain 46, 63% of coal. In this work the coal slurry was dried at 50° C, crushed and passed through 400 mm sieves.

2.3. Fly ash

The fly ash was obtained from the slag heaps of power plants. The density of this material is 1, 9 g / cm^3. The fly ash was also dried at 50°C, crushed and passed through 400 mm sieves.

3. Experimental Programs

3.1. Mixing of Materials

The soil samples were prepared by mixing coal sterile and fly ash with three different dosages (4%; 8% and 12%). After that all were mixed to obtain a homogeneous material. After mixing of the materials, the specimens engineering properties of the treated and untreated soil realized including particle-size analysis, free swell, swell pressure, plastic index, and specific surface areas.

3.2. Particle-size analysis

The particle analyze was realized according the ASTM D422. This test method covers the quantitative determination of the distribution of particle sizes in soils. The test was realized by sieving and sedimentation process.

3.3. Measurement of the free swell and swell pressure

ASTM D 4546-03 was used to determine the free swell and swell pressure. The soil samples are compacted by the static method at the maximum dry density and optimum moisture content. The sample with a diameter of 50 mm and 20 mm high was imbibed and allowed to inflate vertically under the pressure of the piston until stabilization [17]. The free swell (S %) is calculated using the following equation:

$$S\% = \frac{\Delta H}{H0} X100 \quad (1)$$

Where:

ΔH: $H_f - H_0$

H_0: initial height (before swelling)

H_f: final height (after swelling)

After the end of swelling the sample was loaded in stages until the swelled sample returns to its original height. The pressure necessary to recover the initial height H_0 is the swell pressure.

3.4. Measurement of Atterberg consistency limits

The Atterberg limits were obtained in accordance with the Standard NFP 94-051. It presents a procedure to determine the liquid limit (LL) and plastic limit (PL) respectively. Plasticity index (PI) is calculated with the following formula:

$$PI = LL - PL \quad (2)$$

3.5. Specific surface areas

The surface area measurements are a direct reflection of clay mineralogy, but are an indirect reflection of expansion [18]. The specific surface area can be determined by methylene blue value. In this test, the increments of a solution of methylene blue are added successively to a suspension of the test portion in water until the presence of free dye. The specific surface area obtained by the formula:

$$S_s = \left[\frac{V_{BM}}{M_{sol}}\right]\left[m_{BM\,sec}\,\frac{A_v}{373{,}91}\,A_{BM}\right] \quad \left(m^2/g\right) \tag{3}$$

Where: V_{BM}: quantity of blue of methylene adsorbed; Msol: dry mass of the test sample; m $_{BM}$: blue content of the titration solution; Av: Avogadro number; A_{BM},: area covered by a molecule of methylene blue (130 Å2) and the molecular weight of methylene blue is (373.91) [19].

4. Results and Discussions

4.1. Particle size analyses

Fig.1 and fig.2 displays the effects of addition of coal slurry and fly ash on particle size distribution according different percent. It can be noted that when coal slurry and fly ash were increased, the clay percent decreased. In the untreated soil the clay percent is 32%. The addition of 4%, 8% and 12% of coal slurry decrease the clay percent to 29%, 22% and 18% respectively. Concerning the fly ash, with 4%, 8% and 12% the clay percent decrease to 21%,5% and 3%. We can explain the reduction of clay percent by the exchange cation and the flocculation of clay which make the soil more granular.

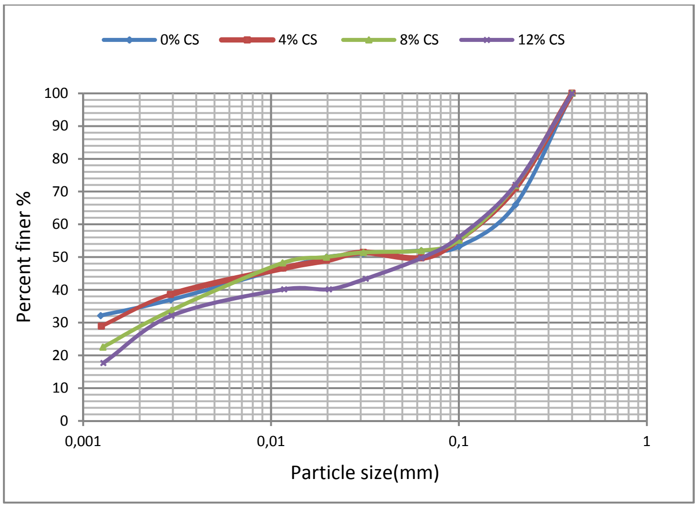

Fig.1 Grain size distribution curves of coal slurry added samples

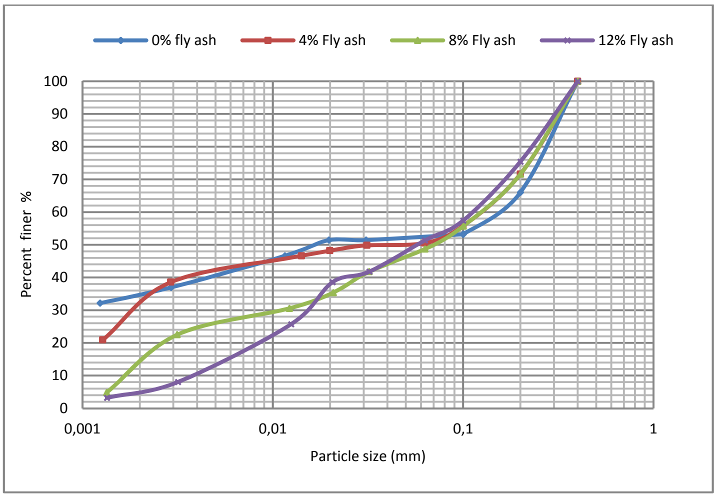

Fig 2. Grain size distribution curves of fly ash added samples

4.2 Free swell and swell pressure

The effect of the addition of coal slurry and fly ash on the free swell and swell pressure is show in the fig 3-6. The result indicates that there is a dramatically decrease in the free swell and swell pressure with the different percent of additives. The free swell of untreated soil is 40% and its swell pressure is 1700 Kpa.The addition of 4% of coal slurry decreases the free swell to 36% and the swell pressure to 1000Kpa. With the addition of 8% the free swell decreases to 24% and swell pressure to 780 Kpa. And finally with 12% of coal slurry the free swell is 10% and the swell pressure is 350 Kpa. Regarding the fly ash the addition of 4% decreases the free swell to 26% and swell pressure to 580 Kpa. And with 8% the free swell decrease to 6,5 % and swell pressure to 200 Kpa. And finally The addition of 12% reduces the swilling potential to 4,9% and swell pressure to 150 Kpa.

Cementation process due to pozzolanic reaction reduces the free swell of treated soils and subsequent reduction in the swell pressure values of soil. Cementation between particles is a major factor in limiting volume increase of clays on swelling.

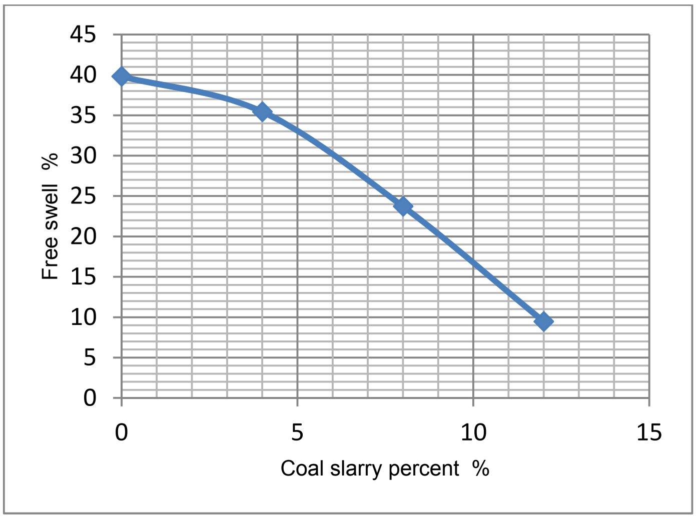

Fig. 3 Free swell (S %) versus different percentage of coal slurry

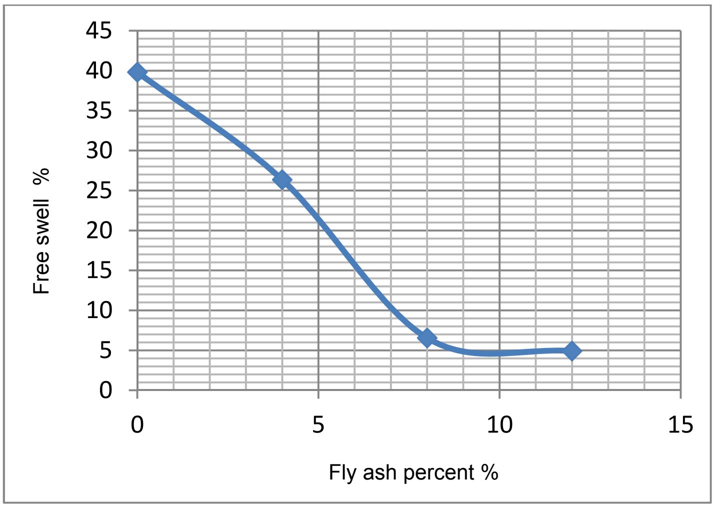

Fig.4 Free swell (S %) versus different percentage of fly ash

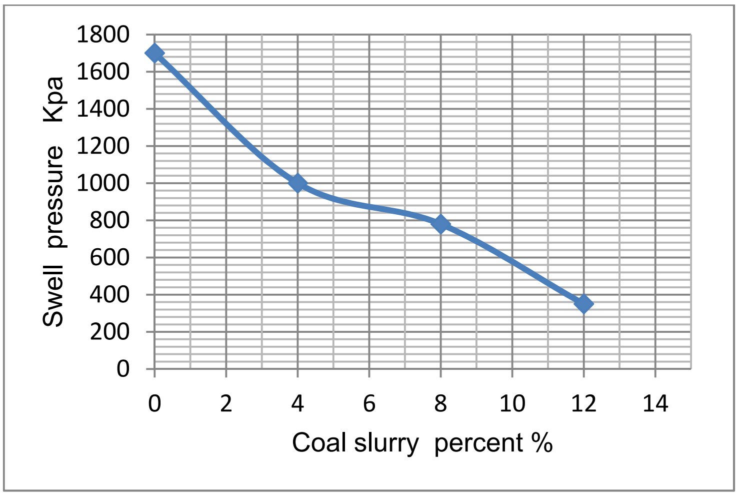

Fig. 5 Swell pressure versus different percentage of coal slurry

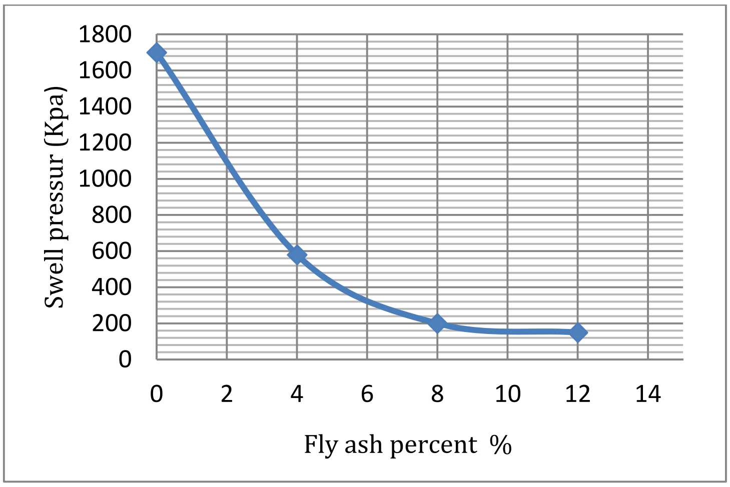

Fig.6 Swell pressure versus different percentage of fly ash

4.3. Plasticity index

Fig. 7 and fig. 8 show the effects of addition of coal slurry and fly ash on plasticity index. It can be noted that the addition of coal slurry and fly ash have an signification effect on the plasticity index. The initial Plasticity index of the soil was 101%. The addition of coal slurry with 4%, 8% and 12% decrease the plasticity index to 69,1%; 50,64% and 31,86% respectively. Regarding fly ash, The Plasticity index reduces to 87; 48%; 44, 05% and 33, 76% with 4%; 8% and 12% of fly ash respectively.

The general decrease in the plasticity index when the addition of coal slurry and fly ash is attributed to the effect of the compounds cementitious formed the treated soil.

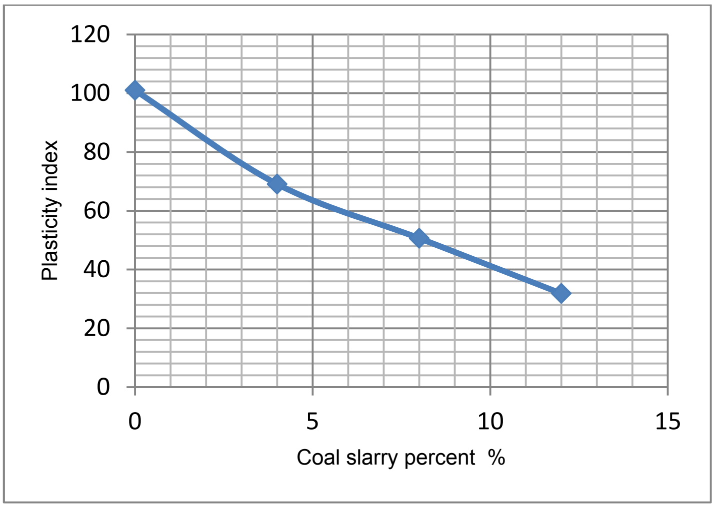

Fig.7 Plastic index versus percentage of coal slurry

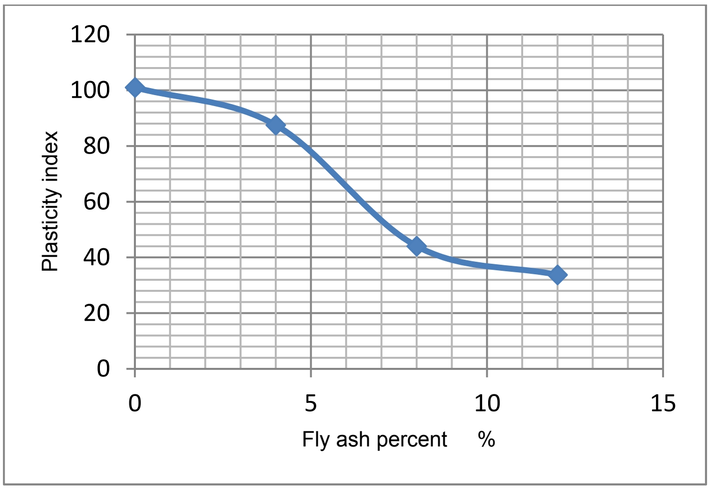

Fig. 8 Plastic index versus percentage of fly ash

4.4. Specific surface areas

The results of the value of specific surface area as a function of the percentage of coal slurry and fly ash are presented in the Fig 9 and Fig10. According to the results, there is a reduction in the specific surface area as a function of the increase in the percentage of coal waste and fly ash. The value of specific surface area of untreated soil was 234 m^2/g. The addition of 4%, 8% and 12% of coal slurry reduces the specific surface area to 164 m^2/g, 122 m^2/g and 105 m^2/g. About fly ash, the specific surface area reduces to 147 m^2/g, 132 m^2/g and 98 m^2/g with 4%, 8% and 12% of fly ash.

The decrease in specific surface areas is explained by the formation of the new phases with coarser particles that result in less water absorption potential. The coal slurry and Fly ash treatment cause the soil to become more granular, resulting in lower surface activity and hence less water absorption potential.

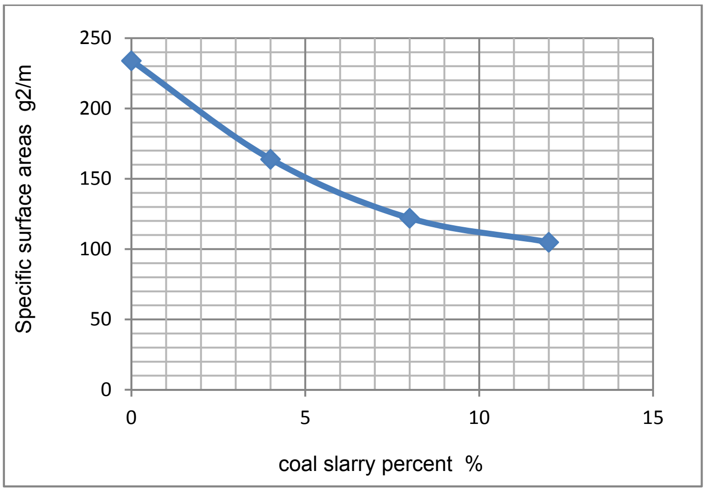

Fig.9 Specific surface areas versus different percentage of coal slurry

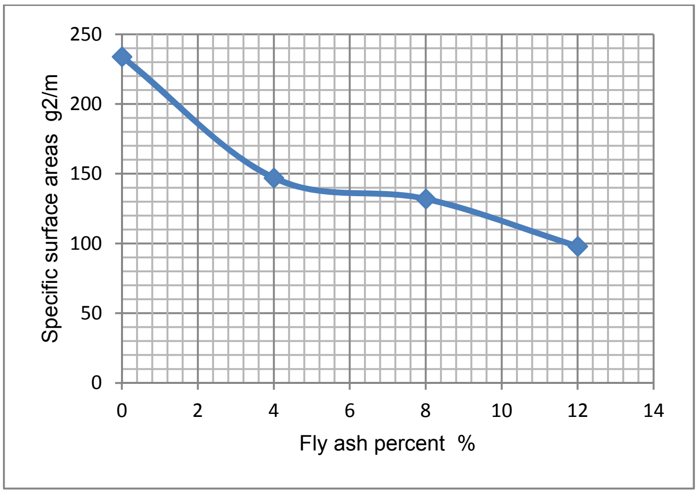

Fig.10 Specific surface areas versus different percentage of Fly ash

5. Conclusions

According to the results obtained, it is found that the effect of coal slurry on the behavior of expansive soil is significant and the improvements in the geo-technical properties with the soil treated by fly ash are converged**.** Based on the results, the following conclusions are drawn:

- Clay percent of treated expansive soils reduced significantly with different percent of coal slurry or fly ash.

-The free swell and swell pressure decrease dramatically with increase of coal slurry or fly ash percent.

- Significantly the Addition of coal slurry or fly ash decrease de plastic index of treated soil.

-The increase of coal slurry or fly ash decreases the surface area of treated soil.

The recycling of industrial waste is important in order to reduce the polluting effects of these materials and to obtain useful results in civil engineering. Soil stabilization with Bechar's coal waste can be defined as an economical solution for improving the characteristics of the expansive soils and also reduces the negative effect of the coal waste on the environment.

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