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Effect of Fly Ash on Geotechnical Properties of Expansive soil

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ABSTRACT

This paper investigated the effect of fly ash addition on geotechnical properties of expansive soil. Classification tests, consistency limits test, specific gravity test, compaction test, direct shear test, swell percentage, and swell pressure tests, were conducted on specimen of expansive soil. Results of tests showed that soil was a clay high plasticity (CH) soil, according to the Unified Classification System (USCS) classification system. Liquid limit reduced from 74 % at 0 % fly ash to 56 % at 20 % fly ash content by dry weight of soil, the plastic limit reduced from 31 % at 0 % fly ash to 25 % at 20 % fly ash content, the plasticity index reduced from 44% at 0% fly ash to 31 % at 20% fly ash. The maximum dry density reduced from17.3 kN/m^3 at 0% fly ash to13 kN/m^3 at 20 % fly ash and optimum moisture content increased from 19.2% at 0% fly ash to 29.3% at 20% fly ash. Shear strength parameters c and Ø were measured after the addition of various contents of fly ash on curing days (7, 14 & 21). The value of cohesion (c) increased with increasing the amount of fly ash added to 15% then decreases. The effect of curing time on cohesion increased until 14 days. While c is decreased at various contents of added fly ash at 0 time (no curing or immediately tested). The increased internal friction angles (Ø) with added fly ash in all samples are independent on curing time of the mixture. The increment in Ø of all the mixtures for 7, 14 and 21 days cure time is more than that of no cure time. Swell percentage decreased when fly ash content increased from 48% at 0% fly ash to 32% at 20% fly ash. Swell pressure decreased from 620 kN/m^2 at 0 % fly ash to370 kN/m^2 at 20% fly ash. Both swell percentage and swell pressure decreased at samples content (15% fly ash) with different curing period time.

الخلاصة

هذا البحث يدرس تاثير اضافة الرماد المتطاير على خواص التربة الانتفاخية. تم اجراء التجارب المختبرية من تصنيف التربة ,حدود القوام ,الوزن النوعي ,تجربة الرص , فحص القص المباشروفحص نسبة الانتفاح وضغط الانتفاخ.
نتائج التجارب بينت ان التربة (طين عالي الدونـة) حسب (نظام تصنيف التربـة الموحد).حد السيولة ينقص من 75% قبل الاضافة الى 56.3% بعد اضافة الرماد المتطاير بنسبة 20% من الوزن الجاف للتربة.حد الدونـة يقل من 30.5 % الى 25% بعد اضافة 20% من الرماد المتطاير.كذالك دليل الدونـة يقل مع زيادة الرماد من 43.5% الى31.3% عند اضافة الرماد بنسبة20% . الكثافة الجافة العضمى تقل من (17.3 كن/ م³) الى (13 كن/ م³) عند اضافة الرماد بنسبة 20%. محتوى الرطوبة العظمى تزداد من19.2% الى% 29.3 عند اضافة الرماد بنسبة 20%.تمت دراسة عوامل مقاومة القص كل من مقدارالتماسك وزاوية الاحتكاك الداخلي للتربة مع تغير نسبة الرماد المتطاير في فترات انضاج مختلفة (21,14,7,0) يوم حيث تبين ان مقدار التماسك يزداد مع زيادة نسبة الرماد المتطاير الى15% ثم يتناقص, باستثناء الفحص بدون فترة انضاج.تزداد زاوية الاحتكاك الداخلي مع زيادة نسبة الرماد المتطاير و زيادة فترة الانضاج يزيد من زاوية الاحتكاك الداخلي .نسبة الانتفاخ تقل مع زيادة نسبة الرماد المتطاير من 48% الى32% عندما تكون نسبة الرماد 20%.ضغط الانتفاخ يقل مع زيادة نسبة الرماد من (620 كن/ م²) الى (370 كن/ م²). كل من نسبة النتفاخ وضغط الانتفاخ يقل مع زيادة فترة الانضاج الى 14 يوم .

INTRODUCTION

The term expansive soil applies to soils that have the tendency to swell when their moisture content is increased and shrink when their moisture content is decreased. The moisture may come from rain flooding, leaking water or sewer lines or from reduction in surface evapotranspiration when an area is covered by buildings or pavement. [1, 2]

In the field of geotechnical engineering, it has been known that swelling of expansive soils caused by moisture change result in significant distresses and hence in severe damage to overlying structures. Expansive soils are known as shrink-swell or swelling soils. Different clays have different susceptibility to swelling. The greatest problems occur in soils with high montmorillonite content. Such soils expand when they are wetted and shrink when dried. This movement exerts pressure to crack sidewalks, basement floors, driveways, pipelines and foundations. The damages due to expansive soils are sometimes minor maintenance but often they are much worse, causing major structural distress. In the United States, 10% of the 250 000 new houses built on expansive soils each year experience significant damage, some beyond repair. [3, 4]

Expansive soils are found in many parts of the world, particularly in semiarid regions with alternating wet and dry seasons. The soils in these regions experience periodic swelling and shrinkage during the alternating wet and dry seasons. Such cyclic swell-shrink movements of the ground cause considerable damage to the structures founded on them. The influence of cyclic wetting and drying on the swelling behavior of natural expansive soils is well documented. [1, 4] The solutions to problems of foundations on expansive soils require understanding the fundamental characteristics of expansive soils and the involved variables that affect the swelling phenomenon. The swelling behavior of soils is influenced by many physical and environmental factors that contribute to the expansive nature of a soil; these factors include the type and amount of clay minerals, physicochemical properties of pore fluid, soil density, water content, plasticity indices, surcharge pressure, temperature, and time. [4]

Fly ash is produced by coal-fired power plants during the combustion of coal. Fly ash consists mainly of inorganic glassy particles formed from the miner matter in the coal. During combustion, these minerals are heated to a molten state and chemically combined and solidified while suspended in the exhaust gas. They are then collected by electrostatic precipitators or bag houses. Fly ash is classified based on the chemical and physical composition of the ash.Self-cementing fly ash is normally produced from lignite or sub-bituminous coal that meets the applicable requirements. [5, 6] In many centuries, coal is the primary fuel in thermal power plant and other industry. The fine residue from these plants which is collected in a field is known as fly ash and considered as a waste material. The fly ash is disposed of either in the dry form or mixed with water and discharged in slurry into locations called ash ponds. The quantity of fly ash produced worldwide is huge and keeps increasing every day. [6]

Fly ash is used for soil stabilization. Soils can be treated with fly ash to modify engineering properties as well as produce rapid strength gain in unstable soils. The volume of fly ash currently used for soil stabilization is less than that used for cement replacement in concrete. As knowledge is gained about the mechanisms of stabilization involving fly ash, the volume used in soil stabilization applications will increase. [7, 8]The primary benefits of using self cementing fly ash for soil stabilization are (1) environmental incentives, because material used does not have to be wasted; (2) cost savings, because fly ash is typically cheaper than cement and lime; and (3) availability. [8]

MATERIALS AND METHODS

The samples used for laboratory tests were collected from a depth of 1 m below the ground level from Karblaa city south of Baghdad. The geotechnical index properties of soil before the addition of fly ash, is as summarized in table 1 .The grain size distribution of the untreated sample is shown in figure 1.

Fly ash was collected from the Baghdad Electrical Power Station. Chemical composition analysis of fly ash used is as shown in table 2.

Preparation of the samples for testing: The soil is oven dried and pulverized then mixed with the desired amount of fly ash. Water is added to the mixture and mixed until it became homogenous.

The laboratory tests [9,10,11] carried out on the natural soil include particle size distribution by ASTM D 422-63(1998), Specific Gravity by ASTM D854-02, Atterberg limits test by ASTM D4318-00, Compaction test by ASTM D698-00a, Direct shear test performed according to ASTM D3080-98 and Swell Percentage and Swell Pressure were determined by oedometer test according to ASTM D4546-96.

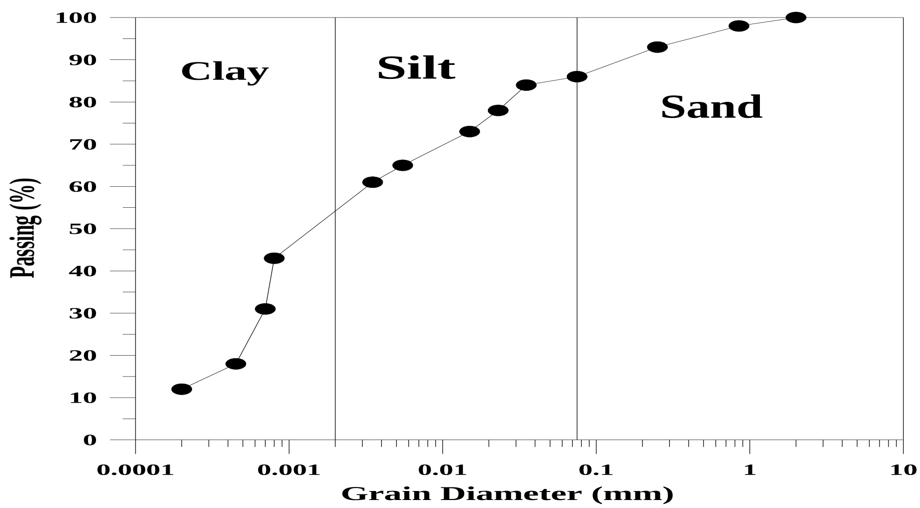

Fig.1 Particle size distribution of soil used.

Table1 Properties of expansive soil

Property	**Quantity**
Specific gravity	2.68
Sand (%)	14
Silt (%)	32
Clay (%)	54
Activity (%)	0.81
Consistency limits : *Liquid limit (%)* *Plastic limit (%)* *Plasticity index (%)*	 74 31 44
Free Swell (%)	48
Maximum dry density (kN/m³)	17.3
Optimum moisture content (%)	19.2
USCS Classification	CH

Table 2 Chemical compositions of Fly ash

Chemical content	(%)
SiO_2	42.3
Al_2O_3	12.5
Fe_2O_3	9.5
CaO	13.5
SO_3	17.3
Dissolved salts	4.9

TEST RESULTS AND DISCUSSON

Effect of fly ash on consistency limits

Atterberg limits where tested with various fly ash content, and the results are shown in figure 2. Liquid limit decreased with increasing fly ash content, and the plastic limit decreased with increasing fly ash content, thereby resulting in a decrease in plasticity index. A possible explanation of the above results may be related to the addition of fly ash, which aids flocculation, and aggregation of the clay particles. Furthermore, fly ash inclusion diminished the clay size fraction of soil in view of flocculation of the clay particles by cementation .Thus, fly ash treatment made the soil more granular due to the reduction of Atterberg limits.

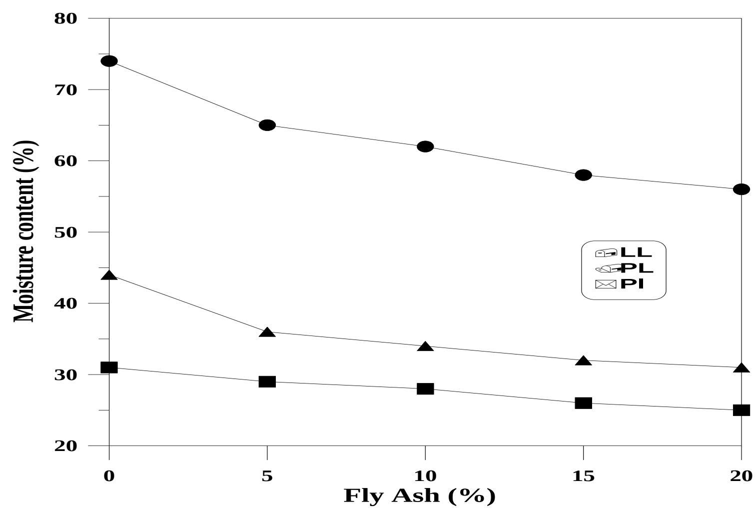

Fig.2 Variation of Atterberg limits with fly ash content.

Effect of fly ash on compaction characteristics

Figure 3 shows the variation of the maximum dry unit weight (MDD) and optimum moisture content (OMC) with fly ash content. The maximum dry unit weight of natural soil sample was 17.3 kN/ m^3; The (MDD) for a soil sample with 20% fly ash content was 13 kN/m^3, this means that (MDD) decreased with increasing fly ash content, and the (OMC) increased with added fly ash content.

The decrease in density may be related to the flocculated and agglomerated clay particles occupying larger spaces leading to a corresponding decrease in dry density, and the effect of fly ash addition to soil sample points out that the specific gravity of soil mixed with different concentrations of fly ash is decreasing by the increasing amount of fly ash added as shown in figure 4.

The increment of OMC was probably produced by the coarse grain size of fly ash compared to that of natural soil, which caused an enlarged void ratio in soil mixtures.

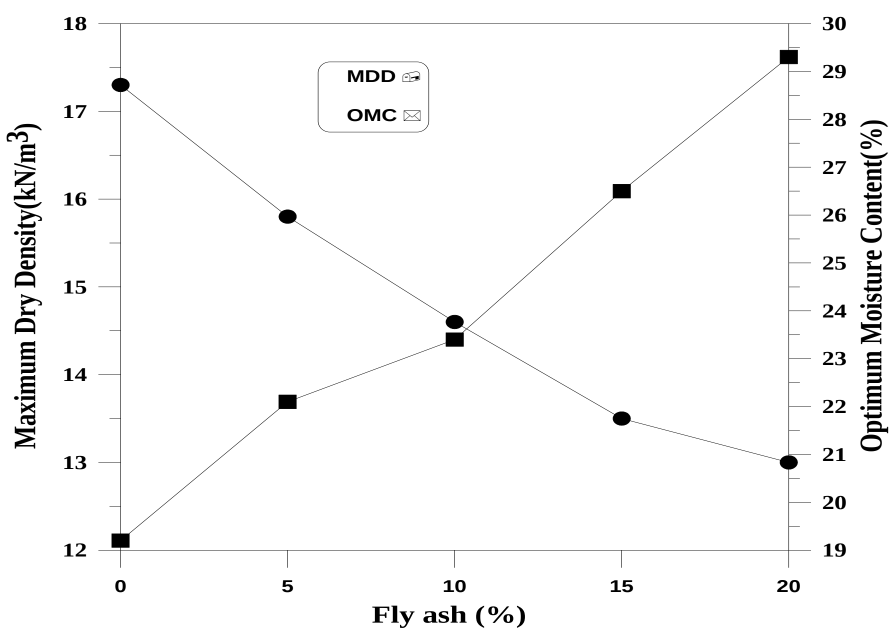

Fig.3 Variation of Maximum dry density & optimum Moisture content with fly ash content.

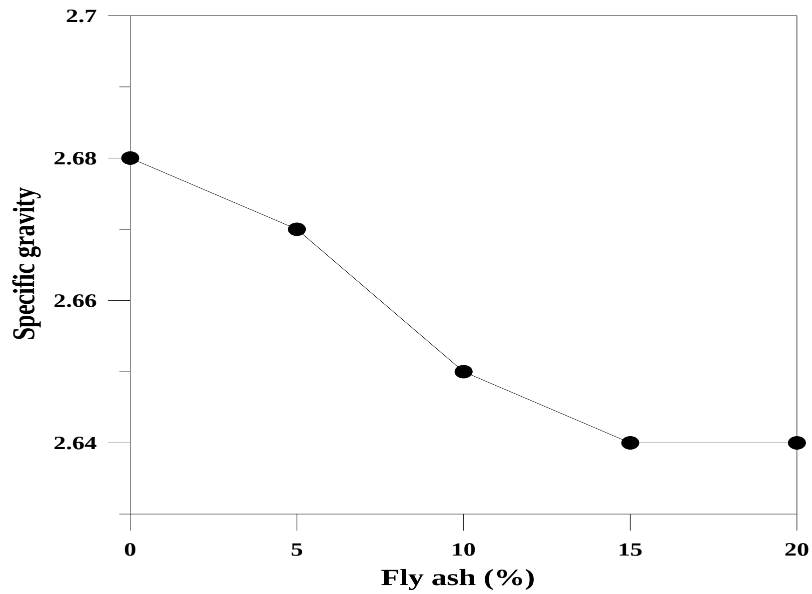

Fig.4 Variation of Specific gravity with fly ash content.

Effect of fly ash on shear strength

Figures 5&6 show the variation of shear strength parameters c and ø with various fly ash contents for 0,7,14 and 21 days of curing. The samples were compacted to their maximum dry densities at the optimum moisture contents. The samples were put in tightly closed nylon bags and left at room temperature from (15Cºto25Cº) for 0,7,14 and 21 days before subjecting them to testing.

The results indicated that the value of cohesion increased with increasing the amount of fly ash added in soil mixtures to 15% fly ash, then decreases. While c is decreased at various contents of added fly ash at 0 time (no curing or immediately tested). The effect of curing time on cohesion increased until 14 days.

When fly ash is added to soils, there is an initial cementation reaction and then long-term pozzolanic reactions between the clay minerals and fly ash particles.This can be seen in figure 5.

The cohesion values decrease with fly ash content for no cured samples. This may be because that cementation by puzzolanic activity is not done in immediately test.

The effects of fly ash on the internal friction angle ø of the mixtures are presented in figure 6. The increase in ø with added fly ash in all samples is independent of curing time of the mixture. The internal friction angle varying with fly ash content shows a linear variation. This effect may be due to that the internal friction angle of the fly ash is more than that of the pure soil. The increment in ø of all the mixtures for 7, 14 and 21 days curing time is more than that of no curing time.

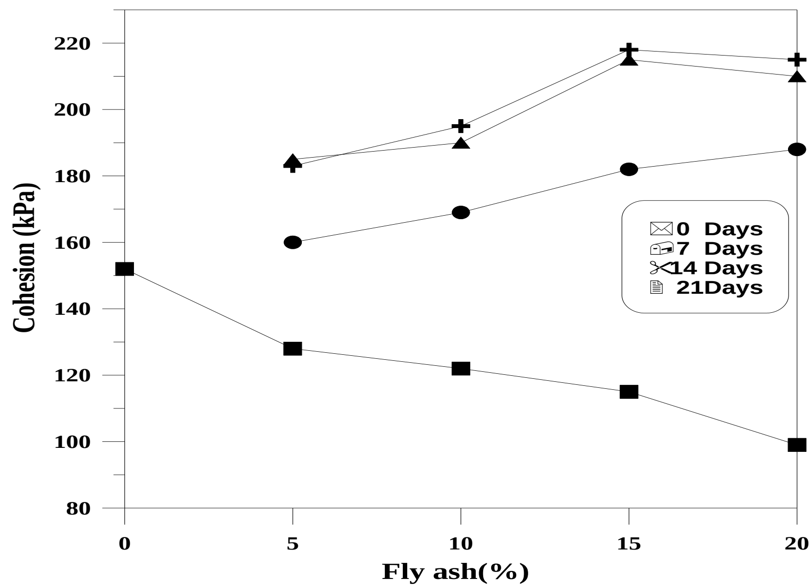

Fig.5 Variation of cohesion with fly ash content.

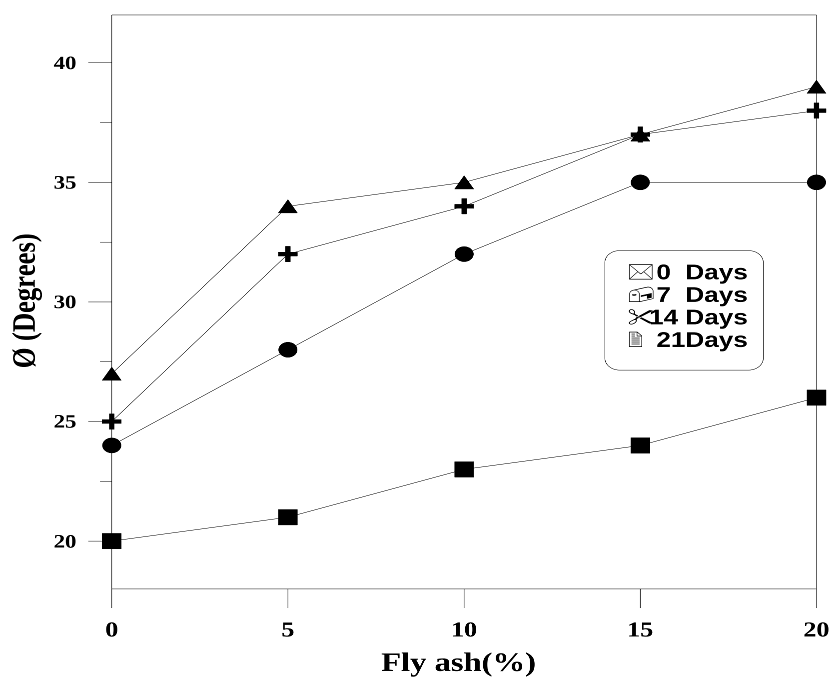

Fig.6 Variation of internal friction angle (Ø) with fly ash content.

Effect of fly ash on swell percentage &swell pressure

The correlation between fly ash content with swell percentage and swell pressure are plotted in figure 7. Both swell percentage and swell pressure decreased with increasing fly ash content .It may be stated that as the fly ash content increases, the clay size fraction is diminished in view of flocculation of the clay particles by cementation.

Effect of curing on swell percentage &swell pressure

This part of the experimental program is planned to investigate the effect of curing time on the swell percentage & swell pressure. Soil samples tested with fly ash constant (15%) at different curing days (0, 14&21). Treated mixture is compacted at optimum moisture content in compaction moulds and then set to cure at room temperature. Samples extracted from these moulds at the time of experiment are then subjected to consolidation tests. Swelling percentage and swelling pressures of the samples are obtained at the end of 14 and 21 days and the results are shown in table 3.

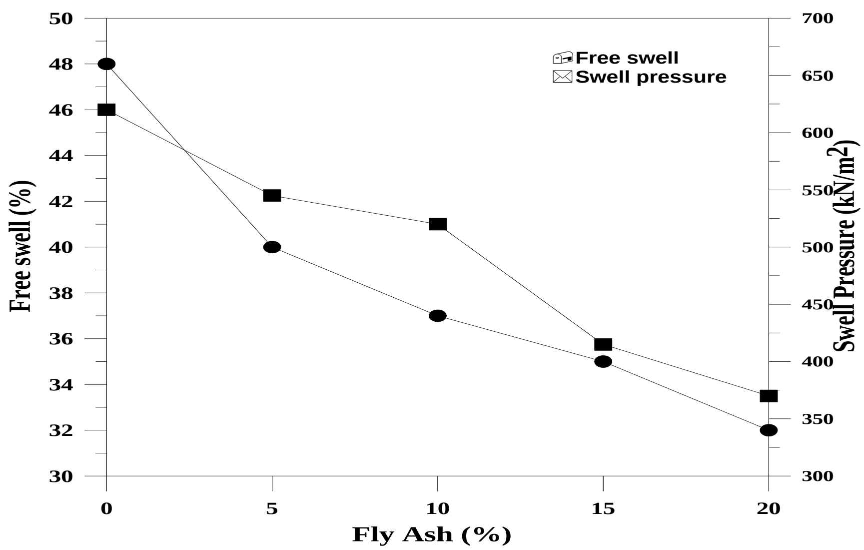

Fig.7 Variation of swell percentage and swell pressure with fly ash content.

Table 3 Variation of swell percentage & swell pressure with curing time for 15% fly ash treated samples.

Curing period (days)	Swell (%)	Swell pressure (kN/m^2)
0	35	415
14	15.2	138
21	13.8	131

It is clear from table 3 that both swell percentage and swell pressure decreased with curing time. This may be produced by the pozzolanic (cementation) activity. After 14 days curing time, the reduction in swell percentage and swell pressure was minimal.

CONCLUSIONS

The main conclusions are:

1. Liquid Limit value, plastic limit value, and plasticity index decreased with increasing fly ash content.
2. Value of maximum dry density (MDD) decreased with increasing fly ash content, while optimum moisture content (OMC) increased with added fly ash.
3. Specific gravity decreased with increasing of fly ash.
4. The value of cohesion increased with increasing the amount of fly ash in soil mixtures to 15% fly ash then decreased.
5. The value of cohesion increased with curing time to 14 days.
6. The increase in Ø with added fly ash in all samples is independent of curing time of the mixture. The increase in Ø of all the mixtures for 7, 14 and 21 days curing time is more than that of no cure time.
7. Swell percentage and swell pressure decrease with addition of fly ash. Both swell percent and swell pressure decrease at (samples content 15% fly ash) with different curing period times. The decreased values of both are behind curing period 14 day not large.

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