Journal of Engineering and Development, Vol. 11, No. 3, December (2007) **ISSN 1813-7822**

Effect of Fly Ash on the Engineering Properties of Swelling Soils

Asst. Lect. Mohammed Hussein Al-Dahlaki
Civil Engineering Department, College of Engineering
Al-Mustansiriya University, Baghdad, Iraq

Abstract

This study reports the influence of different percentage additives of fly ash on the swell characteristics and engineering properties of laboratory-prepared heavy clays. For this purpose the effect of 0-25% of fly ash on the swelling properties of expansive soils have been studied on samples with various curing time (0, 10-days and 30-days). Moreover, the effects of such addition on other mechanical properties of expansive soil (such as grain size distribution and consistency limits) are taken into consideration.

Fly ash proved its efficiency in improving the swelling characteristics. The results show an increase in swelling reduction with increasing fly ash percent increase and curing time.

الخلاصة

ركزت هذه الدراسة على تأثير أضافة نسب مختلفة من الرماد المتطاير للترب ألانتفاخية المعدة مختبريا وذلك بخلط ترب طبيعية غير أنتفاخية بأخرى أنتفاخية (البنتونايت).حيث تم اضافة نسبة تتراوح من (٠ الى ٢٥ %) من الرماد المتطاير الى التربة الانتفاخية ولنماذج معدة للانضاج بفترات مختلفة (٠ – ١٠ أيام و ٣٠ يوما). لقد تم خلال هذه الدراسة بحث تأثير أضافة الرماد المتطاير على باقي الخواص الهندسية للتربة الانتفاخية (مثل التدرج الحبيبي وحدود قوام الطين).

لقد أثبت الرماد المتطاير فعاليته في تحسين خواص الانتفاخ حيث اظهرت النتائج المختبرية انخفاضا كبيرا في الخواص الانتفاخية كنتيجة لزيادة الرماد المتطاير اليها وكذلك زيادة في هذا الانخفاض بزيادة فترة الانضاج.

1. Introduction

The term "S*welling Soils*" usually refers to those clay minerals that possess contradictory behavior in consequence of variation in its moisture content in the course of time. The main reason of such behavior is attributed to the environmental conditions that escort its geological formation. There are many factors that control the behavior of expansive soils. This behavior may endanger the structures constructed on such soils and as a result, complex damages are expected.

Generally, the problem of expansive soil may be divided into two parts: First, heave problems, the soil swells as a result of increasing its moisture content causing a high uplifting pressure which may reach 2500 kN/m^2 if swell is not allowed and heave of 1000% if swell is allowed [1]. Second, shrinkage problems, the soil shrinks as a result of the reduction in its moisture content. Generally, the structures are less susceptible to damage from soil shrinkage than from heave. Therefore, it is more effective to limit heave than to limit shrinkage [1,2].

Swelling "Expansive" soils are dispersivly spread in the middle and north of Iraq. Actually problems associated with expansive clays are worldwide, as it occurred in such countries as Africa, Australia, India, South America, Canada and the United States. Numerous researches have been conducted to investigate the swelling characteristics of expansive soils.

The swelling soils cause cracking and break up of pavement, railway embankment, roadways, building foundations, slab on grade members, channel and reservoir linings, water lines, sewer lines [3].

2. Swelling Soils Stabilization with Fly Ash

When the civil engineer encountered swelling soil type, the engineering properties of the problem soil may be improved to make them suitable for construction and earth work. Soil stabilization, in the broadest sense, is the alteration of any property of a soil to improve its engineering performance. Chemical stabilization of soils is one of the available answers for the geotechnical engineering problems and it may be used to reduce the shrinkage and swelling characteristics of soils. Although it is known that the properties of expansive soils could be substantially altered by the addition of stabilizing agents, the chemical stabilization is still at its infancy [1].

Using the industrials wastes have the attention of researchers recently because of the cheapness of material cost in compare with other material that may be used in chemical stabilization of soil. Fly ash being the most common pozzolanic material encountered in construction is a by-product of coal burning power plants. The fly ash is disposed of either by sluicing to ponds or hauling to solid waste disposal areas. Disposal operations are quite expensive and required the use of land that could be used for other purposes [4].

Fly ash is a fine textured alkaline material which is primarily composed of spherical non-crystalline silicate, aluminum and iron oxides compounded with some microcrystalline material, free lime and unburned carbon. It has the potential to provide multivalent cautions

(Ca^{+2},Al^{+3}, etc.) under ionized conditions, which would promote flocculation of dispersed clay particles by caution exchange. However, fly ash is classified as non-plastic fine silt according to the Unified Soil Classification System. When fly ash mixed with soil, it can develop cementation bonds due to the pozzolanic reaction or an inherent self-hardening property under favorable conditions of moisture and compaction [5].

3. Experimental Work

3-1 Materials

The soils used have been prepared by mixing natural soil (non-swelling), with commercial Na-base Bentonite (swelling soil). **Tables (1)** and **(2)** illustrate the physical properties of the soils used in this work. It should be recalled here that all the tests mentioned in this research are conducted according to the procedures described by [6].

Chemical and physical properties of Ash used as a stabilizer agent may vary significantly in accordance with power plant that produces it.

Table (1) Properties of soil and the effect of fly ash on Atterberge limit with curing time of 10-days, R.F% L.L and R.F% P.I.

Fly Ash %	Maturing time (day)	L.L	P.L	P.I	R.F,% L.L	R.F,% P.I
0	0	75.6	25.14	50.46	-	-
2.5	1	60.30	23.46	36.83	20.2	27.0
	10	56.34	21.07	35.27	25.4	30.1
5	1	50.76	25.14	25.62	32.8	49.2
	10	44.36	22.47	21.89	41.3	56.6
10	1	48.25	28.16	20.09	36.1	60.1
	10	39.85	23.01	16.84	47.2	66.6
15	1	47.52	30.17	17.35	37.1	65.6
	10	36.74	24.31	12.43	51.4	75.3
20	1	45.36	30.00	15.36	40.0	69.5
	10	34.02	24.38	9.64	55.0	80.8
25	1	43.2	29.85	13.35	42.8	73.5
	10	31.41	22.69	8.72	58.4	82.7

* R.F; Reduction Factor

Table (2) Properties of soil and the effect of fly ash on clay and silt content, Specific Gravity, R.F% GS, R.F% clay and I.F% silt for curing time of one day

Fly Ash %	G_S	Clay %	Silt %	R.F GS	R.F Clay %	I.F Silt %
0	2.75	80.10	14.2	-	-	-
2.5	2.72	75.60	18.7	1.09	5.61	31.69
5	2.70	72.5	21.8	1.81	9.48	53.52
10	2.68	65.3	29.0	2.54	18.47	104.2
15	2.67	62.7	31.6	2.91	21.72	122.5
20	2.65	59.8	34.5	3.63	25.34	142.9
25	2.61	57.3	37.0	5.09	28.46	160.5

* I.F; Increasing Factor

3-2 Swelling Tests

The swelling characteristics of compacted soils are determined on samples compacted using static compaction. These samples are compacted at some chosen moisture contents. Before mixing, the soil is first oven dried with (105-110 C^o) and then pulverized by passing it on sieve No.10 for Oedometer-Tests and on sieve No.40 for consistency limits tests. The distilled water is then added to the dry soil, mixed thoroughly by hand and then compacted statically to the required initial dry density using a loading machine operating at a very slow speed. With respect to the stabilized soil the fly ash used is mixed thoroughly with the prepared soil used (soil + bentonite).

All soils are statically compacted to the required dry density in the oedometer ring of diameter 80-mm to a height of 15-mm. The entire assembly is mounted in the consolidation cell and positioned in the loading frame with a nominal surcharge of 7kPa. All specimens used for swelling tests were compacted at dry density of 16.2 kN/m^3 and water content of 18%. With respect to the specimens subjected to the effect of curing time. First, it were mixed well with soil and then covered with a nylon bags and stored with controlled temperature (15-20 C^o). Then, the weight of the sample were continuously monitored to prevent lose of water content that may reflect negatively on swelling tests results.

4. Effect of Fly Ash on Consistency of Clay

Atterberg limits of the soils stabilized with 0-25% of fly ash are determined after a maturing time of 24 hours. Moreover, the effect of curing time is taken in account where the all stabilized soils were tested after a curing time of 10 days are to explore the effect of maturing on atterberg limits values. The results of these tests as a function of the percentages of fly ash and time of maturing are given in **Table (1)**. The relations between fly ash percent versus liquid, plastic limit and plasticity index is plotted in **Fig.(1)**.

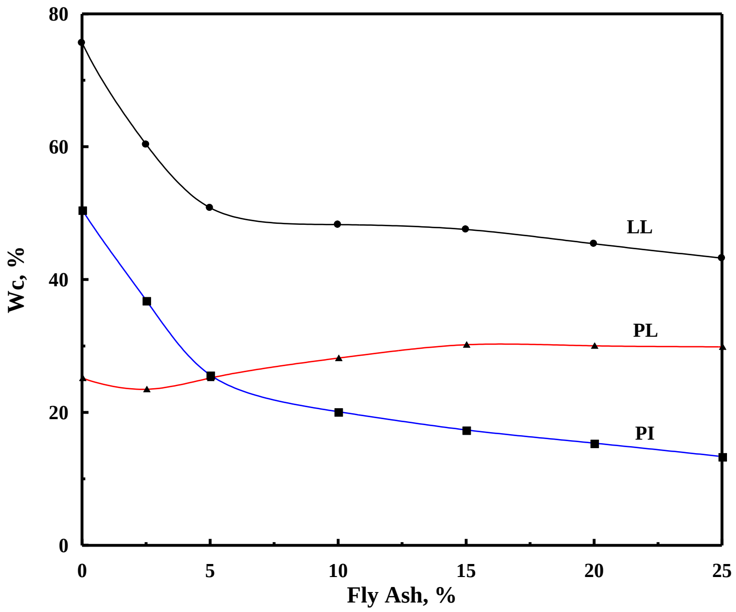

Figure (1) Effect of fly ash percentage on Aterberge limits (L.L, P.L & P.I)

The amount of fly ash has a pronounced effect on the liquid limit, L.L., of the soils used and, consequently, on the plasticity index. The orders of reduction in liquid limit ranges from (20.2-58.4%) depending on flay ash percent, where reduction factor increases as fly ash percent increase. In contrast, the plastic limits, P.L., are not largely affected by the amount of fly ash; where there is a marginal decrease at flay ash percent of 2.5 and 5% while it increases with fly ash of 10-25%.

Generally, the reason of such behavior may be attributed to the reaction that taken place between the fly ash and soil (pozzolanic reaction). However, it is also thought that this is not the only reason because the presence of fly ash with its effects on grain size distribution means that active material would be reduced and consequently the liquid limit and plasticity index reduced. Furthermore, it has been noted that curing time of 10 days appear to have a noticeable influence on the atterberg limits of swelling soils.

5. Effect of Fly Ash on Grain Size Distribution and Specific Gravity

The relations between fly ash percent versus silt and clay content is plotted in **Fig.(2)**, also the values of this plot are given in **Table (2)**. It is seen that the addition of fly ash reduces the clay content and increasing the silt content. The decrease in clay content ranges from (5.6- 28.4%) and the reduction factor increase as the percentage of fly ash increases. In contrast, it is appears that there is an increasing in silt content as fly ash percent increase with range from (31.6-160.5%).

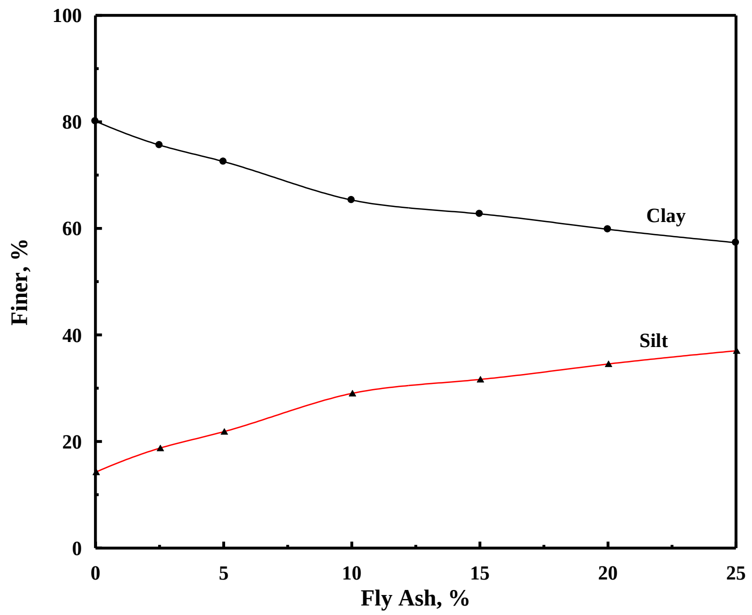

Figure (2) Effect of fly ash percentage on clay and silt content

The reason of such behavior may be explained mainly as a consequence of the addition of silt size particles also there are some pozzolanic reactions which cause the flocculation of clay particles. Clearly, as the fly ash percentage increases, the soil becomes more granular and this depends on fly ash type or source.

The presence of fly ash would decrease the specific gravity values from (2.75 for 0% to 2.61 for 25%) of fly ash. This may be attributed to the light weight of fly ash in compare to the soil and thus any increase of fly ash percent as light weight material it will reflect on the specific gravity values of overall sample mix (stabilized soil).

6. Effect of Fly Ash on Swelling Pressure

6-1 Swell-Time Relationships

The swell percent is plotted against time in, **Fig.(3)**. It can be seen that expansive soils need a long period of time to complete their expansion.

Time may differ in accordance with swelling potential of soil. Also, it shows that the swelling may follow different paths with respect to time for different swelling potentials. The same observation was noticed by [7].

In general, the increase in swelling with log time is initially slow, increased steeply, and then reaches an asymptotic value. It can be observed that the time required to reach an asymptotic value varies considerably depending upon the plasticity of clay. Such behavior was pronounced by [8,9]. They attributed these differences in behavior to the differences in permeability.

From **Fig.(3)** it can be seen that the rate of swell of the non-stabilized specimens within the first two days is high and then it decreases after a deflection point. The treated specimens show somewhat different behavior in comparison with their non-stabilized counterparts. Where, it can be seen that the rate of swelling is slow throughout these tests.

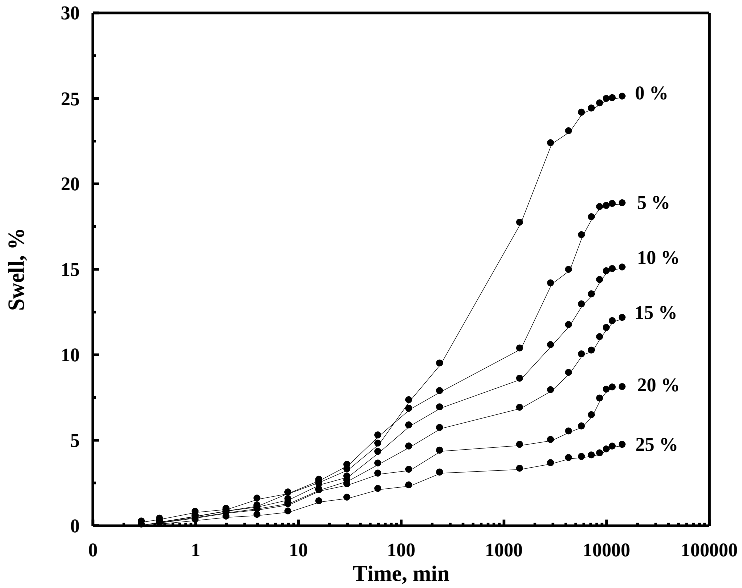

Figure (3) Swell-time relationships with different percentages of fly ash (1-day curing time)

Finally, the rate of swell decreases gradually till reaching an asymptotic value, which corresponds to the electrical equilibrium when the double layer arrives to its full required thickness to balance the net negative charges at the faces of clay particles.

The relations between fly ash percent versus free swell is plotted in **Fig.(4)**, it is clearly seen that swell percent would largely reduced as fly ash percent increase. On the other hand, the swell percent decreases as the time of curing increasing and it may be attributed to the effect of pozzolanic reaction that taken place during maturing process.

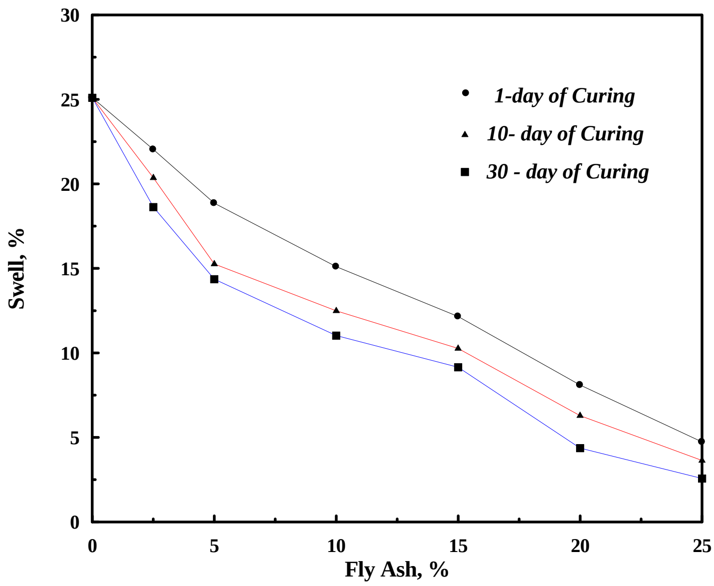

Figure (4) Effect of fly ash percentage on free swell (swell of initial thickness of 15-mm)

6-2 Swell-Pressure Relationships

Figures (5 to 7) demonstrate the results of the oedometer tests carried out under identical conditions on compacted specimens. The values of swelling pressure decrease significantly with the increase in the percentage of addition.

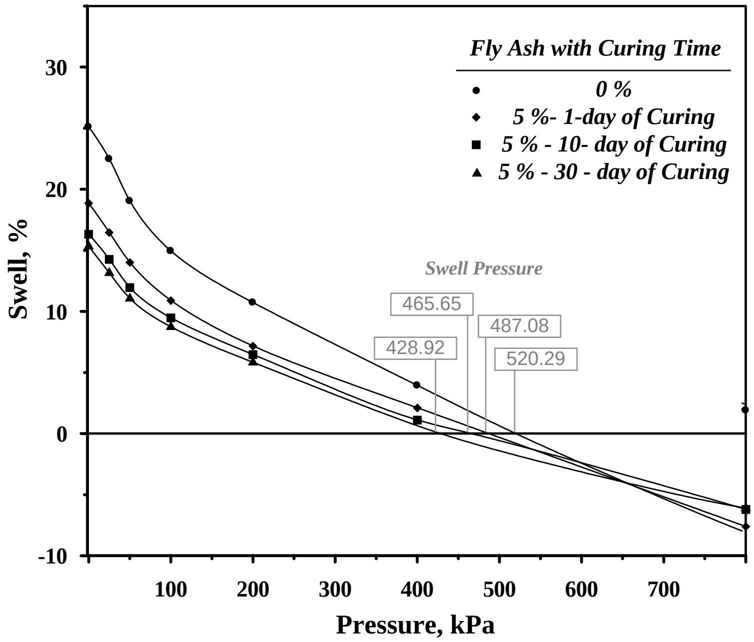

Figure (5) Swell-pressure curves showing the effect of 5% of fly ash

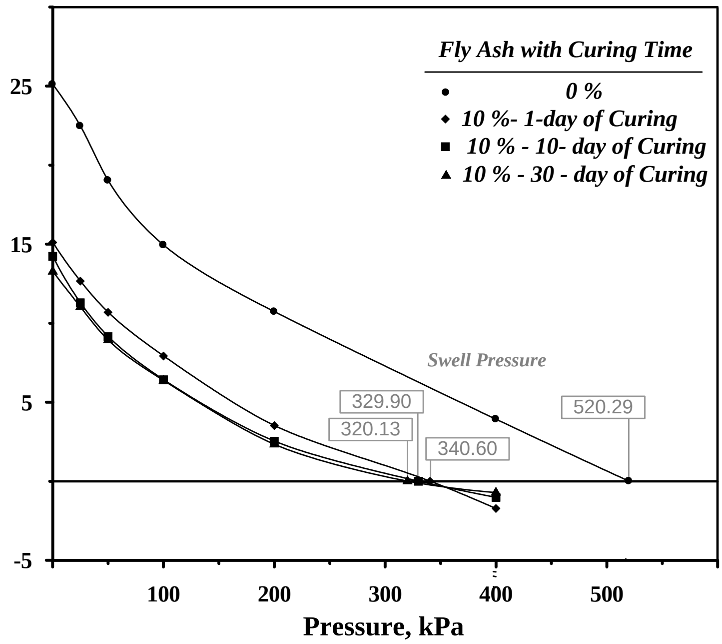

Figure (6) Swell-pressure curves showing the effect of 10% of fly ash

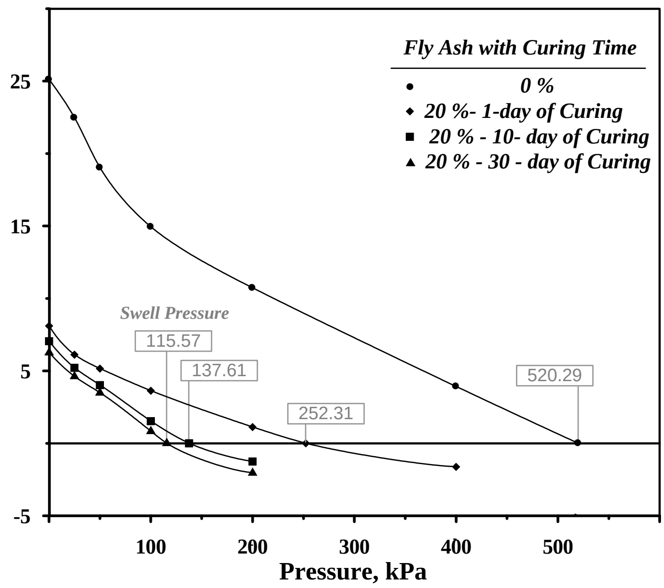

Figure (7) Swell-pressure curves showing the effect of 20% of fly ash

In reality, the presence of fly ash with its pozzolanic reaction with soil beside the expected reduction in the thickness of the double layer, and consequently in the repulsive pressure may be the reason of such reduction in the swell pressure.

The relations between fly ash percent versus swell pressure is plotted in **Fig.(8)**, it can be seen that swell pressure would significantly reduced as fly ash percent increase. On the other hand, the swell pessure decreases as the time of curing increasing and it may be attributed to the effect of pozzolanic reaction that taken place during maturing process which in turn reflect on the values of free swell obtained during swelling tests. Also, it can be seen that the difference of the swell pressure of the stabilized specimen with 20 and 25% are close to each other which may indicate an optimum fly ash percent which is 20% of fly ash.

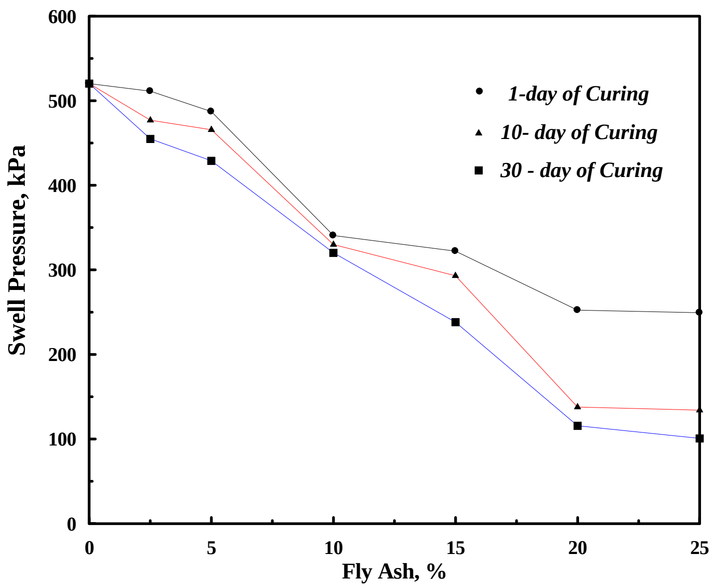

Figure (8) Effect of fly ash percentage on swell pressure with various curing time period

7. Conclusions

The effect of fly ash on some engineering properties in particular the swelling characteristics of swelling soils has been investigated. The following conclusions may be drawn;

1. The addition of fly ash to swelling soils decreases the liquid limit. The reduction increases as fly ash increases. The order of reduction in liquid limit ranges from (20.2-58.4%) depending on fly ash. However, for plastic limit it decreases with 2.5-5% of fly ash and then increases with 10-25%. Moreover, plasticity index of the soil decrease as fly ash percentage increases.
2. Curing time of 10-days appears to have a major influence on the Atterberg limits of soils stabilized using fly ash.
3. An increase in silt content and decrease clay content occur with the increase in the fly ash percent. The increase of silt content ranges from (31.6 to 160.5%). On the other hand, the decrease of clay content ranges from (5.61 to 28.46%) as fly ash increases. Moreover, the value of specific gravity decreases as fly ash increases.
4. The swell percent are significantly decrease as fly ash increases and the amount of reduction increases as curing time increases. No optimum value occurs with respect to the free swell.
5. The swell pressure is largely decreases due to the effect of fly ash and the reduction factors increases as curing time increases. An optimum value of fly ash may be taken as 20% with respect to swell pressure.

8. References

1. Jones, D. E., and Jones, K. A., ***"Treating Expansive Soils"***, Civil Engineering, ASCE, August, 1987, pp. 62-65.

2. Chen, F. H., ***"Foundation on Expansive Soils"***, Elsevier Scientific Publishing Company, Amsterdam, 1975.

3. Gromko, G. J., ***"Review of Expansive Soils"***, Journal of the Geotechnical Engineering Division, ASCE, Vol. 100, No. GT6, 1974, pp. 667-687.

4. Parker, D. G., Thornton, S. I., and Cheng, C. W., ***"Permeability of Fly Ash Stabilized Soils"***, Proceedings of the Specialty Conference of the Geotechnical Engineering Division of ASCE on Geotechnical Practice for Disposal of Solid Waste Materials, 1977.

5. Hassett, D. J., and Heebink, L. V., ***"Environmental Evaluation for Utilization of Ash in Soil Stabilization"***, Energy and Environmental research Center, University of North Dakota, August, 1999.

6. Head, K. H., ***"Manual of Soil Laboratory Testing"***, Pentech Press, London, Vol. 1&2, 1984.

7. Sivapullaiah, P. V., Sridharan, A., and Stalin, V. K., ***"Swelling Behavior of Soil-Bentonite Mixtures"***, Can. Geotechnical Journal, Vol. 33, 1996, pp. 808-814.

8. Seed, H. B., Mitchell, J. K., and Chan, C. K., ***"Studies of Swell and Swell Pressure Characteristics of Compacted Clays"***, Highway Research Board, Bulletin No. 313, 1962, pp. 12-39

9. Al-Omari, R. R., and Oraibi, W. K., ***"Cyclic Behavior of Reinforced Expansive Clay"***, Soils and Foundations, Japanese Geotechnical Society, Vol. 40, No. 2, 2000, pp. 1-8.