EFFECT OF FLY ASH STABILIZATION ON GEOTECHNICAL PROPERTIES OF CHITTAGONG COASTAL SOIL

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ABSTRACT
The use of fly ash has been studied to investigate the strength properties of stabilized soils collected from two sites of Chittagong coastal region namely, Anwara and Banshkhali. In the present study unconfined compressive strength (q_u), compaction properties and flexural properties has been studied. Compaction apparatus was employed to determine the strength of the stabilized soils. Strength tests were carried out on the specimens up to 28 days curing period. The investigated admixture was fly ash with lime; the amount of lime was fixed at 3 percent with the amount of fly ash 0, 6, 12 and 18 percent. The results from the experimental investigation shows that by increasing the amount of fly ash the strength properties of lime-fly ash stabilized soils improve. The use of fly ash with lime gave better strength and it may be more economical. For samples of both the coastal soils, compared with the untreated samples, unconfined compressive strength of fly ash and lime treated increased significantly, depending on the additive content and curing age. Compared with the untreated samples, flexural strength and modulus increased considerably, depending on the additive content. Compared with the untreated sample, the flexural strength and flexural modulus of fly ash treated samples increased up to about 4.6 and 4.7 times and 3 and 4.3 times respectively for both the soils. It could be concluded that fly ash stabilization of the coastal soils studied would be suitable for use in road construction.

1. INTRODUCTION
In early days, engineers could avoid unsuitable sites or unsuitable construction material sources whenever the required conditions for the construction were not fulfilled. It was ease of construction and ease in obtaining material, which governed the choice of site rather than economic factors. As time passed people became more cautious about the economy or, for different reasons, it has been difficult to find suitable sites for construction or suitable material sites for earth structures, such as highways, dams, or runways, within an economic range. It is evident that earth structures, such as embankments, highways, airport runways, dams, or reclamation appurtenance require soils with sufficiently good engineering properties: low plasticity, high bearing capacity, low settlement, etc. Since unsuitable materials, which have low bearing capacity, coupled with low stability and high settlement or excessive swelling or squeezing properties, are frequently encountered, it has been necessary to improve unsuitable materials to make them acceptable for construction. Improvement of soil by altering its properties is known as soil stabilization. An increment in strength, a reduction in compressibility, improvement of the swelling or squeezing characteristics, and increasing the durability of soil are the main aims of soil stabilization. The aim of this research work is to develop a

Hoe I. Ling et al. (eds.), Soil Stress-Strain Behavior: Measurement, Modeling and Analysis, 443–454.

general approach to soil improvement in coastal area by using fly ash for road construction. The study was limited to chemical stabilization by fly ash. A detailed study of the improvement of the strength properties of coastal soil of Bangladesh has been made using fly ash as additives. Investigation was made using commercial fly ash from brickfield, foundry shop and restaurant etc.

2. METHODOLOGY

Index property tests of the two coastal soils without any treatment were carried out to characterize the soils. Index tests include Atterberg limit tests, specific gravity and grain size analysis. Index property tests of the two soils stabilized with different fly ash having 3% lime as constant were also performed.

Modified compaction test, unconfined compressive strength test on molded cylindrical samples of 2.8 inch (71 mm) diameter by 5.6 inch (142 mm) high and flexural strength test using simple beam with third point loading system were carried out on the two coastal soils without any treatment and stabilized with three different fly ash contents (6%, 12% and 18%); having every time 3% lime and both the soil stabilized with 3% lime.

Unconfined compressive strength tests and flexural strength test using simple beam with third point loading were carried out on fly ash stabilized samples cured at 7,14 and 28 days in order to investigate the effect of curing age on the measured compressive strength and flexural strength and stiffness.

3. REVIEW

Fly ash is regularly used as a partial replacement for cement in concrete because of its pozzolanic properties; it is also the form of ash, which has the greatest potential for use in ground modification. Increased use as a partial cement or lime replacement would also represent a savings in energy (fly ash has been called a high-energy waste material).

Besides using fly ash alone as a structural fill material scope exists for employing techniques of ground modification to find more medium-to high-volume applications in the following ways: add cement or lime to stabilize the fly ash, stabilize soil with cement-lime-fly-ash mixes and use fly ash in the containment of toxic wastes.

3.1 ENGINEERING PROPERTIES

The specific gravity of the ash particle ranges from 1.9 to 2.5, which is below that normally measured for soil solids. The average grain size D_{50} of fly ash is likely to be in the range of 0.02 to 0.06mm. The friction angle as measured in consolidated drained triaxial tests is typically on the order of 30^0, but values as low as 20^0 and as high as 40^0 have been reported. The permeability of a fly ash compacted to standard maximum dry density depends on the coal type it is derived from [EPRI (1986)]. Considerable capillary rise of water in fly ash fills can occur on the order of 2 m and possibly more. Negative environmental impacts from a fly ash fill are unlikely, but a study has to be made of the chemical composition of its leachate; its corrosivity on buried pipes, culverts, or other structural elements; and its radioactivity (Radium-226).

3.2 FLY ASH STABILIZED WITH LIME, CEMENT, AND/OR AGGREGATE

The use of mixtures of lime (L) or cement (C) and fly ash (F) with aggregate (A) giving LFA, CFA, or LCFA bases or subbases for pavements is relatively well established in most countries. Guidelines for design and construction were given by Barenberg (1974) and other. Many local authorities have published criteria for the incorporation of pozzolanic materials with cement or lime in aggregate layers, either rated as bound or unbound layers, depending, e.g., on whether their indirect tensile strength is above or below 80 kPa (NAASRA, 1986). To build a sub base or base course with lime-or cement-stabilized ash alone is not yet common, but this is one high-volume ash applications being promoted by ash producers (British and American experience, EPRI (1986)).

3.3 SOIL MODIFIED WITH FLY ASH AND CEMENT

For cohesion less soils or soils with very low plasticity (plasticity index <10), cement will be more effective than lime, either alone or when combined with fly ash. For more plastic soils, either cement or lime may be added with fly ash. Only a soils testing program can indicate optimal mixes and relative economies. Fly ash could also serve as filler in the bituminous stabilization of coarse-grained materials. Stabilization of a sandy road base with a fly-ash-cement mix, rather than cement alone, creates a less-permeable stiffer layer. This may result in reduced long-term maintenance. Initial financial benefits depend on local material and transport costs.

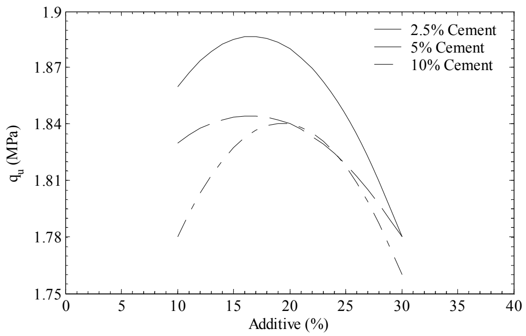

Figure 1: Maximum dry density and fly ash (after hausmann 1990)

Figure 1 demonstrates the effect of fly ash on the strength of cement-stabilized sand. The sand in question is of medium gain size (D50 = 0.3 mm), is fairly uniform (USCS classification SP), and is from the Woy Woy area, New South Wales. Stabilization of a sandy road base with a fly-ash-cement mix, rather than cement alone, creates a less-permeable stiffer layer. This may result in reduced long-term maintenance. Initial financial benefits depend on local material and transport costs. It has also been demonstrated that cement-fly-ash-sand or cement-fly-ash-gravel mixtures shrink less than soil-cement mixtures. Greater shrinkage is observed in these combinations if the cement is replaced by lime.

3.4 LIME FLY ASH-SOIL MIXTURE

Improvement of the strength properties of residual clay using fly ash as sole additive was shown by Nettleton (1962). However, he further observed that the additional of a small amount of lime in fly ash-soil mixtures further improved the strength of the stabilized soil. Subsequently, many authors have indicated the use of fly ash as an additive in lime-soil mixtures to achieve better strength of the mixture. However, there exist about little literature describing the use of fly ash a lesson soil stabilization.

In mechanism of lime, fly ash, and soil in stabilization as describe by Chu et al (1955) as follows: Fly ash is a gray, dust like ash which results from burning powered coal. The coal is burned while in suspension in air, and the resulting ash consists largely of tiny spheres of silica and alumina glass. The ash is similar to volcanic ash used in early Roma construction. It is a pozzolanic material; at is, it is not itself a cement, but it reacts with lime and water to form cementitious material. However, it is the reaction of lime and fly ash which is utilized to stabilize soils. After mixing the proper proportion the mixtures in a moist, non plastic state, but it can be readily compacted to form a dense mass.

Leonard and Davidson (1959) reported that because of the slow reaction of lime absorption, the development of compressive strength of a soil, lime and fly ash mixture is slow. Therefore, the rate of development of compressive strength of lime-fly ash reaction is directly related to the rate of lime absorption by the fly ash. The rate of lime absorption is limited by the rate of diffusion of the calcium through the reaction product. Minnick and Miller (1950) found that the coarser the material to the stabilized with lime and fly ash, the higher the volume of fly ash that is required.

One of the main questions in soil, lime, and fly ash stabilization is how much lime and fly ash are needed. The amount and proportions of the lime and fly ash admixtures are governed by the desired strength in the stabilized soil and by economy. Mateos and Davidson (1962) stated that there is no optimum amount, nor optimum ratio, of lime and fly ash for stabilizing all soils. The amounts of lime and fly ash to be used depend greatly on the kinds of fly ash and soil, and some what on the kind of lime. The authors found that the amount of hydrated lime for granular soils should be from 3 to 6 percent, and the amount of fly ash between 10 and 25 percent. For clay soils, the amount of lime should be between 5 and 9 percent, and the amount of fly ash between 10 and 25 percent.

Viscochil et al (1958) have shown that the density of soil, lime, and fly ash mixtures is dependent on the compactive effort applied, but the density also depends on the lime to fly ash ratio. The density is decreased by higher contents of lime because of two factors: Lime itself is less dense than soil or fly ash, and lime cause aggregation of clay. The authors further stated that the unconfined compressive strength is primarily influenced by cementation and does not give a true measure of the frictional strength developed in a confined state. Therefore, a stabilized granular material with relatively low unconfined compressive strength may show satisfactory stability.

The stability of lime-fly ash-soil mixtures is affected by many variables. According to Chu et al (1955), the following are main factors which affect the stability of a stabilized soil: Properties of Soil, amount and ratio of lime and fly ash in the mixture, properties of Lime and Fly ash, aging of lime, moisture contents of mixture, method and degree of compaction, length of curing period, and condition during curing.

4. LABORATORY INVESTIGATION AND TESTING PROGRAM

The laboratory investigations carried out on the untreated and stabilized samples of the two soil samples collected from coastal region of Chittagong have been described in details in the following sections.

Disturbed soils from two selected sites, namely Anwara and Banshkhali of Chittagong coastal region were collected for the present investigation. Soil sampling was carried out according to the procedure outlined in ASTM D420-87. Proper care was taken to remove any loose material, debris, coarse aggregates and vegetation from the bottom of the excavated pit. Disturbed samples were collected from the bottom of the borrow pit through excavation by hand shovels. The soil samples were designated as follows: Soil-A: collected from Anwara and Soil-B: collected from Banshkhali.

A comprehensive laboratory investigation program was undertaken in order to examine the physical, index and engineering characteristics of base soils (i.e., untreated soils) and soils stabilized with fly ash and lime. Fly ash and air-slaked lime were used as additives for stabilization. Both Soil-A and Soil-B were stabilized with Portland fly ash in percentages of 6, 12 and 18 keeping 3% lime constant. The whole laboratory-testing program consisted of carrying out the following tests on samples of the two coastal soils:

Index property tests on samples of the two coastal soils without any treatment with 3% lime and with different fly ash (6, 12, 18). Index tests included specific gravity test, Atterberg limit tests, and linear shrinkage test and grain size analysis.

Modified compaction test, unconfined compressive strength test on molded cylindrical samples of 2.8-inch diameter by 5.6 inch (142 mm) high, California Bearing Ratio (CBR) tests, and flexural strength test using simple beam with third point loading system were carried out.

Unconfined compressive strength test and flexural strength tests using simple beam with third point loading were carried out on fly ash and lime stabilized samples cured at three different ages (7 days, 14 days and 28 days). CBR tests were carried out on the untreated samples and samples treated with different fly ash with 3% lime contents using three levels of compaction. Table 1 Details of laboratory tests performed on samples of the two coastal soils.

4.1 PHYSICAL AND INDEX PROPERTIES OF UNTREATED SOILS

The samples collected from the field were disturbed samples. These samples were then air-dried and the soil lumps were broken carefully with a wooden hammer so as to avoid breakage of soil particle. The required quantities of soil were then sieved through sieve No.40. (0.435 mm). The following Standard test procedure were followed in determining the physical and index properties of the untreated soils: Specific gravity (ASTM D854), liquid limit (Cone penetrometer Method) (BS 1377), plastic limit and plasticity index (BS 1377), shrinkage limit (ASTM D427), linear shrinkage (BS 1377), percent of material in soils finer than No. 200 sieve (ASTM D1140), grain size distribution (ASTM D422) were carried out both on treated and untreated soil.

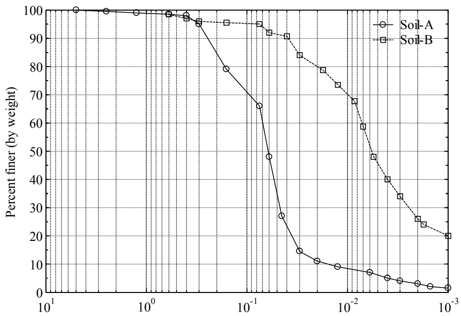

Figure 2: Grain size distribution curve of soil A and soil B.

The grain size distribution curves of samples of the two coastal are presented in Figure 2. The different fractions of sand, silt and clay of samples of Soil-A and Soil- B were found from the grain size distribution curves following the MIT Textural Classification System (1931). The soils were classified according to Unified Soil Classification System (ASTM

D2487) and the positions of the two soils (Soil-A and Soil-B) on the plasticity. The soils were also classified according to ASSET Soil Classification System (AASHTO M145-49). Table 1 presents are values of index and shrinkage properties, grain size distribution and classifications of Soil-A and Soil-B.

Table 1 Index properties and Classification of the coastal soils used

Index Properties and Classification	Soil-A	Soil-B
Specific Gravity	2.70	2.80
Liquid Limit	30	44
Plastic Limit	23	25
Plasticity Index	7	19
Shrinkage Limit	20	23
Linear Shrinkage	7	8
% Sand (0.60 mm to 2 mm)	34	6
% Silt (0.002 mm to 0.06 mm)	62	68
% Clay (< 0.002 mm)	4	26
% of Material Finer than No. 200 Sieve (0.074mm)	68	94
Unified Soil Classification	ML	CL
AASHTO Soil Classification	A-4	A-7-6

4.2 PROPERTIES OF FLY ASH USED FOR SOIL STABILISATION

The fly ash was obtained from different source. The chemical analysis was made by the Department of Chemistry, DU, and Bangladesh. Presented in bellow Table 2 the chemical composition of fly ash:

Table. 2 Chemical Analysis of Fly ash

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SiO_3	Total
Fly ash	10.7	5.00	16.0	40.5	24.7	3.4	100.3

Data based on chemical analysis by department of chemistry, Dhaka University

4.3 INDEX PROPERTIES OF STABILISED SOIL SAMPLES

Liquid limit, plastic limit, plasticity index and shrinkage characteristics including shrinkage limit and linear shrinkage of samples of the two soils (from Anwara and Banshkhali) stabilized with fly ash and lime were determined. Fly ash and hydrated lime (i.e., slaked lime) were used as additives. Fly ash was used in percentages of 6, 12 and 18 while the lime contents were used in percentage of 3 only; Liquid limit, plastic limit and plasticity index of the stabilized samples were carried out on air-dried pulverized samples. The required quantities of pulverized soil were sieved through sieve. No. 40 (0.425 mm). The fly ash and lime treated soils were compacted following ASTM D558 method. The compacted samples were cured in moist environment for 7 days and air-dried. The air-dried samples were pulverized to pass through no. 40 sieve. Liquid limit, plastic limit and plasticity indexes of the stabilized samples were determined following the standard procedure outline in BS 1377 and ASTM D424 respectively. The shrinkage factor comprising the shrinkage limit was determined in accordance with the procedure specified in ASTM D427. Linear Shrinkage of the fly ash and lime treated samples were determined following the procedure outlined in BS 1377.

The samples were never cured with direct water spray or under submerged condition. The samples were always protected from free water for the specified most curing periods of 7, 14 and 28 days. It may be mentioned that the soil samples that were prepared without adding fly ash or lime, i.e., the untreated samples were not cured.

5. RESULTS AND DISCUSSIONS

The findings of the laboratory investigations on the characteristics of untreated and stabilized samples of the two coastal soils are presented and discussed in the following sections. In the following sections the physical and engineering characteristics comprising plasticity and shrinkage properties, moisture-density relations, unconfined compressive strength, California Bearing Ratio (CBR), flexural properties, of untreated and fly ash-treated samples of the two coastal soils are presented and discussed.

5.1 PLASTICITY AND SHRINGKAGE CHARACTERSTICS

The values of plasticity and shrinkage properties of the untreated and fly ash-treated soil samples are presented Table 3 for Soil-A and Soil-B respectively. Compared with the untreated sample, the value of liquid limit of the treated sample increased in Soil A while it is reduced Soil-B. It can be seen from Table 3 that for Soil-A (LL=30, PI=7), both liquid limit and plastic limit increased while for Soil-Between (LL=44, PI=19) liquid limit reduced and plastic limit Increased with increasing fly ash content. Table 3 also shows the changes in shrinkage limit due to increase in fly ash content and the variation of linear shrinkage with the increase in fly ash content. It can be seen that for both the soils shrinkage limit and linear shrinkage reduced slightly with the increase in fly ash content.

5.2 MOISTURE DENSITY RELATIONS

The moisture-density relations of untreated and fly ash treated samples of Soil-A and Soil-B have been determined for both the soils, with the increase in fly ash content with 3% lime, values of γ_{max} increased while the values of ω_{opt} reduced. The increase in ϒmax with the increase in fly ash content for the two soils is shown in Figure 3. Compared with the untreated sample, the values of ϒmax increased up to 8% and 7% for Soil-A and Soil-B respectively. The values of ω_{opt} reduced up to 9% and 10% respectively for Soil-A and Soil-B.

Table 3: Atterberg limits of two coastal soils.

Properties	0% Lime		3% Lime		3% Lime with					
					6% Fly ash		12% Fly ash		18% Fly ash	
	A	B	A	B	A	B	A	B	A	B
LL	43.7	25.5	42.8	29.7	42.5	31.2	41.0	32.3	41.5	33.7
PL	30.4	23.5	29.8	24.8	32.9	28.9	37.1	33.5	38.1	35.8
SL	20.0	23.5	19.8	23.8	21.5	18.3	20.2	18.0	19.0	6.0
LS	6.8	8.0	6.0	6.9	5.5	6.5	5.0	6.0	4.5	5.5

5.3 UNCONFINED COMPRESSIVE STRENGTH

Figures 4 to 7 show the unconfined compression test results for Soil-A and Soil-B. It can be seen from Figures 4 to 7 that for both the soils, compared with the untreated samples, the values of q_u of the treated samples increased significantly, depending on the fly ash content and curing age. Leonard and Davidson (1959) reported that because of the slow reaction of lime absorption, the development of compressive strength of soil directly related with lime absorption by fly ash. It can be seen from Figure 4 to 7 that the values of q_u of samples of Soil-A and Soil-B treated with 6% fly ash and cured at 28 days were found to be about 4 times higher than the strength of the untreated samples and with 18% fly ash it about 5 times higher than untreated sample. It is also evident that the gain in strength with increasing fly ash content and curing age is higher in less plastic Soil-A (Pl=7) than in more plastic Soil-B (Pl=19). Figures also show that for all fly ash contents and all curing ages, the values of q_u of treated samples fulfilled the requirements of soil-fly ash road sub-base for light traffic as proposed by Ingles and Metcalf (1972) with cement. It can also be seen from Figures that compared with the untreated samples, the values of ε_f of the stabilized samples reduced and those values of ε_f of the treated samples reduced with the increase in fly ash content. It can't be seen from Figures 4 to 7 that the values of q_u of treated samples increased with increasing fly ash content and curing age.

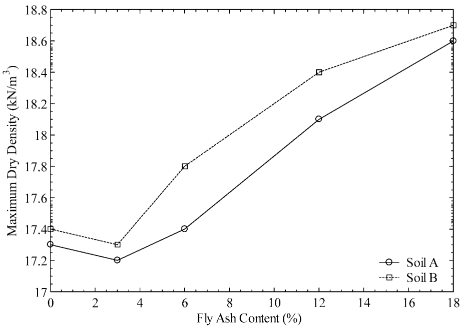

Figure 3: Effect of fly ash content on maximum dry density of fly ash treated soil A and soil B.

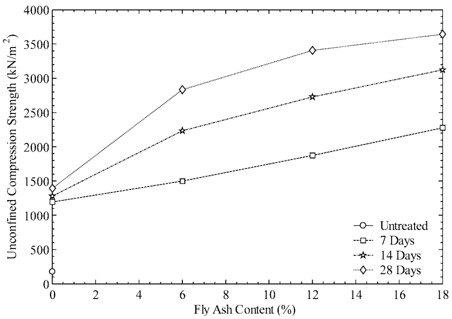

Figure 4: Unconfined compressive strength of lime, fly ash treated soil A.

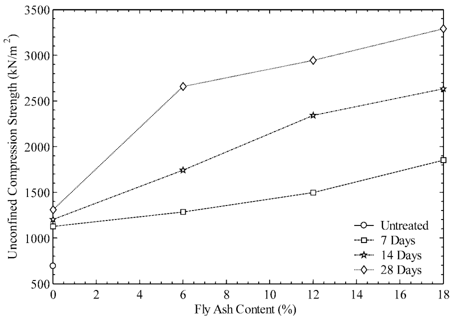

Figure 5: Unconfined compressive strength of lime, fly ash treated soil B.

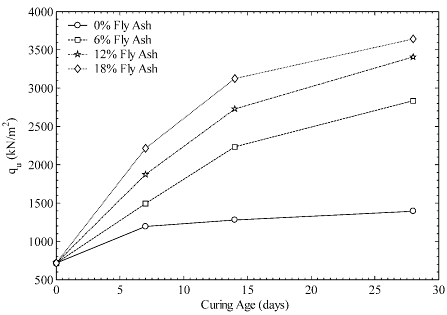

Figure 6: Unconfined compressive strength of lime, fly ash treated soil A.

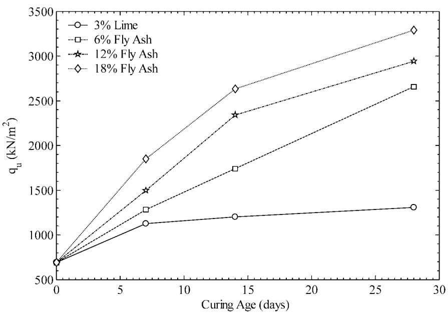

Figure 7: Unconfined compressive strength of lime, fly ash treated soil B.

5.4 FLEXURAL STRENGTH AND MODULUS

The flexural properties of untreated and stabilized samples of the two soils have been investigated by carrying out flexural strength test using simple beam test with third point loading. Typical flexural stress versus defection curves for two stabilized samples of Soil-A and Soil-B are presented in Figure 8 respectively. It can be seen from Figure 8 that flexural stress-deflection curves are approximately linear. From the flexural stress and deflection data flexural strength and modulus were determined. It can be seen from Figures 9 to 12 that for both Soil-A and Soil-B, compared with the untreated sample, flexural strength and modulus of the treated samples cured at 7, 14 and 28 days increased significantly. It can be seen from Figures that compared with the untreated sample, the flexural strength and modulus of Soil-A treated with 6%, 12% and 18% fly ash and cured at 28 days are respectively about 1.5, 3, 4.6 times and 1.8, 2 and 3 times higher respectively. Figures 9 to 12 show that the flexural strength and modulus of Soil-B treated with 6%, 12% and 18% fly ash and cured at 28 days are respectively about 2, 1.5, 6.7 times and 2.6, 3, 4.4 times higher respectively than those of the untreated samples. The maximum deflection and of untreated and stabilized soil-fly ash beams were in the range of 0.15 mm to 0.35 mm respectively. Comparing the flexural strength and modulus of Soil-A with those of Soil-B, it is evident that the values of flexural strength and modulus of samples of more plastic Soil-B (PI=19) is higher than the less plastic Soil-A (PI=7).

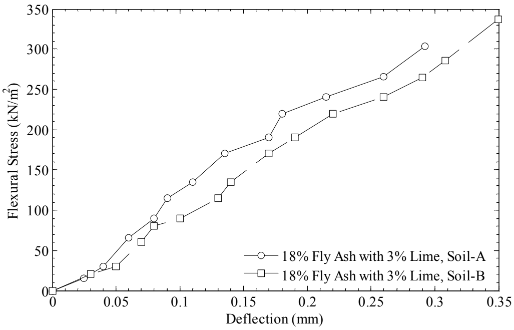

Figure 8: Flexural stress with deflection of fly ash treated soil A and B.

The effect of fly ash content on flexural strength for Soil-A and Soil-B are shown in Figures 24 and 25 respectively while Figures 11 and 12 present the effect of fly ash content on flexural modulus of Soil-A and Soil-B respectively. Figures 9 to 12 show that flexural strength and modulus increases with increasing fly ash content. It is evident from Figures 9 to 12 that curing age has got insignificant effect on increase in flexural strength and modulus.

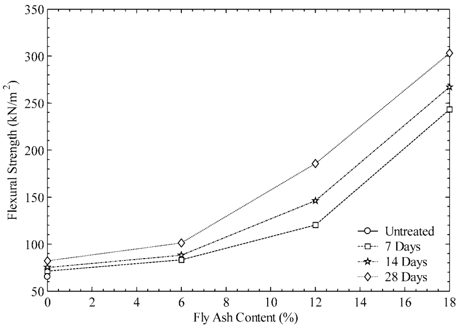

Figure 9: Effect of fly ash content on flexural strength of soil A.

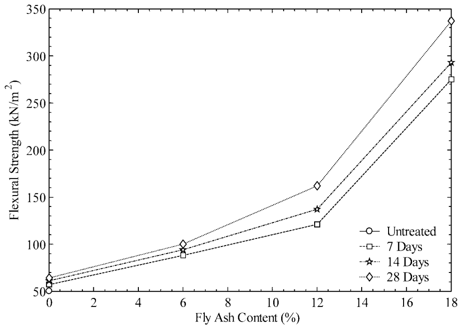

Figure 10: Effect of fly ash content on flexural strength of soil B.

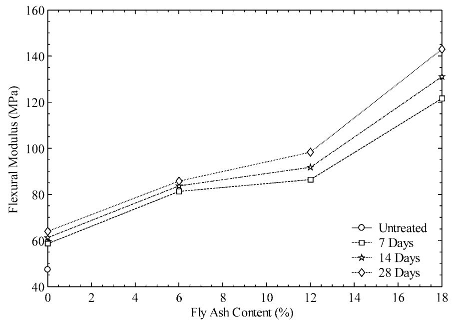

Figure 11: Effect of fly ash content on flexural modulus of soil A.

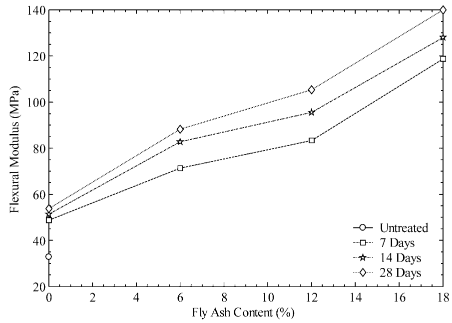

Figure 12: Effect of fly ash content on flexural modulus of soil B.

6. CONCLUSIONS

In this research work, fly ash stabilization of two selected soil (collected from Anwara and Banshkhali) of Chittagong coastal region have been carried out. Fly ash has been used in percentage of 6, 12 and 18 while lime has been added in percentages of 3 as additives with fly ash. The physical and engineering properties of fly ash and lime stabilized soil have been determined in order to asses the suitability of fly ash and lime stabilization further use in road construction. The major findings and conclusions have been separated into three sections relating to the following areas:

Compared with the untreated samples of Soil-A and Soil-B, plastic limit of the stabilized samples increased while plasticity index, shrinkage limit and linear shrinkage reduced. Compared with the untreated sample, the value of liquid limit of the treated sample increased in Soil-A while it is reduced in case of Soil-B. For Soil-A (LL= 30 PI =7) both liquid and plastic limit increased while for Soil-B (LL=44, PI=19) liquid limit reduced and plastic limit increased with increased fly ash content.

For samples of both the soils, compared with the untreated samples, the values of maximum dry density (γ_{max}) increased with fly ash content. Compared with the untreated sample, the values of γ_{max} increased up to 7.5% for both the soil with 18% fly ash. The values of ω_{opt} reduced upto 15% and 10% respectively for samples of Soil-A and Soil-B.

For samples of both the coastal soils, compared with the untreated samples, the values unconfined compressive strength (q_u) of the treated samples increases significantly, depending on the fly ash content and curing age. The values of q_u of samples of Soil-A and Soil-B treated with 6% and 18% fly ash and cured at 28 days were found to be about 4 and 5 times higher than the strength of he untreated samples respectively. It has also been fount that the gain in strength with increasing fly ash content and curing age is higher in the less plastic Soil-A (PI= 7) than in the more plastic Soil-B (PI=19). Compared with the untreated samples, the values of axial strain at failure (ε_f) of the stabilized samples reduced with the increase in fly ash content which evidently indicated that the treated samples became more brittle as fly ash content increased. The rate of strength gain with curing time (determined in terms of strength Development Index, SDI) for samples of Soil-A and Soil-B treated with 6% fly ash are relatively much slower than those of samples treated with 12% and 18% fly ash.

It was found that values of q_u of samples of Soil-A (belonging to A-4 group) and Soil-B (belonging to A-7 group) treated with 6%, 12% and 18% fly ash with 3% lime and cured for 7, 14 and 28 days satisfied the requirements of PCA (1956) for the unconfined compressive strength of soil-fly ash mix.

The flexural stress versus deflection curves have been found to be approximately linear for both Soil-A and Soil-B, compared with the untreated sample, flexural strength and flexural modulus of the treated samples increased significantly, depending on the fly ash content. For comparison, the flexural strength and flexural modulus of Soil-A treated with 18% fly ash and cured at 28 days are respectively about 4 times and 2.7 times higher than those for the untreated sample. The flexural strength and modulus of Soil-B treated with 18% fly ash and cured at 28 days are respectively about 6 times and 4.3 times higher than those of the untreated samples. The curing age, however, has got insignificant effect on increase in flexural strength and modulus. It was also found that the values of flexural strength and modulus of samples of more plastic Soil-B (PI=19) is higher than the less plastic Soil-A (PI=7). The maximum deflection and failure strain of untreated and stabilized soil-fly ash beams were very small and have been found in the range of 0.15 mm to 0.35 mm and 0.11% to 0.24% respectively.

From the aforementioned findings, it is evident that for both samples of the two coastal soils studied, fly ash stabilization provided a substantial improvement in the engineering properties as compared with the samples of the untreated soils. It has also been found that, in general, samples of both the soils stabilized with 12% and 18% fly ash with 3% Limes satisfied the requirements of compressive strength, and durability for their use as base or sub-base materials in roads subjected to light traffic.

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