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CBR and Strength Aspects of Fly Ash-Granular Soil Mixtures

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ABSTRACT- The study of granular sub base stabilized at 25% fly ash showed better results in CBR and strength aspects. As the percentage of fly ash increases from 0% to 25%, the CBR values are decreasing for both the unsoaked and soaked conditions. For tJhe fly ash content beyond 15% addition to soil is causing about 50% to 65% reduction in the CBR values for both the unsoaked and soaked conditions. The percentage of fly ash increases from 0% to 25%, the angle of internal friction of gravel soil is decreasing. This decrease in angle of internal friction is marginal up to about 10% of fly ash and. From 15% to 25% of fly ash, the angle of internal friction observed is almost constant and its value is in the range of 36^0 to 38^0. Up to 25% of fly ash can effectively be utilized along with the granular subbase in the pavement construction

KEY WORDS: CBR, fly ash granular soil mixtures, direct shear, angle of internal friction, Water Content, % FA, Cohesion

1. INTRODUCTION

India has about 70 thermal power plants and coal currently accounts for 70 per cent of power production in the country. The process of coal combustion results in fly ash. The problem with fly ash lies in the fact that not only does its generated annually in India, with 65 000 acres of land being occupied by ash ponds. Such a huge quantity does pose challenging problems, in the form of land usage, health hazards, and environmental dangers. Both in disposal, as well as in utilization, utmost care has to be taken, to safeguard the interest of human life, wild life, and environment. Various Indian collieries supply the coal, which is known to have a very high ash content of almost 40 to 45 per cent.

India's thermal power plants produce an estimated 100 million tonnes of fly ash per annum. This ash needs to be disposed of every day. Primarily, the fly ash is disposed of using either dry or wet disposal scheme. In dry disposal, the fly ash is transported by truck, chute or conveyor at the site and disposed of by constructing a dry embankment (dyke). In wet disposal, the fly ash is transported as slurry through pipe and disposed of in impoundment called "ash pond". Most of the power plants in India use wet disposal system, and when the lagoons are full, four basic options are available: (i). constructing new lagoons using conventional construction material, (ii). hauling of fly ash from the existing lagoons to another disposal site, (iii). raising the existing dyke using conventional constructional material, and (iv). raising the dyke using fly ash excavated from the lagoon ('ash dyke'). The Planning, design and construction of ash disposal facility require the integration of geotechnical, environmental, hydrological engineering and other governing factors. Though the works of numerous researchers in the past have helped in improving understanding of the beneficial use of fly ash in cement concrete, brick manufacturing and other applications, but a comprehensive idea about geotechnical aspects of fly ash–gravelly sand mixtures for various engineering applications especially for pavement construction have not yet understood.

Due to its self-cementing properties, fly ash can be an effective stabilizer for granular and fine grained materials. Fly ash by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. It has a long history of use as an engineering material and has been successfully employed in geotechnical applications. Fly ash consists of often hollow spheres of silicon, aluminium and iron oxides and unoxidized carbon. Expansive soils can be potentially stabilized effectively by cation exchange using fly ash. Utilization of fly ash towards engineering applications can solve two major issues: (i). environmental pollution problem and (ii). wastage of land due to its dump on the agricultural land. Nicholson presented a number of patents (1977, 1982) for a series of investigations on cement kiln dust (CKD) and fly ash mixtures for producing subbase materials with different aggregates. CKD was used up to 16% by weight of the mixture, producing a durable mass by reacting with water at ambient temperatures. The most widely used application for self-cementing fly ash is in increasing the strength of unsuitable or unstable subgrade materials. Generally, clay soils have soaked CBR values from 1.5% to 5% (Rollings and Rollings 1996), which provides very little support to the pavement structure. Addition of 16% self-cementing fly ash increases the soaked CBR values of heavy clay soils into the mid 30s, which is comparable to gravelly sands (Rollings and Rollings 1996). Prasanna Kumar (2011) studied the cementitious compounds formation using pozzolans and their effects on stabilization of soils such as black cotton soils and red earth soils for varied proportions of fly ash. The findings reveals that the maximum dry density of the BC soil increased from 13.6 to 15.2 kN/m^3 for addition of 40% fly ash obtained from Nyveli (NFA). For Red earth MDD changed from 14.6 to 17.8 kN/m^3 for NFA addition. Pozzolanic fly ash has shown considerable improvement in compressive strength from 310kPa to 1393kPa for BC soil and from 590kPa to 2342kPa for Red Earth, for addition of 30% of Fly ash, NFA. But a comprehensive idea about geotechnical aspects of fly ash – gravelly sand mixtures for various engineering applications especially for pavement construction have not yet understood clearly.

2. EXPERIMENTAL STUDY

2.1 Materials used

2.1.1 Soil

The gravelly sand used in the present study was collected from the outer ring road area near Gandi Misamma in Hyderabad, Telangana state, India. The soil collected was kept in controlled conditions in the laboratory and was used for testing as per the Indian Standard specifications given in the respective test codes. For this soil, the basic tests were conducted in the laboratory for its characterization. As per the basic properties of soils are concerned, it indicates that the soil is greyish to brown in colour and has soil proportions of gravel, sand and little fine fraction. The soil has 7% slit and clay, 70% sand and 23% gravel fractions. The grain size distribution curve of the soil is presented in Fig.1. The various basic properties of soil are presented in the Table.1

2.1.2 Fly Ash

The fly ash used in this investigation was collected from Vijayawada Thermal Power Station (VTPS) Vijayawada. The fly ash sample collected was stored in the air tight containers. The grain size distribution curve [IS: 2720 (Part 4)-1985] for fly ash is presented in the Fig.1 The various properties of the fly ash obtained from the Vijayawada Thermal Power Station (VTPS), Vijayawada, AP state, India are presented in the Table.2. The fly ash proportions adopted in the study by dry weight of soil are 0%, 5%, 10%, 15%, 20% and 25%.

2.2 Tests Conducted

The fly ash proportions adopted in the study along with the gravelly sand are 0%, 5%, 10%, 15%, 20% and 25% by weight of dry soil. The tests such as Modified Compaction test [IS: 2720 (Part 7)-1980], California Bearing Ratio (CBR) test [IS: 2720 (Part l6)-1979], and Direct shear tests [IS: 2720 (Part 13)-1986] are conducted. The tests such as CBR and Direct shear are conducted on the specimens compacted at OMC as per the modified compaction. The modified compaction tests are adopted because; the majority highway pavements are designed for high volume traffic loading.

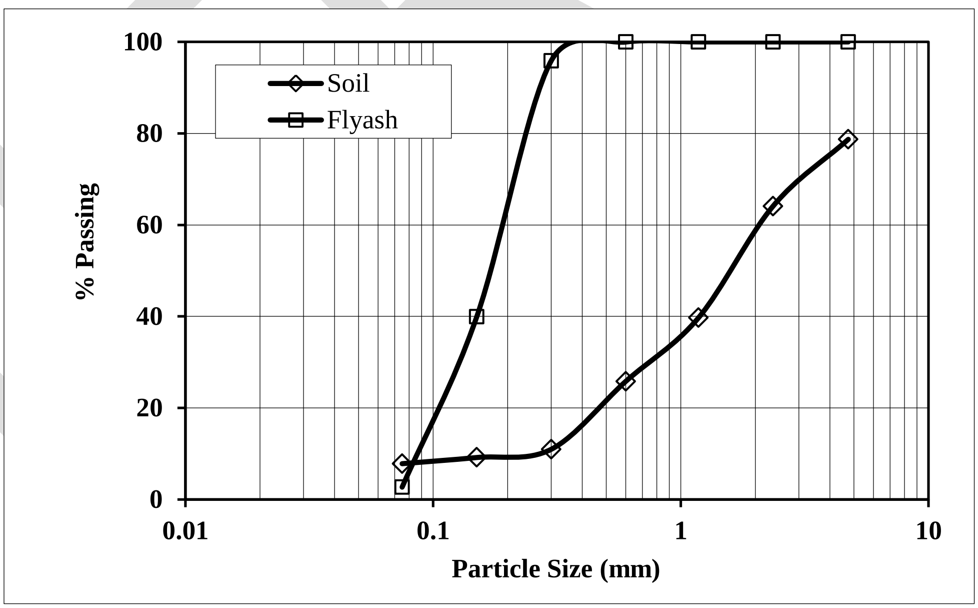

Fig.1 Grain size distribution curve for soil and fly ash

Table.1 Basic properties of soil

Property	Value
Specific gravity	2.68

Cohesion, c (kPa) at OMC	17
Angle of Internal Friction, (deg) at OMC	45^0
Optimum Moisture Content, OMC (%)	7.5
Maximum Dry Density, MDD (kN/m^3)	20.90
Unsoaked CBR (%)	75
% Gravel	23
% Coarse Sand	14
% Medium Sand	38
% Fine Sand	18
% Silt & Clay	7
Soil Classification	SW

Table.2 Properties of fly ash

Property	**Value**
Specific Gravity	1.97
Cohesion ,c (Kpa) at OMC	10
Angle of Internal friction, φ(Deg.)	28
Optimum Moisture Content OMC (%)	18
Maximum Dry Density, MDD (KN/m^3)	13.80
Un soaked CBR (%)	34
% Gravel	0
% Sand	97.5
% Silt and Clay	2.5

2.2.1 CBR Test

In the construction of pavements for low volume and heavy volume traffic conditions, the CBR is the major design parameter of subgrade in the estimation of thickness of pavement. To understand CBR variations of fly ash gravelly sand mixtures, a laboratory testing was carried out for the conditions of modified compaction.

2.2.2 Direct Shear Test

To understand the strength aspects of fly ash gravelly sand mixtures, the direct shear test was conducted in sample mixtures compacted at modified compaction at respective optimum moisture content.

3.0 Results and Discussions

3.1Compaction Results

The water content- dry density curves of fly ash soil mixtures corresponding to modified compaction are presented in Fig.2. From the figure, it can be seen that as the water content increases, there is a gradual increase the in dry density up to certain level of water content and thereafter further increase in water content causing decrease in dry density for all the fly ash – soil mixtures. For a fly ash proportion of 5%, the dry density is shooting up compared to other proportions of fly ash. The compaction curve corresponding to 25% fly ash is lying below compared to curves of other fly ash proportions. It can be attributed that the increased fly ash content is replacing the soil volume and resulting lower dry densities of fly ash – soil mixtures. And it is further noticed that the maximum dry density of fly ash – soil mixtures even at higher proportions of fly ash is just above 20 kN/m^3. It indicates that replacement of soil with 25% fly ash is not compromising with dry density values and it is technically feasible to use fly ash as pavement material along with gravelly sand soil.

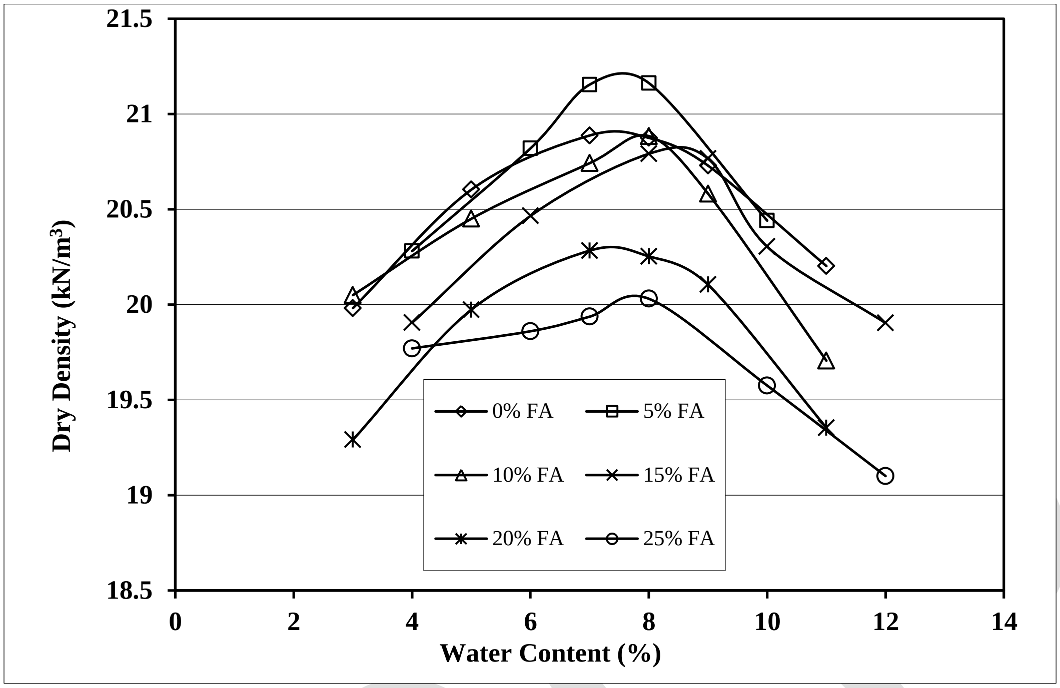

Fig. 2 Compaction curves of fly ash soil mixtures corresponding to Modified Compaction

3.2 CBR Results

The load – penetration curves obtained from modified CBR test are presented in Fig.3. From this figure, it can be noticed that some of the load penetration curves showing initial concave nature and thereafter for all the fly ash soil mixtures tested, the load or resistance is linearly increasing as the plunger penetration increases in soil. It can be clearly noticed that for the 0% and 5% fly ash proportions added to the soil, the resistance offered by the fly ash - soil mixtures is higher as compared to the other proportions of fly ash.

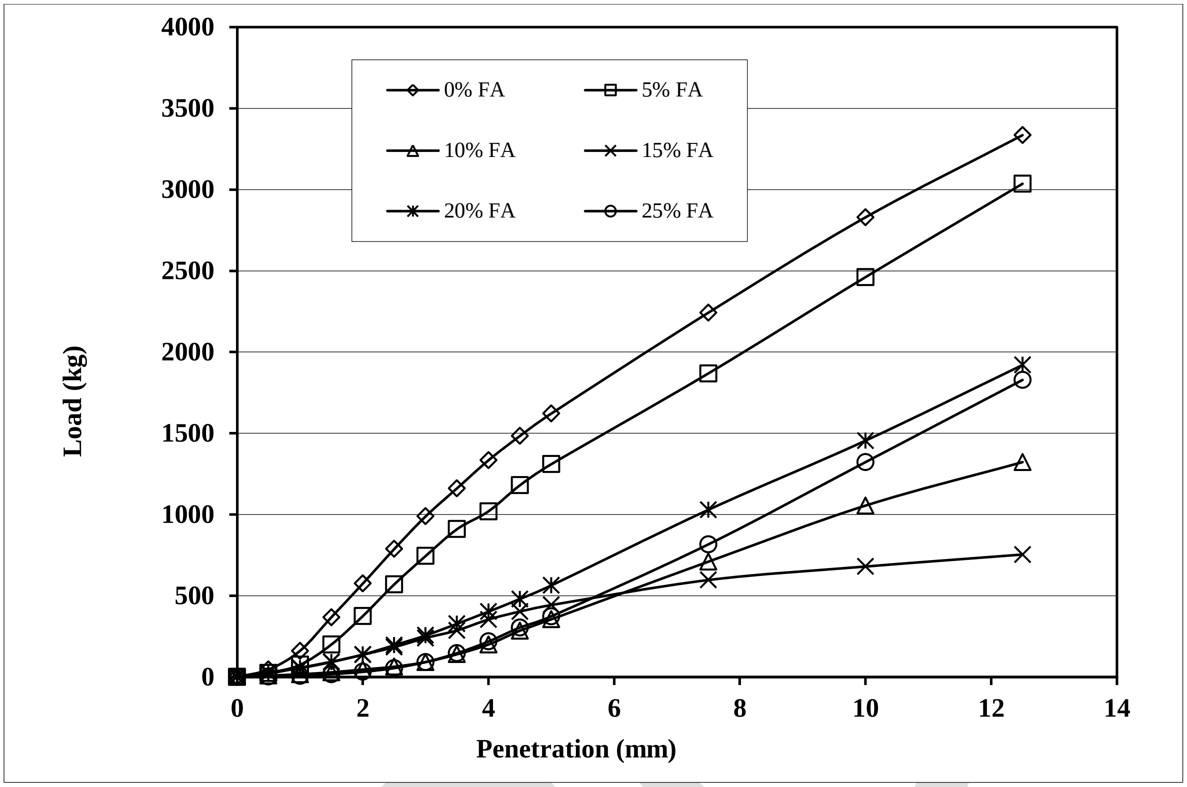

Fig.3 Load-penetration curves of fly ash soil mixtures corresponding to unsoaked Modified CBR test

The variation of soaked and unsoaked CBR with the % of fly ash is presented in Fig.4. The CBR values corresponding to unsoaked condition are showing higher values. At 0% fly ash i.e., for untreated soil, the unsoaked CBR is 75%, whereas for the same soil the soaked CBR noticed is 66%. Similarly, for 100% fly ash tested under modified compaction, the unsokaed and soaked CBR values noticed are 34% and 16% respectively. It can be clearly noticed that there is a marginal influence of soaking on the CBR values in the modified CBR test results. Because, modified compaction could have caused less void spaces and more dry density in the mixture, hence it would result further less permeability of the mixture. As the percentage of fly ash increases the CBR values are decreasing. Up to 5% of fly ash addition to soil has not shown any large decrease in CBR values. For the fly ash content beyond 15% addition to soil is causing about 50% to 60% reduction in the CBR values. As the percentage fly ash increases the granular soil behaving as sandy silty soil and hence causing reduced values of CBR. From this CBR behaviour with the percentage of fly ash, it can be appropriate to say that 10% fly ash can be effectively utilized along with the granular material for road payment constructions. In majority times, though the CBR value of a subgrade soil is high, its value may be limited to 20%. From the results, it can be seen that at 25% fly ash, the CBR of gravelly sand soil is 43%. Hence, even addition of 25% fly ash to gravelly sand can perform better in the pavement construction.

Further, the OMC, MDD and unsoaked CBR values of fly ash soil mixtures are presented in Table 3. From the table, it can be seen that as the % fly ash increases from 0 to 25%, the OMC is varying between 7.5% to 8.5% and this variation is negligible. Whereas the maximum dry density (MDD) is decreasing, but this decrease is not much up to 10% of fly ash, but then onwards there can be noticed decreased MDD. The unsoaked CBR values noticed at 15% fly ash are showing lower values and it is about 33% of untreated soil CBR values.

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Table 3. OMC, MDD and Unsoaked CBR values of soil with % fly ash (%FA)

%FA	% OMC	MDD (kN/m^3)	Unsoaked CBR (%)
0	7.5	20.9	75
5	7.5	21.2	72
10	8	20.9	34
15	8.5	20.82	24
20	7.5	20.3	46
25	8	20.05	43

3.3 Direct Test Results

The strength envelopes obtained as per the samples tested at respective OMCs from modified compaction by using direct shear test are presented in Fig.5. From this figure, it can be seen that up to about 10% of fly ash addition to gravelly sand causing no drastic reduction in the angle of internal friction of fly ash – soil mixtures. Whereas the strength envelopes corresponding to 15%, 20% and 25 % of fly ash are moving parallel. From this behaviour, it can be understand that up to about 10% of fly ash addition to gravelly sand, imparting more inter locking and bonding due to the modified compaction. For some of the fly ash – soil mixtures, pseudo cohesion is noticed.

At 20% fly ash proportion the soil is showing higher cohesion compared to other proportions of fly ash. Almost negligible cohesion can be seen for 0%, 5% and 10% fly ash proportions added to soil.

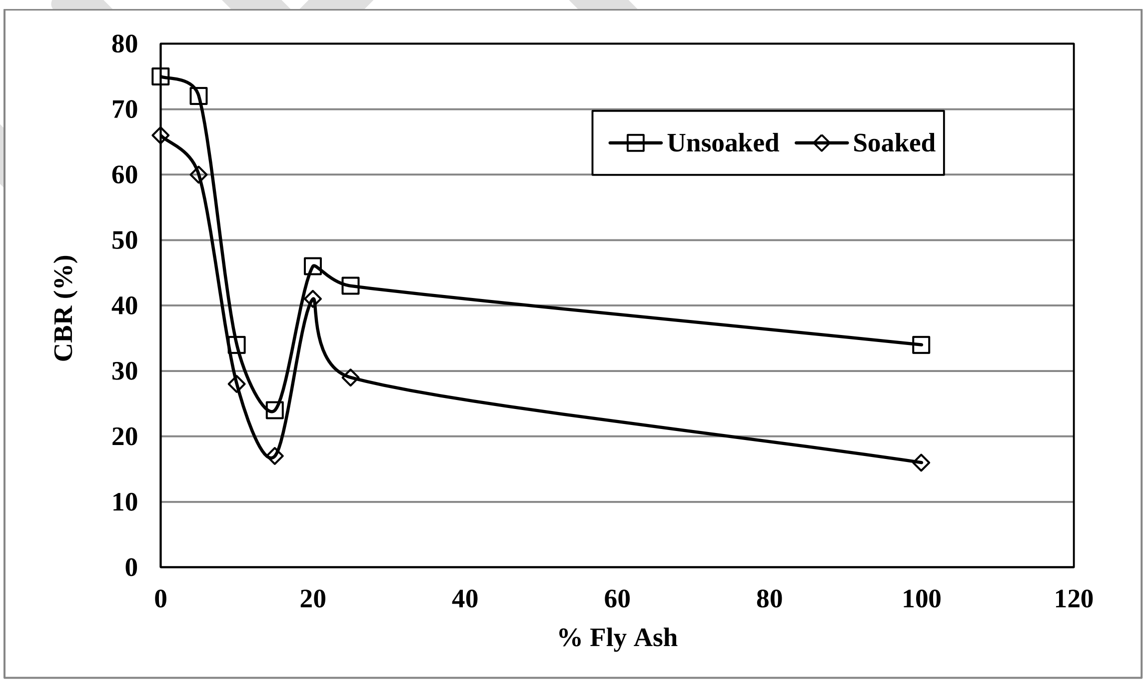

Fig 4. Variation of CBR with the % fly ash tested at OMC and subjected to modified compaction and for unsoaked and soaked conditions

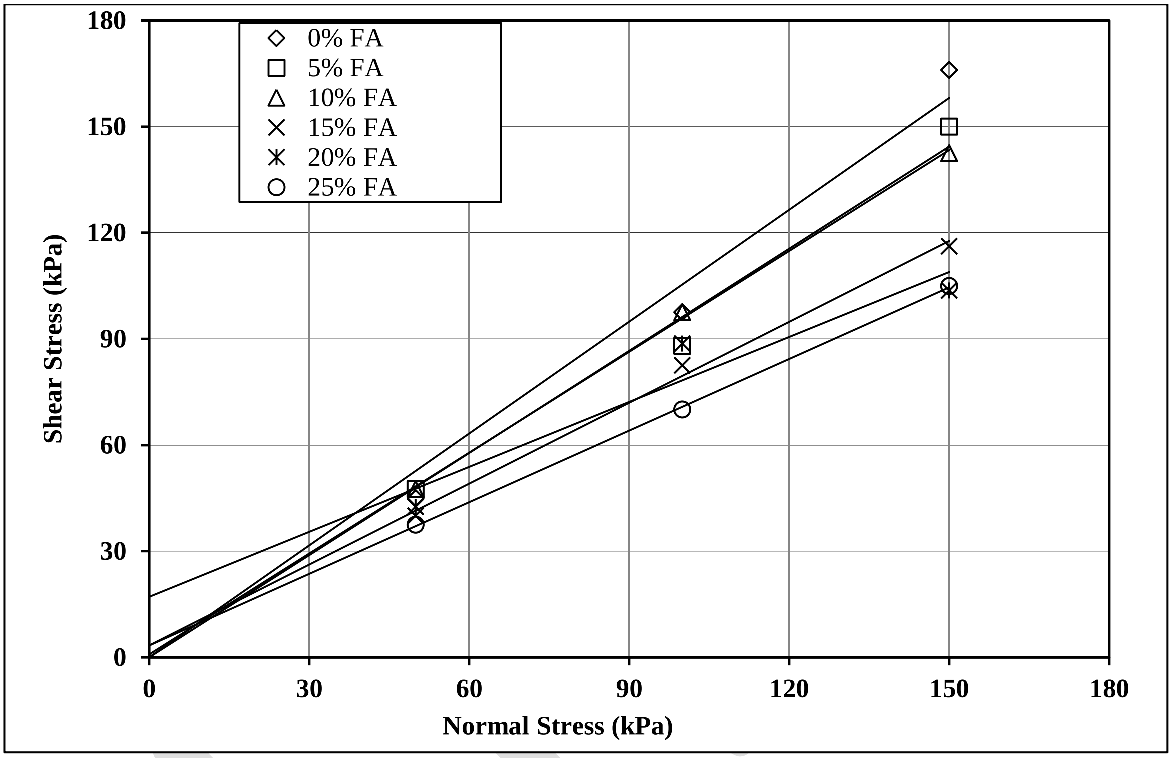

Fig.5 Shear stress vs. normal stress plots of fly ash soil mixtures from direct shear test

The variation in angle of internal friction with the % of fly ash under modified compaction is shown in Fig.6. From the figure, it can be seen that as the % of fly ash increases, the angle of internal friction is reducing. This reduction in angle of internal friction is very minimal for fly ash content up to about 10% and then onwards further addition of fly ash to the gravelly sand causing marked reduction in the angle of internal friction. The angle of internal friction values obtained for different fly ash gravelly sand mixtures under modified compaction are showing higher values.

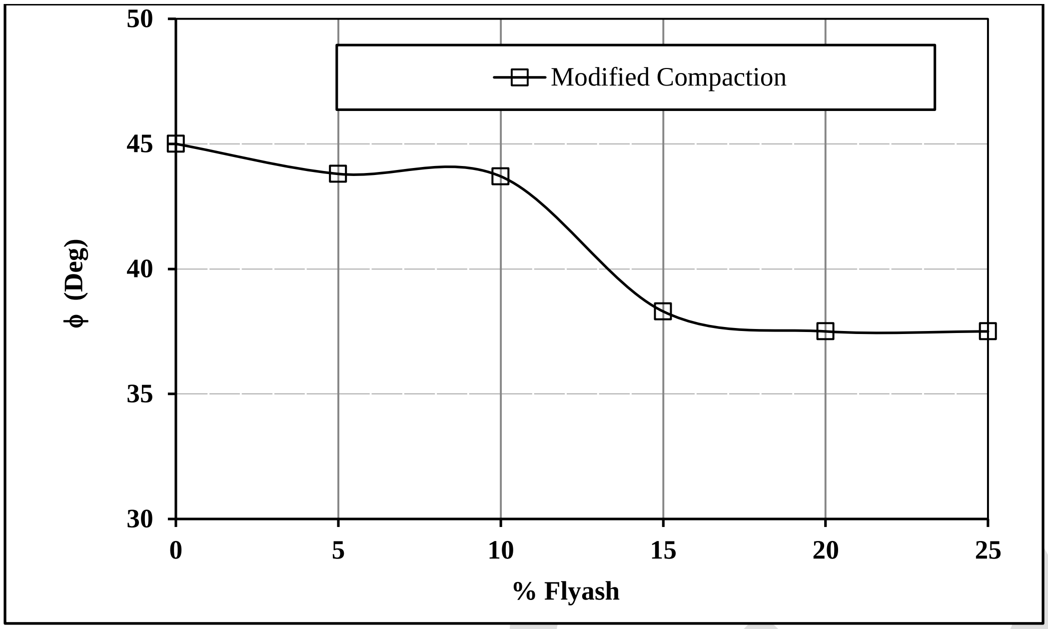

Fig. 6 Variation of angle of internal friction with the % of fly ash for soil tested at OMC of modified compaction

Variation of cohesion with the % of fly ash for soil tested at OMC by employing modified compaction is presented in Fig. 7. From this it is noticed that as the % fly ash increases from 0 to 10%, there is marginal increase in cohesion and it is hardly 1 kPa. From 10% fly ash on wards there is gradual increase in cohesion up to 20% of fly ash proportion. The cohesion of 20% fly ash and soil mixture is noticed as 4 kPa. Pure soil without admixture showed zero cohesion, whereas addition of fly ash to the soil causing development of pseudo cohesion and that to it is in the order of 5 kPa in most of the fly ash – soil mixtures tested in the present work. This development of pseudo cohesion in small scale is added advantage to cause bondage or cohesive behavior in the mixture as road material.

Further, the variation in angle of internal friction, ϕ and cohesion, c for different proportions of fly ash – soil mixtures for the conditions of modified compaction are presented in Table 4. The variation of CBR/ϕ with the % of fly ash for fly ash-soil mixtures are presented in Fig.8. From this figure, a relation obtained is presented in Eqn.1. This equation can be made use to obtain CBR value for the known values of ϕ and % fly ash (%FA). Where CBR is in %.

$(CBR/\phi) = -0.034(\%FA) + 1.859$ --------------Eqn.1

Regression coefficient, $R^2 = 0.890$.

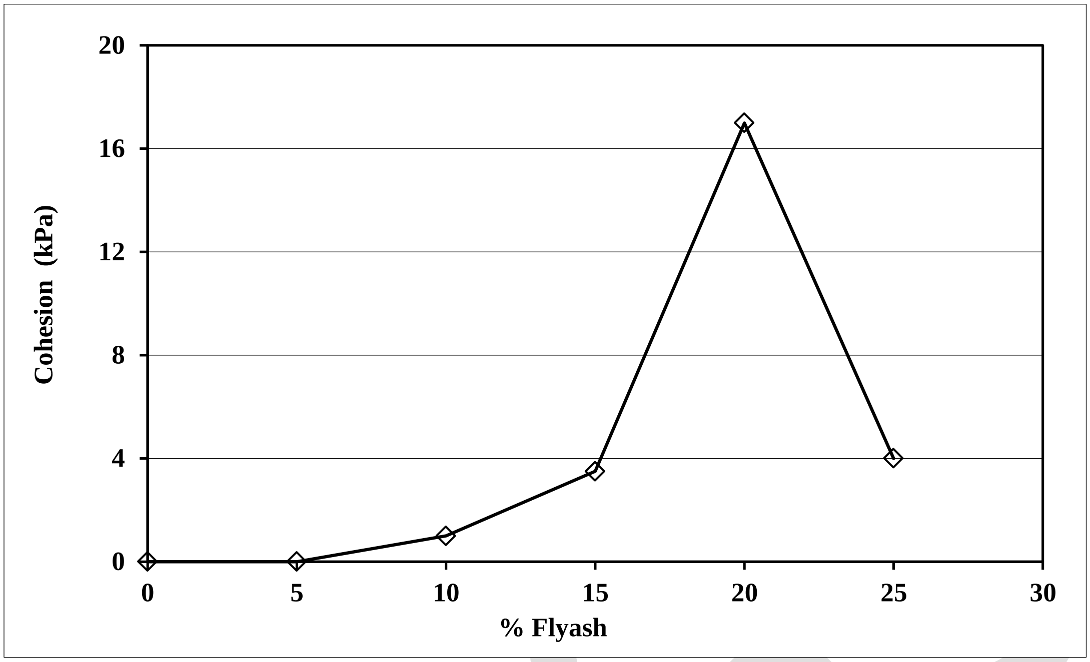

Fig. 7 Variation of cohesion with the % of flyash for soil tested at OMC of Modified compaction

Table 4. Shear parameters c and ϕ of soil with the % fly ash (%FA)

%FA	ϕ (Deg)	Cohesion (kN/m^2)
0	45	0
5	43.8	0
10	43.7	1
15	38.3	3.5
20	37.5	17
25	37.5	4

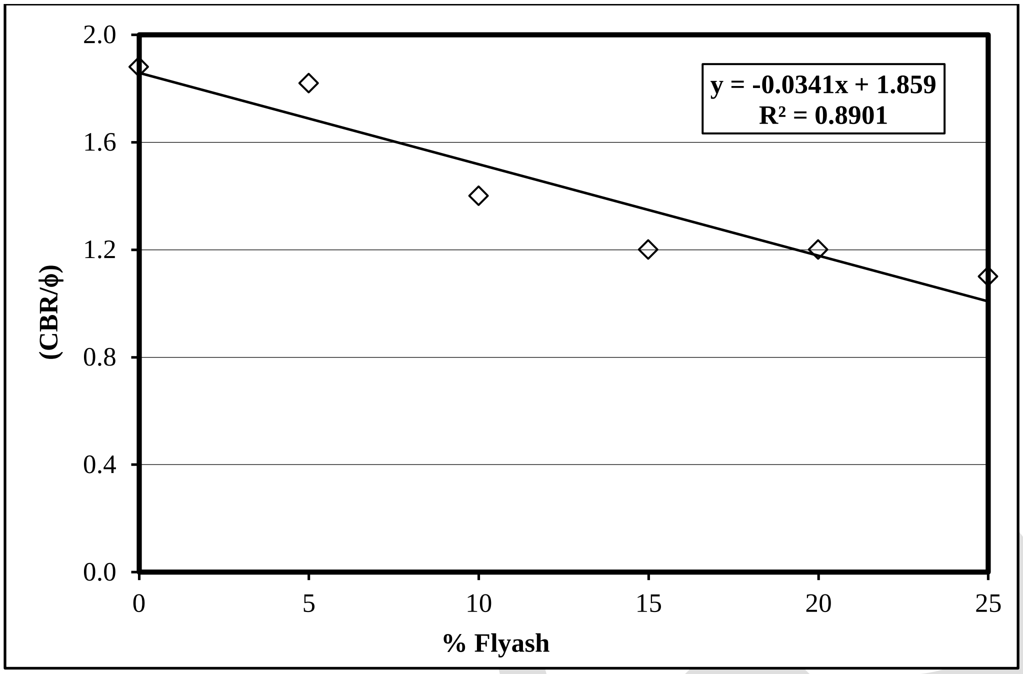

Fig. 8 Relation between CBR/ϕ vs. % fly ash

4. Summary and Conclusions

When the percentage of fly ash increases from 0% to 25%, the angle of internal friction of gravel soil is decreasing. This decrease in angle of internal friction is marginal up to about 10% of fly ash and from 10% to 15% fly ash; there is a sudden drop in friction angle. From 15% to 25% of fly ash, the angle of internal friction observed is almost constant and its value is in the range of 36^0 to 38^0. As the percentage of fly ash increases from 0% to 25%, the CBR values are decreasing for both the unsoaked and soaked conditions. Up to 5% of fly ash addition to gravel soil has not shown any large decrease in CBR values. For the fly ash content beyond 15% addition to soil is causing about 50% to 65% reduction in the CBR values for both the unsoaked and soaked conditions. As the percentage fly ash increases, the granular soil behaving as sandy silty soil and hence causing reduced values of CBR. Even 25% addition of fly ash to the gravelly sand, the CBR value is more than 20%. In general in majority flexible pavement design, though the CBR value is more than 20%, its value is limited to 20%. Hence, from this it can be proposed that even up to 25% addition of fly ash can make the economic construction of pavement without compromising any strength aspects. The relation developed between % fly ash (%FA), CBR and ϕ can be used for obtaining the CBR values of fly ash mixed granular soils of fly ash range 0 to 25%.

REFERENCES:

[1] S.Bhuvaneshwari, R.G.Robinson and S.R.Gandhi,(2005). Stabilisation of expansive soils using fly ash, *Fly ash Utilization Programme (FAUP)*, TIFAC, DST, New Delhi, Fly ash India 2005, VIII 5.1.

[2] Erdal Cokca (2001). Use of Class C Fly Ashes for the Stabilization of an Expansive Soil". *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, July' 2001, pp. 568-573.

[3] G. Ferguson and S.M. Leverson (1999). Soil and Pavement Base Stabilization with Self-Cementing Coal Fly Ash, *American Coal Ash Association*, 1999, Alexandria, VA.

[4] IRC: SP: 72-2007, Flexible Pavement Design for Rural Roads.

[5] IS: 2720 (Part 13)-1986.Methods of test for soils: Part 13, Determination of shear strength parameters using direct shear test.

[6] IS: 2720 (Part 4)-1985 Methods of test for soils: Part 4 Grain size analysis.

[7] IS: 2720 (Part 3/Set I)-1980 Methods of test for soils: Part 3 Determination of specific gravity, Section I Fine grained soils.

[8] IS: 2720 (Part 7)-1980, Methods of test for soils, Determination of water content-dry density relation using compaction.

[9] IS: 2720 (Part l6)-1979, Methods of test for soils, Laboratory determination of CBR.

[10] Lin Li, B. Tuncer Edil and H. Craig Benson (2009). Properties of pavement geomaterials stabilized with fly ash, *World coal ash (WOCA) Conference*,May 4-7, 2009, Lexington, KY, USA, pp.1-11.

[11] D.B. Mahrt (2000). Reclaimed class C Iowa fly ash as a select fill material: hydraulic conductivity and field testing of strength parameters, *MSc thesis*, 2000, Iowa State University, Ames, IA.
[12] A. Misra (1998). Stabilization characteristics of clays using class c fly ash, *Transportation Research Record 1611*, Transportation Research Board, 1998, pp.46-54.
[13] Nicholson, J. P. (1977). Mixture for Pavement Bases and the Like, U.S. Patent #4,018,617, April 19.
[14] Nicholson, J. P. (1982). Stabilized Mixture, U.S. Patent #4,101,332, July 18, 1978, Reissue #30,943, May 25.
[15] P. Paige-Green (1998). Recent Developments in Soil Stabilization, *Proceedings of 19th ARRB Conference*, Sydney, Australia, Dec 1998, pp.121-135.
[16] N.S. Pandian, K.C. Krishna and B. Leelavathamma (2002). Effect of Fly Ash on the CBR Behaviour of Soils, *Indian Geotechnical Conference 2002*, Allahabad, Vol.1, pp.183-186.
[17] Parisara ENVIS Newsletter (2007). Utility bonanza from dust. Parisara ENVIS Newsletter, Vol.2, No.6, State Environment Related Issues, Department of Forests, Ecology & Environment, Government of Karnataka.
[18] S.M. Prasanna Kumar (2011). Cementitious compounds formation using pozzolanas and their effect on stabilization of soils of varying engineering properties, International conference on environment science and engineering, *IPCBEE*, 2011, Vol.8, pp.212-215, IACSIT Press, Singapore.
[19] Rollings, M.P., and Rollings Jr., R.S. (1996). Geotechnical Materials in Construction, McGraw-Hill, New York