International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 4 Issue 11, November-2015

Development of Empirical Relations between Angle of Shearing Resistance and CBR Values of Fly Ash-Granular Soil

Ratna Prasad R[1], Darga Kumar N[2]

[1]Research Scholar, JNTU Kakinada and Professor of Civil Engineering, Vasireddy Venkatadri Institute of Technology (VVIT), Guntur, AP, India
[2]Professor of Civil Engineering College of Engineering, Science and Technology (CEST), Fiji National University (FNU)

ABSTRACT

The gravelly soil compacted at its optimum moisture content is having higher dry density compared to all flyash gravel mixtures both in Light and modified compaction. The variation of maximum dry density (MDD) with percentage of flyash decreases drastically for 10% to 15% and 25 to 30% and from 0% to 10% and 25% to 30% fly ash, the MDD decreases slightly in modified compaction .It was due to increases of addition of flyash and results in excess of finer fraction and leads lesser weight and cause reduced values of dry densities of flyash gravel soil mixtures. As percentage of flyash increases in soil gravel mixtures the optimum moisture content (OMC) increases both in light and modified compaction. The variation of OMC with percentage of flyash is slightly increases from 0% to 10% and increases drastically from 10% to 20% and from 20% to 30%, the OMC increases slightly in modified compaction. It can be attributed that by increase of addition of flyash the water holding capacity increases due to increase of silt fraction in the soil mix. As the percentage of flyash addition increases from 0% to 30%, the CBR values are decreasing for both un-soaked and soaked conditions. The percentage decrease of CBR values from un-soaked to soaked for 0% to 5% flyash soil mixtures are decreases from 12.12% to 9.53% and for 5% to 25% flyash soil mixture the percentage decrease of CBR values increases from 9.53% to 14.88% and for 25% to 30% flyash soil mixture the percentage decrease of CBR values slightly decreases from 14.88% to 14%. Therefore from above results the percentage decrease of CBR values from un-soaked to soaked condition for 0% to 30% is marginal. But for the flyash the percentage decrease of CBR values from un-soaked to soaked condition is drastically by 94% .For both un-soaked and soaked conditions the maximum percentage decrease of CBR values in between each successive percentages from 0% to 30% flyash soil mixture is of 16%. From above results it can be concluded that the 20% to 30% flyash soil mix can be used for both soaked and un-soaked condition. As percentage of flyash increases from 0% to 30%, the angle of internal friction decreases from 36.24° to 29° respectively. The maximum percentage decrease in angle of internal friction in between each successive percentage from 0% to 25% flyash soil mixtures is 5% and there is sudden decrease in angle of internal friction is about 10% from 25% to 30% flyash soil mixture ,that is φ values varies from 32° to 29°. From 10% to 25% flyash soil mixture the angles of internal friction are slightly varies in the range of 33.70° to 32° respectively. From the above results it can be concluded that from 10% to 25% flyash soil mixture the value of angle of internal friction is slightly varying that is in range of 33.70° to 32°,so we concluded that 10% to 25% flyash can be used effectively along with granular soil. The results of CBR and angle of internal friction is presented in the form of their ratio, CBR percentage and angle of internal friction to develop the empirical relations between them with percentage of fly ash from 0% to 30% in un-soaked condition.

Keywords: MDD, OMC, CBR, fly ash granular soil mixtures, direct shear, angle of internal friction, Water Content, percentage fly ash (% 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 flyash. The problem with flyash lies in the fact that not only does its disposal require large quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become airborne. Currently, huge amount of flyash is being 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. Hence, it is necessitated to utilize the abundantly available flyash for the civil engineering construction activities especially in the pavement construction so as to overcome the problems posed by the flyash. According to Ferguson (1993), the application of self-cementing flyash to expansive soils decreases the swell potential in three ways: (1) flyash contains some calcium ions that reduce the surface charge of the clay particles, (2) flyash acts as a mechanical stabilizer by replacing some of the volume held by clay particles, and (3) flyash cements the soil particles together. Generally, clay soils have soaked CBR values from 1.5% to 5% (Rolling and Rolling 1996), which provides very little support to the pavement structure. Addition of 16% self-cementing flyash increases the soaked CBR values of heavy clay soils into the mid-30s, which is comparable to gravelly sands (Rolling and Rolling 1996). According to Ferguson and Elverson (1999) the optimum moisture content needed for maximum strength is typically 0% to 8% lower than the optimum moisture content for maximum density. Mart (2000) reported that the molded moisture content do not appear to affect CBR of flyash mixed soil, but the level of compaction effort does. Sub-standard compaction effort (~95% of standard Proctor) produces un-soaked and soaked CBR values around 40%, while modified compaction effort yields values between 80% and 90%. Parana Kumar (2011) studied the cementations compounds formation using pozzolans and their effects on stabilization of soils such as black cotton soils and red earth soils for varied proportions of flyash. The findings reveals that the maximum dry density of the BC soil increased from 13.6 to 15.2kN/m^3 for addition of 40% flyash obtained from Nyveli (NFA). For Red earth MDD changed from 14.6 to 17.8kN/m^3 for NFA addition. Pozzolanic flyash 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 Flyash, NFA. But there are few studies reported on utilization of flyash in pavement construction along with the gravelly sand. In this study, a study has been planned to understand the behavior of flyash and gravelly sand mixtures for use in pavement construction. The flyash proportions by the dry weight of soil adopted in the study are 0%, 5%, 10%, 15%, 20% ,25% and 30%.

2. MATERIALS AND TEST METHODS

A. SOIL

The gravelly sand used in the present study was collected from sekuru village near Guntur, Andhra Pradesh 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 0.35% slit and clay, 92% sand and 7% 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

B. 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%, 25% and 30%.

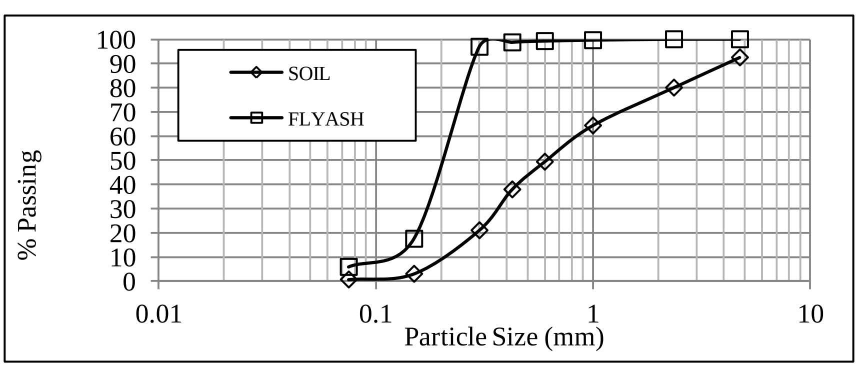

Fig.1 Grain size distribution curve for soil and fly ash

Table. 1: Properties of Granular soil

Property	Value
Specific gravity	2.62
Cohesion,c(kPa)-ModifiedCompaction	10.85
Angle of Internal Friction, ϕ(deg.) - Modified Compaction	36.24
Optimum Moisture Content, OMC (%)i- Modified Compaction	08.00
Maximum Dry Density, MDD (kN/m^3) – Modified Compaction	19.90
Un-soaked CBR(%)Modified Compaction	55.24
Soaked CBR(%)-Modified Compaction	48.54
% Gravel	07.50
% Coarse Sand	12.50
% Medium Sand	42.10
% Fine Sand	37.25
% Silt & Clay	00.35
Effective Diameter, D_{10} (mm)	00.21
Coefficient of Uniformity, c_u	04.28
Coefficient of Curvature, c_c	00.76
Soil Classification	SW

Table. 2: Properties of flyash

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/m3)	13.80
Un soaked CBR (%)	34
% Gravel	0
% Sand	97.5
% Silt and Clay	2.5

C. GRAIN SIZE DISTRIBUTION

The grain size distribution test was conducted as per the specifications given in the IS: 2720 (Part 4)-1985. The graphs plotted between percent passing vs. particle size for the various proportions of flyash in granular soil.

D. COMPACTION TEST

IS light and modified compaction tests have been conducted on the soil with different % of flyash such as 5%, 10%, 15%, 20%, 25% and 30% and determined the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) as per IS:2720 (Part 7)-1980. The modified compaction tests are adopted because; the majority highway pavements are designed for high volume traffic loading.

E. 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 as per [IS: 2720 (Part l6)-1979]. .

F. 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 as per[IS: 2720 (Part 13)-1986] at respective optimum moisture content.

3 RESULTS AND DISCUSSIONS

A. COMPACTION CHARACTERISTICS

The compaction curves for different proportions of flyash added to the gravelly sand and tested under modified compaction presents in fig.2. From this figure, it can be noticed that the compaction curves are following the typical trend of granular soils. The higher MDD is noticed for the flyash proportion of 5% added to the gravelly sand. The MDD for 0% flyash and for 10% flyash is observed to be almost the same. It is noticed that as the percentage of flyash increases, the affinity to absorb water is increasing. From the figure it is further noticed that the dry density of flyash gravelly sand mixtures is maximum in the range of water content of 7.5% to 8.5%. To achieve the optimum condition, about 7.5 to 8.5% water content can be sufficient to add to the flyash gravelly sand mixtures wherein fly ash proportions varying from 0% to 25%. From this figure, it can be presented that the lowest and highest dry density is 19.2kN/m³ to 21.2kN/m³ respectively and in the range of water content 3% to 12%.

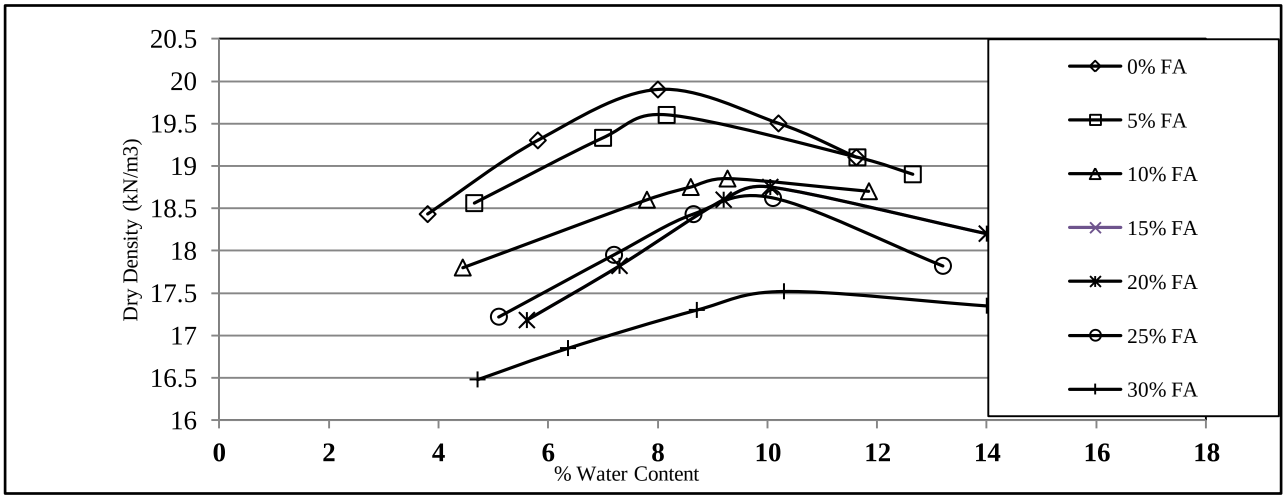

Fig. 2: Compaction curves for flyash gravelly sand mixtures subjected to modified compaction for un- soaked condition

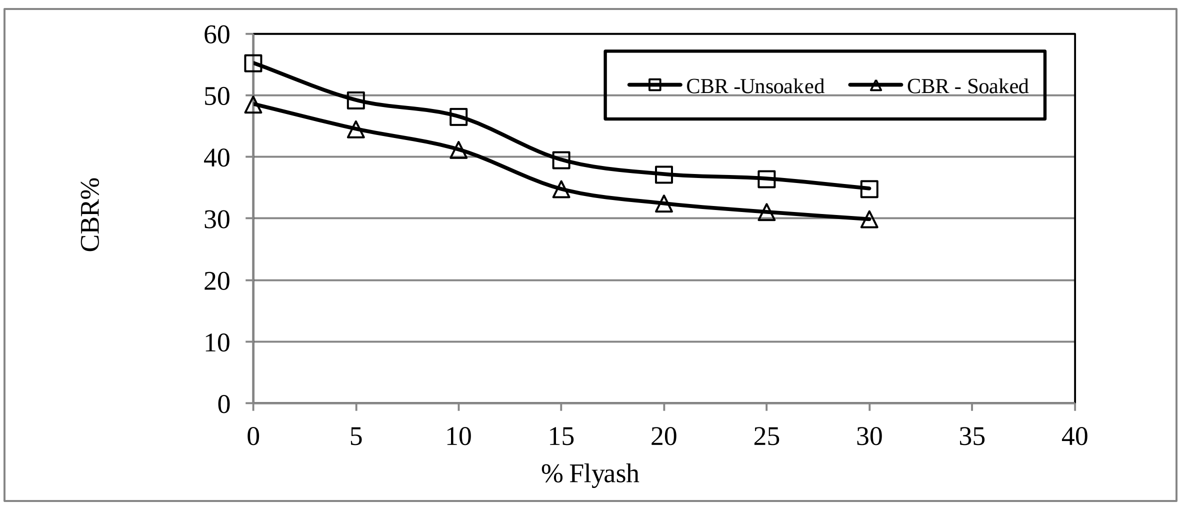

Fig. 3: Variation of CBR% with the % fly ash tested at OMC and subjected to modified compaction for soaked condition

Table 3: CBR values of fly ash Gravelly sand

% Fly ash	CBR- Un soaked (%)	CBR-Soaked (%)
00	55.24	48.54
05	49.21	44.52
10	46.53	41.18
15	39.50	34.80
20	37.15	32.47
25	36.42	31.09
30	34.81	29.92
100	48.8	03.12

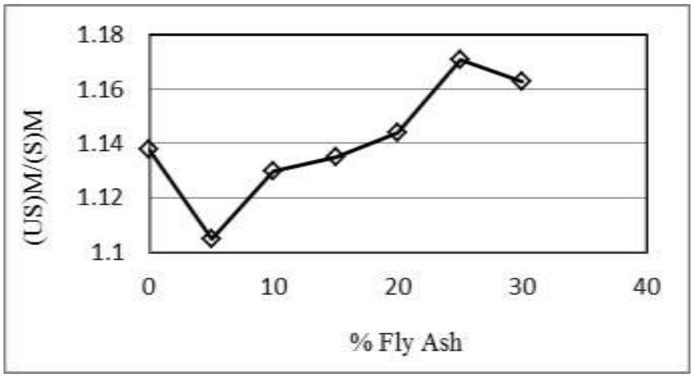

Fig. 4: Variation of ratio of un-soaked and soaked CBR in modified Compaction and percentage fly ash

Table 4: the ratios of un-soaked and soaked CBR in modified compaction with percentage of fly ash

% Flyash	US(M)/S(M)
0	1.138
5	1.105
10	1.130
15	1.135
20	1.144
25	1.171
30	1.163

B. CBR CHARACTERISTICS

To understand CBR variations of flyash gravelly sand mixtures, a laboratory testing was conducted for the conditions of modified compaction. The variation of CBR with the percentage of fly ash for the un-soaked and soaked conditions for modified compaction is presented in Fig 3. The influence of compaction effort is not seen in the case of un-soaked condition and where as in case of soaked condition it can be clearly seen that there is an influence of compaction effort on CBR values. The CBR variation curves of un-soaked and soaked tested for modified compaction are moving parallel with very narrow or negligible gap. The results of ratios of CBR with the % of flyash for the un-soaked and soaked conditions tested at modified compaction presented in the Fig.4 and presented in table 4. From this observation, it can be noticed that the ratio of CBR is more than one for the cases of un-soaked conditions in modified compaction as compared to soaked condition and also it can be seen that as the percentage of flyash increases, the ratio of CBR is almost varying in the range of 1 to 1.5. It means that in case of modified compaction, the un-soaked CBR value is in the range of 1 to 1.5 times than the soaked CBR value. It was understand that especially in un-soaking, the influence of compaction effort is present.

C. SHEAR CHARACTERISTICS

To understand the strength aspects of fly ash gravelly sand mixtures the direct shear test was conducted on sample mixtures compacted at modified compaction at respective optimum moisture contents. Fig 5 presents the strength envelopes of flyash gravelly sand mixtures prepared at respective OMCs obtained from the modified compaction test results. The strength envelopes shown above corresponding to modified compaction and the friction angle is reducing as the % of fly ash increases in the mixture. From this figure, it can be clearly seen that up to about 30% of fly ash addition to gravelly sand causing no drastic reduction in the angle of internal friction Whereas the strength envelopes corresponding 10% to 25% of flyash are moving parallel with a merged manner. From this behavior, it can be understand that up to about 10% to 25% of fly ash addition to gravelly sand, imparting more inter locking and bonding due to the modified compaction.

To understand the variation in angle of internal friction with the % of flyash under modified compaction the results are plotted and presented in Fig.6 and values are tabulated in table 5. From the figure as the % of fly ash increases, the angle of internal friction is reducing. This reduction in angle of internal friction is very minimal for flyash content up to about 25% and afterwards further addition of fly ash to the gravelly sand causing marked reduction in the angle of internal friction.

Further, the results obtained from CBR test and Direct Shear test are presented in the form of ratio as CBR/ϕ . This type of ratio is useful to arrive, the unknown geotechnical parameter from the known geotechnical parameter. Fig. 7 presents the variation of CBR/ϕ with the % of flyash. From this figure, for the known values of angle of internal friction which is corresponding to a particular percentage of flyash, the CBR value can be obtained. The expression, which is being obtained from the trend line, is presented below.

-$\frac{\boldsymbol{CBR}}{\emptyset} = \mathbf{-0.012} \times \% \,\boldsymbol{FA} + \mathbf{1.473}$ **---------. (1)**

The above equation 1 is applicable for the fly ash proportion of range 0% to 30% and for un soaked conditions only. In the above equation, CBR is in %, ϕ is the angle of internal friction in degrees and percentage flyash. From the above equation, by substituting the %FA and ϕ values, the CBR value can be obtained. There is no published data on the correlations between angle of internal friction and the CBR values. In this study, an attempt is being made to correlate CBR values with the angle of internal friction. The CBR is used for the determination of soils suitability for road sub base and subgrade based upon the loading. Fig. 8 presents the CBR% values obtained under un-soaked condition in modified compaction and corresponding angle of internal friction results obtained from the direct shear test. From the Figure, it can be observed that the points are located in a narrow range of band and hence an average linear trend line is drawn as a best fit line and the corresponding equation of the line is presented in Eq.2

$\% \,\boldsymbol{CBR} = \mathbf{2.983} \times \emptyset - \mathbf{56.03}$ **-------- - (2)**

In the above equation, ϕ is in degrees. This equation is valid for un-soaked conditions and for flyash mixed granular soils. From this equation for a given angle of internal friction, the CBR value can be calculated without conducting the CBR test. This equation can be further refined by conducting tests on variety of compaction conditions and soil types. The angle of internal friction for different proportions of flyash gravelly sand mixtures for the conditions of modified compaction is presented in Table 5.

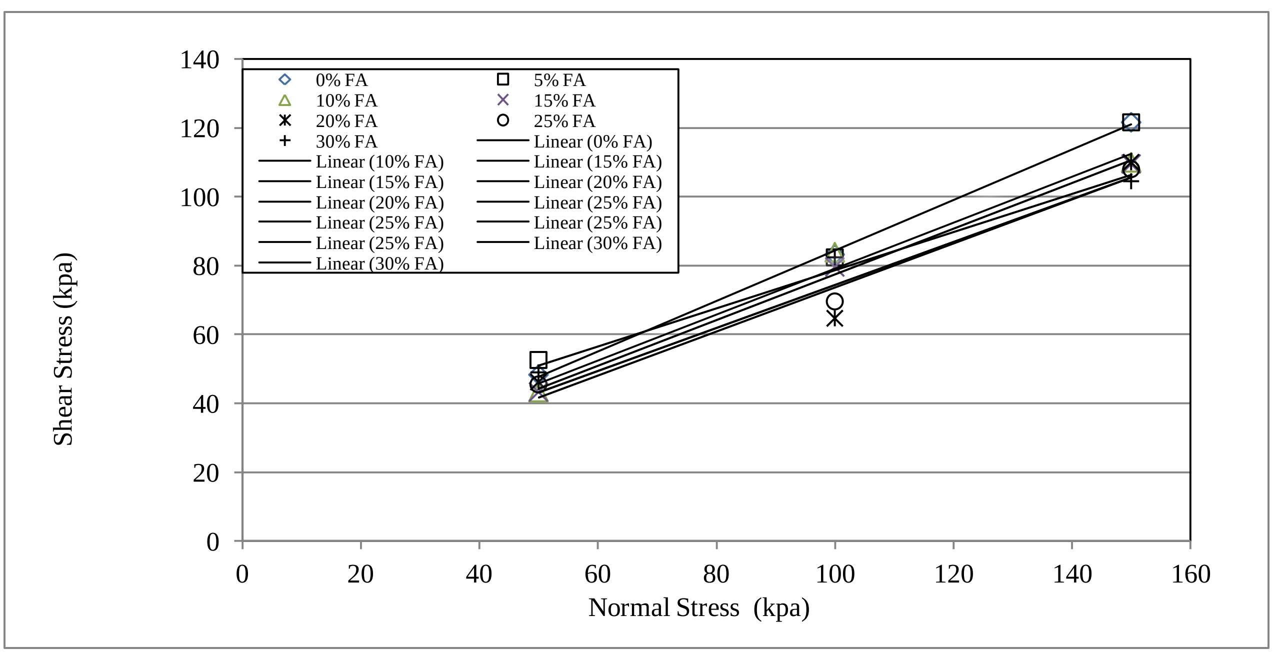

Fig.5 Strength Envelops for fly ash Gravelly sand mixtures Tested in modified compaction

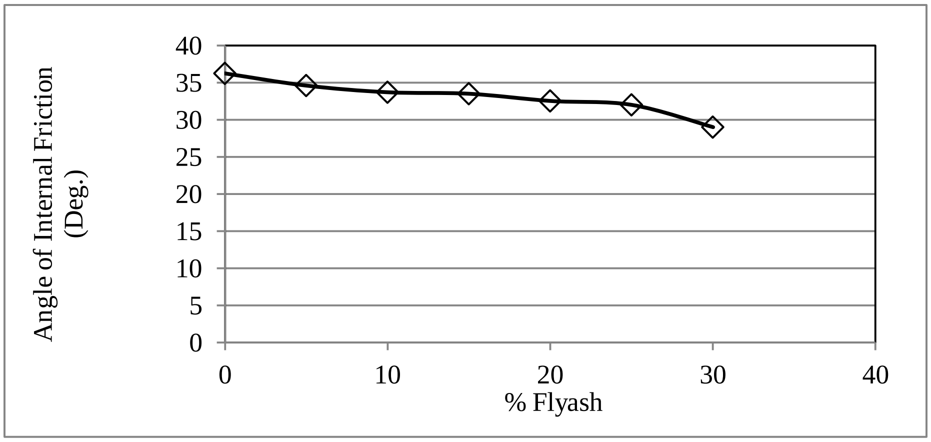

Fig.6 : Variation of angle of internal friction with the percentages of Fly ash for gravelly sand tested at modified compaction

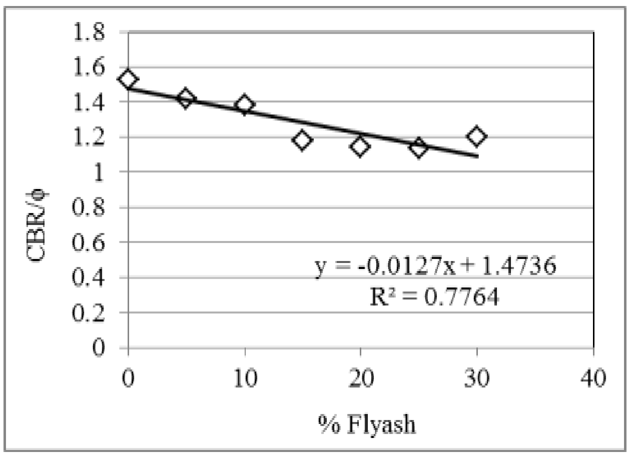

Fig 7: Variation of CBR/ϕ with percentage of fly ash in un-soaked Condition

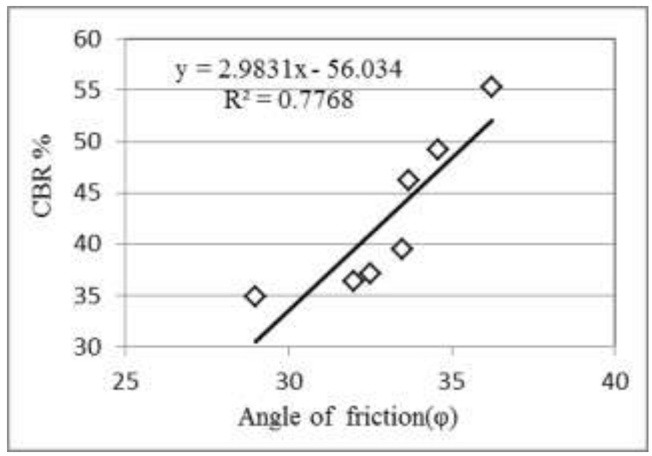

Fig 8: Variation CBR% Vs. Angle of friction in un-soaked condition

Table 5: Values of angle of internal friction of fly ash gravelly sand mixtures

% Fly ash	Angle of internal friction, ϕ (Deg.)
00	36.25
05	34.5
10	33.5
15	33.5
20	32.5
25	32.0
30	29.0
100	29.5

4. SUMMARY AND CONCLUSIONS

The MDD decreases drastically from 10% to15% and 25% to 30% in light compaction with increase of % fly ash from 0% to 30%.But from 0% to 10% and 25% to 30% fly ash, the MDD decreases slightly in modified compaction. The addition of percentage fly ash in soil gravel mixture, OMC increases both in light and modified compaction and increases slightly from 0% to 10% and drastically increases from 10% to 25% and slightly increases from 25% to 30%

in light compaction and modified compaction. The CBR values of un soaked and soaked conditions are decreases for each % fly ash soil mixture of 0% to30%.The percentage decrease of CBR values from un soaked to soaked for 0% to 5% fly ash soil mixtures are from 12.12% to 9.53% and above 15% fly ash soil mixture, 30% to 40% reduction in CBR values were observed for both soaked and un soaked conditions. For both un-soaked and soaked conditions the maximum percentage decrease of CBR values in between each successive percentages from 0% to 30% fly ash soil mixture is of 16%.From the above results it can be concluded that 20% to 30% fly ash soil mix can be used for both soaked and un soaked condition. The CBR values of both soaked and un-soaked are decreases for each % flyash soil mixtures. For 0% to 30% fly ash, the angle 'ϕ' decreases from 36.24^0 to 29^0 and % decrease in each successive % fly ash from 0% to 25% in soil mixture is 5%.There was sudden decrease in the angle'ϕ' and is about 10% for 25% to 30% fly ash soil mixtures. For 10 % to 25% fly ash soil mixtures, the value of'ϕ' slightly varies from 33.7^0 to 32^0.Therefore 10% to 25% can be used effectively along with granular soil. From the results of compaction, strength and CBR tests, 20% to 25% fly ash addition to gravelly sand do not affect the properties of granular soil .The fly ash soil mixture is showing encouraging results towards utilization of fly ash with gravelly sand for low to high volume traffic in pavement construction. The relation developed between percentage fly ash (%FA), CBR and angle of internal friction(ϕ) can be used for obtaining the CBR values of fly ash mixed granular soils of fly ash range 0 to 30%. The equations are (i) $\frac{\boldsymbol{CBR}}{\emptyset} = \mathbf{-0.012} \times \%\,\boldsymbol{FA} + \mathbf{1.473}$ and (ii) $\%\,\boldsymbol{CBR} = \mathbf{2.983} \times \emptyset - \mathbf{56.03}$. 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 the strength.

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]. A. Misra (1998). Stabilization characteristics of clays using class c fly ash, Transportation Research Record 1611, Transportation Research Board, 1998, pp.46-54.
[11]. P. Paige-Green (1998). Recent Developments in Soil Stabilization, Proceedings of 19th ARRB Conference, Sydney, Australia, Dec 1998, pp.121-135.
[12]. 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.
[13]. 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.
[14]. Rollings, M.P., and Rollings Jr., R.S. (1996). Geotechnical Materials in Construction, McGraw-Hill, New York.
[15]. IS 2720(Part 7):1980. Methods of test for soils: Part 8 Determination of water content-dry Density relation using light compaction.
[16]. IS 2720(Part 8):1983. Methods of test for soils: Part 8 Determination of water content-dry density relation using heavy compaction.
[17]. Pandian, N.S., Krishna,K.C.& Leelavathamma B (2002). Effect of Fly Ash on the CBR Behaviour of Soils,Indian Geotechnical Conference,Allahabad, Vol.1, pp.183-186.
[18]. Phani Kumar B.R.&RadheyS.Sharma(2004). Effect of fly ash on Engg properties of ExpansiveSoil. Journal of Geotechnical and Geoenvironmental Engineering Vol. 130, No 7, July, pp. 764-767.
[19]. Prasad, D.S.V., Kumar, M. Anjan, Raju, G.V.R. Prasada, and Kondayya, V (2010). Behaviour of Fly ash Reinforced Sub-bases on Expansive soil subgrades under Cyclic Loading, Indian Geotechnical Conference-2010,GEOtredz,December 16-18-2010,pp 727-730