International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 4, Issue 1, pp: (44-51), Month: April 2016 - September 2016, Available at: www.researchpublish.com

A Study on Bulk Utilization of Industrial Wastes in Geotechnical Applications

Satyanarayana.P.V.V[1], Srinivasa Rao.N[2], Krishna Chaitanya D[3], Ganga Raj.P[4]

[1]Professor, [2,3,4] Post Graduate Students, Department of Civil Engineering, Andhra University, Visakhapatnam, India

Abstract: **Economic growth and industrialization generates huge quantities of waste materials and needs thousands of hectares of land for the disposal which creates environmental pollution. Fly ash and crusher dust come under this category. Utilization of these materials into bulk quantities in civil engineering structures can provide an alternative to natural soils and disposal problems. In this connection an attempt is made for the utilization of crusher dust and Fly ash in Geotechnical engineering applications. Tests like compaction, strength, CBR were performed on mixes prepared from crusher dust and Fly ash by varying their percentages with respect to each other. From the test results it is identified that high strength values in terms of CBR (13-15%) and angle of shearing resistance (38^0) were obtained by maintaining high dry densities. It is also identified that by achieving of high strength values against shear, these crusher dust- Fly ash mixes can be used as sub-grade and fill material. Therefore 30 -50% of Fly ash added to crusher dust can give better results to suit as sub-grade, fill materials in constructional activities.**

Keywords: **Crusher Dust, Fly ash, CBR, Angle of Shearing Resistance.**

I. INTRODUCTION

Industrial wastes like fly ash, pond ash, GGBFS, crusher dust, slag etc collectively touches 200MT annually. These huge quantities require lot of cultivable and useful land for their disposal. To reduce their impact on natural ground these have been under the utilization process in the field of civil engineering as bricks, road material, cement and other applications. Their utilization in bulk quantities to suit as construction and foundation material and to meet specifications similar to natural construction material like stones, sands, gravel soils etc. Civil engineering structures require large quantities of natural soils some of them have been continuously deforming when contacted with water and subjected to abnormal settlements which threat the life of the structure as a whole.

Now-a-days industrial wastes have been gaining their prominence to be used as civil engineering material as an individual or mixed with natural soils or stones or admixture to suit as construction materials. Several thinkers have been in the field of research on the utilization in various parts of civil engineering. Geotechnical engineering is a promising area for the utilization in the areas of road construction material and other geotechnical material.

A number of researchers have made their contributions for the utilization of above said materials in various geotechnical applications. Sridharan A et.al (2005, 2006)[13,14] reported that high CBR and shearing resistance values can enhance their potential use as sub-base material in flexible pavements and also as an embankment material. Praveen Kumar et.al (2006)[6] conducted CBR tests on stone dust as a sub-base material. Wood et.al (1993)[15] identified that the physical properties, chemical composition and mineralogy of quarry dust varies with aggregate type and source. Collins R.J et.al (1994)[3] studied quarry dust in highway constructions. Studies on Fly ash in various applications are Boominathan et.al (1996, 1999)[2], Sridharan.A et.al (1997, 1998)[11,12], studied Use of Fly ash to improve the CBR of soil, Indian Geotechnical Conference, ASHOK KUMAR.R,et.al(2013)[1] studied the Utilization of Crusher Dust in Geotechnical Applications, Krishna Rao C.V et.al(2004)[4] studied Utilisation of lime-Fly ash stabilized expansive soils in Roads and Embankments, Pradeep.N, et.al(2013)[5] studied the Performance of Crusher Dust in High Plastic Gravel Soils As Road Construction Material, Satyanarayana.P.V.V et.al(2013)[7,8,9,10] studied the Use Of Fly ash,Crusher Dust in Geotechnical Applications

Including Flexible Pavements The results showed that the use of crusher dust and Fly ash increase the peak friction angle, peak compressive strength, CBR value. In the present investigation various percentage of crusher dust and Fly ash were mixed and tested for geotechnical characterization such as compaction, strength, drainage, etc., to study their performance.

II. MATERIAL USED

The materials used in this investigation are Crusher dust from stone crushing plants near Srikakulam and Fly ash from NTPC, Visakhapatnam

A) *FLY ASH:*

Fly ash was collected from NTPC Paravada in Visakhapatnam,Andhra Pradesh and laboratory study was carried out for salient geotechnical characteristics of such as gradation, Atterberg limits, compaction and strength. The properties of Fly ash are shown in table 1 and fig 1 to 2.

TABLE 1: GEOTECHNICAL PROPERTIES OF FLY ASH

Property	**Values**
Grain size distribution	
Gravel (%)	0
Sand (%)	28
Fines (%)	72
a. Silt(%)	72
b. Clay(%)	0
Consistency	
Liquid Limit (%)	28
Plastic Limit (%)	NP
I.S Classification	MLN
Specific gravity	2.1
Compaction characteristics	
OMC (%)	21.0
MDD (g/cc)	1.28
Strength parameters	
ϕ (deg)	33
CBR (%)	4.0

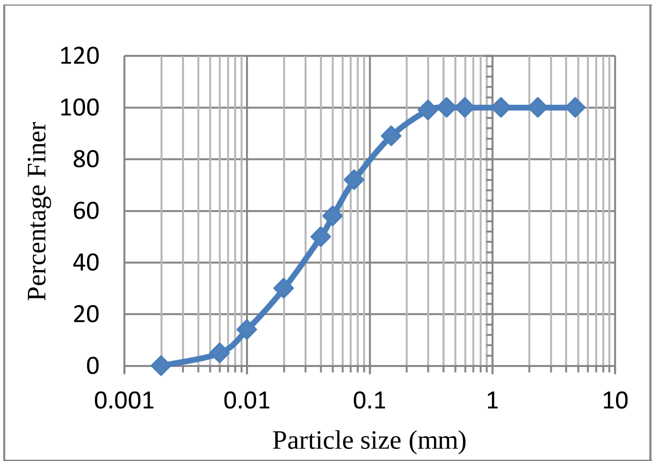


Fig 1: Gradation curve of fly ash

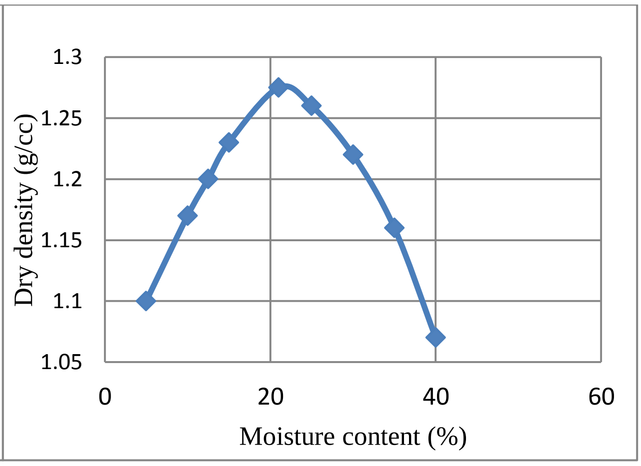


Fig 2: Compaction curve of fly ash

From the physical characteristics of Fly ash it is observed that, it is light grey in colour, majority of Fly ash particles passes through 425µm sieve consisting of fine sand and silt size particles. From the compressibility characteristics it is identified as it is non- plastic and very low compressive in nature. From the compaction curve it can be seen that it attains lower densities with wider variation in moisture contents and identified that maximum dry density (MDD) as 1.28g/cc and optimum moisture content (OMC) as 21%. It is also seen that attainment of lower dry densities at high moisture contents are due to nature and specific gravity of Fly ash particles.

B) CRUSHER DUST:

Crusher Dust was collected from local stone crushing plants near Srikakulam, Andhra Pradesh. The sample was subjected to various geotechnical characterizations such as gradation, consistency, compaction, strength and seepage as per IS 2720. The results are shown in table 2 and figure-3, 4.

TABLE 2: GEOTECHNICAL PROPERTIES OF CRUSHER DUST

Property	**Values**
Grain size distribution	
Gravel (%)	5
Sand (%)	87
Fines (%)	8
a. Silt(%)	8
b. Clay(%)	0
Cu	15.4
Cc	0.62
Consistency	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SP
Specific gravity	2.64
Compaction characteristics	
OMC (%)	13
MDD (g/cc)	1.9
strength parameters	
ϕ (deg)	36
CBR (%)	8

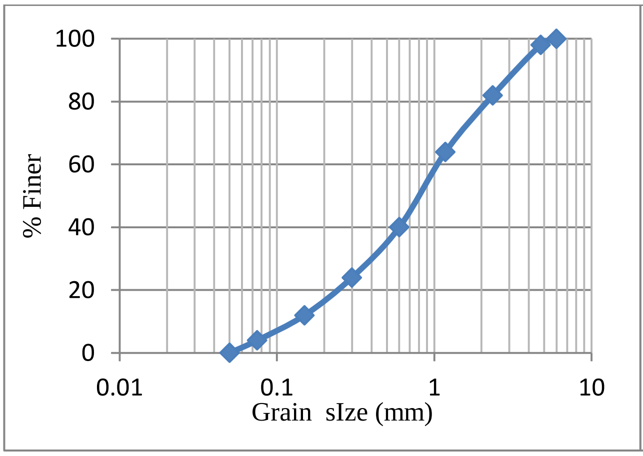


Fig 3: Gradation curve of crusher dust

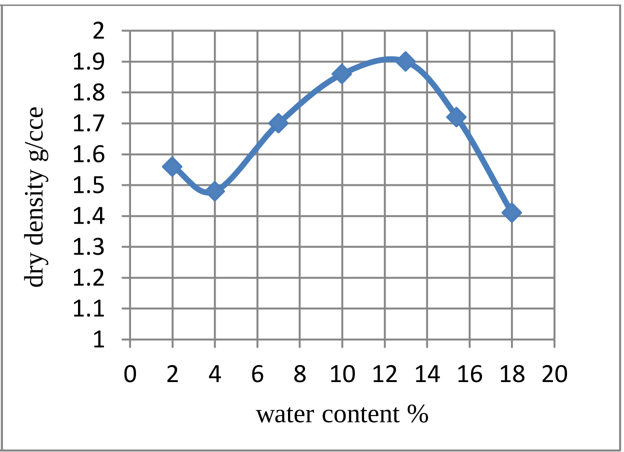


Fig 4: Compaction curve of crusher dust

From the test results of crusher dust, the following identifications are made. The grain size distribution of crusher dust shows that it consists of 87% sand size particles and 8% of silt particles. Majority of crusher dust particles are coarse to medium sand ranges with rough surface texture. Based on BIS, it is classified as well graded particles with non-plastic fines (SPN) with C_u as 15.4 and C_c as 0.62. From the consistency data it is identified as non-plastic and incompressible. Compaction characteristics of crusher dust under modified compaction test have an Optimum Moisture Content of 13% and Maximum Dry Density 1.9 g/cc. From the compaction curve it can also seen that crusher dust attains higher densities with wider variation of moisture contents and increases the workability at high moisture contents. Regarding strength characteristics, it has an angle of shearing resistance (Ø) of 36 degrees under undrained condition and CBR of 8 % and coefficient of permeability as 3.4 x 10^{-3} cm/sec. From the test data it is also identified that it has good strength characteristics and drainage characteristics at soaked condition.

III. RESULTS AND DISCUSSIONS

A) Mixes of Crusher dust and Fly ash:

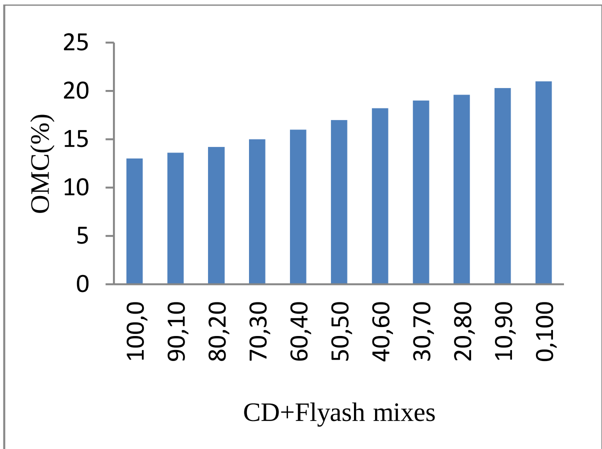
To know the performance of Crusher dust and Fly ash as a geotechnical material like sub-grade and fill material as a replacement to plastic material, various percentages of Fly ash such as 10, 20 so on 100% have been added to Crusher dust, and mixes were prepared and tested for various geotechnical properties like compaction, strength and seepage and the results are shown below.

Compaction characteristics:

Mixes of crusher dust and Fly ash such as M1,M2......M11 have been subjected to heavy compaction by compacting the samples with a rammer of 4.89 kg, five layers each layer subjected to 25 blows and their optimum moisture contents and maximum dry densities are determined as per IS 2720 part-8(1983). The results are shown in table 3 and fig 5&6

TABLE 3: VARIATION OF OMC AND MDD OF CRUSHER DUST AND FLY ASH MIXES

MIXES	CRUSHER DUST (%)+FLY ASH (%)	OMC (%)	MDD (g/cc)
M_1	100+0	13	1.9
M_2	90+10	13.6	1.85
M_3	80+20	14.2	1.8
M_4	70+30	15	1.72
M_5	60+40	16	1.64
M_6	50+50	17	1.56
M_7	40+60	18.2	1.48
M_8	30+70	19	1.42
M_9	20+80	19.6	1.36
M_{10}	10+90	20.3	1.32
M_{11}	0+100	21	1.28



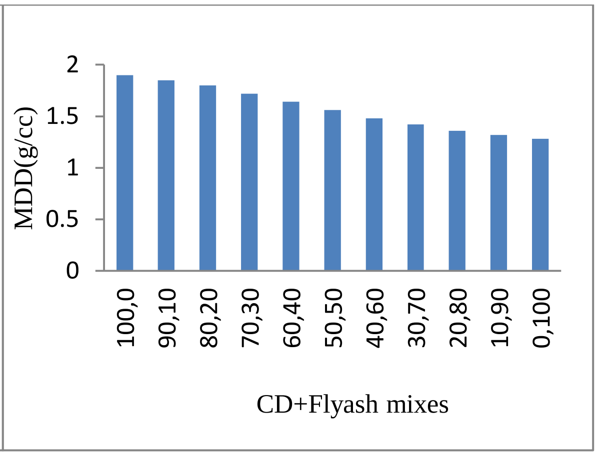


Fig 5: variation of OMC with respect to CD + Fly ash mixes **Fig 6: variation of MDD with respect to CD + Fly ash mixes**

From the experimental data it is observed that as the percentage of Fly ash is increasing, the optimum moisture content values are increasing and maximum dry density values are decreasing. A steady increase in optimum moisture content values were observed up to 20 %, and a rapid increase was observed from 20 to 50% followed by a steady increase was observed up to 90% dosage of Fly ash. Similarly a steady decreasee in maximum dry densities were observed up to 20% and a rapid decrease was observed up to 50% followed by a steady decrease up to 90% dosage of Fly ash. The increase in optimum moisture contents are due to the availability of percentage of Fly ash particles which require more water to coat

Crusher dust and Fly ash mixes with respect to size and shape of Crusher dust and Fly ash particles. Decrease in maximum dry densities was due to the effective replacement of formed voids by Fly ash and Crusher dust particles.

C) Angle of shearing resistance:

To obtain the shear strength values of Crusher dust and Fly ash mixes the samples were compacted at their maximum dry densities (MDD) under heavy compaction and direct shear test was performed as per IS 2720 part-13,1986. The results are shown in table 4 and fig 7

TABLE 4: VARIATION OF ANGLE OF SHEAR RESISTANCE OF CRUSHED DUST AND FLY ASH MIXES

MIXES	CRUSHER DUST (%)+FLY ASH(%)	Ø (degree)
M_1	100+0	36
M_2	90+10	37
M_3	80+20	38
M_4	70+30	38
M_5	60+40	37
M_6	50+50	36
M_7	40+60	35
M_8	30+70	35
M_9	20+80	34
M_{10}	10+90	34
M_{11}	0+100	33

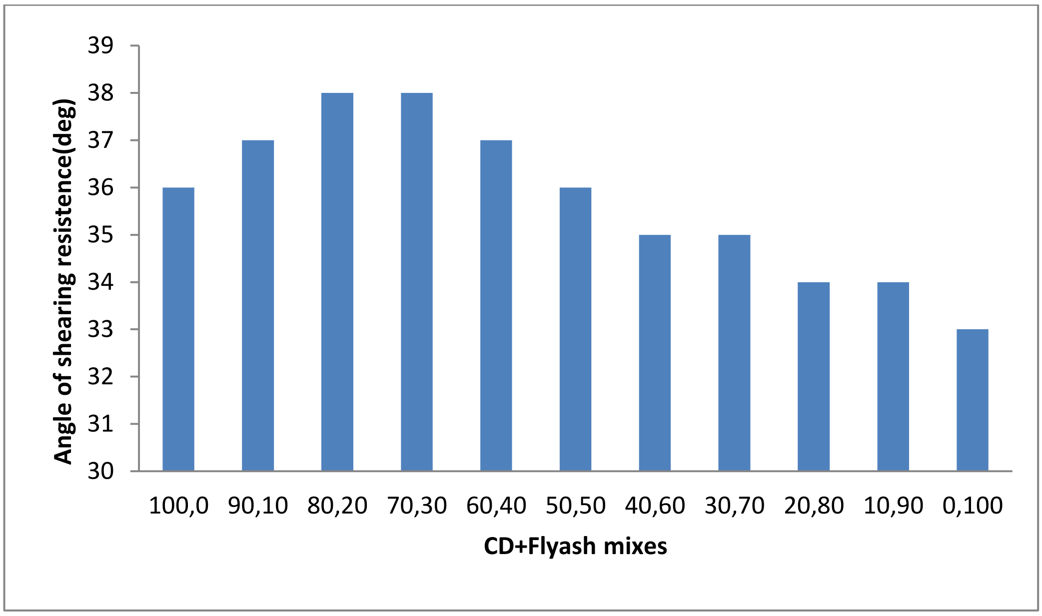


Fig 7: Variation of angle of shear resistance of crushed dust and fly ash mix

From the experimental data it is observed that as the percentage of Fly ash is increasing the angle of shearing resistance values are increasing up to 30% and then decreasing up to 100% of Fly ash. A steady increase was observed up to 30% and a rapid increase was observed in between 30% - 50% followed by a study decrease up to 80% dosage of Fly ash. Maximum values attained at a dosage of 30% - 50%. Increase in angle of shearing resistance values were due to development of frictional resistance by filling up of formed voids of Crusher dust and Fly ash mixes by the lower sizes of Crusher dust and Fly ash particles. Hence a combination of Crusher dust and Fly ash particles mobilizes more frictional resistance than individual Crusher dust and Fly ash particles.

D) Coefficient of Permeability (IS: 2720-part 17- 1986):

Variable head permeability test and constant head permeability test were conducted for all the eleven samples, compacted at their maximum dry densities and tested as per (IS: 2720-part 17 – 1986).

TABLE 5: VARIATION OF COEFFICIENT OF PERMEABILITY OF CRUSHER DUST AND FLY ASH MIXES

MIXES	CRUSHER DUST (%) +FLY ASH(%)	Coefficient of Permeability(k) cm/s
M_1	100+0	0.0054
M_2	90+10	0.0043
M_3	80+20	0.0028
M_4	70+30	0.0012
M_5	60+40	0.00096
M_6	50+50	0.0008
M_7	40+60	0.00076
M_8	30+70	0.00052
M_9	20+80	0.00045
M_{10}	10+90	0.00032
M_{11}	0+100	0.00026

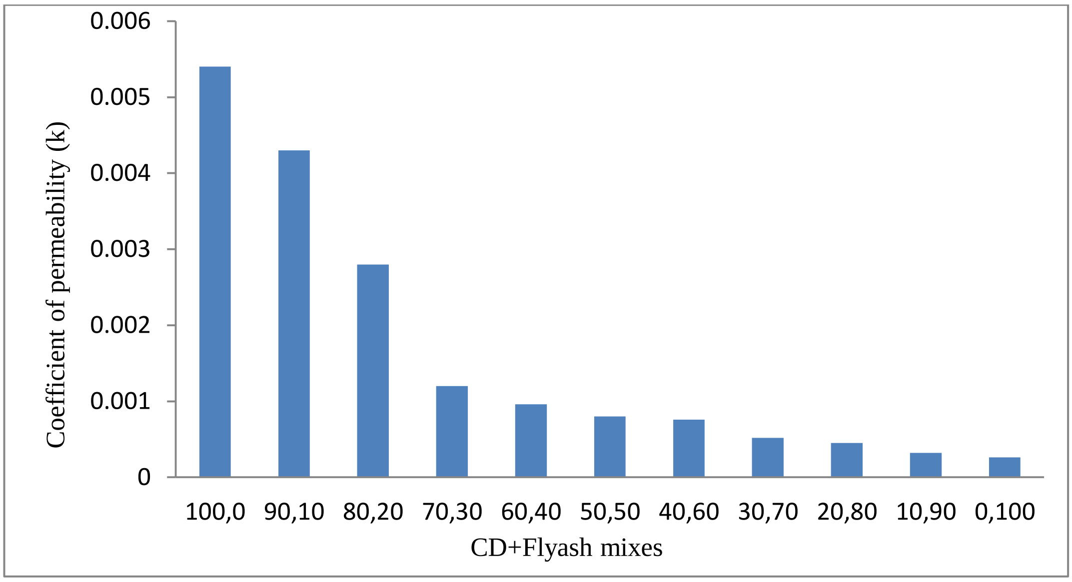


Fig 8: : Variation of coefficient of permeability of crushe dust and fly ash mixes

From the experimental data it is observed that as the percentage of Fly ash is increasing the coefficient of permeability values are decresing up to 100%. A steady decrease was observed up to 30% and a rapid decrease was observed in between 30% - 50% followed by a steady decrease up to 100% dosage of Fly ash. Decrease in the coefficient of permeability values were due to occupation of more Fly ash particles in place of Crusher dust particles. Hence a combination of Crusher dust and Fly ash particles accept pervious conditions($K>10^{-4}$ cm/s) to use as a well drainage material.

E) California Bearing Ratio:

To know the CBR characteristics of Crusher dust and Fly ash mixes, the samples were compacted in the CBR mould at their maximum dry densities under heavy compaction energy and the samples were soaked in water for 4 days. After completion of the required soaking period, the samples were tested at the strain rate of 1.25mm/min as per IS 2720 part - 17. The results are shown in table 6 and fig 9.

TABLE6: VARIATION OF CBR CRUSHED DUST AND FLY ASH MIXES

MIXES	Crusher dust (%) +Fly ash (%)	CBR(%)
M_1	100+0	8
M_2	90+10	9
M_3	80+20	11
M_4	70+30	13
M_5	60+40	15
M_6	50+50	14
M_7	40+60	12
M_8	30+70	10
M_9	20+80	8
M_{10}	10+90	6
M_{11}	0+100	4

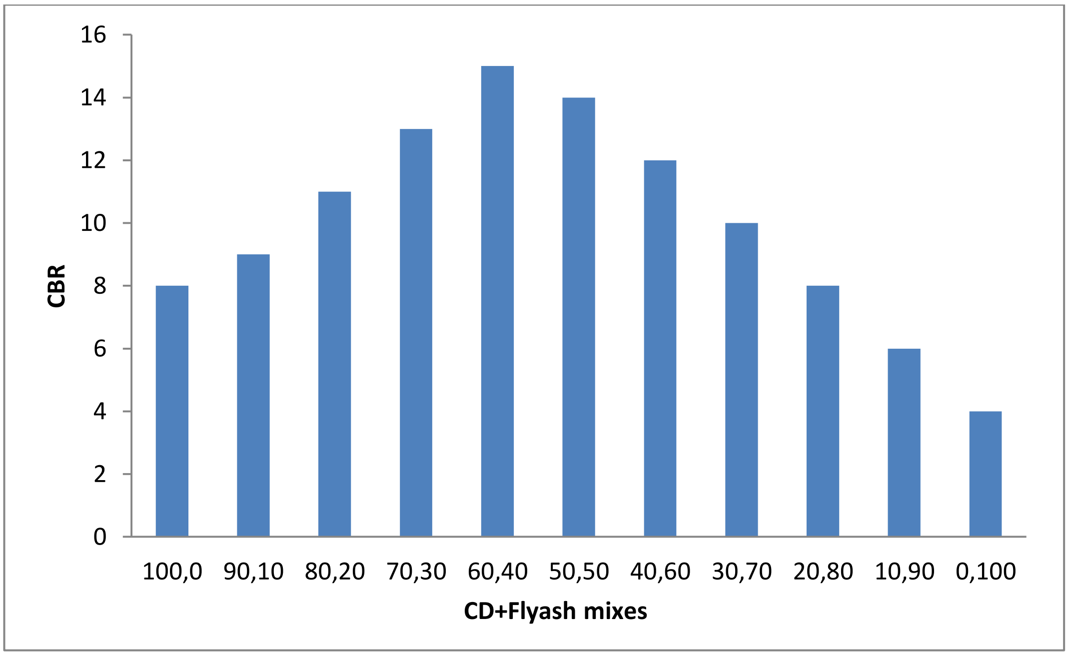


Fig 9: Variation of CBR crushed dust and Fly ash mix

From the experimental data as shown in table-6 and fig 9, it is observed that as the percentage of fly ash is increasing in mixes of Crusher dust and Fly ash CBR values are increasing upto 40% and then decreasing. Maximum value was obtained at 40% dosage of fly ash .High values are due to development of frictional resistance against compression.. At higher percentages of Fly ash (>80%) lower values of CBR were obtained reflecting the behaviour of Fly ash particles. Hence a dosage of 30% to 50 % of Fly ash can be effectively replaced in place of Crusher dust as sub-grade material.

IV. APPLICATIONS

1. Crusher dust attained high dry densities (1.90g/cc) and an angle of shearing Resistance as 36^0 and CBR value of 8% can be used as sub grade ,fill material.

2. 30%- 50% of Fly ash can be considered as effective utilization in the crusher dust – Fly ash mixes by maintaining high strength values such as CBR as13-15% , as 36^0-38 by maintaining pervious conditions against shear and compression .

V. CONCLUSIONS

Test results says that crusher dust and Fly ash are two industrial wastes ,of , non plastic materials can be chosen as construction material. Combination of Crusher dust and Fly ash coherently give high strength values in terms of Angle of shearing resistance (38^0) and CBR (15%) can be effectively used in civil construction as Embankment, Sub-grade, fill material, and Reinforced earth material.

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