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Quantitative analysis of Variation in physiochemical properties of fly ash with increasing sand percentage

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Abstract
The problem of fly ash management is not limited to India; it is a global concern, especially in rapidly industrializing regions like Uttar Pradesh. The state's fast-paced industrial growth has led to a surge in power requirements, putting pressure on thermal power plants to produce more electricity. As fly ash is a cheap and readily available raw material in the state, its management becomes a pressing issue. The issue becomes even more significant when considering the entire country. India's various states are competing for power generation to support their developmental needs, resulting in a high demand for electricity. If all states are striving to generate power independently, the challenges of managing fly ash and ensuring sustainable power generation will become even more critical on a national scale.
To tackle these issues, it is crucial for India to invest in cleaner and more sustainable energy sources, such as renewable energy (solar, wind, hydro) and promote energy efficiency measures. By reducing reliance on coal-based power and adopting eco-friendly alternatives, India can mitigate the adverse environmental impacts associated with coal-based thermal power plants and fly ash production. Additionally, implementing effective fly ash utilization strategies and developing appropriate technologies for its safe disposal can play a significant role in addressing the problem.
Key words: *Fly ash, Thermal power, Energy efficiency.*

I. INTRODUCTION

India is a country rich in natural resources, and coal has been a significant contributor to power generation, accounting for approximately 60% of electricity production. The heavy demand for electricity due to various industries and urbanization has resulted in the continuous operation of thousands of coal-based thermal power plants.

However, the exploitation of coal beds and the operation of these thermal power plants have created a challenge in managing the disposal of their residual materials, such as fly ash. Fly ash is a byproduct of coal burning in thermal power plants, accounting for about 80% of the waste generated, while the remaining 20% is bottom ash. The sheer scale of fly ash production in India has become a problem, with the country facing the challenge of managing around 130 million tonnes of fly ash produced by thermal power plants. However, the heavy exploitation of coal beds and the generation of electricity from coal result in large quantities of fly ash production. Fly ash is a residual material that poses a challenge for thermal power plants to manage. As of the provided information, India faces the issue of handling 130 million tonnes of fly ash produced by thermal power plants annually, Unfortunately, only a small fraction, around 3%, of the produced fly ash has been utilized initially as a cementing material, reflecting the lack of effective recycling and reuse strategies.

Fly ash is considered a major environmental concern, particularly in relation to global warming. It contains various harmful substances and contributes to greenhouse gas emissions, exacerbating climate change. As a result, environmental protection agencies worldwide are increasingly concerned about managing fly ash and reducing its impact on the environment. In the pursuit of sustainable development and following the principles of the 3-Rs (Recycle, Reuse, and Reduce), finding effective ways to manage and utilize fly ash has become essential. Fly ash, along with other greenhouse gases, plays a significant role in contributing to global warming and environmental degradation.

The state of Uttar Pradesh, with rapid industrialization and increasing power requirements, faces a significant challenge in managing the growing production of fly ash due to its heavy reliance on thermal power plants.

India, being a diverse country with various developing states, faces a collective need for power generation to sustain its progress and urbanization. As each state competes for power generation to meet its developmental requirements, the overall scenario of fly ash management and its environmental impact becomes even more complex and critical.

In the pursuit of sustainable development and following the principles of the 3-Rs (Recycle, Reuse, and Reduce), finding effective ways to manage and utilize fly ash has become essential. Fly ash, along with other greenhouse gases, plays a significant role in contributing to global warming and environmental degradation. Without proper strategies for recycling, reuse, and reduction of fly ash, its management will continue to be a challenging issue across the nation. Developing sustainable and environmentally friendly solutions for handling fly ash and reducing its impact on global warming will be essential to ensure India's sustainable development and environmental protection. It is important for the government, industries, and other stakeholders to work together in adopting cleaner and greener technologies for power generation and finding innovative ways to manage and utilize fly ash effectively.

Objective of the study:

- Implementation of the fly ash as mixing component in construction with soil.
- The change in mechanical property of the various mixtures of soil and fly ash.
- Various mixtures of soil and fly ash along with soil had different properties which were use as a definite material for different construction.

Limitation of the study

The fly ashes produced by the thermal power plants were very difficult in storage and transportation as they were very fine in shape and structure but highly reactive with soil as they easily leached out with water and dissolve in ground water lavel. So the accidents during the transportation were leads difficult situation.

II. LITERATURE REVIEW

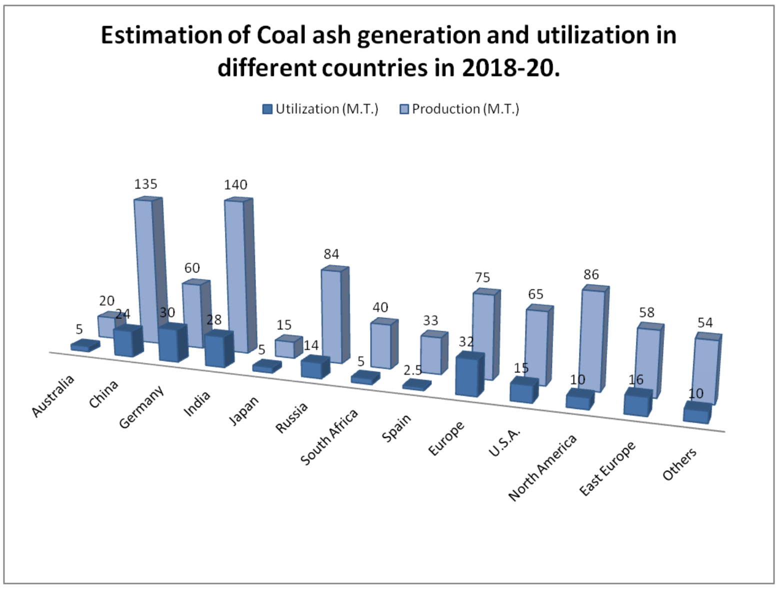
fly ash consists mainly of small spherical particles, and their shape and size can vary depending on the degree of coal pulverization and the efficiency of the collection system used in thermal power plants. One of the primary challenges in the consumption and handling of fly ash has been the development of a financially viable system for collection and assortment. Additionally, the transportation of fly ash from thermal power stations to end-users and the subsequent handling and storage at the user end also pose economic and logistical challenges.

However, advancements in technology have led to increased efficiency in utilizing fly ash, especially in road embankments. As its potential for various applications in construction and infrastructure projects is recognized, there has been a focus on developing better transportation methods to facilitate its use. Nevertheless, it is well-known that both India and China are major producers of coal ash due to their heavy reliance on coal-based power generation. India's increasing demand for electricity, rapid industrialization, and urbanization contribute to its significant coal ash generation. However, as the efficiency of using fly ash in various applications, such as road embankments, has increased, there has been a development of technologies to facilitate its transportation more easily. This has opened up possibilities for increased utilization of fly ash in different sectors.

The utilization of coal ash is a crucial aspect of sustainable waste management and environmental protection. Finding economically feasible and environmentally friendly ways to utilize fly ash can significantly reduce its impact on global warming and promote more sustainable practices in the energy and construction sectors. To address the environmental and economic issues associated with coal ash generation, it is essential for countries to invest in research and development to find innovative ways to utilize fly ash effectively in various industries, construction projects, and infrastructure development. This will not only help in waste management but also contribute to sustainable practices and reduce the environmental impact of coal-based power generation.

Estimation of Coal ash generation and utilization in different countries in 2018-20.

S No.	Country	Production (M.T.)	Utilization (M.T.)
1.	Australia	20	< 5
2.	China	> 135	24
3.	Germany	60	30
4.	India	> 140	28
5.	Japan	15	5
6.	Russia	84	14
7.	South Africa	40	05
8.	Spain	33	2.5
9.	Europe	75	32
10.	U.S.A.	65	15
11.	North America	86	10
12.	East Europe	58	16
13.	Others	54	10



STUDY AREA

Fly ash use in Delhi NCR NHAI Projects:

Delhi is surrounded by the 2 highly active industrial areas of Uttar Pradesh and Haryana. Fly ash, the key component for fly ash bricks, is mainly sourced from thermal power plants. In some places, it is also obtained from other factories. In Haryana, units get fly ash from power plants such as CLP's Mahatma Gandhi Super Thermal Power Project at Jhajjar; NTPC, Jharli; NTPC Badarpur; Panipat Thermal power plant and other factories. In Uttar Pradesh, the only source of fly ash is NTPC, Dadri thermal power plant. For Delhi and Rajasthan, the source of fly ash is NTPC, Badarpur. The characteristics of fly ash may vary depending on the source and may play an important role in the quality of bricks. Unfortunately, the fact that all kinds of fly ash are not same is generally unrecognized, even by the thermal power plants.

III. MATERIALS AND METHODS

This study is based on the fly ash produced by the various TPPs, so we used the fly ash produced by various TPPs near the study are delhi NCR. We used the fly ashes in dry condition so fine powders were oven dried at 110 ^{o}C–160 ^{o}C and kept in air tight bottle for later use. This experiment used with the mixture of fly ashes with sand so we had first identified the various parameter like composition of fly ashes and sand. Fly Ash for the most part consists of Silica (SiO_2), Alumina (Al_2O_3), Calcium Oxide (CaO), and Iron Oxide (Fe_2O_3).The chemical composition of Fly ash is tabulated below in Table.

Compositional Analysis of Fly Ash.

Compounds	**Composition(%) fly ash**	**Sand**
SiO_2	54.5	98.2
Al_2O_3	26.5	0.28
CaO	2.1	0.28
MgO	0.57	0.03
P2O5	0.6	-
Fe_2O_3	-	0.1
SO_3	-	0.07
K_2O	-	0.01
LOI (Loss on ignition)	14.18	0.18

Experimental setup

For the experimental study of the fly ashes in the embankment in road construction. We consider the basic and most natural way of using the fly ash as a mixture with the sand. Most probably with the characteristics of the fly ashes the different concentration of the sand and fly ashes along with sand has different properties which were used in different prospective of using the mixture in road pavement. We will use the fly ash obtained by NTPC Dadri, and common soil used in experiment. Also the mixture ratio is the standard ratio as per used with cement and sand mixture

Mixture

The following procedure was adopted for preparation of fly ash and Sand mixtures in all tests. The materials were first dried for 24 hrs and brought to room temperature. Fly ash and Sand were then mixed together in the required proportions (by dry weight) in dry form. Different proportions of NTPC Dadri fly ash and Sand and their mixed designation are given in table.

Fly Ash and Sand Mix Designation

For the experiment we mix the fly ash and soil in different proportion and these were 0:100, 20:80, 40:60, 60:40, 80:20, 100:0 which were represented in the table below.

Mix Designation	**% of Fly Ash + % Sand**
0:100	0% Fly Ash + 100% Sand
20:80	20% Fly Ash + 80% Sand
40:60	40% Fly Ash + 60% Sand
60:40	60% Fly Ash + 40% Sand
80:20	80% Fly Ash + 20% Sand
100:0	100% Fly Ash+ 0% Sand

TESTING PROGRAMME

Since fly ash generate in huge quantity from thermal power plants. mainly work has been done on fly ash not on Sand so in the project we want to investigate that what is the effect of engineering property on mixing of fly ash and Sand in different proportions and how Sand can be safely used with fly ash in geotechnical applications and other civil engineering projects. So following testing is done on fly ash and Sand and its mixtures in different proportions.

- Grain size analysis
- Specific gravity
- Standard protector test
- Permeability test
- Direct shear test
- California Bearing Ratio test

IV. RESULT AND DISCUSSION

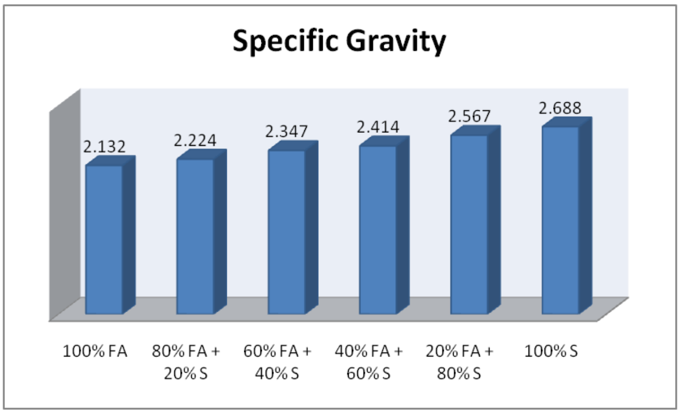
This investigation has been carried out to find the effect of fly ash and Sand mixture on optimum moisture content, maximum dry density, permeability, shear strength, particle size analysis and CBR values. In the present investigation fly ash and Sand has been taken from NTPC Dadri (U.P.) The results of these investigations have been presented in the form of tables and graphs in this chapter. Brief discussions on the laboratory test results are given below.

Specific Gravity

Specific gravity is a significant property being associated to its density and viscosity. It is one of the aspects to conclude density of mixture. If the specific gravity of mixture is more than 3.19 then it has more moisture content, which will affect the mix and bonding. The specific gravity was found out for fly ash, Sand, and fly ash and Sand mixtures in different proportions and it is presented in Table. The specific gravity of fly ash is 2.132 and for Sand it is 2.688.

Table: Specific Gravity for mixtures of Fly Ash and Sand

Mix designation	**Specific Gravity**
100% FLY ASH	2.132
80% FLY ASH + 20% Sand	2.224
60% FLY ASH + 40% Sand	2.347
40% FLY ASH + 60% Sand	2.414
20% FLY ASH + 80% Sand	2.567
100% Sand	2.688

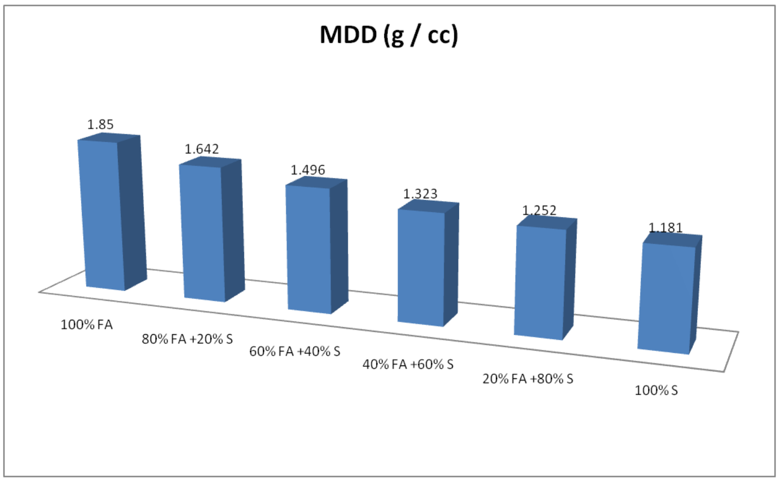


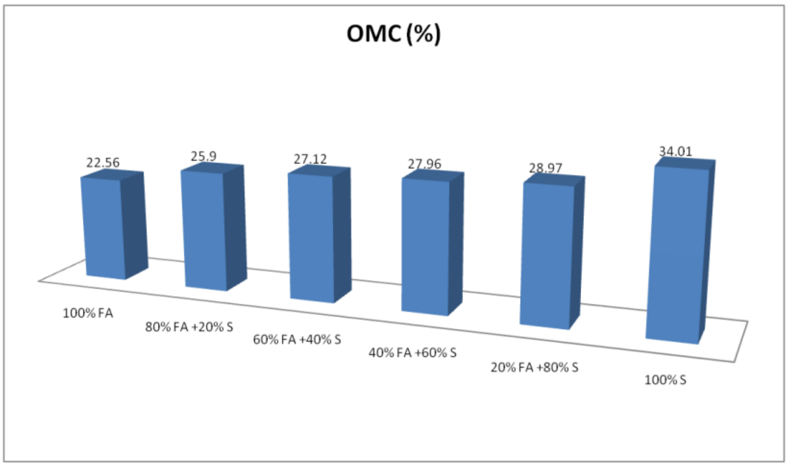
Optimum moisture content and Maximum dry density

When placing mixture of fly ash and soil as fill materials, it is important to achieve suitable compaction, primarily in order to reduce the susceptibility of a mixture to settlement. The ability to attain acceptable levels of compaction is reliant on the moisture content of the mixture of fly ash and soil being placed along with the compactive effort. In order to monitor compaction of soils placed on site, in-situ density testing is frequently undertaken. In the experiment with increasing the amount of sand in the sand and fly ash mixture the MDD decreases. The maximum MDD were for 80% FLY ASH +20% Sand mixture which were 1.252 (g / cc) while the minimum MDD were for 20% FLY ASH +80% Sand mixture which were 1.642 (g / cc). While increasing the amount of sand in the sand and fly ash mixture the OMC increases. The maximum OMC were for 20% FLY ASH +80% Sand mixture which were 28.97 (g / cc) while the minimum OMC were for 80% FLY ASH +20% Sand mixture which were 25.9 (g / cc).

Table: Optimum moisture content and Maximum dry density for mixtures of Fly Ash and Sand

Mix designation	MDD (g / cc)	OMC (%)
100% FLY ASH	1.85	22.56
80% FLY ASH +20% Sand	1.642	25.9
60% FLY ASH +40% Sand	1.496	27.12
40% FLY ASH +60% Sand	1.323	27.96
20% FLY ASH +80% Sand	1.252	28.97
100% Sand	1.181	34.01



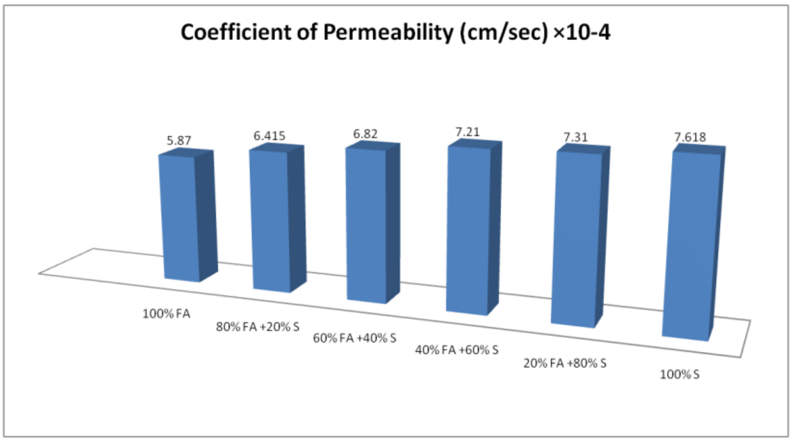


Coefficient of Permeability:

Permeability and porosity as an essential Factors in the Long term Durability of mixture. Permeability of concrete generally refers to the rate at which water or other aggressive substance (sulphates, chlorides ions, etc.). It plays an important role in the long- term durability of concrete material. In the experiment with increasing the amount of sand in the sand and fly ash mixture the coefficient of permeability increases. The maximum coefficient of permeability were for 20% FLY ASH +80% Sand mixture which were 7.310×10^{-4} (cm/sec) while the minimum coefficient of permeability were for 80% FLY ASH +20% Sand mixture which were 6.415×10^{-4} (cm/sec).

Table: Specific Gravity for mixtures of Fly Ash and Sand

Mix designation	**Coefficient of Permeability (cm/sec)**
100% FLY ASH	5.870×10^{-4}
80% FLY ASH +20% Sand	6.415×10^{-4}
60% FLY ASH +40% Sand	6.80×10^{-4}
40% FLY ASH +60% Sand	7.20×10^{-4}
20% FLY ASH +80% Sand	7.310×10^{-4}
100% Sand	7.618×10^{-4}

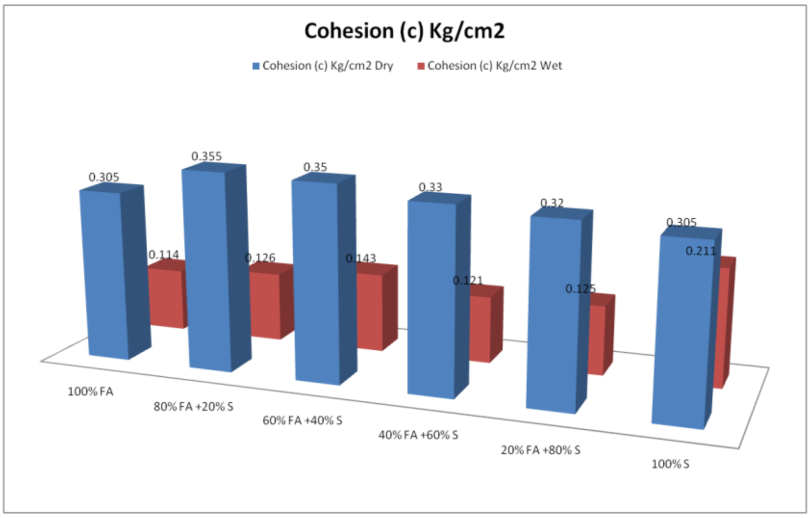


Cohesion:

The role of the cohesion (yield strength) of the grout mixture as the determining factor in the depth of penetration of grout into cracks is emphasized. A simple laboratory or field procedure for determining the cohesion is given. In the experiment with increasing the amount of sand in the sand and fly ash mixture the cohesion decreases in dry state while increase in wet state. The maximum cohesion were maximum for 80% FLY ASH +20% Sand mixture which were 0.36 Kg/cm^2 while the minimum cohesion were for 20% FLY ASH +80% Sand mixture which were 0.32 Kg/cm^2 in dry state while in wet state the trends were a increases maximum cohesion were maximum for 20% FLY ASH +80% Sand mixture which were 0.125 Kg/cm^2 while the minimum cohesion were for 80% FLY ASH +20% Sand mixture which were 0.121 Kg/cm^2

Table: Cohesion for mixtures of Fly Ash and Sand

Mix designation	Cohesion (c) Kg/cm^2	
	Dry	**Wet**
100% FLY ASH	0.305	0.114
80% FLY ASH +20% Sand	0.36	0.121
60% FLY ASH +40% Sand	0.35	0.123
40% FLY ASH +60% Sand	0.33	0.122
20% FLY ASH +80% Sand	0.32	0.125
100% Sand	0.305	0.211



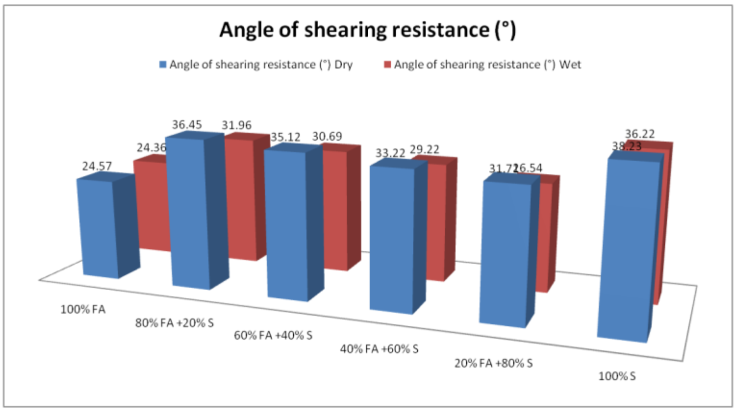
Angle of shearing resistance:

A strength prerequisite is a fundamental hypothesis in engineering purposes of geotechnical materials; accordingly, assessment of the strength characteristics of geotechnical materials is particularly significant and imperative. Direct shear properties is mainly use in appraisal level design or a screening level evaluation of an existing structure. In the experiment with increasing the amount of sand in the sand and fly ash mixture the Angle of shearing resistance decreases in dry state as well as in wet state. The maximum cohesion were maximum for 80% FLY ASH +20% Sand mixture which were 36.45° while the minimum cohesion were for 20% FLY ASH +80% Sand mixture which were 31.71° in dry state while in wet state the trends were also decreases maximum cohesion were maximum for 80% FLY ASH +20% Sand mixture which were 24.36° while the minimum cohesion were for 20% FLY ASH +80% Sand mixture which were 26.54°.

Table: Angle of shearing resistance for mixtures of Fly Ash and Sand

Mix designation	Angle of shearing resistance (°)	
	Dry	**Wet**
100% FLY ASH	24.57	24.36
80% FLY ASH +20% Sand	36.45	31.96

60% FLY ASH +40% Sand	35.12	30.69
40% FLY ASH +60% Sand	33.22	29.22
20% FLY ASH +80% Sand	31.71	26.54
100% Sand	38.23	36.22

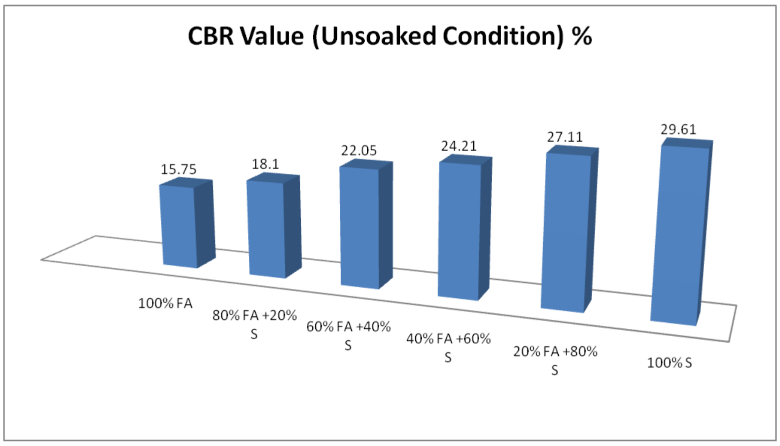


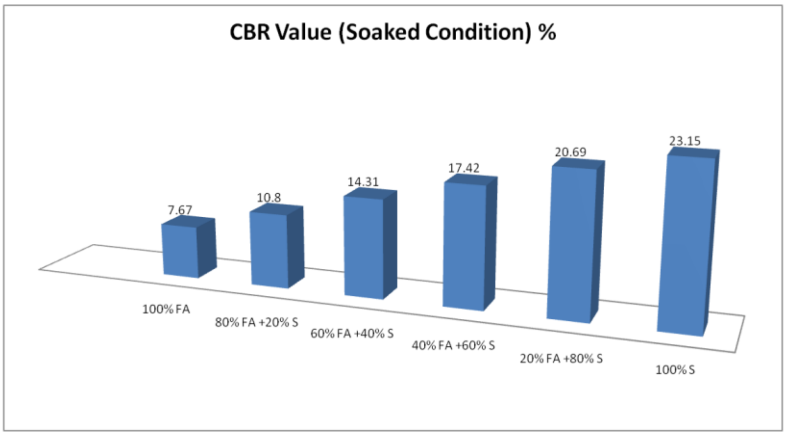
CBR Value :

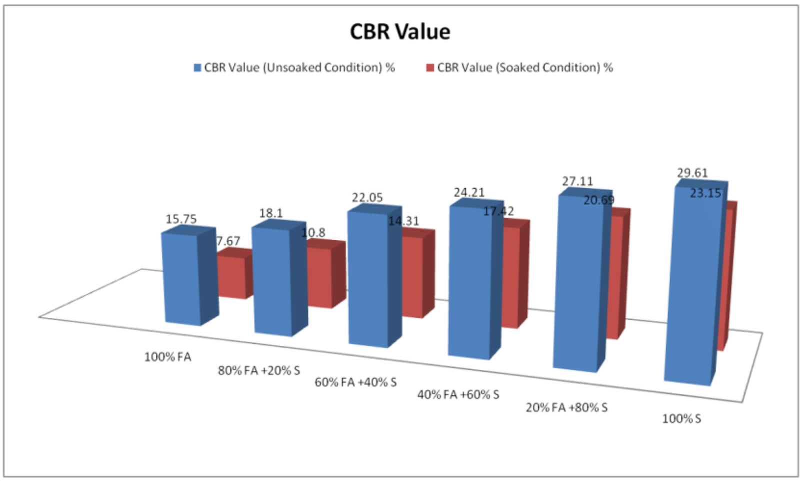
The California Bearing Ratio (CBR) is a measure of the strength of the subgrade of a road or other paved area, and of the materials used in its construction. In the experiment with increasing the amount of sand in the sand and fly ash mixture the CBR Value increases in Unsoaked Condition as well as in soaked Condition. The maximum cohesion were maximum for 20% FLY ASH +80% Sand mixture which were 27.11 % while the minimum cohesion were for 80% FLY ASH +20% Sand mixture which were 18.1% in unsoakesd state while in soaked atate the trends were also increases maximum cohesion were maximum for 20% FLY ASH +80% Sand mixture which were 20.69% while the minimum cohesion were for 80% FLY ASH +20% Sand mixture which were 10.8%.

Table: CBR Value for mixtures of Fly Ash and Sand

Mix designation	**CBR Value (Unsoaked Condition) %**	**CBR Value (Soaked Condition) %**
100% FLY ASH	15.75	7.67
80% FLY ASH +20% Sand	18.1	10.8
60% FLY ASH +40% Sand	22.05	14.31
40% FLY ASH +60% Sand	24.21	17.42
20% FLY ASH +80% Sand	27.11	20.69
100% Sand	29.61	23.15







V. CONCLUSION

fly ash is a by product from the coal based thermal power plant but after long research it has been used as a good construction material for roads and embankments. The benefits obtained by using fly ashes on the place of soil in embankment fill material are distinguished. The replacements of topsoil by the fly ashes were also environmentally effective and also low cost. With leading requirement of urbanization needs more and more road establishment foe proper transportation which leads many problems for road construction industry, but enough consideration should be paid to description and classification of fly ash and quality management at the time of road construction for enhanced. From the above experiment of using fly ash a mixture of fly ash and soil in different proportion will lead to different output.

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