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Comparative changes in the CBR values with increasing concentration of fly ash

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Abstract
It's important to emphasize that the relationship between fly ash content and CBR values is not linear and can be influenced by numerous variables. Laboratory testing is essential to determine the specific effects of fly ash addition on CBR values for a given soil-fly ash mixture. Engineers and construction professionals should carefully analyze test results to determine the optimal fly ash content for achieving the desired engineering properties while considering factors like strength, workability, and long-term durability.

Keywords: Mechanical strength, fly ash, concrete production, highway

Introduction
Fly ash is a by-product of coal combustion that is produced in thermal power plants and industrial boilers. It is created when coal is burned at high temperatures to generate electricity or heat. During this process, various chemical reactions take place, and the inorganic mineral matter in the coal is transformed into fine particles that are carried along with the flue gases. Here's an overview of the production process of fly ash:

1. **Coal Combustion:** Coal, a fossil fuel, is burned in large furnaces or boilers to generate heat. This heat is used to produce steam, which drives turbines connected to generators, ultimately generating electricity.
2. **Formation of Flue Gases:** As coal burns, it undergoes a series of chemical reactions. The carbon in the coal combines with oxygen to produce carbon dioxide (CO2), and other elements in the coal react to form various compounds. The combustion process generates high-temperature flue gases that contain these combustion byproducts, including fine particles of fly ash.
3. **Collection and Separation:** To prevent these fine particles from being released into the atmosphere, power plants and industrial facilities use pollution control equipment, such as electrostatic precipitators or bughouses. These devices capture and collect the fly ash particles from the flue gases before they are released into the air. This collection process helps reduce air pollution and particulate emissions.
4. **Storage and Handling:** Once collected, the fly ash is transported to storage facilities. It is typically stored in large silos or stockpiles. From there, it can be transported to other locations for various applications, such as construction materials or other industrial uses.
5. **Beneficiation and Processing (Optional):** Depending on the quality and intended use of the fly ash, some power plants may subject the collected fly ash to beneficiation processes, such as air classification or separation techniques, to improve its properties and suitability for specific applications.
6. **Utilization:** The collected fly ash is used in a wide range of applications, as mentioned in previous responses. It can be incorporated into construction materials, such as concrete, road base, and soil stabilization, as well as other industrial processes.

It's important to note that the characteristics of fly ash can vary based on factors such as the type of coal burned, combustion conditions, and pollution control equipment used. The composition and properties of fly ash can influence its potential applications and behavior when used in various materials and processes.

Utilization of fly ash
The utilization of fly ash is a significant aspect of sustainable waste management and

resource utilization, as it provides a beneficial use for a material that would otherwise be considered a waste product from coal combustion. Fly ash has a range of beneficial properties, including pozzolanic and cementitious characteristics, which make it a valuable material for various applications. Some common uses of fly ash include:

1. **Concrete Production:** Fly ash is commonly used as a partial replacement for Portland cement in concrete mixtures. Its pozzolanic properties react with calcium hydroxide to form additional cementitious compounds, enhancing the strength, durability, and workability of concrete. Fly ash can reduce heat of hydration and can help mitigate the risk of alkali-silica reaction (ASR).
2. **Grout and Mortar:** Similar to concrete, fly ash is used in grout and mortar mixtures to improve their properties, including compressive strength, workability, and long-term durability.
3. **Stabilization of Soil:** Fly ash is used to stabilize and improve the engineering properties of soils, particularly those with poor load-bearing capacity. When mixed with soil, it can increase cohesion, reduce plasticity, and enhance compaction, making the soil suitable for construction.
4. **Road Construction:** Fly ash can be used as a component in road base and subbase materials. It improves the strength and load-bearing capacity of these layers, leading to longer-lasting and more stable roads.
5. **Embankment and Landfill Construction:** Fly ash can be used to construct embankments and structural fills, providing stability and reducing settlement. It can also be used in landfill construction to create barriers that help contain leachate and reduce environmental impact.
6. Structural Fill and Backfill: Fly ash is used as a lightweight fill material in various construction applications, such as backfilling behind retaining walls or filling voids.
7. **Manufacturing of Bricks and Blocks:** Fly ash is sometimes incorporated into the production of bricks, blocks, and other building materials. It can enhance their strength, reduce shrinkage, and contribute to sustainable construction practices.
8. **Geopolymer Concrete:** Fly ash can be used to produce geopolymer concrete, an alternative to traditional Portland cement-based concrete. Geopolymer concrete has lower carbon emissions and improved chemical resistance.
9. **Oil Well Cementing:** Fly ash can be used in oil well cementing to improve the properties of cement slurries used in well construction and sealing.
10. **Waste Stabilization:** Fly ash can be used to stabilize and immobilize hazardous and radioactive waste materials in containment structures.
11. **Manufacturing of Cellular Concrete:** Fly ash can be used in the production of cellular concrete, which has lower density and improved thermal insulation properties compared to traditional concrete.

These are just a few examples of the diverse applications of fly ash in construction and various industries. The use of fly ash can contribute to sustainable practices by reducing the demand for Portland cement, conserving natural resources, and minimizing waste disposal. However, it's important to consider specific mix design, testing, and regulatory guidelines when incorporating fly ash into various applications.

CBR Value in relation to flash content

The California Bearing Ratio (CBR) is a test used to evaluate the strength and bearing capacity of soils, especially in road construction. Fly ash is a byproduct of burning pulverized coal in power plants and is often used as a supplementary material in construction, including in soil stabilization. The CBR values of a soil-fly ash mixture can provide insights into how the addition of fly ash affects the soil's engineering properties.

Generally, the effect of fly ash on CBR values can vary depending on factors such as the type of soil, the properties of the fly ash, and the concentration of fly ash added. However, there are some common trends that can be observed:

1. **Increase in CBR Value:** In many cases, the addition of fly ash to soil can lead to an increase in the CBR value. Fly ash contains fine particles that can fill voids between soil particles and improve compaction, resulting in higher strength and stiffness. This is particularly true for clayey and silty soils. When you add fly ash to a soil or aggregate mixture, especially in moderate amounts, the CBR value is likely to increase. Fly ash, being a pozzolanic material, can improve the mechanical properties of the mixture by increasing cohesion, reducing voids, and enhancing the material's load-bearing capacity. This initial increase is often seen as a positive effect of fly ash addition.
2. **Optimum Fly Ash Content:** There is usually an optimum concentration of fly ash that leads to the maximum CBR improvement. Adding too much fly ash beyond this optimum can sometimes result in diminishing returns or even a decrease in CBR value. The exact optimum concentration depends on factors like the specific soil type and the properties of the fly ash. There is usually an optimum fly ash content at which the CBR value reaches its highest point. This is the point where the fly ash provides the most significant improvement in material properties, resulting in the highest CBR value. Beyond this optimum content, the benefits may diminish due to factors like excessive cementation, brittleness, or changes in the mixture's workability.
3. **Larger Particle Size Fly Ash:** Fly ash with larger particle sizes can provide better mechanical interlocking with soil particles, contributing to improved CBR values. Coarser fly ash particles can enhance the overall stability of the soil-fly ash mixture. Different types of fly ash (Class C, Class F, etc.) have varying effects on CBR values. Generally, Class F fly ash is more pozzolanic and has a greater potential to enhance CBR values compared to Class C fly ash.
4. **Chemical Reactions:** Fly ash can undergo chemical reactions with soil minerals, leading to cementations properties. This can further contribute to the strength and stiffness of the soil-fly ash mixture over time.
5. **Type of Soil:** Sandy soils might not experience a significant increase in CBR value with the addition of fly ash, as their inherent drainage and compaction characteristics are already better compared to clayey soils. However, fly ash can still provide benefits like

reduced plasticity and improved workability. The natural properties of the soil or aggregate being modified also play a role. Some soils may exhibit more pronounced improvements in CBR values with fly ash addition, while others may show limited changes.

6. **Environmental Factors:** Environmental conditions such as moisture content and curing time can also influence the CBR values of soil-fly ash mixtures. Adequate curing and compaction are essential for achieving optimal results.
7. **Laboratory Testing:** Conducting laboratory tests specifically tailored to the soil type and the fly ash being used is crucial to accurately determine the changes in CBR values with increasing fly ash concentration.
8. **Cementations Properties:** Fly ash contributes to cementitious reactions within the mixture, forming additional binding compounds. These reactions can increase the material's stiffness, strength, and load-bearing capacity, thereby positively affecting CBR values.
9. **Reduced Plasticity:** Fly ash can reduce the plasticity of soils and materials, leading to better compaction and shear resistance. This can result in improved CBR values, particularly in fine-grained soils.
10. **Compressibility and Settlement:** Fly ash can reduce compressibility and settlement in certain soils, contributing to better long-term performance. This effect can be reflected in higher CBR values, indicating improved resistance to deformation.
11. **Potential Negative Effects:** While fly ash can have positive effects, excessive use may lead to over-cementation, brittleness, and reduced deformability. This can impact CBR values negatively, as the material may become too rigid and less able to absorb energy.

It's important to note that the above trends are general observations and can vary based on specific soil and fly ash characteristics. If you're considering using fly ash for soil stabilization, it's recommended to conduct thorough laboratory testing and consult with geotechnical engineers to determine the most suitable fly ash content for your specific project. The exact changes in CBR values with increasing fly ash concentration will depend on the specific materials, testing conditions, and the goals of the road construction project.

Experimental analysis

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 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

CBR ANALYSIS according to Indian standard (IS 2720(XVI):1987)

Penetration Test

- The mould assembly with the surcharge weights
- Placed on the penetration test machine.
- The penetration piston was set at the centre of the specimen
- With the smallest possible load <4 kg
- Full contact of the piston on the sample was established.
- The stress and strain dial gauge was set to read zero.
- Apply the load on the piston
- Penetration rate is about 1.25 mm/min.
- Load gauge
- Readings at penetrations
- 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, & 4.0 where recorded.

For penetration Test

Calibration factor of the proving ring 1 Div. = 1.1236 N

Surcharge weight used (kg) 2.950 kg

Least count of penetration dial 1 Div. = 0.002 mm

Table 1: Standard loads used in a C.B.R. Test

Penetration of plunger(mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

$$CBR = \frac{\text{Test load}}{\text{Standard load}} \times 100$$

Calculation of 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 2: CBR Value for mixtures of Fly Ash and Sand

Mix designation	CBR Value (Unsoakesd 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

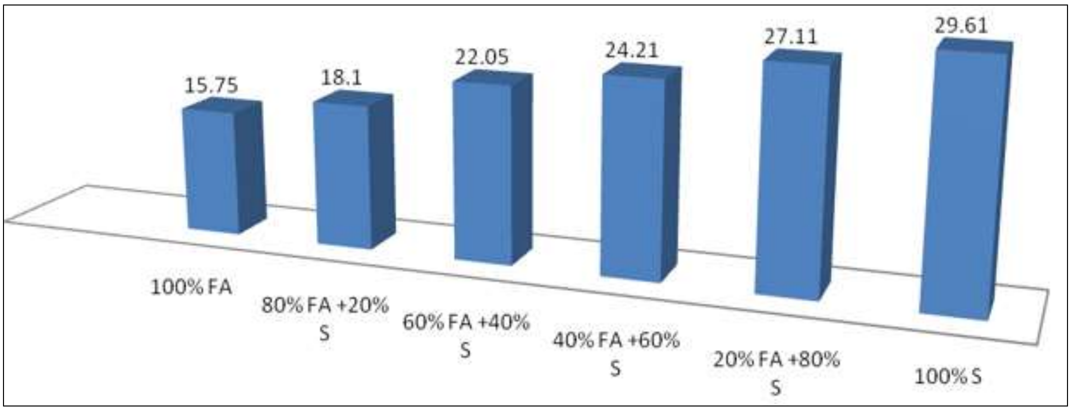

Fig 1: CBR value (Unsoakesd condition) %

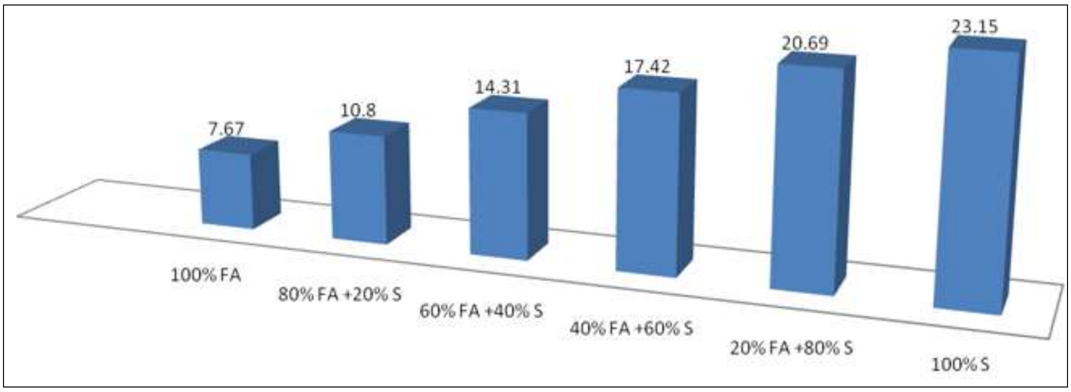

Fig 2: CBR value (Soaked condition) %

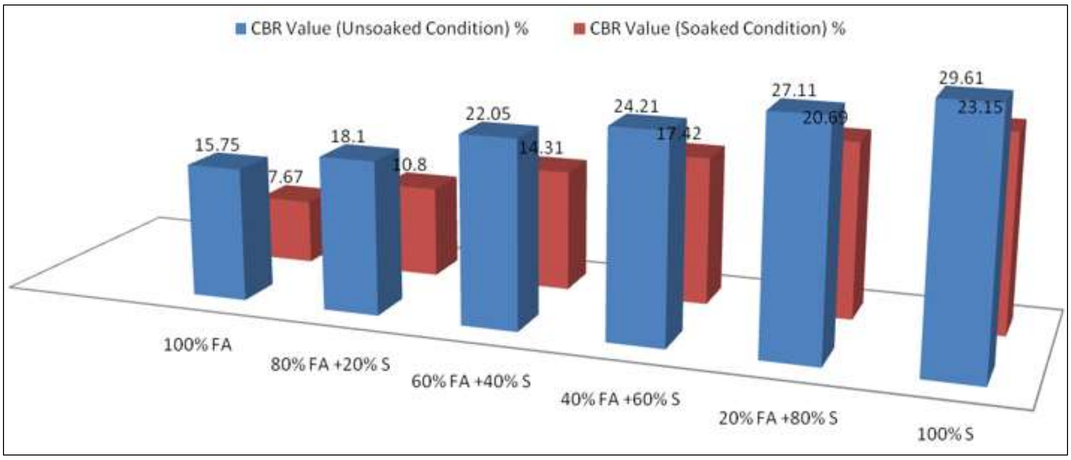

Fig 3: CBR value

Conclusion

Trends for CBR Value increases with increasing the amount of sand in the sand and fly ash mixture the CBR Value increases in Unsoakesd 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%. Therefore fly ash and Sand mixtures can be used as sub-base of road construction as well as fill materials for highway embankments.

References

1. Ravina D, Mehta PK. Properties of fresh concrete containing large amount of fly ash, Cement and Concrete Research. 1986;16:227-238.
2. Ravina D. Mehta PK. Compressive Strength of low cement/high fly ash concrete, Cement and Concrete Research. 1988;18:571-583.
3. Langley WS, Carette GG, Malhotra VM. Structural concrete incorporating high volumes of ASTM class F fly ash, ACI mater J. 1989;86:507-514.
4. Bhanumathidas N, Kalidas N. Fly ash: The resource for construction industry, The Indian Concrete Journal. 2003;77(4):997-1004.
5. Khadilkar SA, Kulkarni VR. Engineering fly ash-based blended cement for durable concrete: A review The Indian Concrete Journal. 1989;77(4):1009-1021.
6. Mishra Dhanada K. Fly ash based Geopolymer Materials-A review of recent Developments Proceedings of Workshop on Fly-ash and it's application, organized by KIIT University at Bhubaneswar; c2004. p 15-23,
7. IS: Indian Standard Recommended Guidelines for concrete mix design, BIS, New Delhi, 10262-1982,
8. Desai JP. First HVFA concrete road in India at Ropar, Punjab The Indian Concrete Journal. 2003;77(4):1022-1025.
9. Carolyne N, Atadero Rebecca A. Optimization of fly ash in concrete: High lime fly ash as a replacement for cement and filler material World of coal ash (WOCA) conference in Lexington, KY, USA; c2009.
10. Kumar D, Kumar N, Gupta A. Geotechnical Properties of Fly Ash and Bottom Ash Mixtures in Different Proportions International Journal of Science and Research (IJSR). 2014;3(9):1487-1494.
11. Kalyoncu RS. Coal Combustion Products Production and Uses, U. S. Geological Survey, Reston, Virginia. 2005;4:13-17.
12. Chauhan MS, Mittal S, Mohanty B. Performance evaluation of silty sand sub-grade reinforced with fly ash and fiber, Geotextiles and Geomembranes. 2008;26(15):429-435.
13. Cokca E. Use of Class C Fly Ashes for the Stabilization of an Expansive Soil Journal of Geotechnical and Geoenvironmental Engineering. 2001;127:568-573.
14. Kim B, Prezzi M, Salgado R. Geotechnical Properties of Fly and Sand Mixtures for Use in Highway EmSnkments J. Geo, Geoenv. ASCE. 2005;131(7):914-924.
15. Acosta HA, Edil TB, Benson CH. Soil Stabilization And Drying Using Fly Ash, Geo Engg; c2005. Report No. 03-03.
16. Phani BR, Sharma RS. Effect of Fly Ash on Engg. Property of Expansive Soil, J Geo, Geoenv. ASCE. 2004;131(7):764-766.
17. Prashanth JP. Evaluation of the Properties of Fly Ash for its Use in Geotechnical Applications. Ph.D Thesis, IISC. Bangalore; c1998.
18. Usmen MA. A critical review of the applicability of conventional test methods and materials specifications to the use of coal associated waste in pavement construction. PhD dissertation. West Virginia Univ., Morgantown. W. Va; c1977.
19. Pandian NS, Krishna KC, Leelavathamma B. Effect of Fly Ash on the CBR Behaviour of Soils, Indian Geotechnical Conference, Allahabad. 2002;1:183-186.
20. Gandhi SR, Dey AK, Selvam S. Densification of Pond Ash By Blasting J. Geo. Geoenv. 1999;125:10 1-2.
21. Bhatta N. Engineering properties of pond ash and pond ash sand mixtures, Indian Highways; c2008. p. 49-59.