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BEHAVIOURAL ANALYSIS AND IMPACT OF SALINITY ON AGRI-WASTE BRIQUETTES FLY ASH BASED GEOPOLYMER CONCRETE

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Abstract:

The current study provides a proximal and ultimate examination of bio-coal briquettes as fuel and fly ash as an end product, as well as an analysis of the effects of salt water. Three bio coal briquettes (Cotton (CB), Maize-Saw dust (MB), and Groundnut shell-Saw dust (GB)) that contained various agricultural waste were examined. Comparing coal-based fly ash (CFA) to BFA demonstrated similar properties in significant investigations on pH, turbidity, and SEM-EDX. Fly ash samples from CB, MB, and GB contained 3.55%, 5.38%, and 10.36% of alumina, 11.40%, 14.24%, and 31.39% of silica, and 20.35%, 18.82%, and 5.39% of calcium, respectively. Compressive strength of different types of concrete, including traditional concrete (TC), coal fly ash geopolymer concrete (CGPC), and bio coal fly ash geopolymer concrete, was tested after 28 days of saline water curing. Samples TC, CGPC, GB-BFA, MB-BFA, and CB-BFA were found to have compressive strengths of 27.8 N/mm2, 23.19 N/mm2, 21.04 N/mm2, 19.57 N/mm2, and 18.65 N/mm2 correspondingly.

Keywords: Agri-waste Fly ash, Geopolymer Concrete, Proximate & Ultimate Analysis, Salinity Shock

1. Introduction:

After water, concrete is the material used most frequently in the modern world. [1]. Ordinary Portland cement (OPC) is the most frequently used binder for making conventional concrete because of its ubiquitous availability worldwide. Concrete has greatly assisted stability, economic progress, civilization, and quality of life while also making it possible to create infrastructure, transportation, and other areas. Numerous initiatives are being attempted to decrease the severe negative environmental effects that OPC production produces, which have been clearly documented by numerous researchers [2]. Numerous research has demonstrated that geo-polymer concrete (GPC), which can replace OPC in applications where it is more advantageous, can be made using fly ash from coal incineration [3,4,5]. However, coal, a non-renewable energy source, endangers the environment since it releases harmful compounds and fly ash [6]. Though somewhat sustainable, the idea of producing GPC from coal-based fly-ash needs to be compared to other environmentally beneficial production methods. Bio-coal/white-coal fly-ash generation of GPC is an alternative and extremely sustainable process. Concrete made with geopolymer reduces greenhouse gas emissions from cement manufacture by more than 80% [7].

Carbon, hydrogen, and oxygen make up the majority of the complex carbon-containing compound known as biomass, with minor amounts of other atoms. The primary source of bio-coal briquette manufacture is combustible agricultural waste, which is frequently used as fuel for industry or home reasons. In the search for a new renewable energy source, bio-coal briquettes may be the best option for supplying the world's energy demands with a sustainable and eco-friendly alternative [8,9]. Carbon-based biomass is a complex substance that mostly consists of the atoms carbon, hydrogen, and oxygen, with trace amounts of additional atoms. The primary raw material for the production of bio-coal briquettes is combustible agricultural waste, which is frequently used as fuel for domestic or commercial reasons. In the hunt for a new renewable energy source, bio-coal briquettes may be the most effective resource for supplying the world's energy needs with a long-lasting and eco-friendly substitute [8,9]. Using waste bio-coal fly ash as a resource to make geopolymer concrete is the best recycling technique, and it is a long-term solution that lowers carbon emissions, raw material consumption (cement, fly ash, etc.), and other environmental issues.

The most widely used building and structural material worldwide is concrete. The selection of durable and affordable replacement materials for installation is difficult [10]. The quantity of water has a crucial role in the creation of concrete. Water impurities may interfere with the cement's ability to set and may harm the properties of strength. The chemical elements in water may work together in chemical reactions, changing the mixture's hardening, setting, and strength advancement. Since oceans comprise the majority of the surface of the globe (almost 80%), many buildings are exposed to the highly salinized seawater. Water quality is a factor in concrete durability [11]. The "ions of chloride, potassium, calcium, sodium, and magnesium" are the main chemical components of seawater. Significant salt components are found in amounts of 2.3% K2SO4, 3.9% CaSO4, 5% MgSO4, 10.5% MgCl, and 78% NaCl. Concrete is harmed over the course of a structure's use by chemical and physical assaults that are controlled by hostile surroundings. The trend of infrastructure development includes meeting the annual demand for clean water. It is urgently necessary to examine freshwater conservation efforts [12]. Additionally, it is more cost-effective to use saltwater that is nearby and easily available for installation purposes rather than potable water that must be imported from sources in other areas. Several experts have recently studied the durability of concrete built using both plain and seawater. [13,14].

The present study which deals with the proximate and ultimate study of bio-coal based fly ash. Also comparing the salinity effect on traditional concrete, coal fly ash based geopolymer concrete and bio coal fly ash based geopolymer concrete. The bio-coal based fly-ash mimics the properties of traditional coal fly-ash in our preliminary studies, which became the base of the present study. Samples of BFA were tested for microstructural properties, physical and leachate properties also.

2. Experimental methodology and material characterization:

The bio-coal fly-ash (BFA) from three types of agricultural waste—cotton (CB), maize-saw dust (MB), and groundnut shell-saw dust (GB)—has been used in the current investigation. Materials utilised and experimental procedures are covered in depth in the sections that follow.

2.1 Materials used

Fly ash from bio-coal briquettes serves as the binder in modified geopolymer concrete. Gather the three different BFA samples of cotton, maize, and groundnut shell from different Jalgaon MIDC sectors. These examples were produced by various factories and businesses using boilers to provide heat. This fly ash is ultimately disposed of in landfills. Fly ash samples were collected and stored in a dry atmosphere. The industrial fly ash samples came in a variety of sizes, ranging from ultrafine to roughly 2.36 mm. To confirm that they were working with fly ash, BFA samples were passed through a standard IS sieve of size 150; samples with a size greater than this were deemed to be bottom ash (BA) and were disregarded for this purpose. The ratio of fly ash to bottom ash was approximately 60:40 [15]

Table 1 Physical properties of BFA

Material / Properties	CBA	MBA	GBA
Sp. Gravity	2.18	2.39	2.59
Surface Area	300 – 550 m^2/Kg	300 – 550 m^2/Kg	300 – 550 m^2/Kg
Particle Size	Less than 150µ	Less than 150µ	Less than 150µ

The chemical constituents of BFA were totally depend on primary material i.e., type of agri-waste. Wide variations of the Bio coal Briquette material which is used in the boiler of MIDC sectors generate a wide range of composition in Bio coal Briquette fly ash. The major elements present in of ash are Alumina (Al), Silica (Si), Calcium (Ca), Magnesium (Mg) and Iron (Fe) are the elements which affects quality of fly ash. The chemical composition of fly ash is represented in the Table 2

Table 2 Chemical compositions % of bio coal briquette fly ash

Chemical Composition %	Cotton	Maize	Groundnut shell
Al	3.58	5.48	10.46
Si	11.42	14.34	31.40
Ca	20.36	18.80	5.49
Mg	3.21	2.19	3.01
Fe	13.91	9.68	7.23

The BFA based geopolymer concrete is cast and cured as per mix design and standard materials i.e. sand, aggregate, alkaline activator solution (NaOH : Na2SiO3). After the curing of Geopolymer concrete the salinity shock is applied on cube for 28 days. The salinity is prepared as per the standards of sea water (33-37 gm per Liter). Comparing the data from literature for salinity effect on traditional concrete, coal fly ash based geopolymer concrete and bio coal fly ash based geopolymer concrete.

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2.2 Experimental Methodology:

Since the strength performance of concrete is useless without durability, durability is one of the key criteria for any concrete. Thus, durability tests on the geopolymer concrete were conducted with great care and attention. The testing approach was carried out in accordance with accepted practises. In order to test for salinity shock, all specimens of the geopolymer concrete mixture were immersed in water that had a salinity of 35 mg per litre. 150 mm geopolymer concrete cubes were immersed in saline solution at a concentration of 35%, or 35 gramme per litre, after 28 days of curing. Regular tests and refills were performed on the salted water. The samples were taken out of the salty water and cleaned after being exposed to it for 28 days. Place the concrete cube beneath the compression testing machine to conduct the compressive strength test.

3 Result and Discussion:

3.1 Proximate Analysis:

By releasing considerable amounts of trace metals including Cu, Zn, Mo, and Mn as well as other metals with high toxicity levels like Se, Ni, Pb, Co, Cr, and As, fly ash has a negative impact on ground water. These substances have detrimental effects on human, animal, and plant health. It is well known that one of the most frequent and dangerous components produced by the leaching of fly ash is arsenic. Due to the high concentration of soluble salts in fly ash, pollutants can rapidly leach from soil and into groundwater. In areas where fly ash pollution may be a problem, the quality of the groundwater is frequently found to have declined. The findings indicate that samples of fly ash have a high potential to contaminate the groundwater environment.

3.1.1 pH of BFA:

The results of the leaching properties of BFA samples advocate that some of the chemical species that are released in the water environment caused an increase in pH level of water with BFA samples as shown in Fig. 1 The pH value of bio coal fly ash is referred with distilled water (pH=7). The pH of bio coal fly ash is 10.4, 9.7, and 8.8 for cotton, maize and groundnut shell respectively. Depending on pH value, fly ash is differentiating as acidic, mildly alkaline and strongly alkaline ash [16].

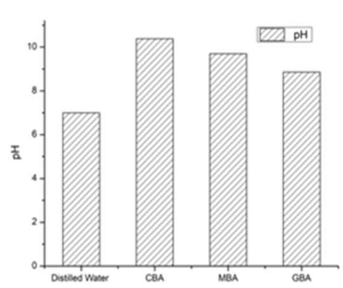

Fig. 1 pH of Bio coal Briquettes fly ash with Distilled water

3.1.2 Turbidity of BFA:

The BFA samples used in the study were very fine in size. The study of BFA sample interaction with water revealed that small particles of BFA remained suspended in the water environment that caused in increase in turbidity of samples containing BFA as shown in Fig.2. With reference to distilled water (turbidity is 0) the turbidity of bio sampled bio coal fly ash is 1.2, 1.0, and 0.8 of cotton, maize and groundnut fly ash respectively.

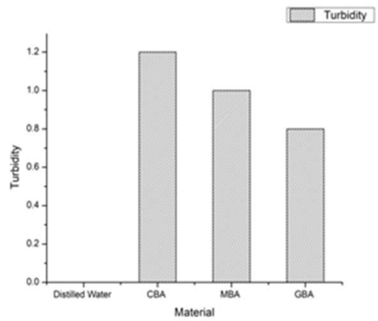

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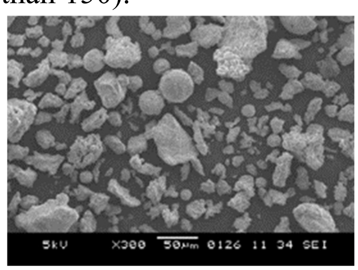
Fig. 2 Turbidity of Bio coal Briquettes fly ash with Distilled water

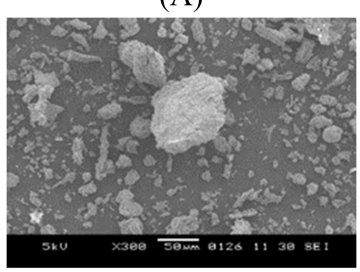
3.2 Ultimate Analysis:

3.2.1 Energy Dispersive X-Ray Spectroscopy with a Field Emission Scanning Electron Microscope (FESEM) -

A Nova Nano-SEM 450 from USA PTE LTD by FEI Company scanning electron microscope was employed. The surface characteristics, dimensions, and shapes of the BFA, GGBS, and Alccofine 1203 binder particles utilised in the experiment are depicted in Fig. 3. The BFA particles had a smooth texture, curved angularity, and were formed during the incineration process as solid microspheres or cenospheres (less than 150).



(A)



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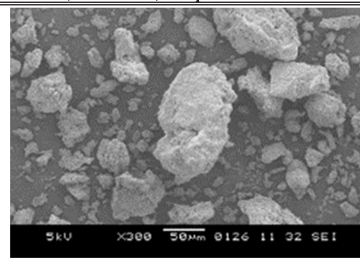
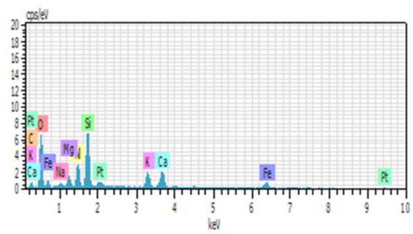


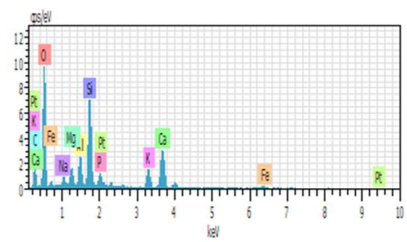
(C)

Fig.3 SEM image of bio coal fly ash (A) Cotton (B) Maize (C) Groundnut

The energy-dispersive X-ray (EDX) spectroscopy of bio coal fly ash is shown in Fig. 4. The fly ash from bio coal has a significant proportion of silica and alumina, according to EDX spectroscopy. Information on the chemical composition of various samples can be found in Table 3. The calcium concentration in the CBA sample was found to be higher than that of the BFA samples from MBA and GBA. The pozzolanic process is aided by the release of Ca+ ions from the high calcium content, which ensures that they will enter the NaOH solution.



(A)



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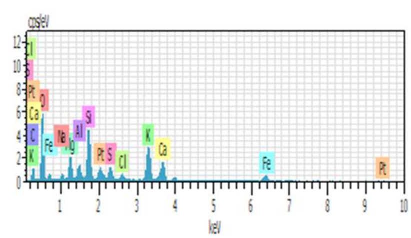

(C)

Fig. 4 EDXA of bio coal fly ash of (A) Cotton (B) Maize (C) Groundnut

Table 3 Chemical compositions of bio coal based fly ash from SEM-EDX

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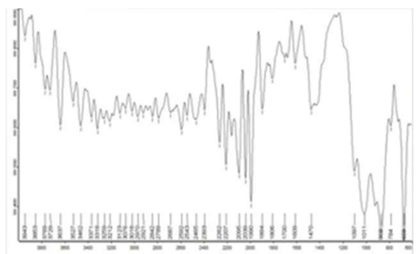
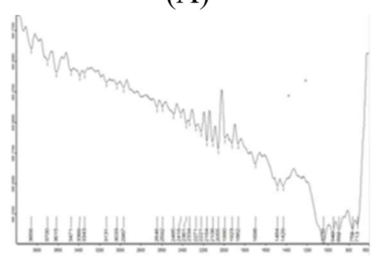
Chemical Composition %	Cotton Fly Ash	Maize Fly ash	Groundnut shell Fly ash
Si	11.42	14.34	31.40
Mg	3.21	2.19	3.01
Ca	20.36	18.80	5.49
Al	3.58	5.38	10.46
Fe	13.91	9.68	7.23

3.2.2 Fourier Transform Infrared Spectroscopy (FTIR):

Figure 5 shows the Fourier Transform Infrared Spectroscopy (FTIR) results, which showed that BFA with coal-based fly ash had imitating qualities. Figure 5 displays the FTIR data of the CBA, MBA, and GBA samples alongside the GGBS and Alccofine samples. The CBA and GBA samples' infrared spectra show a similar general pattern. Bio coal fly ash exhibits mimic behavior and chemical composition in comparison to coal fly ash based on the micro structural features.



(A)



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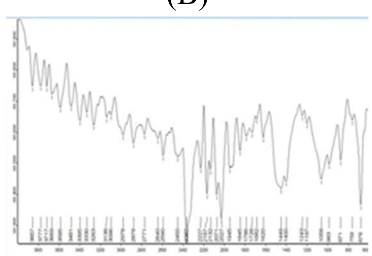

(C)

Fig. 5 FTIR graphs of bio coal fly ash (A) Cotton (B) Maize (C) Groundnut Shell

3.3 Salinity Effect:

Three distinct samples of BFA (CB, MB, and GB) employing a bio coal fly ash mix for geopolymer concrete were investigated. Here are the laboratory results that were acquired. Figure 6 shows the findings of the compressive strength of BFA-based geopolymer concrete after 28 days for saline water shock. When used for curing, saline water has an impact on the strength of geopolymer concrete. It displays striking strength reductions. The average values of the three specimens were found for compressive strength. The geopolymer concrete sample made from GBFA had the highest strength of all the samples. After 28 days of curing in saline water, the compressive strength of geopolymer concrete for the GB specimen is 21.04 N/mm2. Compressive strength for the MB specimen is 19.57 N/mm2, which is slightly lower than for the GB specimen. The compressive strength of the CBFA geopolymer concrete specimen is 18.65 N/mm2, the lowest result among the three BFA-based geopolymer concrete specimens.

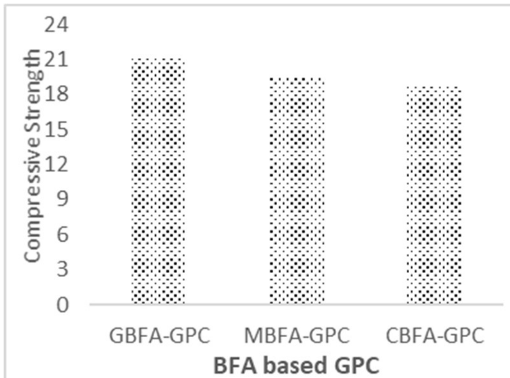

Fig.6 Compressive Strength of BFA based geopolymer concrete after 28 days of saline water curing

The impact of 28 days of saline water on the compressive strength of conventional concrete, conventional geopolymer concrete, or coal-based fly ash, and modified concrete, or bio coal-based fly ash (CB, MB, GB), has also been studied by numerous researchers [12, 17,18]. Saline water's compressive strength falls in all three circumstances when compared to potable water, ambient temperature, or temperature curing, as seen in fig. 7.

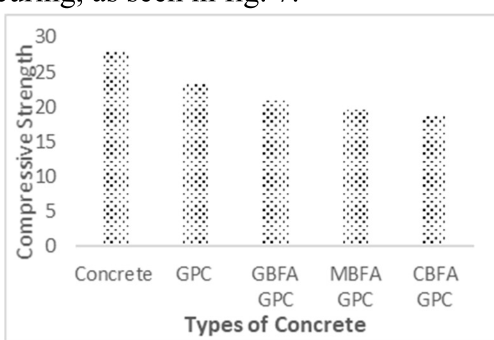

Fig. 7 Comparison of compressive strength of concrete, GPC and BFA based GPC after 28 days of saline water curing

The study's findings are a component of a holistic sustainable approach to managing fly ash, meeting energy needs, and creating a circular economy where waste is converted into resources. A proof-of-concept study was conducted on BFA to determine whether it could be used to make geopolymer concrete. The findings indicate that BFA possesses qualities that are similar to those of coal-based fly ash, which is frequently utilised in the construction industry. It can be used well in suburban and rural regions as paver blocks, bricks, pre-cast concrete, etc. It may also have other uses. Portland cement can be swapped out for the BFA-GGBS-based mortar as an environmentally friendly alternative when repairing damaged and ageing concrete structures.

Conclusion

Following a saline shock, a BFA and compressive strength examination of concrete yielded the following key findings:

1. According to the microstructural analysis, samples of bio coal-based fly ash from three different sources, namely CB, MB, and GB, had compositional mimicking features that served as the foundation for the current study and can be used to produce BFA-based geopolymer concrete.
2. Based on BFA's leachate qualities, bio coal ash has a pH greater than 7. The fly ash is therefore acidic or hardly alkaline. The bio coal fly ash sampled is neatly 1NTU in terms of turbidity.
3. Compressive strength of geopolymer concrete made with bio coal fly ash is reaching its maximum level as a result of salinity shock. Among the three, maize and cotton bio coal fly ash based geopolymer concrete has the most strength, followed by groundnut shell bio coal fly ash based geopolymer concrete.
4. All varieties of concrete, including traditional concrete, coal fly ash-based geopolymer concrete, and bio coal fly ash-based geopolymer concrete, exhibit reduced strength when compared to compressive strength following the saline effect.
5. Traditional concrete has less strength loss for the same grade of concrete as geopolymer concrete. In the case of geopolymer concrete, coal fly ash-based geopolymer concrete, particularly groundnut bio coal fly ash, has a little bit greater strength than bio coal fly ash-based geopolymer concrete.

The study's conclusion is that industrial wastes like BFA can be effectively used as long-lasting, environmentally benign, and affordable building materials, but not for constructions at saltwater shorelines.

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