International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 01 Jan. 2025, pp: 612-637 www.ijaem.net ISSN: 2395-5252

Investigating the Effects of Metakaolin Blended with Sugarcane Bagasse Ash and Rice Husk Ash Based Geopolymer on the Engineering Properties of Geopolymer Concrete

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Date of Submission: 20-01-2025 Date of Acceptance: 30-01-2025

ABSTRACT
Concrete is a major construction material, that is largely made up of cement; however, its high cost and ecological unsustainability has been a source of concern over the years in construction industry. In recent years, innovative cementitious materials that can be used as an alternative for ordinary Portland cement (OPC) with improved performance and emission, are locally source to reduce CO2 emission into the atmosphere during cement production and high cost of cement in concrete production. Therefore, geopolymer is an innovative and environmentally beneficial binder material that was developed to reduce Portland cement's harmful environmental consequences. Geopolymer is one of the trending research areas in composite materials; there are many areas in geopolymer that unexplored still need to be explore. This study investigates the effects of blended metakaolin concrete produced with Sugarcane bagasse ash(SCBA), Rice husk ash(RHA) and alkali solution in concrete production. The optimum percentage of Metakaolin replacement was investigated and the concrete samples were tested for strength, dry shrinkage and elastic modulus.

The effectiveness of two materials was examined with Metakaolin in concrete. The percentage replacement of MK with SCBA and RHA was at 50%, 60% and 70% respectively. The]samples of the concrete cubes were cured in ambient temperature and aging period of 7, 14, 28 and 56days were used to cure the samples. The fresh, mechanical properties, shrinkage and modulus of elasticity of geopolymer were investigated.

Geopolymer was observed to have medium workability and mechanical sproperties, showed good results. The optimum mix maximum strength was observed. The target strength from the design is 25N/mm2, though; 88% of its was achieved. The strength is decreasing with increase of MK percentage and also the elastic modulus decrease; whereas the shrinkage increased as the % of MK increases. This study emphasizes, the potential for global adoption, cost saving, environmental friendly and also provide valuable insight for environmentally sustainable development.

I. INTRODUCTION

In construction industry nowadays, many attempts have been carried out in the research community to identify Low-Carbon technologies and products, which support the concept of environmental friendly materials and sustainable development. The alternative low-carbon cementing binders have been extensively studied to reduce that amount of greenhouse gas. One of the efforts to promote alternative binders by utilizing abundant of alumina-silicate (pozzolanic) wastes from industrial sector or environment e.g. fly ash Chindaprasirt, et al.,(2007), bottom ash, Hardjito& Fung(2010), cement kiln dust Khater(2012), Utilisation of waste material Nuruddin, et al.,(2011) and GBFS Nath&Sarker, (2014). It has also, been found that, many different kinds of biomass ashes can be used as supplementary cementitious materials, such as elephant grass ash, rice husk ash and sugarcane bagasse ash, Cordeiroet al, (2009).

Ordinary Portland cement (OPC) manufacturing process is known as one of the main participators which consumes intensive energy and releases a large amount of greenhouse gas to atmosphere during its production (Maholtra, 2006). There are many environmental issues associated with the production of OPC such as consumption of 5% of natural resources and generation of 5-7% of total global anthropogenic carbon dioxide (CO_2) emission. Xie&Kayali(2014). Shi, et al. (2011), reported that, around 7% of the worldwide carbon dioxide (CO_2) emission is accounted for this clinker process which seriously contributes to the global climate change. Likewise, by Sherwin Mathachan Michael (2018); Portland cement is the conventional binding material that, actually, is responsible for about 5%–8% of global CO_2 emissions and this environmental problem will most likely be increased due exponential demand of Portland cement: By 2050, demand is expected to rise by 200% from 2010 levels, reaching 6000 million tons/year.

This led to an urgent need for the development of alternative materials that may provide technically viable solutions to conventional cementitious concrete, with more favourable environmental credentials. The world's population growth rate currently, at the levels of Ordinary Portland cement (OPC) production will only increase and providing enough cement to build infrastructures, that will ensure adequate lifestyles. Its production is a unit of measure of economic growth of many country, considering the demand for Portland cement is directly linked to the rate of development. In terms of its capita consumption, it is second most consumed material in a construction industry, next only to water(Yashwanth, 2014).

Climate change due to global warming is a critical environmental issue having considerable negative impacts on all living organisms in the world. Global warming is causes by greenhouse gases emission including methane, nitrous oxide and carbon dioxide into the atmosphere (Muhammad et, al., 2015). Ingraoet, al. (2015) reported that, with regarding the European(EU) context, buildings are responsible for almost a third of the total carbon dioxide emissions. Therefore, the introduction of a novel binder called "geopolymer" by Davidovits (1978), promises a good prospect for the application in the concrete industry as an alternative binder to Portland cement. In terms of reducing the CO_2 emissions to the atmosphere causes by cement and aggregates industries by 80% (Hardjitoet al., 2004). Geopolymer concrete manufacturing is one of the most promising techniques which has been developed in the last few years. Utilization of geopolymer materials can reduce 80% of greenhouse gas emissions associated with cement production and unregulated disposals of agricultural or industrial materials by recycling these materials in geopolymer manufacturing (Islam et al., 2014).

Initiatives are emerging worldwide to control and regulate the management of sub-products, residuals and industrial wastes in order to preserve the environment from contamination. Rithuparna et al, (2021) reported that, a good solution to the problem of recycling of Agro-wastes would be burning in a controlled environment and use the ashes (waste) for more noble means. Utilization of such wastes as cement replacement materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes. Silica fume, rice husk ash, fly ash, metakaolin and ground granulated blast furnace slags are well established wastes with pozzolans because of high silica content in their chemical compositions.

Various researchers have produced Geopolymer Concrete (GPC) using different geopolymer binder but very limited research have been carried out, at the time of this work in producing Metakaolin blended Sugarcane Bagasse and Rice husk ash geopolymer concrete. In this research, Metakaolin blended Sugarcane Bagasse and Rice husk ash-based geopolymer binder were used to produce concrete and its properties evaluated.

1.2Statement of Research Problem

Concrete is a major construction material that is largely made up of cement. Unfortunately, the manufacturing process for the cement currently used to produce concrete releases a great deal of CO_2, which endangers the environment. Cement production are significance sources of sulphur oxide, nitrogen oxide and carbon monoxide in cement plant as well as carbon dioxide emissions. These are associated with the health problems and environmental damages. The world-cement consumption in the year 2010 was measured at 3,313 million metric tons and Among that 7.0% in India, 57.7% in China, 9.4% in Developed Countries, 25.9% in other Emerging, which shows that, it is the most used material in construction industry next to water (Vignesh et al, 2014). An according to Bangudu, (2013); reported that, the global cement demand is expected to reach 4billion tons by the end of the year 2013while in Nigeria, the demand for and consumption of cement is expected to increase in line with global demand.Srinivasreddy, McCarthy &Lume (2013), from an energy viewpoint, it has been reported that to produce one tonne of cement, 4KJ of energy is required and raw materials.

According to Ali et al. (2015), raw materials used in the manufacture of cement, in particular limestone, release about 65% of the total CO_2 assigned to this industry and the remaining 35% of emissions are caused by burning fossil fuels for the decomposition of limestone during cement production. These give rise to environmental effects of increase in atmospheric carbon dioxide, causes global warming, raises sea level, increases threats to human health and severe increase in earth temperature. These changes will impact our food supply, water resources, infrastructure and ecosystem (United States environmental protection agency report, 2017). The cement industry contributes to global warming and climate change, being one of the most important industries responsible for major emissions of greenhouse gases, contributing (in 2015) by almost 8.0% of the total global emissions (Olivier et al., 2016), and being the third largest source of industrial pollution. Ali et al. (2015) reported that, cement manufacturing processes are highly energy-intensive with high fuel consumption which results in emits more than 500,000 tonnes per year of sulfur dioxide, nitrogen oxide and carbon monoxide and Wang et al. (2013) cited by Salas et al. (2016), identify four factors that induce changes in emissions of greenhouse gases from the production of cement: energy emission, energy structure, energy intensity and clinker production. The activity of clinker production represents the dominant factor to the increase of greenhouse emissions. Therefore, to address global warming and the imperative environmental changes, it was suggested that CO_2 emissions had to be reduced by 50% until 2050 (Ali et al., 2015).

In view of this and other problems associated with production and use of cement, a lot of research efforts were made to find an alternative material that will partially or fully replace cement in concrete production. The use of waste materials for partial replacement of cement provides for greater economic and environmental benefits Naziriet al,(2011). A considerable amount of work has been reported in the literature on how to use agricultural waste products as supplementarycementitious materials (Mehta, 2001). Ideally, the development of such materials serves three separate purposes simultaneously. Cement as an important constituent of concrete is becoming gradually expensive compared to other ingredients of concrete.

Shraddha et al, (2014); explains the growing concerns on environmental impact caused by the extraction of raw materials to the process of cement production, packing and loading. The USGS(US Geology Survey) reported that, global cement manufacturing hit 4.1 Gt amount of CO_2 during 2017. Therefore, such a large amount of CO_2 could make anthropogenic climate change inevitable. In effort to comply with this trend a new technology of geopolymer cement was introduced. The concept of geopolymer which is environmentally friendly was developed to be used as an alternative to OPC in concrete production. Many researchers have utilized different materials in the production of geopolymer concrete but few researches have been carried out producing concrete using blended metakaolingeopolymer and sugarcane bagasse or rice husk ash. Some studies on mechanical properties of geopolymer concrete shows good compressive strength, tensile and elastic modulus properties.Abdulkadir et al, (2014), reported that, the SCBA was used to replace OPC by weight in ratio of 0% 10%, 20% and 30% and the results show good compressive strength at 28days.Abdulwabet al. (2021),revealed that, incorporation of Metakaolin at both 5% and 10% was found to increase compressive strength and thereafter, TRHA was added by weight of the cement in varying percentages of 1%, 2%, and 3% to the optimum MK replacement (5%). From the results, it was found that concrete with 5% MK and 2% TRHA had enhanced compressive strength as against the control.likewise,Dr.Sivakumar et al. (2017), also reported that the maximum strength should obtained in 10% and 12% of replacement of Metakaolin. Currently very few researches have been carried out exploring the properties of metakaolin blend geopolymer concrete. For this study, the effects of Metakaolinblended with sugarcane bagasse ash and Rice husk ash on the fresh and hardened properties of the geopolymer concrete was determined.

1.3Aim of The Research

This study aimed to investigate the effects on the engineering properties of ageopolymer concrete made with Metakaolin blended with sugarcane bagasse ash and Rice husk ash.

1.5 Research Objectives

As aforementioned, the main objectives of this research are to:

i. To determine the Chemical composition of Metakaolin, Sugarcane bagasse ash and Rice husk ash.
ii. To determine the Physical properties of the Metakaolin,Sugarcane bagasse ash and Rice husk ash.

II. LITERATURE REVIEW

Concrete is a versatile construction material and ready availability have ensured that, it has been and will continue to be of great and increasing importance for all types of construction throughout the world by Shelton&Harper (1982). Various definitions of concrete were suggested as a result of various researches carried out across the world. According to Neville (2011), defined concrete as any product or mass made by the use of cementing medium, generally, this medium is the product of reaction between hydraulic cement and water. Furthermore, concrete was also defined by Alaa Hussein Ali (2022), as a mixture of cement (11%), fine aggregate (26%), coarse aggregate (41%), water (16%) and air (6%). The Portland cement is the main binder in conventional concrete production whilst fly ash for concrete production are normally used for geopolymer concrete production respectively.

The main binder in concrete is cement such as Portland cement for conventional concrete production and fly ashes mostly nowadays, uses for geopolymer concrete production.

2.2.1Admixtures

The admixture in cement or concrete are known as a material other than water, aggregates, hydraulic cement and fibre reinforcement used before or during mixing (ASTM C125-15B:2015) and according to BS 8443:2005, the materials added during mixing process of concrete to modify the properties of mix in the fresh and/or hardened state'. The mineral admixtures are mainly classified into three types, which are Low-activity admixtures (e.g. limestone and dolomite), Cementitious admixtures (e.g. natural cement and blast furnace slag) and Pozzolanic admixtures. In contrast, the pozzolan could be subdivided into natural pozzolan(e.g. volcanic clay) and by-products pozzolan (e.g. pulverised fly ash and silica fume) (Soroka, 1993). To address environmental concerns, the main effort of this issue focuses on utilizing pozzolanic industrial by-products, especially for pulverized fly ash (PFA) from the coal-fired power station. Fly ash is one of by-products from coal combustion, particularly from generating electric power generating process in coal-fired power plants (Silo Transport, 2016). When coal is burned off at the furnace, impurity minerals, e.g. clays, quartz and feldspar, are fused together in that high temperature.

It is then solidified to glassy spherical particles and flies out with flue gas stream, known as fly ash. Most of fly ash particles are solid sphere shapes and could be observed with either or both hollow sphere (cenosheres) or packed with numerous of small spheres (plerospheres). Its particle sizes vary from <1 μm to 100 μm. Fly ash is subsequently collected by electrostatic precipitator and moved to storage area for further handling (Mehta, 1986). Amount of average fly ash production worldwide during 2010 to 2013, was approximately 610 to 650 million tons. Around 60 to 70% of total fly ash are produced in China (Tang, et al., 2013), 20 to 30% in the US and 10 to 20% in EU (ACAA, 2014). With those large quantities produced annually, the utilizing of fly ash as admixture in cement and concrete is globally carried out.

Many advantages of fly ash replacement in Portland cement have been revealed and applied in various applications in order to improve the properties of hardened cement and concrete.

2.4 Background of Geopolymers

Victor Glukhovsky (1967), assumed the geological process of cementitious systems, described that the formation of volcanic rocks or sedimentary rocks under low temperature and pressure can transform into zeolites. After the zeolitic materials were combined with strong alkaline solutions, the cementitious binder called 'Alkaline activated cement' was formed with distinguish high pH values. In 1940, the important event of alkaline activated binder was recorded by activating blast furnace slag with sodium hydroxide solution. The results showed that the formation of alumina-silicate hydrated product appeared together with a good load bearing capability (Pacheco-Torgal, et al., 2008). Later, in

1950, a synthesis of alkaline alumina-silicate minerals was developed in Ukraine as a mixed of calcium silicate hydrate (C-S-H) and alumina-silicate phases and also recorded for tall building use in Russia (Komnitsas&Zaharaki, 2007).

In 1978, Professor Joseph Davidovits introduced the development of a new family of mineral binders with an amorphous structure, named geopolymers. This was a class of solid materials, produced by the reaction of an aluminosilicate powder and an alkaline liquid. The initial goal for the research done on these geopolymers was to find a more fire-resistant binder material due to the high amount of fires in Europe at that time. This research led to the material being used as coatings for the fire protection of cruise ships and thermal protection of wooden structures etc. (Proviset al. 2009). The main focus shifted to a use in the construction industry after an observation that it was possible to produce high performance and reliable concrete with cement-like properties when fly ash was alkaline activated (Proviset al. 2009).

Geopolymer materials represent an innovative technology that is generating considerable interest in the construction industry, particularly in light of the ongoing emphasis on sustainability. In contrast to the Portland cement, the most geopolymer systems rely on minimally processed natural materials or industrial by-products to provide the binding agents. Since Portland cement is responsible for upward of 85 percent of the energy and 90 percent of the carbon dioxide (CO_2) attributed to a typical readymixed concrete, the savings of the potential energy and carbon dioxide through the use of geopolymers can be considerable. Consequently, there is growing interest in geopolymer application in construction industry. On this backdrop, the geopolymer technology introduced by Davidovits (1994), provides an alternative binder to the OPC. Geopolymer concretes (GPC) are cementless concrete which utilize by product materials like fly ash in the presence of alkaline solution to produce binders. The alkaline activated cement is typically represented by zeolitic materials containing alkaline activators, the formation of which requires a relatively high setting temperature in the range of 150 to 180°C. On the other hand, geopolymer cement requires such from ambient temperature to less than 90°C. Forming chain rings polymer of silicon-oxygen-aluminate (Si-O-Al) Sialate chain (Davidovits, 1991). Even though different terminologies have been stated by many researchers (e.g. alkaline activated cement, hydroceramic, geocement, inorganic polymer concrete and low-temperature aluminosilicate glass), the term ‘Geopolymers’ is still widely used to represent this cementitious technology (Davidovits, 2011and Petermann, et al., 2010).

2.4.1 Geopolymerisation reaction and its chemistry

As aforementioned, Portland cement hydration (forming C-S-H) is totally different from Geopolymerisation of the geopolymer formation process. In geopolymerisation, when the silicate and aluminate oxide (Si^{4+} and Al^{3+} in IV-fold coordination) extend their bonding/cross-link to sialate (SiO-Al) and poly-sialates, the ring chain of polymer silicate (Si) and aluminate (Al) was suggested in the formation of amorphous to semi-crystalline phases. It could be categorised into 3 types, namely (i)

Poly-(sialate) type (-Si-O-Al-O-), (ii) Poly-(sialate-siloxo) type (-Si-O-Al-O-Si-O-), and (iii) Poly(sialate-disiloxo) type (Si-O-Al-O-Si-O-Si-O-) with a structure model (Davidovits, 2002).

The empirical formula of geopolymer resultant product is:

$$Mn\,[-(SiO_2)z - AlO2 -]n \cdot wH_2O \quad \text{- - - - - - - - (1).}$$

where M is the alkaline element such as potassium (K^+) or sodium (Na^+), n is the degree of polymerisation, z is Si/Al ratio which varies from 1, 2, 3 or higher, and “–” indicates the presence of bonding (Davidovits, 1991).

A chemical reaction known as geopolymerisation involves aluminosilicate oxides (Si_2O_5 and Al_2O_2) to react with polysilicates, yielding three dimensional polymeric bonds (Si-O-Al-O) under highly alkaline conditions. This reaction is also known as a geosynthesis, better described as a reaction that chemically integrates minerals (in this case polymeric bonds) which eventually forms the main building blocks of the final geopolymer material (Khale&Chaudhary 2007). The polysilicates used are usually sodium or potassium silicate, produced by the chemical industry and these materials are either crystalline (glassy structure) or non-crystalline (amorphous) (Wallah; Rangan 2005 and Davidovits 1991). The geopolymer process mainly depends on the parameters, including the chemical and mineralogical composition of the binder material, the concentration of the alkaline solution, the water content and curing temperature (Temuujinet al. 2009).

The silica to aluminium ratio has an influence on the strength of geopolymer concrete and this ratio mainly depends on the chemical composition of the starting material, concentration of the alkali solution, curing temperature and the curing time (Fernández-Jiménez et al. 2006). Fernández-Jiménez et al. (2006), concluded that not all the aluminium and silica ions are reactive in the binder. They also found, by experimenting with different fly ashes, that the percentage of silica reactive in the material was similar but the percentage of aluminum reactive in the mixture varied. Three types of polysialates have been distinguished by Davidovits are:

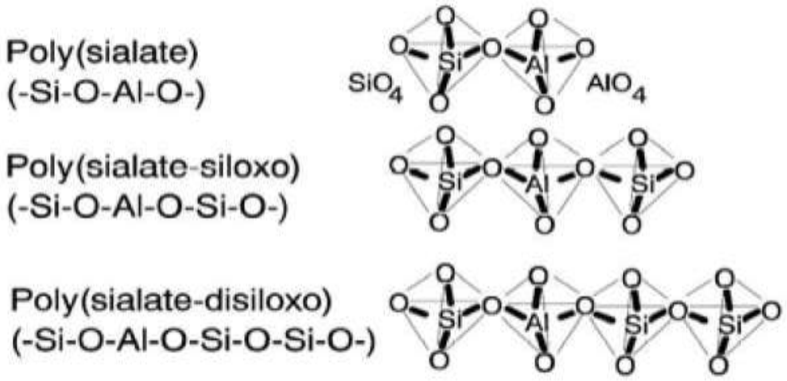

Fig. 2.Polysialates structures

2.4.2 Geopolymer Binder Constituents

2.4.2.1 Main raw materials involved in geopolymer synthesis

Generally, the manufacture of geopolymer binders uses a wet mixing method which combines the pozzolan material and the alkali activator solution with the composition of a certain chemical molarity ratio (Abdullah et, al. 2013). However, in its application among the public, the geopolymer binder has not been as large as the Portland cement binder because it still has weaknesses, namely: the mix design which involves calculation of chemical composition (alkali activator solution) and pozzolan materials (scientific understanding of ordinary people is still very limited and need supervisionby who understoodgeopolymers) (Abdullah, et, al. 2013). Portland cement binders are easily accepted by the public, because to use them as a mixture of pasta, mortar, or concrete is very easy (just add water by water to cement ratio concept).

2.4.3 Geopolymer categories

Geopolymers are formed by alkali-activating a variety of materials including fly ash, blast furnace slag, thermally activated clays etc. to produce a cement-like material. The three most common raw binders used in geopolymerisation are slag, calcined clays (metakaolin) and coal fly ash. The binder materials should contain high levels of aluminium (Al) and silicon (Si) in amorphous form.

Many different materials have already been investigated and used as the binder in geopolymer concrete mixes, including:

- Class F fly-ash (low amount of calcium)
- Class C fly-ash (high amount of calcium)
- Calcined kaolin or metakaolin
- Natural minerals containing Al and Si
- Silica fume
- Slag
- Red mud
- Albite

(Motorwala et al. 2008, Swanepoel and Strydom 2002, Davidovits 1999, Palomo et al. 1999)Metakaolin was widely used as the binder in the early stages, but due to its flat shape it tends to have an unviable high-water demand (Provis et al. 2009). Fly ash particles have a rounder shape, ensuring more promising workability and a low water demand. There are currently four different geopolymer categories (Davidovits 2013), including:

- Slag based geopolymer
- Rock based geopolymer
- Fly ash based geopolymer
- Ferro-sialate based geopolymer

2.4.3.1 Slag based geopolymer

The first geopolymer developed was a slag based geopolymer in the 1978. It was a type (K, Na, Ca) poly(sialate) which resulted from the research of Davidovits and Sawyer at Lone Industries in the USA. This research resulted in an invention well known today as Pyrament cement (Davidovits, 2013).

Slag is a partially transparent material and a by-product in the process of melting iron ore. It usually consists of a mixture of metal oxides and silicon dioxide. Slag has many purposes for which it can be used, including assisting temperature control during smelting and minimizing the final liquid product before the molten metal is removed from the furnace (Slag Cement Association 2002).

It is also used in the cement and concrete industry. The reaction of slag in alkali activating systems and in cement blends are dominated by the small particles. The particles that are above 20 µm usually react slowly, while particles under 2 µm react completely within 24 hours. Thus, when slag is used in geopolymerisation, careful control of the particle size distribution must be ensured to control the strength of the binder (Proviset al. 2009).

2.4.3.2 Rock based geopolymer

To compose this type of geopolymer, a fraction of the MK-750 in the slag based geopolymer is replaced by natural rock forming materials such as feldspar and quarts. This mixture yields a geopolymer with better properties and less CO_2 emissions than that of the ordinary slag based geopolymer (Davidovits, 2013). However, not much research has been done on the reaction kinetics of these natural rock forming materials under alkaline conditions.

The "MK" is an abbreviation for metakaolin and the "750" represents the temperature at which it was produced. The components of rock based geopolymer cement is metakaolin MK-750, blast-furnace slag, natural rock forming materials (calcined or non-calcined) and a user-friendly alkali silicate.The raw material input in the manufacture of metakaolin is kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain.

III. MATERIALS AND METHODS

3.1 Materials

Materials used in this research include:Metakaolin as source material andsugarcane bagasse ash, rice husk ash as by-product, coarse aggregate, fine aggregate, alkaline solution, which consist of sodium hydroxides (NaOH) & sodium silicate (Na_2SiO_3) and water.

3.1.1Metakaolin

Metakaolin (MK) is produced by heat-treating kaolin and one of the most abundant natural minerals. MK is a supplementary cement material (SCM) that conforms to ASTM C168, Class N pozzolan specifications. MK is unique in that, it is not the by-product of an industry process nor is it entirely natural.

Metakaolin used for this research was obtained from kaolin sourced from Baguria/SabuwarGwaram, Alkaleri Local Government Area of Bauchi State, Nigeria. The sample was sieved in the Department of Building Laboratory, AbubakarTafawaBalewa University Bauchi. It was sieved through 150microns sieve after calcined in the Industrial Design Department of the University at a temperature of 700^{o}C for about $3\,^1\!/_2$ hours by using projerize tank with Burner ring/Klin.

3.1.2 Sugarcane bagasse ash (SCBA)

Sugarcane bagasse (SCB) is the waste produced after juice extraction from sugarcane. The Sugarcane bagasse ash (SCBA) is obtained as by-product of control burning of sugarcane bagasse. SCBA constitutes an environmental nuisance as they form refuse heaps in areas they are disposed.

The Sugar cane bagasse for this research was collected from sugarcane market located opposite Kofar Ran, Mudalawal market Bauchi, Bauchi state, Nigeria. The sugarcane bagasse was calcined at 600°C temperature in ceramic section, Industrial Design Department Abubakar Tafawa Balewa University Bauchi.

3.1.3 Rice Husk Ash (RHA)

Rice husk was collected from rice mill within Bauchi metropolis and calcinedat 500°C temperature using kiln, in ceramic section, Industrial design department of AbubakarTafawaBalewa University Bauchi. The RHA was sieved through British Standard sieve of 75 microns. The portion passing through the sieve had the required degree of fineness of 63 microns and below while the residue was thrown away.

3.1.4Coarse Aggregate(CA)

The coarse aggregate was obtained within Bauchi, Bauchi state. Sieve analysis was carried out in accordance with BSEN Standard to distribute the aggregate into various sieve sizes. The aggregate size of 20mm at maximum and 4.75mm as its minimum size were used in the saturated surface dry (SSD) condition.

3.1.5 Fine Aggregate (FA)

River sand was obtained from a stream in Bauchi as fine aggregate. It was kept in the saturated surface dry (SSD) condition prior to use in the laboratory of the Department of Building, ATBU Bauchi. The physical properties tests were carried out in accordance with BS EN 1097: Part 2 (2000), BS 812: Part 2 (1975), BS EN 933: Part 1(1997) specifications respectively. These tests include: specific gravity, bulk density, particles sizes distribution analysis respectively.

3.1.6 Water

Portable water was used for this research. It was used for mixing and dissolving the alkaline activator and also used for the production of the concrete specimens. The water used conformed to BS EN 1008-2 (2002).

3.1.7 Alkaline Solution

A combination of sodium hydroxide (NaOH) and sodium silicates (Na_2SiO_3) were used as the alkaline activator. The process is described as follows:

3.1.7.1 Sodium Hydroxide (NaOH)

Sodium Hydroxide (NaOH) which is in pellet form with 97% - 98% purity was obtained from a supplier and dissolved in water to make the solution of the sodium hydroxide which is white crystalline in appearance, odourless and absorb moisture from air. For this work, 10 and 12 Molar concentrations were used, which means that, the molarity multiplied by the molecular weight of NaOH (40). This means (16 x 40 = 640) gives the quantity in grams of NaOH solids per litre of water.

3.1.7.2 Sodium Silicate (Na_2SO_3)

Sodium silicate is usually in form of water glass, Na_2SO_3.It is white in appearance and pH value of 12.4, stable in neutral and alkaline solutions. In acidic solution, the silicates ion reacts with H^+ to form silicates acid, which when heated and roasted forms silicates gel. It forms a glassy solid with very useful properties of being soluble in water. The sodium silicate solution (Na_2O = 13.7%, SiO_3 = 29.4%, and H_2O = 55.9% by mass) was purchased from a supplier within Bauchi and used for this work.

3.2Research Methods

The research was carried out through the following processes:

3.2.1 Experimental Design

The experiment was conducted as follows:

3.2.1.1 Preliminary investigation

The tests carried out include the physical, mechanical and chemical properties of the constituent materials used for the research, which include:

3.2.1.2 Particle Size Distribution

The particle size distribution for both the course aggregate and fine aggregate were carried out using sieve analysis as described in accordance with BS 812-103 (1990). This was done to determine the grading of the aggregates.

3.2.1.3 Specific Gravity

The specific gravity (Gs) of the metakaolin, alkaline solution, fine aggregate and was determined by using pycnometer method in accordance to BS 812:2 EN 12390-7(1999). The apparatus used include density bottle and stopper, funnel, spatula and weighing balance. The relationship used to find the specific gravity is given by:

Specific Gravity = [W2−W1/(W4–W1)(W3−W1)] - (1)

Where:
W1 = Weight of density bottle,
W2 = Weight of density bottle + Sample
W3 = Weight of density bottle + Water (full) + Sample,
W4 = Weight of density bottle + Water (full).

3.2.1.4 Bulk Density

This was determined in accordance with BS 812: Part 2 (1995) for the natural coarse and fine aggregates used for this research. The relation below was used to determine the bulk density of the sample:

Bulk Density = (W1−WV) - - - - - - - - - - - - - - (2)

Where:
W1 = Weight of container + sample
W = Weight of empty container
V = Volume of container

3.2.1.5 Water Absorption Capillary

The Absorption capacity test was carried out on the aggregates (that is the coarse and fine aggregate. This was done as stipulated by BS 1881-122 (1993).

3.2.1.6 Moisture Content

This test was determined in accordance with BS 812: 109 (1990). The procedure for the test was carried out as adopted by Gambo (2014).

3.3 Chemical Composition

Chemical analysis was carried out on the metakaolin, sugarcane bagasse ash and rice husk ash using XRF test to determine the oxide composition such as Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron Trioxide (Fe_2O_3) and others, in order to investigate if they are in line with the ASTM C 618-94: (1994) classes of pozzolana. The ASTM standard stipulates that for any material to be used as pozzolana, it has to fall within the following classes; Class N, Class F or

Class C.

3.4 Test on hardened specimens

The tests carried out on hardened concrete specimensinclude the following**:**

1. Compressive strength
2. Modulus of elasticity
3. Shrinkage
4. Water absorption

3.5 Production of Concrete Specimens

3.5.1 Mix Design

Currently, no standard mix design is available for the production of Geopolymer concrete (More, 2013). This means that the mix design for the production of geopolymer concrete is based on trial and error.

For this reason, the method adopted by Anuradha, Sreevidya, Venkatasubramani&Rangan (2011), in designing fly ash based geopolymer concrete was used to design grade 25 metakaolin based geopolymer concrete. In designing for the quantity of alkaline, Ramujee and Potharaju (2014), method was adopted after series of trial and error.

3.5.1.1 Preparation of alkaline solution

A combination of NaOH and Na_2SiO_3 were used as the alkaline solution for this research. For the purpose of this research, the 10 and 12 molar concentrations of NaOH pallet were dissolved in water to make a solution. The alkaline solution was mixed together a day before its usage to produce the geopolymer concrete.

3.5.1.2 Mixing and Casting of geopolymer Concrete

The method used for mixing the geopolymer Concrete (GPC) specimens was similar to that, used when producing ordinary Portland cement concrete. All the aggregates used for the casting were kept in the saturated surface dry condition (SSD). Metakaolin, sugarcane bagasse ashand rice husk ash were mixed by percentage compositions of their massesand the aggregates (both fine aggregate and coarse aggregate) were mixed together thoroughly, after which the alkaline solution was added and the geopolymer concrete specimen mixed together. After mixing, the fresh geopolymer concrete was cast into 100mm x 100mm x 100mm moulds and 300mm x 150mm cylinder moulds in 3 layers while each layer was compacted by rodding with a tapping rod in order to achieve a smooth compaction of the specimen.

3.5.2 Production of Control specimen

3.5.2.1 Mix Design

Grade 25 concrete was designed for the ordinary Portland cement concrete. This was done to create a basis for comparison with geopolymer concrete specimens. In this case, Building Research Establishment (BRE) method of mix design was used for designing the grade of concrete. (Details in Appendix).

3.5.2.2 Mixing and Casting of Control specimen

The method used in mixing the geopolymer concrete specimens was also used in mixing the 100%MK concrete as control. After mixing, the controlspecimen were casted into 100mm x 100mm x 100mm mould in 2 layersand 300mm x 150mm cylinder moulds in 3 layers; while each layer was compacted by giving it 25 blows with a tapping rod in order to achieve a smooth compaction of the specimens.

3.4.3 Curing of Geopolymer Concrete

After casting, the specimens were kept for 24hrs rest period. The blended geopolymer concrete specimens were then de-moulded, covered with polythene bag and cured in the oven at 60^{o}C for 24hrs. According to Suresh &Manojkumar (2013), heat curing assists the chemical reaction in the geopolymer paste. After heat curing for 24hrs, it was then removed from the oven and left to cure at the room temperature in the laboratory until the days required for testing which is 7, 14, 28 and 56 days.

3.4.4 Curing of Control

Specimens were allowed to set for 24hrs before de-moulding and were immersed in portable water tank for ages 7, 14, 28 and 56 days to allow for effective curing by using BSEN Standard.

3.5 Testing of fresh concrete

3.5.1 Workability Test

Before casting the fresh geopolymer concrete and ordinary Portland cement specimen into moulds, the slump value of each fresh concrete was measured to determine the workability of the mix. This was done as recommended by BSEN Standard. The apparatus used in carrying out the slump test includes steel tamping rod, base plate, hand scoop, trowel and metal cone.

3.5.1.1 MK concrete slump test

The MK concrete slump test was carried out in accordance with the BS 12350: Part 2 (Testing of fresh concrete). The cone was filled in three layers. Each layer was compacted 25 times by means of a steel rod. The difference in vertical displacement was measured after the cone was removed.

3.5.1.2 Geopolymer concrete slump test

Due to its self-compacting characteristics of GPC, compaction with a rod is not necessary when the cone filled with geopolymer concrete. After filling, the cone has lifted from the plate in such a way that the geopolymer concrete is able to flow without any obstruction. The test finished when the geopolymer concrete flow ceased. The largest diameter of the flow spread will be measured, together with one measurement perpendicular to the largest diameter. The average of the two measurements to take as the diameter slump.

3.6Testing of Hardened concrete

After curing the geopolymer specimens, they were subjected to the following test at the end of each curing ages which include:

3.6.1 Compressive strength test

Compressive test was carried out after different curing ages of 7, 14, 28 and 56 days for geopolymer concrete specimens. A total of72specimens were tested for compressive strength and it was done as stipulated by BSEN Standard. Three (3) cubes each were tested to failure for all specimens. The maximum failure load was then recorded and the compressive strength calculated using the relation:

$$\delta = \frac{F}{A} \text{ ------------------------------------- } (3)$$

where: δ – Compressive strength (MPa)
F - Maximum force obtained from the contest (N)
A - Surface area on which force is applied (mm^2).
The average compressive strength of the three cubes will takes as the compressive strength of a certain mix.

3.6.2 Shrinkage

Shrinkage is the process of contraction of concrete volume due to loss of water from capillary pores which occurs in two stages; autogenous shrinkage and drying shrinkage.Autogenous shrinkage is the result of consumption of interior water by cement hydration. In contrast, drying shrinkage is caused by the escaping of water from capillary pores of concrete to the unsaturated outside air. Although, autogenous shrinkage results a very small strain (40 to 50 microstrain)by Neville, 1995.It is not applicable in geopolymer concrete because geopolymerizationreaction recycle water molecules (Davidovits, 1999). Shrinkage strain can cause of curling and axial shortening of concrete element and initiates shrinkage cracking. Some earlier studies on flay ash and or slag base geopolymer concrete advised higher drying shrinkage of geopolymer concrete cured at ambient conditions(Douglas, et al. 1992 and Wallah&Rangan,2006). However, Deb, Nath&Sarker (2014) reported a smaller drying shrinkage of ambient cured geopolymer concrete from fly ash and slag which was 482 micro-strains at 180 days compared to 562 micro-strains in OPC concrete of similar grade. Experimental results of drying shrinkage of high-strength geopolymer,shows that high-strength geopolymer concrete undergoes drying shrinkage in the same range to the OPC concrete (Neupane, et al. 2016).

According to ACI-363R (2010), high-strength concrete may suffer higher drying shrinkage because of having substantial amount of binder than in normal-strength concrete. A detailed investigation of drying shrinkage on powder-activated geopolymer concrete of different grades found that drying shrinkage of geopolymer concrete gradually decreases with ratio of water to binder and independent of paste amount. And therefore, high-strength geopolymer concrete were found to be suffered significantly lower drying shrinkage than normal-strength one (Neupane, K., et al.,2016). This study was concerned about drying shrinkage in geopolymer made. According to Steenie Edward Wallah(2009), shrinkage is the decrease in volume of concrete with time. Unlike creep, another long-term property of concrete, shrinkage is independent of the external actions to the concrete. There are some types of shrinkage in the concrete which should be distinguished. Gilbert (2002) divided them into plastic shrinkage, chemical shrinkage, thermal shrinkage and drying shrinkage.

Drying shrinkage is the reduction in volume which is primarily caused by the loss of water during the drying process. Drying shrinkage normally accounts for the biggest proportion of the total long-term shrinkage. Factors which affect the drying of concrete also affect the magnitude and rate of development of drying shrinkage. Those factors include the type and content of cement or binder, water content and water to cement ratio, type of aggregate, maximum size and its proportion in the concrete, relative humidity and the size and shape of the member. The aggregates play a significant role in affecting the shrinkage of concrete (de Larrard et. al., 1994; Neville, 2000).

The shrinkage test is according to ASTM C157 and there is formula or equation that has been developed to estimate/ calculated the shrinkage of mortar according to ASTM C305 using the following relation:

Shrinkage $(\varepsilon) = \frac{L1 - L2}{L1} X\,100$ - (4)

Where:
L1 = Wet length after 28days curing
L2 = Dry length after 24hrs curing.

3.6.2 Modulus of elasticity

Modulus of elasticity is a serviceability property of concrete which governs the deformation of concrete structures. Higher elastic modulus results on lower deformation of structures. Past studies reported a lower elasticity modulus of geopolymer concrete when compared with OPC concrete of similar strength level (Hardjito and Rangan,2005,Fernandez-Jimenez, et al. 2006 &Nath and Sarker, 2017). The modulus of elasticity represents the stiffness of the geopolymer concrete and can be defined as the ratio of uniaxial force to the resultant strain (Haranki 2009). From a structural point of view, the modulus of elasticity is an important aspect as the deflection of an element is directly dependent on it.

Cylindrical specimens with an aspect ratio of 3 (300mm depth, 150mm diameter) were used to conduct the modulus of elasticity test. The modulus of elasticity was determined in accordance with the ASTM C469/C469M–10. The specimens were tested on the 2000KNContest compression testing machine. A constant loading rate of kN/min was applied to the specimen as required by the code. Kamal Neupane et al. (2016), defined Modulus of elasticity as a serviceability property of concrete which governs the deformation of concrete structures. Higher elastic modulus results on lower deformation of structures. Past studies reported a lower elasticity modulus of geopolymer concrete when compared with OPC concrete of similar strength level (Hardjito&Rangan 2005 and Fernandez-Jimenez, 2006).

Previous investigations suggested that modulus of elasticity of concrete depends on the types and properties of coarse aggregates used; higher modulus of elasticity of aggregate resulted higher modulus of elasticity of concrete (Aïtcin and Mehta, 1990; Beshr et al., 2003).

3.6.2.1 Relationship between modulus of elasticity and compressive strength

In most of the concrete standards of current practice, modulus of elasticity of concrete is estimated from its density and compressive strength.

For OPC concrete, the Australian Standard (2005) recommends the following expression to calculate the value of the modulus of elasticity within an error of plus or minus 20 %:

- modulus of elasticity recommended by Australian Standard (2005)

Ec = ρ 1.5 x (0.024 √ fcm + 0.12) ± 20% (MPa) - - - - - - - - - - - - - - - (5)

- American Concrete Institute (ACI) Committee 363 (1992) has recommended the following expression to calculate the modulus of elasticity.

Ec = 3320 √ fcm + 6900 (MPa) - - - - - - - - - - (6)

- modulus of elasticity recommended by European Standard (EN)-1992-1-1 (2004) is:

$E_c = 22*(f_{cm}/10)^{0.3}$ - - - - - - - - - - - - - - - - - - (7)

Where:
ρ = concrete cylinder density (kg/m^3),
f_{cm} = mean compressive strength (MPa)
Ec = modulus of elasticity.

The average density of fly ash-based geopolymer concrete was 2350 kg/m^3 by DjwantoroHardjito (2005). All these three difference standards were adopted in this research for the evaluating of elastic modulus in relation to the compressive strength.

3.6.3 Density of the geopolymer concrete

The density of the various geopolymer concrete specimens was determined before the cubes were crushed. Three specimens were tested on 7 days and three specimens were tested on 28 days for each mix design. Thus, the densities of the three cubes were obtained and the average was taken as the density of the specific mix design. The density was determined using:

Density $(\rho) = \frac{m}{v}$ - - - - - - - - - - - - - - - - - (8).

where ρ is the density (kg/m^3), m the mass of the geopolymer concrete cube in kg and V is the volume of the cube in m^3. The volume of the cubes was measured with a verniercaliper to the nearest mm.

3.6.4 Water absorption capillary test

This test was conducted at the curing ages of 28 and 56 days on geopolymer and ordinary cement concrete specimen in accordance with BS 1881-122:(1983). A total of 36 specimens were tested for absorption capacity and on each day of testing, three cubes each were placed in the electric oven to dry the specimens at 105^0C for 24 hours. The specimens were then removed from the oven and allowed to cool at room temperature before determining the initial weight which was recorded as (W1). The final weight was determined after the concrete specimen was immersed in water for 24hrs. It was then removed and dried with a piece of cloth; then re- weighed and recorded its weight as W2. The equation used to compute the absorption capacity for the specimens is given as:

Water Absorption Capacity=

$$\frac{W2-W1}{W2} \times 100\% \text{ - } (9)$$

Where: W1 = Weight of the concrete sample after oven dry

W2 = Weight of the saturated surface dry concrete sample

3.7 Method of Data Analysis

The results obtained for different test carried were analyzed using simple statically tools (mean and percentage). According to Tavakoli (2012) mean also called arithmetic mean, represented by M or X is the most commonly used measure of central tendency which is the sum of scores divided by the total number of scores, often represented by equation

$$x = \frac{\mathcal{E}X}{N} \qquad \text{- - - - - - - - - - - - - - - - - } (10)$$

Where: X (read as X-bar) is symbol for the mean.

IV. RESULTS AND DISCUSSIONS

This chapter presents experimental results, which represented the average of three consecutive measurements of geopolymer synthesized from Metakaolin, Sugarcane bagasse ash and Rice husk ash. Cement is completely replaced with metakaolin, Sugarcane bagasse ash and Rice husk ash as blended cement and also alkaline activators are used in this study for the polymerization, which is the solutions of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) for binding of materials to prepare Geopolymer Concrete. And is an eco-friendly construction material and it gains compressive strength rapidly faster than OPC.

The results presented in this chapter are obtained from the test carried out on the type of materials and concrete samples used in the research. Physical properties and chemical analysis for the materials used in the experiment as well as the test for both fresh and hardened properties of concrete are discussed in this chapter.The control is (100%MK) specimen while 50% MK + 20% SCBA + 30% RHA, 60% MK + 15% SCBA+ 25% RHA and 70% MK + 10% SCBA+ 20% RHA are partially replacement of MK.

4.1Chemical and Physical Properties Materials

4.1.1 Chemical Composition Metakaolin

The oxide composition of Metakaolin carried out in this research achieved 97.21% for silicon oxide, iron oxide and aluminium oxide as presented in Table 9, which satisfies the requirement by ASTM C618-05 which state that for material to be a pozzolana the summation of aluminium Oxide (Al_2O_3), Silicon Oxide (SiO_2) and Iron Oxide (Fe_2O_3) must be 70% minimum.

Table 1: Chemical analysis of Metakaolin

Oxide Compositions	% Composition by Mass
SiO_2	52.70
Al_2O_3	44.23
Fe_2O_3	1.11
CaO	0.08
TiO_3	0.60
MgO	0.05
Na_2O	0.07
K_2O	0.20
SO_3	0.76
SO4	NA
LOI	0.18

Source: Laboratory work, (2021).

4.1.1.1 Characterization of Metakaolin

The results of chemical compositions for metakaolin using XRF technique showed that the composition of the major oxides (SiO_2+ Al_2O_3 + Fe_2O_3) was 98.04% for metakaolin treated at a temperature of 800°C. Particle size analyser was used to study the physical properties of the resulting metakaolin produced in the laboratory from purified kaolin, in order to compare their properties. The XRD patterns show that some ingredients are insoluble for the temperature of metakaolin that peaks 2θ (between 17° and 27°). Means that, the XRD shows some insoluble ingredients which are insoluble at 800°C temperature of Metakaolin.

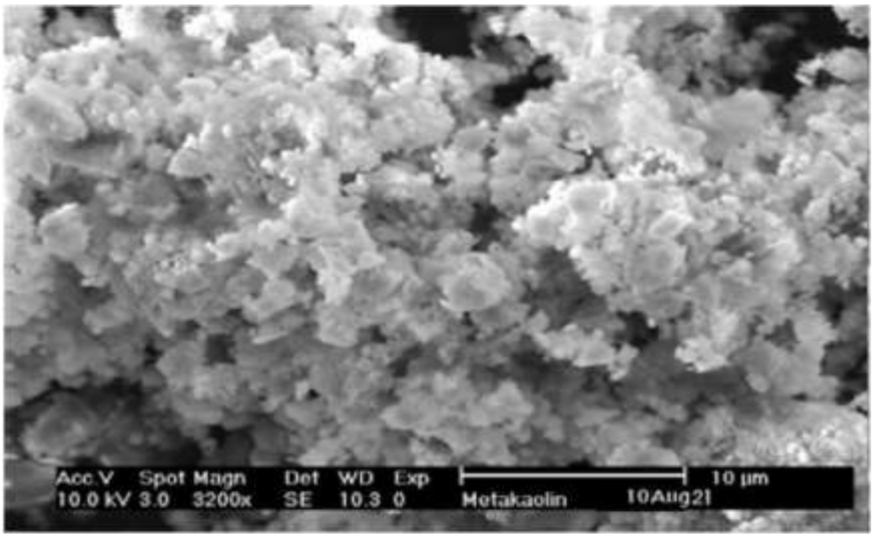

Figure 1: SEM images of Metakaolin

The figure 1, provided microstructure characteristics and explore the hydration process as well as detailed, AccV 10.0Kv, Spot 3.0, magnitude 3200X, WD 10.3 likewise, the expo. From0 – 10µmand date.

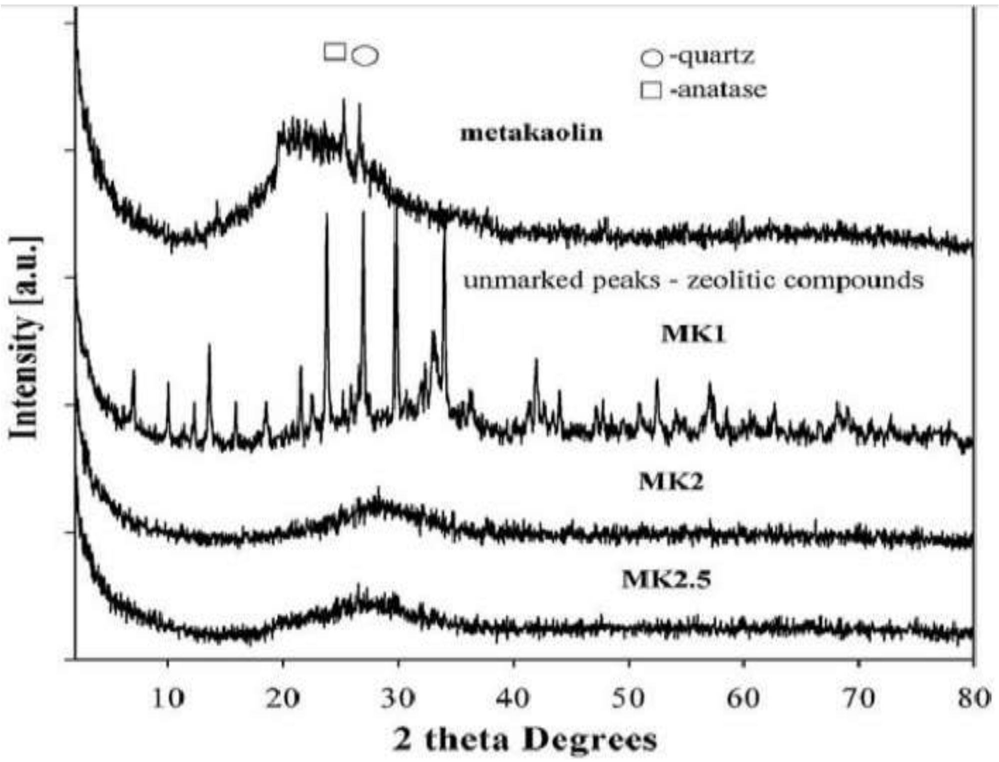

Figure 2: XRD patterns of Metakaolin

The samples of Metakaolin(MK); MK-1, MK-2 and MK-2.5were used to determine the XRD, which represented in the diagram; showing temperature range and their intensity. The unmarked peaks (Zeolitic compounds)and the marked peaks indicated/shows the mineralogical component of the Metakaolin, Quartz and anatase using cycle and square symbols.The 2ɵdetails the actual range temperature, means if ɵ = 5°C then 2ɵ = 10°C and if ɵ = 10°C then 2ɵ = 20°C etc.

4.1.2 Chemical Composition of Sugarcane Bagasse Ash

The results of chemical compositions for bagasse ash using XRF technique showed that the composition of the major oxides (SiO_2+ Al_2O_3 + Fe_2O_3) was 72.56% for bagasse treated at a temperature of 600°C. Particle size analyser was used to study the physical properties of the resulting bagasse ash produced in the laboratory from purified bagasse, in order to compare their properties. The XRD patterns show that some ingredients are insoluble for the temperature of metakaolin that peaks 2θ. The oxide composition of SCBA carried out in this research achieved 72.11% for silicon oxide, iron oxide and aluminium oxide as presented in Table 2.

Table 2: Chemical Composition of Sugarcane Bagasse Ash (SCBA)

Oxide Compositions	% Composition by Mass
SiO_2	64.23
Al_2O_3	3.05
Fe_2O_3	4.83
PbO	ND
CaO	6.71
TiO_3	NA
MgO	4.37
Na_2O	1.87
K_2O	6.43
CuO	NA
P2O5	NA
SO_3	1.57
SO_4	NA
LOI	6.93

Source: Laboratory work, (2021).

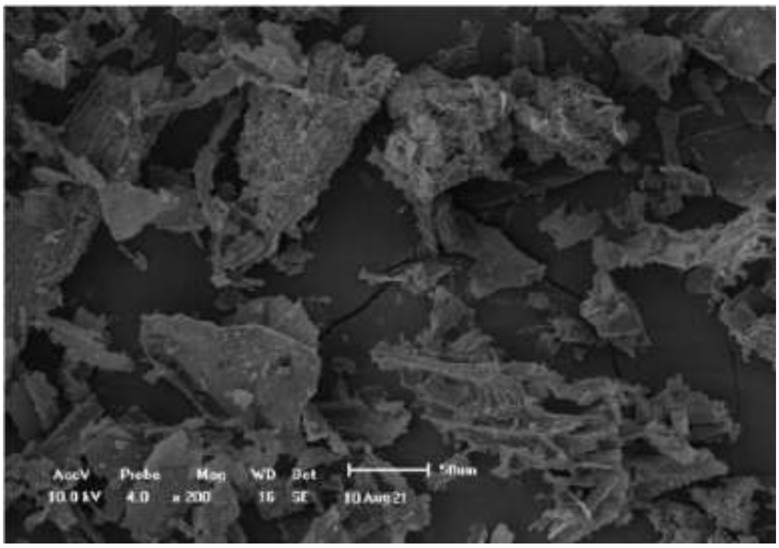

Figure 3: SEM images of SCBA

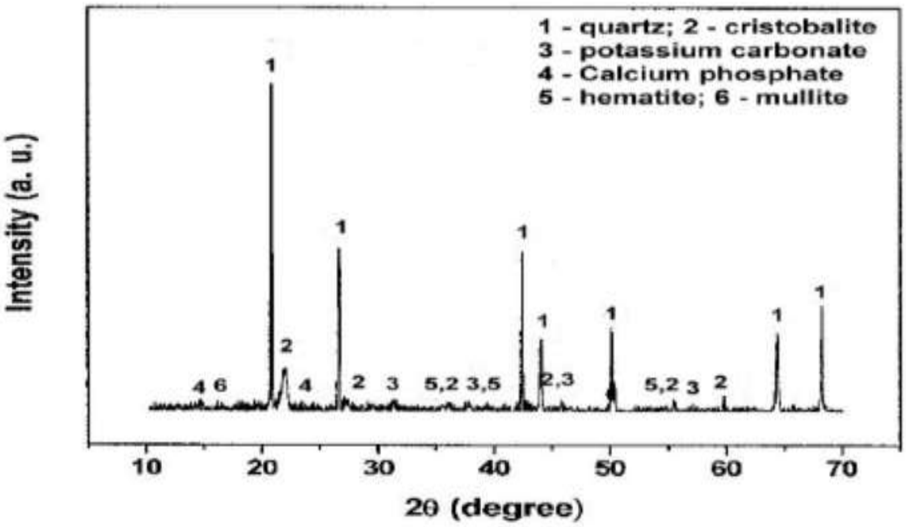

Figure 4: XRD patterns of SCBA

The figure shows that the mineralogical components of SCBA as quartz, cristobalite, potassium carbonate, calcium phosphate, hematite and mullite. The intensity against the temperature θ(2θ) and peaks.

4.1.3Chemical Composition of Rice Hush Ash

The Silicon oxide of RHA obtained is 81.71% which is higher than that of MK and RHA. The oxide composition of RHA carried out in this research achieved 84.54% for silicon oxide, iron oxide and aluminium oxide which meet the minimum requirement of pozzolana material set by ASTM C618-05 is 70% by mass of oxides composition (SiO_2, Al_2O_3& Fe_2O_3) as presented in Table 3. The Rice husk was treated at 700°C temperature.

Table 3: Chemical Composition of Rice Hush Ash (RHA)

Chemical Compositions	% Composition by Mass
SiO_2	81.71
Al_2O_3	1.23
Fe_2O_3	1.60
CaO	1.73
TiO_3	NA
MgO	0.56
Na_2O	0.08
K_2O	1.58
P2O5	NA
SO_3	1.21
SO4	NA
C_3S	_
C_2S	_
C_3A	_
C_4AF	_
LOI	2.01

Source: Laboratory work, (2021).

The figure below shows summary of RHA scanning electron microscopic and the determined factors such as EHT, WD, Magnitude and signal at scanning electron one (SE 1-part A).

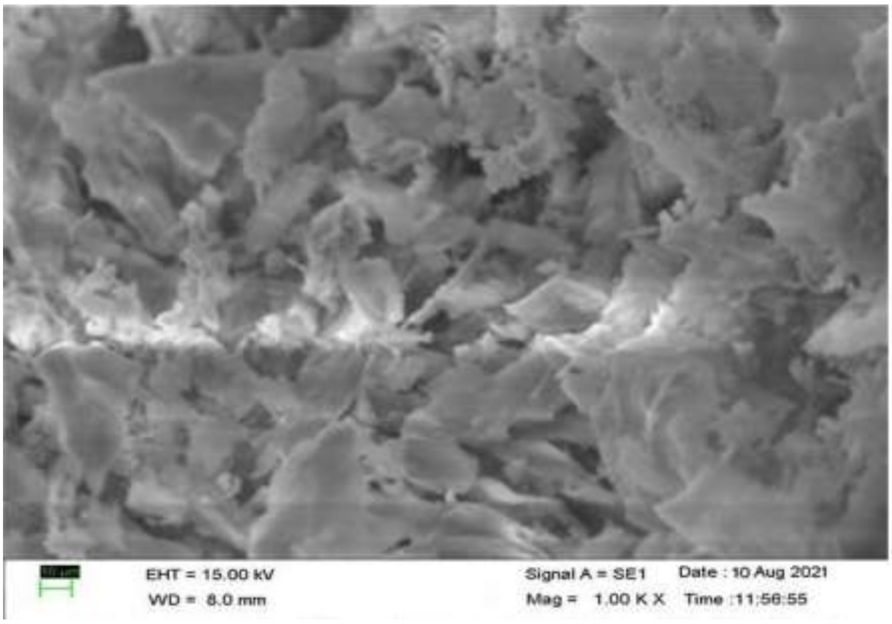

Figure 5: SEM images of RHA

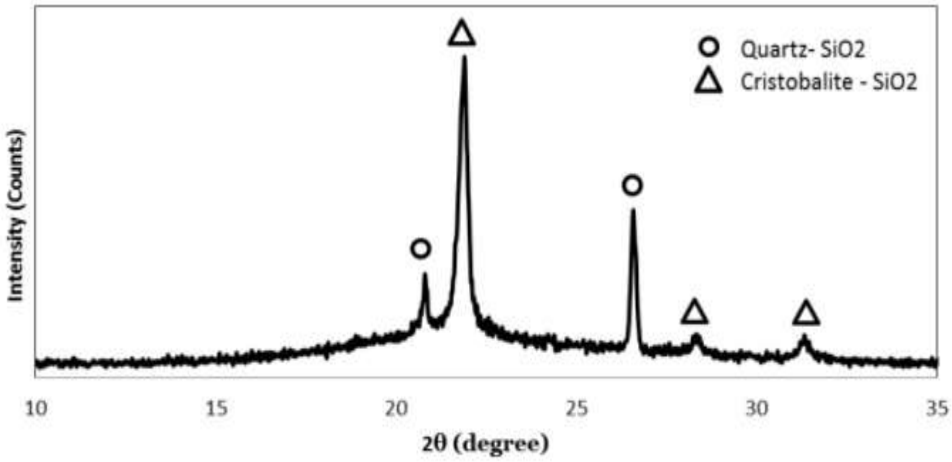

Figure 6: XRD patterns of RHA

This figure shows two mineralogical components of RHA as quartzand cristobalite, which represented by cycle and square symbols.

4.2Physical Properties of Constituent materials

The constituent materials used in this study were mineral Metakaolin from calcination of kaolin and agricultural waste Sugarcane bagasse ash and Rice husk ash.

4.2.1 Physical Properties of Metakaolin

Table 4: Physical Properties of Metakaolin

Physical form	Power
Colour	Off-white, Grey to Buff
Specific surface area	8 -15m^2/g
Odour	Odourless
Specific gravity	2.40 to 2.60 **2.51**

Source: (Malagavelli et al. 2018).

4.2.2 Physical Propertiesof Sugarcane Bagasse Ash

Table 5: Physical of Sugarcane bagasse ash

Appearance	Power
Particle size	28.9 micron-mean
Density	2.52
Blaine Surface	5140 g//m3
Colour	Reddish grey
Odour	Odourless
Specific gravity	2.41

4.2.3 Physical Propertiesof Rice Hush Ash

Rice husk ash (RHA) used in the present experimental study was obtained from rice mill Bauchi. Specification and properties and of this RHA are given in Table.

Table 6: Physical Properties of RHA

Physical State	Solid-No-Hazardous
Appearance	Very fine powder
Particle size	25 micron-mean
Colour	Grey
Odour	Odourless
Specific gravity	2.3

The specific gravity of the constituent was determined and the specific gravity of Metakaolin, sugarcane bagasse ash and Rice husk was 2.51, 2.41 & 2.30 respectively. These specific gravities of the constituent materials fall within the range of pozzolanic specific gravity 2.30 to 2.60 as stated by Abdulwab et al. (2021) and according to Malagavelli et al. (2018), the range is 2.40 to 2.60.

The specific gravity of fine aggregate and coarse aggregate determined was 2.81 in the research was within the range of specific gravity of aggregates given by ACI Education Bulletin (2007), the range from 2.30 to 2.90. Thus, the results of specific gravity of fine and coarse aggregate are within the acceptable limits for aggregates (Abdulwab et al., 2021). Whereas the bulk density of coarse aggregate was 1623m^3/g.

4.3Fresh Properties of the Blended Geopolymer Concrete

4.3.1 Workability

From Table 16 present the result for slump and compacting factor test made with MetakaolinSugarcane bagasse ash and Rice husk ash as fully replacement of OPC.

Table 7: The result for slump and compacting factor Tests

Mixes	**Slump (mm)**	**Type of Slump**	**Compacting Factor (%)**	**Degree of workability**
100% MK (CO)	44	Low workability	0.90	Medium workability
M1 = 50% MK+20%SCBA +30%RHA	44	True	0.90	Medium workability
M2 = 60% MK+15%SCBA +25%RHA	40	True	0.91	Medium workability
M3 = 70% MK+10%SCBA +20%RHA	34	True	0.89	Medium workability

Source: Laboratory work, (2021).

From Table 16 shows that, the slump test for all mix were low workability range from 34 – 44mm. This falls within the limit range index of workability, for slump from 25 - 50mm is low and the compacting factors were medium workability, this shows falls within the range of 0.85 to 0.95

degree of workability index as stated by Pranay et al. (2020). The slump test value for percentage replacement of cement decrease with increase pozzolana and the compacting factor results shown for percentage replacement of 60% MK+15%SCBA +25%RHA with high compacting value of 0.91 while 70% MK+10%SCBA +20%RHA replacement with lower compacting value 0.89. The workability range index used, was given by Pranay et al. (2020).

According to Neville & Brooks (2010) and BS 812, specified that mix with percentage replacement more than % replacement (control) were workable as shown in Figure . The slump test value for percentage replacement of cement decrease with increase pozzolana.

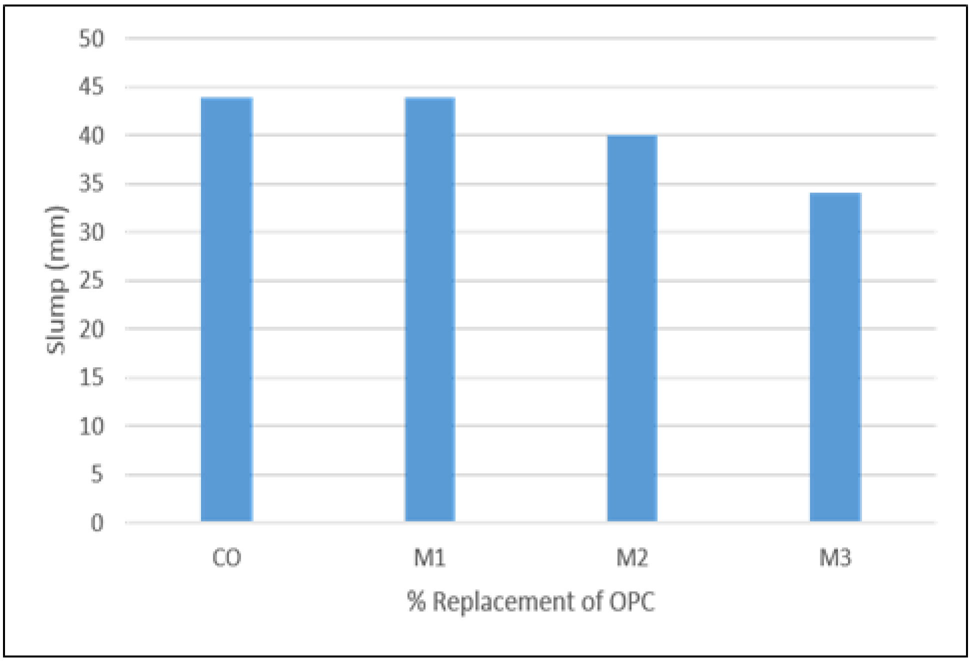

Figure 7: Slump versus percentage replacement of OPC GPC

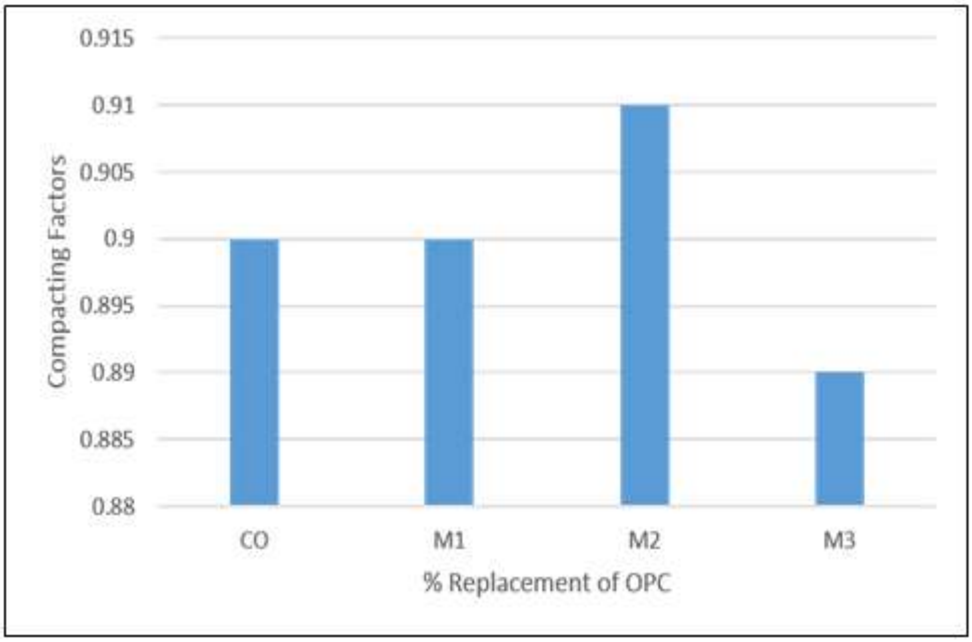

Figure 7: Compacting Factor versus percentage replacement of MK

CO	20.16	24.80	25.95±5.2	0.96	21.81	1.14	27.15	0.94
M1	22.18	23.80	26.55±5.3	0.90	21.81	1.09	27.94	0.96
M2	21.78	22.90	26.43±5.3	0.87	22.39	1.02	27.79	0.98
M3	18.29	19.30	25.36±5.1	0.76	21.10	0.91	26.37	0.97

Source: Laboratory work, (2021).

4.6 Discussion

a. The Chemical properties of MK, SCBA and RHA have reached the requirements for a good pozzolanas as set by the ASTM C618-05, which state that for material to be a pozzolana, the summation of Al, Si & Fe oxides must be 70% minimum. The XRD peaks in the geopolymer concrete mixes show some insoluble quantities of quartz present in RHA & BA. The insoluble amounts of quartz are quite large in GPC mix.

b. The Physical properties of the constituents are normally rounded with smooth surfaces and naturally occurring or crushed as carried out by Ibrahim (2018); similarity Specific gravity in coarse aggregate & fine aggregate.

c. The workability of fresh geopolymer concrete produced with blended geopolymer was found to improve with the increase in sodium silicate (Na_2SiO_3) to sodium hydroxide (NaOH) ratio until certain limit and reduced subsequently due to the increase in mix viscosity. The blended geopolymer concrete possesses a better slump than OPC.

V. CONCLUSSION AND RECOMMENDATIONS

i. Revealed that, the concrete with blended constituents of MK, SCBA & RHA replacement has an average density within the range of 2000Kg/m^3 to 2350Kg/m^3 at different curing ages.

ii. The drying shrinkage were investigated in both control and replacement. The results showed that, drying shrinkage was increased as the increases as the replacement of MK increases. According to Davidovits (1999), stated that, it is not applicable in geopolymer concrete because geopolymerizationreaction recycle water molecules. While modulus of elasticity properties shown a comparable elastic modulus to control concrete at both 7 & 28 days.

5 Conclusion

Metakaolin, sugarcane bagasse ash and rice husk ash are used as the source materials instead of the Portland cement, to make concrete. From the various tests, discussions and analysis carried out in this study, the following conclusion can be drawn.

- ➢ The EDXRF Chemical analysis on Sugarcane bagasse ash and Rice husk ash classified as F-Class and Metakaolin is classified as N-Class by ASTM. They both satisfied the ASTM C618-05 requirement as a pozollanic materials.
- ➢ Physical properties of Metakaolin, Sugarcane bagasse ash and Rice husk ash were found to be in conformity with ACI E1-99, Setting time and consistency OPC/blended constituents materials satisfied the BS EN 197-1 (2000) requirements.
- ➢ Hat, drying shrinkage was higher in m3 mix replacement concrete than m1 & m2 concrete and Modulus of elasticity properties shown a comparable elastic modulus to control concrete.

5.3 Recommendations

From the results of this research, the following recommendations were made:

- ✓ The research recommends the use of Metakaolin blended with sugarcane bagasse ash and rice husk ash to replace cement concrete production because it is economical means due to its availability.
- ✓ The research recommends by using these replacements, based on the fact that, we are trying to reduce the consumption of huge quantity of virgin materials required during production of cement and global warming because by emissions of CO_2during the cement production which cause severe effect on the ecosystem.
- ✓ The use of 60% MK+15%SCBA +25%RHA replacement level is the optimum replacement level that can be used to produce concrete with required strength for general construction purposes.

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