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Effect of Cassava Peel Ash and Epoxy Resin as Partial Replacement on the Flexural Strength of Concrete

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Abstract: *This work reports the outcome of an experiment carried out on the flexural strength of concrete using cassava peel ash and epoxy resin as partial replacement for cement in concrete. A lot of types of agricultural waste today pollute the environment and occupy great soil surfaces, and cassava peels is not an exception. One way for consuming waste is to use them in obtaining green materials. And polymer concrete such as epoxy resin concrete is a new advanced composite material which is used in construction industry due to its superior properties in comparison with ordinary Portland cement concrete such as higher mechanical strength and chemical resistance. The cassava peel ash was obtained by calcination of cassava peel at 360˚C temperature. The design of the experiment used 0, 5, 10, 15, 20, and 25% for both cassava peel ash and epoxy resin. The concrete was batched with a ratio of 1:2:4. The result obtained showed that there was no appreciable change in slump but slight increase by the increase in percentage of concentrations and the flexural strength result shows that concrete samples of various percentage concentrations increases with increase in the epoxy resin concentrations. It can be concluded that epoxy resin when used in conjunction with cassava peel ash performs equally as a good binder in concrete without reducing the flexural strength properties of the concrete*

***KEYWORDS*:** *Flexural Strength, Epoxy Resin, Cassava Peel Ash, Slump, Agricultural Waste Management*

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I INTRODUCTION

Significant amounts of different types of wastes are disposed worldwide and they are polluting the environment. For their elimination, a lot of studies and technologies were elaborated especially for using them as resources for different industries. In building materials industry, they use different types of waste for obtaining new materials, for improving the mechanical and durability characteristics of ordinary materials, for obtaining materials with specific properties. By using the silica fumes, slag, fly ash or ferrochromium, new materials such as high strength or high performance concretes are prepared (Hunchate *et. al.*, 2014; Bharatkumar *et. al.*, 2005; Kayali, 2008; Parmar and Patel, 2013).

A significant number of these attempts have been at incorporating agricultural and industrial wastes as partial or full replacement of concrete ingredients including cement, fine aggregate, and coarse aggregate (Nagaratnam *et. al.*, 2016; Tangchirapat *et. al.*, 2007; Khankaje *et. al.*, 2016).

Recently, there has been a growing trend in the use of polymers to modify cement mortar and cement concrete with research focusing on both the physical and the chemical characteristics of such use of polymers. These recent developments towards improving the sustainability of reinforced concrete notwithstanding, there are still great potential for the use of alternative materials and techniques in order to make this industry more environmental friendly. A novel technique in this regard is the use of epoxy resin as a binding material in concrete (Wang *et. al.*, 2016; Ferdous *et. al.*, 2020; Jafari *et. al.*, 2018).

Pozzolana is composed of inorganic materials that are non-biodegradable and non-combustibles, which are bio-accumulated in the process of plant growth and development. They are primarily metals and oxides of a metal which serve for structural up-building of plants and also facilitate plants' biochemical and physiological functions (Ibrahim *et al.*, 2015). Like silicious materials, they have the potentials of contributing to strength and cementing properties as does Calcium Carbonate and lime in the production of cement (Malhotra and Mehta, 1996). These calcareous (calcium carbonate) and argillaceous materials (clay) could be altered in quantity, depending on the nature and strength requirement of the particular construction work. Portland cement basically contains lime, iron (III) oxide, magnesium oxide, calcium sulphate and silica in given relative quantities, depending on the specific nature of the cement (Punmatharith *et al.*, 2010).

Cellulosic materials are agro-waste which is of economic values and which also constitutes environmental nuisance particularly during little or harvest season. These include, rice husk, cassava peel, groundnut shell, palm oil chaff, maize cob and maize stalk (Ugwuoke *et al.*, 2018). When they are heated 700°C for about 90 minutes, they provide pozzolana which can be used as adjunct in concrete as part of replacement for Portland cement. This partial replacement of cement has the effect of reducing the total cost of the concrete cement and indirectly ridding the environment of nuisance agricultural waste materials. Cassava (Manihot Esculenta) peel is an attractive candidate in this regard and part of the challenges causing substandard constructions and collapse of building and structures is compromise in the mix ratio arising from the desire to save cost. This compromise is becoming more severe with the rise in cost of materials being experienced now, particularly in the developing world. There is the need therefore to prospect for cheap but competitive materials that could be used as adjunct to the most expensive component – Cement, in the concrete formulation. This could lead to a reduction in the quantity of cement used without compromising quality, and safety in concrete production. It will also boost the dire need to develop blended cement which will be readily available to provide low-cost housing for the continually increasing population (Osuide *et. al.,* 2021).

A. Progress of epoxy resin in concrete in civil engineering field

According to Buyukozturk and Lau (2004). In order to improve the concrete performance, the following three aspects are considered: (a) the hydrated cement paste should be strengthened, (b) the porosity in concrete should be lowered, and (c) the interfacial transition zone should be toughened. Therefore, the expression 'high-performance concrete' became more and more widely used to describe the overall improvement in the properties of this new family of concretes modified by partial replacement of one or more of the supplementary cementing materials and addition of polymers (Aitcin, 2011). For that, high-performance concrete is defined as a concrete has been designed to be more durable and stronger than conventional concrete according to Nawy (2001).

Gul *et. al.* (2021) studied using epoxy resin as partial cement replacement in concrete with silica sand as fine aggregate. That plain concrete has low tensile strength; therefore, it is reinforced with steel for structural use. Both the production of concrete and the manufacture of steel adversely affect the environment. Moreover, there is a new developing technology of 3D printing complex structural shapes, which makes it difficult to provide conventional steel reinforcement. This can be addressed partially by increasing the efficiency of concrete with respect to its properties; specifically, the tensile strength. Traditionally, silica fume is used for this purpose. This research is exploratory in nature in that it is breaking new ground by incorporating epoxy resin to partially replace cement in concrete with the fine aggregate partially replaced by silica. It was hypothesized that an increase, especially in the strength of concrete in tension, by the incorporation of epoxy resin will reduce the requirement of reinforcing steel, and thus making it a more suitable material for 3D printing of complex structural shapes.

Chandran (2016) carried out investigation on mechanical properties of concrete elements made with partial replacement of cement with card-board sludge. And that the rapid increase in the development of infrastructure has led to shortage of conventional materials such as cement, fine aggregate and coarse aggregate. Numbers of researchers have started searching the alternatives for the above materials for better concrete. Nowadays many artificial pozzolana are found from researches such as blast furnace, slag, silica fume, rice husk ash and fly ash. Other than this, the recent studies have shown that the waste from the card-board industries has pozzolanic properties termed as card-board sludge which contains low calcium and minimum amount of silica. Card board sludge behaves like cement due to silica and magnesium properties. In this paper, an attempt is made to investigate the mechanical properties of concrete elements made with M20 grade of concrete with water cement ratio 0.5 as a control specimen and card board sludge replaced in different percentages like 5% and 6% continued casting with an increase in the sludge percentage with addition of an admixture epoxy with 7.5% sludge and 0.5% of epoxy and 10% sludge with 1% of epoxy. Totally 30 beams of dimension 50cm x 10cm x 10cm were cast to study the properties and behaviour of card board sludge in concrete.

Fernandez-ruiz *et. al.* (2018) studied in their research, the tensile behavior of concrete mixtures incorporating epoxy resin with and without hardener and ground rubber (tyre powder) as cement replacement was investigated. Various experimental mixes were produced varying the polymer/cement mass ratio. A general design criterion was adopted in the design of the mixtures in order to have a fair comparison between polymer-cement and traditional concretes. Concrete mixes were characterized and the flexural strength results indicate that the use of polymer-cement concrete modifies the post-peak slope of the stress-strain curve, showing a better ductility, having a special interest in earthquake engineering.

Kanchana and ebilin (2018) carried out experimental investigation of epoxy polymer concrete with partial replacement of cement by alccofine. And that concrete is the most flexible, durable and reliable construction material in the world. Epoxy resins are more commonly used thermoset plastic in polymer matrix composites. Epoxy is an adhesive used for bonding concrete. Epoxy resins have good adhesion to other materials, good chemical, environmental resistance and insulating properties. Therefore the addition of epoxy resin into the concrete improves higher strength and adhesion and has lower permeability, better water resistance and chemical resistance. Replacement of cement with a more environment friendly alccofine will help to reduce the emission of carbon dioxide gas into the atmosphere. Alccofine is a new generation micro fine material of particle size much finer than other hydraulic material like cement, fly ash, silica etc. being manufactured in India. Concrete is highly durable due to pozzolanic action of alccofine leading to pores refinement and denser concrete matrix. Alccofine has unique properties to enhance performance of concrete in fresh and hardened stages due to its optimized particle size distribution.

Lei *et al.* (2017) studied the influence of rubber particle content and particle size on flexural and deformation properties of epoxy resin concrete. From the study of the rubber particles on the tensile behavior and deformation characteristics of epoxy resin concrete, the deformation result under the loading of 7 days of epoxy resin concrete with different particle sizes and different content of rubber particles was drawn. The experiment was carried out with different sand substitution ratio in the research of rubber particles with different proportion of different size of epoxy resin concrete non-standard specimen of tensile strength and deformation characteristics. The flexural strength properties of particle size and ultimate strain values of different rubber content were obtained.

Liu *et al*. (2008) carried out experimental study on shrinkage performance of epoxy resin concrete. And used the independent research and development of epoxy resin concrete adhesive to make the experiment of temperature contraction coefficient, when the initial temperature and the final temperature difference reached 40 degrees Celsius, the concrete temperature shrinkage coefficient curve is drawn. The temperature shrinkage performance of epoxy resin concrete was analyzed by using cement concrete and epoxy resin concrete at the same level. The flexural strength of epoxy resin concrete and cement concrete were tested at room temperature and high temperature. It is concluded that mechanical properties of epoxy resin concrete is better than that of cement concrete under the high temperature.

II. MATERIALS AND METHODS

The cement for this research is ordinary limestone portland cement, sourced from the open market. The fine aggregate is sharp river sand, passing through Sieve 4.75mm size with water absorption of 1.0% and was air dried to obtain saturated surface dried. The sieve analysis conforms to zone III as per the specification of the recent European standard. The coarse aggregate used in this study wascleaned and dry before concrete mixing. Coarse aggregate was of minimum size of 5mm and maximum size of 20 mm. The coarse aggregate was sourced from market of building materials in Benin. The cassava peel ash was successfully obtained by close burning up to 360˚c for 60 minutes to produce the ash. Sieved and large particles retained on the 75μm were discarded and those passing were used. Well pulverized to attain a very unique and well fined ash. The epoxy resin used in this study is the Ciba Araldite 6010 (diglycidyl ether of bisphenol A). It was produced by the Ciba Products Company, which came in two parts; A, and B. The curing agent used was Ciba Hardener 951 (triethylene tetramine). The two parts were mixed in equal volume, as recommended by the manufacturer, for use in this study. It is worth noting here that other brands of such resin are available in the market and that this research did not intend to test any particular brand. The resin used in this study was obtained from supplier of laboratory materials without informing the manufacturer. It is assumed that the performance of any other brand of resin with the similar chemical composition and physical characteristics will also be the same as the one used here. Portable water available in the laboratory was used for mixing and curing the concrete specimen.

A. Mix Proportions and the Preparation of Specimens

The concrete investigated (cement-cassava peel ash concrete) according to raheem *et. al.* (2015), oladipo *et. al.* (2013), musbau *et. al.* (2012) and osuide *et. al.* (2021) was of mix ratio 1:2:4 (cement and cassava peel ash: sand: granite) with optimum water/binder ratios of 0.7. But from this experimental study, specimens were prepared including the control with the side dimension of 500mm x100mm x 100mm. The cubes were tested for the flexural strength. With a mix ratio of 1:2:4 and with optimum water/binder ratio of 0.6, the cement was replaced with cassava peel ash at 0%, 5%, 10%, 15%, 20% and 25% by weight of cement. Also, epoxy resin had proportions of 0%, 5%, 10%, 15%, 20%, and 25%, of the total resin to cement percent respectively. Batching of the concrete mix was by weight. The ingredients except water and epoxy resin were first dry-mixed in the appropriate proportions to obtain a homogenous mix. This was followed by the addition of water gradually until a homogenous paste was obtained. The two parts of the epoxy resin were mixed at this stage and added to the concrete mix. Once the epoxy resin was added and mixed well, the concrete was swiftly poured into moulds. In order to make sure there were no voids inside the specimens, a mechanized vibrating tray was used.

III. RESULTS AND DISCUSSION

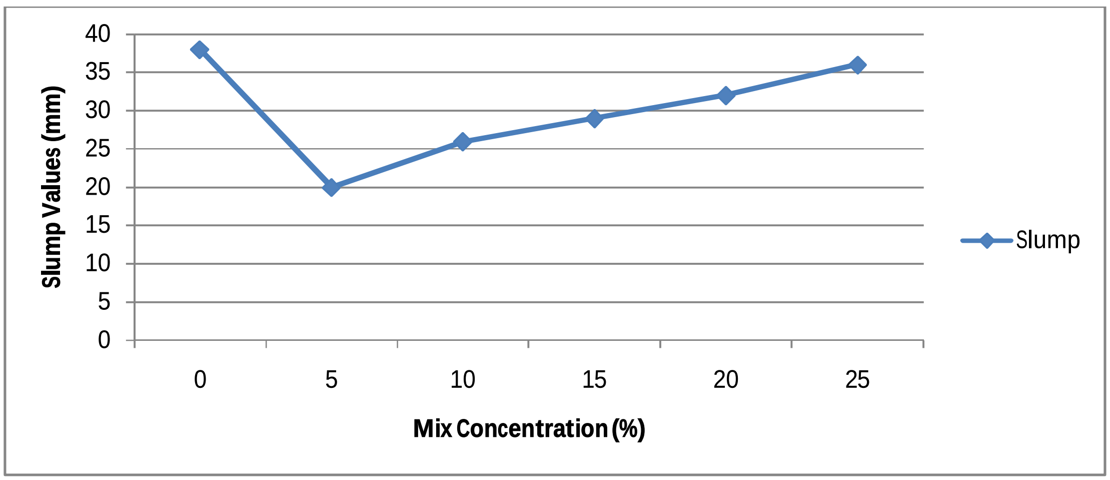

Fig. 1: Graph of slump values of the concrete samples.

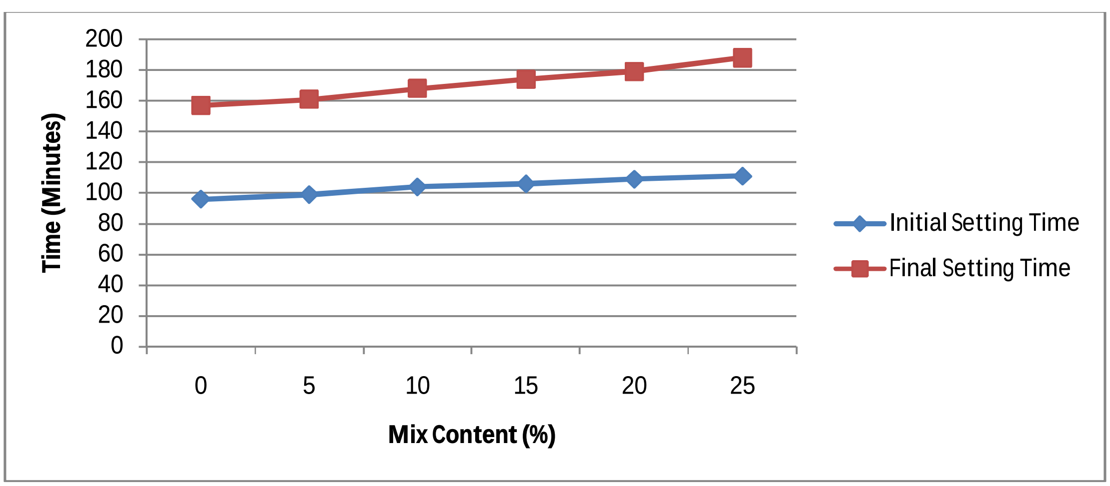

Fig. 2: Graph of setting time (initial and final) values of the concrete samples.

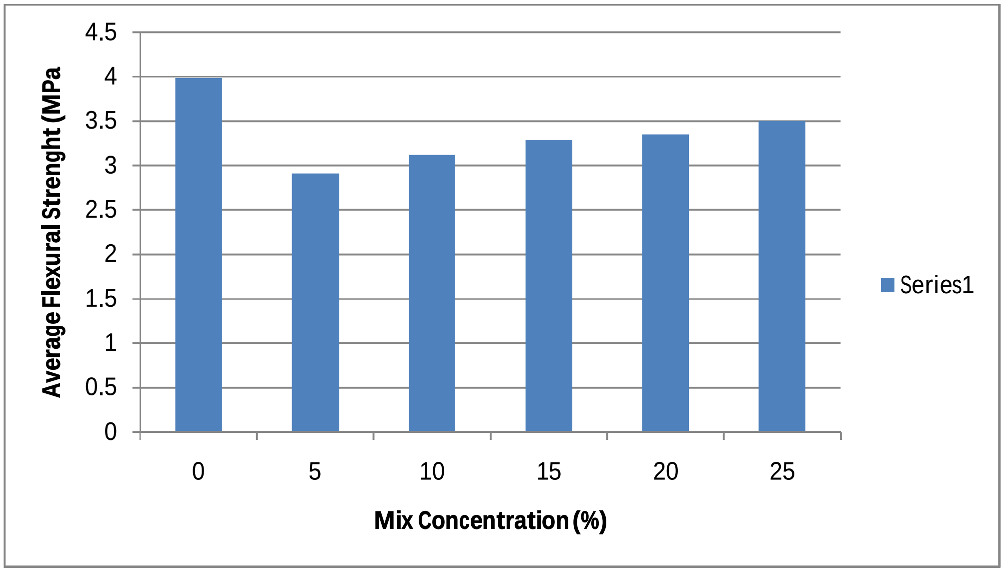

Fig. 3: Graph of flexural strength of concrete samples.

Fig.1 shows the slump values for the concrete as regards the various percentages comprising of cassava peel ash and epoxy resin concentrations, which has lower slump values compared to the control mix. This was as a result of the fact that epoxy resin concentrations has eventually helped in reducing the water absorption of the cassava peel ash and hence reduces the water binder ratio which happens to be within the range of (0.5, 0.55, and 0.6) respectively. The increase in the ratio was necessary because as the proportions of cassava peel ash increases the mixture was becoming stiffer and hence the increase. The increase in concentration of epoxy resin reduces water absorption and improves workability even though the cassava peel ash concentration increases as well. The effect of epoxy resin concentrations in cement-CPA on fresh properties of concrete is not very large. The test result shows that there is no appreciable change in slump due to the increase in percentage of epoxy resin concentrations even though the slump values tends to slightly increase with increase in the concentration of both cassava peel ash and epoxy resin.

Fig.2 shows the trend of variation of setting times shows a slight increase of both setting times with the increase of CPA-epoxy resin content. The control mix (0%) has an initial setting time of 96 minutes and a final setting time of 157 minutes. And with the replacement of CPA-epoxy resin concentrations of 5%, 10%, 15%, 20% and 25%, the initial setting times were 99, 102, 106, 109 and 111 minutes. While that of final setting times were 161, 168, 174, 179 and 188 minutes respectively. It was observed that as the CPA-resin content is increased from 0% to 25%, the initial setting time was found to slightly increase from 96 minutes to 111 minutes and the final setting time also slightly increased from 157 minutes to 188 minutes. This is logical as the increase of CPA-resin content reduces the cement content in the mix and decreases the surface area of the cement but not necessarily the hydration process because the epoxy resin is compensating for the decrease in the surface area of cement with it adhesive properties though with some variations due to the cement-CPA-resin replacement.

Fig.3 shows the flexural tensile strength values tend to increase as the CPA-epoxy resin concentrations increases. The control mix has a flexural strength of 3.98MPa and the flexural strength values for 5%, 10%, 15%, 20% and 25% concentrations are; 2.91MPa, 3.12MPa, 3.28MPa, 3.35MPa and 3.50MPa respectively. This is 73.12%, 78.39%, 82.41%, 84.17% and 87.94% showing a progressive increase in strength. It can be observed that epoxy resin when used in conjunction with a hardener performs better as a binder in concrete compared to other polymers.

IV. CONCLUSION AND RECOMMENDATIONS

From this work, the performances of cassava peel ash and epoxy resin as partial replacement for cement in concrete were determined. Based on the experimental study conducted, the following conclusions were drawn;

Perhaps, this study has clearly shown that concrete strength produced from cement, cassava peel ash and epoxy resin replacement are higher and meets up with the regulated standard compare to just cement and cassava peel ash replacement (results from literature). And the use of epoxy resin as partial replacement alongside cassava peel ash or any other pozzolanic material should be encouraged as this would improve the strength characteristics of the concrete. This will be useful for stakeholders in the industry for a more robust structural integrity.

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