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

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ABSTRACT: *This work reports the outcome of an experiment carried out on the compressive 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 cubes produced were allowed to cure for 7, 14, 28 and 56days. The result obtained showed that there was no appreciable change in slump but slight increase by the increase in percentage of concentrations and the result for compressive strength shows that the concrete strength increases with increase in concentrations and curing age. 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 compressive strength properties of the concrete.*

***KEYWORDS**:* Compressive 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 CASSAVA PEEL ASH IN CONCRETE IN CIVIL ENGINEERING FIELD

Raheem et al. (2015) investigated the effects of cassava peel ash (CPA) as alternative binder in Concrete. This work reports the outcome of an experiment carried out by using cassava peel ash (CPA) of varying quantities to partially replace cement in concrete work. The experiment was carried out by partially replacing cassava peel ash (CPA) of 0 to 20 percent by weight of cement at 5% interval. The concrete was batched with a mix ratio of 1:2:4. The cubes produced were allowed to cure for 7 – 28 days. Compressive strength test was conducted on the samples at interval of 7 days. Slump test and setting time of the concrete cubes were conducted. The result obtained showed that compressive strength of the concrete increased with increase in length of curing age, but decreased as the percentage of CPA increases. However, the strength still remained in the allowable range of workability for concrete in line with the British standard. CPA replacement of 5 – 15 percentages was found to be suitable considering the strength and safe use of the concrete. It was concluded that CPA replacement of 5%, 10% and 15% showed no significant loss in strength compare to the control sample and is stable and could be acceptable in most concrete.

Ofuyatan et al. (2018) carried out in their research titled "Assessment of Strength Properties of Cassava Peel Ash-Concrete. The work, investigated the effect of partial replacement of cassava peel ash with ordinary Portland cement at 5, 10, 15, 20 and 25%. The cassava peel ash was obtained by calcinations of cassava peel to 7000c temperature. Cube samples of size 150 x 150 x150 were prepared for concrete grade 30 and cured in water for 7, 14, 28, 90, 120 and 180 days after which they were subjected to compressive strength. Water/cement ratio of 0.60 and mix of 1:1:1.5 was adopted. The results showed that partial replacement of 10 and 15% gave compressive strength comparable to the control with 0% replacement and optimum replacement is 10%. It was discovered that the cassava peel ash contains all the main chemical constituents of cement though in lower percentage compared with OPC which shows that it can serve as a suitable replacement if the right percentage is used. However, its durability and sulphuric acid resistance improved considerably at 10% replacement of cement with cassava peel ash.

Oladipo et al. (2013) studied using cassava peelings to reduce input cost of concrete. A waste-to-wealth initiative in southwestern Nigeria. This work reports the outcome of an experiment using cassava peelings ash (CPA) of varying quantities to supplement cement in concrete work. The design of the experiment used 0, 5, 10, 15, 20, 25 and 30 per cent cassava peeling ash. The concrete was batched with a ratio of 1:2:4. The cubes produced were allowed to cure for 28 days. Compressive strength test was conducted on the samples at interval of 7 days. The result obtained showed that compressive strength of the concrete increased with increase in length of setting, but decreased as the percentage of CPA increases. However, the strength still remained in the allowable range of workability for concrete in line with the British standard. With concrete mix using 15 – 20 per cent CPA was found to be the most suitable mix considering the strength and safe use of the concrete. It was concluded that this alternative use of cassava peelings will at the long run create supply paucity, attract higher economic value to cassava peelings, increase the economic return of the farmers and improve the environmental management of the study area.

Salau et al. (2012) also investigated the structural strength characteristics of cement-cassava peel ash blended concrete. This study focuses on structural strength characteristics of cement-CPA blended concrete. Cement was replaced partially by CPA between 5% and 25% by weight of cement at 5% interval. Water binder ratios (w/b) of 0.5, 0.55, 0.6, 0.65 and 0.7 were used to produce the blended concrete of mix 1:2:4. The results of the investigation indicated that as the replacement of CPA increases, more water was required to make the blended concrete workable, hence, w/b of 0.7 was found to be optimum to produce workable blended concrete. The compressive strength of the blended concrete increases with age and reduces with increase in CPA content but at 5, 10 and 15% CPA the strength activity indices (SAIs) are 83, 82 and 79% at 28-day while at 120-day strength SAIs are 99, 95 and 87% showing that CPA contributes to later strength development than early strength development, a property that is peculiar to pozzolanic materials. Also, these values were greater than 75% specified by ASTM C311-98 showing that up to 15% is adequate.

Osuide et al. (2021) carried out an assessment of the compressive strength of concrete made with cement partially replaced with cassava peel ash by determining the suitability of Cassava Peel Ash (CPA) as partial replacement of cement in concrete in a bid to devise more economical construction measures while preserving strength and protecting the environment. Tests to determine the chemical composition of the CPA, specific gravity and sieve analysis of the aggregates in accordance with BS 812 standards and slump test of the concrete were carried out. In the experiments, 0-50% with 5% increment of CPA was used as partial replacement of cement in concrete. The concrete was batched by weight with a ratio of 1:2:4. Compressive strength test was conducted on the samples at interval of 7 days and some of the results obtained in N/mm2 of partial replacement conducted for 7, 14, 21 and 28 days curing respectively. The result showed that compressive strength of the concrete increased with increase in length of curing, but decreased as the percentage of cassava peel ash was increased. However, the strength still remained in the allowable range of workability for concrete in line with the British standard. Also, it was found out that the entire mix was suitable since the results were within the acceptable limits as concrete strength made with varying amounts of cassava peel ash did not fall below half of the original strength of the concrete made with zero percent CPA. This alternative use of cassava peelings will in the long run reduce cost of construction, attract higher economic value to cassava peels and increase the economic return of the farmers and preserve the environment.

B. 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).

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 cubes of dimension 15cm x 15cm, 30 cylinders of dimension 15cm diameter and 30cm height and 30 beams of dimension 50cm x 10cm x 10cm on a overall count of 90 moulds were cast to study the properties and behaviour of card board sludge in concrete.

Fernandez-ruiz et. al. (2018) studied in their research, the compressive 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 compressive 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 compressive and deformation properties of epoxy resin concrete. From the study of the rubber particles on the compressive 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 compressive strength and deformation characteristics. The compressive 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 compressive 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 was cleaned 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, a total number of 72 specimens were prepared including the control with the side dimension of 150mm x150mm x 150mm. The cubes were tested for the compressive 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

Table 1: Results of the mix proportions of concrete components and workability

S/N	Mix (%)	Cement (kg)	CPA/Resin (kg)	Fine aggregate (kg)	Coarse aggregates (kg)	W/C	Slump (mm)
1	0	21.00	0	39.43	78.86	0.5	38
2	5	18.90	2.10	39.43	78.86	0.55	20
3	10	16.80	4.20	39.43	78.86	0.55	26
4	15	14.70	6.30	39.43	78.86	0.55	29
5	20	12.60	8.40	39.43	78.86	0.5	32
6	25	10.50	10.50	39.43	78.86	0.5	36

Table 2: Effect of different concrete ages with respect to compressive strength for all cement-CPA-epoxy resin concentrations

S/N	Ages (days)	Mix concentrations (%)	Average compressive strength (N/mm^2)
1	7days	0%	21.42
2		5%	16.83
3		10%	18.39
4		15%	19.04
5		20%	19.78
6		25%	20.77
7	14days	0%	27.14
8		5%	20.02
9		10%	21.79
10		15%	22.68
11		20%	22.99
12		25%	24.02
13		0%	31.70
14		5%	25.28

15	28days	10%	26.43
16		15%	27.38
17		20%	29.14
18		25%	30.95
19	56days	0%	34.38
20		5%	28.86
21		10%	30.36
22		15%	30.92
23		20%	31.79
24		25%	32.50

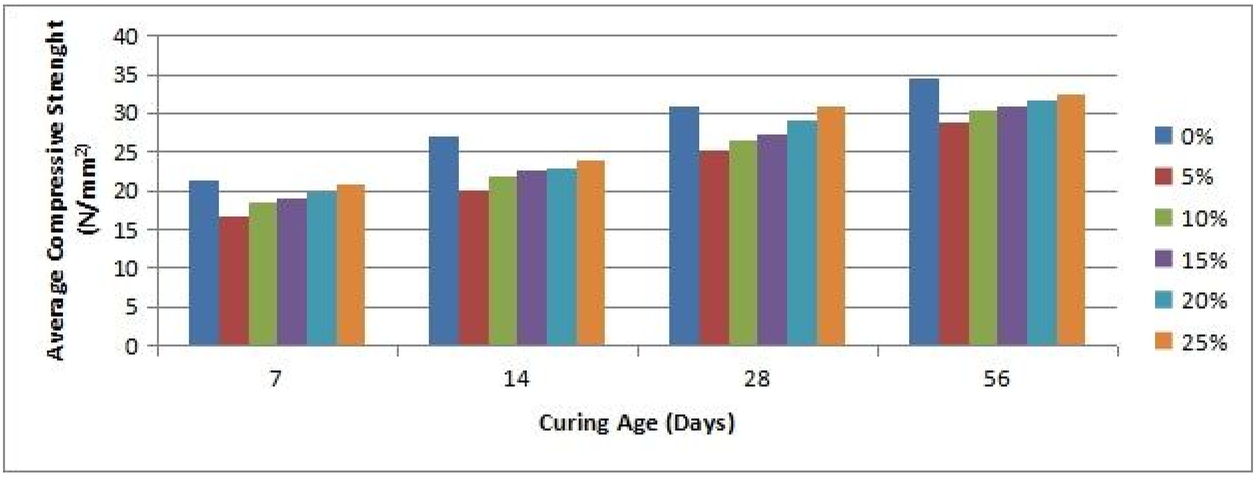

Fig.1: Graph relating the effect of different concrete ages with respect to compressive strength of all cement-CPA-epoxy resin concentrations.

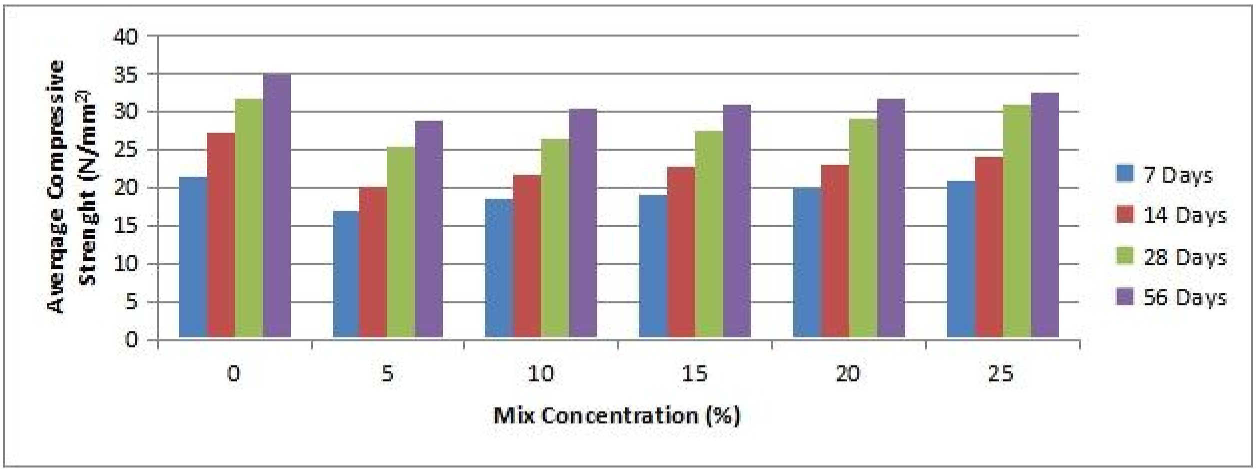

Fig.2: Graph relating the effect of all cement-CPA-epoxy resin concentrations with respect to compressive strength of the different concrete curing ages

Table 1 shows the result and the breakdown of the mix proportions of the different concrete components comprising of the weight of cement, cassava peel ash and epoxy resin as well as fine and coarse aggregates used. The results as presented shows that six different mixes was carried out with percentage replacement of 0% to 25% and their various weight values are in accordance with the table shown above inclusive of their water cement ratio and workability. The findings demonstrated that increasing epoxy resin concentration enhances workability because the increased 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.

In view of the positive influence of both cassavas peel ash and epoxy resin on the behaviour of concrete as briefly reviewed above, it was expected that the combined addition of both cassava peel ash and epoxy resin as partial replacement for cement would have a similar effect in the concrete from this study. The results obtained in this experimental study, in the limit of 56days curing, validate this hypothesis because it shows that strength development in concrete is continuous even after 28days curing. Table 2 presents the comprehensive results of the compressive strength test with varying proportions of both cassava peel ash and epoxy resin after 7, 14, 28 and 56 days of curing.

From this study, the increase in the concrete strength can be linked to the materials used; first, the cassava peel ash has same chemical constituent material as cement but of low quantity most especially for calcium oxide (CaO) but will in the presence of water react chemically with calcium hydroxide (slaked lime) at ordinary temperature to form compounds possessing cementitious properties. And because cassava peel ash is a pozzolan material that influence the performance characteristics of concrete based on it slower rate of chemical reaction which reduce the rise in temperature, and this can likely leads to strength gain especially when the right proportion is used (say 5% - 15%) and more significant and noticeable with increase in curing days with regards to the literatures on cement cassava peel ash concrete even when the strength is not up to that of the control mix.

Secondly, the epoxy resin used contributed to the strength gain especially when the strength tends to reduce due to increase in cassava peel ash proportions because of it toughness and adhesive properties. And with the addition of epoxy resin mixed with the hardener to the concrete, there is need to maintain good ambient temperature that is not too high because epoxy resin possesses low chemical reactivity. Curing agent is necessary to effect the conversion of the pure epoxy to a solid. This conversion is accompanied by a production of heat hence the sprinkling curing method was adopted in this study. Also worthy of note is that a rise in curing temperature speeds up the chemical reactions of hydration and thus affects beneficially the early strength of concrete without any ill-effects on the later strength.

IV. CONCLUSION

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;

The workability of normal cement concrete was 38mm and that of the cassava peel ash and epoxy resin concentration with 5%, 10%, 15%, 20% and 25% was 20mm, 26mm, 29mm, 32mm and 36mm respectively. It was observed that the increase in epoxy resin concentration most likely, slightly reduces water absorption and improves workability even when the cassava peel ash proportions increases. The effect of epoxy resin concentrations on the fresh properties of the concrete in this study 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.

The average compressive strength at 28 days of curing for the control mix (0%) is 31.70N/mm^2 while for CPA-epoxy resin concentrations of 5%, 10%, 15%, 20% and 25% are 25.28N/mm^2, 26.43N/mm^2, 27.38N/mm^2, 29.14N/mm^2 and 30.95N/mm^2 which are 79.75%, 83.38%, 86.37%, 91.92% and 97.63% which shows strength increment as concentrations increases. From the results so far, it could be observed that the compressive strength for the control mix concrete (0% CPA-Epoxy resin), are slightly higher compare to the cement-CPA-epoxy resin concentrations. But however the compressive strength for the cement-CPA-epoxy resin concrete appreciates and tries to measure up in strength with that of the control mix as the concentration increases. 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.

To overcome the problems of parking vehicles on parking lot in some cities, the automatic vehicle smart parking system is the main idea in the traffic and this system can be controlled without human interference. The electronic data keeps information of the available number of parking lot using the transducer and the transducer collects and post records of the available parking lot for the light, medium and heavy weighted vehicles once a park lot is free. The vehicle detection at the entry can be achieved when using the weight transducer to detects when a vehicle tries to enter the park and when a vehicle leaves the park. The availability of the parking lot for a sensed weighted vehicle and the availability of the parking lot depend on the presence of the RFID reader of different categories of vehicles.

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