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EFFECT OF CASSAVA PEEL ASH AND EGG SHELL POWDER BLENDED CEMENT CONCRETE IN SODIUM CHLORIDE ENVIRONMENT

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ABSTRACT Concrete stability has become one of the most important considerations in construction industries in recent years. Concrete is vulnerable to acid and salt attack because of its alkaline nature. The financial losses associated with infrastructure deterioration due to acid and salt attack exceed trillions of naira all around the world. An experimental investigation into the behaviour of sustainable concrete in 10% sodium chloride environment by replacing cement with combination of cassava peel ash and egg shell powder. Mix proportions 1:2:4 with water/cement ratio of 0.45 was used. The partial replacement of cement in concrete with CPA and ESP of 0, 5, 10, 20, 30 and 40% respectively by weight of cement were investigated in accordance with standard procedures. CPA and ESP were mixed in a proportion of 10:90, 20:80, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90 respectively for the partial replacement of 0, 5, 10, 20, 30 and 40% by weight of cement and cured for a periods of 3, 7, 28, 60, and 90 days on the compressive strength tests of concrete were investigated and also the effect of sodium chloride (NaCl) concentrations 10%, exposure periods of 7, 14, 21 and 28 days on the compressive strength of concrete were investigated. It was found that the compressive strength loss of concrete in these acid environments was severed, when cement was replaced by CPA/ESP. This mix also showed high mass loss when exposed to these salt.

Keywords: Concrete, Cassava Peel Ash, Egg Shell Powder, Compressive Strength, sodium chloride

Introduction

The solid waste from industries and agro wastes are habitually dumped into landfill thus causing unavoidable environmental issues like groundwater pollution, soil and air contamination and hazardous effects on plant and animal life, as a result comprising ecological contamination that would need appropriate treatment. Egg shell also creates some reactions with unpleasant odor when kept for longer time in garbage. Disposal of these solid wastes are great challenge to researchers on how to preserve nature and environment.

The capacity of wastes generated in the world has increased over the years, in which agricultural wastes constitute a major component. Nigeria, being the highest producer of cassava in Africa, has the highest volume of Cassava Peel (FAO, 2013). Cassava as a total production of 278.6 million tons in 2013 and a prediction production of 288.8 million tons for 2016 (FAO 2015); Nigeria is among the top ten countries in the world in terms of cassava production (Phillips et al., 2004). Gin et al (2014) reported that 450,000 tons of cassava peel waste is generated annually and much more volume of cassava peel is expected annually, especially as the Federal Government is trying to diversify the economic base of the country and importance is placed on agriculture, with cassava being one of the economic products. The cassava peel is currently considered as a waste with little use and therefore needs to be properly disposed in order to prevent environmental pollution. On the other hand, egg shell is another agricultural waste, which was estimated between 10,000–11,000 tons to be disposed annually by egg processors and producers of hard cooked eggs (Adeleye, 2009). Sahel (2015) stated that the Nigerian poultry industry is estimated at approximately 165 million birds, which produced 650,000 metric tons of eggs in 2013; and from the market size perspective, Nigeria's egg production is the largest in Africa. According Agnieszka et al. (2019) the global egg production in 2016 was estimated at 73.9 million metric tons; though, Carvalho et al. (2011) stated that the eggshells represent 11% of total weight of egg and this gave 8.13 million metric tons of by-products. Most of these eggshells by-product are disposed in landfills without any pretreatment. A global egg production in 2017 was estimated at 80.0 million metric tons (www.statista.com).

Production of cement is associated with high energy demand and at the same time lead to high emission of CO_2, which is responsible for global warming that has negative impact on the ecology and health of human beings arising from global warming (Oluremi, 1990).

Cement which is undisputable an important material in the production of concrete is expensive compared to the other materials. This out of many other reasons has led to the exploration for unconventional matrix or cement surrogate stuffs which had been an unrelenting effort for the most recent decades (Ogunbode and Akanmu, 2012).

This research is set out to use cassava peel ash and egg shell powder; both are agro waste product to serve as supplementary binding materials in mortar and concrete production. A huge amount of cassava peels and egg shells are available in Nigeria. The disposal of such a huge waste as a landfill become a challenging problem for the Nigerians as it create environment and health related issued. In order to reduce this burden, let's use cassava peel ash and egg shell powder as a partial replacement of cement in the manufacturing of mortar and concrete. However, this will address the problems of disposal of waste product and the environmental hazards associated with the production of cement.

The ability of concrete to resist weathering action, chemical attack, abrasion, or any other process of deterioration is durability (ACI Committee 201, 2001). A concrete is durable if and only if it can retain its original form, quality and serviceability when exposed to the environment hazard, such as acidic and salty environment. Zivica et al, (2012) reported that, acid attack on concrete may come from different sources such as air pollution and bacterial contamination. Acidic and salty environment is destructive to concrete durability because acid neutralizes the alkalinity of concrete by reacting with the hydration products of the concrete matrix to form gypsum and ettringite, (Neville, 2008 and Larreur-Cayol, 2011).

Materials and Methods

Materials

The sand was obtained from a River in Bida, Niger State, Nigeria; and the particle size distribution curve of the sand is shown in Figure 1. The coarse aggregate is crushed granite of nominal size of 20 mm obtained from local vendors. The physical properties of the materials are shown in Table 1. Dangote brand of ordinary Portland cement of Grade 42.5N (3X) was used for this research, which complied with BS EN 197-1 (2009). The oxide composition of the cement is shown in Table 2. Cassava peel and Egg shell were sourced from a local Garri Industries and Bakeries in Bida, Niger State, Nigeria. The Cassava peel and Egg shell were sundried. The cassava peel ash (CPA) was obtained by burning the cassava peel to ash and under a controlled temperature of about 600^{o}c in a kiln and controlling the firing at that temperature for about two (2) hours and the ash was allowed to cool. After cooling, the resultant CPA grounded and sieved using BS sieve No.200 (75μm) sieves. The egg shells powder was obtained by cleaning and removing the remains from the shells The resultant egg shells were dried naturally and subsequently grounded in to a powder form, and the powder was sieved using BS sieve No.200 (75μm) sieves. Chemical composition analysis of the CPA and ESP was conducted using X-Ray Fluorescence (XRF) analytical method and the results are shown in Table 2. The sodium chloride solution was procured from the Department of Chemistry laboratory, federal Polytechnic, Bida, Niger State. The concentrations of the solution were prepared in the laboratory.

Methods

Sieve analysis was used to find the particle size distribution of fine and coarse aggregates, in accordance with standard BS EN 12620 (2013). The result is shown in Figure 1. The specific gravity test was conducted on cement, CPA, ESP, sand and crushed granite in accordance with BS 8500 (2000). The result is shown in Table 1; while the oxide composition of cement, CPA and ESP was conducted based on ASTM C311 at the Centre for Energy Research and Training (CERT) Zaria, Kaduna State. The results from this analysis is presented in Table 2. Compressive strength test was conducted on the concrete samples using different percentage of CPA and ESP (0, 5, 10, 20, 30 and 40%). Cube mould of sizes 150mm×150mm×150mm was used to cast a total of 810 cubes for testing the effect of CPA and ESP on the compressive strength of concrete, for a proportion of 10:90, 20:80, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90 respectively for the partial replacement of 0, 5, 10, 20, 30 and 40% respectively by weight of cement.

Durability analysis for the specimens involved water absorption, acid and salt resistance. The concrete cubes were selected to identify the durability performance, including mechanical properties and mass change. A water absorption test was performed to identify the rate of water absorption in the concrete specimens. The concrete cube specimens were dried in the oven for 24 hours. The initial weight (w_1) of the specimens was measured before the specimens were submerged in water and the weight (w_2) of the specimens was taken. The concrete cubes were repeatedly measured at 7, 14, 21 and 28 days. The testing procedure was conducted according to BS 1881: Part 122 (2011).

3.0 Results and discussions

Chemical composition

The oxide composition of cassava peel ash (CPA) is presented in Table 1 and it indicated that the predominant oxide is Silicon oxide (56.73%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 66.75%; the oxide composition of egg shell powder (ESP) is presented in Table 2 and it indicated that the predominant oxide is of Calcium oxide (52.75%) Calcium oxide is one of the key elements required for strength development during the hydration process, and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 0.22%. This shows that ESP is cementitious and may combined with CPA containing high silicon, iron and aluminium oxide in a hydrated mix and due to pozzolanic reactions yield final products that are similar to those obtained from cement hydration process. The SO_3 content was found, which according to ASTM C618 (1993) should not be more than 5.0%. Nuruddeen, (2012) reported that, the SO_3 content affect the strength of mortar and concrete specimens to some degree. The higher the SO_3 content, the higher the resultant strength.

Table 1: Oxide Composition of OPC (Dangote brand) CPA and ESP

	Oxide Value (%)										
	SiO_2	Fe_2O_3	Al_2O_3	CaO	K_2O	SO_3	MgO	Na_2O	MnO	ZnO	LOI
Cement	18.1	4.82	3.10	68.37	0.35	1.82	1.48	0.32	0.03	0.00	1.27
CPA	56.73	2.78	7.24	8.65	3.93	1.30	2.58	0.41	0.78	0.05	342
ESP	0.09	0.06	0.07	52.75	0.31	1.54	0.73	0.00	0.00	0.00	---

Compressive strength

The compressive strength performance of cassava peel ash and egg shell powder (CPA/ESP) concrete is shown in Figures 1a and 1b. it was observed that the hydration process and pozzolanic reaction took place, resulting in a larger amount of calcium silicate hydrate (C–S–H) gel filling the voids, thus ultimately increasing concrete strength (Khairunisa et al., 2015).

CPA/ESP concrete shows high compressive strength compared with the control specimen at 10% replacement. The partial replacement of cement with CPA/ESP improved the reaction between silica from the cement and cassava peel ash; and calcium oxide from the eggshell powder, a byproduct of the cement hydration process in the continuous presence of moisture leading to the formation of the secondary C–S–H gel. Furthermore, the cassava peel ash and eggshell powder also acted as a filler by filling up the existing voids, which made the internal structure of the concrete more packed and led to the development of higher compressive strength up to 10% replacement of cement with CPA/ESP at 28 days of curing.

It was observed that the 28days compressive strength of concrete with up to 20% CPA and ESP content exceeded the design characteristics strength, and basically meet the minimum standard in BS 1881: Part 116: (1983) which recommend that compressive strength for 28 days to be 20N/mm^2 to 34N/mm^2 for normal weight concrete. The decrease in compressive strength of concrete with increase in CPA and ESP content would be due to dilution effect of Portland cement and weaker formation of C-S-H gel as a result of slow in the pozzolanic reaction of CPA and ESP. This is behavior was concluded by Salau (2012) report on CPA and Oyekan and Kamiyo (2011) reports on

RHA. The drastic reduction in the compressive strength of concrete containing CPA and ESP of 20% and above, may be due to the fact that CPA and ESP is a slow reactive pozzolana, which may not be combine with the lime liberated during the process of hydration and hence leading to excess silica leached out of the concrete and causing a deficiency in strength (Ogork, 2012).

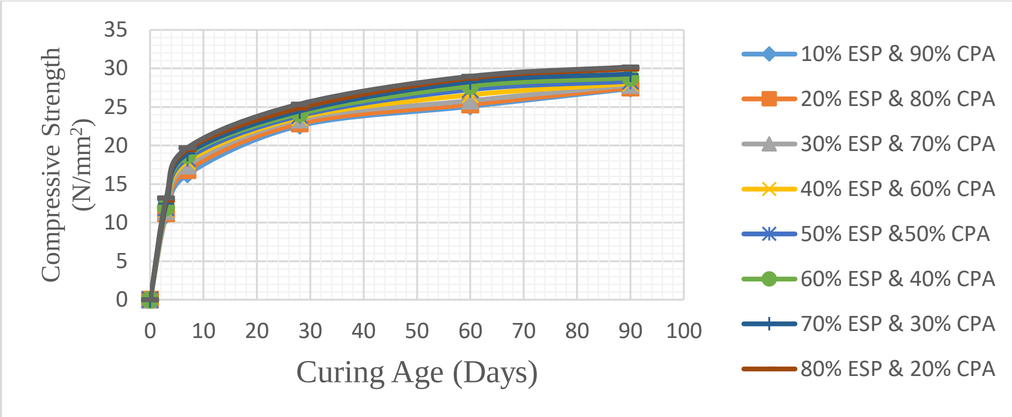

Figure 1a: Compressive Strength of CPA/ESP – Concrete (5% Replacement)

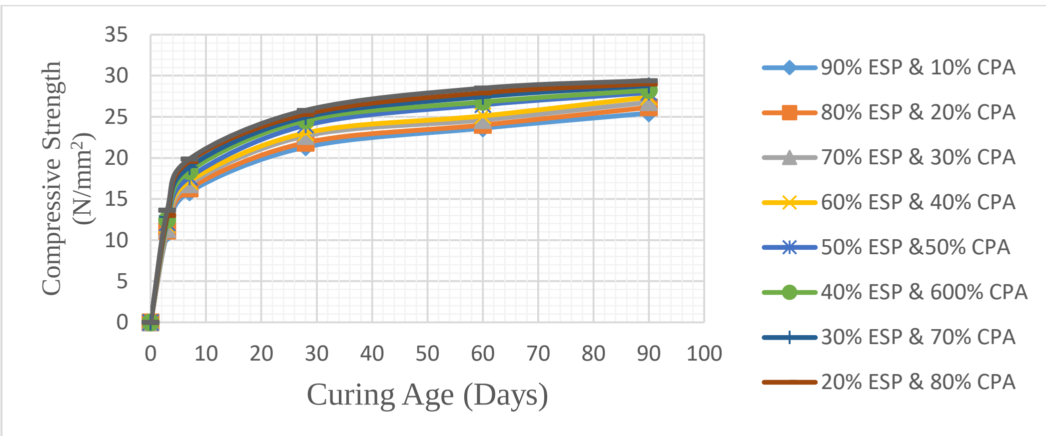

Figure 1b: Compressive Strength of CPA/ESP – Concrete (10% Replacement)

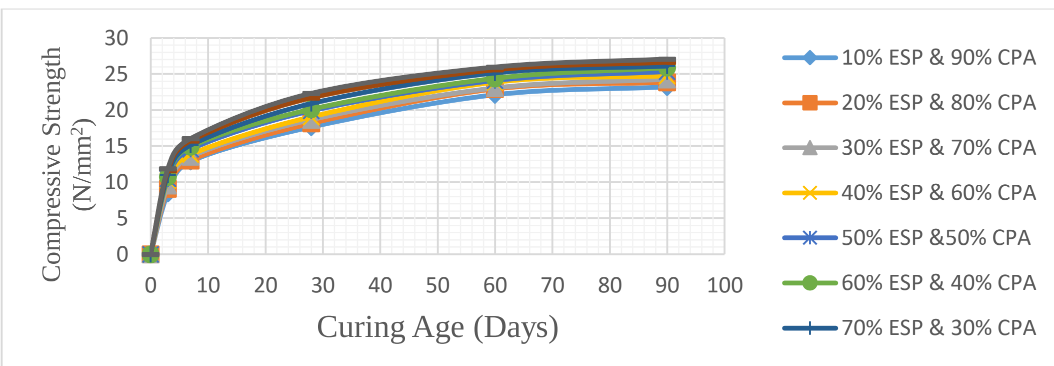

Figure 1c: Compressive Strength of CPA/ESP – Concrete (20% Replacement)

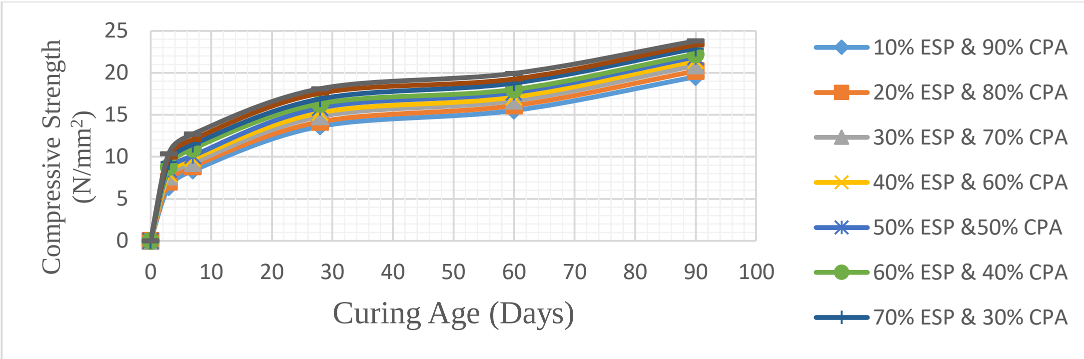

Figure 1d: Compressive Strength of CPA/ESP – Concrete (30% Replacement)

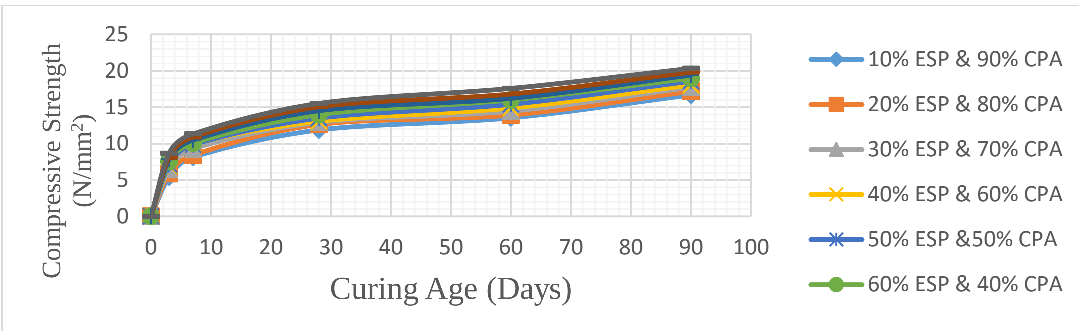

Figure 1e: Compressive Strength of CPA/ESP – Concrete (40% Replacement)

Water Absorption of CPA/ESP

The result of water absorption of CPA and ESP blend concrete are shown in Figure 2, was observed that water absorption increased with increase in CPA but decrease with increase in ESP content. However, the variation of the water absorption capacity of ESP – concrete shows that the water absorption of concrete containing up to 20% of CPA/ESP are nearly the same water absorption capacity as that of control, while, 30% and 40% mix of CPA/ESP blend show higher water absorption capacity than the control. At 5% CPA/ESP replacements, the rate of water absorption was reduced, thus. ESP may be okay as filler for concrete production to provide extra calcium and more secondary C–S–H gel (Doh et al., 2014). According to Okonkwo et al., (2012), the gel can fill up the existing voids in the concrete, which resulting in a lower rate of water absorption. Also, the absorption capacity of concrete revealed that using CPA in production increased its absorption capacity from 0% of pure cement to that of 40% mix of CPA. Yerramala (2014) study on the water absorption of ESP, and Parande et al (2011) reported same behavior with respect to chloride permeability on cement mortars.. The low water absorption is attributed to the incomplete formation of calcium silicate hydrate gel during hydration.

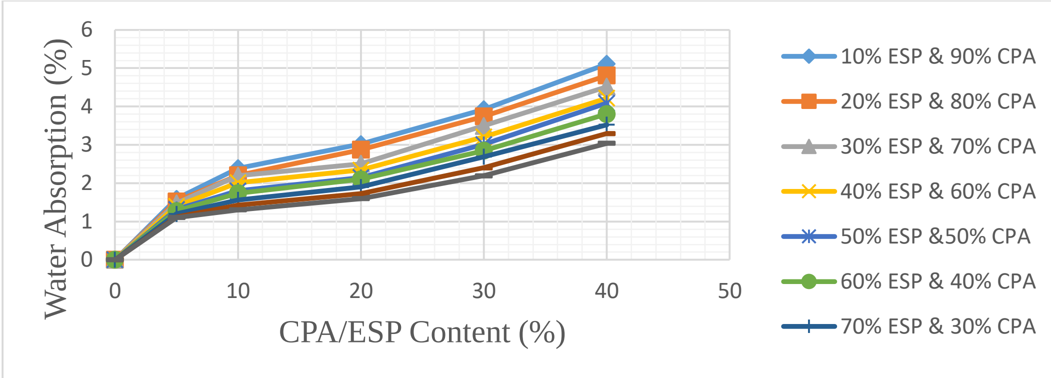

Figure 2: Water Absorption of CPA and ESP-Concrete

Sodium Chloride Resistance of CPA/ESP – Concrete

The result of chloride effect on CPA/ESP concrete is shown in Figure 5a to 5e and Figure 6a to 6e. the figures revealed the weight loss and strength retained of CPA/ESP-Concrete after immersion in a 10% concentration of sodium chloride (NaCl) salt medium, and shows that the effect of NaCl was severe to both CPA/ESP concrete and Portland cement concrete. It was observed that OPC concrete offered better resistance to NaCl aggression than CPA/ESP-Concrete. The weight loss of plain Portland cement concrete (control) after 28days immersion was 97.84% as opposed to an average weight loss for CPA/ESP-Concrete at all percentage of replacements.

The poor resistance of CPA/ESP-Concrete to NaCl when compared with control can be attributed to higher porosity of CPA/ESP-Concrete due to incomplete formation of calcium silicate hydrate gel during hydration, as explained in Parande et al (2011). The weaker resistance of CPA/ESP-Concrete to NaCl when compared with CPA-Concrete at low replacement levels may be due to the more porous nature of ESP with higher specific surface compared to CPA subjected to NaCl attack. Though, at high replacement levels the combined pozzolanic reaction of CPA and ESP reduced the effect of NaCl attack when compared with ESP.

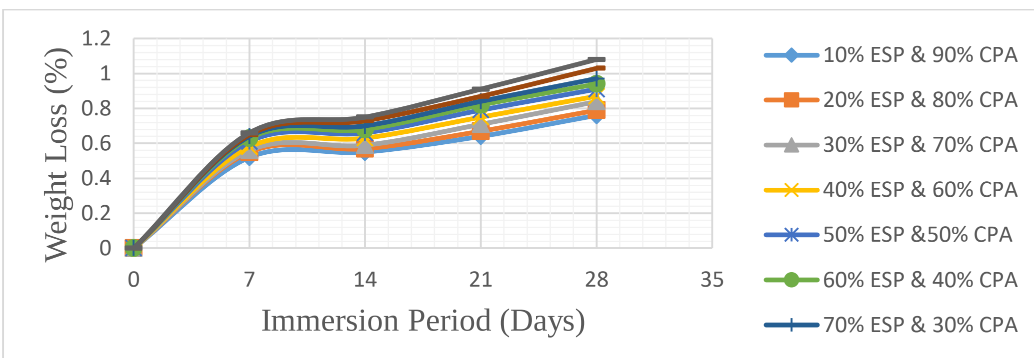

Figure 5a: Weight loss of CPA/ESP-Concrete from salt attack (NaCl medium) (5% Replacement)

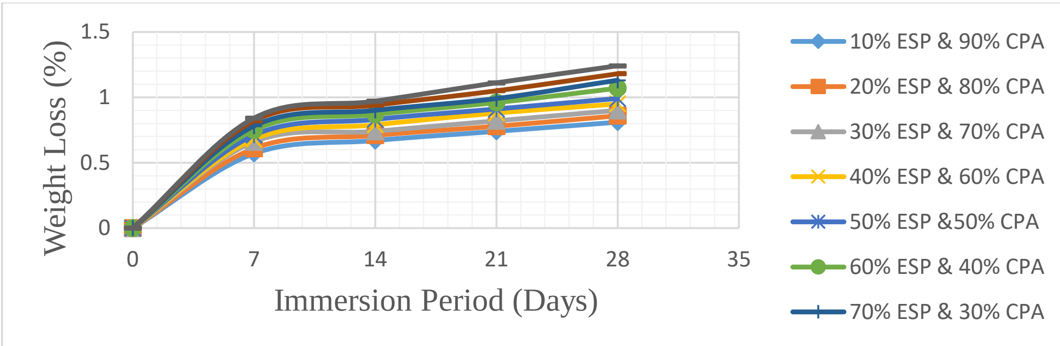

Figure 5b: Weight loss of CPA/ESP-Concrete from salt attack (NaCl medium) (10% Replacement)

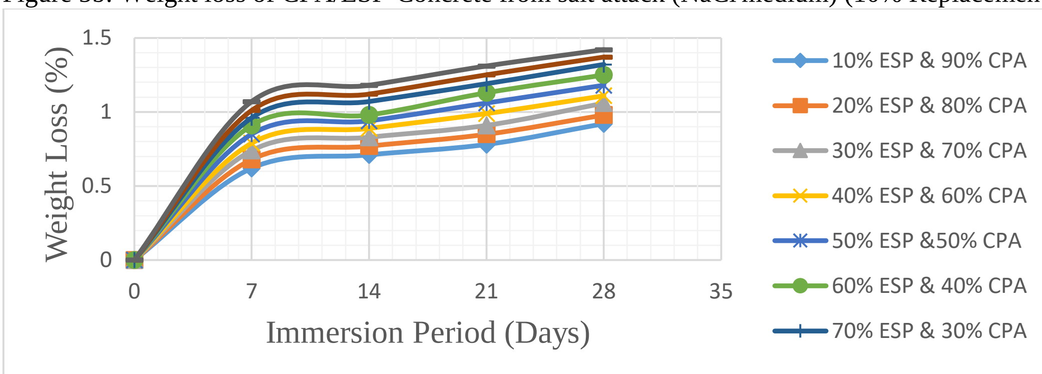

Figure 5c: Weight loss of CPA/ESP-Concrete from salt attack (NaCl medium) (20% Replacement)

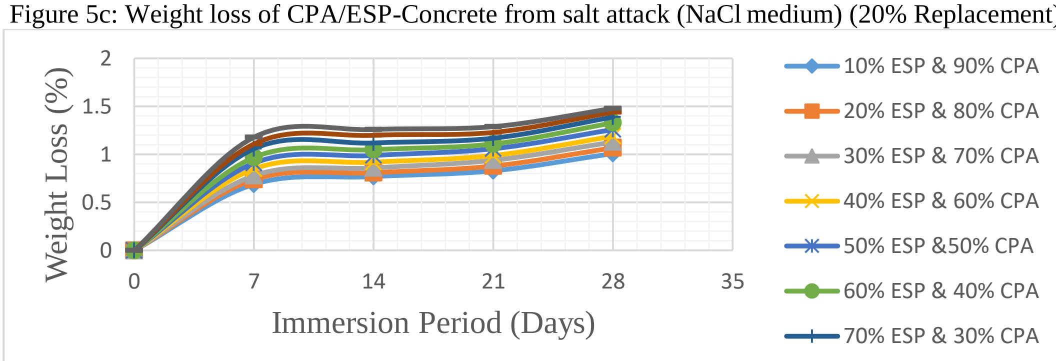

Figure 5d: Weight loss of CPA/ESP-Concrete from salt attack (NaCl medium) (30% Replacement)

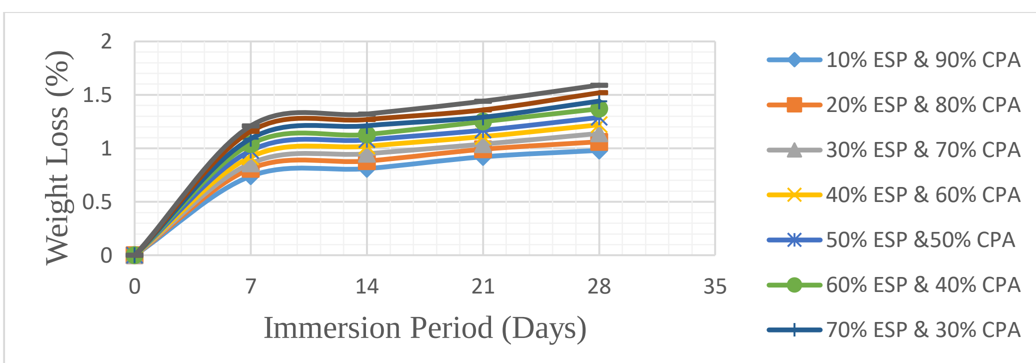

Figure 5e: Weight loss of CPA/ESP-Concrete from salt attack (NaCl medium) (40% Replacement)

The result of chloride effect on the strength retained of CPA/ESP concrete is shown in Figure 6a to 6e. The average strength retained of CPA/ESP-Concrete after immersion in a 10% concentration of sodium chloride solution (NaCl) medium, and shows that the effect of NaCl was very harsh to both CPA/ESP concrete and OPC concrete.

The poor resistance of CPA/ESP-Concrete to NaCl attack when compared with plain OPC concrete could be attributed to incomplete pozzolanic reaction of CPA/ESP after 28 days curing in water. This is in line with the report by Sideris and Sarva (2001) that the replacement of OPC by a pozzolanic material usually has beneficial effect on cement durability at ages up to 1.5years. Also the pozzolanic reaction usually reduces the $Ca(OH)_2$ available for reaction with acids, but ESP with a high content of CaO produced additional $Ca(OH)_2$ for reaction with NaCl to produce aquerous calclium chloride salt which is deleterious in concrete.

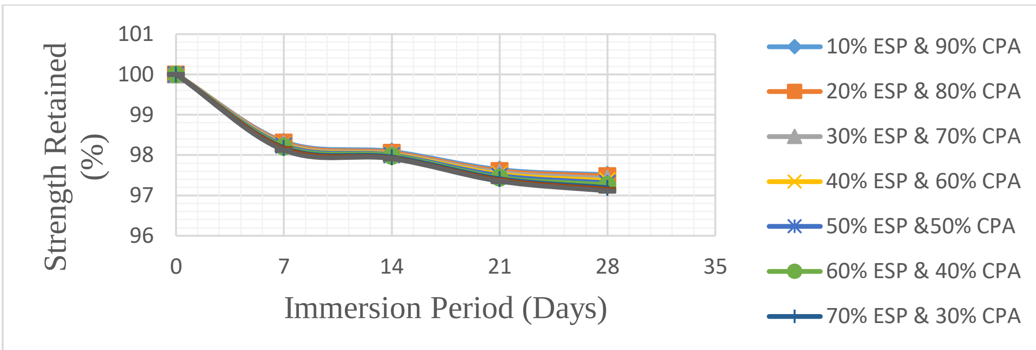

Figure 6a: Strength retain of CPA/ESP-Concrete from salt attack (NaCl medium) (5% Replacement)

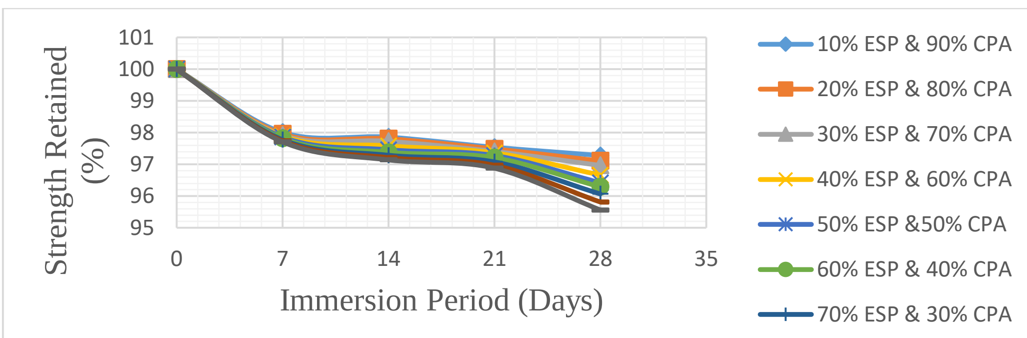

Figure 6b: Strength retain of CPA/ESP-Concrete from salt attack (NaCl medium) (10% Replacement)

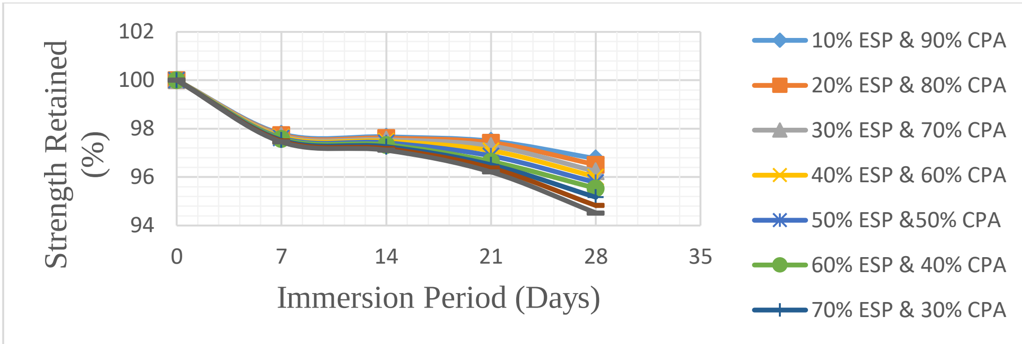

Figure 6c: Strength retain of CPA/ESP-Concrete from salt attack (NaCl medium) (20% Replacement)

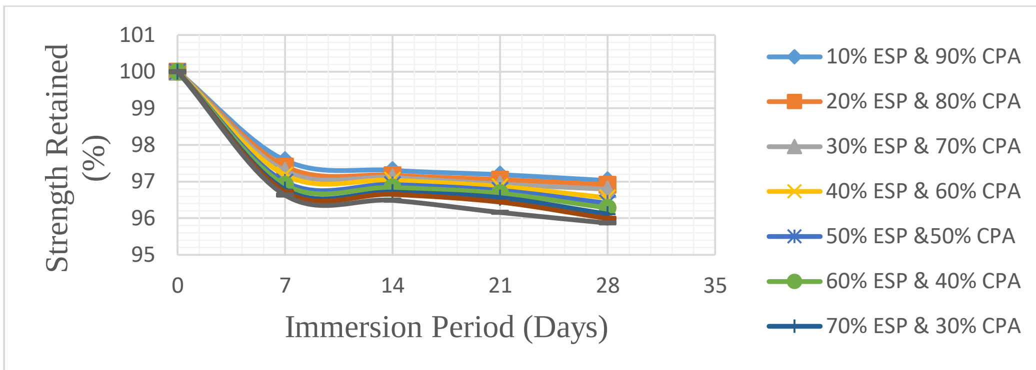

Figure 6d: Strength retain of CPA/ESP-Concrete from salt attack (NaCl medium) (30% Replacement)

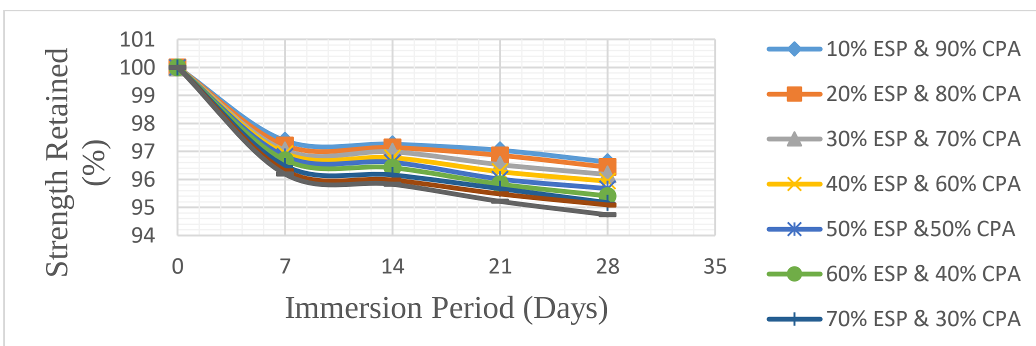

Figure 6e: Strength retain of CPA/ESP-Concrete from salt attack (NaCl medium) (40% Replacement)

Conclusion

The effect of curing blended cement – CPA/ESP concrete in 10% concentrations of sodium chloride has been studied and the following conclusions were reached:

i. Compressive strengths increase with age but reduce with increase in CPA/ESP content in the mix especially when more than 10% CPA/ESP is used. CPA/ESP appears to contribute to late strength development of concrete when up to 10% by weight of cement is used.

ii. The rate of water absorption for CPA/ESP concrete was higher than the control when more than 10% CPA is used. This was because the availability of moisture and eggshell powder allowed the CPA/ESP concrete to generate more C–S–H gel to fill up the existing voids and reduce the permeability of the concrete.

iii. The use of sodium chloride solution in concrete production reduce the strength of concrete.

iv. The use of sodium chloride solution inhibits pozzolanic reaction between CPA/ESP. and calcium hydroxide to take place.

v. The presence of sodium chloride solution in water reduces strength of concrete.

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