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ORIGINAL RESEARCH ARTICLE

EFFECTS OF RICE HUSK ASH ON DURABILITY OF SELF-COMPACTING CONCRETE MADE WITH CASSAVA PEEL ASH

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ABSTRACT

Self-compacting concrete (SCC) is a highly flowable concrete with improved strength and surface smoothness. The preparation of SCC requires high amount of cement. This utilizes tremendous amount of energy and releases carbon dioxide into the atmosphere. It is critical to reduce CO_2 emissions during Portland cement (PC) manufacture by partially replacing cement in the SCC. This study evaluates the durability characteristics of SCC produced using cassava peel ash (CPA) combined with rice husk ash (RHA) at 5, 10, 15, 20, and 25 percent cement replacement levels respectively. The effects of water absorption, H_2SO_4 attack, $MgSO_4$ attack, and high heat on SCC made with CPA and RHA blends were examined. The results show that, as CPA and RHA proportions rise by approximately 5% CPA and 10% CPA+RHA substitution, SCC compressive strength equates to design strength (grade 35). It was also discovered that CPA and RHA both enhance resistance to H_2SO_4 and $MgSO_4$ degradation, but perform poorly when exposed to elevated temperatures when compared to the control specimen. However, when CPA is utilized with RHA in SCC, the rate of water absorption is reduced to a minimum due to an enhanced pore structure of the CPA-SCC specimen. Generally, a 5% CPA content is considered as the optimum replacement of cement for self-compacting concrete with grade 35.

1.0 Introduction

Concrete is important in most structures and projects in general. It is a composite material composed of fine and coarse aggregates bonded together with cement and a precise proportion of water. According to CSI (2009) the global use of concrete is estimated to rise to around 25 billion tons per year, which translate to more than 3.8 tons per person per year.

Self-Compacting Concrete (SCC) has become one of the most sought types of concrete since it was first launched in the early 1990s (Schutter and Audernaert, 2007), and it has created a new area of research in the field of concrete technology. According to Mohammed (2011) SCC is a concrete that can be poured and compacted under its own weight with little or no vibration effort while being cohesive enough to be handled without segregation or bleeding of the fresh concrete. It has various advantages, including easier placement, the elimination of the requirement for compaction, and the saving of time and labour costs. For improved slump flow and segregation resistance, the SCC depends on increased binder (cement) proportion and the use of super-plasticizers. Conversely, the significant energy consumption and release of carbon dioxide into the environment while manufacturing cement is a major source of worry (Kong and Sanjayan, 2008). According to Malhotra (2002), the quantity of carbon dioxide exhaled when manufacturing 1000 kg of cement is approximately one (1) ton per year, which is caused by limestone calcination and fossil fuel burning. Furthermore, the international energy agency (IEA) estimates that the cement industry releases 2.4 billion tons of CO_2 as at the year 2020, accounting for 7% of total emissions.

It is noteworthy that the use of new and environmentally friendly concrete with a low cement percentage through partial substitution with agricultural wastes such as cassava peel, rice husk, and millet husk become a very appealing way to reducing this risk.

According to Adesanya *et al.* (2008), the cassava peel accounts for 20-35 percent of the weight of the tuber, especially when hand peeling. The presence of huge amounts of cassava peel waste near garri processing centers is a source of concern and pollution, as attempts to eliminate them through combustion or natural decomposition are occasionally futile. According to Ettu *et al.* (2013b), the rate of dumping of cassava peelings is 5-8 times higher than the rate of biodegradation in open-air dumpsites.

Rice husk, on the other hand, had commonly been thrown into water streams, causing pollution and contamination of springs until it was discovered to be a beneficial mineral additive for concrete (Sua-iam and Makul, 2012; Krishna *et al.,* 2016). It contains a large amount of silicon dioxide (SiO_2), is a super-pozzolana, and is recommended for use in concrete production (Sheth *et al.,* 2014; Aboshio *et al.,* 2018).

Hence, recycling such agricultural wastes into new construction materials might be a realistic key to the ecological pollutant. Therefore, this study is aimed at investigating the durability performance of self-compacting concrete using different percentage of ternary blends (CPA and RHA) as substitute to cement.

2. Materials and Methods

2.1 Materials

The materials used for this study are Portland cement of Dangote brand 42.5R (main binder), cassava peel ash and rice husk ash as pozzolanic binders with specific gravities of 2.01 and 2.07, respectively.

Cassava peels were gathered from various cassava farmers' disposal sites in Dadin-Duniya Village, Gabasawa Local Government Area, Kano, Nigeria. They were collected in 50 kg bags, washed, and then air-dried for 48 hours to remove moisture. Rice husks were obtained from rice milling plants in Kura Town, Kura Local Government Area, Kano, Nigeria.

They were each burned for two (2) hours at a controlled temperature of 600°C, allowed to cool, and then sieved through a 75 µm British Standard sieve to generate fine ash. The chemical composition of cement, CPA, and RHA as determined by X-Ray Fluorescence (XRF) test using XRF Nitron 300 machine is shown in Table 1.

Table 1: Oxides Analysis of binders

Oxide	Cement	CPA	RHA
SiO_2	15.614	43.164	82.171
Al_2O_3	3.222	3.945	0.403
Fe_2O_3	3.343	3.320	1.680
CaO	74.088	21.090	5.518
MgO	0	3.395	1.331
CuO	0.003	0.003	0.002
MnO	0.045	0.056	0.345
Cr_2O_3	0	0.005	0
TiO_2	0.058	0.475	0.164
ZnO	0.004	0.055	0.222
LOI	3.13	15.27	4.940
SG	3.16	2.01	2.07
Fineness	13	26	28

Clean river sand (fine aggregate) with a specific gravity of 2.62 sourced from River Challawa in Kano, Nigeria was used. Sieve analysis was conducted on the fine aggregate, and it was classed as Zone 2 using BS EN 882 (1992) grading limitation as depicted in Figure 1.

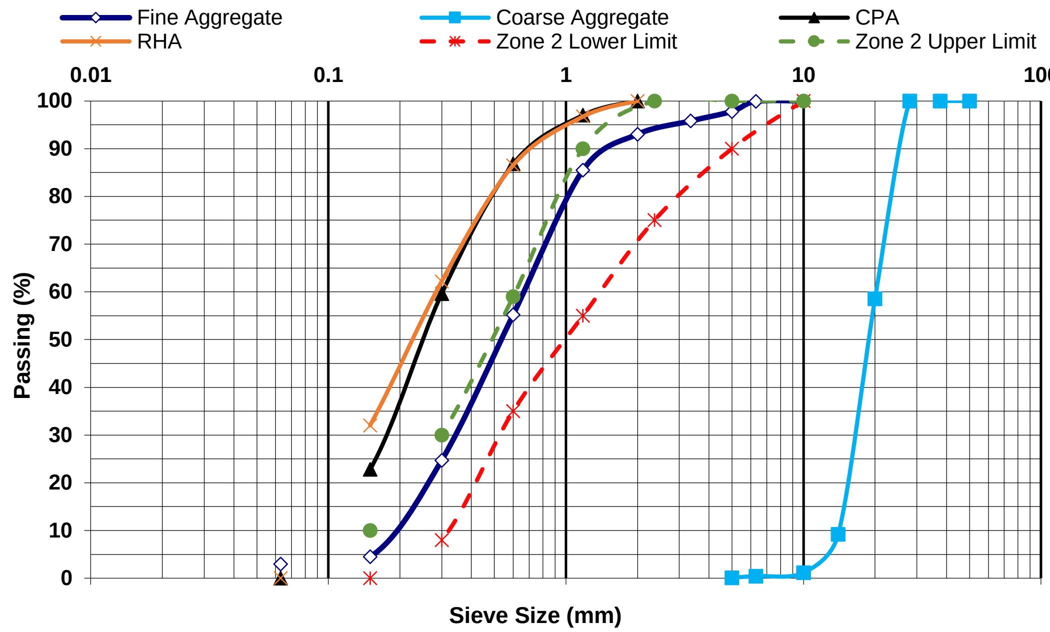

Figure 1: Sieve analysis chart of ashes and aggregates

A 20 mm sized machine crushed gravel stone was used as the coarse aggregates. The aggregate's specific gravity and crushing value are 2.7 and 22 % respectively. Drinking water that meets the ASTM C1602-12 (2012) was used for the SCC's batching and curing. A chloride-free liquid super-plasticizer was added to the SCC's mix at 1.4% weight of binder as described by the manufacturer to improve its workability.

2.2 Sample preparation and testing

EFNARC (2005) and ACI (2002) specifications and guidelines were used in conjunction with trial experiments to achieve a mix design with grade 35 strength of SCC. As recommended by the manufacturer, 1.4% of weight of the binder's weight was utilized as the dosage of the superplasticizer. The proportions for varied CPA and RHA substitutions are as shown in Tables 2-3 respectively.

Table 2: SCC Mix Proportion for CPA Contents

Mix No.	CPA (%)	Cement (kg/m³)	CPA (kg/m³)	Fine Aggregates (kg/m³)	Coarse Aggregates (kg/m³)	Water (kg/m³)	Super-plasticizer (kg/m³)
MCP-00	0	500	0	805.46	884.56	200	7
MCP-01	5	475	25	805.46	884.56	200	7
MCP-02	10	450	50	805.46	884.56	200	7
MCP-03	15	425	75	805.46	884.56	200	7
MCP-04	20	400	100	805.46	884.56	200	7
MCP-05	25	375	125	805.46	884.56	200	7

Table 3: SCC Mix Proportion for CPA + RHA Blends

Mix No.	CPA (%)	RHA (%)	Cement (kg/m³)	CPA (kg/m³)	RHA (kg/m³)	Fine Aggregates (kg/m³)	Coarse Aggregates (kg/m³)	Water (kg/m³)	Super-plasticizer (kg/m³)
MCR-00	0	0	500	0	0	805.46	884.56	200	7
MCR-01	0	10	450	0	50	805.46	884.56	200	7
MCR-02	5	10	425	25	50	805.46	884.56	200	7
MCR-03	10	10	400	50	50	805.46	884.56	200	7
MCR-04	15	10	375	75	50	805.46	884.56	200	7

For compressive strength testing, fifty-four (54) samples of SCC made with CPA and forty-five (45) specimens made with RHA blends were used following the mix proportions from Tables 2 and 3. Cement, CPA, and RHA were thoroughly dry mixed and added to fine aggregate, which was then mixed with the coarse aggregate. Water and super-plasticizer were manually added while mixing, and the material was cast using a 100 mm diameter and 200 mm length steel cylinder moulds. They were allowed to set for 24 hours at room temperature and were demoulded before curing in water for 3, 7, and 28 days, according to BS EN 12390-2 (2019).

2.2.1 Water absorption

The water absorption test was carried out in accordance with BS EN 1881-122 (2020) on eighteen (18) 100 mm x 100 mm x 100 mm cubes made at 0, 5, 10, 15, 20, and 25% cement substitution with CPA and then immersed in water for 28 days. The specimens were air-dried for 24 hours before being weighed and recorded. They were then cured in water for 7 days before being air-dried and re-weighed to calculate the amount of water absorbed using Equation 1. When blending with RHA, the procedure was repeated.

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100\% \qquad (1)$$

where: W_1 = weight of dried cube (g), W_2 = weight of saturated cube (g)

2.2.2 Acid and sulfate attack

In a container, a 5% solution of Hydrogen Tetraoxosulphate (VI) acid (H_2SO_4) was prepared, and eighteen (18) concrete cylinders of 100 mm diameter and 200 mm height were weighed and immersed in the acidic solution after curing in water for 28 days. The specimens were then cured in the solution for 3, 7, and 28 days, respectively. The specimens were air dried and reweighed after the curing intervals to evaluate the weight loss of SCC containing CPA subjected to acidic aggression using Equation 2. Another set of SCC specimens were made using CPA+RHA at 10%, 15%, 20%, and 25% cement substitution, and the procedure was repeated. The whole experiment was repeated to assess the effect of salt, but this time using a 5% solution of Magnesium Tetraoxosulphate (V) ($MgSO_4$). This method is similar to that of Ogork and Uche (2014).

$$Percentage\ weight\ loss = \frac{Loss\ in\ weight}{Initial\ weight} \times 100\% \qquad (2)$$

2.2.3 Effect of elevated temperature

After curing for 28 days in water, hardened CPA SCC and those of CPA + RHA cubes of 100 mm x 100 mm x 100 mm were weighed and then exposed to excessive temperature for one (1) hour using a Carbolite CWF1100 model furnace at a temperature range of 0 °C to 1000 °C at 200 °C intervals and then allowed to cool. After reweighing, the effect of the increasing temperature was analyzed using Equation 3. This is in conformity to the procedure followed by Ogork and Auwal (2017).

$$\text{Percentage weight loss} = \frac{W_1 - W_2}{W_1} \times 100(\%) \qquad (3)$$

Where:

W_1 = Initial weight (g)

W_2 = Final weight (g)

3. Results and Discussion

3.1 Strength development

Figure 2 depicts the compressive strength obtained from various CPA SCC mixtures utilized in this investigation. The strength increases with curing age at 3, 7, and 28 days, while it declines with increasing CPA content. Also, when mix MCP-01 is utilized, the strength (36 MPa) after curing for 28 days is somewhat higher than grade 35 SCC (35 MPa) being design strength. The pozzolanic interaction of $Ca(OH)_2$ during cement hydration and CPA SiO_2 could explain the increase in strength with curing age. The observation is also consistent with Raheem *et al.* (2015) report that CPA has the ability to contribute to 28-day strength growth when utilized at 5%.

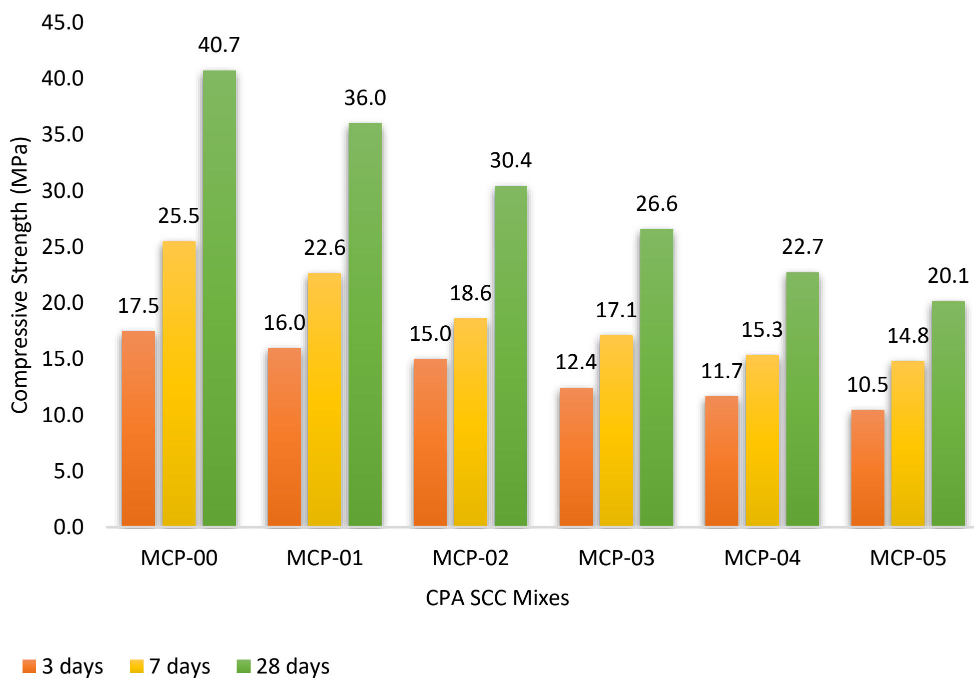

Figure 2: Compressive Strength of CPA SCC

As RHA is blended into the CPA SCC using mix MCR-01 (0 % CPA + 10 % RHA), the strength increases above the control samples and then decreases with increased cement content replacement, as shown in Figure 3. This increase in strength could be attributed to the stronger pozzolanic reaction of RHA content, as well as a superior filler effect than CPA. This is comparable to the conclusions reached by Ogork and Uche (2014) while dealing with groundnut husk waste.

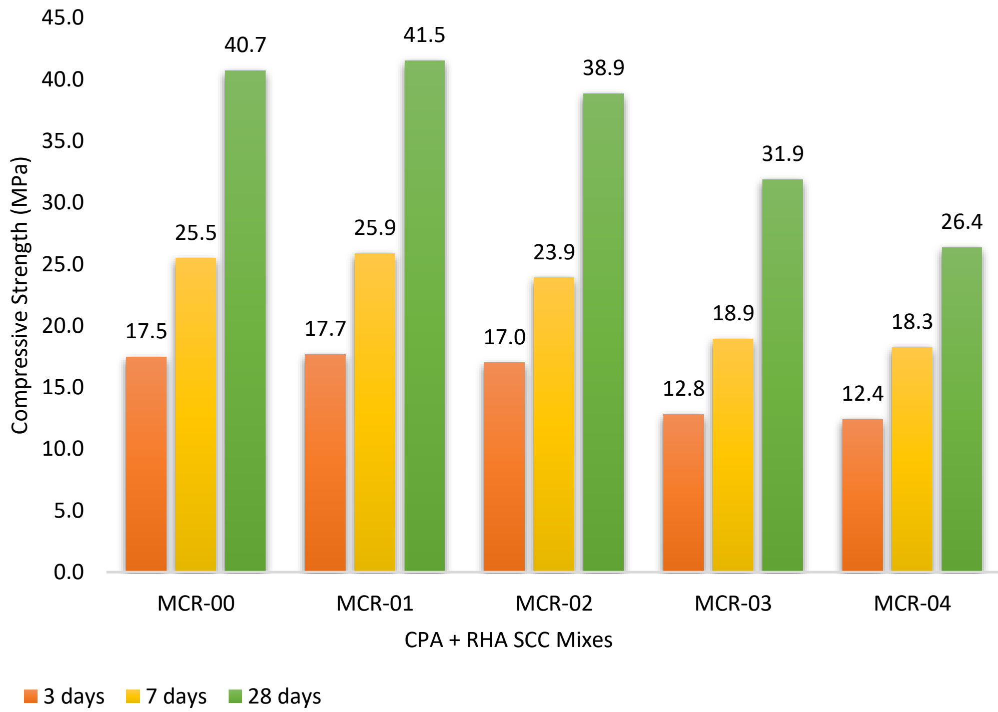

Figure 3: Compressive Strength of CPA + RHA SCC Blends

3.2 Water absorption

As shown in Figure 4, the water absorption capacity of CPA SCC reduces as the percentage of cement replaced with CPA increases (Raheem *et al.,* 2015).

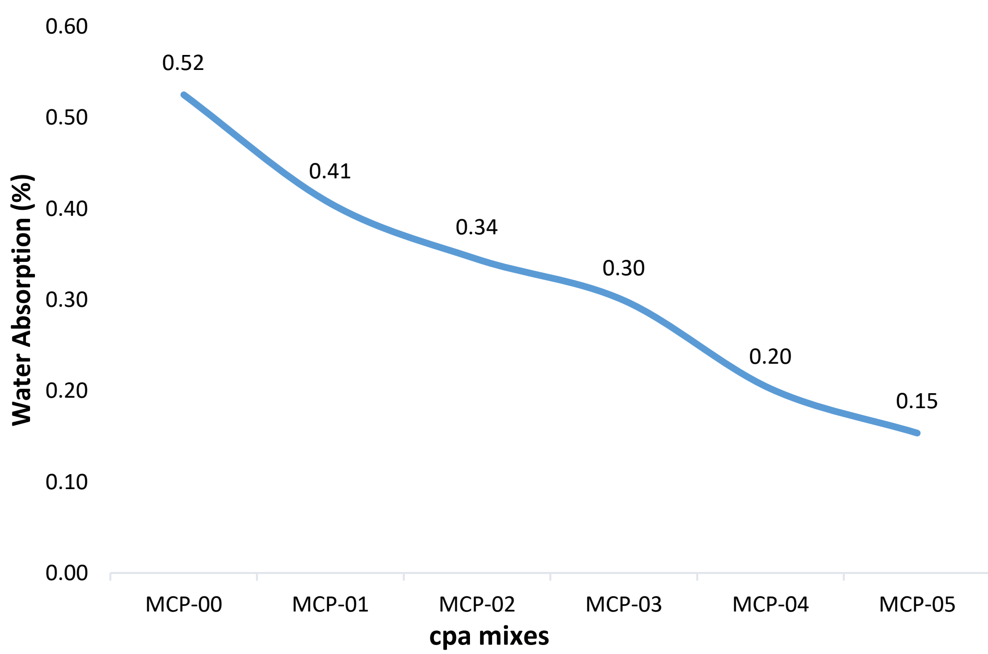

Figure 4: Water Absorption for CPA SCC

The decrease in water absorption may be due to the reduction of holes as the CPA concentration increases, which also improves the uniformity of the SCC.

It was also discovered that when RHA was introduced to the CPA SCC for MCR-01 (10%) and MCR-03 (20%) mixes compared to the CPA SCC without RHA, there was a slight decrease in water absorption, as shown in Figure 5. The reduced water absorption could be related to the further lowering of porosity of CPA SCC as RHA with smaller particles is blended to fill more voids (Safiuddin *et al.,* 2011).

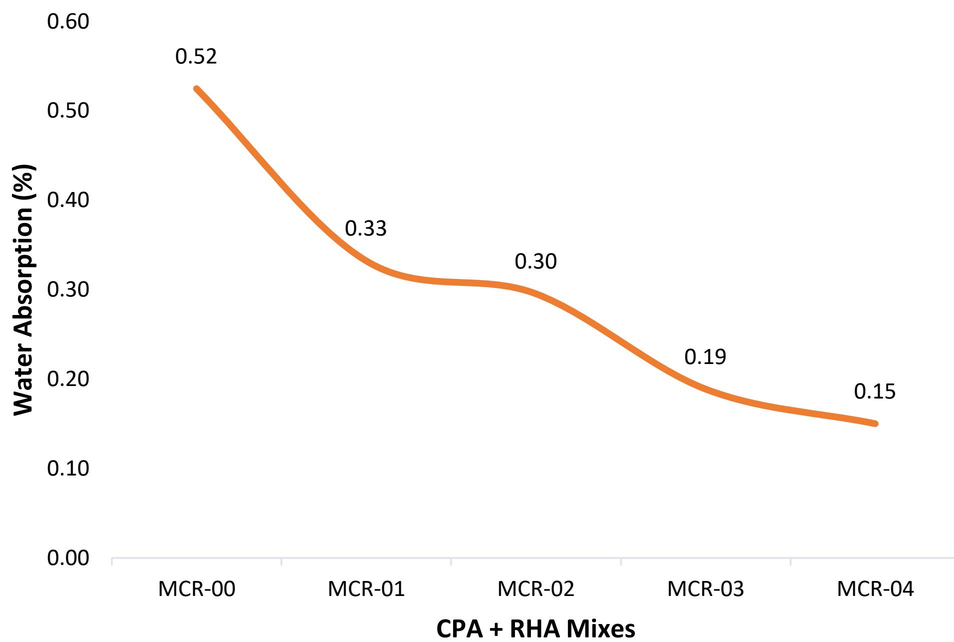

Figure 5: Water Absorption for CPA + RHA SCC

3.3 Immersion in sulphuric acid (H_2SO_4)

The weight of SCC made with CPA and RHA when immersed in a 5% solution of H_2SO_4 decreases with age, as shown in Figures 6 and 7. This is consistent with Olonade's *et al.* (2014) conclusion that when cured in sulphuric acid solution, the mass of CPA concrete cubes gradually decreases with age. The weight loss might be attributed to the greater CaO content of Portland cement and the weaker gypsum generated as a result of the neutralization reaction between H_2SO_4 and $Ca(OH)_2$.

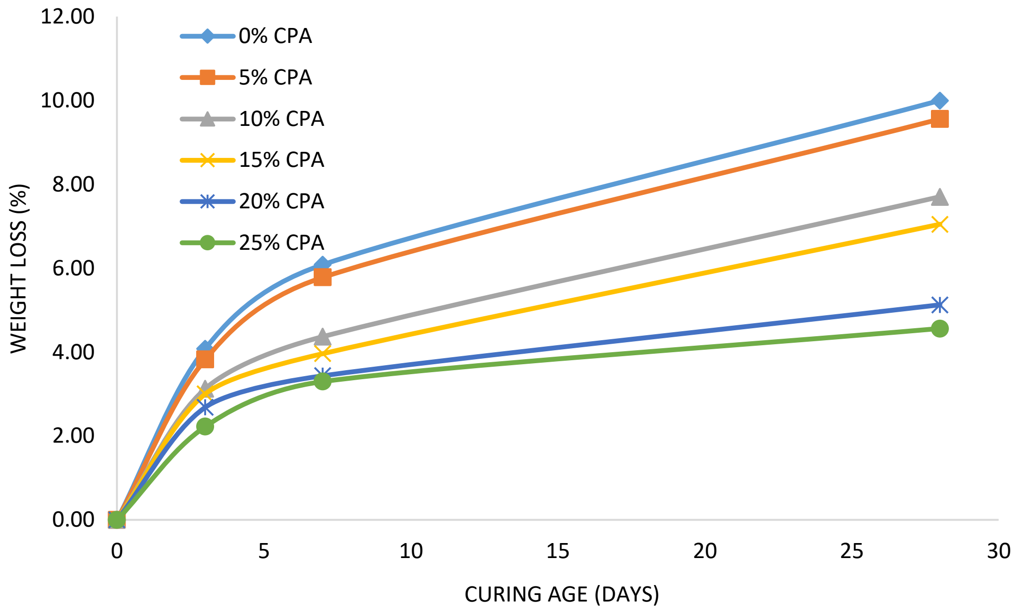

Figure 6: Effect of Immersion in H_2SO_4 for CPA SCC

It was also discovered that during the sulphate attack, sulphate ions react with cement hydration products, resulting in an alteration of the C-S-H structure and a decrease in SCC strength. It is worth mentioning that the sulphate attack on the CPA SCC decreases below the control with increasing CPA concentration, which could be attributed to the lower CaO content of CPA particles compared to Portland cement (Chatveera and Lertwattanaruk, 2011). However, when RHA is combined with CPA SCC, there is a modest improvement in sulphate attack, as reported by Sakr (2006).

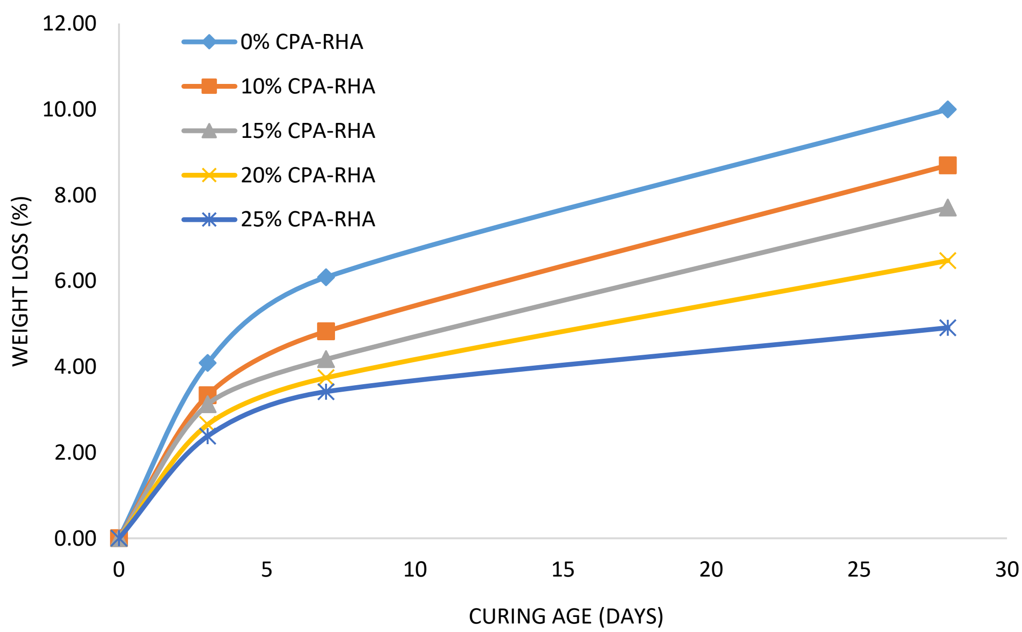

Figure 7: Effect of Immersion in H_2SO_4 for CPA + RHA SCC

3.4 Immersion in magnesium sulphate ($MgSO_4$)

As shown in Figures 8 and 9, the attack of sulphate on CPA SCC rises with immersion age, which reduces its weight. This could be due to continual sulphate exposure over time.

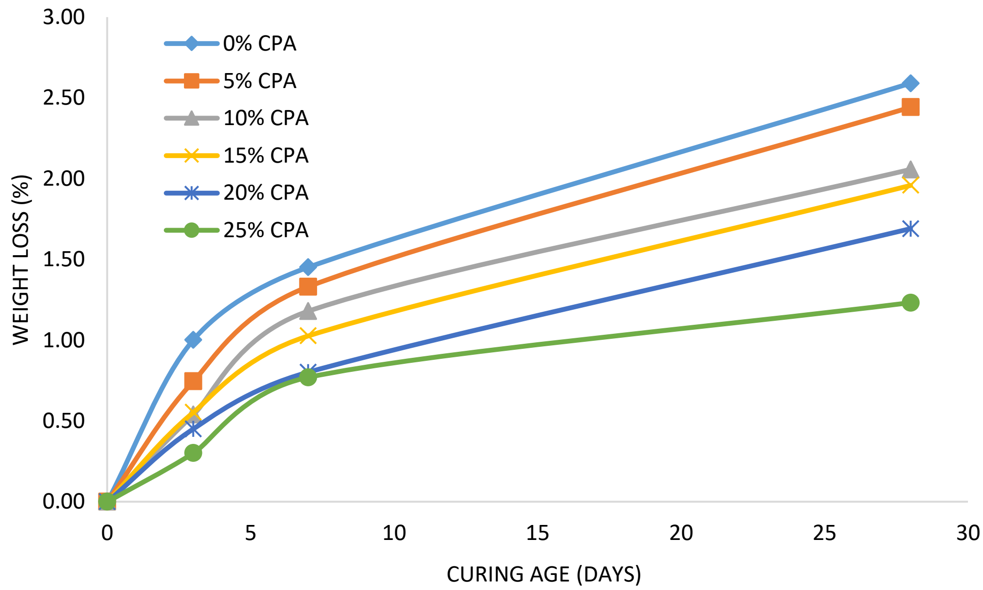

Figure 8: Effect of Immersion in $MgSO_4$ for CPA SCC

The weight loss experienced by the CPA + RHA SCC, on the other hand, decreased as the CPA content blended with RHA increased. This was due to the pozzolanic reaction and the ability of both CPA and RHA to fill empty voids in the CPA-RHA SCC (Chatveera and Lertwattanaruk, 2011).

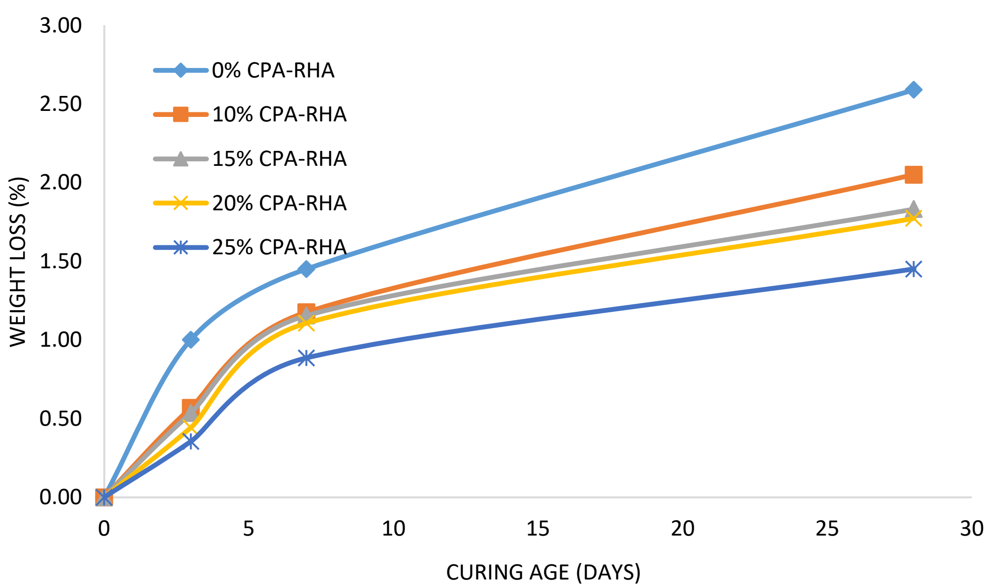

Figure 9: Effect of Immersion in $MgSO_4$ for CPA + RHA SCC

3.5 Effect of elevated temperature

The effect of increased temperature on CPA SCC, as shown in Figures 10 and 11, demonstrates that SCC produced with CPA and RHA loses weight as the temperature rises and the CPA ratio rises. This could happen due to dehydration of hydrated calcium silicate, which increases internal stresses and causes micro cracks on the specimens (Othuman and Wang, 2012).

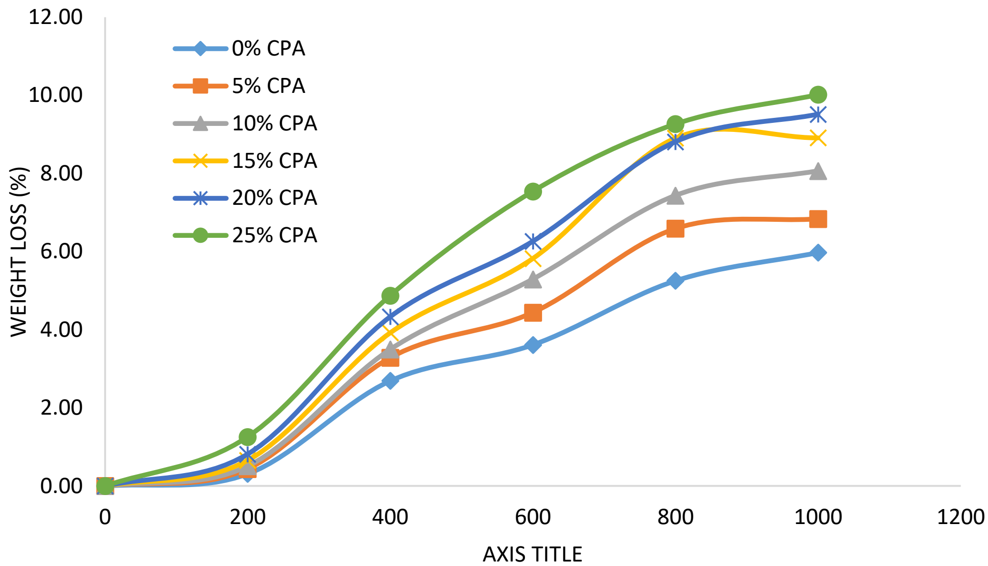

Figure 10: Effect of Elevated Temperature on Weight Loss of CPA SCC

According to Ogork and Auwal (2017), the weight loss could potentially be attributable to the removal of excess pore water in the SCC specimen. However, when the temperature exceeds 600°C, the CPA SCC changes colour from grey to slightly yellowish grey, whereas it changes from 400°C and above when RHA is added.

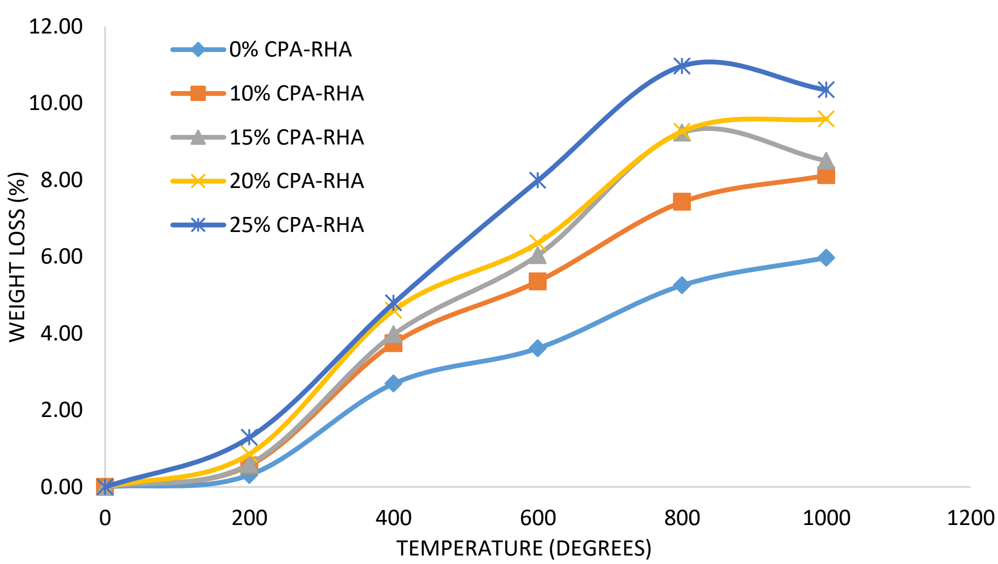

Figure 11: Effect of Elevated Temperature on Weight Loss of CPA + RHA SCC

4. Conclusion

The findings of the study revealed that SCC compressive strength equates to the design strength (35N/mm^2) as CPA and RHA proportions rise by no more than 5% CPA and 10% CPA+RHA substitution, respectively. The usage of CPA and RHA in SCC reduces the SCC's water absorption. Also, the resistance to H_2SO_4 and $MgSO_4$ degradation increase with increase in the content of CPA in SCC while it experiences more resistance when RHA is added to the CPA SCC. Furthermore, the heat resistance of CPA and CPA+RHA SCC decreases as the content of CPA and RHA increases.

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