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PERMEABILITY OF CORNCOB ASH, ANTHILL SOIL AND RICE HUSK ASH REPLACED CONCRETE

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Abstract: Durability of concrete is defined as its ability to resist any form of deterioration, allowing it to retain its original form and quality after exposure to the environment of its intended use. Permeability is the most important aspect of durability and service lives of concrete structures, and is measured by the ease with which a gas or liquid can get into and pass through concrete, or rate at which water under pressure can flow through interconnected voids within concrete. It has been suggested that pozzolanic reactions from Supplementary Cementitious Materials (SCMs) help in filling up pores using the Calcium Silicate Hydrate (C-S-H) gel that is formed during the secondary hydration of cement, through the reaction of calcium hydrixide [$Ca(OH)_2$] with silicon dioxide (SiO_2), which densifies the pore structure and transition zone, thereby reducing permeability from the packing effect of unreacted particles. This work investigated the water absorption performance of Corncob Ash (CCA), Anthill Soil (AHS) and Rice Husk Ash (RHA) concrete specimens. Tests were conducted on specimens that were found to have achieved the highest compressive strengths from strength tests and also on specimens that were made out of 30% (per cent) cement replacements. Results indicated that the water performance of all the three materials, including that of the ternary specimens of CCA and AHS were above those of the control specimens at highest compressive strength, and highlight the potential of using CCA, AHS and RHA at lower replacements to improve the durability of concrete.

Keywords: Permeability, water absorption, supplementary cementitious materials, corn cob ash, anthill soil, rice husk ash

INTRODUCTION AND BACKGROUND

Durability of concrete is defined as its ability to resist any form of deterioration, allowing it to retain its original form and quality after exposure to the environment of its intended use [1, 2]. Permeability is the most important aspect of durability and service lives of concrete structures [3-5]. It is measured by the ease with which a gas or liquid can get into and pass through concrete as is shown in figure 2.12, or rate at which water under pressure can flow through interconnected voids within concrete [4, 6-8].

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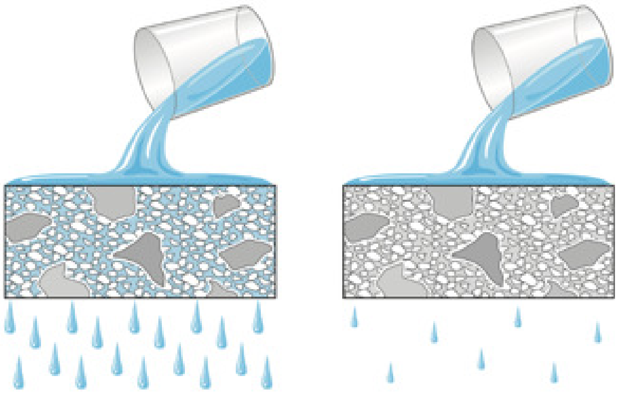

Figure 1. A highly permeable concrete readily allows water in and through it [6]

Low permeability not only increases the time to the initiation of corrosion of embedded reinforcement, but also reduces the rate of corrosion after its initiation [7]. Atkinson and Hearne [9] and Mehta [10] are in agreement with Arya [7] that maintaining low permeability is more important than controlling the chemistry of cement because it inhibits the diffusivity of sulfate ions, thereby improving the durability of concrete. Arya [7] and Neville and Brooks [4] posited that durability is directly proportional to the compressive strength of concrete, even though Ghoddousi, et al. [11], Lawrence and Ringot [12], Shetty [13] and Taylor [14] cautioned against using compressive strength on its own to characterise durability because of the complex nature of durability such as design characteristics, workmanship, grading of aggregates and severity and duration of exposure among others. Pozzolanic reactions from Supplementary Cementitious Materials (SCMs) fill up pores using the Calcium Silicate Hydrate (C-S-H) gel that is formed during the secondary hydration of cement by the reaction of calcium hydrixide [$(Ca(OH)_2$] with silicon dioxide (SiO_2), densifiying the pore structure and transition zone, thereby reducing permeability from the packing effect of unreacted particles, [1, 15-22]. Corncob Ash (CCA), Anthill Soil (AHS) and Rice Husk Ash (RHA) are such materials, which have neither been studied nor applied extensively [17]. CCA, AHS and RHA's suitability as SCMs have been reported by Adesanya [23], Adesanya and Raheem [24], Le and Ludwig [25], Kamau, et al. [26], Kamau, et al. [27], Kamau, et al. [28] and Zerbino, et al. [29]. Limited work was found on the water absorption of CCA and RHA, while no work was found on AHS. For CCA, an anormally was found in literature, whereby Adesanya and Raheem [1] reported a decrease in permeability of between 1.5% and 34.4% at CCA replacements of between 2% and 15%, while Udoeyo and Abubakar [30]'s reported that the control specimens were superior to all CCA specimens at all levels of replacement in resisting water absorption. This work investigated the water absorption of CCA, AHS and RHA at two different levels of replacement.

METHODS

Compressive tests were carried out on CCA, AHS, and ternary specimens of CCA and AHS at replacements by weight of cement of 0% (per cent), 7.5%, 10%, 15%, 20%, 25% and 30%. Due to a high water demand, RHA was replaced by the volume of cement using the same replacement steps. The 0% replacement, also referred to as the control in this work was used as the point of reference from which performances were measured [1]. The water absorption test was conducted to BS EN 772-11 [31] on two different sets of specimens. The first set was one which had achieved the highest compressive strengths, from the argument by Arya [7] and Neville and Brooks [4] that durability is directly proportional to the compressive strength of concrete, while the second set was one that had made out of 30% cement replacements, which was the highest replacement level for the study. The highest compressive strengths had been recorded on the 7.5% CCA, 7.5% AHS, 7.5% RHA and 5% ternary CCA and AHS. The apparatus were a water tank fitted with a supporting device, stop watch, ventilated oven capable of maintaining a temperature of 70^0 C ± 5^0 C and a weighing instrument capable of measuring to an accuracy of 0.1% of a gram (g). The test specimens were cured in water for 270 days after which they were dried to a constant mass in the ventilated oven at a temperature of 70^0 C ± 5^0 C. They were then allowed to cool down at room temperature and the dimensions to be immersed were taken conforming to BS EN 772-16 [32] . The gross area was calculated before the test specimens were immersed in water to a depth of 5mm for a total immersion time of 10 minutes conforming to BS EN 772-11 [31]. The results were calculated using [3.3] conforming to BS EN 772-11 [31]

$$C_{w.s} =(M_{so.s}-M_{dry.s}/A_{s.t\ so})\ x\ 10^{6}\ [g/(m^{2}.s)] \qquad [1]$$

Where $C_{w.s}$ is the coefficient for water absorption, $M_{dry.s}$ is the mass in grams (g) of the specimen after drying, $M_{so.s}$ is the mass in grams of the specimen after soaking for time (t), A_s is the gross area in square millimetres (mm^2) of the face of the specimen immersed in water and t_{so} is the time of soaking in seconds (s)

RESULTS AND DISCUSSIONS

Table 1 and Figure 2 represent results of the coefficient of water absorption in grams obtained from specimens at replacements that were found to have achieved highest compressive strengths and also at 30% cement replacements. Results showed that at highest compressive strengths, all SCM replaced specimens achieved lower coefficients of water absorption than those of the control specimens. For highest replacement levels, the specimens of CCA, AHS, ternary CCA and AHS and RHA showed higher coefficients of water absorption than those of the control specimens, with CCA showing the worst performance.

Table 1. Coefficient of water absorption at replacements that achieved the highest compressive strengths and at 30% cement replacements [$C_{w.s}$ (g/m^2.s)].

Specimens at highest compressive strengths	$C_{w.s}$ (g/m^2.s)	30% replacement	$C_{w.s}$ (g/m^2.s)
Control	0.5767	Control	0.5767
7.5% CCA	0.5317	30% CCA	1.3025
7.5% AHS	0.4492	30% AHS	0.5867
2.5% CCA + 2.5% AHS	0.4358	15% CCA + 15% AHS	0.8342
7.5% RHA (by volume)	0.5075	30% RHA (by volume)	0.7583

Low permeabilities of SCMs have been attributed to their hydration products precipitating in the small spaces between cement particles, blocking pores and resulting in a refined pore structure and reduced number of pores [13, 17, 33-39]. By the pozzolanic activity, SiO_2 in SCMs reacts with water and $Ca(OH)_2$ to form a foil-like C-S-H gel, that inhibits bleeding by filling capillary channels and voids which were occupied by water and water-soluble lime, resulting in a denser concrete with low permeability [3, 17, 20, 35, 40-43]. The coefficient of water absorption of CCA specimens at 7.5% replacement was lower than that of the control specimens by 8% but was 126% higher at the 30% replacement. These results were consistent with those of Adesanya and Raheem [1], who reported a decrease in permeability of between 1.5% and 34.4% at CCA replacements of between 2% and 15% but not consistent with Udoeyo and Abubakar [30] that the control specimens were superior to all CCA specimens at all levels of replacement in resisting water absorption.

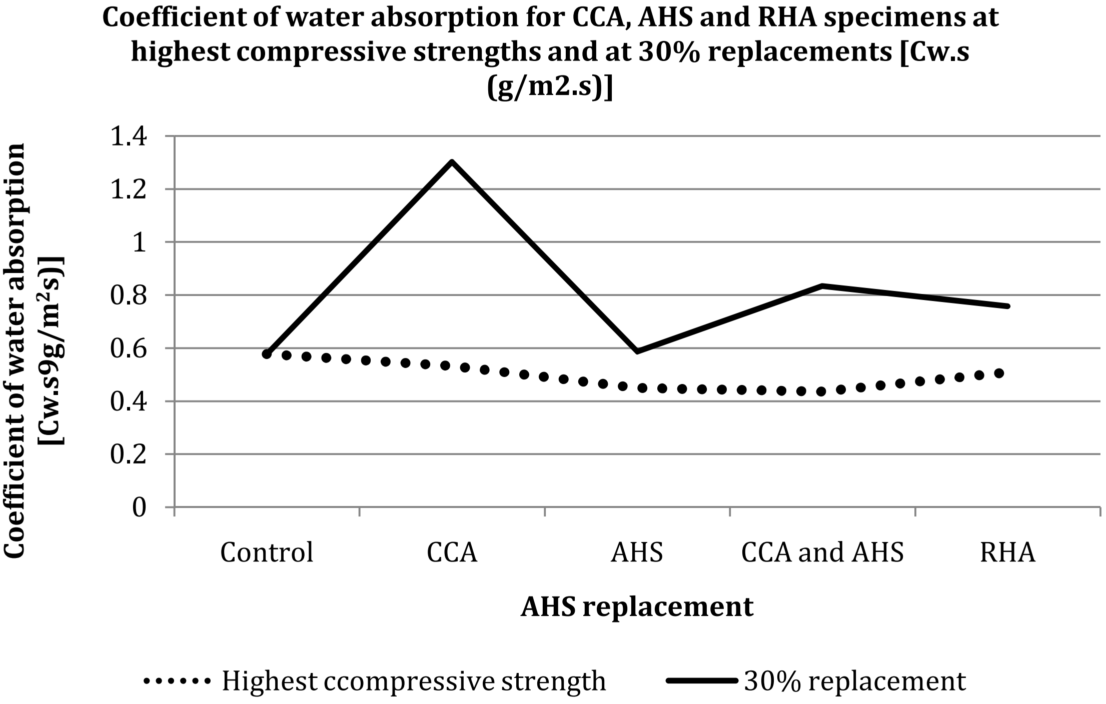

Figure 2. Coefficient of water absorption at replacements that achieved highest compressive strengths and at 30% replacements [$C_{w.s}$ (g/m^2.s)]

For AHS specimens, the coefficient of water absorption was 22% lower and 2% higher than that of the control specimens at the 7.5% and 30% replacements respectively, while for the ternary specimens of CCA and AHS, a water absorption reduction of 24% and an increase of 45% at the 5% and 30% replacements respectively was observed. AHS appeared to reduce the permeability of CCA at both replacements consistent with Bapat [17], Le and Ludwig [25], Kannan and Ganesan [44], Nehdi, et al. [45], Sathawane, et al. [46], Güneyisi and Gesoğlu [47], Rao, et al. [48], Poon, et al. [49], Khatib and Hibbert [50] that SCMs used together in concrete can improve each other's properties. For the RHA specimens, a reduction of 12% was recorded at the 7.5% replacement. These findings are consistent with Bapat (2012), Le and Ludwig (2013) and James and Rao (1986), who reported that amorphous silica in RHA reacts at latter ages with the $Ca(OH)_2$ that is produced during the hydration of cement in early ages to form strength giving C-S-H, which also improves the microstructure of the cement matrix by filling in the capillary pores. However, at the 30% replacement, the coefficient of water absorption of RHA was 31% higher than that of the control. The high coefficients of water absorption at higher SCM replacements was attributed by Adesanya and Raheem [1] to reduced levels of $Ca(OH)_2$ that is available to react with excess SCMs to form the foil like C-S-H that results in a less well-interconnected capillary pore structure, thereby leading to the creation of pores and consequently increasing water absorption. From the evidence obtained by this research, it can be concluded that CCA, AHS and RHA reduced the water absorption of concrete at highest compressive strengths, but increased it at the higher replacement. These findings highlight the potential of using CCA, AHS and RHA them at lower replacements to improve the durability of concrete.

CONCLUSION

This work investigated the water absorption performance of Corncob Ash (CCA), Anthill Soil (AHS) and Rice Husk Ash (RHA)-replaced concrete on specimens which, were found to have achieved the highest compressive strengths as well as on specimens that were made out of 30% cement replacements. Results indicated that the water performance of all the three SCMS, including that of the ternary specimens of CCA and AHS were above those of the control specimens at highest compressive strength, but were below the control at 30% replacements. The findings highlight the potential of using CCA, AHS and RHA at lower replacements to reduce the permeability of concrete and consequently improve its durability.

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