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# Rice-Husk and Sugarcane-Bagasse Ash as a Partial Replacement of Cement in Self-Compacting Concrete

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**Abstract**
The necessity for reasonable and sustainable different construction materials to cement in emerging countries cannot be underrated. However, cement among the constituent material in concrete production is broadly identified to be the most costly. Therefore, in developing countries, research into the use of alternative materials for civil and building construction is necessary due to the increasing cost of construction materials like cement. Alternative construction materials like agro and industrial wastes etc., are nowadays employed to substitute cement in concrete production. In this paper, Rice-Husk Ash (RHA) and Sugarcane-Bagasse Ash (SBA) as agro-wastes were used to replace cement partially in Self-Compacting Concrete (SCC) in order to determine their influence on the mechanical properties of the SCC hardened specimens. The percentage replacements used were 0%, 5%, 10%, 15% and 20% of the ashes in the corresponding concrete mixes. Concrete cubes and prism specimens were cast, cured and their mechanical properties (compressive and flexural strengths) were evaluated at 7, 14, 21 and 28 days. The results show that remarkable strength values of compressive and flexural strengths were manifested, when compared with the control specimens. In conclusion, it was established that 5% cement replacement of the ashes used was found to be a favorable value among the percentage replacements considered. Moreover, the study demonstrated the use of agro-wastes which may enhance the reduction of cement usage and will pave the way of innovative and sustainable construction.

## 1.0 Introduction

For quite a number of decades, the most generally used material in construction around the globe is concrete, and it is irreplaceable for large-scale infrastructure development since it has several benefits such as durability, energy-efficiency, little maintenance, affordability, fire-resistance, excellent thermal mass and also adaptability. Among the ingredients in concrete production, cement is the most versatile material which is widely known to be very expensive [1]. Nowadays the utilization of agro-waste as pozzalanas in cement-mortar or concrete productions is on the increase and has been reported by many research studies [2–4]. In developing countries like Malaysia, Nigeria, Uganda and many others, several efforts are made to utilize the application of locally available waste materials in building and civil engineering constructions as a result of the expensive nature of cement in the production of mortar or concrete [5-7]. Apart from getting cleared of these waste materials, their usage as alternative source of construction materials may save the environment from contamination; and it may also pave a way to explore the idea of using local materials especially those regarded as waste for construction purposes [8]. Conventionally, Rice-Husk, Sugarcane-Bagasse, Saw-dust and many more has been regarded a unwanted materials and has largely been discarded off by dumping or sometimes burning. However, Rice-Husk Ash (RHA) and Sugarcane-Bagasse Ash (SBA) has been magnificently employed as a pozzolanas in moneymaking and marketable production in a large number of countries in the world [9, 10].

RHA usage in civil and building construction fields may be a possible way to its removal as waste on the surroundings. Mehta [11] in (1977), observed that ashes high in silica (in crystal-like or glossy state) could be obtained subject on the combustion circumstances. He added that in the glossy silica case, vastly pozzolanic ash residues could be achieved, which may be suitable for partial replacement of Portland cement. Therefore, workability and stability improves with the employment of RHA with cement, heat evolution decreases as well as thermal cracking and plastic shrinkage etc. The process also proliferates strength advancement, impenetrability and robustness by consolidating transition zone, pore-structure transformation, covering the huge cavities in the hydrated cement mix through pozzolanic response [12]. RHA lessens expansion, enhances pore structure and deters diffusion of alkali ions to the surface of aggregate by micro permeable structure, it also decreases alkali-aggregate response. These possessions are challenging to attain by the usage of Portland cement only. Significant number of studies on the application of RHA as a material in construction has been conveyed by [12-16], where the quantity of replacement varies from 0 to 20%.

Sugarcane-bagasse which is a by-product in the sugar mills which is generally used as a fuel to fire furnaces in the mill when the juice is extracted, that resulted about 8-10% ashes containing huge quantity of un-burnt substance, such as silicon and some minor components of aluminium, iron and calcium oxides [10, 17]. The sugarcane bagasse ash contains approximately 62% of silica or more, whereas quartz and cristobalite are the major crystalline phases found in the SBA [17]. Some research studies conducted proved that the SBA when partially replaced cement had a significant effect on the strength and durability of concrete [18, 19].

In this paper, SCC is employed to replace the conventional Normal Vibrated Concrete (NVC) as its compaction inadequacy and passing insufficiency to a desired position as well as the flow of the latter is controlled by vibration. Therefore, employing a flow able and cohesive concrete as SCC may abolish the incapability of the concrete passage to a desired location as it compacts by its own self weight while its homogeneity is sustained been a self-compacting. Because of the above mentioned problem that is associated with NVC, it is therefore recommended that SCC could be employed as a substitute of the conventional concrete. Thus, the possibility of using RHA and SBA as a partial replacement of cement in SCC is investigated in order to ascertain their feasibility.

## 2.0 Experimentation

### 2.1 Materials

The materials employed in this study were cement, fine aggregates, coarse aggregates, RHA, SBA, water and superplasticizer (master glenium ACE 456). The RHA and SBA used are as shown in Figure 1 and 2.


**Figure 1** (a) Rice husk before burning (b) Rice husk after burning (c) Rice husk ash


**Figure 2** (a) Sugarcane-bagasse before burning (b) Sugarcane-bagasse after burning (c) Sugarcane-bagasse ash

#### 2.1.1 Preparation of rice husk and sugarcane bagasse to ashes

The rice husk and the sugarcane bagasse were locally sourced and obtained in Kano. The sourced materials were thoroughly washed with clean water to remove impurities and other solid debris. They were then air dried at a room for almost five (5) days. The dried specimens were burnt between 600ºC to 800ºC to collect the RHA and SBA. The collected specimens were allowed to cool and were sieved through a BS sieve size 75µm. Chemical content test on the specimens was conducted and the result is shown in Table 1.

**Table 1** Chemical content test result

| Oxides parameters | Values in (%) | |
|---|---|---|
| | SBA | RHA |
| $S_iO_2$ | 73.02 | 76.51 |
| $C_aO$ | 1.05 | 0.26 |
| $Al_2O_3$ | 1.50 | 1.05 |
| $Fe_2O_3$ | 0.78 | 0.75 |
| $M_gO$ | 0.29 | 0.28 |
| $K_2O$ | - | - |
| $SO_3$ | - | - |
| $Na_2O$ | - | - |
| MnO | - | - |
| $P_2O_5$ | - | - |
| LOI | - | - |

#### 2.1.2 Mix proportions

This is the process of choosing appropriate ingredients of concrete and defining their relative quantity with the objective of producing a concrete of a desired workability, strength and durability as economically as possible. The principle for the selection and proportioning of the SCC ingredients was based on the procedures laid by European guidelines for self-compacting concrete [20]. The amount of mix quantities of different mixes is as presented in Table 2. In summary, sixty (60) concrete cube specimens of 150 mm x 150 mm x 150 mm and forty (40) concrete prism specimens of 100 mm x 100 mm x 500 mm were prepared for compressive and flexural strengths test for both RHA and SBA specimens. The concrete used was designed for a strength of 20 N/mm$^2$ at 28 days of curing.

**Table 2** Summary of concrete mix proportions for RHA and SBA

| Constituent Materials | RHA 0% SBA 0% | RHA 5% SBA 5% | RHA 10% SBA 10% | RHA 15% SBA 15% | RHA 20% SBA 20% |
|---|---|---|---|---|---|
| Cement (Kg/m$^3$) | 376.30 | 358.50 | 337.80 | 320.00 | 302.20 |
| RHA (Kg/m$^3$) | 0.00 | 17.80 | 38.50 | 56.30 | 74.10 |
| SBA (Kg/m$^3$) | 0.00 | 17.80 | 38.50 | 56.30 | 74.10 |
| Fine Aggregate (Kg/m$^3$) | 874.10 | 874.10 | 874.10 | 874.10 | 874.10 |
| Coarse Aggregate (Kg/m$^3$) | 1312.60 | 1312.60 | 1312.60 | 1312.60 | 1312.60 |
| Water (Kg/m$^3$) | 207.40 | 207.40 | 207.40 | 207.40 | 207.40 |
| Water/cement ratio | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| Superplasticizer Dosage (Ltr/m$^3$) | 7.41 | 7.41 | 7.41 | 7.41 | 7.41 |

### 2.2 Methods

#### 2.2.1 Test procedure

Concrete mixes were examined for slump flow test in accordance with provisions in [20 - 22]. The slump flow considered in this study is slump flow class 1 (i.e., SF1) which is ranged between 550 mm to 650 mm. Compressive strength values were evaluated using cube sizes of 150 mm as earlier mentioned based on the recommendations of BS EN 12390-3 [23]. The flexural strength test was carried out in line with BS EN 12390-5 [24] procedures, using a concrete prism specimens of 100 mm x 100 mm x 500 mm as also earlier mentioned.

# 3.0 Results and Discussions

## 3.1 Fresh Properties of the SCC

The concrete mixes were identified as B1, B2, BA, BB etc., for specimens with RHA and SBA respectively. The slump flow test was conducted on the fresh concrete mixes containing zero RHA and SBA (control specimens) and those with the percentage addition (test specimens). The result of the slump flow and T500 test is presented in Table 3.

**Table 3** Slump flow and $T_{500}$ results

| Mix | RHA % Replacement | Average Slump Flow (mm) | Average $T_{500}$ (s) |
|---|---|---|---|
| B1 (control) | 0 | 595 | 1.00 |
| B2 (test specimens) | 5 | 585 | 1.05 |
| B3 ( test specimens ) | 10 | 575 | 1.10 |
| B4 ( test specimens ) | 15 | 565 | 1.30 |
| B5 ( test specimens ) | 20 | 560 | 2.00 |
| Mix | SBA % Replacement | Average Slump Flow (mm) | Average $T_{500}$ (s) |
| BA (control) | 0 | 640 | 1.00 |
| BB (test specimens) | 5 | 635 | 1.00 |
| BC (test specimens) | 10 | 625 | 1.20 |
| BD (test specimens) | 15 | 610 | 1.50 |
| BE (test specimens) | 20 | 595 | 1.75 |

Standard range is between 550 mm to 650 mm for SF1 and $T_{500} \leq 2$s according EG (2005)

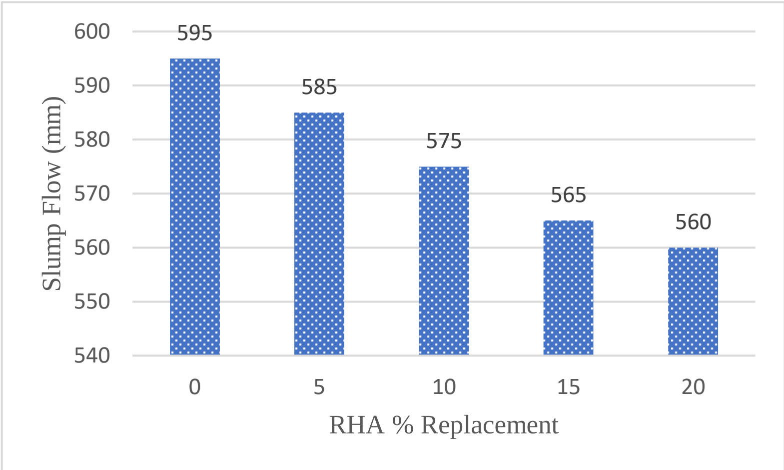


**Figure 1** Variation of slump flow with different RHA replacement

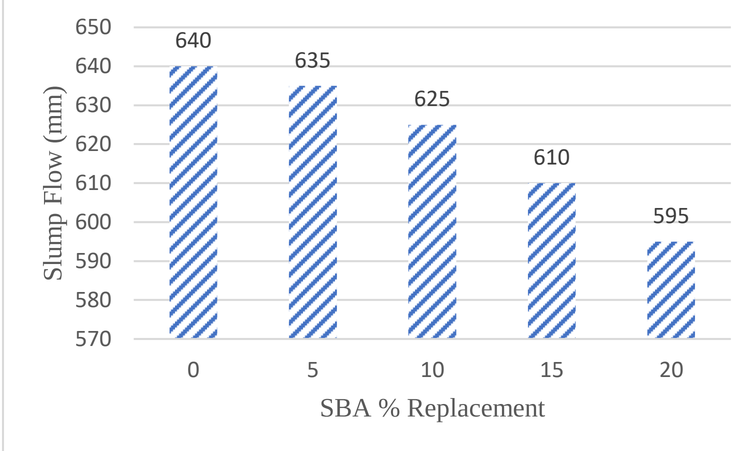


**Figure 1** Variation of slump flow with different SBA replacement

It can be observed that the slump flows of the mixes dropped when the RHA and SBA were added to the corresponding mixes (see Fig. 3 and 4). The slump flow of the mix without the RHA and SBA were noted to be 595 mm and 640 mm respectively. However, with the inclusion of the RHA and SBA by 5%, 10%, 15% and 20% the slump flows dropped to 585, 575, 565 and 560 mm for RHA specimens and 635, 625, 610 and 595 mm for specimens with SBA correspondingly. The dropped in the slump flows were as a result of the percentage addition of the RHA and SBA in the mixes. It is evident that mixes with RHA and SBA influenced the flowing ability of the corresponding mixes which resulted in slower slump flows.

### 3.2 Compressive and Flexural Strengths

Table 4 presents the results of compressive and flexural strengths with and without the RHA and SBA replacements. The results show that inclusion of RHA and SBA reduces the compressive and flexural strengths of the concrete specimens. However, remarkable increase in compressive and flexural strengths were observed with a RHA and SBA replacement of 5%. This is evident as they had a strength values both in compression and flexure close to the control specimens. This phenomenon is also illustrated in Figures 3, 4, 6 and 7. It is also evident that the compressive and flexural strengths were influenced by the addition of RHA and SBA. It can also be observed that a good correlation coefficient of $R^2$ = 0.98 for eqn. (1) was obtained between flexural and compressive strength values for specimens with RHA as shown in Figure (5). While a correlation coefficient of $R^2$ = 0.891 for eqn. (2) was obtained between flexural and compressive strength values for specimens with SBA as shown in Figure (8). This value also stands to be acceptable, hence a good correlation exist between the two strength parameters.

$$y = 0.1326x - 0.7381 \quad (1)$$

$$y = 0.0765x + 0.5712 \quad (2)$$

**Table 4** Compressive and flexural strengths of the concrete mixes

| Mix | % replacement | Average compressive strength (N/mm²) | | | | Average flexural strength (N/mm²) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 7-day | 14-day | 21-day | 28-day | 7-day | 14-day | 21-day | 28-day |
| Specimens with and without RHA replacement | | | | | | | | | |
| B1 | 0 | 15.10 | 18.02 | 21.20 | 26.95 | 1.51 | 1.80 | 2.15 | 2.80 |
| B2 | 5 | 13.78 | 17.03 | 19.25 | 26.22 | 1.40 | 1.70 | 2.03 | 2.72 |
| B3 | 10 | 12.59 | 14.63 | 17.20 | 20.89 | 1.26 | 1.50 | 1.72 | 2.09 |
| B4 | 15 | 11.41 | 13.89 | 16.50 | 19.56 | 1.14 | 1.39 | 1.65 | 1.96 |
| B5 | 20 | 10.96 | 12.00 | 15.25 | 16.63 | 1.20 | 1.20 | 1.53 | 1.36 |
| Specimens with and without SBA replacement | | | | | | | | | |
| BA | 0 | 15.00 | 18.00 | 21.00 | 26.00 | 1.45 | 1.58 | 2.00 | 2.50 |
| BB | 5 | 12.90 | 16.00 | 21.33 | 25.33 | 1.33 | 1.55 | 1.98 | 2.45 |
| BC | 10 | 11.78 | 12.89 | 16.98 | 19.78 | 1.25 | 1.50 | 1.68 | 2.33 |
| BD | 15 | 11.10 | 11.34 | 14.50 | 17.56 | 1.05 | 1.25 | 1.55 | 1.90 |
| BE | 20 | 10.67 | 11.22 | 14.00 | 13.56 | 1.11 | 1.20 | 1.45 | 1.50 |

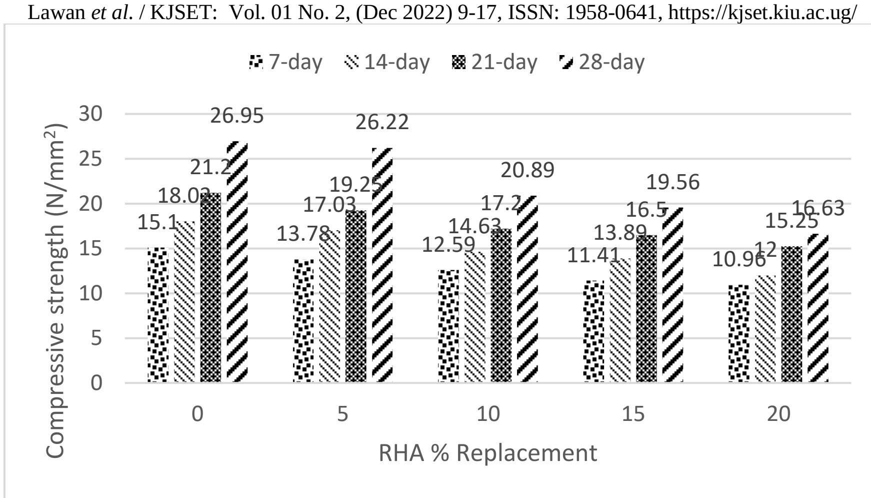


**Figure 3** Variation of compressive strength with different RHA replacement

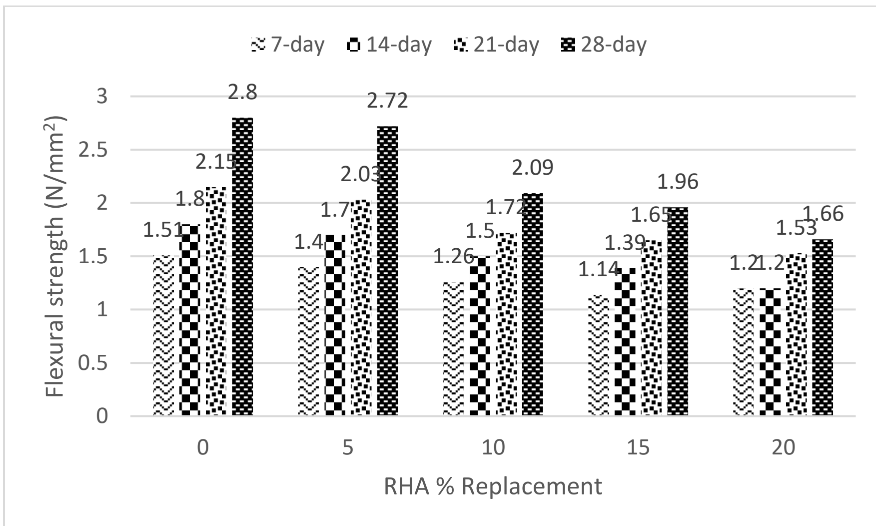


**Figure 4** Variation of flexural strength with different RHA replacement

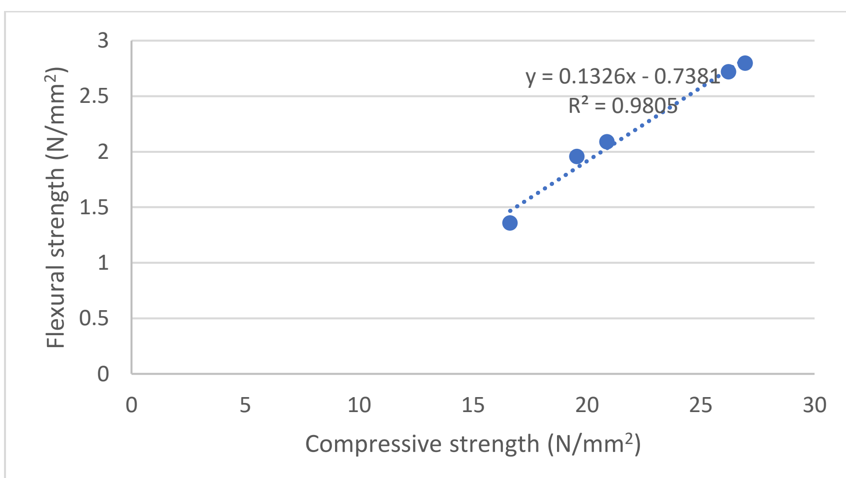


**Figure 5** Relationship between flexural and compressive strength values for RHA specimens

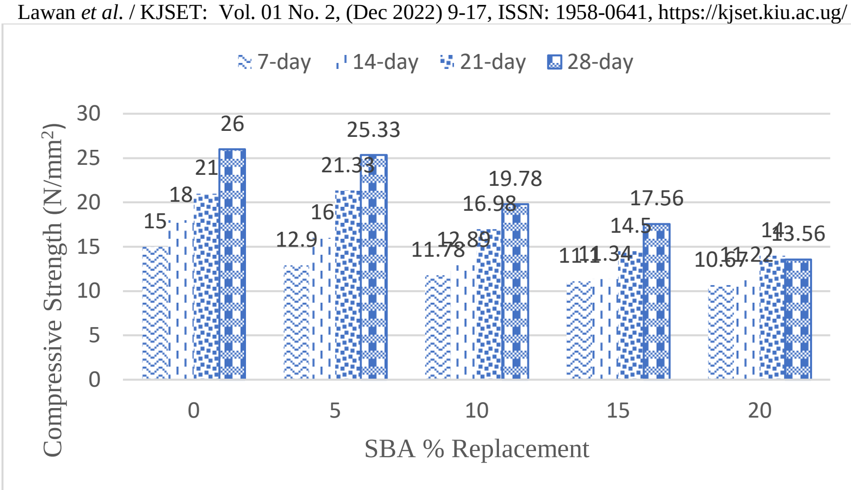


**Figure 6** Variation of compressive strength with different SBA replacement

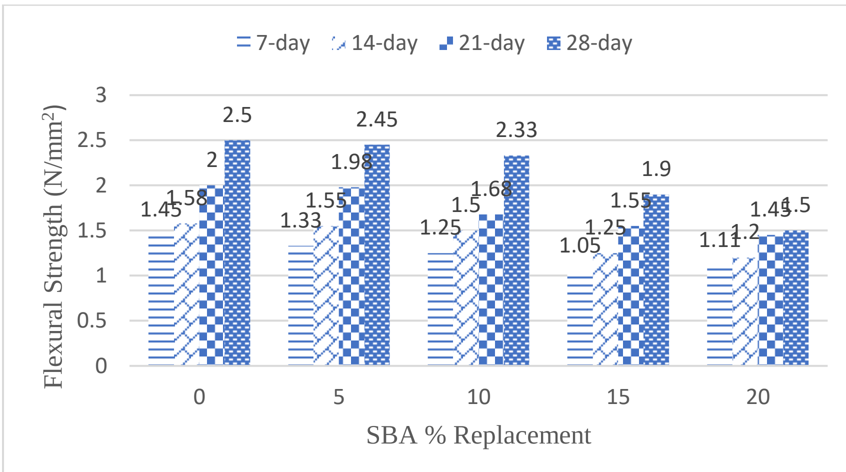


**Figure 7** Variation of flexural strength with different SBA replacement

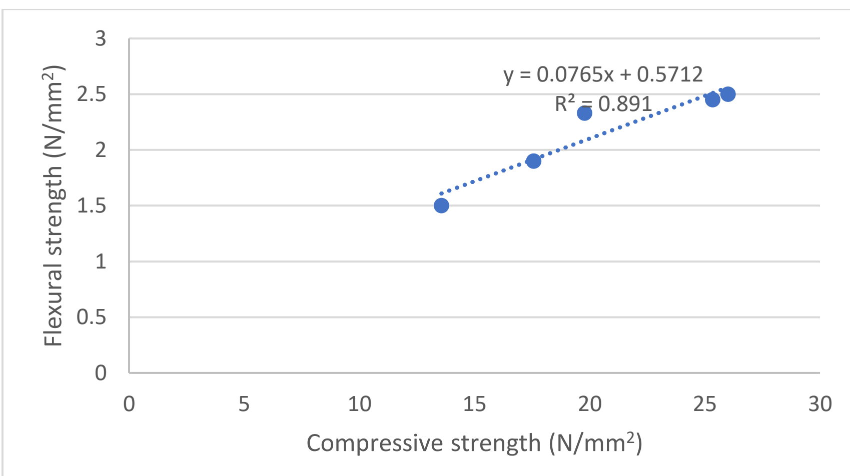


**Figure 8** Relationship between flexural and compressive strength values for SBA specimens

## 4.0 Conclusions

In this paper, the mechanical properties of self-compacting concrete incorporating RHA and SBA were explored. The employment of RHA and SBA in concrete helps to have a cleaner environment as well as the production of green concrete by reusing agricultural-wastes. The following are concluded based on the investigations conducted.

I. By using RHA and SBA into the concrete mixes, the concrete became a little harsher, and its slump flows were seen to have decreased.
II. Compressive and flexural strengths were observed to be influenced by the replacement of RHA and SBA.
III. However, favourable increased in compressive and flexural strengths were observed with 5% replacement for both RHA and SBA.
IV. It is therefore recommended that 5% of RHA and SBA could be employed to replace cement in civil and building constructions based on the study findings.

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## Declaration of conflict of interest

No conflict of interest between the authors.

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