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Effect of Meta-Kaolin Blended With Sugarcane Bagasse Ash in Mortar

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ABSTRACT

This study focused on determining the suitability of blending Mata-kaolin (MK) and Sugarcane Bagasse Ash (SCBA) at equal proportion, to partially replaced cement in mortar. Percentage replacement of 5, 10, 15 and 20% by mass of cement is used to assess the workability (flow), compressive strength of mortar and other properties. Twelve (12) cubes of mortar were cast for each percentage replacement. X-ray Fluorescence (XRF) was conducted to find out the chemical properties of SCBA and MK, the results showed that the sum of Iron oxide (Fe_2O_3), Silicon oxide (SiO_2) and aluminium oxide (Al_2O_3) are 94.83% and 63.91% for MK and SCBA respectively. The flow test was conducted to find out the workability of fresh mortar containing various percentages of the MK-SCBA with 0.5 water to cement ratio, and the result showed a decrease in the flow as the percentage of MK-SCBA increased. Additional tests, such as specific gravity, water absorption, density and compressive strength were conducted. Specific gravity test having the result of 2.63 falls within a specified range of 2.6-2.9, the mortar absorbs water with an increase in the addition of SCBA-MK from 0, 5, 10, 15, and 20% respectively. Much interest were on the performance of the mortar cubes in relation to compressive strength. The compressive strength test result shows that mortar cubes with 10% MK-SCBA yield optimum result at 28 day of curing as compared to the control.

1. INTRODUCTION

Cement is an adhesive substance capable of uniting fragmented or masses of solid materials and of uniform consistency. Kawande and Rathi, (2013) investigated the effect of using SCBA on strength of concrete by partially replacing cement at the ratio of 0, 10, 15, 20 , 25 and 30% by weight for compressive strength. It was found that the cement could be advantageously replaced with SCBA up to a maximum limit of 15%.
Pozzolanic materials, including silica fumes, MK and SCBA are been used as cement replacement material for developing concrete with improved strength properties and reduced permeability. The waste produced after juice extraction from sugarcane is called Sugarcane bagasse and the ash produced after control burning of sugarcane bagasse (SCB) is the Sugarcane SCBA. The SCB constitutes an environmental nuisance as they form refuse heaps in areas where they are disposed of. It is cultivated in about 74 countries, approximately encompassing half of the globe (Agboire *et al*., 2002). Nigeria produced over 15 million tons of sugarcane annually. Some states where sugarcane is mostly produced in Nigeria are Sokoto, Taraba, Niger, Kogi and generally most northern part (Abdulkadir *et al*., 2014). Sugarcane bagasse ash is composed

of SiO_2 and it has been demonstrated that it presents potentialities to be used as a mineral addition and partial replacement of cement in concrete and mortars (Codeiro *et al*, 2009).

Kumar and Krishna (2014) carried out a study on strength of concrete with quarry dust and metakaolin (MK) as partial replacement of cement. The results showed that the compressive and flexural strength were increased up to 10% replacement of Quarry dust and metakaolin and decreased for 12.5% replacement. Patil and Kumbhrar (2012) performed an experiment on strength and durability properties of high performance Concrete incorporating high reactive metakaolin. Based on their findings, they concluded that the workability and strength properties of high performance concrete mixes improved by incorporating reactive metakaolin up to 7.5% of weight of cement.

The aim of this study is to determine the suitability of blending MK and SCBA in enhancing the properties of the mortar production.

2. MATERIALS AND METHODS

Materials

The materials used in this research include cement, fine aggregate, sugarcane bagasse, metakaolin and water.

Cement and fine aggregate

The cement used for this research is Dangote Portland Lime Stone Cement, which was obtained from Samaru market, Zaria, Kaduna State. And clean, sharp sand obtained from a local supplier in Zaria, Kaduna State, Nigeria was used.

Sugarcane bagasse ash (SCBA)

Table 1 shows the chemical composition of SCBA, it also shows that the sum of Iron oxide (Fe_2O_3), Silicon oxide (SiO_2) and aluminium oxide (Al_2O_3) is 63.91% which proves to class C pozzolan.

Table 1: Chemical composition of SCBA

Chemicals	Percentage (%)	Chemicals	Percentage (%)
SiO_2	50.107	P_2O_6	4.802
Al_2SO_3	9.304	SO_3	4.088
Fe_2O_3	4.494	Cl	1.888
MgO	3.628	Cr_2O_3	0.008
CaO	9.730	Mn_2O_3	0.106
Na_2O	1.644	ZnO	0.072
K_2O	8.771	SrO	0.066
TiO_2	1.294		

Metakaolin

Table 2 presents the oxides composition of metakaolin and the sum of iron oxide (Fe_2O_3), silicon oxide (SiO_2) and aluminium oxide (Al_2O_3) is 94.83% which proves that metakaolin is a high reactive pozzolan.

Table 2: Chemical composition of metakaolin

Chemicals	Percentage (%)	Chemicals	Percentage (%)
SiO_2	52.78	Na_2O	1.85
Al_2SO_3	36.80	K_2O	0.17
Fe_2O_3	5.25	TiO_2	1.20
MgO	0.16	LOI	0.18
CaO	1.8		

Water

For preparation of the mix and curing of mortar samples, portable water supplied from a borehole located in the campus at the Civil Engineering Department, Ahmadu Bello University Zaria, Nigeria was used.

Methods

Mix Proportion

Mix ratio of 1:3 was used to prepare the mortar mix using water/cement ratio of 0.5. Sixty (60) 70 x 70 x 70 mm mortar cubes were cast with the addition of SCBA-MK using 0, 5, 15 and 20 % replacement with respect to cement. Table 3 shows the amounts of constituents used.

Table 3: Mix Proportion

S/No.	Description	Cement (Kg)	SCBA-MK (Kg)	fine aggregate	W/C (%)
1	SCBA-MK = 0%	2.142	0	6.426	0.5
2	SCBA-MK = 5%	2.035	0.1071	6.426	0.5
3	SCBA-MK = 10%	1.928	0.2142	6.426	0.5
4	SCBA-MK = 15%	1.821	0.3213	6.426	0.5
5	SCBA-MK = 20%	1.714	0.4284	6.426	0.5

Standard consistency test

This test was done to find out the quantity of water needed to produce a cement paste with standard consistency based on BS EN 197-1:2009 standard. When the plunger penetrates the paste to a point 5 to 7mm above the bottom of the mould, the paste is considered to be at “normal consistency”.

Initial setting times test
This was conducted to find out the initial of cement based on BS EN 196-3:1995 standard. The initial setting time (min) is taken when the initial setting time needle penetrates between 5-7mm above the bottom of the mould, and the final setting time (min) taken when the annular on the final setting time needle does not make an impression on the paste.

Final setting times test
The test was conducted to determine the final setting time of cement based on BS EN 196-3:1995 standard. The final setting time (min) is taken when the annular on the final setting time needle does not make an impression on the cement paste.

Water absorption and compressive strength tests
This test was done in accordance to BS 812-2:1995. The compressive strength of mortar with the addition of SCBA-MK was conducted in accordance with BS EN 12390-3 2001, for the prescribed mortar mix of 1:3 and water/cement ratio 0.5. A total of sixty (60) 70 x 70 x 70 mm cube specimens were cast and cured in water for 1, 3, 7, and 28 days.

3. RESULTS AND DISCUSSION

Sieve Analysis
Figure 1 showed the result of sieve analysis carried out on fine aggregate. BS 882-2 (1992), specifies that the fine aggregate particle suitable for construction should be smaller than 5 mm, about 97% of the sample pass the 4.76 mm aperture sieve, which makes it suitable for the use as fine aggregate. Based on BS 882 (1992) grading limits for fine aggregates, the fine aggregate is classified as zone 1.

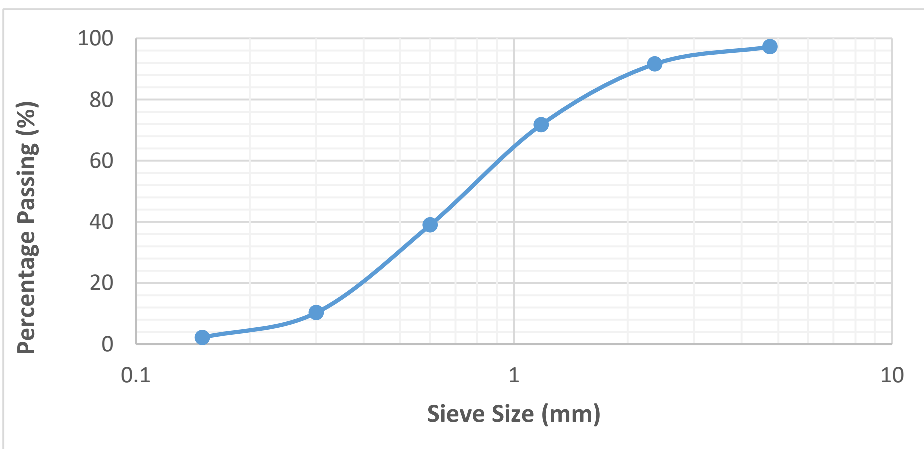

Fig. 1: Sieve analysis graph

Consistency Test

Table 4 showed the result of Standard Consistency tests carried out on cement paste containing different percentages of SCBA-MK. The normal consistency of MK-SCBA-cement paste increased with an increase in MK-SCBA content. This indicated that additional water is needed the particles to be wetted as the total surface area of the particle is increased (Marthong, 2012). However, table 4 indicated that the MK-SCBA-cement met the requirement as specified in BS EN197-1 2009, which states that when the plunger penetrates the paste to a point 5-7 mm above the bottom of the mould, the paste is considered to be at "normal consistency".

Table 4: Standard consistency on cement used

% of SCBA-MK	Weight of SCBA-MK (g)	Cement (g)	Volume of water (ml)	Plunger penetration
0	0	400	126	5.8
5	20	380	132	6.0
10	40	360	144	6.3
15	60	340	156	6.5
20	80	320	168	6.9

Initial and Final Setting Time

The results of the initial and final setting time of MK-SCBA-cement paste were presented in figure 2. The setting times of MK-SCBA-cement paste increased as the MK-SCBA content increased. This behaviour may be due to the formation of magnesium silicate ($MgSiO_3$) which is known to be a retarder thereby causing a delay in the setting time of MK-SCBA-cement paste (Sulaiman and Aliyu, 2020). And also may be as a result of potassium oxide (K_2O) presents in MK-SCBA which hinders complete combination of lime and causes setting negative effect on setting time of cement (Stocchi, 1990).

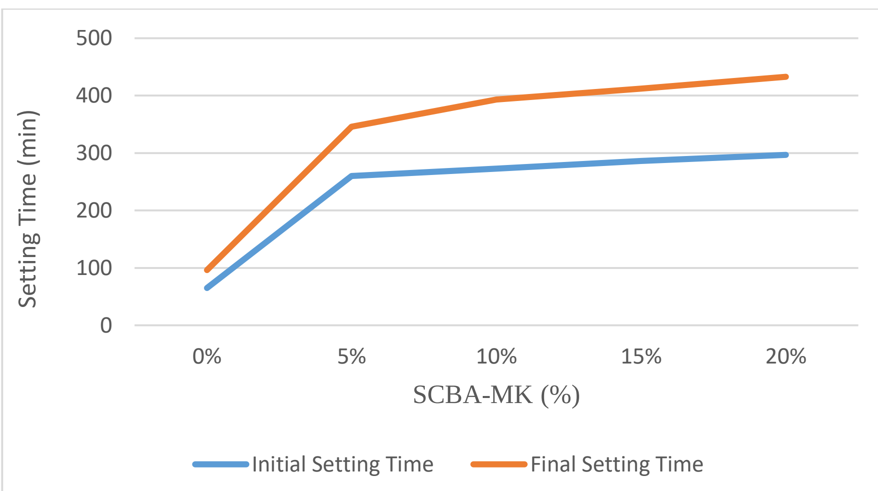

Fig. 2: Initial and Final Setting Time versus SCBA-MK (%)

Soundness test

Figure 3 showed the result of a soundness test conducted on cement paste containing various percentages of MK- SCBA. It has been observed that the soundness of cement paste increased as the MK-SCBA content increased, but then drop at 20%. According to BS EN 196-3:2016, the value of soundness should not exceed

10 mm. However, above 10 mm is unsound. So, the results obtained show that the MK-SCBA-cement paste is within the acceptable limit.

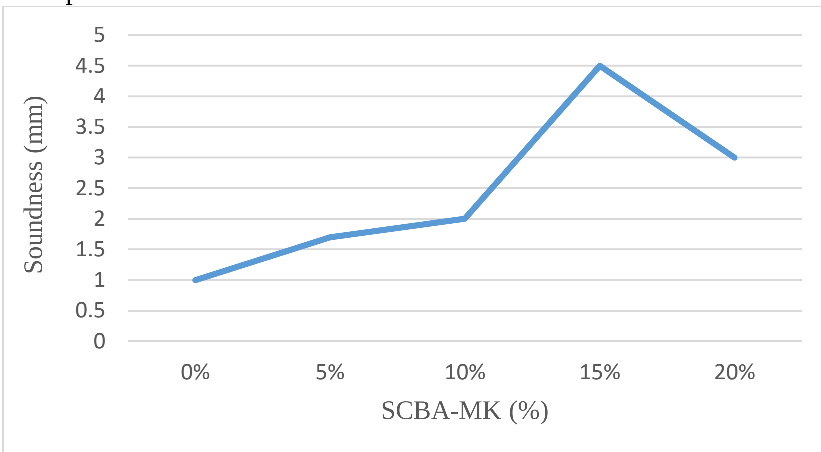

Fig. 3: Soundness versus SCBA-MK (%)

Flow (workability) test

The result of the flow test carried out to determine the workability of the fresh mortar is displayed in Figure 4. It showed that the flow of the mortar decreased as the MK-SCBA content increased. The decrease may be due increase water demand as a result of the high specific surface area of MK and SCBA as explained by Sulaiman and Aliyu, (2020). It can be noted that the results of 0 and 5% replacement are the same, after which the value begins to decrease for 10, 15, and 20%.

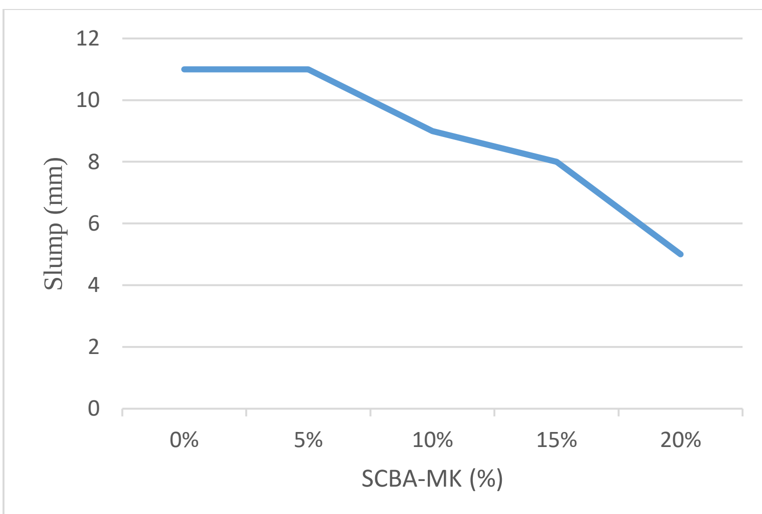

Figure 4: Slump versus SCBA-MK

Water Absorption test

Figure 5 showed the behaviour of the mortar cubes cast with different percentages of the MK-SCBA. It can be seen that as the MK-SCBA content increased the rate at which the mortar absorbed water increase, this trend indicates that MK-SCBA absorbs more water than cement.

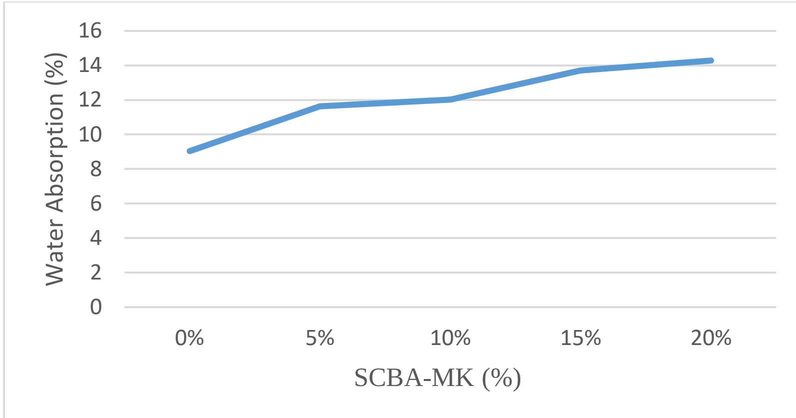

Fig. 5: Water absorption versus SCBA-MK

Compressive strength of mortar

The result for the compressive strength of MK-SCBA mortar indicated that the compressive strength of mortar cubes increased with an increment of curing age but decreased as the MK- SCBA content increased. However, the best performance was obtained at 10% replacement of MK- SCBA at 28 days of curing. The increase in the compressive strength of mortar with an increment of curing age may be because of the hydration of cement and MK-SCBA. While the decrease in the compressive strength of mortar with the addition of MK-SCBA may perhaps be due to saturation of the cement blend with oxides of K_2O and MgO in MK-SCBA, which created composites that might subdue the strength of mortar, constituting calcium silicate hydrates from hydration of cement, this is in agreement with Sulaiman and Aliyu, (2020). However, the best performance was obtained at 10% replacement of MK- SCBA at 28 days of curing.

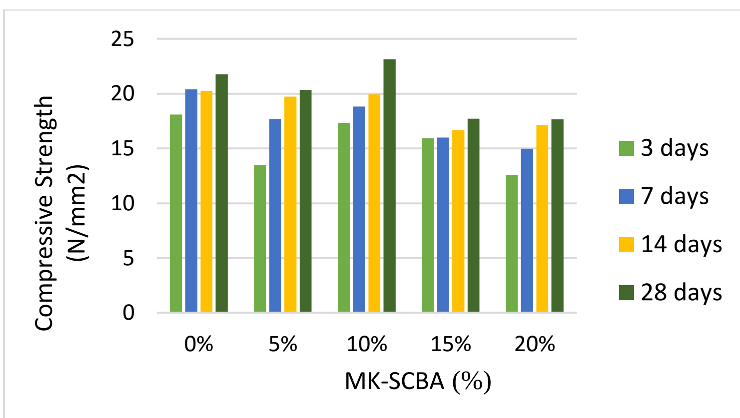

Fig. 6: Compressive strength versus MK-SCBA

4. CONCLUSION

The MK has higher (94.83%) sum of Fe_2O_3, SiO_2 and Al_2O_3 compared with SCBA (63.91%), while the CaO content of SCBA (9.73%) was higher than that of MK (1.8%,). The combined effect of the high content of CaO in SCBA and high sum of Fe_2O_3, SiO_2 and Al_2O_3 in MK might be the cause of the formation of more Calcium Silica Hydrates (CSH) bonds which contributes to increased compressive strength equal to 10%, it was discovered that inclusion of MK-SCBA as cement replacement reduces the workability (flow) of mortar but increases the setting time. The strength of mortar was detected to increase with age of curing and with cement replaced by a combination of MK-SCBA up to 10% and then decreased. This means that the optimum blend of MK-SCBA as cement substitute in mortar should not be more 10% for best compressive strength values. The percentage increase in strength at optimum level was found to be 12.1%.

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