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Mechanical Properties and Workability of Self-Compacting Concrete Using Metakaolin and Wood Ash as Partial Replacement for Cement.

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ABSTRACT: This study is aimed to achieve the fresh and hardened state properties of self-compacting concrete (SCC) using Metakaolin and wood ash content, the particle parking model (PPM) was applied. The cementious materials were varied at (5%, 10%, 15% & 20%) for Metakaolin and (2.5%, 5%, 7.5% & 10%) for Wood Ash (MK+WA), while (2.5%, 5%, 7.5% & 10%) for Metakaolin (MK) content only at 0.25 and 0.30 water/binder ratios, and also 1.2% superplasticizer dosage was used. At 0.25 water/binder ratio, the compressive, split tensile and flexural strengths of self-compacting concrete (SCC) yielded 58MPa, 2.6MPa and 10.0MPa for addition of 7.5% Metakaolin content when compared to addition of 5% Metakaolin and 2.5% Wood Ash, yielded 50MPa, 2.12MPa and 8.40MPa and also yielded 52MPa, 2.3MPa & 8.97MPa for control mix. Therefore, the target strength of 42MPa was achieved. The fresh state properties improved workability and satisfied appropriate standards.

KEYWORDS: Self-Compacting Concrete, Metakaolin, Wood ash, Compressive Strength, Split Tensile and Flexural Strength.

I. INTRODUCTION

Self-compacting concrete (SCC) also known as self-consolidating concrete. SCC is a concrete considered to be flowable, which can be placed with minimal or no vibration and compacted under its self-weight. SCC was first developed in Japan in the late nineteen eighties to be used in the construction of skyscrapers (Ozawa et al. 1990). It is used in the construction of high-rise buildings and it allows the construction of complicated structures and slender building elements (Holton, 2004). When properly proportioned and placed, it results in both economic and technological benefits for the end user. The manufacturing of SCC allows the propelling of concrete to a great height and cover the reinforcement bars so that it will not touch each other, without any mechanical consolidation. Thereby leading to a reduction in construction time, labour cost and noise level on the construction site (Persson 2003).

In recent years, the use of SCC has rapidly increase and a number of research works have been published (Okamura and Ouchi, 2003). The reasons of this rapid increase is as a result of the ease of placement of this type of concrete, significant reduction of the construction period, labour cost, noise level on the construction site and also the incorporation of secondary raw materials.

Concrete is a protean construction material which is widely used in the construction industries. It is composed of cement, aggregates, water and admixtures. The cement used in concrete production acts as binder for the constituent materials of the concrete. It is pozzolanic in nature and is the most commonly used material for construction works. This binding property of cement can be enhanced by adding non-conventional materials having binding properties (Salim, 2015).

AIM AND OBJECTIVE

The aim of this study is to investigate the mechanical properties and workability of self-compacting concrete using Metakaolin and wood ash as partial replacement for cement

a. To develop a mix design based on Metakaolin and wood ash as partial replacement of cement for compressive, split tensile and flexural strengths tests of self-compacting concrete.

b. To determine the optimum percentage for cement replacement with Metakaolin and wood ash content that could give a target strength of 42MPa at 28 days curing age.

c. To investigate the mechanical properties and workability of self-compacting concrete using Metakaolin and wood ash as partial replacement for cement.
d. To compare the mechanical properties of conventional self-compacting concrete with concrete made with Metakaolin and wood ash as partial replacement for cement.

II. LITERATURE REVIEW

Metakaolin which is obtained from kaolin, is one of the most natural abundant minerals, which is discovered in Kogi state, Edo state and other Northern parts of Nigeria by Raw Materials Research Development Council of Nigeria (RMRDC). The following literature review below were observed in extent past work.

Barisua et al. (2018) studied the workability and mechanical properties of high-strength self-compacting concrete blended with Metakaolin. Metakaolin was partially replaced cement in the range 5 to 15% at different water/binder ratios of 0.25, 0.30, 0.35 & 0.40. PPM was adopted in the mix design. After various tests for both workability and mechanical properties, the results show that 15% of Metakaolin for 28 days fresh water curing, and 0.25 water/binder ratio and mix ratio of 1:1.33:1.44:0.25 gave optimum compressive strength of 69.6MPa.

Prema-Kumar et al. (2015) studied effect of partial replacement of cement in SCC by fly ash and Metakaolin. It was observed that the use of mineral admixture such as fly ash and Metakaolin as partial replacement of cement in SCC can bring down the cost of concrete production. It also observed that the combination of fly ash and Metakaolin in the range of 8 to 34% incorporation has no adverse effect on the workability properties of SCC, but inclusion of (15%MK and 9%FA) combination gave optimum compressive strength of 48.76Mpa at 28 days curing age.

Mehetre et al. (2014) conducted a comparative study of properties of self-compacting concrete with Metakaolin and cement kiln dust as mineral admixtures and its impact. It was stated that the adding of 10 % Metakaolin together with Cement Kiln Dust in self-compacting concrete specimens improves several self-compacting features like workability, segregation resistance etc.

Akeem et al. (2019) Investigation of workability and compressive strength of wood ash cement concrete containing nanosilica. The wood ash was partially replaced cement for 0%, 5%, 10% and 15% while nanosilica were replaced with 0.5%, 1.0%, 1.5% and 2.0% with 0.5 water/binder ratio and also, the following tests were investigated, which includes: workability and compressive strength. It was reported that concrete improved workability` with incorporation of nanosilica. Also, it was reported that 10% replacement of wood ash yielded maximum compressive strength of 27.53MPa at 28 days curing ages with 1.5% nanosilica inclusion.

Chowdhury et al. (2015) studied the hardened state of concrete such as compressive, flexural and tensile strengths with different percentages (5, 10, 15, 18 and 20) % of Wood Ash blended with cement. They concluded that these strengths reduced slightly with increase in wood ash contents at 5% for 28 days curing age but recovered at later ages.

From the previous literature reviewed, it can be seen that the research has been carried out on the following additives, such as metakaolin, micro-silica, fly ash, nano-silica and wood ash etc., to improve strength and effect on its mechanical and structural properties. However, there is limited research on the impact of combination of metakaolin and wood ash as additives for self-compacting concrete. This research thus investigates the mechanical properties and workability of self-compacting concrete using metakaolin and wood ash as partial replacement for cement.

III. MATERIALS AND METHODS

MATERIALS

The following experimental materials were used in this study;
i.Grade 42.5N Portland limestone cement (PLC) manufactured by Dangote cement PLC conforming to NIS 444.
ii.Fine aggregate (River Sand) conforming to EN 12620.
iii. Coarse aggregate (Granite) with a maximum size of 10mm (conforming to EN 12620).
iv.The water used throughout the study was obtained from Civil Engineering Laboratory of Rivers State University water mains and it is also fit for drinking and in accordance with BS 3148:1980
v.Metakaolin conforming to (EN 934-2), manufactured by Beijing Toodudu E-commerce Company Limited.
vi.Wood Ash.
vii. Superplasticizer (SP) Poly Carboxylate Ether (PCE) was used.

TEST DETAILS

The specimen preparation and tests were carried out in the Civil Engineering structural laboratory of Rivers State University, Port Harcourt Nigeria.

The tests to evaluate the fresh state properties of self-compacting concrete were conducted as per EFNARC standards and the limits are presented in Table 1. The tests to access thehardened properties of self-compacting concrete were conducted on samples. Details of tests conducted and samplesused are given in Table 2. All results of various tests conducted on self-compacting concrete samples aregiven in Table 4and 5.

Table 1: List of Test Methods and Standards for Workability Properties for Self-Compacting Concrete (EFNARC, 2002)

CHARACTERISTIC	TEST METHOD (S)	RANGE
Flowability	Slump-flow test	650 – 800mm
Viscosity	T_{50cm} Slump flow test or	2 – 5 sec
	V-funnel test	6 – 12 sec
Passing Ability	L-box test	0.8 -1.0 mm
	J-ring test	500 -700 mm
Segregation	V-funnel at $T_{5minutes}$ or Segregation resistance (sieve) test	

Table 2: Details of Sample Used and Test Conducted

Type of tests conducted	Size of sample	No. of sample (for each mix)	Total No. of sample
Compressive strength	100x100x100mm, cubes	9x20	180
Split Tensile Strength	150x300mm, cylinder	3x20	60
Flexural Strength	100x100x500mm, beam	3x20	60

MIX DESIGN METHOD

The mix design method adopted in this research is the Particle Packing Method (PPM). The PPM method guarantees compatibility amount aggregate of SCC concrete and also helps to reduce void in concrete Barisua et al. (2018). The optimum size of coarse aggregates is limited 10mm.

The three proportions of coarse and fine aggregate applied are as follows; A (60:40), B (55:45) and C (52:48) for coarse and fine aggregates respectively. Hence, the evaluation of compacted bulk density and specific gravity of concrete aggregate were carried out. The properties of coarse and fine aggregate that produced the least amount of void was then adopted Barisua et al. (2018).

For the selected mixture of C (52:48), the bulk density of the blended mixture was measured experimentally and packing density (PD) and void content (VC) were computed using equation (1) and(2) respectively in accordance with EN 1097-3; 1998.

$$\text{Packing Density} = \Sigma \frac{\text{Bulk density X weight fraction}}{\text{specific gravity}} \quad (1)$$

$$\text{Void Content} = \Sigma \frac{\text{Bulk density}}{\text{specific gravity}} \quad (2)$$

Mix design calculation

The mix design used in this research work is packing density method for SCC.

Void content in percent volume

$$= \frac{\text{Specific gravity} - \text{bulk density}}{\text{Specific gravity}} \text{x} \frac{100}{1}$$

From the experiment:

For aggregate combination (A) (40% sand + 60% granite)

Specific gravity = 2300kg/m^3 and bulk density 2100kg/m^3

$$= \frac{2300 - 2100}{2300} \text{x} \frac{100}{1} = 8.7\%$$

For aggregate combination (B) (48% sand + 52% granite)

Specific gravity = 2250kg/m^3 and bulk density 2125kg/m^3

$$\text{Void} = \frac{2250 - 2125}{2250} \text{x} \frac{100}{1} = 5.56\%$$

For aggregate combination (C) (45% sand + 55% granite)

Specific gravity = 2400kg/m^3 and bulk density 2150kg/m^3

$$\text{Void} = \frac{2400 - 2150}{2400} \text{x} \frac{100}{1} = 10.42\%$$

The least void is found in aggregate combination B Therefore, its packing density was computed

$$\text{Packing Density (P.D)} = \frac{\text{Bulk density X weight fraction}}{\text{specific gravity}}$$

Packing Density (10mm) coarse aggregate = $\frac{2185 \times 0.52}{2810}$ = 0.4040 kg/m^3

Packing Density of fine aggregate (sand) = $\frac{1875 \times 0.48}{2660}$ = 0.3383 kg/m^3

Total packing density = packing of coarse aggregate + packing density of fine aggregate

0.4040 + 0.3383 = 0.7241 kg/m^3

Minimum paste content is sum of the void content in combined aggregate and excess paste over and above it to coat the aggregate particle.

Voids content = 1 – P.D, = 1 - 0.7241 = 0.2759 m^3

Assuming paste content as 10% in excess of void content

Paste content 10% in excess of void content.

Paste content = 0.2759 + 0.1 x 0.2759 = 0.3035 m^3

The paste volume in SCC is significantly larger than that in ordinary concrete. It is expected to fill the void volume between aggregate particles and make sufficient lubricating layers on the surface of aggregate particles.

V_{exp} = the excess paste volume

V_p = the primary paste volume required for filling ability

V_{void} = the void volume of the compacted aggregate blend (vol %)

$V_p = V_{exp} + V_{void}$

V_p = 0.3035 + 0.0556 = 0.3591 m^3

Volume of aggregate = 1 – 0.3591 = 0.6409 m^3

Total solid volume of aggregate

$$= \frac{\text{weight fraction of coarse aggregate}}{\text{specific gravity}} + \frac{\text{weight fraction of fine aggregate}}{\text{specific gravity}}$$

Total solid volume of aggregate = $\frac{0.52}{2.81} + \frac{0.48}{2.66}$ = 0.1851 + 0.1805 = 0.3656

Weight of 10mm coarse aggregate = $\frac{0.6409}{0.3656}$ x 0.52 x 1000 = 911.56 kg/m^3

Weight of fine aggregate = $\frac{0.6409}{0.3656}$ x 0.48 x 1000 = 841.44kg/m^3

For the first water/binder ratio of 0.25

Water/cement ratio = 0.25, $\frac{W}{C}$ = 0.25

W = 0.25C. Total paste = C + W + S.P, where S.P = 1.2% of cement content

$\frac{C}{3.15} + \frac{0.25C}{1.0} + \frac{0.012C}{1.06}$ = 0.3175C + 0.25C + 0.011C = 0.5785

Cement content = $\frac{0.3035}{0.5785}$ x 1000 = 526.09 kg/m^3

Water content = 0.25 x 526.09 = 135.52 kg/m^3

Superplasticizer = $\frac{1.2}{100}$ x 526.09 = 6.31 kg/m^3

Mix Proportion:

Cement = 526.09 kg/m^3, Sand = 841.44 kg/m^3, Coarse (granite) = 911.56 kg/m^3

Water = 135.52 kg/m^3 andSuperplasticizer = 6.31 kg/m^3**1:1.60:1.73:0.25**

For the second water/binder ratio of 0.30

Water/Binder ratio = 0.30, $\frac{W}{C}$ = 0.30

W = 0.30C. Total paste = C + W + S.P, where S.P = 1.2% of cement content

$\frac{C}{3.15} + \frac{0.30C}{1.0} + \frac{0.012C}{1.06}$ = 0.3175C + 0.30C + 0.011C = 0.6289

Cement content = $\frac{0.3035}{0.6289}$ x 1000 = 484.82 kg/m^3

Water content = 0.30 x 484.82 = 145.45 kg/m^3

Superplasticizer = $\frac{1.2}{100}$ x 484.82 = 5.82 kg/m^3

Mix Proportion:

Cement = 484.82 kg/m^3, Sand = 841.44 kg/m^3, Coarse (granite) = 911.56 kg/m^3, Water = 145.45 kg/m^3 and Superplasticizer = 5.82kg/m^3**1:1.74:1.88:0.30**

Table 3: Summary of the mix design proportion

Mix ratios	Cement kg/m^3	Fine (sand) kg/m^3	Coarse (granite) kg/m^3	S.P kg/m^3	Water kg/m^3
1:1.60:1.73:0.25	526.09	841.44	911.56	6.31	135.52
1:1.74:1.88:0.30	484.82	841.44	911.56	5.28	145.45

Batch Volume:

i. Number of 100mm x 100mm x 100mm concrete cubes per batch = 9

Volume (0.10m x 0.10m x 0.10m) x 9 = 0.009m^3

ii. Number of 100mm x 100mm x 500mm concrete beam per batch = 3

Volume (0.1m x 0.1m x 0.5m) x 3 = 0.015m^3

iii. Number of 300mm long x 150mm diameter concrete Cylinder per batch = 3

Volume = $\left(\frac{3.142x0.0225x0.30}{4}\right)$ x 3 = 0.0159m^3

Therefore, Batch Volume = (0.009 + 0.015 + 0.0159) = 0.0399m^3

Addition of 5% void = 0.0399 + 0.05 x 0.039906 = 0.0419m^3

Total batch volume calculated = 0.0419m^3

Batch Weight:

Batch Volume = 0.0419m^3

i. Weight of 10mm Coarse Aggregate = 911.56 x 0.0419 = 38.19kg

ii. Weight of Fine Aggregate (sand) = 841.44 x 0.0419 = 35.26kg

iii. Weight of Cement = 526.09 x 0.0419 = 22.04kg

iv. Weight of Superplasticizer (S.P) = 6.31 x 0.0419 = 0.26kg

v. Weight of Water (w) = 135.52 x 0.0419 = 5.67kg

TOTAL WEIGHT FOR 0.25 W/B RATIO = <u>101.42kg</u>

At average speed i.e the valve opening or closing time is 40ms

For 1 sec 25 openings and closings is possible

For 1 min for one valve 25*60=1500

With a force of 1.31N the inlet valve opens for 1500 times and exhaust valve opens fo 1500 times.

Table 4: Mix Design Summary for Metakaolin and Wood Ash

Mix	MK (%)	WA (%)	SP (%)	Super Plasticizer (kg)	Cement (Kg)	Fine Agg. (Kg)	Coarse Agg. (Kg)	Mk (Kg)	WA (Kg)	Water (kg)
Control	0	0	1.2	0.26	22.04	35.26	38.19	0	0	5.67
	5	2.5	1.2	0.26	20.39	35.26	38.19	1.10	0.55	5.67
1:1.60:1.	10	5	1.2	0.26	18.74	35.26	38.19	2.20	1.10	5. 67
73	15	7.5	1.2	0.26	17.08	35.26	38.19	3.31		5.67
w/b 0.25	20	10	1.2	0.26	15.43	35.26	38.19	4.41	1.65	5.67
	0	0	1.2	0.24	20.31	35.26	38.19	0	2.20	6.09
Control	5	2.5	1.2	0.24	18.78	35.26	38.19	1.02	0	6.09
	10	5	1.2	0.24	17.26	35.26	38.19	2.03	0.51	6.09
1:	15	7.5	1.2	0.24	15.74	35.26	38.19	3.05	1.02	6.09
1.74:1.8	20	10	1.2	0.24	14.22	35.26	38.19	4.06	1.52	6.09
8									2.03	
w/b 0.30										

IV. RESULTS AND DISCUSSIONS

4.1. Fresh State Concrete

The effect of replacement of cement with percentage variation of Metakaolin and wood ash on properties of fresh concrete was studied by conducting Slump flow, V-funnel, L-box, and J-ring tests. The obtained values are presented in Table 5. The variations of test results are presented in Fig.1 to 4.

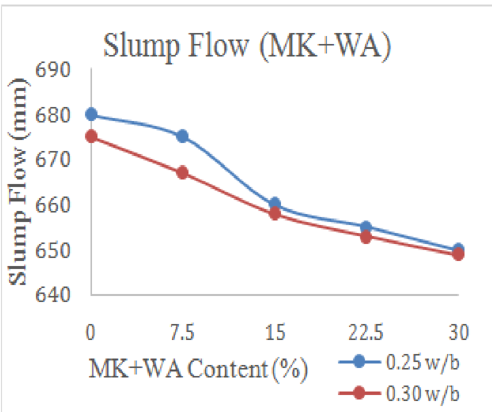
4.1.1. The observations drawn are as below:

- As the percentage of Metakaolin and wood ash increases, the horizontal slump flow value decreases. The variation is following a linear decreasing trend.
- As the percentage of Metakaolin and wood ash decreases, the distance of slump flow at 50 cm diameter slump value also increases. The variation is following a linear increasing trend.
- The time observed with V-funnel set up decreases as there is increases in the quantity of Metakaolin and wood ash in the mix.
- As the percentage of Metakaolin and wood ash increases, the horizontal slump flow value decreases. The variation is following a linear decreasing trend **4.2. Hardened State Concrete**

The effect of Metakaolin and wood ash replacement of cement on the properties of hardened state concrete was studied by conducting Compressive, Split Tensile and Flexural Strengths. The obtained values are presented in Tables 6 to 8. The variations of test results are presented in Fig. 5 to 9.

Table 5: Laboratory Test Result for Fresh Concrete with two Water/Binder Ratio at varying Metakaolin and Wood Ash Content

W/B+ MK +WA Ratios	MK (%)	WA (%)	Slump Flow (mm)	T_{50cm} Slump Flow (sec)	J-Ring Flow (mm)	J-Ring (sec)	V-Funnel (sec)	L-Box (h_2/h_1)	SP (%)
	0	0	680	4.4	625	6.5	6.10	0.85	1.2
	5	2.5	675	4.7	610	7.0	7.15	0.84	1.2
0.25	10	5	660	4.8	550	7.3	8.0	0.82	1.2
	15	7.5	655	4.9	520	8.2	9.5	0.81	1.2
	20	10	650	5.0	515	9.0	10.13	0.80	1.2
	0	0	675	4.5	620	7.10	7.15	0.84	1.2
	5	2.5	667	4.8	600	8.0	8.5	0.83	1.2
0.30	10	5	658	4.9	518	8.8	9.0	0.82	1.2
	15	7.5	653	5.0	510	9.0	10.5	0.81	1.2
	20	10	649	5.1	500	9.2	11.25	0.79	1.2
(EFNARC) 2002			650-800	2-5	500-700	0-10	6-12	0.8-1	



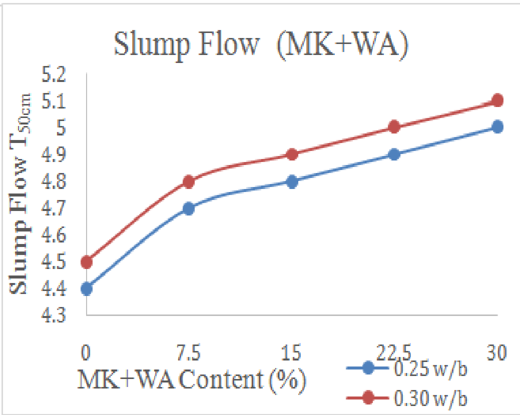
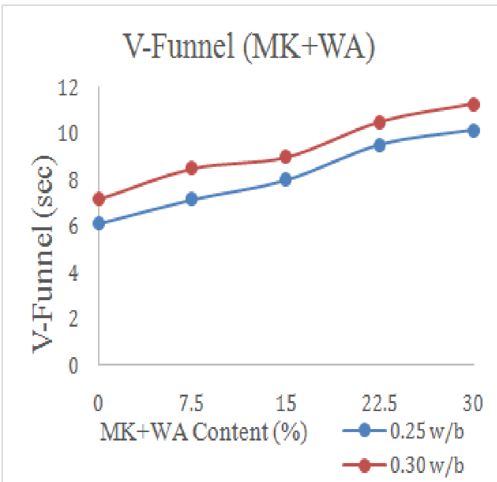


Fig 1: MK+WA ash (%) Vs Slump flow **Fig 2:** MK+WA ash (%) Vs Slump flow T_{50cm}



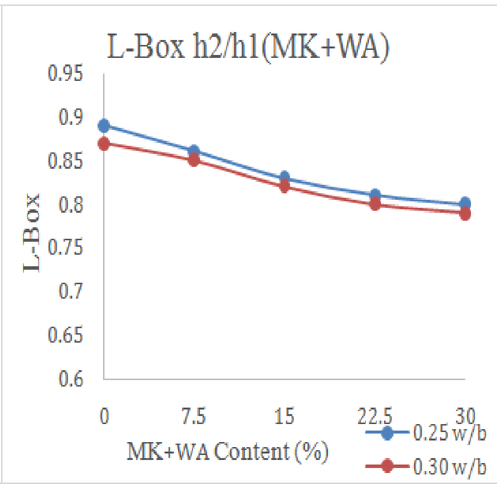


Figure 3: MK+WA ash (%) Vs V-funnel **Figure 4:** MK+WA ash (%) Vs L-box

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Table 6: Average Compressive Strength Test Results of Control, Metakaolin and Wood Ash (MK+WA) and Metakaolin (MK) at Various Curing Age (MPa)

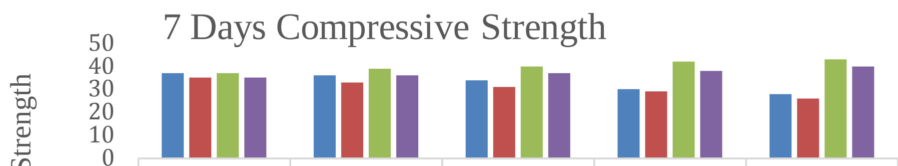
W/B Ratio	Curing Days	Control	5% MK + 2.5 %WA	2.5% MK	10%MK +5%WA	5% MK	15%MK+ 7.5%WA	7.5% MK	20% MK+ 10% WA	10% MK
	7	37	36	39	34	40	30	42	28	43
0.25	14	44	42	46	38	47	32	49	30	50
	28	52	50	54	43	55	36	58	31	60
	7	35	33	36	31	37	29	38	26	40
0.30	14	40	37	42	32	43	31	45	28	47
	28	47	46	50	41	53	34	55	29	58

Table 7: Average Split Tensile Strength of Metakaolin and Wood Ash (MK+WA) and Metakaolin (MK) at Various Curing Age (MPa)

W/B Ratio	Curing Days	Control	5%MK+ 2.5% WA	2.5% MK	10%MK +5%WA	5% MK	15%MK+ 7.5%WA	7.5% MK	20 %MK+ 10 %WA	10% MK
0.25	28	2.3	2.12	2.4	1.98	2.5	1.84	2.6	1.61	2.7
0.30	28	2.12	1.89	2.3	1.79	2.45	1.65	2.55	1.56	2.6

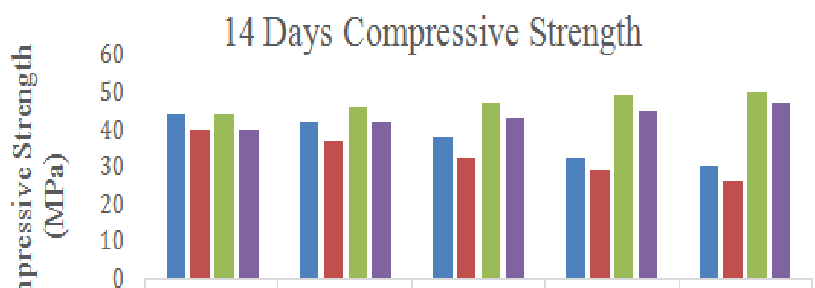
Table 8: Average Flexural Strength of Metakaolinand Wood Ash (MK+WA) and Metakaolin (MK) Content at Various Curing Age (MPa)

W/B Ratio	Curing Days	Control	5%MK+ 2.5%WA	2.5% MK	10%MK +5%WA	5% MK	15% MK+ 7.5% WA	7.5% MK	20%MK+ 10%WA	10% MK
0.25	28	8.97	8.40	9.20	7.37	9.50	6.37	10.0	5.95	10.20
0.3	28	7.50	7.00	8.50	6.71	9.10	5.99	9.40	5.04	10.10



	0	7.5	15	22.5	30
	0	2.5	5	7.5	10
0.25 w/b (MK+WA)	37	36	34	30	28
0.30 w/b (MK+WA)	35	33	31	29	26
0.25 w/b (MK)	37	39	40	42	43
0.30 w/b (MK)	35	36	37	38	40

Figure. 5:shown the Bar chart of compressive strength (MPa) against varying control, Metakaolin (MK), Metakaolin and Wood Ash (MK +WA) content.



	0	7.5	15	22.5	30
	0	2.5	5	7.5	10
0.25 w/b (MK+WA)	44	42	38	32	30
0.30 w/b (MK+WA)	40	37	32	29	26

Figure. 6:14 days Compressive Strength (MPa) Bar chart against Varying, control, Metakaolin (MK), Metakaolin and Wood Ash (MK+WA) content.takaolin and Wood Ash (MK+WA) content.

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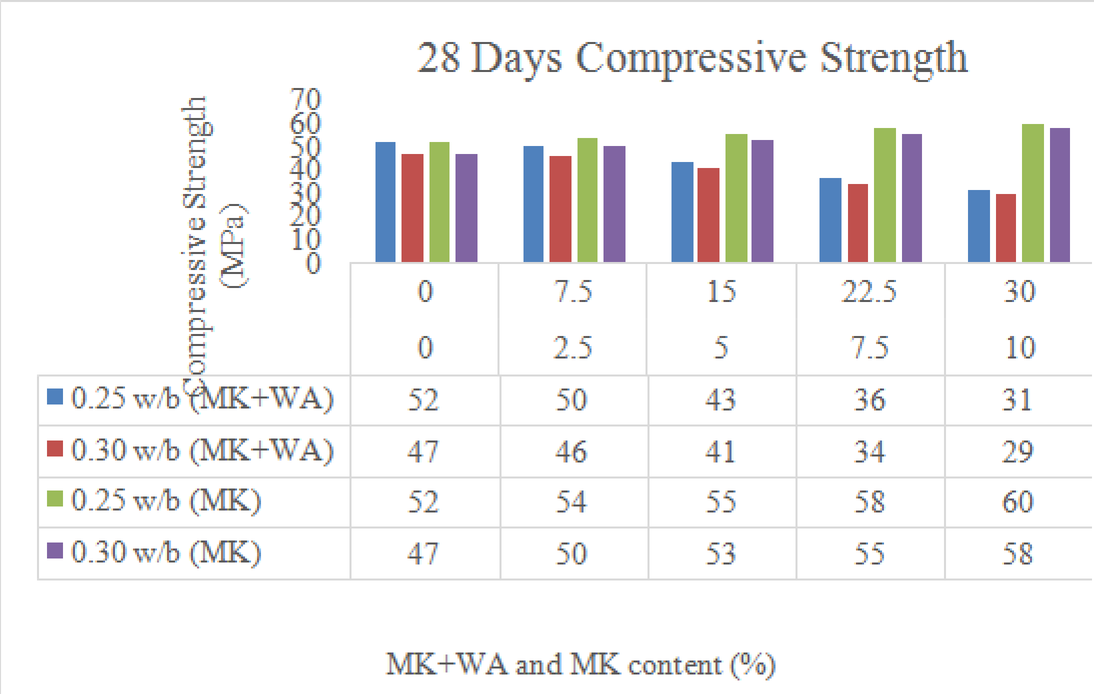
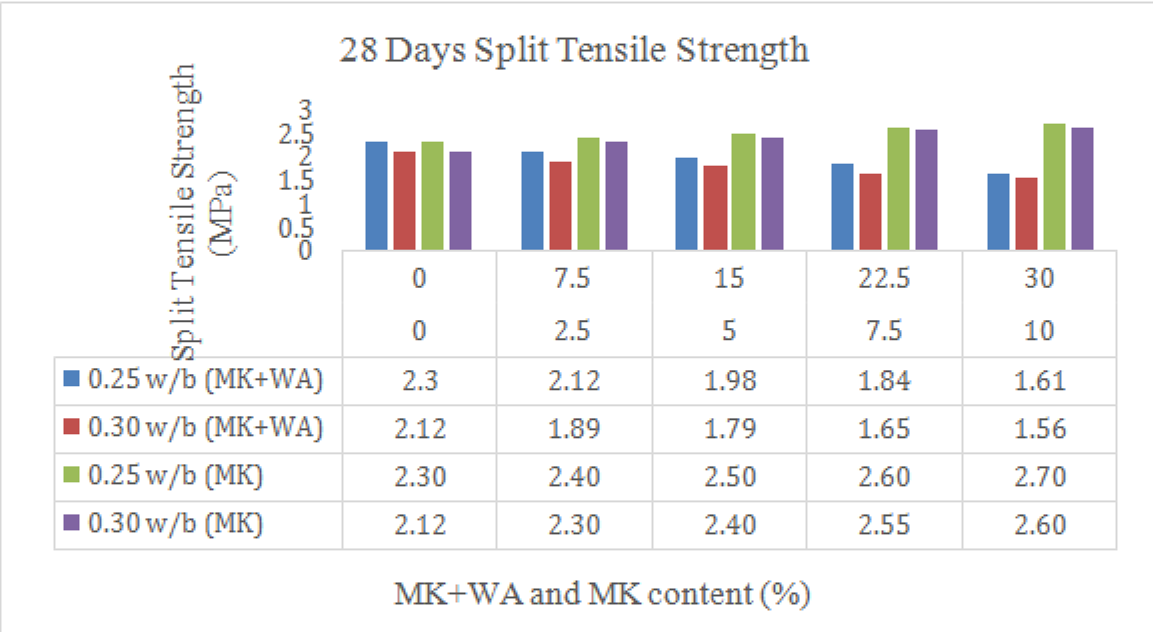


	0 / 0	7.5 / 2.5	15 / 5	22.5 / 7.5	30 / 10
0.25 w/b (MK+WA)	52	50	43	36	31
0.30 w/b (MK+WA)	47	46	41	34	29
0.25 w/b (MK)	52	54	55	58	60
0.30 w/b (MK)	47	50	53	55	58

Figure. 7:28 days Compressive Strength (MPa) Bar chart against Varying Control, Metakaolin & Wood Ash (MK+WA) and Metakaolin (MK) Content**.**



	0 / 0	7.5 / 2.5	15 / 5	22.5 / 7.5	30 / 10
0.25 w/b (MK+WA)	2.3	2.12	1.98	1.84	1.61
0.30 w/b (MK+WA)	2.12	1.89	1.79	1.65	1.56
0.25 w/b (MK)	2.30	2.40	2.50	2.60	2.70
0.30 w/b (MK)	2.12	2.30	2.40	2.55	2.60

Figure. 8:28 days Split Tensile Strength (MPa) Bar chart against Varying Control, Metakaolin & Wood Ash (MK+WA) and Metakaolin (MK) Content.

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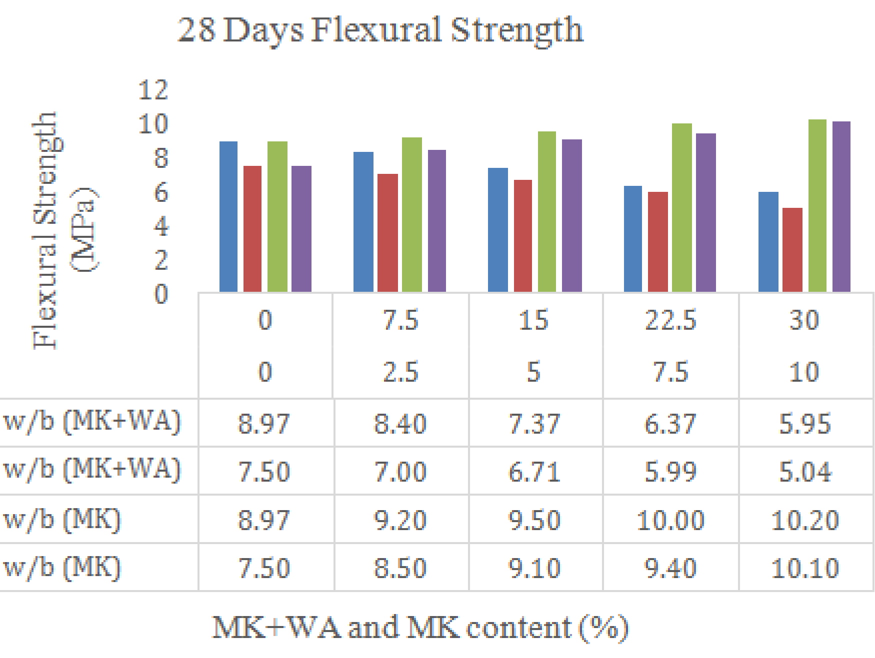

	0 0	7.5 2.5	15 5	22.5 7.5	30 10
0.25 w/b (MK+WA)	8.97	8.40	7.37	6.37	5.95
0.30 w/b (MK+WA)	7.50	7.00	6.71	5.99	5.04
0.25 w/b (MK)	8.97	9.20	9.50	10.00	10.20
0.30 w/b (MK)	7.50	8.50	9.10	9.40	10.10

Figure.9: 28 days Flexural Strength (MPa) Bar chart against Varying Control, Metakaolin & Wood Ash (MK+WA) and Metakaolin (MK) Content.

V CONCLUSION

From the Tests Results, Discussion and Analysis of the Results based on Reviewed Literature.
The following conclusions are drawn from the experimental and numerical results.

1. The particle parking model applied in this research leads to low binder content, the application of the primary paste volume with the addition of Metakaolin and wood ash in self-compacting concrete achieved the target strength of 42MPa at 28 days curing.
2. At 0.25 and 0.30 water/binder ratios and super-plasticizer dosage of 1.2% of the binder content is within the range of Slump flow (650-695) mm, J-Ring (500 -630) mm, V-Funnel (6.3-11.60) sec and L-Box test (0.8-0.88)h2/h1. Therefore, the addition of Metakaolin and wood ash improved workability and satisfied appropriate standards.
3. At 0.25 water/binder ratio, the compressive, split tensile and flexural strength tests results yielded 58MPa, 2.6MPa and 10.0MPa for addition of 7.5%MK and 52MPa, 2.3MPa and 8.97MPa for control mix and also 50MPa, 2.12MPa & 8.40MPa for addition of (5%MK+2.5%WA) for 28days curing age. Therefore, Metakaolin increase strength of concrete, while increase in Wood Ash content reduced strength slightly.

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