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Effects of Water- Cement Ratio on Workability of Bagasse Ash Concrete

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Abstract: **Among several variables which influence the workability of fresh concrete is water/cement ratio (w/c), hence the need to investigate the latter's effect on concrete blended with BA. Traditionally, w/c ratio probably is the most important parameter within cement materials technology such as concrete and mortar. An extensive experimentation was performed to study the workability of wet concrete in which pozzolanic portland cement (PPC) was partially replaced with fine (< 0.075mm) BA. Samples of the latter were purposely selected from the Nzoia Sugar Company (NSC) dump sites in western Kenya. The w/c ratio was varied from 0.40 to 0.60 for different sets of BA replacement of cement levels ranging from 0 to 30%. The study showed that the optimum BA replacement of PPC is 10% for all w/c ratios that gives the highest workability. In the study conclusion, it was further stated that 0.55 was the optimum w/c.**

Keywords: **Baggase Ash, water/cement ratio, Pozzolanic Portland cement, Nzoia Sugar Company.**

1. INTRODUCTION

Among several variables which influence the workability of fresh concrete is water/cement ratio (w/c), hence the need to investigate the latter's effect on concrete blended with BA. Traditionally, w/c ratio probably is the most important parameter within cement materials technology such as concrete and mortar Vladimir *et al*. (2012) [1]. A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self compacting ability. Few research works had been conducted to test BA concrete workability performance by varying w/c ratio. Among the research works conducted on BA concrete was by Jayminkumar and Raijiwala [2], who attributed increase in workability due to the increase in the surface area of BA after its addition hence reducing the amount of water required to wet the cement particles. Shafana and Venkatasubramani [3] showed that water requirement is enhanced as the percentage of BA was increased. This they attributed due to the porous nature of BA particles whereby a greater surface area and larger average particle size serve to enhance absorption of water. According to Piyanut et al. (2013) [4], the initial increase in workablities may have been due to BA hydrophilic nature, therefore, water has more affinity to BA than cement and that the structure of the former is irregular in shape and has porous surface thus confining a lot of water. Eltayed and Salih [5] showed workability tests results indicated that addition of BA reduced the workability which could have been caused by adsorption of water at the surface of BA. The higher the proportion of BA, the higher was the adsorption of water and hence lower amount of water reduced the workability, further. Noor *et al*. [6] investigated that all BA mixtures (0%, 10%, 15% and 20%) had high slump values and acceptable workability. This they attributed that it may have been due to the increase in the surface area of BA that needed less water for wetting the cement particles. Abdulkadir *et al*. [7] showed that for the 0%, 10%, 20% and 30% replacement of BA, that workability of the fresh paste decreases with increase in percentage of BA. This shows that BA absorbed more water than cement. Various authors among them Sirirat and Supaporn [8] and Ahmed et al. [9] have explained that reduced BA size enhance both the filler

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and the pozzolanic effects, hence the choice of BA grain size of < 0.075mm in this research. This BA grain size of < 75µm was achieved through sieve analysis tests. For this purpose, the performance of workability of a set of concrete mixes for varying w/c ratios is studied. A detailed discussion of all results is also provided.

2. MATERIALS

BA samples were purposely selected from the Nzoia sugar company (NSC) dump sites in western Kenya. Different grain sizes were sort to produce various BA samples. BA consists of particles with various shapes and sizes. The boiler furnace temperature was around 450°C. Burning baggase between 400ºC and 600ºC produces an increase in the Pozzolanic Activity Index (PAI) due to loss of carbon during the calcination process Cordeiro *et al*. [10]. Cement used in this study was type 1 PPC as per BS 12 [11] and purposely procured locally. Sand, free from debris was purposefully purchased locally. The sand particles were packed to give minimum void ratio and high voids content leading to requirement of more mixing water. The sand had a minimum size of 150micron to maximum particle size of 4.75 mm and was used as fine aggregate as stipulated in BS 812-103.2 [12]. The water used was of drinking quality as per BS 3148 [13]. It starts the reaction between the cement and aggregates and helps in hydration of the concrete mix. The apparatus used to determine the grain size distribution of all the aggregates were; Balance, a set of sieves and an oven. The sieve sizes used were 75µm, 150µm. 300µm, 600µm, 1mm. 2mm, 3mm, 6mm, 7mm, 8mm, 9mm, 10mm, 14mm and 20mm.

3. METHODS

Five series of tests designated as series A (mix I, II, III, IV and V); series B (mix VI, VII, VIII, IX and X); series C (mix XI, XII, XIII, XV and XVI); series D (mix XVII, XVII, XVIII, IVXX and XX) and E (mix XXI, XXII, XXIII, XXIV and XXV) XXVII, XXVIII, IVXXX and XXX) were prepared with five water-to cement (W/C) ratios of 0.40, 0.45, 0.50, 0.55, and 0.60 respectively. In each series, the replacement level (R) of PPC with BA, was 0, 5, 10, 15, 20, 25 and 30% by weight. The mix proportions are shown in Table 1, for each mix workability tests were conducted. This method of test covered the procedure for determining the slump of freshly mixed concrete and reflects testing procedures found in ASTM C143 [14]. Batching was by weight for all samples. Mixing was done manually on a smooth concrete slab. The BA was first thoroughly blended with PPC at the required proportion and the homogenous blend was then mixed with ballast at the required proportions as shown in Table 1. Water was then added gradually at stipulated ratios to the entire concrete heap and mixed thoroughly to ensure homogeneity.

Table 1 Concrete mix proportions and workability results

Series	Mix	W/C	R	Weight (Kg/m^3)			
				SC	C	S	A
I	A	0.40	0	0	1.0	3.0	4.0
	B		5	0.05	0.95	3.0	4.0
	C		10	0.1	0.9	3.0	4.0
	D		15	0.15	0.85	3.0	4.0
	E		20	0.2	0.8	3.0	4.0
	F		25	0.25	0.75.	3.0	4.0
	G		30	0.3	0.7	3.0	4.0
II	A	0.45	0	0	1.0	3.0	4.0
	B		5	0.05	0.95	3.0	4.0
	C		10	0.1	0.9	3.0	4.0
	D		15	0.15	0.85	3.0	4.0
	E		20	0.2	0.8	3.0	4.0
	F		25	0.25	0.75.	3.0	4.0
	G		30	0.3	0.7	3.0	4.0
III	A	0.50	0	0	1.0	3.0	4.0
	B		5	0.05	0.95	3.0	4.0
	C		10	0.1	0.9	3.0	4.0
	D		15	0.15	0.85	3.0	4.0
	E		20	0.2	0.8	3.0	4.0
	F		25	0.25	0.75.	3.0	4.0
	G		30	0.3	0.7	3.0	4.0

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IV	A	0.55	0	0	1.0	3.0	4.0
	B		5	0.05	0.95	3.0	4.0
	C		10	0.1	0.9	3.0	4.0
	D		15	0.15	0.85	3.0	4.0
	E		20	0.2	0.8	3.0	4.0
	F		25	0.25	0.75.	3.0	4.0
	G		30	0.3	0.7	3.0	4.0
V	A	0.60	0	0	1.0	3.0	4.0
	B		5	0.05	0.95	3.0	4.0
	C		10	0.1	0.9	3.0	4.0
	D		15	0.15	0.85	3.0	4.0
	E		20	0.2	0.8	3.0	4.0
	F		25	0.25	0.75.	3.0	4.0
	G		30	0.3	0.7	3.0	4.0

W/C = Water – cement ratio: **R** = BA replacement level of PPC (%): **SC** = BA; **C** = PPC; **S** = Sand; **A** = Aggregate

4. RESULTS AND DISCUSSIONS

Summary of workability results for the five series at different concrete mixes is shown in Table 5.

Table 2 Workability results

Series	Mix	SH (cm)
I	A	77
	B	79
	C	80
	D	73
	E	69
	F	62
	G	60
II	A	91
	B	92
	C	94
	D	76
	E	70
	F	65
	G	62
III	A	95
	B	99
	C	103
	D	79
	E	75
	F	72
	G	64
IV	A	101
	B	115
	C	121
	D	85
	E	79
	F	77
	G	73
V	A	88
	B	89
	C	94
	D	72
	E	69
	F	66
	G	60

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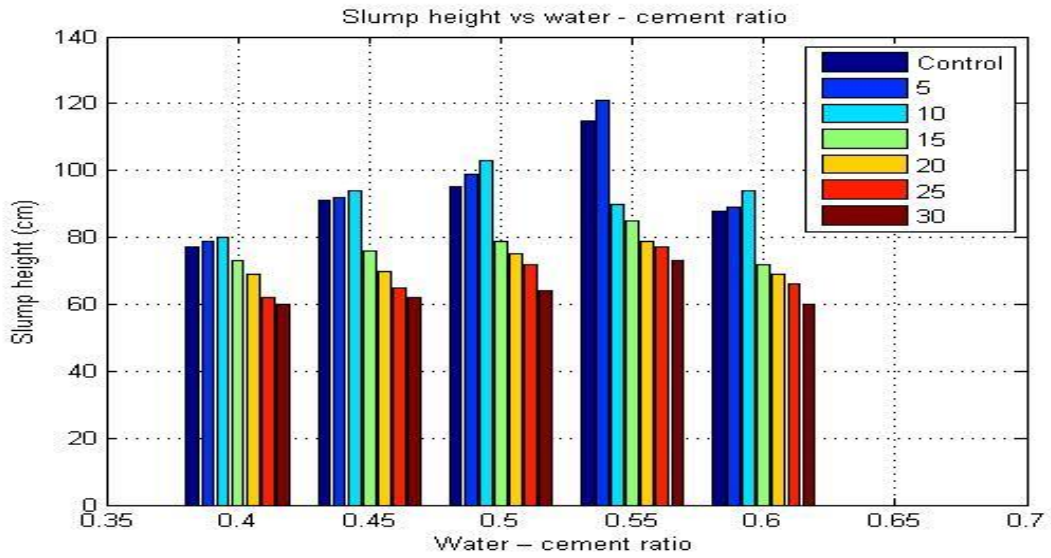

SH = Slump height

Figure 1. Slump height vs water – cement ratio of BA concrete

From the results in Figure 1, there is a general increase of workability up to BA replacement of 10% than a sharp decline at specific water cement ratios. There is also general initial increase of workability to an optimum water cement ratio of 0.55 for all BA replacement. Similar initial increase in workability was also achieved by Jayminkumar and Raijiwala [2], who attributed this due to the increase in the surface area of BA after its addition hence reducing the amount of water required to wet the cement particles. Shafana and Venkatasubramani [1] showed that water requirement increased as the percentage of BA was enhanced. This is consistent with the porous nature of BA particles whereby a greater surface area and larger average particle size serve to enhance absorption of water.

5. CONCLUSIONS

The study shows that the optimum BA replacement of PPC is 10% for w/c ratios that gives the highest workability. It also concludes that the optimum w/c that provides maximum workability is 0.55 for concrete with fine BA (< 0.075). From these results characterization of compressive strengths of BA concrete at these optimum values can be carried out. Further, prediction compressive strength models of the same can be developed.

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