CONSISTENCY AND WORKABILITY PROPERTIES OF BAKERY ASH IN SELF- COMPACTING CONCRETE FOR SUSTAINABLE CONCRETE INFRASTRUCTURE

BUSARI Ayobami*

Department of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa
Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria

Kupolati Williams, Sadiku Emmanuel, Jacques Snyman, Ndambuki Julius

Department of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa

Institute of Nano Engineering Research (INER) and Department of Chemical,
Metallurgical and Materials Engineering, Tshwane University of Technology,
Pretoria, South Africa

*Corresponding Author: ayodebamiakinbode@gmail.com

ABSTRACT

Workability, flow and consistency are unique parameters that contribute to the quality and mechanical properties of Self-Compacting Concrete (SCC) in the hardened stage, in a bid not to compromise strength and quality. Workability, flow and consistency can be controlled in the fresh stage of SCC. This research assessed the workability and strength properties of self-compacting concrete using bakery ash as the need for a green approach in concrete technology is paramount in track with the trash to treasure initiative. To achieve the aim of this study, two brands of Portland limestone cement were used in developing twelve (12) concrete samples. The additive was used at 0, 5, 10, 15, 20 and 25% replacement of cement. The flow, segregation and filling ability were investigated using the L-box, V-Funnel and the slump flow apparatus. The result of the experimental research showed that at 10% and above addition of bakery ash, the workability was unsatisfactory using EFNARC specifications. The compressive strength increased up to 10% addition of the bakery ash. However, at higher percentage addition, the strength reduced. The use of this concrete is recommended for the construction of low load bearing concrete infrastructures. The outcome of this research will serve as a guide for engineers, researchers and construction worker on the optimum quantity of this waste in the development of self-compacting concrete with satisfactory rheology.

Keywords: Workability, Rheology, Consistency, Self-Compacting Concrete, Bakery ash, Sustainability.

Cite this Article: BUSARI Ayobami, Kupolati Williams, Sadiku Emmanuel, Jacques Snyman and Ndambuki Julius, Consistency and Workability Properties of Bakery Ash in Self-Compacting Concrete for Sustainable Concrete Infrastructure. *International Journal of Civil Engineering and Technology (IJCIET)*, 11(1), 2020, 172-181.
<https://iaeme.com/Home/issue/IJCIET?Volume=11&Issue=1>

1. INTRODUCTION

The production of a flowable Self-Compacting Concrete (SCC) mixture is essential for quality and satisfactory mechanical properties in the hardened state. Self-compacting concrete is a unique innovation in concrete technology Wu Q. and An [1]. In a bid not to compromise strength and quality, workability and consistency are a critical factor in SCC development (Ranjbar [2]. According to the same author, the composition of this unique concrete involves two active stages which are the mortar stage and the gravel phase Wu Q. and An [2]. Several methods have been developed in the past for SCC by altering these active stages. The research of Okamura and Ozawa stated that this is the most used method for the achievement of satisfactory rheology. Concrete workability (rheology) can be defined as the assessment of the flowing behaviour of concrete by considering its plastic viscosity state (η) and yield stress (τ). This phenomenon is greatly determined by the water/cement ratio (w/c), the type of cementitious material (binder) used, mix temperature and several other factors. In 2008, Bingham developed a material model to assess the yield value and plastic viscosity of SCC which also proved to be effective. Tomasz and Gołaszewski, [3], De Schutter, [4] and Maghsoudi [5] used a rheometer to assess the rheological parameters of self-compacting concrete. The shortcoming of this method is the cost and technicality involved.

Recently, the use of supplementary cementitious material has been adopted in improving the workability of SCC. These materials have been used as a partial replacement for cement and aggregate in SCC development. The materials have improved the cohesiveness, flowability and segregation resistance of SCC Browsers *et al.*, [6]. The use of low carbon fly ash in SCC production has been done by Idowu *et al.*, [7], according to the author, the use of this material altered the workability of the SCC developed. Furthermore, the use of plastic waste as a partial replacement for aggregate in the development of self-compacting concrete has been investigated by Maghsoudi *et al.*, [8]; Persson [9].

The result of the investigation showed that plastic waste, when used in lower quantity, showed strength retention in SCC mix. Slump flow reduces with increment in plastic waste. However, the shape and size of the plastic waste affect the rheology of the SCC paste matrix. A similar replacement for plastic waste called Polystyrene aggregate has a negative influence on the strength and rheology of SCC according to (Aslani and Kelin, [10] Law *et al.*, [11]; and Bogas *et al.*, [12]. The effect of supplementary additives on the strength and rheology of SCC have been widely shown in numerous studies (Aitcin, [13]; Neville, [14]; Busari *et al.* [15]; Navid *et al.*, [16], Gritsada and Natt [17], Shetty, [18], Erhan *et al.*, [19], Khaloo and Houseininan [20], Khayat *et al.*, [21], Bouzoubaa, N. and Lachemi, [22], Carballosa *et al.*, [23].

This research, however, focused on the use of bakery ash as supplementary cementitious material in SCC development. The choice of the material was adopted because the ash from this waste is usually open dumped creating an environmental problem. With the waste to wealth initiative and the nation's alertness to economic resource management, solid waste re-use waste is a sustainable approach to solid waste management. This will serve as a guide for engineers and construction workers on the effect of this additive on the workability and consistency of bakery ash in self-compacting concrete.

2. METHODOLOGY

2.1. Material

Two brands of cement conforming to NIS [24] of grade 42.5R were used for the research. It was purchased in an open market of Ota, Ogun State Nigeria. Fine and coarse aggregate were also sourced from the same location. It met the requirement of normal-weight aggregates, and was between the range of 35% to 45% by mass and volume of the total aggregate, according to the specified requirements of NIS 13:1974, AASHTO M 6 [25], and AASHTO M 80 [26]. Air-dried samples were used all through the research for both particle size distribution and the specific gravity test according to Ukpata and Ephraim, [27]. The bakery ash was obtained from an open dumpsite very close to a local bakery in Ado-Odo Ota local government, Ogun State Nigeria.

2.2. Sample Preparation

The grading of the particle was achieved by sieve analysis in the Geotechnical laboratory of the Department of Civil Engineering, Covenant University Ota, Ogun State. However, mid-sized aggregate, around the 4.5mm and 19mm size, was used all through the research-based on availability. The sieve analysis was done using an electric shaker.

2.3. Methods

Physical properties of the aggregates used were assessed in the laboratory using AASHTO M80 [26] specification. Self-compacting concrete was developed using Okamura and Ozawa method. The workability of the self-compacting concrete was adjusted using a High Range Water Reducer with brand name CONPLAST superplasticizer. The water and HRWR were added together before mixing with the concrete to avoid unnecessary balling of the fresh concrete according to the research of Navid *et al.*, [16]. The consistency and workability properties of the concrete were assessed according to EFNARC, [28] specification. To this end, the L-Box, V-Funnel and slump flow test was conducted on the fresh concrete.

2.4. Mix Design

Twelve samples of concrete were batched using bakery ash as a partial replacement for cement varying Portland limestone cement. The samples batched is shown in Table 1.

Table 1 Self-Compacting Concrete Samples

SAMPLES	COMPOSITION	CONDITION
A1	PLC BRAND A + 0% BAKERY ASH	Compacted
A2	PLC BRAND A + 5% BAKERY ASH	Self-compacted
A3	PLC BRAND A + 10% BAKERY ASH	Self-compacted
A4	PLC BRAND A + 15% BAKERY ASH	Self-compacted
A5	PLC BRAND A + 20% BAKERY ASH	Self-compacted
A6	PLC BRAND A + 25% BAKERY ASH	Self-compacted
B1	PLC BRAND B + 0% BAKERY ASH	Self-compacted
B2	PLC BRAND B + 5% BAKERY ASH	Self-compacted
B3	PLC BRAND B + 10% BAKERY ASH	Self-compacted
B4	PLC BRAND B + 15% BAKERY ASH	Self-compacted
B5	PLC BRAND B + 20% BAKERY ASH	Self-compacted
B6	PLC BRAND B + 25% BAKERY ASH	Self-compacted

*PLC- Portland Limestone Cement

A polycarboxylate based high-range water-reducing admixture (HRWRA), CONPLAST superplasticiser according to EFNARC, [29] specification was used in improving the workability. A medium grade of concrete was developed as shown in Table 2.

Table 2: Mix Design

MIX DESIGN PROPORTIONS (per m³)	Weight	Unit	Unit
Coarse aggregate	526		Kg
Fine aggregate	526		Kg
Type 10 Cement	285		Kg
Bakery ash	0-71.5		Kg
Water	100		L
Water Reducer	3		mL\100 kg
W/C	0		

3. RESULT AND DISCUSSION

3.1. Physical Properties of the Aggregates

Physical properties of the aggregates used were assessed in the laboratory using AASHTO M80 [26] specification. The test showed a satisfactory result even for pavement construction (Table 3). Concrete mix composition and proportions were done according to EFNARC, [28].

Table 3: Physical Properties of the Aggregate

	FINE AGGREGATE
Specific Gravity	2.5
Apparent Specific Gravity	2.61
Absorption	1.66
Average Impact Value (A.I. V%)	28
Aggregate Crushing Value	43

3.2. Microstructural Assessment of the Aggregate

The result of the Microstructural assessment displaying the edge conditions (Figure 1) showed that it is rough-textured (indicated by the arrows) and this may affect the water/cement ratio based on AASHTO M80, [28] specification. The microstructural assessment implies that the aggregates may have a higher affinity for the cement to maintain the w/c ratio (Figure 1 and 2).

Figure 1: Microstructure (Coarse Aggregate)

Figure 2: Microstructure (Coarse Aggregate)

3.3. Physical Properties of the Cement

The physical properties of the cement are as shown in Table 4. Brand B had the highest initial setting time, which showed that the paste starts losing its plasticity early while Brand A had the lower setting time. Final setting time is the time when the paste completely loses its plasticity, which is (395min) for brand A having the highest setting time. This indicates a very low rate of loss of plasticity (Table 4). The result showed similar attributes with the findings of Sahana, [30] and Akash and Mishra, [31].

The fineness of Portland cement is an important quality index. It represents the average size of the cement grains. The two brands of cement had similar fineness quality (Table 4). This controls the rate and completeness of hydration [15] due to the exposed surface of cement particles in the water. ASTM C786 [32].

Table 4: Cement Test

Cement Brands	Finess Test (%)	Consistency	Initial Setting Time (min)	Final Setting Time (min)
Brand A	5.00	30	45	395
BRAND B	5.00	30	48	391

The composition of silicon and aluminium oxide also had strength implication (Table 5).

Table 5: Chemical Composition of the oxides

PARAMETERS	BRAND A	BRAND B
K ₂ O	0.34	0.39
SiO ₂	19.07	22.03
NaO	0.42	0.46
CaO	64.22	65.24
Fe ₂ O ₂	0.72	0.61
MgO	2.2	1.92
MnO	0.08	0.05
Al ₂ O ₃	4.96	4.61

3.4. Rheology

The mix with the lowest T₅₀ time (Figure 5) is the SCC with no bakery ash addition. This is a function of aggregate size and pastes Uygunoglu and Topçu, [33]. From the result, an indirect relationship was established with bakery ash quantity, and slump flow (Figures 3 and 4). The higher the bakery ash quantity, the lower the slump flow obtained.

Figure 3: Slump flow of BASCC(A)

Figure 4: Slump flow of BASCC(A)

Figure 5: T50 Slump flow of BASCC(A) and BASCC(B)

Segregation Resistance Test

The V-funnel result is between 6 and 12 seconds (Figure 4.7 and 4.8) and the visual inspection is as shown in Table 6. The result showed that the plastic viscosity as a function of dosage of bakery ash.

Table 6: Visual Inspection of the BASCC samples

% REPLACEMENT	V-FUNNEL BASCC(A)	V-FUNNEL BASCC(B)	VSIBASCC(A)	VSI BASCC(B)
0	9.8	10.1	1	1
5	10.1	10.7	1	1
10	10.8	10.9	1	1
15	11	11.5	1	1
20	11.1	11.8	1	0
25	11.7	12.4	0	0

Passing Ability Test L-Box

L-box height ratios were measured, and the corresponding outcomes were presented in Table 4.8. This is as against the V-funnel and slumps flow, which was unsatisfactory at 15% bakery ash addition (Table 4.8). The result showed unsatisfactory results at 10% and above bakery ash addition according to EFNARC, (2002) specification.

Figure 6: L-Box of BASCC(A)

Figure 7: L-Box of BASCC(B)

3.5. Compressive Strength

Figure 8 shows the compressive strength of the control and several bakery ash additions. From the result at 10% addition of the bakery ash, the strength became unsatisfactory. This implies that the application of this material in self-compacting concrete should be done with caution. Additionally, this type of concrete based on the mechanical strength may be used in concrete with low traffic or low axle.

Figure 8: Compressive strength of BASCC(A)

Figure 9: Compressive strength of BASCC(B)

4. CONCLUSION

This experimental research assessed the effect of bakery ash addition on the workability and consistency of self-compacting concrete. This becomes necessary as too stiff concretes, or concretes that segregate are not suitable for pumping operations in concrete infrastructure construction. These concrete demand too high pressures or will cause blocking during pumping operations. To this end, the flowability, viscosity and passing ability test was carried out in the laboratory by using bakery ash as a partial replacement for cement in SCC production. The result of the experimental research showed that:

- Plastic viscosity as a function of dosage of the bakery ash

- The result revealed that as bakery ash decreased the workability of the concrete
- The result showed unsatisfactory results at 10% and above bakery ash addition according to EFNARC, (2002) specification.
- SCC mix with the bakery ash addition of 15% and above did not satisfy the segregation resistance criterion.
- An indirect relationship was established with bakery ash quantity, and slump flow. The higher the bakery ash quantity, the lower the slump flow obtained.
- From the result at 10% addition of the bakery ash, the strength became unsatisfactory.

ACKNOWLEDGEMENT

The authors are grateful to the management of the Tshwane University of Technology, Pretoria for the financial sponsorship of the research.

REFERENCES

- [1] Wu Q. and an X. (2014). Development of a mix design method for SCC based on the rheological characteristics of paste. *Construction and Build Materials*. 53: 642-651.
- [2] Ranjbar M.M. (2013). Effect of natural zeolite on the fresh and hardened properties of self-compacted concrete. *Construction and Building Materials*; 47: 806-813.
- [3] Tomasz Ponikiewski, Jacek Gołaszewski (2017). The Rheological and Mechanical Properties of Self-Compacting Concrete with High Calcium Fly Ash the need for the knowledge of the rheology of concrete is also paramount when supplementary cementitious material is utilized.
- [4] De Schutter G., Bartos P.J.M., Domone P., Gibas J. (2008). Self-Compacting Concrete, Whittles Publishing, Dunbeath.
- [5] Maghsoudi A.A., Mohamadpour S. and Maghsoudi M. (2011). Mix design and mechanical properties of self-compacting lightweight concrete. *International Journal of Civil Engineering*. 9(3): 230-236.
- [6] Brouwers H.J.H. and Radix H.J. (2005). Self-compacting concrete: Theoretical and experimental study. *Cement and Concrete Research*. 35: 2116- 2136.
- [7] Idowu H. Adebakin, K. Gunasekaran and R. Annadurai (2006). Mix Design and Rheological Properties of Self-Compacting Coconut Shell Aggregate Concrete. *ARPN Journal of Engineering and Applied Sciences* ©2006-2018 Vol. 13, No. 4, February 2018 ISSN 1819-6608.
- [8] Şahmaran M. et al. (2006). The effect of chemical admixtures and mineral additives on the properties of self-compacting mortars. *Cement and Concrete Composites*. 28: 432-440.
- [9] Felekoğlu, B. (2007). Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete. *Building and Environment*; 42: 1795-1802.
- [10] Aslani, F.; Keli, J. (2018). Normal and High-Strength Lightweight Self-Compacting Concrete Incorporating Perlite, Scoria, and Polystyrene Aggregate at Elevated Temperatures. *J. Mater. Civ. Eng.* 2018, 30, 04018328.
- [11] Law Yim Wan, D.; Aslani, F.; Ma, G. (2018). Lightweight self-compacting concrete incorporating perlite, scoria, and polystyrene aggregates. *Journal of Material and Civil Engineering* 2018, 30, 04018178.
- [12] Aitcin. P.C. (1998). *High-performance concrete*, E and FN Spon, London.

- [13] Neville, A.M. (1971). *Properties of concrete*. 4th Edition, Essex, England, Prentice- Hall. (Concrete Pavement Design, Construction, and Performance).
- [14] Busari A, Akinmusuru J, Dahunsi B, Ofuyatan T, Ngene B (2017). Pavement construction using self-compacting concrete: mechanical properties. *International Journal of Advanced and Applied Sciences* 4(8):50–55.
- [15] Navid, R., Arash, B., Belal, A., Payam, M., Birgani, M., Zamin, J., (2016). Durability and mechanical properties of self-compacting concrete incorporating palm oil fuel ash. *Journal of Cleaner Production*, 112(4):723-730.
- [16] 17. Gritsada, S. and Natt, M. (2014). The utilisation of high volumes of unprocessed lignite coal fly ash and rice husk ash in self-consolidating concrete. *Journal of Cleaner Production*, 78 (4):184-194.
- [17] Busari Ayobami A, Akinmusuru Joseph.O. Dahunsi Bamidele.I (2018). Review of Sustainability in Self Compacting Concrete: the use of waste and mineral additives as supplementary cementitious material and aggregate. Portugaliae Electrochimica Acta. SCOPUS, ISI Thompson Reuters.
- [18] Busari A, Akinmusuru J, Dahunsi B, Ofuyatan T, Ngene B (2017). Pavement construction using self-compacting concrete: mechanical properties. *International Journal of Advanced and Applied Sciences* 4(8):50–55.
- [19] Khaloo, A. R. and Houseinian M. R. (1999). *Evaluation of properties of silica fume for use in concrete*. International Conference on Concretes, Dundee, Scotland, pp 42-49.
- [20] Khayat, K.H., M.Vachon, and M. C. Lancot, (1997). Use of Blended Silica Fume Cement in Commercial Concrete Mixtures. *ACI Materials Journal*, 7(3):183-192.
- [21] Bouzoubaa, N. and Lachemi, T. (2001). Self-compacting concrete incorporating high volumes of Class F Fly Ash preliminary results. *Cement and Concrete Research*, 31(4): 413-420.
- [22] Carballosa, P.L., García, J. L. Revuelta, D., Sánchez, J.J., Gutiérrez, J.P. (2015). Influence of cement and expansive additive types in the performance of self-stressing and self-compacting concretes for structural elements. *Construction and Building Materials*, 93(6):223–229.
- [23] NIS 444-1: (2003). Composition, specification and conformity criteria for common cements. Standards Organization of Nigeria.
- [24] American Association of State Highway and Transportation Officials (AASHTO) M 6 (1989). *Standard specification for fine aggregate for portland cement concrete*. AASHTO, Washington
- [25] America Association of State and Highway and Transportation officials AASHTO M80, (1989). *Standard specification for fine aggregate for hydraulic cement concrete*. American Association of State Highway and Transportation Officials, Washington, D.C.
- [26] Ukpata, J. O and Ephraim, M. E (2006). *Flexural and tensile strength properties of concrete using lateritic sand and quarry dust as fine aggregate*. International Conference on Concretes. Texas USA, August 5-7, pp 78-83.
- [27] EFNARC (2002) *Specification and guidelines for self-compacting concrete*
- [28] EFNARC (2006): Guidelines for viscosity modifying admixtures for concrete
- [29] Sahana, R. (2013). Setting time, compressive strength and microstructure of geopolymer paste (2007). *International Journal of Innovative Research in Science, Engineering and Technology*. Special Issue 1, December 2013 Proceedings of International Conference on Energy and Environment, 2(1):14-17.

- [30] Akash, S. A. and Mishra, S. P. (2015). Analysis for strength in different types of cement available in chhattisgarh. *International Journal for Scientific Research and Development*, 3(9): 21-26.
- [31] ASTM C1611 / C1611M - 09be1. *Standard test method for slump flow of self-consolidating concrete*. ASTM International, West Conshohocken, PA, 2016, www.astm.org
- [32] Topçu, I. B. and Canbaz, T. (2011). Influence of aggregate type on workability of self-consolidating lightweight concrete (SCLC). *Magazine of Concrete. Research*, 63(1):1-12.