AN EVALUATION OF THE RELATIONSHIP BETWEEN FRESH PROPERTIES OF SELF-CONSOLIDATING CONCRETE INCORPORATING BLENDED PALM OIL FUEL ASH AND PULVERISED BURNT CLAY

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Abstract: Although the application of palm oil fuel ash and pulverised burnt clay in self-consolidating concrete is gaining prominence, their application singly in binary mixes is associated with some setbacks. In this study, a blend of Palm oil fuel ash (POFA) and pulverised burnt clay (PBC) was used as partial replacement of Ordinary Portland cement (OPC) to produce self-consolidating high performance concrete (SCHPC). Fifteen different mixes were prepared with varying percentages of blended POFA/PBC, high range water reducing admixture (HRWR) and water to binder ratio (W/B) ranging from 0.30-0.40. Three key fresh properties were investigated. The filling ability was evaluated based on the slump flow, 500mm slump flow time (T_{500}), inverted slump cone flow spread and time, Orimet flow time and v-funnel flow time. The passing ability was evaluated with respect to J-ring flow and L-box blocking ratio. Furthermore, the segregation resistance was determined based on the sieve segregation index and column segregation factor. A comparative analysis was carried out on the results based on the correlations established among the fresh properties of the respective mixes. The research findings revealed strong correlations between most of the fresh properties of the respective SCHPC.

Keywords: *Blended, concrete, self-consolidating, palm oil fuel ash, pulverised burnt clay*

1.0   Introduction

With the advent of new generation Superplasticizers (SP) commonly referred to as high range water reducers (HRWR), the production of SCHPC has become industrially feasible. Self-consolidating high performance concrete (SCHPC) is an advanced class of concrete that can flow through congested reinforcement or intricate geometric configurations under its own weight without any means of compaction and does not segregate (Koehler & Fowler, 2007; Okamura, 1997). To produce SCHPC with homogeneous and cohesive characteristics, large amount of powder is usually required

(De Schutter, *et al*., 2008; Okamura & Ouchi, 2003). Furthermore, the production of SCHPC with excellent fresh characteristics requires limiting the coarse aggregate size and content and the use of a very low water-binder ratio in the presence of high range water reducer (HRWR) (Okamura & Ozawa, 1995). In addition, the inclusion of suitable quantity of supplementary cementing materials (SCM) can improve the segregation resistance while achieving the required filling ability and passing ability (Safiuddin, Abdus Salam and Jumaat, 2011). Extensive research work have been undertaken to investigate the effect of various SCM such as silica fume, ground granulated blast-furnace slag, fly ash, rice husk ash and even palm oil fuel ash (POFA) on the workability of self-consolidating concrete (SCC) (Gettu, *et al*., 2001; Okamura & Ozawa, 1995; Sam *et al.,* 2014; Safiuddin, Isa, & Jumaat, 2011; Safiuddin, West, & Soudki, 2012). In recent years, extensive studies on the rheology and workability of self-compacting concrete have been carried out (Belaidi, *et al*., 2012; Ferrara, *et al*., 2012; Petit & Wirquin, 2010). In an earlier study on the fresh properties of SCC, Khayat, Assaad, & Daczko (2004) reported that the L-box and the J-ring tests can be employed to investigate the passing ability as well as the deformability and segregation resistance of SCC to a reasonable degree of accuracy. In combination with the slump flow test, the L-box test is a convenient method for on-site quality control of SCC (Wu, *et al*., 2009). Generally, the three key fresh properties of SCHPC are influenced by the W/B, the quantity and the surface area of SCM, volume fraction of paste, volume fraction of fine and coarse aggregates and the dosage of HRWR (Saak, Jennings, & Shah, 2001; Safiuddin, West, & Soudki, 2011; Tang, *et al*., 2001). The flowing ability, passing ability and segregation resistance of SCHPC may be alternately influenced, either directly or indirectly by the aforementioned factors. Therefore, evaluation of the correlation between these properties will be the key to successful design, production application of SCHPC.

2.0   Materials and Methods

2.1   Materials

The materials used in this research work include; normal ASTM C150 type I Portland cement (OPC) with a specific gravity of 3.15, BET surface area of 5.067 m^2/g, Palm oil fuel ash and pulverised burnt clay brick with a specific gravity of 2.42 and 2.69 and BET surface area of 23.751 and 2.979 m^2/g respectively. A well graded pit sand having a fineness modulus of 2.4, a specific gravity of 2.55, bulk density of 1682 kg/m^3 and absorption value of 1.8% was used. The coarse aggregate used was crushed aggregate with a specific gravity of 2.56, bulk density of 1609 kg/m^3 and absorption value of 1.6%.

A polycarboxylic-based polymer was used as the high range water reducer (HRWR). The HRWR is amber in colour and has a specific gravity of 1.10 at 25°C with a pH value of 8. The mixing water used was normal tap water.

2.2 Mix Proportions

Fifteen different mixes of SCHPC were prepared using a blend of POFA and PBC at a replacement levels ranging between 0-30% (0%/0%, 5%/5%, 10%/5%, 10%/10%, and 15%/15% of POFA/PBC respectively) as partial replacement of OPC. The W/B used was 0.30, 0.35 and 0.40 respectively. The W/B was selected based on ACI 211.4R-08 (2008) guidelines. The water and the cement contents were determined based on the selected W/B using a developed rational mix design procedure. Saturation dosages of HRWR were determined for each of the respective mixes to achieve slump flow values in the range of 650-800mm based on EPG-SCC (2005) guidelines. The designation of the mixes was based on the on the selected W/B, and the percentage of the blended POFA/PBC. For example, 30C1P0:0 is a designation for SCHPC mix with W/B of 0.30, blended POFA and PBC content of 0%/0%. The details of the mix proportions of the various SCHPC mixes are presented in Table1.

Table 1: Details of the mix proportions for various ternary blended SCHPC

Concrete Numenclature	POFA (% of B)	PBC (% of B)	W/B Ratio	Coarse aggregate	Fine aggregate	Cement (kg)	POFA (kg)	PBC (kg)	Water (kg)	HRWR (% of B)
30C1P0:0	0	0	0.30	811.20	811.20	532.99	0.00	0.00	181.27	1.50
30C2P5:5	5	5	0.30	811.20	811.20	473.93	26.33	26.33	178.64	1.75
30C3P10:5	10	5	0.30	811.20	811.20	444.26	52.27	26.13	176.74	2.00
30C410:10	10	10	0.30	811.20	811.20	416.28	52.04	52.04	175.32	2.25
30C5P15:15	15	15	0.30	811.20	811.20	359.98	77.14	77.14	172.82	2.50
35C1P0:0	0	0	0.35	811.20	811.20	493.06	0.00	0.00	195.00	1.25
35C2P5:5	5	5	0.35	811.20	811.20	438.83	24.38	24.83	192.42	1.50
35C3P10:5	10	5	0.35	811.20	811.20	411.52	48.41	24.21	190.54	1.75
35C4P10:10	10	10	0.35	811.20	811.20	385.78	48.22	48.22	189.19	2.00
35C5P15:15	15	15	0.35	811.20	811.20	333.89	71.55	71.55	186.73	2.25
40C1P0:0	0	0	0.40	811.20	811.20	458.70	0.00	0.00	206.82	1.00
40C2P5:5	5	5	0.40	811.20	811.20	408.56	22.70	22.70	204.29	1.25
40C3P10:5	10	5	0.40	811.20	811.20	383.32	45.10	22.55	202.47	1.50
40C4P10:10	10	10	0.40	811.20	811.20	359.45	44.93	44.93	201.16	1.75
40C5P15:15	15	15	0.40	811.20	811.20	310.91	66.62	66.62	198.51	2.00

2.3 Preparation of Concrete

The fresh concrete mixes were prepared with the revolving type, pan concrete mixer with a nominal capacity of 0.015 m^3 as specified by ASTM C192/C192M (2013). First, the coarse and fine aggregates were first blended and charged into the concrete mixer with one-quarter of the adjusted water required for mixing for 180 seconds. The mixer was stopped and allowed to rest for 180 seconds so as to give room for the air-dried aggregates to absorb water required for saturation. This was done in order to avoid the absorption of the HRWR by the aggregates. Thereafter, the cementing materials (OPC with and without blended POFA and PBC) were charged in the mixer. Immediately, the mixer was restarted and the mixing was continued for 120 seconds with the addition of the second and the third quarter of the mixing water. Then the HRWR was dispersed in the fourth quarter of the mixing water and then added to the concrete mix and the mixing was continued for another 180 seconds.

2.4 Test on the Fresh Properties

The respective fresh SCHPC mixes were tested for filling ability, passing ability and segregation resistance.

Filling ability is the property of concrete that enables it to reach every corner of formwork under its self-weight without any means of compaction. It was measured with respect to slump flow (SF), 500mm slump flow time (T_{500}), inverted slump cone flow (ISCF) and time (T_{ISCF}), V-funnel flow time (T_V) and Orimet flow time (T_O). The SF and the T_{500} were determined in accordance with ASTM C1611/C161M (2009) procedure. The T_V was determined according to EPG-SCC (2005) guidelines while the T_O was determined according to EFNARC (2002). The ISCFS and T_{ISCF} were determined by using an Abram's slump cone in an inverted position. The inverted slump cone was placed at the middle of a plywood table with a trap door fitted to the lower opening of the cone. The height of the lower end of the cone was 430 mm from the floor. The trap door was closed and the cone was filled with fresh concrete without any compaction. After it was filled up, the trap door was opened to allow the fresh concrete to flow out. A stopwatch was started at the same time to record the time it takes the concrete to flow out (T_{ISCF}) (s). From the same test, the ISCFS was determined by measuring the diameter of deformed concrete at two perpendicular directions that bisects the concrete into eight equal segments.

On the other hand, the passing ability is the property of SCHPC that allows it manoeuvre its way through sections with congested reinforcement under its self-weight. J-ring and L-box were both used to determine the passing ability of the fresh SCHPC. The J-ring test was carried out according to ASTM C1621/C1621M (2009) guideline. The vertical deformation of the concrete sample was measured with the J-ring in position and reported as the slump with J-ring. In addition, the diameter of the concrete

spread that passes through the J-ring was measured in a similar way as mentioned in the case of slump flow. The average diameter was recorded as the slump flow with J-ring (JF). The difference between the slump flow with and without J-ring (SF - JF), which is referred to as J-Ring blocking index (BI) and the J-ring blocking step (B_J) were used to evaluate the concrete passing ability. On the other hand, the L-box test was carried out according to EPG-SCC (2005) guideline. The result of the L-box Passing ratio (PR) was also used to evaluate the passing ability of the respective concrete samples.

Segregation resistance of the respective SCHPC was determined using both sieve segregation and column segregation tests. The sieve segregation test was carried out in accordance with EPG-SCC (2005) guideline and the resistance of the fresh concrete to segregation was evaluated based on the sieve segregation index (SI). The column segregation was carried out according to ASTM C1610/C1610M (2010) specified guideline and the resistance of the fresh concrete to segregation was evaluated based on the column static segregation factor (CSF).

3.0   Results and Discussion

Table 2 presents the summary of the fresh properties of the various SCHPC mixes investigated. It can be seen from Table 2 that the inclusion of Blended POFA and PBC at varying percentages have significant influence on the filling ability, passing ability and segregation resistance of the respective SCHPC. However, the scope of this study is limited only to the evaluation of the correlation between these respective properties.

Table 2: Fresh properties of various self-consolidating high performance concrete

Concrete Numenclature	Filling ability						Passing ability				Segregation resistance	
	Slump flow (mm)	ISCF (mm)	T_{500} (s)	T_{ISCF} (s)	Tv (s)	T_o (s)	JF (mm)	BI (mm)	B_J (mm)	PR (ratio)	SI (%)	CSF (%)
30C1P0:0	720	710	3.00	3.60	9.00	6.22	710	10	9	0.89	5.98	5.68
30C2P5:5	735	725	3.20	3.90	9.30	6.60	725	10	8	0.90	4.50	6.87
30C3P10:5	720	715	3.40	4.10	9.90	6.70	715	5	8	0.90	4.20	8,18
30C410:10	740	730	3.60	4.20	10.70	6.80	730	10	7	0.91	3.80	9.26
30C5P15:15	740	730	3.80	4.40	11.70	6.90	730	10	6	0.92	2.40	10.18
35C1P0:0	700	695	2.40	2.40	8.60	5.00	695	5	10	0.88	6.20	6.00
35C2P5:5	730	720	2.60	2.80	9.00	5.30	720	10	10	0.88	5.80	7.20
35C3P10:5	740	730	3.00	3.10	9.50	5.50	730	10	11	0.87	5.20	8.50
35C4P10:10	740	730	3.10	3.30	10.50	5.60	730	10	9	0.89	4.60	9.70
35C5P15:15	740	730	3.50	3.60	11.00	5.70	730	10	8	0.89	3.90	10.40
40C1P0:0	690	680	2.10	2.20	8.30	4.00	685	5	11	0.86	7.00	6.30
40C2P5:5	720	710	2.20	2.50	8.40	4.40	710	10	10	0.87	6.20	7.50
40C3P10:5	720	710	2.40	2.70	8.70	4.60	715	5	11	0.86	5.40	8.60
40C4P10:10	730	720	2.50	2.90	9.00	4.70	720	10	10	0.87	4.80	9.80
40C5P15:15	730	720	2.80	3.20	9.20	4.90	720	10	10	0.88	4.10	10.80

3.1   Relationship between Slump Flow and Inverted Slump Cone Flow

A correlation coefficient was established in order to evaluate the relationship between slump flow (SF) and the inverted slump con flow (ISCF). As can be seen in Table 2, the slump flow values of the respective SCHPC range between 690 and 740mm, while the inverted slump cone flow varied in the range of 680 to 730. Thus, the difference between the two variables ranged between 5-10mm. These differences are considered very low when compared with the values of 20-40 mm reported by Safiuddin, Abdus Salam, & Jumaat (2011) for SCC containing POFA. This could due to higher deformability characteristics of the SCHPC containing a blend of POFA and PBC and the size of aggregate used. Nonetheless, the reduction in the flow spread of the ISCF could be attributed primarily to the size and height of the discharge opening and the impact resistance between the discharged concrete and the testing surface. Similar opinion was reported by Safiuddin (2008) after carrying out similar investigation on SCHPC containing rice husk ash (RHA).

A positive correlation coefficient value of 0.9881 was obtained between the SF and ISCF as can be seen in Figure 1. This level of correlation was established due to the fact that both SF and ISCF are affected by the W/B and the content of blended POFA and PBC.
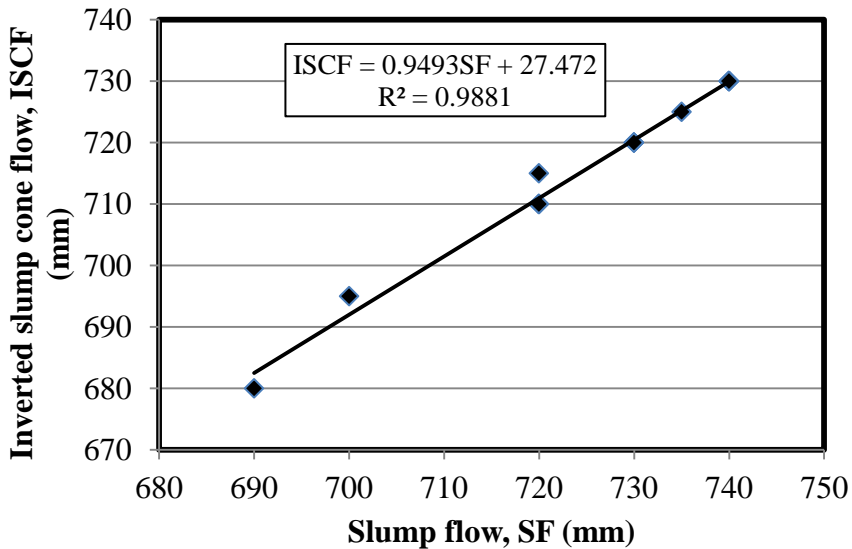

$$ISCF = 0.9493SF + 27.472$$
$$R^2 = 0.9881$$

Figure 1: Correlation between slump flow and inverted slump cone flow

3.2   Relationship between Slump Flow and Slump Flow with J-Ring

The relationship between the slump flow and slump flow with J-Ring was evaluated with respect to the level of correlation between the respective variables. The slump flow values of the respective SCHPC ranges between 690 to 740mm. These flow range satisfied both the ACI 237R-07 (2007) and EPG-SCC (2005) flow requirement for the most stable class of SCC. On the other hand, the slump flow with J-Ring values varied in the range of 685 to 730mm. The difference between the slump flows with and without J-Ring which is referred to as the blocking index (BI), varied in the range of 5-10mm. These values were considered adequate since they are below the maximum recommended limit of 50 mm as specified by EFNARC (2002). Thus, all the SCHPC mixes were said to have exhibited excellent passing ability, irrespective of the W/B and the percentage content of blended POFA and PBC.

An evaluation of the relationship between the slump flow with and without the J-Ring, revealed that a linear and positive correlation exist between the two variables. The correlation coefficient calculated was 0.9885 as shown in Figure 2. This nature of correlation may be strongly attributed to the fact that both variables are affected by the W/B and the contentment of blended POFA and PBC. Similar behaviour was reported by (Safiuddin, Abdus Salam, & Jumaat, 2011) to have been exhibited by SCC containing POFA.
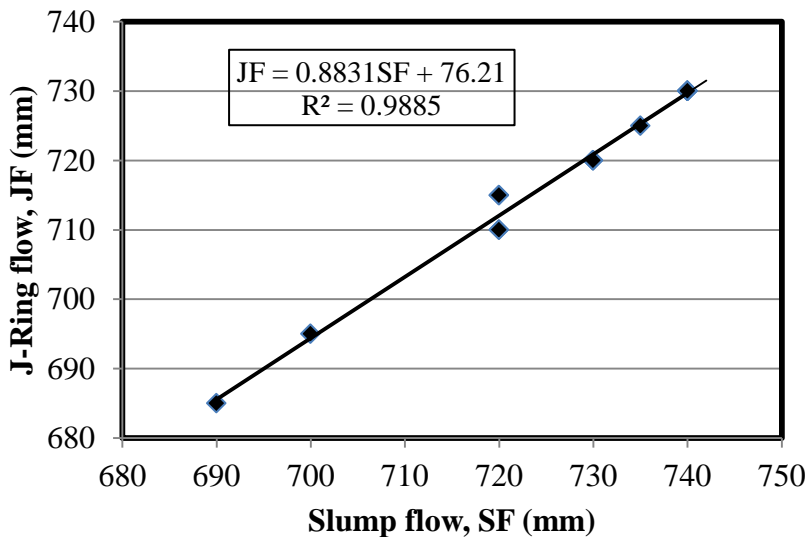

Figure 2: Correlation between slump flow and slump flow with J-Ring

3.3   Relationship between T_{500} Slump Flow Time and Inverted Slump Cone Flow Time

The 500mm slump flow time of the respective SCHPC mixes varied in the range of 2.1 to 3.8 s. These range of values falls within the EPG-SCC (2005) viscosity range for class VS2/VF2, for which the value is greater than 2s. On the other hand, the inverted slump cone flow time (T_{ISCF}) varied in the range of 2.2 to 4.4 s. Although the T_{ISCF} is greater than the T_{500} by 0.1 and 0.6 margins respectively, the values still fall within the acceptable limits for class VS2/VF2.

The correlation coefficient value between T_{ISCF} and T_{500} was found to be 0.9149 as shown in Figure 3, which can be considered positive and excellent. This level of correlation could be attributed to the fact that both parameters are affected by the level of viscosity of the respective SCHPC mixes. Furthermore, viscosity of the mixes is dependent upon the W/B and the content of the blended POFA and PBC in the mix (Table 1). Similar behaviours were reported by Safiuddin, Isa, & Jumaat (2011).
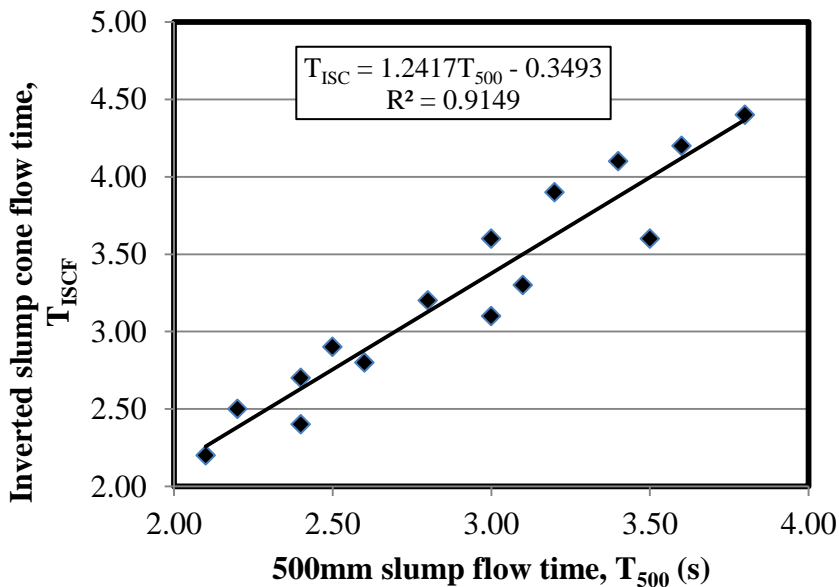

Figure 3: Correlation between T_{500} slump flow time and inverted slump cone flow time

3.4   Relationship between T_{500} Slump Flow Time and V-Funnel Flow Time

The V-funnel flow time (T_V) is an important tool for the determination of the flowing ability and viscosity of SCHPC. In this study, the T_V for the respective SCHPC varied in the range of 8.3 to 11.7 s (Table 2). Thus the T_V for all the respective SCHPC falls

within the limits of 9 to 15 s as recommended by EPG-SCC (2005) for VF2 viscosity class. The correlation between T_{500} and T_V as shown in Figure 4 has a value of 0.8384, which is an indication of a strong correlation. Both variables are dependent on the viscosity of the respective concrete mixes. Thus, they are both affected by changes in the W/B and the content of blended POFA and PBC. Consequently, the higher the T_{500}, the higher will be the T_V.
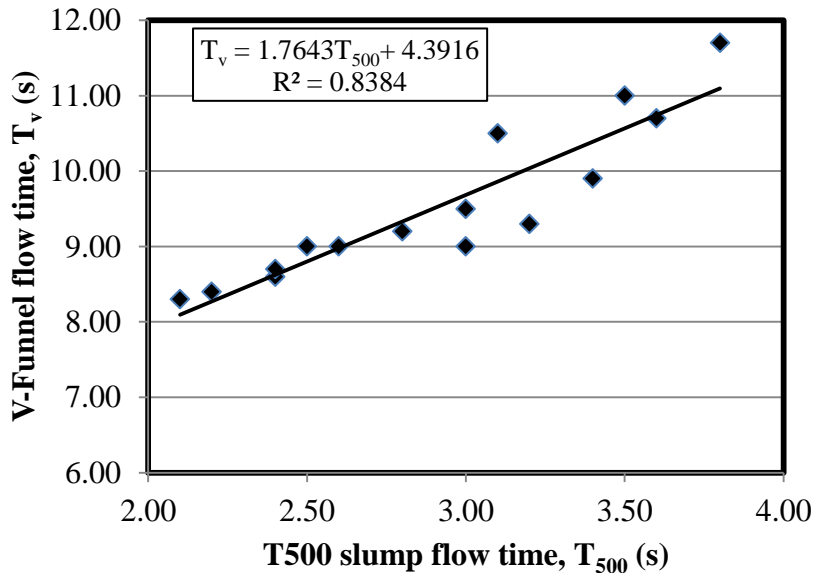

Figure 4: Correlation between T_{500} slump flow time and V-funnel flow time

3.5   Relationship between T_{500} Slump Flow Time and Orimet Flow Time

The Orimet flow time (T_o) is an indicator of the level of workability and fluidity of concrete mixes usually employed on the construction sites. The test is capable of simulating the flow of fresh concrete during actual placement on site. The values of the T_o obtained in this study varied in the range of 4.0 to 6.9 s. It is linearly correlated with T_{500} and has a correlation coefficient of 0.8403 (Figure 5). This positive correlation can also be attributed to the same conditions as mentioned for T_{ISCF} and T_V.
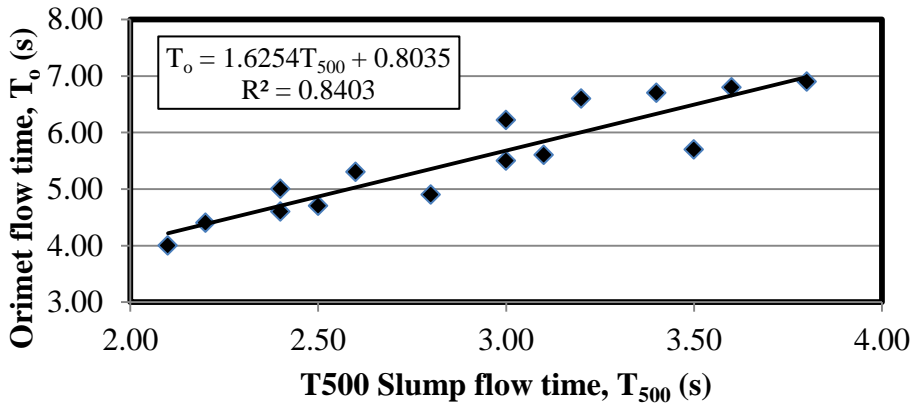
$$T_o = 1.6254T_{500} + 0.8035$$
$$R^2 = 0.8403$$

Figure 5: Correlation between T_{500} slump flow time and Orimet flow time

3.6   Relationship between Slump Flow and Sieve Segregation Index

The sieve segregation index (SI) of the respective SCHPC ranges between 2.4 to 7.0 %. As can be seen in Table 2 the segregation index decreases as the concrete flowing ability increases. This result is contrary to the findings reported by Safiuddin, Abdus Salam, & Jumaat (2011) on the correlation between SI and SF of SCC containing POFA. This difference in the relationship can be attributed to the viscosity enhancing property of PBC that was incorporated into the mix. The incorporation of the PBC and adequate dosage of HRWR improves the deformability of the concrete by lowering the yield stress while maintaining adequate viscosity and stability. Consequently, the flow kinetic is improved, resulting in increase in slump flow and reducing lateral segregation. This is evident from the very low values of the blocking index (BI) exhibited by the respective concrete mixes as shown in Table 2. Similar opinion was reported in EPG-SCC (2005) for concrete with high viscosity especially class VS2 concrete.

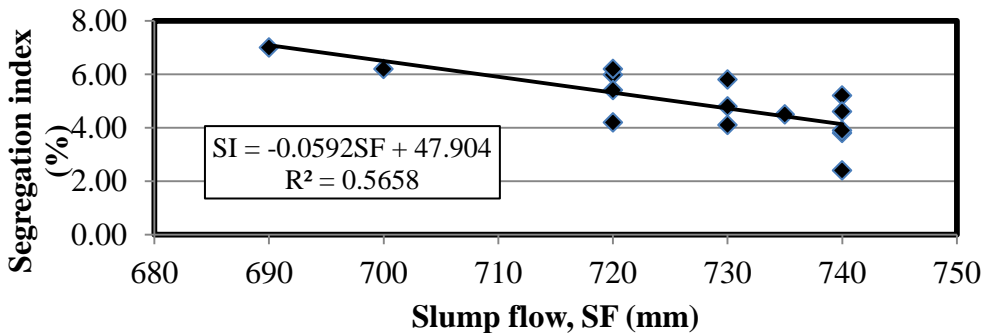$$SI = -0.0592SF + 47.904$$
$$R^2 = 0.5658$$

Figure 6: Correlation between slump flow and segregation index

Nevertheless, all the SCHPC mixes show SI lower than the maximum recommended limit of 18% (EPG-SCC, 2005) for segregation resistance class SR2. The correlation between segregation index and slump flow was found to be 0.5658. This shows that the two parameters have a good negative and linear correlation. The negative correlation is due to the same reason as earlier mentioned concerning SI and flow kinetics. Also, the correlation further shows that both SF and SI are affected to a varying extent by changes in the W/B and the content of blended POFA and PBC (see Table 2).

3.7   Relationship between Slump Flow and Column Segregation Factor

The column segregation factor (CSF) of the respective SCHPC ranges between 5.68 to 10.8 %. As can be seen in table 2 the CSF increases as the concrete flowing ability increases. Nevertheless, the CSF of all the respective SCHPC mixes falls within the permissible limit of 15% as recommended by Koehler & Fowler (2006).
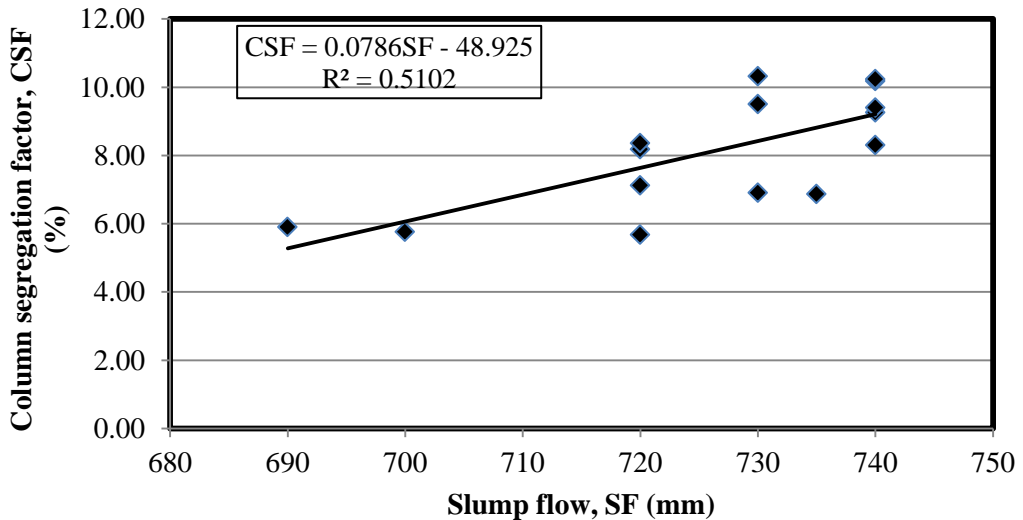

Figure 7: Correlation between slump flow and column segregation factor

The correlation between segregation factor and slump flow was found to be 0.5102. This shows that the two parameters have a good positive and linear correlation. The positive correlation is due to the fact that increase dosage of blended POFA and PBC improves the flow kinetics thereby increasing the slump flow. On the other hand, though the increase in the dosage of the blended POFA and PBC increases the viscosity of the mix, it resulted into decrease in the matrix density in comparison to the aggregate density. Safiuddin (2009) reported the same behaviour with SCC containing rice husk ash (RHA). Consequently, the concrete shows increase in column segregation. Since the viscosity of the respective mixes cannot be too high, otherwise the concrete will not

flow, the ability to control the column segregation rate by increasing the viscosity is limited to permissible limits. Similar opinion was given by Bonen & Shah (2005).

3.8 Relationship between Segregation Index and Column Segregation Factor

Both segregation index and segregation factors range as previously mentioned depending on the W/B and the blended POFA and PBC content. As earlier mentioned, all the respective SCHPC mixes exhibited SI and CSF within the stipulated limits.
The correlation between SI and CSF as shown in Figure 8 was found to be 0.8002. The correlation is very strong and negative. The negative correlation is due to the fact that the increase in the content of Blended POFA and PBC increased the viscosity of the mix while the increase dosage of HRWR reduces the yield stress. These combined effects improve the mix kinetics by maintaining the aggregate buoyancy during lateral deformation and consequently reducing the SI. On the contrary, the combined effects lead to the reduction in the matrix density in relation to the aggregate density. Thus, the tendency of the aggregate migrating downward increases leading to increase in CSF. Similar scenarios were reported by Bonen & Shah (2005) and Safiuddin (2009)
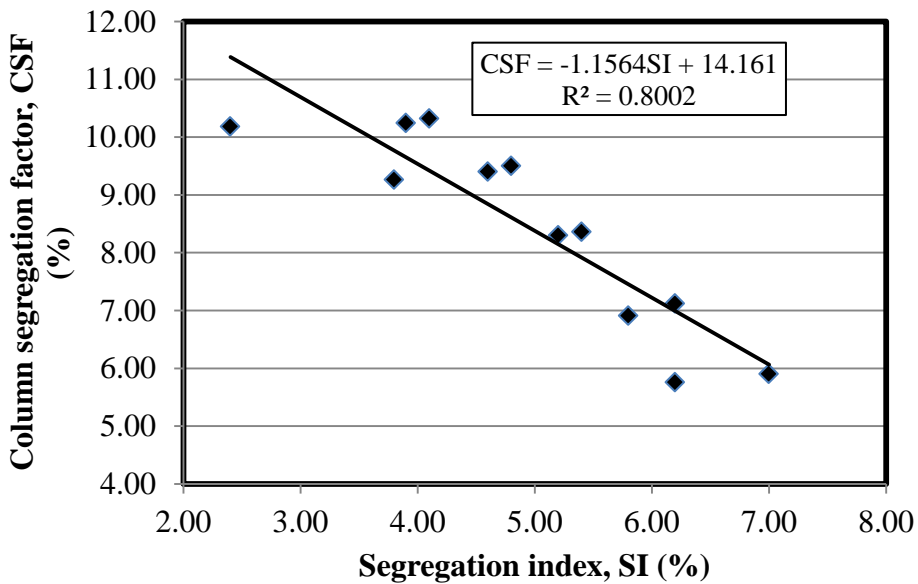

Figure 8: Correlation between segregation index and column segregation factor

3.9   Relationship between L-Box Passing Ratio and J-Ring Blocking Height

The J-Ring blocking step (B_J) varied in the range of 8 to 11mm and the L-box passing ratio (PR) varied in the range of 0.86 to 0.92. The recommended maximum value for the B_J provided by (De Schutter, *et al*., 2008) is 15mm for passing ability class PA2. On the other hand, the range of values for the L-Box PR recommended by EPG-SCC (2005) for passing ability class PA2 is between 0.8 and 1.0. Therefore, all the SCHPC mixes satisfied the requirement for the passing ability class PA2.

The correlation coefficient between B_J and PR as can be seen from Figure 9 is 0.9351. The two parameters are therefore strongly correlated with a negative correlation. The negative correlation implies that the concrete passing ability increases with increase in the value of the PR and decrease in the value of B_J and vice vasa. Invariably, the linear correlation implies that the two variables are similarly affected by changes in the W/B, blended POFA/PBC content and the dosage of the HRWR.
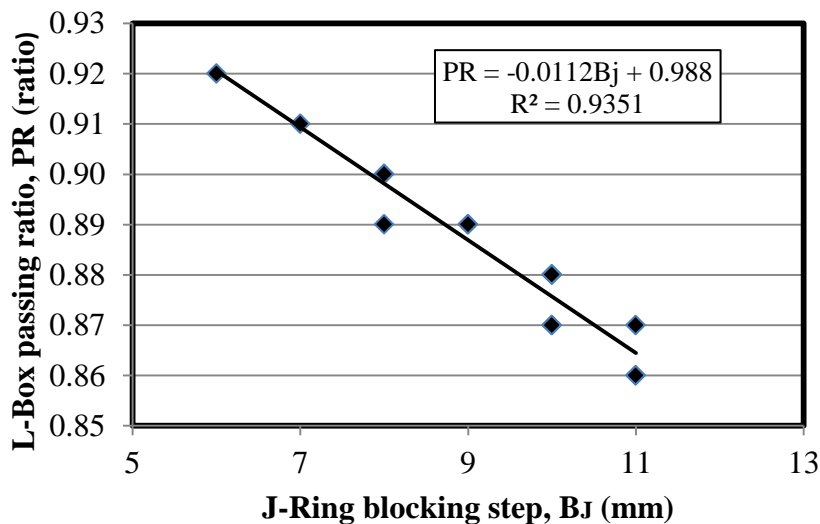

Figure 9: Correlation between segregation index and column segregation factor

4.0   Significance of the Relationship between Variables

The establishment of the relationship between the fresh characteristic of the respective SCHPC will provide a very good platform for the determination of one property of the concrete if the other is known without necessarily passing through the rigor of undertaking tedious laboratory experimentation. This study is therefore very significant in the sense that it will minimise cost by reducing material wastage during optimisation

test and time for carrying out the laboratory work. Consequently, the following relationships have been established between and among the respective fresh properties of the respective SCHPC:

$$ISCF = 0.9493SF + 27.472 \tag{1}$$

$$JF \quad = 0.8831SF + 76.210 \tag{2}$$

$$T_{ISC} = 1.2417T_{500} - 0.3493 \tag{3}$$

$$T_V \quad = 1.7643T_{500} + 4.3916 \tag{4}$$

$$T_O \quad = 1.6254T_{500} + 0.8035 \tag{5}$$

$$SI \quad = -0.0592SF + 47.904 \tag{6}$$

$$CSF = 0.0786SF - 48.925 \tag{7}$$

$$CSF = -1.1564SI - 14.161 \tag{8}$$

$$PR \quad = -0.0112Bj + 0.988 \tag{9}$$

5.0   Conclusion

Based on the analysis carried out on the relationship between various fresh properties of SCHPC containing blended POFA and PBC, the following conclusion can be drawn;

1. The slump flow and the inverted slump cone flow were strongly correlated with a correlation coefficient value of 0.9881. This was attributed to the fact that they responded similarly to changes in W/B, blended POFA/PBC content and other mix parameters.

2. The slump flow and the slump flow with J-Ring were positively correlated with a correlation coefficient value of 0.9885. The level of correlation was attributed to the fact that both parameters were affected similarly by changes in W/B and blended POFA/PBC content.

3. All the concrete mixes were found to satisfy the requirements for viscosity class VF2/VS2 with respect to T500 slump flow time, inverted slump cone flow time, V-funnel flow time and the orimet flow time. The T500 slump flow time had a very strong correlation with the inverted slump cone flow time, V-funnel flow time and the orimet flow time with coefficient values of 0.9148, 0.8384 and 0.8403

respectively. Such a good correlation was possible because all the four parameters are identically influenced by the mix design procedure, W/B, blended POFA and PBC content, HRWR dosage and other design factors and considerations.

4. The sieve segregation index and the slump flow of the fresh SCHPC were found to have a weak correlation with a coefficient value of 0.5658. Such a weak correlation was due to differential effects of viscosity and flow kinetics on the two parameters.

5.   The column segregation factor and the slump flow of the fresh SCHPC were found to have a weak correlation with a coefficient value of 0.5102. Such a weak correlation was due to differential effects of viscosity, matrix density and the aggregate density on the column segregation factor and the slump flow.

6. Although all the fresh mixes of the SCHPC tend to exhibit certain level of segregation, they satisfied the requirements for the limit of segregation with respect to sieve segregation and column segregation.

7. A negative and linearly strong correlation was found to exist between the sieve segregation index and the column segregation factor. The correlation coefficient was found to be 0.8002. The negative correlation was due to the fact that the two parameters were inversely affected by the W/B, the dosage of HRWR, the content of blended POFA/PBC, aggregate density and the matrix density.

8. The J-ring blocking height BJ and the L-Box passing ratio PR were strongly correlated with negative coefficient of 0.9351. As the passing ratio of the respective mixes increases, the blocking height decreases. This complimentary behaviour is due to the fact that as the mix kinetics increases, the passing ratio increases while the blocking height decreases. Generally, all the SCHPC mixes showed a very good passing ability.

5.0   Acknowledgement

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