Jurnal
Teknologi

Full Paper

FRESH STATE AND MECHANICAL PROPERTIES OF SELF COMPACTING CONCRETE INCORPORATING POFA

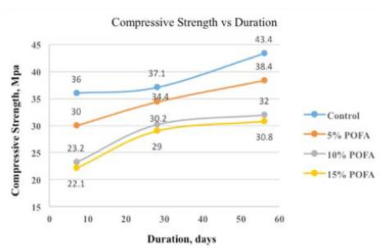
Noridah Mohamad*, Abdul Aziz Abdul Samad, A. Nadjua, W. I. Goh, A. Anas

Department of Structure and Material Engineering, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, Johor, Malaysia

Article history
Received
4 June 2015
Received in revised form
15 December 2015
Accepted
4 March 2016

*Corresponding author
noridah@uthm.edu.my

Graphical abstract



Abstract

Self-compacting concrete (SCC) is considered as a concrete, which can be placed and compacted under its own weight without vibration. The elimination of the need for compaction leads to better quality concrete and substantial improvement of working conditions. This paper investigates the fresh state and mechanical properties of self-compacting concrete incorporating palm oil fuel ash (POFA) as a substitute for cement. Portland cement (PC) was partially replaced with 0%, 5%, 10% and 15% POFA. The water to cement ratio was fixed at 0.4 for all mixtures. The workability of self-compacting concrete in terms of viscosity was determined from slump flow test (Diameter and T_{500}), and V-funnel. The mechanical property tests were conducted on SCC cubes and cylinders to determine its compressive strength and modulus of elasticity. The results indicate that replacement of 5% POFA is the optimum value for cement replacement to obtain high workability and mechanical properties of concrete. SCC achieved the highest compressive strength at 28 days, which is 38.4 MPa, and MOE of 31.6 GPa with 5% POFA replacement.

Keywords: Self compacting concrete, palm oil fuel ash, workability, compressive strength, modulus of elasticity

Abstrak

Konkrit mampat sendiri (SCC) adalah konkrit yang dimampat oleh berat nya sendiri. Tanpa keperluan untuk dimampatkan dengan menggunakan alat mampatan dapat menghasilkan suasana kerja dan kualiti konkrit yang lebih baik. Kajian ini melihat bagaimana abu kelapa sawit (POFA) mempengaruhi ciri-ciri awal konkrit ketika basah dan juga ciri-ciri mekanikalnya. Simen Portland (PC) digantikan dengan 0%, 5%, 10% dan15% POFA. Nisbah air simen ditetapkan pada kadar 0.4 bagi semua bancuhan. Ujian runtuhan dan V-funnel dijalankan pada setiap bancuhan bagi menentukan kadar kebolehkerjaan dari aspek kelikatannya. Ujian mekanikal dijalankan keatas kiub dan silinder SCC bagi menentukan kekuatan mampatan dan modulus keanjalan konkrit. Hasil kajian menunjukkan 5% POFA adalah nilai optimum peratusan bagi menggantikan simen untuk mendapat kadar kebolehkerjaan dan sifat mekanikal konkrit yang baik. SCC mencapai nilai kekuatan mampatan maksima dan modulus keanjalan iaitu masing-masing 38.4 MPa dan 31.6 GPa pada hari ke 28 dengan campuran 5% POFA.

Kata kunci: Konkrit mampat sendiri, abu kelapa sawit, kebolehkerjaan, kekuatan mampatan, modulus keanjalan

1.0 INTRODUCTION

Self-compacting concrete (SCC) is a highly flow able non-segregated concrete which spread into place. Self-compacting concrete was first developed in 1988 in Japan [1]. It does not require vibration and able to flow under its own weight, completely filling formwork and achieving full compaction even in the presence of congested reinforcement. Self-compacting concrete is the modified concrete with the use of chemical (super plasticizers and viscosity modifiers) and mineral (fly ash, slag, silica fume) admixtures in the concrete. It is generally designed with high content of fine material.

Advantages of SCC include faster construction, reduction in manpower, easier placing, uniform and complete consolidation, better surface finishes, improved durability, increased strength and safer working environment [1]. Malaysia is the largest producer of palm oil and palm oil products [2, 3]. It has been estimated that the total solid waste generated by this industry in some two hundred palm oil mills in the country has amounted to about ten millions tons a year [4]. More waste is produced yearly and the government need to allocate more dump area for disposal in the form of landfills. Dumped waste has been a major issue in this country. One oft the solution for this problem is to recycle the waste. Fortunately, the waste materials from oil palm have the potential to be used as construction materials to replace cement or at least to be used together with it [5].

This paper reports the fresh state and mechanical properties of SCC incorporating with POFA. POFA is a by-product in palm oil mill. It is a waste obtained from burning the palm oil fibers, shells and empty hit bunches as fuel to produce steam for generating the electricity for palm oil extraction process. The fresh state properties of SCC were determined by using mixture designed by Bouzoubaa and Lachemi [6]. The mechanical properties of SCC, which include its compressive strength, and modulus of elasticity were determined by conducting a compressive strength test on SCC cubes and cylinders. All tests were conducted according to the British Standard code [7, 8, 9]. Substituting Portland cement with POFA will make the concrete more workable and suitable for the construction. SCC concrete incorporating POFA is able to produce concrete with compressive strength similar or higher than conventional concrete.

2.0 MATERIALS AND METHODS

Self-compacting concrete specimens were formed by mixing cement, water, fine aggregate, coarse aggregates, POFA and super plasticiser.

2.1 Mixture Design

The mix design method in this study was based on the design by Ghezal & Khayat, 2002, as shown in Table 1 [10].

Table 1 Concrete mix design (Ghezal & Khayat, 2002)

Composition of SCC POFA	Cement (kg/m³)	POFA (kg/m³)	Sand (kg/m³)	Coarse (kg/m³)	SP (%)	Water Powder Ratio
0%	400	0	718	850	2	0.55
5%	380	20	718	850	2	0.55
10%	360	40	718	850	2	0.55
15%	340	60	718	850	2	0.55

2.2 Laboratory Tests

The laboratory tests conducted in this study are categorized into two types; namely, fresh state property test and mechanical strength test on SCC cube and cylindrical specimens containing POFA. Fresh concrete test were performed to investigate the properties of fresh SCC mixture which include slump flow test, slump flow T50 test, and V-funnel test to determine its filling ability, passing ability and resistance to segregation. The mechanical strength tests include compressive strength test on the SCC cubes and cylinders to determine its compressive strength and modulus of elasticity.

3.0 RESULTS AND DISCUSSION

3.1 Workability

Table 2 shows the results for workability of the fresh SCC as obtained from slump flow test (Slump flow diameter and T_{500}), V-funnel, and V-funnel at T_{5min} for various percentage of POFA used.

Table 2 The result of Slump flow test and slump flow T_{50} test

Sample	Slump Flow Test Diameter,mm			
	Max diameter, d_{max} (mm)	Perpendicular diameter, d_{perp}(mm)	Average Diameter, S (mm)	$T_{500\ (s)}$
CONTROL	540	560	550	6
5% POFA	680	620	650	1
10% POFA	660	600	630	2
15% POFA	600	600	600	2.5

3.2 Slump Flow Test

Results showed that for the SCC control mixture, the slump flow spread diameter was 400 mm while for T_{500} it did not achieve 500 mm flow spread. With the presence of 20% fly ash the slump flow spread diameter and T_{500} showed increment up to 625 mm and 7 s, respectively. The 40% fly ash mixture recorded optimum workability compared to 60% fly ash SCC mixture. However, the spreading range obtained was all within the acceptable range, which is from 500mm to 700mm [6]. The results are as shown in Figure 1 and Figure 2.

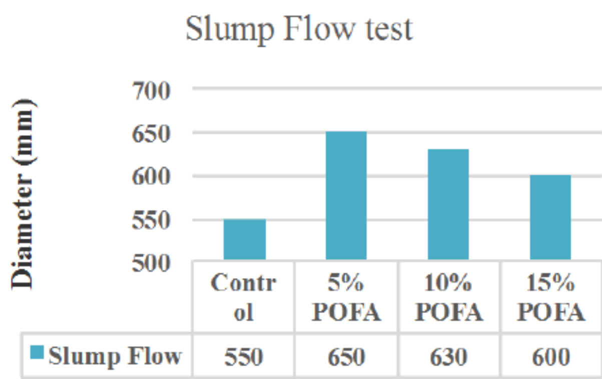


Figure 1 The bar graph of Slump Flow Result

From the bar graphs in Figure 1 and Figure 2, for the SCC control mixture, the slump flow spread diameter is 550 mm while for T_{500}, the 5 s was not achieve because it did not achieve 600 mm spread. For the mixture with 5% POFA, the slump flow spread diameter and T_{500} showed the increase up to 650 mm and 1 s. The 10% POFA mixture recorded optimum workability when compared to the slump flow spreading with 15% POFA SCC mixture. The spreading range obtained was between 550 mm to 650 mm and still within the acceptable range which is from 600 mm to 655 mm [11]. There are three typical slump flow classes and flow rate (T_{500}) classes as shown in Table 3 and Table 4, respectively according to European Guideline (EN 206-1).

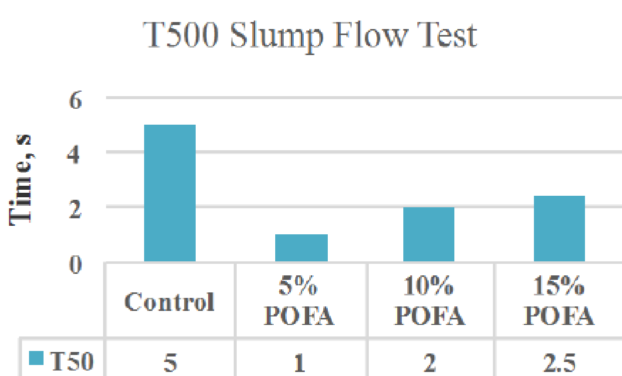


Figure 2 The bar graph of Slump Flow T_{500} Result

Table 3 Slump Flow Classes (EN 206-1)

Slump Flow (SF) Class	Limit Values (mm)
SF 1	550 to 650
SF 2	660 to 750
SF 3	760 to 850

Table 4 T_{500} Slump Flow (EN 206-1)

Viscosity(T_{500}) class	Limit value (s)
VS 1	≤ 2
VS 2	< 2

The slump flow results indicated that the control specimens did not fulfill the limit values provided. The utilization of 5%, 10% and 15% POFA recorded increased workability of the fresh concrete. Based on Table 3, all specimens fall in the group of SF 1 class. From Table 4, the viscosity of the specimens with 5% and 10% POFA recorded from T500 test is in VS 1 class.

3.3 V-Funnel Test

The main purpose of V-funnel is to determine the filling ability of the concrete whereby the flow time is measured. The funnel is filled with the concrete and the time taken for it to flow through the apparatus is measured. T_{5min} is also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly.

Table 5 The result of V-funnel test

Percentage of POFA (%)	V-funnel	
	V-funnel (sec)	T_{5min}
CONTROL	10	5
5% POFA	5	1
10% POFA	6	1.5
15% POFA	9	2

Table 5 shows the result from the V-funnel test. The time measured using the V-funnel was in the range of 6 to 12 s (EFNARC, 2002) depending mainly on the SCC mixture used. The lowest V-funnel flow time of 5 s was measured for the SCC contains 5% POFA while the mixture standard SCC had highest flow time of 10 s. The graphical result is shown in Figure 3.

Based on the Table 6 there are two typical V-funnel classes according to European Guideline (EN 206-1). The V-funnel result indicated that SCC contains 5% and 10% POFA are in VF1 class where range from 8-25 sec though the control SCC and SCC contains 15% POFA are in class VF2 where the range from 9 s until 25 s. it is shown that all mix design are in the range of EFNARC requirement.

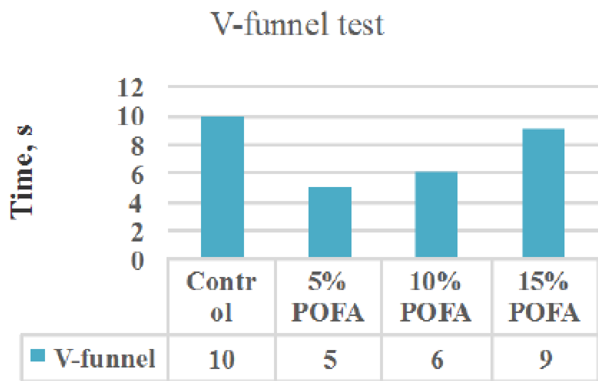


Figure 3 The bar graph of V-funnel Result

Table 6 V-Funnel Class (EN 206-1)

V-funnel class	Limit value (s)
VF 1	≤ 8
VF 2	9 - 25

3.4 Mechanical Properties

3.4.1 Compressive Strength

Figure 4 shows the average value of compressive strength for each type of concrete for the respective age of curing. The control SCC recorded compressive strength of 42.7, 46.1 and 50.5 MPa, at 7, 28, and 56 days of age, respectively. SCC contains 40% fly ash recorded the highest value of compressive strength which is 27.2, 39.4 and 43.9 MPa at 7, 28 and 56 days, respectively. The lowest value of compressive strength goes to 60% fly ash which is 17.0, 22.6 and 28.5 MPa at 7, 14 28 and 56 days.

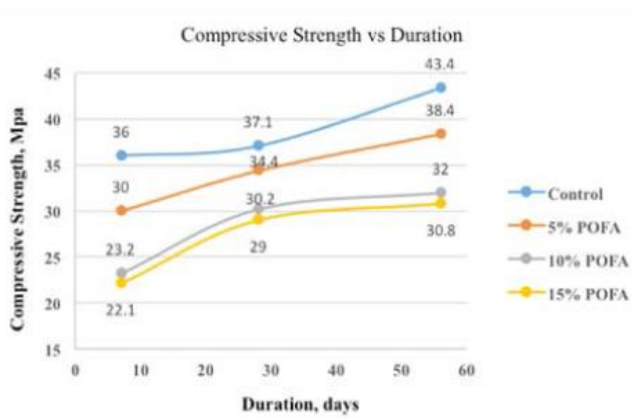


Figure 4 Average value of compressive strength for each type of concrete

From the result, it can be conclude that there is a limit of POFA content to increase the concrete performance. The fineness of POFA has affected the workability of the concrete. The higher amount of POFA incorporated in the concrete mixture will results with lower value of compressive strength.

3.4.1 Modulus of Elasticity

From the outcome result shown in Figure 5, concrete cylinder containing 5% POFA show the highest value of Modulus Of Elasticity (MOE) which is 31.6 MPa. However, overall result of Modulus of Elasticity for Control SCC and other mixture are in the typical range for the static modulus of elasticity at 28 days based on British Standard, BS 8110 part 2.

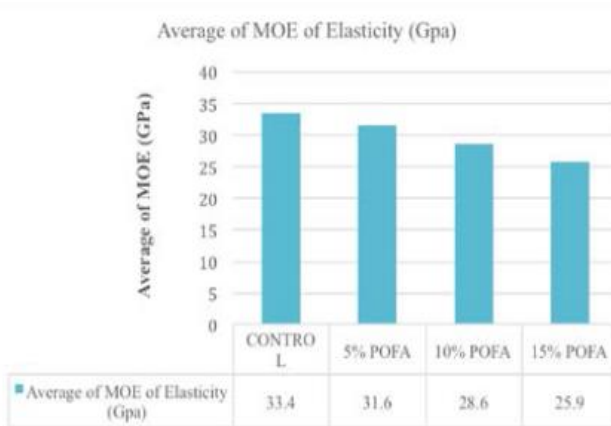


Figure 5 Results of Modulus of Elasticity

4.0 CONCLUSION

The workability of the SCC concrete with POFA decreases with increased dose of POFA. The optimum percentage of POFA with adequate strength is found to be about 5%. The highest compressive strength was achieved in SCC mixture with 5% of POFA which is 34.4 MPa at 28 days. MOE tend to decrease with the increase in POFA used except for mixture with 5% POFA.

Acknowledgment

The authors gratefully acknowledge the support of Universiti Tun Hussein Onn Malaysia

References

[1] Hajime Okamura & Masahiro Ouchi. 2003. Self-Compacting Concrete. *Journal of Advance Concrete Technology*. 1(1): 5-15. Japan Concrete Institute.

[2] Deepak, T. J., Elsayed, A., Hassan, N., Chakravarthy, N., Tong, S. Y., & Mithun, B. M. 2014. Investigation on Properties of Concrete with Palm Oil Fuel Ash as Cement Replacement. *International Journal of Scientific & Technology*. 3(1): 1-5.

[3] Galau, D., & Ismail, M. 2010. Characterization of Palm Oil Fuel Ash (POFA) from Different Mill as Cement Replacement Material.

[4] Ahmad, M. H., Tun, U., & Onn, H. 2008. Compressive Strength of Palm Oil Fuel Ash Concrete. *International Conference On Construction and Building Technology*. 27: 297–306.

[5] Sooraj, V. M. 2013. Effect of Palm Oil Fuel Ash (POFA) on Strength Properties of Concrete. *International Journal of Scientific and Research Publication.* 3(6): 1-7.

[6] Bouzoubaâ, N., & Lachemi, M. 2001. Self-compacting Concrete Incorporating High Volumes Of Class F Fly Ash: Preliminary results. *Cement and Concrete Research.* 31(3): 413-420.

[7] British Standards Institute. 1983. Determination of Density of Hardened Concrete. BS 1881: Part114: 1983.

[8] British Standard Institution. 1983. Method for Determination of Compressive Strength of Concrete Cubes. BS 1881: Part 116: 1983.

[9] British Standard Institution. 1983. Method for Determination of Static Modulus of Elasticity in Compression BS 1881: Part 121: 1983.

[10] Ghezal, a., & Khayat, K. H. 2002. Optimizing Self-Consolidating Concrete With Limestone Filler By Using Statistical Factorial Design Methods. *ACI Materials Journal.* 99(99): 264-272.

[11] Safiuddin, M., Md.Isa, M. H., & Jumaat, M. Z. 2011. Fresh Properties Of Self-Consolidating Concrete Incorporating Palm Oil Fuel Ash As A Supplementary Cementing Material. *Chiang Mai Journal of Science.* 38(3): 389-404.