MATERIAL PROPERTIES OF SELF-COMPACTING CONCRETE INCORPORATING PALM OIL FUEL ASH (POFA) AND GYPSUM POWDER AS CEMENT REPLACEMENT

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Abstract

This study explores the feasibility of utilizing palm oil fuel ash (POFA) and gypsum powder (GP) as partial replacements for cement in self-compacting concrete (SCC). Various proportions of POFA (20%) and GP (5%, 10%, 15%) were examined to assess their impact on the material and fresh properties of SCC. Physical properties of raw materials were determined, revealing differences in specific gravity and water absorption. Microstructural analysis using Scanning Electron Microscope (SEM) with Energy Dispersive X-Ray Analysis (EDX) indicated higher silica content in POFA (5.96%) and increased calcium content in GP (18.78%). Fresh properties tests, including slump flow, T500, J-Ring, and segregation, demonstrated that the 20P 0GP mix achieved optimal workability and self-compatibility without external compaction. The study highlights the potential of using agricultural waste and natural resources as sustainable alternatives in SCC production.

Keywords: *Self-compacting concrete (SCC), Palm oil fuel ash (POFA), Gypsum powder (GP), Scanning Electron Microscope (SEM), Energy Dispersive X-Ray Analysis (EDX)*

1. INTRODUCTION

Self-consolidating concrete (SCC) is a highly flow able type that spreads effortlessly without mechanical vibration, offering advantages such as enhanced constructability, reduced labour, and simplified pumping. Malaysia, a major palm oil producer, generates significant solid waste, with palm oil fuel ash (POFA) constituting about 5% through steam boiler combustion (Tangchirapat et al., 2007). The country faces challenges in solid waste disposal, generating approximately 30,000 tons daily (Clean Malaysia, 2015). POFA, with higher silica oxide but lower calcium oxide than gypsum powder (GP), is explored alongside GP as potential cement alternatives. This utilization of agricultural waste in construction materials not only reduces production costs but also addresses environmental concerns by minimizing landfill activity and pollution. The combination of POFA and GP exhibits a promising chemical composition for cement substitution (Khalid et al., 2016; Maneesh & Aravind, 2022). The integration of waste materials into usable products holds great potential for multiple industries, including agriculture, food manufacturing, and construction. This concise summary is based on findings detailed in the technical report.

Self-compacting concrete (SCC) addresses compaction issues by providing benefits such as enhanced powder content, coarse aggregate volume limits, and self-compatibility (Gupta et al., 2021; Bradu et al., 2016). Exploration of waste materials as supplemental cementitious materials, particularly agricultural waste such as palm oil fuel ash (POFA), contributes to environmental sustainability by lowering the industry's impact on raw resources (Hamada et al., 2021).

POFA is another significant waste that must be recycled in Malaysia. Malaysia is believed to be one of the major annual producers of palm oil waste (Kushairi, 2019). POFA is the ash created by burning the palm oil shell and husk as fuel in a palm oil mill boiler to generate steam to power the palm oil extraction process. This material is often disposed of in a landfill with little commercial benefit. To counteract this, various studies attempted to reuse POFA in a sustainable manner, and it was discovered that POFA possesses pozzolanic qualities, which allow it to be utilized as an alternative to cement in the building sector. Specifically, as a one-of-a-kind cement alternative in building materials.

Gypsum is a soft sulphate mineral made of calcium sulphated hydrate, having the chemical formula CaSo4.2H2o. Gypsum is made up of calcium, sulphur, oxygen, and water. Gypsum is a plentiful mineral that comes in a variety of forms. Gypsum is utilised to replace cement in concrete mixes since it has been proven to be a pozzolanic substance. Carbon-dioxide emissions into the atmosphere can be minimised by limiting the use of regular Portland cement. Due to growing environmental concerns and the need to conserve energy and resources, efforts have been made to use waste material from industrial and agricultural goods in the building industry as a pozzolanic mineral additive to replace standard Portland cement. Considering all the circumstances, gypsum, a pozzolanic material, is used to substitute cement, lowering the percentage of cement in the concrete mix globally (Reddy Thumma, 2017). Gypsum is becoming more popular as a building material because it is one of the most environmentally friendly binders (Doleželová et al., 2018).

This study investigates the physical properties of self-compacting concrete incorporating POFA and GP as partial cement replacements. The tests, including Specific Gravity, and Water Absorption, were conducted on specimens containing 20% POFA and varying percentages (0% to 15%) of gypsum. Additionally, SEM with EDX tests were performed to assess the microstructural properties of the hardened concrete. The workability of fresh concrete was evaluated using slump flow, T500, J-Ring, and segregation tests due to the potential impact of waste material additions. The study focuses on the usage of recycled POFA and GP in the manufacturing of SCC. Many developments and modifications have been used to reduce natural resource consumption. The purpose of this study is to investigate the potential of POFA and GP as cement replacements in SCC. The assessment of various qualities of concrete to determine whether it is suitable or not to replace cement in SCC.

2. LITERATURE REVIEW

In this investigation, GP and POFA will be used at levels of 5% and 20%, respectively, to replace a portion of the cement used in the production of self-compacting concrete (SCC). It is necessary to evaluate the methods, hypotheses, and findings of previous research in order to achieve this objective. This topic will cover SCC's use and other qualities in addition to its advantages and disadvantages. Additionally, the characteristics of POFA and GP as well as earlier research on their use as partial cement substitutes in concrete will be studied.

2.1. Microstructure Study

Microstructure study involves the microscopic analysis of a material's constituents, including type, size, amount, shape, and distribution phases. Pore structure, a crucial microstructure characteristic in porous solids, significantly impacts the physical and mechanical properties of the material. SEM is a valuable tool for characterizing cement and concrete microstructures, aiding in the assessment of cementing materials' impact, addressing durability concerns, and predicting material service life. Tiedt and Pretorius (2018) note that SEM provides topography images for analysing particle size, shape, surface, roughness, and fracture surfaces. It utilizes X-Ray Microanalysis, Secondary Electron Imaging, and Backscattered Electron Imaging modes. Rajak et al. (2015) explored the influence of POFA on cement microstructure, revealing that POFA particles inhibited ettringite growth in the hardened cement paste, as observed in Figure 1 of their study.

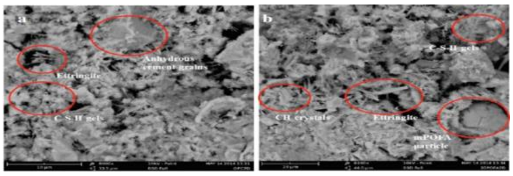


Fig. 1 Morphology of (a) Control sample-hcp (b) 20% POFA-hcp of cement pastes at 7 days of curing age (Rajak et al., 2015)

2.2. Fresh Properties

In general, POFA is the high pozzolanic activity that allows it to reduce the use of cement in concrete. Furthermore, the high fineness of POFA reduces concrete expansion due to the alkali-silica reaction, improving concrete performance (Syaizul et al., 2019). POFA has a low pozzolanic reaction because of its porous nature and big particle size. According to EFNARC, new concrete features such as filling capacity, passage ability, and segregation resistance were evaluated. Slump flow and T500 mm tests were used to evaluate horizontal flow in the absence of limitations. The J-ring flow test was used to determine passage capacity, which ensures movement across congested locations without vibrating. According to EFNARC (2005), passage ability, crucial for movement through tight spaces without segregation, was evaluated through J-ring and L-box tests. Segregation resistance, ensuring cohesiveness during casting, was verified using the GTM screen stability test method.

Table 1 Summary of fresh properties of POFA to SCC carried out by various researchers

Author/ Year	POFA (%)	Fresh Properties				
		Slump Flow (mm)	T500mm time (s)	J-Ring (mm)	Segregation Index (%)	Type of SCC
Safiuddin, M., Jumaat, M. Z. (2011).	0	630	2.0-5.0	590	10.4	High Strength
	10	640		610	10	
	15	665		630	11.2	
	20	670		635	11.7	
	30	675		650	12	
Alsubari, B., Shafigh, P., Jumaat, M. Z., & Alengaram, U. J. (2014)	0	700	3.5-4.8	690	6.7	High Strength
	10	690		670	8.7	
	15	680		650	10.8	
	20	660		630	13.9	
Alsubari, B., Shafigh, P., & Jumaat, M. Z. (2015)	0	700	2.9-3.5	690	6.7	High Strength
	10	710		690	6.9	
	20	715		695	7.3	
	30	720		700	7.8	
	50	730		710	8.2	
Ranjbar, N., Behnia, A., Alsubari, B., Birgani, P. M., & Jumaat, M. Z. (2016)	0	700	3.0-4.57	690	6.67	High Strength
	10	690		670	8.7	
	15	680		650	10.8	
	20	660		630	13.9	
Salam, M. A., Safiuddin, M., & Jumaat, M. Z. (2018)	0	630	-	590	10.4	High Strength
	10	640		610	10	
	20	665		630	11.2	
	30	675		650	12	

2.3. Replacement of Cement as POFA and GP

Agricultural waste, including materials like POFA, fly ash, and micro silica, poses a significant environmental challenge, leading to contamination in various ecosystems. These wastes, when improperly disposed of, end up in landfills, coastal waters, and rivers. Gypsum, a natural resource, plays a crucial role in cement hardening and has gained traction as an environmentally friendly construction material. Reducing the use of conventional Portland cement is identified as a method to minimize carbon-dioxide emissions (Reddy Thumma, 2017).

Previous researchers had not extensively researched the combination of POFA and GP as a cement replacement, and very little information had been found. By referring research of Kamaruddin, (2020) which is eggshell and POFA as a cement replacement, eggshell is a poultry waste with a composition as rich in calcium as limestone. The researcher succeeded in producing and proving that eggshell powder and POFA as a cement replacement in SCC. The material from previous study will be changed to the GP. As a result, the combination of POFA and GP as cement replacement in SCC is thought to be studied in this study.

3. MATERIAL AND METHOD

Methodology was one of the research stages that went through the steps of methodologies, material preparation, and experimental work. This chapter outlined or defined the approach that was used in fulfilling the objectives in this study. An experiment was carried out to investigate the material properties of self-compacting concrete (SCC) with POFA and GP as partial cement replacements.

3.1 Materials

Ordinary Portland Cement (OPC): In this experimental study, OPC was used. When cement was mixed with additional chemical admixtures, different chemical and strength characteristics resulted. In this study, concrete grade 35 was designed, and the cement was approved by SIRIM as complying with MS 197-1:2007.

Fine aggregate: The sand was prepared from UTHM laboratory "Makmal Bahan Termaju." The sand dried in the oven at a temperature of 100°C for 1 day or 24 hours to remove the moisture in the sand particles. Fine aggregates were small-sized materials in which the particles passed through a 4.75mm sieve mesh, were retained on a 0.075mm filter after oven drying and were used in this study.

Coarse aggregate: Coarse aggregate had a wide range of construction applications. When blended with other elements in concrete, good concrete mixes comprised aggregates that were clean, strong, and hard. Quarry rock was crushed to generate aggregate that had been passed through a 12mm screen.

Water: POFA was put in the oven for drying at a temperature of 105°C ± 5°C for 1 day or 24 hours and sieved through a sieve size of 300 μm to remove larger particles and other substances. POFA was also sieved through a sieve size of 75 μm to collect good ashes with the same cement size. After the sieving process, POFA was put in a container to maintain the moisture content.

POFA: POFA was collected from Band Dung Palm Oil Industries Sdn. Bhd. at Sri Medan, Batu Pahat, Johor Darul Takzim and put in the oven for drying at a temperature of 105°C ± 5°C for 1 day or 24 hours and sieved through a sieve size of 300 μm to remove larger particles and other substances. POFA was also sieved through a sieve size of 75 μm to collect good ashes with the same cement size. After the sieving process, POFA was put in a container to maintain the moisture content.

Gypsum powder: It contributes to the hardening of cement and the rapid setting of cement. Gypsum is dehydrating calcium sulphate (CaSO4.2H2O). White gypsum powder was used as a cement replacement.

Superplasticizer: The superplasticizers that were employed in this research as an admixture in each mix proportion. The admixture is systematically specified in the ingredient selection to generate high early strength in the concrete mixture, lower the water-cement ratio, accelerate the initial set, increase strength, reduce shrinkage, and improve workability.

3.2 Method

Mix design proportion: The proportion of the concrete mixture was according to the listed weights in Table The composition of the mix that was used for the duration of this study is shown in terms of cement, sand, aggregate, and water content. In order to study the workability of fresh concrete on the day the concrete was cast, this study included 5 samples. The mix proportion involves using 20% of POFA and varying amounts of GP from 0% to 15% as substitutes for cement in self-compacting concrete (SCC). The mix concrete was labelled for 20% of POFA with 20P and 0% to 15% of GP with 0GP, 5GP,10GP and 15GP.

Table 2 Mix proportion of sample

Mix Name	Cement (kg/m^3)	POFA (kg/m^3)	GP (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)
Control	451	0	0	902	767	180	9.02
SSC 20P 0GP	361	90.19	0	902	767	180	9.02
SSC 20P 5GP	338	90.19	22.54	902	767	180	9.02
SSC 20P 10GP	316	90.19	45.1	902	767	180	9.02
SSC 20P 15GP	293	90.19	67.65	902	767	180	9.02

Concrete Testing: EFNARC (2005) European requirements for SCC specified every testing. This table 3 shows the specifications and standards used for testing the SCC in accordance with British and European standards (BS EN) and American Society for Testing and Materials (ASTM) standards. The testing is being conducted followed by standard and the material undergoes testing.

Table 3 Mix proportion of sample

Description	Testing	Standard BS EN	Material
Physical Properties	Specific Gravity	ASTM C128-15	POFA, GP, Cement
	Water Absorption	BS 1881-122:201	Concrete
Microstructure Study	Scanning Electron Microscopy (SEM)	ASTM E1508-12	POFA, GP, Cement
	Energy Dispersive X-Ray Analysis (EDX)	ASTM E1509-20	Concrete
Fresh Properties	Slump flow	ASTM C1611M-21	Concrete
	T500	BS EN 12350-12:2010	
	J-Ring	BS EN 12350-11:2010	
	Segregation	BS EN 12350-8:2017	

Sample Preparation: The sample preparation and material handling were based on mixed design proportions. Water absorption testing utilized cube molds with dimensions of 100 mm x 100 mm. The water absorption test involved three samples for each proportion at an age of 28 days, totaling 15 cube samples. Therefore, material testing, including specific gravity tests with 50 g for each material, and SEM with EDX tests with 20 g for each material, along with concrete samples aged 28 days for each batch, was prepared with a 2-3 mm sample. Other tests, such as slump flow, T500, J-Ring, and segregation tests, were conducted during the casting process.

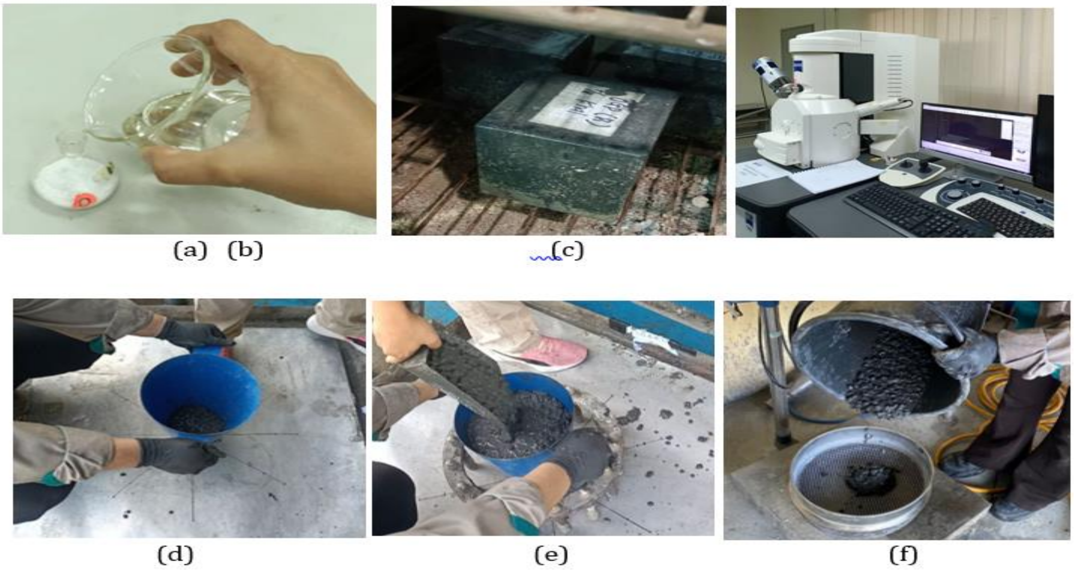


Fig. 2 Methodology of research (a) Specific gravity test; (b) Drying concrete for water absorption test; (c) Zeiss Evo LS10 instrument for SEM and EDX testing; (d) Slump flow test and T500 test; (e) Poured concrete for J-ring Test; (f) Segregation test

. Table 4 Sample preparation physical properties and microstructure study

Description	**Testing**	**Material**	**Amount**
Physical Properties	Specific Gravity	POFA, GP, Cement	50g
	Water Absorption	Concrete	15 samples cube
Microstructure Study	Scanning Electron Microscopy (SEM)	POFA, GP, Cement	20g
	Energy Dispersive X-Ray Analysis (EDX)	Concrete	2-3mm concrete sample

Table 5 Sample preparation fresh properties

Type of Test	**Mix Name**	**Amount of Material**		
		% of POFA	**% of GP**	**% of Cement**
Slump flow test & T500 test	Control	0%	0%	100%
J-Ring test	SSC 20P 0GP	20%	0%	80%
Segregation test	SSC 20P 5GP	20%	5%	75%
	SSC 20P 10GP	20%	10%	70%
	SSC 20P 15GP	20%	15%	65%

4. RESULTS AND DISCUSSION

4.1 Physical Properties

Specific Gravity: The purpose of this test is to determine the specific gravity of the materials. Cement, POFA, and GP are the samples. The formula and calculation for SG are shown below. The results of the SG test for cement, POFA, and GP are shown in Table 6 below.

Table 6 Sample preparation physical properties and microstructure study

Material	Weight of empty flask (W1)	Weight of flask + material (W2)	Weight of flask + material + kerosene (W3)	Weight of flask + kerosene (W4)	Specific gravity (SG)
Cement	33.86	44.03	80.95	73.37	2.43
POFA	33.89	43.92	78.95	72.25	2.12
Gypsum	31.47	41.5	77.81	70.92	2.19

According to table 6, the SG values for cement, POFA, and GP are 2.43, 2.12, and 2.19, respectively. POFA and GP both have lower SG values than cement. Because POFA is organic waste and GP is a natural resource. The presence of pores and voids from POFA and GP results in a lower SG value. All of the materials sunk in kerosene because their SG values were higher than SG of kerosene value.

Water Absorption: Water absorption is a deceptive technique for determining the durability of concrete. Hazardous substances are commonly found in water. These substances interact with cement components, changing the performance of concrete. The water absorption test calculation is shown below.

Fig. 3 shows the result of the water absorption test. Concrete mix with 0% of GP replacement of cement having a lower percentage absorption with 3.24% compared to other specimen. Meanwhile, specimen with 15% of GP gave higher percentage absorption with 9.43%. Specimen with 20P 15GP have the lowest workability due to high percentage of POFA and Gypsum powder which absorb the water. Both materials of POFA and GP have porous structure of surface area.

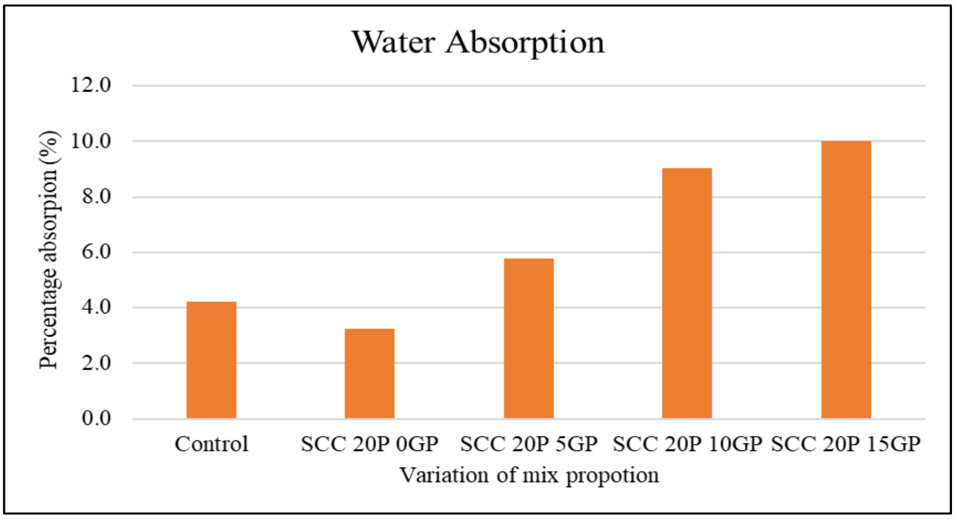
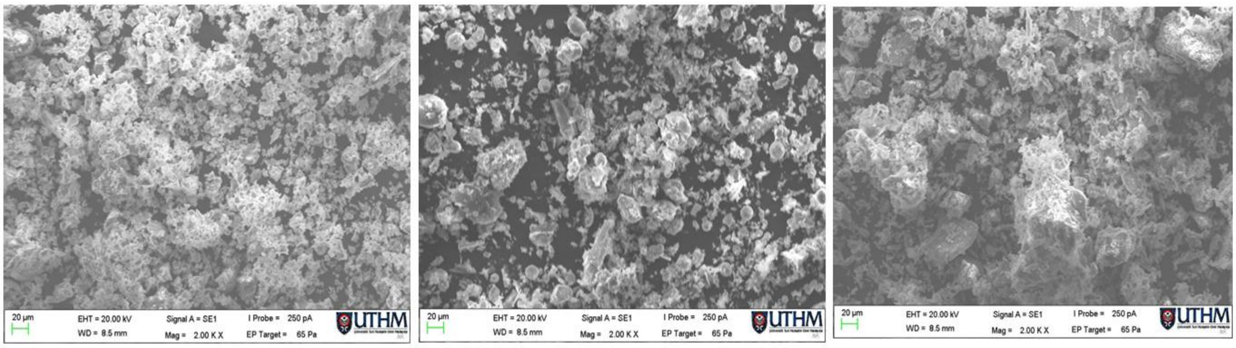


Fig. 3 Result of water absorption

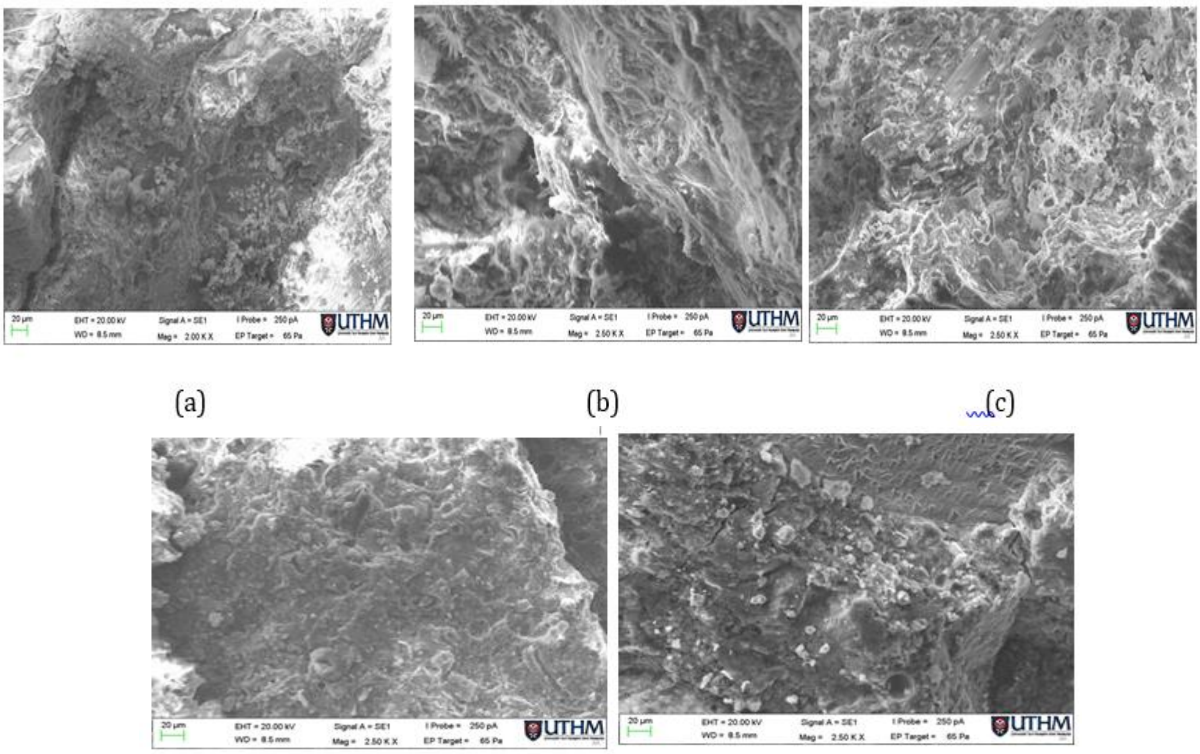
4.2 Microstructure Study

Scanning Electron Microscope (SEM) with Energy Dispersive X-Ray Analysis (EDX): SEM analysis was conducted on all the concrete samples with and without the POFA and GP including all material samples which is cement, POFA and GP. The application of SEM improves the capacity to analyse the concrete microstructure and can assist in the determination of the chemical elements concrete. In Figures 4 and 5, the SEM plays an important role in clarifying the microstructure of concrete. SEM analyses their topography as well as their composition. In this investigation, concrete specimens were collected at a curing age of 28 days after the compressive strength testing.



(a) (b) (c)

Fig. 4 SEM image (a) Cement; (b) POFA; (c) GP



(a) (b) (c) (d) (e)

Fig. 5 SEM image (a) Control sample; (b) 20P 0GP; (c) 20P 5GP; (d) 20P 10GP; (e) 20P 15GP

According to Table 7, shows the percentage of elements in the material of cement, POFA and Gypsum. POFA have a high percentage element of Silica (Si) with 5.96% compared to GP have 0.35% only. Meanwhile, the percentage element Calcium (Ca) in GP is high with 18.78% compared to POFA. From the previous study, GP is high with Ca and POFA high with Si. As a result, the element has been proved by EDX test.

Table 7 Percentage element from EDX test

Element	**Material**		
	Cement (%)	**POFA (%)**	**Gypsum (%)**
Oxygen (O)	37.28	25.56	47.3
Calcium (Ca)	34.59	1.47	18.78
Calium (C)	13.46	56.97	20.68

Silicon (Si)	6.46	5.96	0.35
Ferum (Fe)	2.3	0.33	-
Aluminium (Al)	2.03	-	2.09
Magnesium (Mg)	1.21	0.96	-

The effect of POFA and GP on the SCC as cement replacement was investigated using microstructural properties. The microstructure images influence the percentage of POFA and GP of cement replacement. Based on the findings of this study, the microstructure of the samples of the respective concrete mixtures was examined using SEM. Figure 5 show the changes in microstructure forms from mix to mix.

4.3 Fresh Properties

Slump Flow and T500 Test: The workability and filling ability of concrete mixture were determined using slump flow and slump time for the T500 test. Table 8 shows the results of the slump flow test and T500. Figure 6 shows the result of the slump flow until it reaches T500. The result for slump flow was obtained in this test by calculating the average of the diameter and the time of spread to reach 500mm of diameter. The slump flow calculation is shown below.

Table 8 Result for Slump Flow Test and T500

Specimen	**Slump Flow Test**			
	Diameter of Spread			**Time of Spread to T_{500}**
	d1	**d2**	**davg** **550mm ≥ SF ≤ 850mm**	**time (s)**
Control	650	680	665	3.5
SCC 20P 0GP	620	625	623	4.1
SCC 20P 5GP	610	620	615	4.8
SCC 20P 10GP	580	570	575	5.3
SCC 20P 15GP	550	560	555	5.8

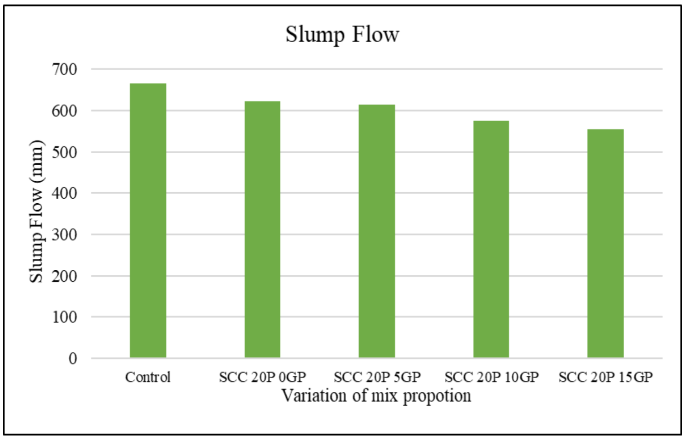


Fig. 6 Result for slump flow test

According to Figure 6, slump flow for all specimens is different. The control specimen had the highest slump flow of 665mm because it was not mixed with POFA or GP. Besides that, all of the specimens with results ranging from 20P 0GP to 20P 15GP were lower than the control. This is due to the material POFA and GP absorbing liquidity in the concrete. As a result, the replacement of cement at 20P 15GP has the lowest value in slump flow, which is 555mm. This could be because both materials absorb more water. Slump flow was 623mm, 615mm, and 575mm for specimens with POFA and GP as cement replacement, which were 20P 0GP, 20P 5GP, and 20P 10GP. The presence of POFA and GP in concrete was observed to affect the water content of the concrete mixture. According to EFNARC (2005), the limitation slump flow for SCC is between 550mm and 850mm. To summarize the results, all specimens are within the acceptable range of limitation.

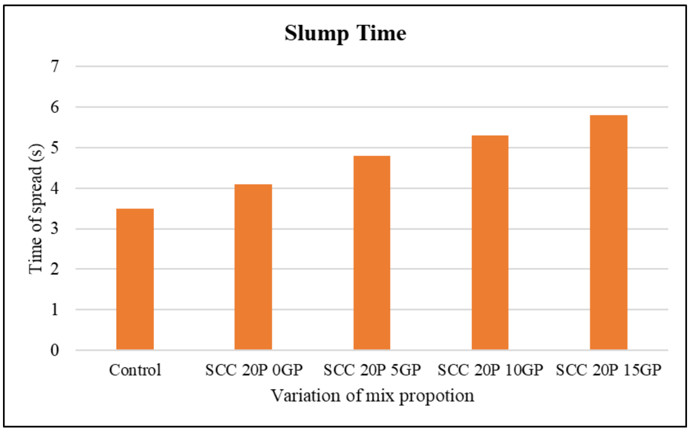


Fig. 7 Result for slump time until reach T500

According to Figure 7, The concrete mix with 0% replacement has a shorter time of 3.5 seconds for T500. Through the presence of POFA and GP in the concrete mix, this indicates that more time is required. The longest time required for 20P 15GP as cement replacement is 5.8 seconds. This could be because the combination of 20% POFA and 15% GP absorbs more liquid in the concrete mix. According to the graph, the concrete mix with 15% GP as a cement replacement takes the longest time to reach 500mm when compared to specimens with 0%, 5%, and 10% GP. It shows a higher percentage of GP replacement in the sample produced a longer time than a lower percentage of GP replacement in the sample. According to EFNARC (2005), the required time for the T500 test is between two until six seconds. As a result, the results show that all specimens with cement replacement are within the acceptable range.

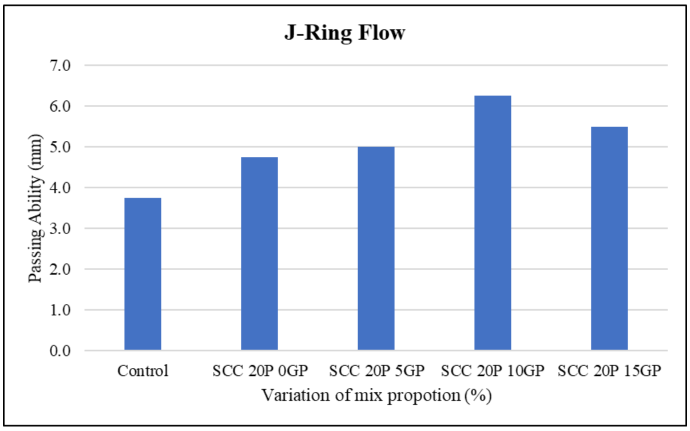
J-Ring Test: J-Ring test methods are used to determine the ability of SCC to pass under its own weight when combined with a slump mold. The results of the J-ring test are shown in Table 9 below. Figure 8 represents a bar chart of J-ring flow. The calculations are shown below.

According to the result, a specimen with 0% GP showed high passing ability. It shows that the material has a high absorbance towards liquid in the concrete mix. Meanwhile, the specimen 20P 10GP with 10% GP as cement replacement has the lowest workability because it has the highest passing ability, 6.25mm, when compared to other specimens. It is due to the fact that POFA and GP absorb water in the concrete mix. Both materials may have a porous structure area. According to EFNARC (2005), the passing ability of the J-Ring test must be less than 10mm. To summarize, all the specimen of J-Ring flow results met the requirement.

Table 9 Result for J-Ring test

Specimen	**J-ring Flow**						
	Height of Spread (mm)						**Passing ability**
	hx1	**hx2**	**hy1**	**hy2**	**havg**	**ho**	**hx1 - ho ≤ 10mm**
Control	110	120	118	115	116.75	113	3.75
SCC 20P 0GP	110	120	115	110	113.75	109	4.75
SCC 20P 5GP	110	115	105	110	110.00	105	5.00
SCC 20P 10GP	120	110	115	120	116.25	110	6.25
SCC 20P 15GP	118	115	110	115	114.50	109	5.50

Fig. 8 Result for J-Ring flow



Segregation Test: The segregation test is used for determining the sieve segregation resistance of SCC. The test aims at investigating the resistance of SCC to segregation by measuring the portion of the fresh SCC sample passing through a 5mm sieve. Table 10 and Figure 9 show the result of segregation test on SCC samples.

Table 10 Result of Segregation test

Specimen	Segregation Sieve						
	Mass of the pan, Wp (g)	**Mass of the sieve + pan, Wsp (g)**	**Mass of pan + sieve + total poured concrete, Wspc (g)**	**Mass of pan+ passed concrete, Wppc (g)**	**Mass of passed concrete through the sieve , Wpc (g)**	**Initial mass of concrete placed onto the sieve, Wc (g)**	**Segregated portion, SR (%) ≤ 20%**
Control	680	1830	3650	760	80	1820	4.40
SSC 20P 0GP	490	1580	3070	540	50	1490	3.36
SSC 20P 5GP	710	1860	3650	770	60	1790	3.35
SSC 20P 10GP	680	1810	3560	770	90	1750	5.14
SSC 20P 15GP	490	1640	3560	540	50	1920	2.60

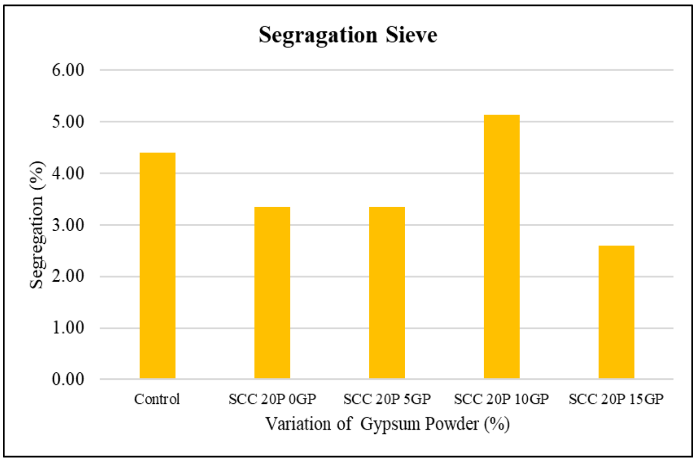
Table 10 shows the result for segregation sieve test. Figure 9 shows the result of segregation sieve for various percentage of GP and 20% POFA as cement replacement. The main objectives of the test are to investigate SCC's resistance to segregation using a 5mm sieve and to see if any fresh SCC sample passed through the sieve. According to the results, the 20P 15GP specimen has the lowest percentage of segregation. As shown in the results for specimen 20P 10GP, concrete with a high workability produces a higher percentage of segregation. Due to of the absorbance characteristics of both materials, the percentage of segregation varies depending on the percentage of material used as cement replacement. EFNARC

(2005) requires that the percentage of sieve separation results be less than 20%. As a result, all of the concrete mixtures met the requirement.

Fig. 9 Result of segregation sieve test

5. CONCLUSION

The experimental study on POFA and GP as a cement replacement for concrete can be concluded



based on the laboratory results. The first objectives are to study the physical properties of POFA and Gypsum Powder as cement replacement. This was achieved by determining the physical properties using specific gravity and water absorption. POFA and GP both gave SG values of 2.12 and 2.19. Meanwhile, the cement SG test result is 2.43. Due to the presence of pores in the materials SG of cement exceeds that of POFA and GP. Due to the SG value of kerosene is lower than the SG value of the material, all the materials tested in this test were immersed in it. The water absorption of concrete was conducted to determine the durability of the concrete. The specimen with 0% GP replacement of cement had the lowest absorption with 3.24%, while the specimen with 15% GP replacement had the highest absorption with 9.43%. The reduced workability of the 20P 15GP specimen was attributed to the high percentages of POFA and gypsum powder, which are known for their water-absorbing properties due to their porous surface structures.

The second objective is to determine the microstructural analysis of self-compacting concrete incorporating POFA and Gypsum Powder as cement replacement. Through SEM/EDX analysis of particles, it was found that OPC particles were discovered to be non-spherical and irregular in shape, whereas GP particles were cubical and angular in shape. POFA particles are spherical in shape and have a porous and honeycomb structure.

The final objectives are to undergo the fresh properties of self-compacting concrete incorporating POFA and Gypsum Powder as cement replacement. Slump flow, T500, J-Ring, and segregation tests were performed on fresh properties. According to the results of all experimental testing to determine fresh properties, it has been verified by slump flow test, T500 test, J-Ring test, and segregation test that successfully achieved workability and self-compactibility under its own weight without compaction or using any mechanical vibrator.

ACKNOWLEDGEMENTS

The author expresses thankful to the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support for the endless support and complete facilities for being able to conduct the case study.

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