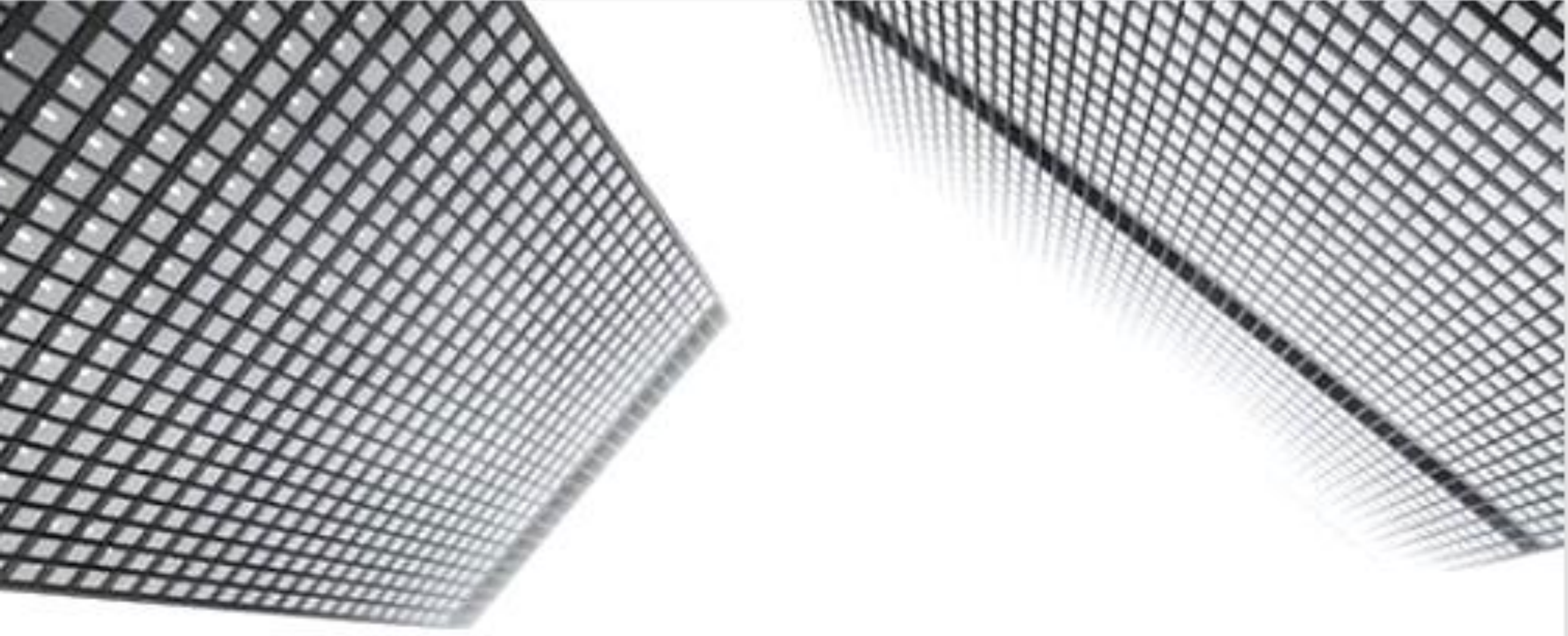

CIVIL ENGINEERING, SCIENCE AND TECHNOLOGY CHALLENGES: STRUCTURAL ENGINEERING AND CONSTRUCTION MATERIALS

EDITED BY

Wan Hashim Wan Ibrahim
Siti Noor Linda Taib
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The book is based on scientific and technological advances in various Structural Engineering and Construction Materials areas of Civil Engineering. It nurtures therefore the exchange of discoveries among research workforces worldwide including those focusing on the vast variety of facets of the fundamentals and applications within the Structural Engineering and Construction Materials arena. To offer novel and rapid developments, this book contains original contributions covering theoretical, physical experimental, and/or field works that incite and promote new understandings while elevating advancement in the Structural Engineering and Construction Materials fields. Works in closing the gap between the theories and applications, which are beneficial to both academicians and practicing engineers, are mainly of interest to this book that paves the intellectual route to navigate new areas and frontiers of scholarly studies in Structural Engineering and Construction Materials.

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CHAPTER 18

INFLUENCE OF SILICA BASED WASTE MATERIALS ON THE MECHANICAL AND PHYSICAL PROPERTIES OF MORTAR

S.I. Balang[1], N. Mohamed Sutan[1]*, I.Yakub[1], M.S. Jaafar[2] and K.A. Matori[2]

ABSTRACT

This is an investigation on the influence of silica based waste materials namely silica fume (SF) and recycled vase (RV) on the physical and mechanical properties of mortar. Results showed that 15%SF modified mortar achieved the highest strength and lowest water absorption capability compared to Control mortar and other mixtures. The result was confirmed by water absorption capability test for the same mixtures where 15% SF modified mortar was found to absorb the least. Furthermore, combination of 15% SF and 10% RV achieved the lowest water absorption compared to other combinations samples but higher than Control and 15% SF modified mortar. The results of this study indicated that SF is highly pozzolanic material that can be an excellent cement replacement material to produce high- performance concrete. Study on pozzolanc behavior of SF samples subjected to longer hydration time is needed. Further microstructural investigation is needed to confirm the hypothesis on retardation of hydration due to unreactive RV.

Keyword: Silica Fume, Recycle Vase, Mortar, Compressive Strength, Water Absorption

INTRODUCTION

The increased in the utilization of waste materials in construction product came from greater awareness of current and potential potential uses of alternative and recycled materials and wider realization of the environmental benefits accrued. The practice of partially replacing cement in concrete and mortar with waste and other less energy intensive processed materials will contribute environmental protection and sustainable construction in the future. To be qualified as a candidate for cement replacement for concrete or mortar, the waste material must be silica based and very fine. The specific chemical property is the classification of a material to be pozzolanic. Pozzolan is defined as a siliceous material which, in itself, possesses little or no cementing property but which will, in finely divided form and in the presence of moisture, react chemically with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties that can improve concrete and mortar properties [1].

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Silica Fume (SF), a byproduct or waste from silicon metal or ferrosilicon alloys production, is a very reactive pozzolan due to its chemical and physical properties which are high in silica and fine particle size, therefore it can be used as partial cement replacement for concrete and mortar production [2-6].

One possible source of pozzolanic waste material is calcined clay [7-9]. Waste calcined clay used in this study, which is derived from recycled vase (RV) in the form of vase powder. Therefore, this study is designed to investigate the combination of waste calcined clay and silica fume as partial cement replacement or only silica fume as partial cement replacement on the improvement of durability properties of concrete modified mortar. The purpose of this research is to investigate the pozzolanic activity of binary binder system of by-product silica fume (SF) as partial cement replacement, and ternary binder of SF and waste calcined clay (RV). The objective of this research is to investigate the mechanical and physical properties of SF, RV modified mortar and their combination on namely their compressive strength and water absorption capability. These properties can be used as an indirect indication of extent of hydration and pozzolanic reactivity of modified mortar.

MATERIALS

MATERIALS AND METHODS

Silica based materials chosen as cement replacement were Silica Fume (SF) according to ASTM C 1240 obtained from Grace Construction and Recycle Vase (RV) or waste vase collected from Naga Emas Ceramic Ind. Sdn. Bhd. The waste vase was cleansed with water to remove dirt and washable contaminants. It was then crushed into smaller pieces and finely grounded to particle size finer than 75 µm. Table 1 shows the chemical composition of OPC and RV obtained from X-ray fluorescence (XRF) analysis. Cement used was Ordinary Portland Cement (OPC) (ASTM Type 1 recognized by ASTM C150) manufactured by Cahaya Mata Sarawak Cement Sdn. Bhd. (CMS). The physical properties and chemical compositions of the OPC and RV are shown in Table 1. SF contains up to 97% SiO_2. Water and fine aggregate used in this study were regular tap water and natural river sand, respectively. Glenium was used as superplasticizer (SP).

Table 1. Physical properties and chemical composition of OPC and RV

		Ordinary Portland Cement (OPC) ASTM Type 1	
Physical Properties	Bulk density	1.2 – 1.4 kg/L	
	Specific gravity	3.15	
	Amount retained on 90 um sieve (%)	2 %	
	Amount retained on 45um sieve (%)	18 %	
		OPC	Recycle Vase (RV)
Chemical Composition (%)	Silicon dioxide, SiO_2	19.34	53.30
	Aluminum oxide, Al_2O_3	5.20	18.36
	Ferric oxide, Fe_2O_3	3.41	16.43
	Sulphur trioxide, SO_3	2.85	0.73
	Magnesium oxide, MgO	1.44	-
	Potassium oxide, K_2O	0.47	5.54
	Calcium oxide, CaO	64.75	2.12
	Titanium Dioxide, TiO_2	-	1.92
	Barium oxide, BaO	-	0.61
	Sodium oxide, Na_2O	0.10	-
	Manganese oxide, MnO	-	0.26
	Loss on ignition, LOI	3.42	0.24
	Free Cao	1.39	0.17
	Total Alkali	0.41	0.41

SAMPLE PREPARATION FOR COMPRESSIVE STRENGTH (CS) AND WATER ABSORPTION TESTS.

The mix proportion for mortar was set at 0.6 binder to sand ratio (b/s) and 0.5 water to binder ratio (w/b) for all specimens that were casted into 150 mm cubes for compressive strength (CS) and water absorption tests. Cement was replaced by SF (10%, 15% and 20%) by weight as binary binder and combination of SF (15%, 20%) and RV (10%, 20% and 30%) by weight as ternary binder. All samples were prepared using the mix proportion as shown in Table 2 and were wet cured in the concrete laboratory at Universiti Malaysia Sarawak for 3, 7, 14, 21, and 28 days. All mixes except Control has an SP dosage of 1 litre per 100kg of binders.

Sample	SF (kg/m^3)	RV Powder (kg/m^3)	OPC (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)
Control	-	-	683.36	1138.86	341.66
SF=10%	68.34	-	615.02	1138.86	344.51
SF=15%	136.67	-	547.00	1138.86	342.62
SF=20%	205.00	-	478.36	1138.86	344.51
15% SF, 10% RV	136.67	68.34	478.66	1138.86	343.51
15% SF, 20% RV	136.67	136.67	342.00	1138.86	343.51
15% SF, 30% RV	136.67	205.00	205.00	1138.86	343.51
20% SF, 10% RV	205.00	68.34	410.02	1138.86	343.51
20% SF, 20% RV	205.00	136.67	273.63	1138.86	343.51
20% SF, 30% RV	205.00	342.00	136.63	1138.86	343.51

Table 2. Mix proportions for all specimens

COMPRESSIVE STRENGTH (CS) AND WATER ABSORPTION TESTS.

CS and water absorption tests were performed on day 3, 7, 14, 21, and 28 according to BS 1881-116 (1983) [10] and BS 1881 Part-5 (1983) Part 122, respectively [11]. CS test was used to determine the maximum compressive load that a sample can carry per unit area. Meanwhile water absorption test was used to evaluate water absorption capability of a sample. Both tests give the overall picture of the quality of mortar as it hydrates. Each strength and water absorption values were the average of value of three specimens. Compressive strength for each sample was calculated by using Equation (1)[10]. Meanwhile, water absorption capability for each sample was determined by using Equation 2[11].

$$\text{Compressive strength} = \frac{\text{Failure loading} \times 1000\ (N)}{\text{Surface area of cubes}\ (mm^2)} \qquad (1)$$

$$\text{Water Absorption}\ (\%) = (B-A)/A \times 100\% \qquad (2)$$

where, A= weight of dry cube and B= weight of wet cube

RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH (CS) TEST

Figures 1 and 2 show the compressive strength of SF and SFVC samples compared to Control samples. The increasing compressive strength as cement hydration proceeded from day 3 to 28 in both figures is an expected and established trend [12]. Figure 1 shows 15%SF sample has the highest 28 day comprehensive strength compared to other samples. This is caused by pozzolanic reaction of silica in SF with Calcium Hydroxide (CH) from cement hydration that produced more Calcium Silicate Hydrate (C-S-H) that refines the pores and densifies the cement matrix[1-9][12].

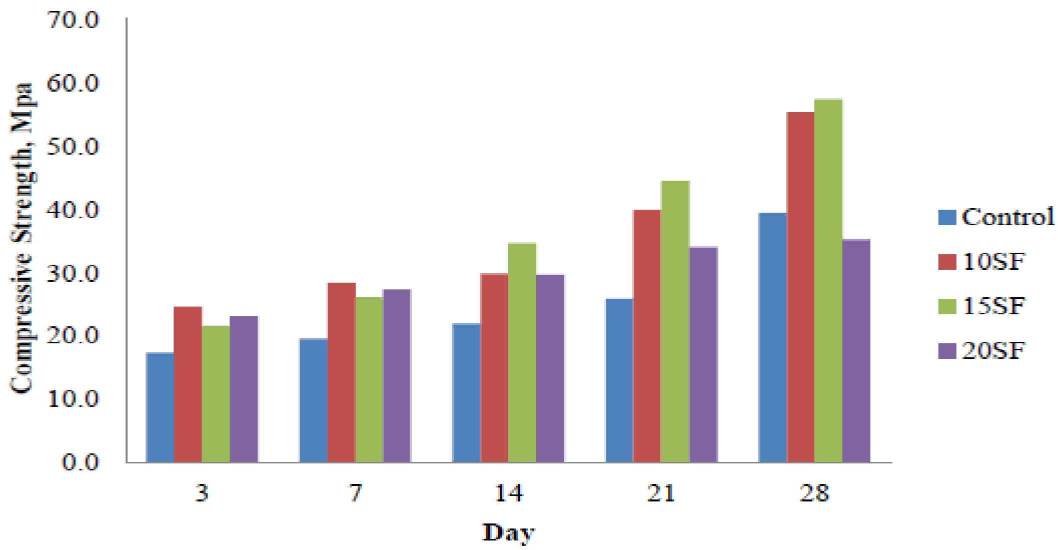

Figure 1. Comparison of Compressive Strength between Control and SF modified mortars

Figure 2 shows that the combination of 15% SF and 10% RV produced higher strength than other combinations of SF and RV but there was no significant reduction in the compressive strength of these mixtures when compared to the control mortar and 15% SF sample.

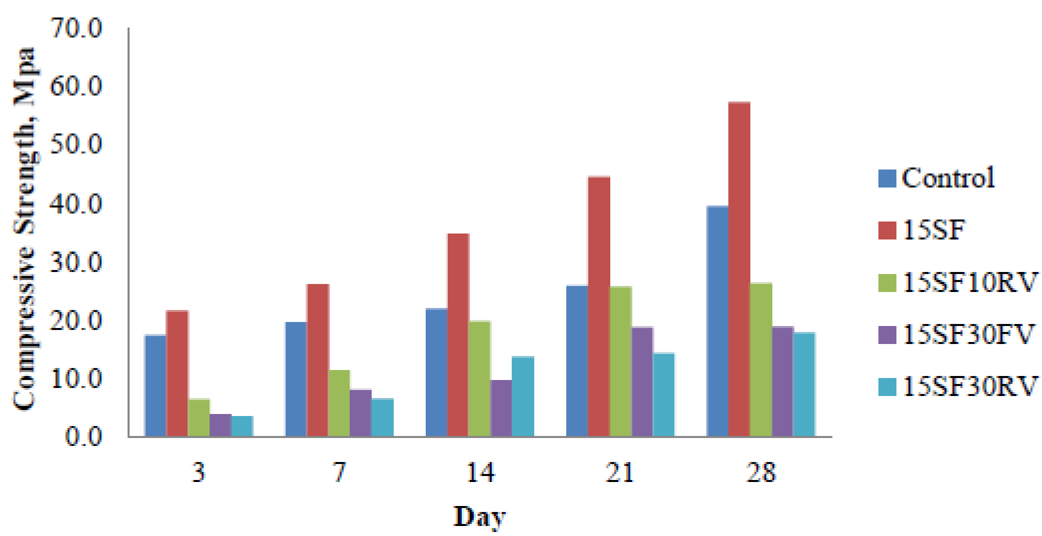

Figure 2. Comparison of Compressive Strength between Control, SF and SFRV modified mortars

RV may not have reactive silica that can produce pozzolanic behaviour. Besides, the presence ofRV may retard the reactivity of SF and cement hydration. Further microstructural investigation need to be done to confirm this hypothesis.

WATER ABSORPTION TEST

Figure 3 and 4 show the water absorption of SF and SFVC compared to Control samples. From Figure 3,15% SF sample has the lowest water absorption at day 28 which indicated that there are less interconnected capillary voids in the sample [4][5].Figure 4 shows that the combination of 15% SF and 10% RV achieved the lowest water absorption compared to the other combinations samples. However, the absorption is still higher than 15% SF and Control. This is an indication that the unreactive RV may retard hydration [8][9]. The water absorption trend for all samples is the opposites of compressive strength trend and this fact has already been an established trend [12].

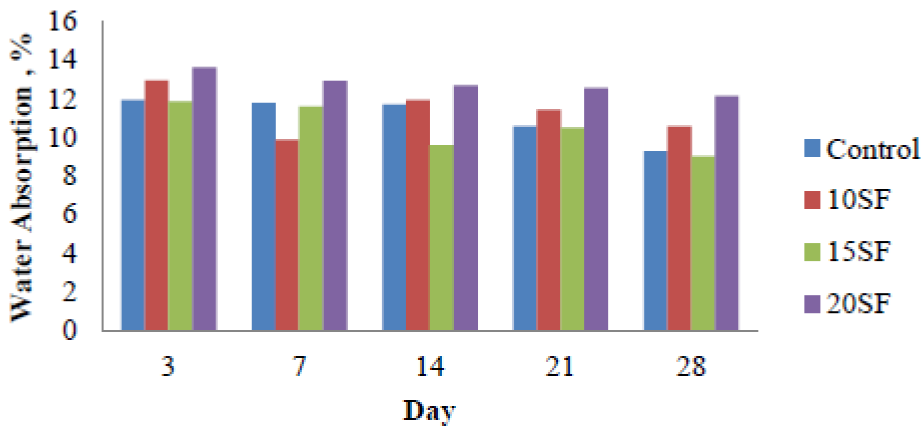

Figure 3. Comparison of 24-hr water absorption capability between Control and SF modified mortars

CONCLUSIONS

The results of this study confirmed that SF is highly pozzolanic material that can be an excellent cement replacement material to produce high-performance concrete. In terms of compressive strength, 15% SF modified mortar achieved the highest strength and lowest water absorption capability compared to Control mortar and other mixtures. The result was confirmed by water absorption capability results for the same mixtures where 15% SF modified mortar absorbed the least. Furthermore, combination of 15% SF and 10% RV achieved the lowest water absorption compared to other combinations samples but higher than Control and 15% SF modified mortar. The results of this study indicated that SF is highly pozzolanic material that can be an excellent cement replacement material to produce high-performance concrete. Study on pozzolanc behavior of SF samples subjected to longer hydration time is needed. Further microstructural investigation is needed to confirm the hypothesis on retardation of hydration due to unreactive RV.

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