HYDRATION AND PROPERTIES OF BLENDED CEMENT SYSTEM INCORPORATING AEROGEL

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Abstract

The utilization of supplementary cementing materials (SCMs) to produce economical cement that is cheaper and greener is an ongoing issue. The objectives of this study are to determine the effect of SCMs on the hydration and properties of blended cement. In this study, OPC was improvised by addition of GGBS and RHA with different weight percentages. Both types of respective were added with 1%, 2% and 3% of aerogel to improve its strength and hydrated for 7 and 28 days. The specimens was characterized by using compressive strength test, FTIR, FESEM, XRD and TGA techniques. The compressive strength test show all specimens have increase in strength for 7 and 28 days in which the composition of OPC-GGBS with 1% aerogel shows the highest compressive strength at early hydration. FTIR shows the functional group present in the OPC- GGBS-Aerogel and OPC-RHA-Aerogel blended cement which are the water lattice of CH, CSH and CASH. The hydration product formed such as CH, CSH and ettringite were observed by using FESEM having plated shaped, foil honey-comb and fine needle-like crystal structure respectively. The formation of the hydrated was confirmed by XRD technique. The TGA technique indicates that there were 3 stages of percentage decomposition of weight loss occur on both type of specimens associated with aerogel.

Keywords: SCM, GGBS, RHA

INTRODUCTION

Cement have many properties that contribute to its strength setting and quality. These properties is assessed and control by measuring the parameter involved such as compressive strength of cement , surface area, particle size distribution, fineness and mineral composition. The production of cement is very expensive nowadays. The rapid growth in construction industry increase the demand on cement production. The cement industry is considered to be one of the most energy consuming industries, with a high rate of carbon dioxide (CO2) emissions. Every year, it is responsible for approximately 5% of the global manmade CO2 emissions [1]. Supplementary cementing materials (SCMs) is a proven material addressing a climate change and clean air. SCMs can be divided into natural materials and artificially mades which both exhibit cementitious properties [2-3]. Some of these materials are called pozzolans (natural), which by themselves do not have any cementitious properties, but when used with portland cement, react to form cementitious compounds. Artificial SCMs have been investigated before, such as fly ash, rice husk ash, and silica fume. Their utilization has been an interesting subject of research for economic, environmental and technical reasons. When different material replaced, each materials possess different chemical and mineralogical compositions as well as different particle characteristics that have various effect on the properties of cement and concrete [4].

EXPERIMENTAL

Materials

The material that used in this study were Type 1 OPC, manufactured by Tasek Cement Corporation Berhad with 340 m2/kg specific surface. GGBS with 465 m2/kg specific surface area manufactured by YTL Cement Berhad. RHA that have been burn at 650-700 °C with excess air. Aerogel was synthesized by sol gel method followed by supercritical carbon dioxide drying.

Characterization of Blended Cement

Compressive Test Machine

The mixture of different composition blended cement were prepared by 50 mm x 50 mm x 50 mm cubes. The compressive strength test was done in accordance with ASTM C109/C109M [35]. After 24 hours, the test specimens were demolded and then cured in water. Three cubic test specimens were made from each mixture, covering two different ages of 7 and 28 days.

X-Ray Diffraction (XRD)

Phase purity and crystallinity of the samples were determined by XRD using a powder diffractometer with Cu K_α as the radiation source with $\lambda = 1.5418$Å. The X-ray tube voltage and current were fixed at 40 kV and 40 mA, respectively. The scan step size was 2θ in the range from 5° to 80° and the reflection position and δ-spacing were calculated from the raw data using automated data analysis programs.

Fourier Transform Infrared Spectroscopy (FTIR)

KBr technique was used. About 1/100 of sample to KBr ratio was taken by using microspatula and teaspoons respectively. Next mix both throughly in a mortar while grinding with the pestle. A force of approximately 10 ton was applied under vacuum for 2 minutes to form transparent pellet. Then, the pellet formed was inserted in the pellet holder and go into the sample chamber. Lastly the measurement was performed and the IR spectra was observed.

Field Emission Scanning Electron Microscope with Energy Dispersive X-ray spectroscopy (FESEM-EDX)

FESEM equipped with energy dispersive X-ray spectroscopy (EDX) was used to analyze the surface morphology and elemental information of the cement paste. A small fractured sample was soaked in acetone to stop hydration and dried at 80°C for 2 h. Then the sample was coated with 20 nm of gold to make it conductive. The accelerating voltage was set at 10 kV.

Thermogravimetry Analysis (TGA/DTA)

The percentage decomposition OPC-GGBS-aerogel and OPC-RHA aerogel for 28 day was determined using TGA/DTA. The parameter used to operate the TGA was heating rate 20 °C/min under nitrogen atmosphere. The temperature range was 50-900°C.

RESULTS AND DISCUSSION

Compressive Strength Test

The compressive strength of cement paste containing OPC-GGBS-aerogel 1% was greater than others composition due to the high pozzolanic reaction at early age. But when compared to control mix at 28 days the strength of other mix was lesser, this decline was result of low pozzolanic reaction of the SCMs

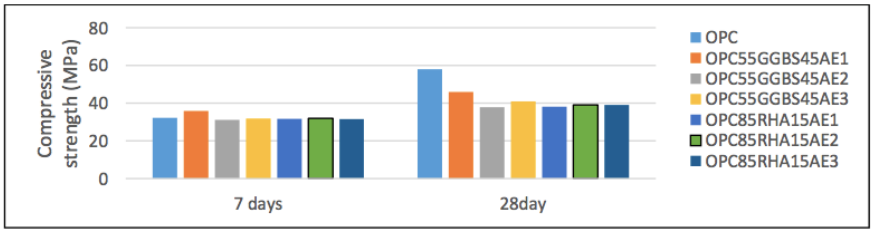


Figure 1 : Compressive strength development for 7 and 28 days

Determination of functional group in blended cement

The broad bands located at 3434 cm^{-1} and 1643 cm^{-1} are assigned to the stretching and bending vibrations of water lattice in CSH, CAH and hydrated calcium sulfoaluminates (CASH) hydrates. The band that appeared around 970 cm^{-1} is attributed to CSH.

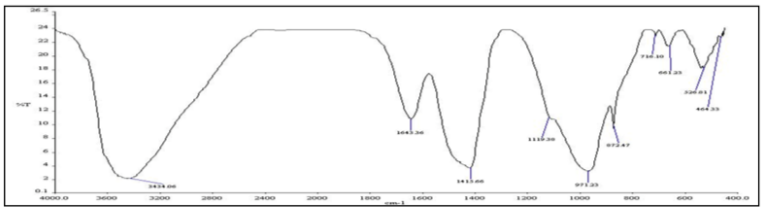


Figure 2 : FTIR spectra of OPC-GGBS-Aerogel 1%

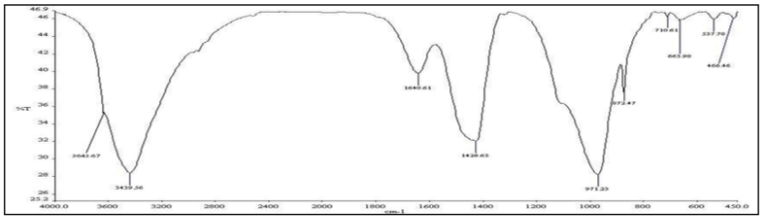
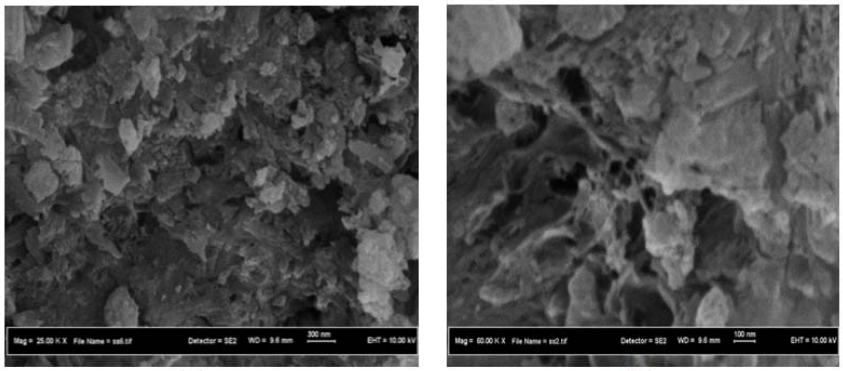


Figure 3 : FTIR spectra of OPC-**RHA-Aerogel 2%**

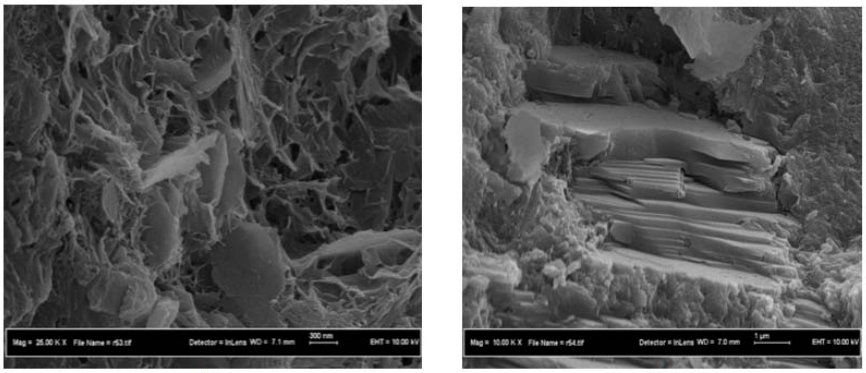
Morphology Characteristic

There were great deals of plated shaped of CH (a) formed at 28 day. A foil honey-comb structure of CSH are present in the micrograph (b). It is indicate that the hydration reaction occurring. Some of the hydrated product are still surrounded by fine needle-like crystal which reveal a clear improvement in the performance characteristic of cement paste in (d). A large hexagonal shaped crystal CH present that contribute to higher strength in (e)



(a) **(b)**

Figure 4 : (a) and **(b)** FESEM images of OPC-RHA-Aerogel 2% at 28 days



(d) **(e)**

Figure 5 : **(d)** and **(e)** FESEM images of OPC-GGBS-aerogel (1%) at 28 days

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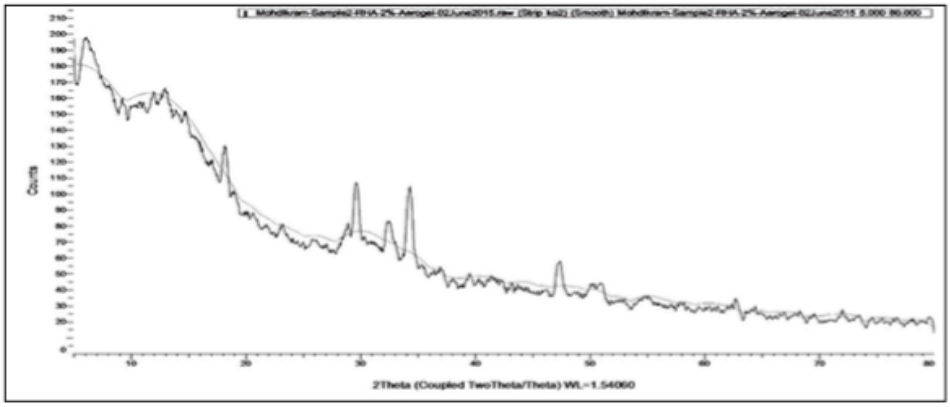

Figure 6 : OPC-RHA-Aerogel 1%

Figure 7 : OPC-GGBS-aerogel 1%

Calcium hydroxide, also known as portlandite (CH), presented at 34.259°, 18.133°, 47.358° and 34.213°, 18.133°, 47.282° in Figure 6 and Figure 7 respectively. The low intensity peak of CH in Figure 7 is due to pozzolanic reaction of the active silica and alumina of the GGBS during hydration to form CSH.

Percentage decomposition of blended cement

The first weight loss for OPC-GGBS-Aerogel 1% was lower than OPC-RHA-Aerogel 2% by 2.51%. This indicate that the amount hydrated product like water, ettringite or CSH was higher. The second weight loss is due to the decomposition of CH. Based on the table, OPC-GGBS- Aerogel 2% has the highest weight loss that is 2.74% that can relate to its strength. Due to the low third weight loss, it can be proved that OPC-RHA-Aerogel 2% has carbonate ion but the amount was low.

Table 1 : Weights loss of sample

Sample	Weight Loss (%)			
	First	Second	Third	Total
OPC-GGBS-Aerogel 1%	21.24	2.74	0.87	24.85
OPC-RHA-Aerogel 2%	23.75	1.86	0.28	25.89

CONCLUSION

The uses of SCMs have been experimentally proven to give some effect on the blended cement paste. In this study, OPC have been partially substituted with GGBS and RHA which the percentage of aerogel for both specimen were 1%, 2% and 3%. The sample were characterized by using variety of instruments. From the compressive strength test, all the specimen have increase in strength with curing time. OPC-GGBS-Aerogel 1% has higher strength at early hydration than other mix. Based on the IR spectrum, the main bands located at 3440 cm^{-1} and 1640 cm^{-1} related to the stretching and bending vibrations of water lattice in CSH, CAH and CASH. Another main band appeared around 970 cm^{-1} which attributed to the present of CSH. It is observed from the spectrum that the hydration product are formed. In FESEM images, the structure of hydration product observed. At 28 days, a fine needle-like ettringite was observed followed by hexagonal plate-like crystal that is CH or portlandite. The CSH structure was present as foil honey-comb. In the XRD pattern fine crystalline formation was observed that are CH, CSH and C_3S. Based on the weight loss from TGA, there are 3 main decomposition occur with first decomposition are continuous weight loss start at 100-300°C followed by 450-550°C and lastly 650-900°C. CH decomposition start in the range of 450–550°C. It is proven that GGBS, RHA and addition of aerogel has pazzolanic effect in the cement paste which provide positive result on physical properties of the blended cement.

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