Influence of Mortar Incorporating Silica Based Waste Material on the Formation of C-S-H and Mechanical Strength Properties

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Abstract. Recent studies have been carried out to utilize waste glass in construction as partial cement replacement. This paper investigates the formation of Calcium Silicate Hydrate (C-S-H) and strength characteristics of mortar in which cement is partially replaced with glass powder by replacement level of 10%, 20% and 30%. Mortar cubes containing varying particle sizes in the ranges of 150-75µm, 63-38 µm and lower than 38 µm and in a water to cement ratio of 0.45 and 0.40 have been prepared. Replacement by 10% cement with glass powder reveals high compressive strength and produces more C-S-H at 28 days than other levels of replacement.

Introduction

Glass is one of the most indispensable materials used in a wide variety of applications in daily life. The amount of waste glass has increased with the increased use of glass in day to day life that not only accumulate on the landfills but also contribute to the environmental problems in the present time due to low rate of recycling [1]. Recently, waste glass has introduced as cement replacement in concrete production [2-3]. The feasibility of waste glass as cement replacement depends on its microstructure and mechanical strength properties. Waste glass can be used to replace cement but it must show either binding properties or pozzolanic properties [4-7]. 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 [8]. Being amorphous and containing relatively large quantities of silicon and calcium, glass is in theory pozzolanic or even cementitious in nature [9]. The glass might satisfy the basic requirements for a pozzolan if it is ground enough to passify the alkali silica reaction and to activate the pozzolanic behavior. This paper deals with the strength characteristics of mortar containing different sizes of glass powder with different water to cement ratio and an eventual focus on the formation of hydration compounds Calcium Silicate Hydrate (CSH) and Calcium Hydroxide (CH) which indicates thepozzolanic properties of the sample. Cement is replaced by glass powder varying from 10 to 30 percent by weight.

Material and Methods

Ordinary Portland Cement (OPC) ASTM Type 1 which is manufactured by Cahaya Mata Sarawak Cement Sdn. Bhd (CMS) was used throughout the research, and it confirmed to the requirements specified by the Malaysian Standard MS 522: Part 1: 1989 Specifications for OPC. Waste Glass used in this study was soda-lime clear glass that grinded in the grinding machine (Los Angeles

Abrasion Machine) in civil engineering laboratory and separated by sieving in three particle size ranges, as follows: 150-75 µm, 75-38 µm and <38 µm. Sand used as a fine aggregate was river sand obtained from Civil Engineering Laboratory, UNIMAS which is free from organic or chemical substance and water to cement ratio was maintained 0.45 and 0.40 throughout the research.

Characterization of CH and C-S-H using Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy (FT-IR) analysis was conducted to characterize the formation of calcium hydroxide (CH) and calcium silicate hydrate(C-S-H) during cement hydration. Strong band centered around 947 cm^{-1} due to Si–O asymmetric stretching (ν3) vibration of C_3S and/or C_2S shows the formation of C-S-H in Figure (A) and a small but defined absorption band appeared at center around 3645 cm^{-1}corresponds to the stretching vibration of O-H from portlandite in Figure (B). Absorption band at 947cm^{-1} in 10% replacement indicates higher intensity than all other samples at 28 days at Figure 2-4. The sharpest band will result in strong bonding and indicate the production of additional C-S-H by addition of 10% waste glass as cement replacement. For glass particle 150-75 µm and 75-38 µm, control samples display the higher intensity than 20% and 30% replacement indicating less C-S-H formation at 20% and 30% replacement level due to agglomeration of waste glass in figure 2 and 3 . In case of <38 µm particles, only 30% replacement level show lower intensity of formation C-S-H. Cement paste with 10% and 20% glass powder produce more additional C-S-H suggest pozzolanic reaction occurred in samples indicating figure 4.

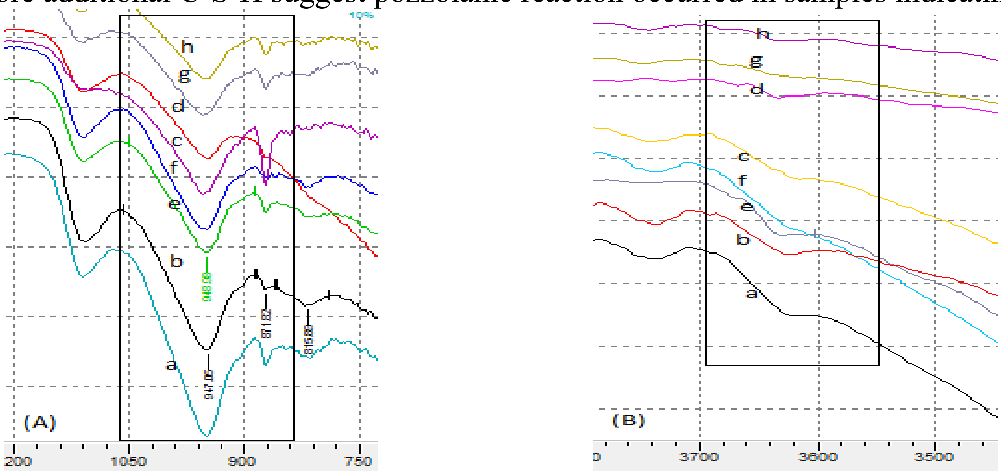

Figure 2: FT-IR analysis of waste glass 150-75micron (a)10%, w/c 0.40, (b)10%, w/c 0.45, (c) 20%, w/c 0.40, (d) 20%, w/c 0.45, (e) Control w/c 0.45, (f) Control w/c 0.40, (g) 30%, w/c 0.40 & (h) 30%, w/c 0.45

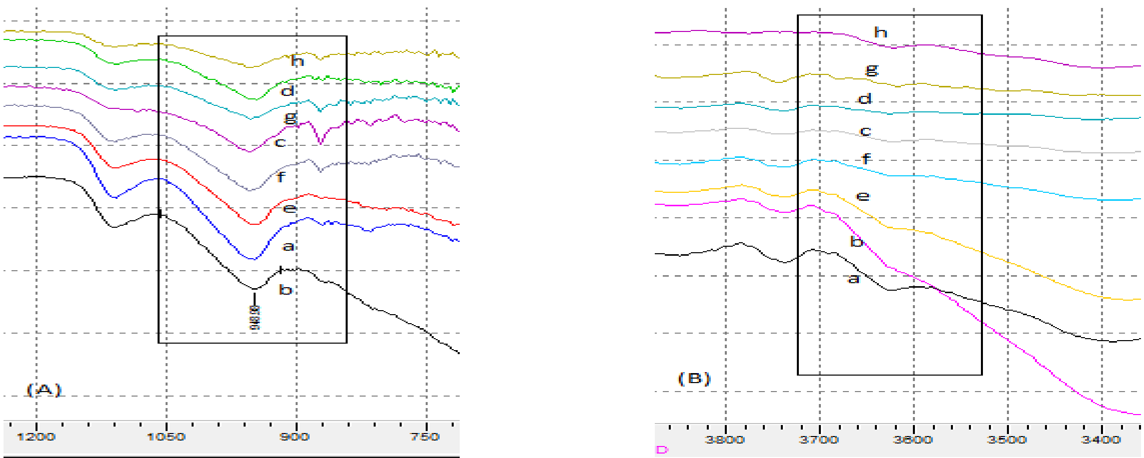

Figure 3: FT-IR analysis of waste glass 75-38micron (a)10%, w/c 0.40, (b)10%, w/c 0.45, (c) 20%, w/c 0.40, (d) 20%, w/c 0.45, (e) Control w/c 0.45, (f) Control w/c 0.40, (g) 30%, w/c 0.40 & (h) 30%, w/c 0.45

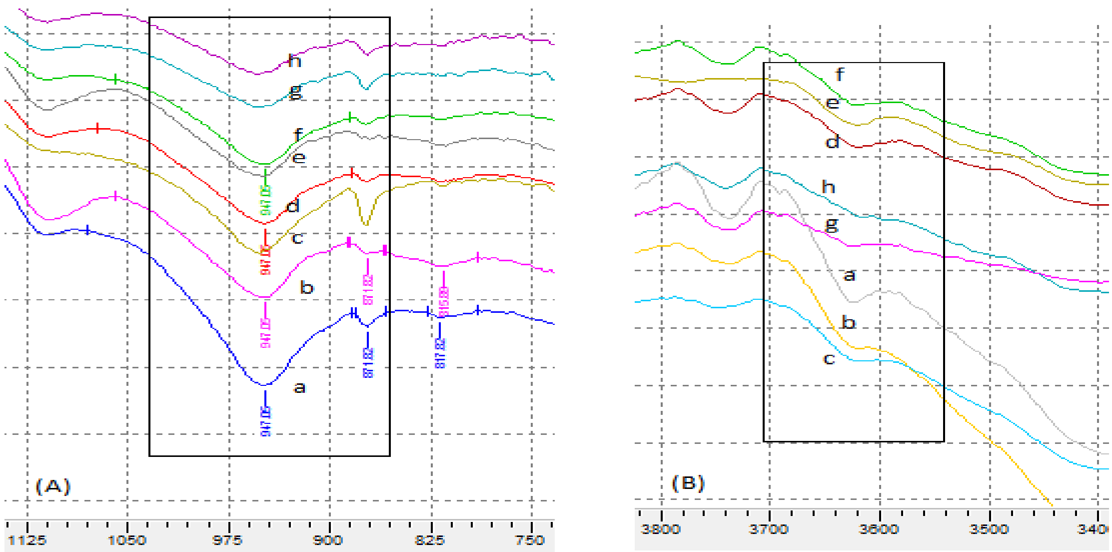

Figure 4: FT-IR analysis of waste glass <38micron (a)10%, w/c 0.40, (b)10%, w/c 0.45, (c) 20%, w/c 0.40, (d) 20%, w/c 0.45, (e) Control w/c 0.45, (f) Control w/c 0.40, (g) 30%, w/c 0.40 & (h) 30%, w/c 0.45

Band centre around 3645 cm^{-1} shows the same result as Si-O stretching. 10% replacement is the steepest among all the samples resulting strong bonding of O-H stretching which implies more production of calcium hydroxide (CH) at 28days. Excess calcium hydroxide participates to produce additional Calcium Silicate Hydrate forming pozzolanic reaction. Samples with 20% and 30% show flat band due to lower formation of C-H. Sample with 0.40 w/c ratio gives the steeper band than sample with 0.45 w/c for both absorption band.

EXPERIMENTAL RESULT AND DISCUSSION

Compressive strength test of mortar

The average of three samples compressive strength results for all glass powder mortars at 28days are shown in figure. The effect of different sizes with varying amounts of glass powder and different water to cement ratio are illustrated in Fig. 4. All mortar samples display lower compressive strength than the both control samples containing water to cement ratio 0.45 and 0.40 at 28 days, except mortar bearing <38 µm glass powders with 10% replacement.

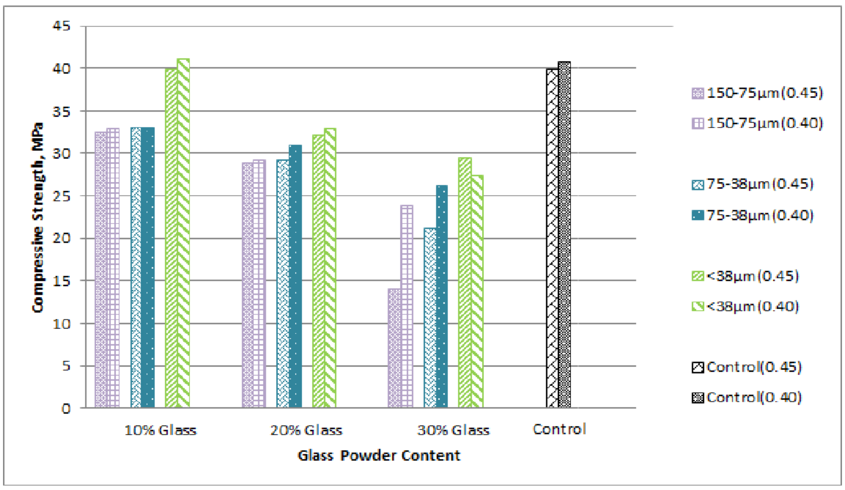

Figure 4: Variation of compressive strength of different batches at 28days

Mortar containing <38 µm glass particle at 10% replacement with w/c 0.45 and 0.40 shows higher strength than control sample with w/c 0.45 and 0.40 respectively. Water to cement ratio 0.40 presented higher strength for all batches of mortar indicating the enhancement of hydration explained with FT-IR analysis and making mortar higher strength, durable and less permeable.

Excess water used in mortar than actually required, will make the mortar weak. The 150-75 μm and 75-38 μm gives almost the same strength at replacement level 10% and 20% while at 30% replacement shows a large difference between two water to cement ratio. Samples with 30% of replacement by glass powder show lower strength due to reduction of cement in mortar samples. It can be seen that the reduction in compressive strength increases with the level of cement replacement. The reduction in compressive strength is caused by a reduction in the quantity of cement content available for the hydration process.

Conclusions

Cement replacement by 10% glass of <38μm size indicates the highest compressive strength compared to the all the other samples which is confirmed by Khatib et al. [10]. This also improves the microstructure of cement paste by promoting pozzolanic reaction between waste glass and Calcium Hydroxide (CH) to produce additional C-S-H within the hydrated cement paste. Besides, the additional waste glass improved the hydration rate of samples and produced more CH in early stage of hydration.

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