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An Experimental Study on the Strength of Mortar due to Filler Effect of Pozzolanic Materials

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Abstract: The filler effect of pozzzolanic materials is defined as proper arrangement of small particles into the microstructure that fill the voids and contribute towards improvement of compressive strength without any chemical reaction. This effect of pozzolan plays a vital role for the production of high strength mortar. The filler effect is dominating when pozzolan particles are in chemically inactive form. The individual contribution of physical and chemical effect in concrete and mortar still not determined. Several studies have been found in the published literature on finding the filler effect of pozzolans by replacing cement with chemically inactive materials which size is same as pozzolans. The chemically inactive materials used in previous studies are carbon black, limestone filler and ground river sand, which used bigger range size of replacement percentages (like 5%, 10%, 15% or 10%, 20%, 30%etc). However in this study, lower range size of replacement percentages (like 2.5%, 5%, 7.5% etc) were examined. This is due to probabilities of peak value of compressive strength due to filler effect may lie in between two replacement percentages used in previous studies. In order to determine the filler effect, chemically inactive material (ground river sand) with various particle sizes used as supplementary material of cement to produce mortar specimens. Result shows that compressive strength of ground river sand mortar at smaller replacement percentages is very near to the compressive strength of control mortar. The loss of compressive strength indicates the only filler effect of small size ground sand whereas pozzolanic effect was inactive in the concrete microstructure.

Keywords: *Pozzolanic Materials, Filler Effect, Replacement Percentages, Voids, Compressive Strength.*

1. Introduction:

There are many types of pozzolans are used globally such as Rice Husk Ash (RHA), Fly Ash (FA), Palm Oil Fuel Ash (POFA), Olive Oil Ash (OOA), Sugarcane Baggasse Ash (SCBA) etc. After proper incineration and ground (Khan et. al. 2013) [1]. These pozzzolans mainly used as a partial replacement for Portland cement in paste, mortar and concrete. It is seen that the compressive strength of control mortar and concrete is lower than the compressive strength of concrete and mortar which is partially replaced by pozzolans. When pozzolans present in mortar or concrete contributes to the total compressive strength of mortar or concrete in two ways: by the physical or filler effect and by the pozzolanic or chemical reaction named as chemical effect of pozzolans (Jaturapitakkul *et al*., 2011) [2]. The concomitant action of both physical and chemical effect gives higher compressive strength of mortar and concrete. But it is essential to know the exact contribution of each effect. Normally filler effect is defined as the packing charateistics of the mixture, which depend on size, shape and texture of the particles and also chemically inactive (Cordeiro *et al*., 2008) [3]. Whereas chemical effect is occurred due to chemical reaction between cement hydration product ($Ca(OH)_2$) and active silica (SiO_2) present in pozzolans (Jamil *et al*., 2013) [4]. Determining how much of the compressive strength is due to the filler effect or the pozzolanic reaction is still unknown to the researchers. Because ASTM C618 [5] does not separate the filler effect from chemical effect of pozzolans. As a result to distinguish these two effects different researchers were followed different methods. Detwiler and Mehta (1989) [6] and Goldman and Bentur (1994) [7] used carbon black to check microfiller effect or packing effect through the cementitious system. They found that a large amount of strength increased due to filler effect only. According to (Isaia et. al. 2003) [8] was used limestone filler (chemically inactive) and reported that filler effect greater than pozzolanic effect. Recently researchers preferred to use ground river sand as partial replacement of cement to verify filler effect. This due to the availability of river sand as well as chemically inactive nature. According to (Jaturapitakkul et. al. 2011) [2] was examined the filler effect using ground river sand with three different particle sizes up to 40% replacement of ordinary Portland cement. Filler effect was found clearly when used small ground sand. Most of the researchers used bigger range of percentages replacement (such as 5%, 10%, 15% or 10%, 20%, 30% etc) of cement to verify filler effect. But they found less compressive strength when used insoluble material compared to control mortar. It is important to know how much effect will occur when using lower range lower range of percentages replacement (such as 2.5%, 5%, 7.5% etc), because the probabilities of peak value of compressive strength (i.e. greater compressive strength of insoluble material mortar compared to the control mortar) due to filler effect may lie in between two replacement percentages used in previous studies. This paper describes a method to determine compressive strength of mortar due to filler effect of pozzolans. In this study only used small sized ground sand with lower range of percentages replacement of cement up to 20%.

2. Experimental Investigation:

2.1. Materials:

The materials used in this investigation consisted of Portland cement type I, Standard sand (BS EN 196-1, 2005) [9] was used as fine aggregate. Natural sand found in Malaysia was to prepare non-reactive material. The sand was washed by water and sun-dried for 2–3 days to reduce its moisture content to be less than 0.1%.Then, it was ground by ball mill to reduce its size as much as possible.

Small ground sand (SGS) particles:

About 5 ± 2% by weight of the materials were retained on a 45-µm sieve. This size was selected for this study.

2.2. Detail of mortars and test of specimens:

The ratio of cementitious materials (Portland cement type I plus small ground sand) to standard sand was set constant as 1:2.75 by weight according to ASTM C109 [10], and water to cementitious materials ratio was maintained 0.485 to 0.545 and 0.485 for control mortar. The mix proportions of mortar containing small ground sand are shown in Table 1. Portland cement type I was replaced by ground sand at the rate of 20% by weight of cementitious materials. All mortars were casting 50*50*50-mm standard molds and removed from the molds after casting for 24 h are shown in Figure 1.

Figure 1: Prepared small ground sand mortar specimens

3. Materials characterization:

3.1. Analysis of chemical composition:

The chemical composition of ordinary Portland cement and small sized ground sand was determined by using X-ray fluorescence (XRF) technique are shown in Table 2. For small ground sand the major constituent SiO2 with a concentration of 85.72% and the Al_2O_3 concentration was 3.73%. Other constituents, such as CaO, MgO, SO3, were less than 1%.

Table 1: Mix proportions of mortar

Specimen	Cement	Fine aggregate	SGS	W/B ratio
Control	1	2.75	0	0.485
SGS2.5	0.975	2.75	2.5	0.485
SGS5	0.95	2.75	5	0.49
SGS7.5	0.925	2.75	7.5	0.50
SGS10	0.9	2.75	10	0.51
SGS12.5	0.875	2.75	12.5	0.52
SGS15	0.85	2.75	15	0.52
SGS17.5	0.825	2.75	17.5	0.53
SGS20	0.8	2.75	20	0.545

Table 2: Chemical composition of materials (in mass)

Compounds (%)	**Small ground sand**	**Ordinary Portland Cement**
SiO_2	85.72	17.78
Al_2O_3	3.73	3.89
Fe_2O_3	1.08	2.96
CaO	0.32	62.69
MgO	0.09	2.32
Na_2O	0.09	---
K_2O	0.85	0.32
SO_3	0.04	4.11
P_2O_5	0.04	0.05
MnO	0.01	0.08

3.2. X-ray diffraction analysis:

The X-ray diffraction analysis was performed to identify differences in the formation of crystalline or amorphous silica. The very sharp peak for ground sand are shown in Figure 2 indicates the crystalline nature of silica, whereas amorphous form due to the broad peak on 2θ angle of 22° (Nair D.G. et.al. 2008) [11].

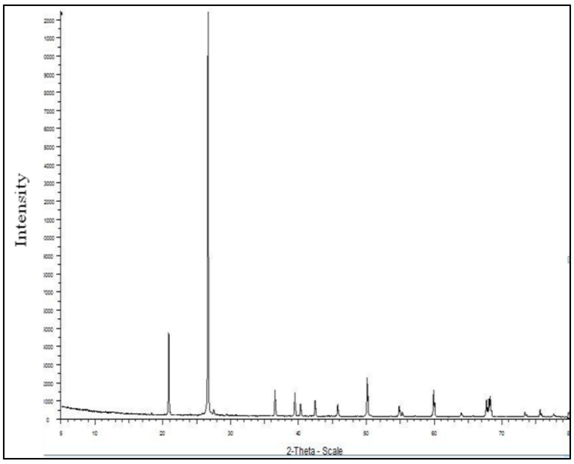

Figure 2: X-ray spectrum for small ground sand

4. Results and Discussion:

The compressive strengths of the ground sand mortars with a cement replacement proportion of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% at 7 days are shown in Table 3. The mortar containing small ground sand showed lower compressive strength than control mortar at 7 days curing. The difference of compressive strength between control mortar and ground sand mortar is gradually increasing with the percentages replacement. This is due to the chemically inactive nature of ground sand and it only took part in filler effect into the microstructure. As a results at lower replacement percentages the compressive strength of ground sand very near to the control mortar and it was the lowest and only 2.12 shown in Figure 4 when 2.5 % cement replaced by ground sand. But when cement is replaced by pozzolans extra compressive strength found due to pozzolanic reaction [12,13].

Table 3: Compressive strength of small ground sand mortar

Specimen	Compressive strength (MPa)
	7 days
Control	36.40
SGS2.5	34.28
SGS5	33.36
SGS7.5	32.90
SGS10	31.00
SGS12.5	30.60
SGS15	30.14
SGS17.5	29.30
SGS20	29.14

Compressive strength of mortar was determined using 50 mm cube specimens based on ASTM C109 (2009) [10] testing standard. Compressive strength test was performed with maintaining a loading rate of 1600N/sec (900-1800 N/sec) according to ASTM C109 (2009) [10] testing standard shown in Figure3.

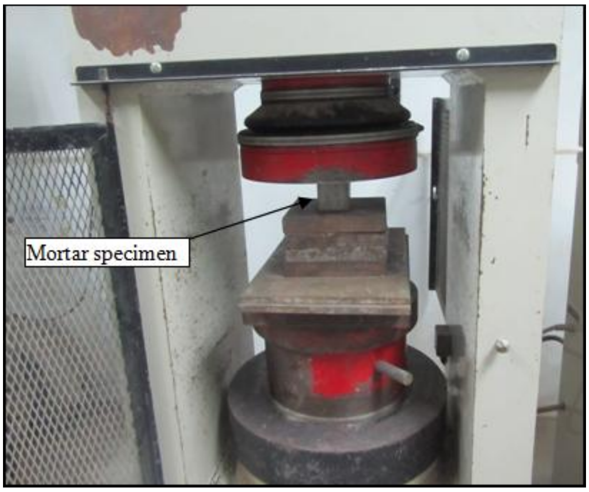

Figure 3: Compressive strength test of mortar cube

Figure 4 shows the loss of compressive strength of small ground sand mortar compared to the control mortar at 7 days curing in different percentages replacement rate.It is seen that the relation between these two were linearly increasing. Moreover, the figure also suggested that no or little compressive strength of the ground sand mortar was contributed from the pozzolanic reaction and filler effect only reponsible for this strength.

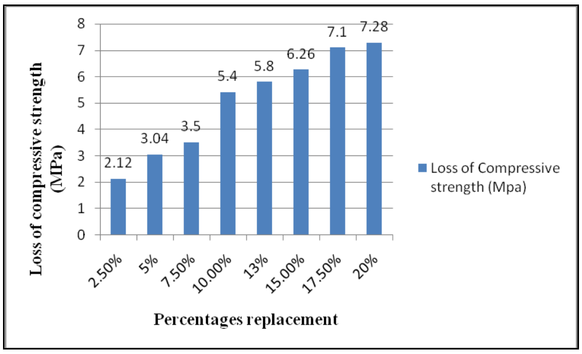

Figure 4: *Relation between percentages replacement and compressive strength of mortar*

5. Conclusions:

This study was aimed to determine compressive strength due to filler effect of pozzolans through an experimental program. It is seen that when using the small ground river sand, the compressive strength of ground sand mortar is always lower than that of control mortar due to the absence of any kind of chemical reaction between cement and ground sand. However, at 2.5% replacement, the difference of compressive strength between control mortar and ground sand mortar very low because of the filler effect of small ground sand mortar. It is also seen that at 20% replacement gives significant compressive strength. Therefore, it is clear that the filler effect is also important beside the chemical effect of pozzolans.

6. Acknowledgements:

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