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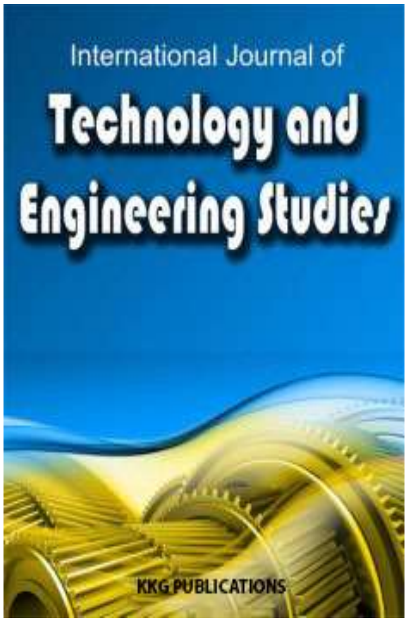

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PROPERTIES OF MICRO FINE QUARRY DUST CONCRETE

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Index Terms
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Compressive Strength
Water Absorption

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Abstract. In this paper, the replacement of cement by Micro Fine Quarry Dust (MFQD)- a white material produced by-product from the quarry, in concrete mixture seen to be a reliable source in terms of strength and rate of water absorption. There were five (5) percentages of cement replacement with MFQD, which are 3%, 5%, 10%, 15%, and 20%, and tested at 7, 28, 60, and 90 days after water curing. The concrete mixture was prepared using a 0.6 and 0.3 w/b ratio. The results showed that the replacement of MFQD up to 15% could improve the strength of the concrete since the mix from both w/b ratios achieved the targeted strength. While in terms of water absorption, the highest MFQD replacement is at 20%, in which the rate of water absorption was below 10% by mass. This study shows that about 20% of MFQD can be used to replace cement. This study would be beneficial for the construction industry.

INTRODUCTION

Cement production is growing by 2.5 billion tonnes annually and is expected to rise from 3.7 to 4.4 billion tonnes by 2050 [1]. With the increased in the production, it is expected that contribution to greenhouse gases (GHG) affected, as the cement industry is one of the major sources that contribute to the GHG which came from carbon dioxide emission. [2] stated that about 1.8 Giga tonne of carbon dioxide emission were produced. While, [3] stated that about 15% of total GHG emission in China, which is the biggest cement producer and carbon dioxide emitter in the industry. The percentage increased with increasing cement production is expected due to the extensive use of concrete in construction industry.

The demand for cement is quite high in developing countries especially owing to rapid infrastructural development. Overall, Malaysia presents significant potential increased in cement demand due to growing population as well as scope for growth in gross domestic product per capita which stimulate the needs for better infrastructure. However, cement production poses problems in many areas with respect to its availability of natural resources, cost and environmental impact such emission of airborne population due to dust, gases, noise and vibration when operating machine and during the blasting process in quarries.
Quarry Rock Dust (QRD) can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm [4]. While, Quarry dust (QD) defined as the material less than 4 mm in size used in construction industry [5]. QD have been used as a replacement in concrete either as a sand or aggregate replacement. According to [6] the quarry waste was used as an alternative constituent material as a partial sand replacement in making concrete and its effects on the strength and workability of the concrete. The utilisation of QRD as a building material also has been accepted in the industrial advanced countries for the past three decades [7]. While QD has been used for road construction and manufactured building material such as light weight aggregate, tiles and bricks [8].

MFQD in the by-product of QD obtained from the quarry plant, after undergoing grinding process. The MFQD then were sieved using pan sieve passing 90 µm sieve size. Some studies had provided a glimpse of the probability for granite MFQD for replacing cement in concrete mixture which is sludge residue from granite stone processing. Since the study on the MFQD replacing of cement is limited, thus this paper reported the study on the properties of the MFQD concrete with various water binder (w/b) ratios *i.e.* 0.6 and 0.3.

EXPERIMEN

MFQD Materials and its Production

In producing MFQD, about 5kg of QD were grinded in Los Angeles Machine (LA Machine) for 24,000 revolutions with a speed of 33.3 rpm. In determining the fineness of MFQD, 16 nos. of balls bearing (427 $\pm$ 5 g of each) were placed inside the machine.

The chemical property of Ordinary Portland Cement (OPC) and MFQD is shown in Figure 1. From this figure, the MFQD can be classified as mineral admixture under category of class N (pozzolan) as the sum of SiO_2, Al_2O_3 and Fe_2O_3 for both results achieved was almost equal to 70% as according to [8]. The loss on ignition (LOI) of MFQD was 1.39% which is less than 10% limitation as stated in ASTM C 618:2003. [9] stated that the LOI shows the extended of carbonation and hydration of free lime and free magnesia due to the exposure of cement to the

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atmosphere.

Physical properties (fineness and specific gravity) of OPC and MFQD were tabulated in Table 1. In term of the fineness of MFQD, the percentage passing 90 µm was about 92.1%, while OPC was about 98.6%. The MFQD is 6.5% coarser than OPC. [11] the fineness of the cementitious material is very important in determining the compressive strength of the concrete, in which higher fineness resulted in an increased in compressive strength. The fineness of OPC and MFQD as a partial cement replacement may affect the rate of hydration, hydrolysis and development of strength in concrete. The fineness test was carried out based on BS EN 196-6:2010 [10]. The Specific Gravity Test was conducted to determine the specific gravity of OPC and MFQD, which complying to [11] The specific gravity of MFQD was 2.56, while for OPC was 3.11, indicated that the lower weight of MFQD when it is used in concrete compared to OPC. The specific gravity of MFQD obtained by [12], [13] was in the range of 2.54 to 2.60.

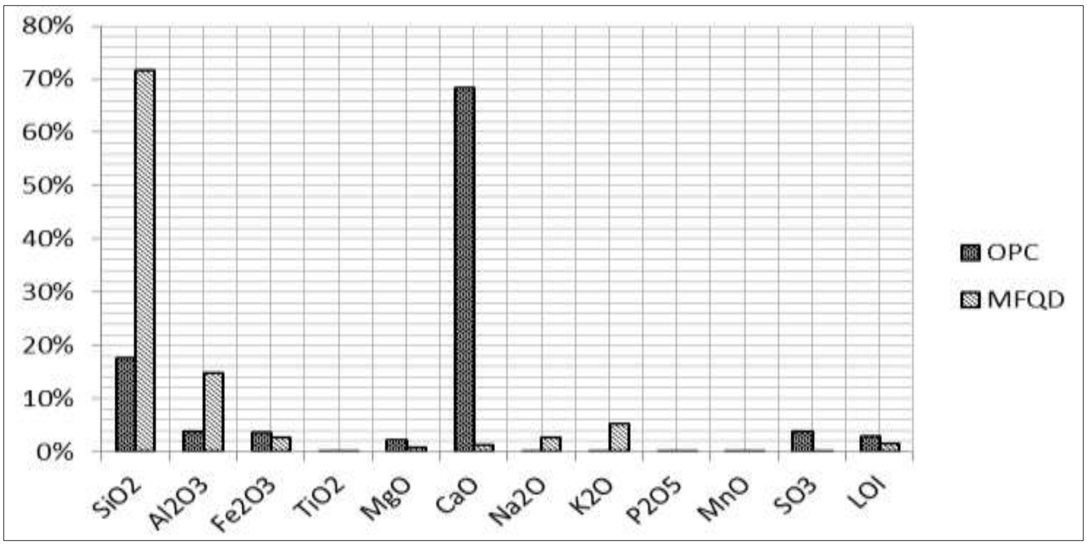

Fig. 1. Chemical composition of OPC and MFQD.

TABLE 1
PHYSICAL PROPERTIES OF OPC AND MFQD

Properties	OPC	MFQD
Fineness (90µm)	98.6%	92.1%
Specific Gravity	3.24	2.56

Preparation of Specimens

There are two (2) types of mould prepared in this study *i.e*. 100x100x100mm and 50dia x100mm. All the requirements in making concrete specimens were according to BS EN 12390-1:2000 [13], while the mix design was prepared based on the designated mix design [14]. From these mix design, with 0.6 and 0.3 w/b ratio, the cement used were 380 kg/m^3 and 559 kg/m^3 respecti vely. Five (5) series of MFQD were designated based on the replacement level *i.e*. 3%, 5%, 10%, 15% and 20% of MFQD. All the specimens were water cured for 7, 28, 60 and 90 days.

Measuring Techniques

The compressive strength test was conducted based on [14]. This test was done after the specimens were removed from its curing condition at the age that was prescribed. Compression Auto Test with pace rate of 3 kN/sec was used. While, the water absorption test was conducted in order to determine the absorptive level of concrete specimens. This test was conducted based on [15]. The specimens were placed in the well ventilated drying oven for 72$\pm$ hours at 105$\pm$5^0 C and cooled in the air tight vessel for 24$\pm$0.5 hours and the readings were recorded for every 30 minutes for 240 minutes after immersed in the water.

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RESULTS AND DISCUSSION

Compressive Strength

The strength of the concrete plays an important role in determining the properties of hardened concrete. Figure 2 and 3 showed the results of the compressive strength for OPC (control) concrete and 5 series of MFQD concrete for w/b ratio 0.6 and 0.3 respectively tested at ages 7, 28, 60 and 90 days of water curing. From the figures, for the 3MFQD, 5MFQD, 10MFQD, 15MFQD and 20MFQD, the compressive strength of concretes increased from 7 to 90 days of water curing for both w/b ratios (0.6 and 0.3). It can be observed that prolong the period of curing resulted in an increased in the compressive strength for all replacement of MFQD concrete. This is in line with [16] who stated that concrete moist cured improved in strength as compared with concrete without any curing. This was also agreed with [17] who quoted that compressive strength increased with increasing days of curing.

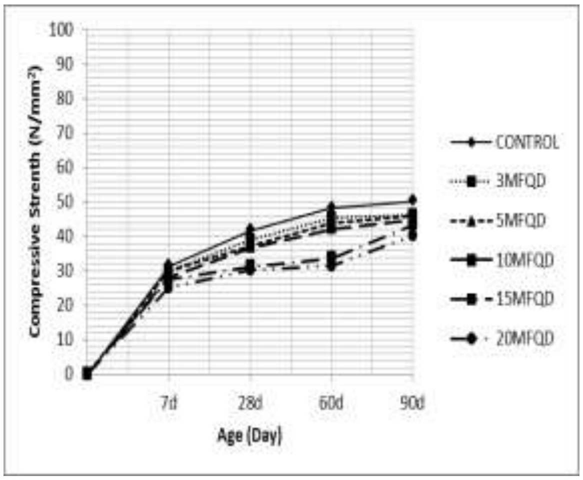

Fig. 2. Compressive strength versus age of OPC and MFQD concrete at 0.6 w/b ratio.

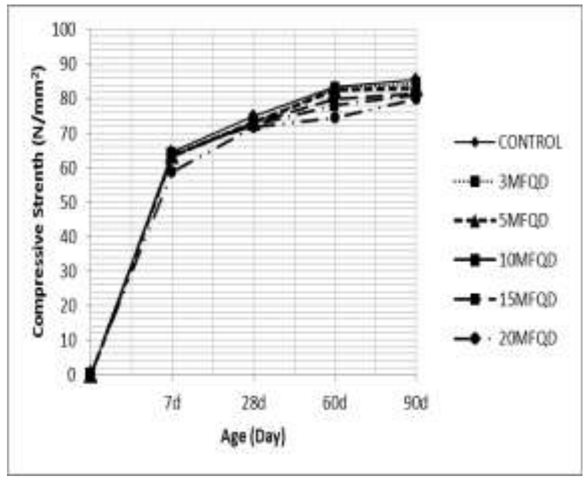

Fig. 3. Compressive Strength versus age of OPC and MFQD concrete at 0.3 w/b ratio.

From figure 2 and 3, the compressive strength of OPC concrete for both w/b ratios were higher than the compressive strength of MFQD concrete. It also can be seen that both w/b ratios were showing the same trends, *i.e.* the compressive strength slightly decreased with increased of the percentages replacement of cement. This might be because of higher fineness of OPC compared to MFQD which resulted in higher compressive strength of OPC concrete. As it can be seen, the fineness of OPC was 98.6%, while MFQD was 92.1%. When the replacement of MFQD increased, the voids in the concrete also increased as the particle of MFQD is coarser compared to the particle of OPC. When the particle of MFQD is coarser, the porosity of the concrete also high thus resulted the empty voids in the concrete filled up with water, hence strength reduced. [18] also stated that as the w/b ratio increased, the porosity of the cement paste in the concrete also increased which resulted in reduction in the compressive strength of the concrete.

Figure 4 shows the results of OPC and MFQD in which it is observed that for 0.6 and 0.3 w/b ratios, all replacement achieved targeted strength at 28 days. It is widely accepted that strength at 28 days is consider as governing strength for concrete mix design. [19] stated that the good compressive strength is attributed from proper hydration of cement and reduction in voids in the presence of pozzolanic material.

It also can be seen from the figure 4, at high w/b ratio (0.6) of concrete, it resulted in lower compressive strength. This result is agreeable with [20] in which they stated that concrete with low w/b ratio showed higher in compressive strength compared to concrete produced with higher w/b ratio. This is also in line with the study conducted by [21], where they stated that higher in w/b ratio resulted in lower strength of MFQD concrete. This might be due to too much water in the matrix resulted in more pores and as water in the pores dried up leaving voids, thus resulted in lower compressive strength. While, according to [22], increased in w/b ratio causes the reduction effect on the compressive strength of the concrete.

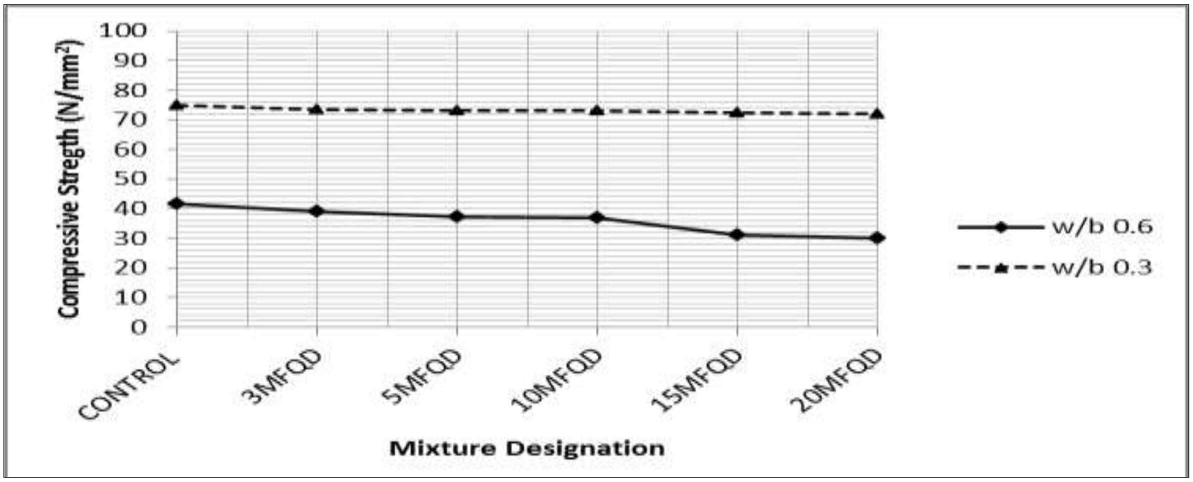

Fig. 4. Compressive strength versus mix designation for OPC and MFQD concrete at 0.6 and 0.3 w/b ratios taken at 28 days of curing.

Water Absorption

Figure 5 and 6 showed the water absorption for OPC, 3MFQD, 5MFQD, 10MFQD, 15MFQD and 20MFQD at w/b ratio 0.6 and 0.3 respectively taken at 7, 28, 60 and 90 days of water curing. It shows that the water absorption decreased with prolong curing period. This might be due to the transformation of large pores to fine pores as a consequence of the pozzolanic reaction between OPC and MFQD and also might be due to the discontinuity of capillary pores. From the figure 5, the water absorption for concrete with 0.6 w/b ratio decreases from 4.84% to 4.63% - control, 4.89% to 4.70%-3MFQD, 4.90% to 4.81% - 5MFQD, 4.98% to 4.89%-10MFQD, 5.08% to 4.95%-15MFQD and 5.51% to 5.16%-20MFQD. Its shows that the absorptive level of MFQD concrete are higher than the control concrete for all ages of curing; however the values are still lower than 10% of mass as satisfied in the [15].

While for concrete with 0.3 w/b ratio (figure 6), the water absorption also decreases from 3.30% to 2.62%-control, 3.44% to 2.84%-3MFQD, 3.78% to 2.86%-5MFQD, 4.15% to 2.89%-10MFQD, 4.41% to 3.08%-15MFQD and 4.43% to 3.22% - 20MFQD. Furthermore, concrete with 0.3 w/b ratio showed the lower water absorption compared to concrete with 0.6 w/b ratio for all replacements. It indicated that water absorption decreases as w/b ratio decreases. This in line with the statement made by [21], in which they stated that the decreased in w/b ratio, decreased the water absorption of the concrete.

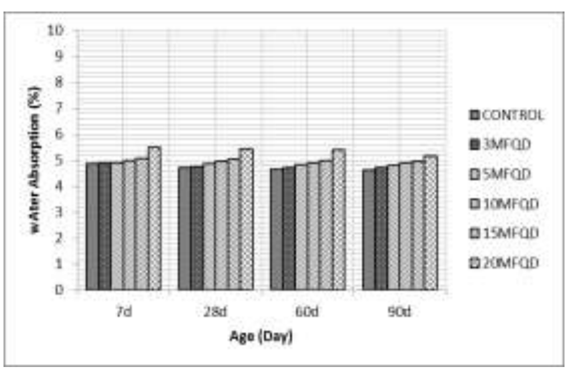

Fig. 5. Water absorption for OPC and MFQD concrete at 0.6 w/b ratio taken at 7, 28, 60 and 90 days of curing.

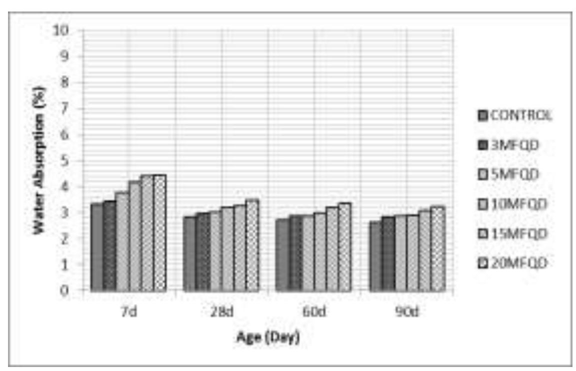

Fig. 6. Water absorption for OPC and MFQD concrete at 0.3 w/b ratio taken at 7, 28, 60 and 90 days of curing.

From the figure 5 and 6, it also can be seen that water absorption for OPC concrete (control) is lower than water absorption for MFQD concrete for both w/b ratios (0.3 and 0.6). It can be concluded that the finer the particle of cementitious, the absorptive level will be lower. This is because of when there is more finer cementitious particles, it will fill up the empty voids in the concrete. This also might be due to the presence of the discontinuity capillary pores in the concrete mixtures as stated by [23]. However, the MFQD concrete for both w/b ratios (0.6 and 0.3) can be classified as good qualities of concrete as the percentage of water absorption were below than 10% by mass [9].

CONCLUSION AND RECOMMENDATIOINS

Based on above discussion, following conclusions are drawn:

i. MFQD can be classified as mineral admixture under categories of class N (pozzolan) according to ASTM C 618-2003 with fineness of 92.1% passing the 90µm sieve and having specific gravity of 2.56.

ii. Compressive strength of MFQD concrete for 0.6 and 0.3 w/b ratios reduced as the amount of replacement increased. However, the strength of the MFQD concretes obtained achieved the targeted strength of grade 30 and grade 60. The optimum replacement of MFQD can be considered up to 15%.

iii. The durability of the MFQD concrete for 0.6 and 0.3 w/b ratios decreased as the percentage replacement of cement increased. However, the MFQD concretes can be classified as a good quality concrete as the percentage of water absorption were below than 10% by mass.

Declaration of Conflicting Interests

This study has no conflicts of interest.

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