Properties of blended cement paste with diatomite from Aceh Province Indonesia

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Abstract. This paper presents the properties of blended cement paste, i.e. water demand, setting time, flow, flexural strength and compressive strength with diatomite from Aceh Besar District, Aceh Province, Indonesia. Diatomite was calcined at the temperature of 500 °C for 4 hours, ground and sieved with sieve #200. The diatomite content used in this study was 0%, 10%, 20% and 30% of blended cement weight. The diatomite powder, cement, and water were mixed in a mixer to produce blended cement paste. EN and ASTM Standards were used for the test procedures. Water demand for normal consistency, setting time and flow was tested on freshly blended cement paste. Flexural and compression tests were performed on the 40 mm x 40 mm x 160 mm prism and 50 mm size cube specimens at the specimen age of 28 days. The test results show that the water demand increases with increasing the diatomite content. Initial setting time, flow and flexural strength decrease with increasing the diatomite contents. The use of 10 % and 20 % diatomite does not significantly alter the compressive strength.

1. Introduction
Indonesia is a country rich in mineral and energy resources, one of which is diatomite. Based on the data from the Aceh Province Mining and Energy Office the deposit of diatomite in Aceh Besar District, Aceh Province, Indonesia was quite high with an estimated 40,353,700 tons. Chemically, the main composition of diatomite is amorphous silica which reaches about 55-70%, depending on the local environment. The contents of silica compounds in diatomite vary widely, as well as the structure and are very much influenced by its origin [1]. The utilization of silica-rich material for partially cement replacement has been studied [2-3].

There have been some studies on using diatomite to produce blended cement. The water demand for blended cement with diatomite is higher than that of ordinary Portland cement [4-6]. Using calcareous diatomaceous rock from Zakinthos Island, the Ionian Sea, which contained mainly CaCO₃ and amorphous silica of biogenic origin with the form of opal-A in cement blended up to 35 % reduces the 28 days compressive strength by 24.14 %. However, blended cement containing 10 % of the diatomite develope the same compressive strength as corresponding Portland cement [4]. Diatomite rocks could be used for the production of blended cement with high strength. The higher the reactive silica content of diatomite, the higher the strength of blended cement. However, the type and morphology of the amorphous silica (diatome frustules) and the presence of friable, fine-grained biogenic calcite are additional parameters that need to be taken into consideration since they might also affect the strength of the resulting cement [5]. Blended diatomite cement with Blaine exceeding 1

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5000 cm²/gr, the compressive strength is higher than that ordinary Portland cement [6]. Using diatomite as cement replacement in the concrete mixture can increase the resistance of concrete to chloride and sulfate [7,8].

The aim of this study is to evaluate the water demand, setting time, flow, flexural strength and compressive strength of blended cement paste with diatomite originating from Aceh Besar District, Aceh Province, Indonesia.

2. Materials and Methods
The materials used in this research were Ordinary Portland Cement (OPC) and diatomite from Aceh Province, Indonesia. Diatomite was crushed and calcined at a temperature of 500 °C for 4 hours. The calcined diatomite was then ground and sieved with sieve #200 to have diatomite powder. The density and absorption of diatomite powder used in this study are 767 kg/m³ and 6.54 %. The chemical composition of the diatomite powder is 58.87 % SiO₂; 12.2 % CaO; 2.25 % Fe₂O₃ and 0.39 % Al₂O₃.

The diatomite was blended with OPC with diatomite content (w/w) of 0 %, 10 %, 20 % and 30 %. The water demand and setting time – initial and final – of blended cement paste were determined according to EN 196-3 and ASTM C191-01a [9,10]. The cement and diatomite powder was mixed in the mixer. In order to determine the water demand, the water was added little by little while the mixer continues to rotate until normal consistency measured by the Vicat test was reached. The initial and final setting time was measured on the normal consistency blended cement paste using the Vicat test.

The flow of normal mortar was measured according to ASTM C1437-07 and ASTM C230/C230M-08 [11,12] using the standard flow table. The standard cone was put on the center of the table and the freshly blended cement paste was filled in the cone about 25 mm in thickness and tamped 25 times with the tamper. Then the second layer of blended cement paste was filled in the cone and again tamped 25 times until the cone was full. Later the cone was lifted away from the blended cement paste 1 minute after completing the mixing operating and immediately the table was dropped 25 times in 15 seconds. The flow of the mixture was measured in two perpendicular diameters.

The flexural and compressive strength measurement was conducted according to EN 196-1 and ASTM C109/C109M-02 [13,14]. The prisms specimens with 40 x 40 x 160 mm³ size (EN 196-1) and cube specimens with 50 x 50 x 50 mm³ size (ASTM C109/C109M-02) were prepared by casting the blended cement paste in the mold. The mold was removed from the specimens at the specimen age of 24 hours. The specimens were then cured in the water until the age of the specimens of 28 days. The flexural test was conducted on the prism specimens. The specimens were supported by two simple supports and the one-point load was applied on the specimens until the specimens get failure as shown in Figure 1 [13]. The compression test was carried out on the remaining half of the flexural test specimens. Two steel plate with 40 mm x 40 mm size was placed on the bottom and top surface of the specimens and the compression load was applied on the specimens through those plates as shown in Figure 2 [13]. In addition, the compression test was also carried out on 50 x 50 x 50 mm³ cube specimens [12]. The specimens were put on the universal testing machine and the compression load was applied until the specimens get failure.

![Figure 1. Flexural test on prism specimen](image1.png)
![Figure 2. Compression test](image2.png)
3. Results

Figure 3 shows the water demand for blended cement paste as a function of diatomite content. The water demand is the quantity of water that is required in order to prepare a cement paste of normal consistency as specified in EN 196-3 [9]. From Figure 3, it can be seen that by increasing the diatomite content, the water demand also increases. The increasing water demand for blended cement paste is due to that the diatomite is an absorbent material and the finest grain size of diatomite. With the absorption of diatomite powder of 6.54 %, some mixing water is absorbed into diatomite powder while the water needs for the hydration process remain constant, hence the water demand for blended cement increases as increasing the diatomite powder content. By using 30 % diatomite, the water demand increases by 31.67 %. Same with the finding in this study, by using calcareous diatomite from Zakinthos Island, Ionian Sea, Greece, Kastis et al [4] reported that the water demand for blended cement is also higher than that for ordinary Portland cement. Water demand for blended cement can be expressed as follows:

\[ a = a_o \exp (0.009 d) \]

(1)

where: \( a \) = water demand for blended cement paste (% w/w), \( a_o \) = water demand for ordinary Portland cement paste (% w/w), \( d \) = diatomite content (% w/w).

![Figure 3. Water demand for blended cement](image)

Figure 4 shows the initial and final setting time of blended cement paste. Initial setting time decreases with increasing the diatomite content. The final setting time of blended cement with 20 % and 30 % of diatomite content is almost the same as that of ordinary Portland cement. Blended cement with 10 % diatomite content has a lower final setting time. The flow of normal mortar of blended cement is shown in Figure 5. The flow of normal mortar decreases with the increase of diatomite content. This result confirms that the diatomite powder in blended cement absorbs some water into its particles.

Flexural strength of blended cement paste is shown in Figure 6. Blended cement paste has lower flexural strength than ordinary Portland cement paste. The lower flexural strength of blended diatomite cement paste leads to concrete structures composed of this type of cement that will experience crack at lower load [16].

The compressive strength of blended cement paste is shown in Figure 7. The blended cement paste has good compressive strength. Compare to ordinary Portland cement, the compressive strength of blended cement with 30 % diatomite reduces for only 9.26 %. This reduction of compressive strength of blended cement paste is related to the late reaction of SiO\(_2\) in diatomite powder with Ca(OH)\(_2\) resulting in cement hydration. This reaction to produce calcium silicate hydrates (CSH) usually occurs.
progressively after the age of cement paste of 56 days. More SiO\(_2\) will react with Ca(OH)\(_2\) after the cement paste age of 90 days makes blended cement paste denser, hence increases the compressive strength. Therefore, to obtain the contribution of SiO\(_2\) in diatomite powder on the compressive strength of blended cement paste, it is necessary to test the compressive strength of blended cement paste at the age of 90 days. The study on this issue will be conducted in the next stage. The use of 10 \% and 20 \% diatomite does not significantly alter the compressive strength. The ratio between the compressive strength of blended cement paste to that of ordinary Portland cement is shown in Figure 8.

Using the formula proposed by Kastis et al [4], the relative compressive strength (RS) is the corrected value of blended diatomite cement paste compressive strength taking into account the pure cement content can be calculated. The relationship between the relative compressive strength of blended cement paste and the diatomite content is shown in Figure 9. Relative compressive strength indicates the effect of the addition of diatomite on the cement paste hydration process. From Figure 9, it can be seen that the relative compressive strength increases with increasing the diatomite content. This indicates that the addition of diatomite powder favors hydration and improves the development of the compressive strength of cement paste. This is attributed to the pozzolanic reaction of diatomite powder. With lower content of ordinary Portland cement in blended cement leads to less available Ca(OH)\(_2\) in blended cement paste.

![Figure 4. Setting time of blended cement](image)

![Figure 5. The flow of normal mortar](image)

![Figure 6. Flexural strength of blended cement paste](image)
Figure 7. Compressive strength of blended cement paste

Figure 8. Reduction of compressive strength of blended cement paste

Figure 9. Relationship between relative compressive strength of blended cement paste and diatomite content

4. Conclusions
The addition of diatomite originating from Aceh Province, Indonesia to Portland cement results in a drastic increase in water demand. The initial setting time of blended cement increases as increasing the diatomite content. The flexural strength of blended cement decreases significantly with increasing of diatomite content. Blended cement having up 20 % diatomite content develop the almost same compressive strength as the ordinary Portland cement.

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