Characterization of Pozzolanicity Bromo’s Volcanic Ash

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Abstract—This study focuses on the mineralogical, chemical, and physical characterization of Bromo ash from East Java. The suitability of the raw ash material from Bromo Mountain to produce building material is not fully tested yet. The accelerated pozzolanic strength activity index (APSAI) of Bromo’s Volcanic Ash (BVA) with Ordinary Portland Cement (OPC) was obtained according to the procedure, as given in ASTM C 1240 (2004) and the APSAI obtained was 4.89%. This was caused by the amorphousness, silica content and the large surface area of BVA which was highly effective to react with Calcium Hydrate (CH) and produce large amount of Calcium Silicate Hydrate (C-S-H). This C-S-H later will promote the acceleration of concrete strength development.

Keywords—Bromo Ash, pozzolan, cement replacement material, X-Ray Diffraction, X-Ray Fluorescence, mortar, building material, ordinary portland cement, compressive strength, chemical and physical properties

I. INTRODUCTION

The impact of volcanic ash heavy rain from eruptions of Bromo mountain since 19 December 2010 was immense. Agricultural area and people’s houses was covered with Bromo’s volcanic ash (BVA) by at least 20 cm thick. Heavy rain of material coverage was up to a radius of 2 km from the caldera wall Sand Sea [1].

This study is attempting to convert locally available pozzolanic material like volcanic ash, rice husk ash, sawdust ash, millet husk ash, pulverize fuel ash, bagasse ash, and other in concrete. The efforts to explore the introduction finding [2, 3] of the Volcanic Ash (VA) and its potential use in concrete technology have been conducted [2, 4-8]. The significant use of such volcanic debris can convert them into natural resources and cannot only present low cost cement and concrete but can also help to diminish environmental hazard [9].

One of the basic aspects of the production of high strength concrete is the use of supplementary cementing material. Due to growing environmental concerns, the need to conserve energy and resources considerable efforts have been made worldwide to utilize local natural waste.

The use of BVA (an apparently waste and supposed potential hazardous material of volcanic eruption) into concrete research is limited. This study is categorized laterized concrete. The aim of the study is to characterize whether BVA known as locally potential material from Jawa Timur, Indonesia, can be used as a supplementary cementitious material for concrete.

II. FUNDAMENTAL THEORY

Pozzolanic materials are typically defined as cementitious materials that contain silica or alumina and silica [3], when they are ground finely will react chemically with Calcium hydroxide, Ca(OH)₂, at normal temperature and in the presence of water to form insoluble product with cementitious properties [10]. Ramachandran’s study [11] showed the general classification of mineral admixture with their chemical and mineralogical composition and particle characteristics.

Definition of pozzolanic reaction is the chemically reaction between a pozzolan (S) and calcium hydroxide (CH) in the presence of water (H). It can be generalized by the simplified equation shown in Equation (1) [12].

\[
Pozzolan + CH + H \rightarrow C-S-H
\]  \hspace{1cm} (1)

There are many benefits of using pozzolanic material in cement and concrete amongst them are:

1. Their ability to convert calcium hydroxide to calcium silicate hydrate (C-S-H), therefore, the capillary voids are either eliminated or reduced in size. This in turn improves cement-concrete material such as strength and durability of the hydrated paste.

2. Pozzolans can also be used as cement replacement material (it is also economical since most pozzolans are cheaper then cement they are replaced). This promotes the use of waste products and thus conserves energy and resource.
Studies into utilisation of Volcanic Ash as a cement substitute for binding in concrete production for building purposes [2, 4-8, 13, 14] has been carried out as attempts in direction of the need to use locally available materials disfiguring our construction sites as waste products.

III. METHODS

Material

To reach the purposes of this research, an experimental laboratory study was developed using the following materials:

The Ordinary Portland Cement (OPC) Type 1 was used throughout this research. The physical and chemical properties as listed in Table 1. Type 1 was chosen because of the observation on mortar properties could be done in normal hydration process without any addition of admixture to the concrete, hence the advantages of BVA usage in mortar can be maximally observed. The cement density and the surface area were found to be 3.15 and 359 m²/kg respectively. The composition of the cement (in oxides) is presented in Table 1.

Natural quartzite sand as fine aggregate was used in this study; it was obtained from the deposit of Mojokerto. The fine aggregate used was natural sand with fine modulus 1.54 and its density was 2.73. The absorption of sand obtained was 0.60%. The absorption of fine aggregate generally varies in the range of 0.2 to 3.0% [10, 15].

The Bromo’s Volcanic ash (BVA) samples used in this investigation were collected from four regions of Bromo’s mountain. They were classified by BVA-A, BVA-B, BVA-C and BVA-D from Sapikerep, Ngadisari, Ngadirejo Tengah, Ngadirejo Atas respectively. The detail position of collecting samples can be shown in figure 1.

IV. Experimental Detail

X-Ray Diffraction (XRD) analysis was carried out using Diffractometer of Philip type X’pert to analyze the crystalline properties of BVA sample and to detect the presence of various crystal system of SiO₂ in BVA. A small amount of BVA powder sample was provided into the X-Ray Diffractometer in a specific container and the analysis results will be displayed using installed software. Later the XRD result will be used to describe the amorphous characteristic of BVA. Since the pozzolanic reactivity of BVA is determined by the silica content and amorphousness of BVA, description about its content will determine the quality of BVA to be used in this research. Graph patterns of XRD analysis can show whether the material is in amorphous, partially crystalline, or crystalline state. This is previous information to understand the possibility of BVA as cement replacement material on concrete.
X-ray fluorescence (XRF) is a spectroscopic method that is commonly used for solids in which secondary X-ray emission is generated by excitation of a sample with X-rays. X-Ray Fluorescence (XRF)-Minipal4 type PW4030/45B analysis was performed to determine the content of various chemical oxides in BVA.

Scanning Electron Microscopy (SEM) analysis was carried out to describe the inner microstructure condition of BVA samples. Energy dispersive X-ray (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. Figure 2 shows the SEM used in this research.

![Fig. 2 the SEM-EDX apparatus (Zeiss EVO MA 10) used in this investigation](image)

Thermogravimetry (TGA) may be defined as a technique whereby the weight of substance, in an environment is heated or cooled at a controlled rate and recorded as a function of time or temperature. The apparatus used in this was Mettler Toledo as shown in Figure 3.

![Fig. 3 the thermogravitry apparatus used in this study](image)

V. EXPERIMENTAL RESULTS

Particle Size Distribution and Surface Area

The relative density of BVA obtained is generally 2.36 to 2.52. The BVA particles are mostly in the size range of 150 to 600 μm. The majority of the particles pass 600-μm (No. 325) sieve. The specific surface area of BVA was observed by Quantachrome Autosorb iQ typically 11.648 m²/g.

Accelerated Pozzolanic Strength Activity Index (APSAI)

The accelerated pozzolanic strength activity index of BVA with OPC was obtained according to the procedure as given in ASTM C 1240 (2004). Figure 4 shows that the APSAI of BVA-C was 88.6 %. The APSAI of BVA was lower than the control. It was due to the specific surface area of BVA which was much lower than that of cement.

![Fig. 4. The accelerated pozzolanic strength activity index](image)

It could be concluded that BVA had the no ability to accelerate the early strength reaction. The APSAI of BVA-C obtained was 5.71%, 39.04% and 42.9% higher than BVA-D, BVA-A and BVA-B respectively. These were caused by the amorphousness, silica content and the large surface area of BVA-C which was highly effective to react with CH and produce large amount of C-S-H. This C-S-H latter will promote the acceleration of concrete strength development.

Chemical Compositions

The pozzolanic reactivity of BVA depends on the amorphous state of BVA particles and the high SiO₂ content. X-Ray Fluorescence (XRF) analysis was proficient in analyzing material contents inside BVA, hence the amount of SiO₂ can be observed. Table 2 shows various chemical oxide contents of BVA from XRF analysis.

<table>
<thead>
<tr>
<th>Oxide composition</th>
<th>BVA-A</th>
<th>BVA-B</th>
<th>BVA-C</th>
<th>BVA-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>25</td>
<td>25</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>SiO₂</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>21,1</td>
<td>24,9</td>
<td>15,2</td>
<td>20,4</td>
</tr>
<tr>
<td>CaO</td>
<td>12</td>
<td>14,9</td>
<td>9,74</td>
<td>11,6</td>
</tr>
<tr>
<td>K₂O</td>
<td>4,5</td>
<td>5,39</td>
<td>3,94</td>
<td>4,67</td>
</tr>
<tr>
<td>TiO₂</td>
<td>2,1</td>
<td>2,4</td>
<td>1,59</td>
<td>2</td>
</tr>
<tr>
<td>MnO</td>
<td>0,32</td>
<td>0,39</td>
<td>0,23</td>
<td>0,3</td>
</tr>
<tr>
<td>V₂O₅</td>
<td>0,05</td>
<td>0,03</td>
<td>0,03</td>
<td>0,04</td>
</tr>
<tr>
<td>CuO</td>
<td>0,071</td>
<td>0,085</td>
<td>0,049</td>
<td>0,07</td>
</tr>
<tr>
<td>Ag₂O</td>
<td>0,8</td>
<td>0,9</td>
<td>0,7</td>
<td>0,6</td>
</tr>
<tr>
<td>BaO</td>
<td>0,31</td>
<td>0,34</td>
<td>0,21</td>
<td>0,3</td>
</tr>
<tr>
<td>Eu₂O₃</td>
<td>0,1</td>
<td>0,2</td>
<td>0,1</td>
<td>0,1</td>
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<tr>
<td>Re₂O₇</td>
<td>0,29</td>
<td>0,18</td>
<td>0,1</td>
<td>0,1</td>
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<tr>
<td>As₂O₃</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y₃O₅</td>
<td>1</td>
<td>1</td>
<td>0,8</td>
<td></td>
</tr>
</tbody>
</table>
The calibration standard materials used for the XRD analysis were tridymite (NIOSH TY-27) and cristobalite (NIST SRM 1879). The integrated intensities of the peaks at 20.5° (4.32Å) and 21.8° (4.06Å) were used for the determination of tridymite and cristobalite, respectively [17]. X-Ray Diffraction (XRD) technique is used to analyze the crystalline phases of a material. A representative XRD pattern of the BVA samples was shown in Figure 5-8.

In Figure 5, a strong peak at 21.8° indicated by arrows was identified a strong cristobalite peak and an additional weak peak at 27.5° was identified as tridymite. The gradual dense scatter of XRD graph was used to indicate the amorphous state of a material. The XRD pattern of cristobalite crystallized in BVA samples (Figure 5) has a feature in which the cristobalite peaks are broad compared with well-crystallized cristobalite. This type of cristobalite has been called disordered cristobalite and opal-C [17]. The XRD patterns of some opal-C and disordered cristobalite silicas are similar to each other, such as the peak position and peak width of the strongest peak. Some researchers considered that any forms of opal are not crystalline silica because opal-C is considered to be transformed from other forms of opaline silica at lower temperatures in nature, disordered cristobalite is an appropriate term to describe this type of cristobalite in BVA samples. The BVA pozzolanic reactivity was observed to be high if utilized as cement replacement material in concrete technology.

**Microstructure Analyses**

The sample of initial raw BVA was examined by SEM analysis and results are presented in Fig. 9-12.
VI. CONCLUSIONS

In conclusion, it can be confirmed that treated Bromo’s Volcanic Ash from Ngadisari, Probolinggo, Jawa Timur, Indonesia can be characterized as a cement replacement material. Utilization of this material, as cement replacement material, that is available in abundance in Ngadisari can not only mitigate social and environmental problems but also improve concrete properties.

VII. REFERENCES


