SERTIFIKAT

Direktorat Jenderal Pendidikan Tinggi, Riset dan Teknologi
Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi Republik Indonesia

Kutipan dari Keputusan Direktorat Jenderal Pendidikan Tinggi, Riset dan Teknologi
Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia

Nomor 105/E/KPT/2022
Peringkat Akreditasi Jurnal Ilmiah Periode 1 Tahun 2022

Nama Jurnal Ilmiah

JGEET (Journal of Geoscience, Engineering, Environment, and Technology)

E-ISSN: 25415794

Penerbit: UIR PRESS

Ditetapkan Sebagai Jurnal Ilmiah

TERAKREDITASI PERINGKAT 2

Akreditasi Berlaku selama 5 (lima) Tahun, yaitu
Volume 6 Nomor 1 Tahun 2021 Sampai Volume 10 Nomor 2 Tahun 2025

Jakarta, 07 April 2022
Plt. Direktur Jenderal Pendidikan Tinggi, Riset, dan Teknologi

Prof. Ir. Nizam, M.Sc., DIC, Ph.D., IPU, ASEAN Eng
NIP. 196107061987101001

JOURNAL OF GEOSCIENCE, ENGINEERING, ENVIRONMENT AND TECHNOLOGY

Volume 7. No 1. March 2022

ISSN (print) : 2503-216x
ISSN (online): 2541-5794

UIR PRESS

JGEET

P-ISSN 2503-2161
E-ISSN 2541-5794

(Journal of Geoscience, Engineering, Environment, and Technology)

Publish periodically four times annually

Scope of Journal

Paper covering the following aspects of Geology, Earth and Planetary Science, Engineering, Environtment,
and Technology

Address of Secretariat and Paper Submitting

Jl. Kaharuddin Nasution No 113 Marpoyan Damai
Pekanbaru, Riau 28284 Phone.(0761) 72126 , Fax. 0761-674834
e-mail: jgeet@journal.uir.ac.id; web: http://journal.uir.ac.id/index.php/JGEET

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E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 7 No 1 2022

RESEARCH ARTICLE

Characteristics of Kedondong Trass and Bobos Trass as Cement Raw Material, Cirebon, West Java, Indonesia

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Received: Nov 26, 2021; Accepted: Mar 30, 2022.
DOI: 10.25299/jgeet.2022.7.1.8180

Abstract

The use of cement materials in construction continues to increase every year, consumes lots of raw material and emits CO_2 from clinker production. To eliminate this negative effect, alternative materials are needed. Trass is natural pozzolan which is formed from silica-alumina rich volcanic rocks. As supplementary cementitious material, trass is sufficiently durable and reduce clinker proportion in cement mixture, thus more environmentally friendly.

This research aims to determine characteristics and composition of Kedondong trass and Bobos trass, Cirebon, West Java as raw material for pozzolan cement. The study was conducted using petrography and XRD analysis to determine mineralogy of rocks. XRF analysis was carried out to determine chemical composition as well as other tests to determine trass quality.

Kedondong trass is originated from andesite intrusion and andesitic breccia, while Bobos trass is formed from hypersthene-andesite intrusion. Based on mineralogy analysis, trasses have similar mineral composition consist of plagioclase, quartz, pyroxene, hornblende, and sanidine. XRD analysis shows abundance of cristobalite and tridymite from each samples. This mineralogy is confirmed by geochemistry result, which is the samples contain more than 70% SiO_2 + Al_2O_3 and less than 4% SO_3. Other chemical characteristics that have been tested are moisture content, ignition loss, and clay content in which all of those parameters meet the industrial standard for cement material.

Keywords: Trass, Supplementary Cementitious Material (SCM), Pozzolanic Cement, Cirebon

1. Introduction

Cement production in Indonesia has dubbed to be one of the largest in the world. By the last decade, domestic sales is consistently rising every year to fulfill demand from development of national infrastructures.The highest growth is in 2011, which was 17.7% with volume of 48 million tons. Later, local and multinational cement producers are expanding their production capacity (Asosiasi Semen Indonesia, 2018). Regular Portland cement production has massive carbon footprint which significantly contribute to climate change. More than 4 billion tonnes of cement manufactured each year emits for around 8% of the world's CO_2 emissions (Lehne and Preston, 2018).

This high emissions is linked to the clinker production, a mixture of raw materials fused together by heat, for the main ingredient of cement. Clinker is a product of chemical conversion called calcination in which limestone ($CaCO_3$) is converted to lime (CaO). During its process, CO_2 is released in the kiln at 600 – 900 C (Gibbs et al., 2001) as follows:

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Natural pozzolans can be used as clinker substitution in cement blends because its cementitious properties, known as pozzolanic activity. Pozzolan is defined as siliceous and aluminous materials that has little to no cementitious properties on its own, but when finely grounded and combined with calcium hydroxide in water, it has ability of hydraulic binding (Çullu et al., 2016). Benefit of pozzolans including low heat of hydration, high strength, low permeability, and low alkaline-silica reaction. Mineral deposits with pozzolanic Rocks of volcanic origin, particularly pyroclastic materials from explosive eruption possess pozzolanic properties without extensive processing. Trass is one of variety of volcanic ash which possesses pozzolanic properties.

As a volcanic active regions, Indonesia is rich in volcanic rocks which some of these are already used as natural pozzolan in national's cement industry. One of national cement manufacturer operate in the study area (Fig.1) at Palimanan, Cirebon Regency, West Java, produced ordinary Portland cement and pozzolanic cement. By local people, natural pozzolans in the study area is more commonly referred to as trass. Kedondong and Bobos are two quarries location used by the manufacturer, hence the name, Kedondong trass and Bobos trass. Aims of this study is to provide information on trass characteristics and its prospect in this country as supplementary cementitious materials (SCM).

2. Geological setting

Study area is part of Bogor Zone physiography, a Neogene sedimentary sequences intruded by many volcanic rocks, now is a strongly folded anticlinorium (Satyana et al., 2002; Van Bemmelen, 1949). Rock formations in the study area is mainly dominated by

http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

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RESEARCH ARTICLE

Clean Water Supply in Tasikmalaya Municipality, Opportunities and Challenges

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Received: Jul 6, 2021; Accepted: Mar 30, 2022.
DOI: 10.25299/jgeet.2022.7.1.7293

Abstract

Currently, there are three sub-districts in Tasikmalaya City that are still vulnerable to clean water, namely Kawalu, Tamansari, and Cibeureum sub-districts. PDAM Tirta Sukapura, owned by the Tasikmalaya Regency Government, has not been able to meet clean water needs, so the Tasikmalaya Municipality Government plans to build a new PDAM as an alternative. PDAM is a regional company with the main task of providing services and providing drinking/clean water to the community. The Ciwulan river in Cibeuti Village is a source of water that will be used as a collection point. Rain data was taken from 2 stations, namely Gunung Satria and Cikunten II stations, for ten years. The evapotranspiration value was calculated using the Penman-Monteith method. The calculation of the discharge in the intake area, namely Ciwulan-Cibeuti with a watershed area of 405 km^2, used the NRECA method using parameters taken from the calibrated Ciwulan-Sukaraja station. The calibration parameters are PSUB = 0.86; GWF = 0.22, reduction coefficient = 0.80; and NSE = 0.764. The determination of the dependable flow is calculated using the Weibull method. The magnitude of the Q90 dependable flow is 4.3 m^3/s. The projected population for the next 15 years is estimated at 307,857 people, so the amount of water needed is around 0.535 m^3/s. Opportunities for business entities to participate in building PDAM are wide open, with the certainty of return plus profits or independent management by business entities within a certain period of time. The challenge for the government and business entities is to provide reasonable prices to customers and new networks.

Keywords: Ciwulan-Cibeuti, Dependable flow, NRECA Calibration.

1. Introduction

The establishment of Tasikmalaya City is inseparable from the history of the establishment of Tasikmalaya Regency as its parent regency. In 1976 its status was increased to an Administrative Municipality. The milestone of the birth of the City of Tasikmalaya occurred on October 17, 2001, through Law Number 10 of 2001 concerning the Establishment of the Tasikmalaya Municipality. The Tasikmalaya Municipality has ten sub-districts and 69 urban villages with a population of 716,160 people (Pemerintah Kota Tasikmalaya, 2019).

Sources of drinking water supply generally come from surface water such as rivers, reservoirs, and lakes. As a result of anthropogenic activities, there is an uncontrolled decrease in water quality and a decrease in quantity due to drought (Shaheed & Mohtar, 2015). Water is one of the natural resources which is very vital not only for life but also for the development of the nation (Sukereman et al., 2015).

Clean water is currently a vital need for the community. Currently, three sub-districts in Tasikmalaya Municipality are still vulnerable to clean water, namely Kawalu, Tamansari, and Cibeureum sub-districts. Until now, the need for clean water is supplied by the PDAM Tirta Sukapura. PDAM Tirta Sukapura is one of the regional-owned enterprises owned by the Tasikmalaya Regency Government whose task is to provide drinking/clean water for the people of Tasikmalaya Regency and Tasikmalaya Municipality. PDAM Tirta Sukapura is owned by the Tasikmalaya Regency Government. Until now, PDAM Tirta Sukapura has not fully served the needs of the people of the Tasikmalaya Municipality, so the Tasikmalaya Municipality Government plans to build its PDAM, primarily to help do the people in the three sub-districts. The development of this PDAM is an opportunity and a challenge for the Tasikmalaya Municipality Government and business entities/investors to participate in the development.

The river used as the source of extraction is the Ciwulan river, which is located in Cibeuti Urban village, Kawalu sub-district. This river is the boundary between Tasikmalaya Municipality and Tasikmalaya Regency. The Ciwulan river has an automatic water level measuring station, namely the Ciwulan-Sukaraja station and its tributary, the Cikunir river, namely the Asta station. Figure 1 shows the location of the study area and the location of the Gunung Satria and Cikunten 2 rain stations.

2. Methodology

2.1. Rainfall

The hydrological cycle is an important process because it maintains the availability of surface water for living things. Evapotranspiration is part of the hydrological cycle playing an important role in the domestic water supply (Farah et al., 2017). The impact of climate change results hydrological processes, including increased rainfall, especially when extreme events occur (Othman et al., 2016). The Ciwulan river is managed by the Ciwulan-Cilaki River Basin Technical Service Unit. The government has widely used the Ciwulan River for public welfare, such as

http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience, Engineering, Environment, and Technology
Vol 7 No 1 2022

RESEARCH ARTICLE

Identification of Geothermal System In "Diana" Area, Indonesia Based On Magnetotelluric Data Modelling

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Received: Jul 31, 2021; Accepted: Mar 30, 2022.
DOI: 10.25299/jgeet.2022.7.1.7448

Abstract

These days, the number of geothermal explorations is being increased to obtain a greater new potential of geothermal energy. One of the methods that is often used is magnetotelluric (MT). By MT, the components of a geothermal system can be delineated based on the resistivity values. This research's main purpose is MT data modelling in 1 D and 2 D to delineate the geothermal system in the research area. There are 18 point of soundings, with a distance of about 1 – 3 km for each point. Bostick Transformation is used in 1 D modelling while Non-Linear Conjugate Gradient inversion is used as 2 D modelling with L – curve analysis as a method to obtain an optimal value of regularization parameter. Based on the analysis of 1 and 2 D models, the caprock zone was identified with a resistivity value of < 50 Ωm at a depth of 500 m with a thickness of about 250 m. The reservoir zone was identified with a resistivity value range of (50 – 100) Ωm located at a depth of 1000 with a thickness of about 500 m. Also, fault structures have been identified at the center of the research area. The regularization parameter used for the 2 D modelling is 5, which has obtained RMS values of 2.25% and 2.21% for each line.

Keywords: Geothermal System, Inversion, Magnetotelluric, Resistivity

1. Introduction

Indonesia had an increase in population from year to year, which has made Indonesia the 4th country in the world with the greatest population. Along with the increase of the population, the energy needs increased too. Energy supply should at least be 1.25% - 1.30% greater than the population growth. However, the energy availability in Indonesia is not proportional with Indonesia's population which keeps increasing. In the case of 2012, there was an increase of 6.20% in population, while only 3.15% of increase in total primary energy supply (TPES) (Purnomo, 2014).

Indonesia is at the meeting of three plates which are the Australian Plate, Eurasian Plate, and Pacific Plate, and perhaps also the Phillipine Sea Plate at the North of Sulawesi (Katili, 1975). The meeting of those plates has a role in the making of the most complex geology setting in the world. Indonesia has 129 active volcanoes, which spread along Indonesia's islands. Geothermal energy has a connection with volcanic events, which is why lots of geothermal systems were created in Sumatra, Java, Southeast Nusa, Sulawesi, and Maluku. Indonesia is a country with 29 GW of geothermal reserve. Geothermal energy is planned to be utilized in a greater number to become one of the renewable energies to contribute as the national energy, reaching 4% by 2025 (Purnomo, 2014).

One of the geophysical methods used for geothermal explorations is MT. This method used the propagation of electromagnetic wave with a great depth of penetration, which reached tens of metres to tens of kilometres (Vozoff, 1991). MT can represent the subsurface of a geothermal system based on the resistivity values. MT is effective to delineate the conductive layer compared to the resistive ones (Wameyo, 2005). This method is suitable for geothermal exploration because the caprock in a geothermal system can be delineated due to its conductivity which will have a contrast in values with the layer below it, reservoir.

Before this research was conducted, an earlier research has been done in "Diana" Area by Kholid and Marpaung (2011). This research was conducted on 36 MT sounding points, which resulted in 2-D models. The results have identified the caprock zone with resistivity value of < 100 Ωm in the center of the area, which spreads to the North. The caprock zone is located in the elevation of – 1000 asl with a thickness of 500 – 1000 m. The reservoir zone is located below the caprock zone, which is at the depth of 1000 – 1500 m, which deepens to the East and West direction. The reservoir zone is bordered by a fault structure with East – West direction.

In this research, Bostick Transformation will be used for 1 D modelling and Non-Linear Conjugate Gradient inversion for 2 D modelling. The results will be analysed based on resistivity values to identify the geothermal system components in Diana "Area", which are caprock, reservoir, and fault, based on the contrast in the resistivity values shown. Then, the regularization parameter tau (τ) which gives the most optimal 2-D model will be decided. Last, both models will be compared and the most optimal model will be decided.

2. Geology and Stratigraphy

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by Tri Winarno

Submission date: 17-Mar-2023 10:12AM (UTC+0700)
Submission ID: 2039050428
File name: JGEET_2022_2nd_author.pdf (1.39M)
Word count: 4374
Character count: 21528

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
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Plio-Pleistocene volcanic rocks on top of Miocene-Pliocene marine sediments (Fig.1). Kromong Limestone consists of Miocene reef limestone complex in the northern part of study area, which is the main material for cement. Kaliwangu Formation is Pliocene marine sediments rich in molluscs, consist of shale intercalated with sand and gravel. On top of those, Plio-Pleistocene volcanic rocks are andesitic-tuffaceous Kromong Breccia, undifferentiated volcanic rocks, and andesite intrusions (Aswan et al., 2013; Djuri, 1995; Jambak et al., 2015).

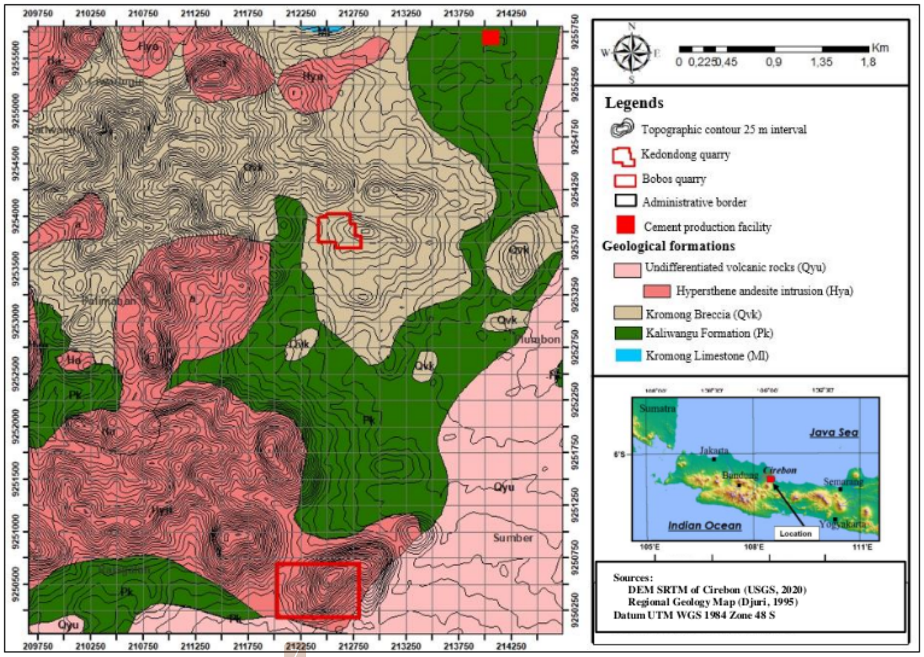

Fig 1. Location and regional geology map of study area

3. Methodology

3.1 Research methods

From geological map, the two locations have different rock type in which Kedondong trass is originated from Kromong Breccia while Bobos trass is originated from Andesite Intrusion. Samples were obtained directly in the field from existing quarries of two locations, 9 samples from Kedondong and 10 samples from Bobos. Laboratory analysis were carried out to determine characteristics of trass as follows:

a. Thin section samples were prepared to identify mineralogical and petrographical characteristics under polarizing microscope. Both fresh rock and altered rock samples were used to compare this aspect.
b. X-ray diffraction (XRD) analysis of powdered bulk samples was conducted to determine whether silica minerals were present in trass. This is to accomodate one of requirement in which trass must contain crystalline silica such as tridymite and cristobalite. Geochemistry of samples were determined using X-ray fluorescence (XRF) analysis, most importantly to identify some of the major elements comprising SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, and SO_3.
c. Moisture content was determined by weighing 100 gr of samples before and after drying 1-2 hours in the oven. For loss on ignition parameter: 1 gr of finely ground samples was heated in the crucible at 500°C for 30 minutes. Followed by igniting the samples in the furnace of 1000°C for 1 hour. After being cooled in the dessicator, samples are weighed again.
d. Clay content was determined by adsorption test: mixing 5 gr of finely ground samples 25 ml aquades using magnetic stirrer for 5 minutes, and then adding 2 ml methylene blue. Clay particle will react and adsorbed by methylene blue. Stain test on filter paper was conducted until a light blue halo showed in the paper by adding more methylene blue, that means all clay was adsorbed (Chiappone et al., 2004). The more methylene blue is added to show the blue halo, the higher is clay content in the samples.

3.2 Specifications of trass

The intrinsic capacity of pozzolans is depend of chemical composition, which is varies greatly in volcanic deposits (Yu et al., 2017). After chemical criteria meets the requirement, most raw materials need to be processed to meets the physical criteria such as fineness, moisture, and strength (Sleep and Masley, 2018). American Standard for Testing Materials (ASTM) C618-94a 1993 (ASTM, 1993) specifies standard chemical composition of raw and calcined natural pozzolans for use in concrete as shown by Table 1. According to national standard of SNI-04-1989-F (Badan Standardisasi Nasional, 1989), trass can be used in light construction with several requirements based on building classes (Table 2.). Trass commonly used for Portland Pozzolan Cement (PPC) mixture, concrete, plastering, or brick mixture.

Table 1. ASTM C618-94a 1993 for natural pozzolans.

Chemical compound	Wt % range
SiO_2	40.76 – 56.20
Al_2O_3	17.35 – 27.95
Fe_2O_3	7.35 – 13.15
H_2O	3.35 – 10.70
CaO	0.82 – 10.27
MgO	1.95 – 8.05
$SiO_2 + Al_2O_3$ minimum	70.0%
SO_3 maximum	4.0%
Na_2O maximum	1.5%
Moisture content maximum	3.0%
Loss in ignition maximum	10.0%

Table 2. Trass requirement from SNI-04-1989-F

Requirement	Class 1	Class II	Class III
1. Free moisture at 110°C in wt%	< 6	6-8	8-10
2. Fineness (% maximum of particle larger than 0,21 mm)	< 10	10-30	30-50
3. Maximum binding time in days	1	2	3
4. Compressive strength after 14 days (kgf/cm²)	100	100-75	75-50

Based on ASTM and SNI standard, PT. Indocement Tunggal Prakarsa Tbk at Palimanan Unit establishes a modified standard parameter of trass for its manufacture as shown by Table 3. To meet the standard several samples of trass must go through chemical and physical analysis such as XRF analysis, moisture, loss on ignition, and clay content. XRD analysis is also conducted to make sure any crystalline silica presents in trass samples.

Table 3. Trass quality requirement in PT. Indocement Tunggal Prakarsa Tbk Palimanan Unit

Parameter	Requirement
1. Total $SiO_2 + Al_2O_3$	Minimum 70.0 wt. %
2. SO_3	Maximum 4.0%
3. Moisture	1% – 5.6%
4. Loss on ignition	Maximum 10%
5. Clay content	Maximum 5%
6. Silica	Must be present (tridymite, cristobalite)

5. Results

5.1 Lithology of the quarries

Lithology observed in the field from the two quarry are slightly different as expected by regional geology map. Kedondong quarry which from regional geology map is part of Kromong Breccia, is covered by two type of andesitic rocks (Fig.2). The first one is andesitic breccia which characterized by moderately weathered, brownish color, cobble-pebble sized andesite fragment inside tuffaceous matrix. This breccia is intruded by dark-grey andesite which formed a morphologically distinctive intrusion hill than its surroundings. Andesite has sheeting joint structure, intensively weathered with some fresh andesite still present, composed by plagioclase and hornblende phenocryst in fine grained groundmass.

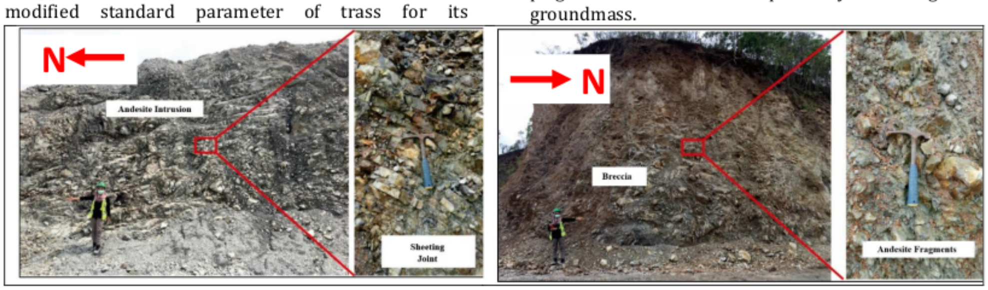

Fig 2. Lithology found in Kedondong quarry

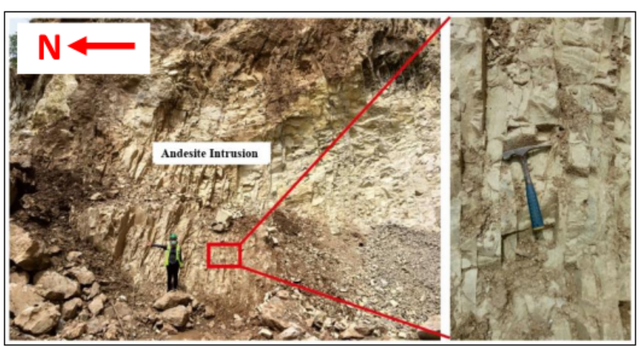

Fig 3. Weathered hypersthene-andesite in Bobos quarry

Bobos quarry located in volcanic hills morphology and identified as Andesite Intrusion from regional geology map. From the quarry observation, we also found fine grained hypersthene-andesite which consistent to the reference. Exposed rocks also exhibit moderately to highly weathered condition, resulted in softer and yellowish rocks (Fig.3). Dominant phenocryst is plagioclase with pyroxene accessory in aphanitic groundmass.

In both location, the degree of weathering greatly changes original texture, structure, and overall appearance of rocks even though the fresh rocks are still present to be observed. Beside of original rock composition, this process is important to bring in pozzolanic properties of trass deposits.

5.2 Mineralogy and petrography of rocks

Mineralogy is inspected by thin section observation of samples from both locations. While both Kedondong and Bobos have similar composition of andesitic rocks, there is slightly difference in mineralogical and petrographical aspect as shown by Table 4. Both rocks are composed of plagioclase as dominant phenocryst (40-50%), pyroxene, hornblende, quartz, and opaque mineral.

The fragments have similar composition with andesite from intrusion. Bobos andesite contains more pyroxene (hypersthene) and less glassy groundmass (Fig.6). Other than fresh hand specimens, altered samples were also being inspected through thin section, showing leached texture, altered rim in some phenocryst, and finer groundmass in all rocks. Kedondong andesite has less phenocryst and more glassy groundmass than Bobos andesite (Fig,4). Meanwhile, thin section of andesitic breccia from Kedondong shows abundant volcanic glass matrix, along with minor fine grained crystal and opaque mineral surround the andesitic fragments (Fig.5).

Table 4. Mineralogy of rocks from Kedondong and Bobos

Samples	Mineral content	Characteristics
Kedondong		
Andesite	Plagioclase (labradorite), hornblende, pyroxene, quartz, opaque minerals	Porphyritic texture, glassy groundmass
Andesitic Breccia	Volcanic glass, plagioclase, quartz, opaque mineral, hornblende	Tuff as dominant matrix supporting andesite fragments
Bobos		
Hypersthene-Andesite	Plagioclase (labradorite), orthopyroxene, hornbende, quartz, opaque mineral	Porphyritic texture, little to no glassy groundmass

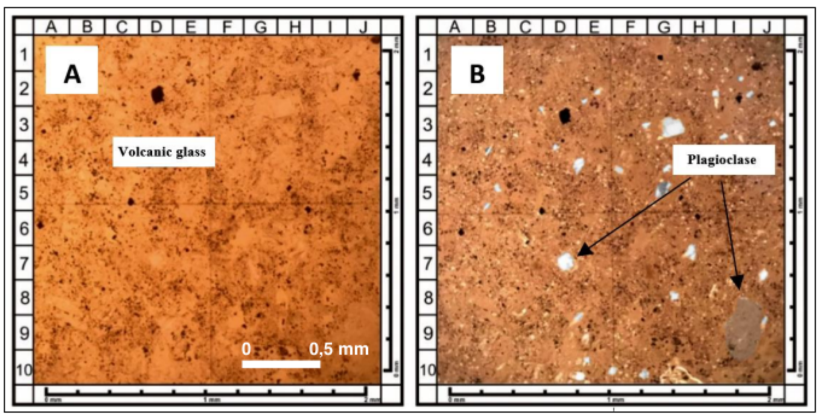

Fig 5. Thin section of matrix part from Kedondong's andesitic breccia: (A) plane polarized and (B) cross polarized

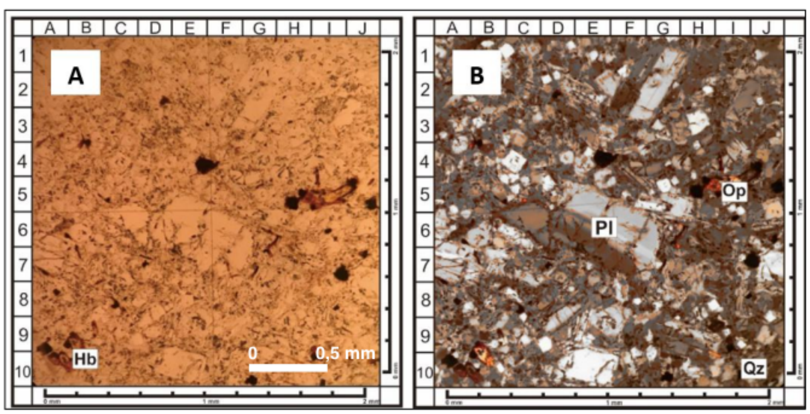

Fig 6. Thin section of Bobos andesite: (A) plane polarized and (B) cross polarized (Pl : Plagioclase, Qz : Quartz (I10), Hb : Hornblende (B10), Op : Orthopyroxene (H5))

5.3 Trass mineralogy

The result from petrographical analysis is supported by XRD analysis of powdered bulk sample, as summarized by Table 5. All of the samples show R-WP less than 10% which are considered good and fit (Toby, 2021). Although there are two different rocks in Kedondong, they are regarded as one because in this section, we are focusing on trass characteristics which is the main commodity of the quarry. According to the XRD analysis, trass samples from both quarry contain quartz, plagioclase, kaolinite, sanidine, tridymite, cristobalite, and hematite. Tridymite and cristobalite are crystalline silica which are important to contribute pozzolanic activity. Kedondong trass contains 0.67% - 9.42% tridymite and 6.0% - 20.26% cristobalite. At Kedondong quarry, samples from breccia have higher quartz content but lower in other silica. Andesite samples are relatively more weathered than breccias, so it is related to the lower abundance of quartz as resistant mineral. Bobos trass contains 0.8% – 2.52% tridymite and 0.2% - 5.36% cristobalite. The abundance of crystalline silica is differ significantly, where Kedondong trass are higher in tridymite and cristobalite than Bobos samples. This might be correspond with higher percentage of groundmass in Kedondong rocks as shown by petrographical analysis. Kaolinite as alteration product also present, in which Kedondong trass also contains at higher percentage than Bobos trass.

Table 5. Test results of XRD analysis from Kedondong and Bobos trasses (in percent)

Code	R-WP*	Quartz	Sanidine	Plagioclase	Kaolinite	Tridymite	Cristobalite	Hematite
Kedondong								
KD 1	6.86	26.48	20.17	40.55	5.37	0.84	5.73	0.86
KD 2	6.34	26.75	20.75	40.65	4.91	0.93	5.60	0.41
KD 3	6.68	25.88	20.17	41.70	5.65	0.67	5.53	0.40
KD 4	7.67	0.06	12.30	52.38	7.94	8.42	18.70	0.20
KD 5	7.92	0.55	14.35	56.73	2.64	5.47	20.05	0.21
KD 6	7.40	0.33	17.39	53.29	3.43	7.59	17.61	0.36
KD 7	8.05	0.21	17.84	49.24	5.35	8.55	18.17	0.65
KD 8	9.06	0.42	17.36	46.80	8.79	9.4	16.92	0.32
KD 9	7.58	0.19	15.62	46.60	10.57	6.81	19.80	0.41
Bobos								
SLS B1	6.69	28.95	21.01	42.6	2.83	1.48	3.13	0.13
SLS B2	6.39	30.80	20.90	42.64	1.84	0.80	3.02	0.65
SLS B3	5.48	30.87	21.21	31.18	14.31	1.26	1.17	0.13
SLS B4	6.94	27.97	20.38	47.24	0.31	1.30	2.80	0.28
B2	8.07	23.16	20.94	47.51	0.56	2.52	5.31	0.08
B3	7.93	31.55	20.71	45.60	0.46	1.38	0.30	0.20
B4	7.21	23.89	21.66	46.82	0.16	2.30	5.17	0.11
B5	6.28	33.46	20.47	42.25	2.74	0.94	0.14	0.09
B6	6.83	24.26	20.92	47.67	0.20	1.59	5.36	0.11

Table 6. Test results of geochemistry analysis using XRF method from Kedondong and Bobos trasses

Code	Moisture content (%)	LOI (%)	Clay content (%)	Major oxides (wt%)								SiO_2+ Al_2O_3
				SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	
Kedondong												
KD 1	10.80	3.26	4.4	69.69	15.84	3.39	3.37	0.00	2.97	1.41	0.024	85.5
KD 2	13.62	3.20	3.0	68.44	15.9	3.61	3.6	0.17	3.01	1.44	0.022	84.3
KD 3	4.15	2.88	2.5	71.67	15.91	3.15	2.98	0.00	3.08	1.57	0.023	87.6
KD 4	1.58	2.27	2.6	70.88	15.06	3.39	3.69	0.00	3.17	1.46	0.020	85.9
KD 5	2.83	1.88	1.6	71.21	15.04	3.25	3.77	0.06	3.37	1.48	0.021	86.3
KD 6	4.77	2.50	2.0	71.15	15.43	3.30	3.45	0.00	3.25	1.45	0.018	86.6
KD 7	3.09	1.74	1.2	71.81	15.43	3.00	3.51	0.00	3.32	1.50	0.020	87.2
KD 8	2.80	2.19	1.6	71.24	15.34	3.32	3.47	0.02	3.20	1.48	0.032	86.5
KD 9	4.08	2.68	1.4	69.67	15.82	3.32	3.69	0.00	3.11	1.54	0.026	85.5
Bobos												
SLS B1	5.05	4.37	1.6	70.52	15.12	3.03	3.60	0.39	2.99	1.55	0.037	85.6
SLS B2	6.55	5.05	2.0	70.86	15.77	2.89	3.62	0.00	3.35	1.65	0.037	86.6
SLS B3	12.8	2.68	4.6	68.21	16.10	3.17	3.05	0.28	2.66	1.59	0.035	84.8
SLS B4	4.77	2.61	2.5	70.44	15.19	3.24	3.52	0.07	3.38	1.62	0.034	85.6
B2	1.14	1.63	1.4	69.47	14.86	2.91	4.56	0.37	3.58	1.59	0.036	84.0
B3	0.93	2.6	1.2	68.75	14.76	2.61	3.69	0.00	3.57	1.57	0.028	83.0
B4	1.60	1.03	1.4	71.87	15.23	2.97	3.28	0.38	3.69	1.59	0.011	87.0
B5	4.62	2.77	2.6	70.95	15.42	3.28	2.99	0.28	3.07	1.59	0.007	86.3
B6	1.68	1.57	1.8	70.67	15.02	2.94	3.67	0.34	3.55	1.60	0.025	85.6

5.4 Chemical properties of trass

In the quarries, trasses have a variation of physical appearance that rather different than fresh rocks. Kedondong trass still contains fine-medium grained minerals between highly weathered groundmass. Bobos trass has finer mineral grains but relatively more compact than Kedondong trass. Chemical properties have been analysed from 18 samples as summarized by Table 6. Result of water content analysis showed that most of samples contain less than 5.6% moisture within the standard criteria, with the exception 4 samples have 6.55%-13.62% moisture. This high moisture results might be correlated with weather, sampling, and preparation technique as the sampling was conducted in January when rainfall is quite high. Loss on ignition (LOI) of samples ranges between 1.57% - 5.05% which is also meet the standard. Clay content in trass samples is determined by adsorption test using methylene blue. The result showed range of 0.4% - 4.6% clay content among the samples. The standard trass has less than 5% clay content.

Geochemistry have been analysed from 18 powdered bulk samples using XRF method. All samples have no striking difference chemistry as follows: SiO_2 as highest compound at 68.21% - 71.81% and Al_2O_3 at 14.76% - 16.10%, That make the sum of silica and alumina constituent at about 83.0% - 87.58%. SO_3 as one of quality parameter is present at very small amount of 0.007% - 0.037%. The chemical analysis shown the sum of $SiO_2 + Al_2O_3 > 70\%$ and SO_3 content $< 4\%$. This result is within the standard of chemistry criteria from ASTM and the manufacturer.

6. Quality of trass as SCM

Kedondong trass and Bobos trass have been used as supplementary cementitious material by PT. Indocement Tunggal Prakarsa Tbk Palimanan Unit. Bobos quarry located farther than Kedondong quarry from the production facility. Lithology of Kedondong quarry are andesitic breccia and andesite intrusion, composed of minerals such as plagioclase, quartz, pyroxene, and hornblende with abundant volcanic ash/glass. Bobos' hypersthene-andesite intrusion contains less volcanic glass due to the abundance of crystals. Volcanic glass is a highly reactive, unstable, and vulnerable to alteration. This alteration activates pozzolanic properties in material (Montanheiro et al., 2004). Tridymite and cristobalite are crystalline silica detected by XRD analysis in all trass samples. The presence of silica is also required as a condition that material has pozzolanic activity (Waani and Elisabeth, 2017).

Nearly all results from chemical test of trass samples are within the company standard and ASTM standard as well. As natural pozzolans, Kedondong and Bobos trass contain 83% - 87% silica and alumina originated from intermediate volcanic rocks. In addition to durability aspect, silica and alumina compounds are responsible for reacting with hydroxides to produce calcium silica hydrate (C-S-H).This byproduct of water and cement reaction is a strong binding agent which desired in the mixture (Sleep and Masley, 2018). Generally, the higher SiO_2 in natural pozzolans, the better pozzolanic activity (Çavdar and Yetgin, 2007). Sulfur trioxide in trass samples is far below the maximum threshold standard of 4%. Moisture content, LOI, and clay content also conform to the standards of trass. Based of all chemical requirement, Kedondong and Bobos trass can be used as one of the cementitious material to reduce clinker.

Conclusions

Kedondong trass and Bobos trass are originated from andesitic breccia and andesite intrusion, product of intermediate volcanic activity. Rock composition shows abundant volcanic glass and silica as pozzolanic agent. Trass samples have been tested chemically including silica+alumina content, sulphur trioxide content, moisture content, LOI, and clay content. The results are meet the company and ASTM standard for supplementary cementitious material. While all of chemical requirements are within standard, it is recommended to test the physical requirement which correspond to pozzolanic properties such as fineness and compressive strength.

Acknowledgements

The authors want to thank to Universitas Diponegoro, especially to Faculty of Engineering that has been supported the research fund and the opportunity given to publish the manuscript. The author also thank the support of PT. Indocement Tunggal Prakarsa Tbk.

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