

# *Methodology*

## Utilising Lapindo Sidoarjo Mud and Mount Merapi Yogyakarta Ash as Alternative Materials for Earthenware and Stoneware Manufacture

**Kasiyan\* and B Muria Zuhdi**

*Department of Fine Arts Education, Faculty of Languages and Arts, Universitas Negeri Yogyakarta, INDONESIA*

\*Corresponding author: [kasiyan@uny.ac.id](mailto:kasiyan@uny.ac.id)

**Published online:** 15 November 2019

**To cite this article:** Kasiyan and B Muria Zuhdi. 2019. Utilising Lapindo Sidoarjo mud and Mount Merapi Yogyakarta ash as alternative materials for earthenware and stoneware manufacture. *Wacana Seni Journal of Arts Discourse* 18: 125–142. <https://doi.org/10.21315/ws2019.18.6>.

**To link to this article:** <https://doi.org/10.21315/ws2019.18.6>

### **ABSTRACT**

*The explosion of hot mud in Sidoarjo, East Java Indonesia in 2006 was a human catastrophe that has had devastating social, environmental, economic and health consequences. This article presents a fresh perspective on how some benefit might be derived from this disaster. It reports the results of a study that aimed to assess the feasibility of using a combination of Lapindo Sidoarjo mud (LSM) and Mount Merapi Yogyakarta ash (MMYA) as raw materials in the manufacture of earthenware and stoneware ceramic products. The project's methodology was adapted from the four-step Research Development Model (e.g., define, plan, develop and validate). The results showed that a combination of 60% LSM and 40% MMYA can be used to make earthenware ceramics and a 50:50 mix can be used to make stoneware ceramics. The ceramics were successfully tested using the techniques of throwing, moulding and handbuilding.*

**Keywords:** *Lapindo Sidoarjo mud, Mount Merapi Yogyakarta ash, raw materials, earthenware and stoneware, ceramics*

## INTRODUCTION

Since 27th May 2006, the disastrous explosion of hot mud in Sidoarjo, East Java, 35 kilometres to the south of Surabaya in Indonesia has spread a million cubic metres of mud over the nearby area. Because it resulted from the drilling of oil wells by Lapindo Brantas Inc., it is often referred to as so "Lapindo Sidoarjo hot mud". In October 2008, hot mud was estimated to have been flowing at a rate of 100,000 to 180,000 m<sup>3</sup> per day (Plumlee et al. 2008; Jalil et al. 2010; Mazzini, Etiope and Svensen 2012) and covered a total area of more than 2,000 acres (810 hectares) at that time. Hot mud bursts continue to erupt till today (Schiller, Lucas and Sulistiyanto 2008). According to the Indonesian Geologist Association, it is expected to continue to do so for the next three decades (Duta 2015).

The disaster has had complex economic and socio-cultural consequences. For instance, about 90,000 people have lost their homes in 19 affected villages in Tanggulangin sub-district, Jabon sub-district and Porong sub-district, Sidoarjo (*Kompas*, 15th June 2016). The mud is also expected to have a major impact on the wider marine and coastal environments, with knock-on effects for many thousands of people who depend on fish and shrimp for their living (Pohl 2007). Up to 2015, the overall economic loss was estimated at more than Rp60 trillion (*Kompas*, 15th June 2016).

A number of research studies have investigated the impact of the Lapindo Sidoarjo mud (LSM) disaster from various disciplinary perspectives, including medicine and ecology (Drake 2016a; Krisnayanti and Agustawijaya 2014), sociology (Richards 2011; Farida 2014; Darmawan et al. 2014), economics (McMichael 2009; Muhtada 2008), politics (Drake 2013; 2016a) and education (Kusumaningrum, Triwiyanto and Gunawan 2016).

In addition several studies have focused on the possibility of utilising the Sidoarjo hot mud as raw material for making bricks, paving blocks and tiles (Rochman and Hudi 2012; Wiryasa, Sugita and Wedasana 2008) and as a component of concrete (Rifai 2013).

Other natural disasters such as the eruptions of Mount Merapi in Yogyakarta Indonesia, the most recent of which occurred in 2010, have produced millions of cubic meters

of material in the form of ash (Voight et al. 2010). To date, no attempt has been made to investigate the potential economic value of Mount Merapi ash, other than its traditional use as a component of cement.

This research aims to examine ways of developing the economic potential of LSM and Mount Merapi Yogyakarta Ash (MMYA). One possibility is to use it as an alternative raw material for the clay in ceramics manufacture. Indonesia has many ceramics industry centres spread over a number of areas. These include:

1. East Java (Dinoyo and Pagelaran, Malang),
2. Central Java (Bayat, Klaten dan Klampok, Banjarnegara),
3. Yogyakarta (Kasongan and Pundong, Bantul),
4. West Java (Sukabumi),
5. Lombok, West Nusa Tenggara (Banyumelik) and
6. West Kalimantan (Singkawang).

One of the obstacles that hinder the development of the ceramics industry in Indonesia, especially in Java, is related to the availability of raw materials, especially clay. For example, many centres, such as those in East Java, Central Java and Yogyakarta, lack available sources of clay in their own area and therefore rely on clay imported from as far away as Sukabumi in West Java and even Singkawang in West Kalimantan. This factor increases the cost of the raw materials, making manufacture less economical and less sustainable.

Against this background, the present study is significant in two ways. First, the potential to exploit the LSM for clay manufacture will help to reduce the massive amount of this material and curb its spread. Second, the development of ways to process LSM and MMYA as new raw materials for clay will increase the long-term availability of raw materials, thus enhancing the sustainability and economic competitiveness of the industry.

Clay is the main raw material for the manufacture of ceramics. It is formed from small crystals or minerals called kaolinite (Astuti 2008a; Osman 2012: 98). In terms of chemical composition, clay belongs to the category of alumina hydrosilicate (Adeyemo,

Adeoye and Bello 2017). In its pure state, it has the formula  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ ; the weight ratio of its elements is 47% silica oxide ( $\text{SiO}_2$ ), 39% alumina oxide ( $\text{Al}_2\text{O}_3$ ) and 14% water ( $\text{H}_2\text{O}$ ) (Astuti 2008a). The present study seeks to produce clay from a mixture of LSM and MMYA.

Clay produced from LSM and MMYA can potentially be used as raw material for two categories of ceramics: earthenware and stoneware. The earthenware form (pottery) is manufactured using a firing process with a low categorical temperature of about  $1,000^\circ\text{C}$ – $1,200^\circ\text{C}$  (Amber 2008: 9; Reason 2010: 9). This low temperature is used to prevent the ceramic body from melting or becoming deformed. The ceramic properties of this category include low body density and high water impregnation (approximately 10%) (Alexander 2001: 40).

In contrast, stoneware is made using a high temperature in the firing process of about  $1,200^\circ\text{C}$  and above. The material in stoneware has a higher melting point than earthenware; hence the properties of the body are very strong, the density is high and the water impregnation is low (1%–2%) (Rawson 1984: 25, 48–49; Cosentino 1993; Christy and Pearch 1991; Waal 1999; Alexander 2001: 81–82; Astuti 2008a). In the community, this type of stoneware is used in household utensils, such as those for eating and drinking (Triplett 2000; Harper 2001; Bengisu 2001), which mainly require the application of a glassy finish (Burlson 2003).

## **RESEARCH METHODS**

This research employs the research and development method proposed by Gall, Gall and Borg (2003), which is implemented in four stages: preliminary study, design, development and validation. In the present study, these stages involved the following:

1. Preliminary study of the material quality of Lapindo mud and Mount Merapi ash.
2. Design of the products and development process.
3. Development of a process and technology to utilise LSM and MMYA as raw materials for ceramic manufacture.
4. Validation.

The instrument used in this study reflects the nature of the data needed to develop the ceramic model, which is both quantitative and qualitative. Quantitative data related to

chemical content was analysed using Atomic Absorption Spectrophotometry (Brandon and Kaplan 2013). Quantitative data related to the quality and quantity of the mixture used to manufacture the ceramic models and prototypes was analysed using descriptive percentage analysis.

Qualitative data was evaluated using the model proposed by Miles and Huberman (1992: 15–21) that employs three steps: data reduction, data display and conclusion or verification.

## **FINDINGS AND DISCUSSION**

This section describes the physical characteristics and chemical content of LSM and MMYA, presents the results of various tests of LSM and MMYA, describes the processes of developing ceramics from the clay and shows examples of finished ceramic products.

### **Physical Condition and Chemical Content of LSM and MMYA**

Physical observation showed that LSM is greyish black, slippery and plastic, possibly due to the presence of impurities, especially oil. MMYA sand is black. The results of laboratory tests using Atomic Absorption Spectrophotometry on the content of LSM and MMYA illustrated the presence of some metals in units of parts per million (ppm) or parts per million mg/litres of solution. For LSM, these consisted of iron (Fe), aluminum (Al), lead, silicon, manganese (Mn) and copper (as shown in Table 1).

**Table 1** Metal content of LSM.

Material	Amount (ppm)
Iron (Fe)	77.3760
Aluminum (Al)	42.969
Lead	14.1600
Silicon	11.423
Manganese (Mn)	1.8715
Copper	0.1181

Table 2 shows the metal content of MMYA. In descending order, this comprised iron, silicon, aluminium (Al), lead, manganese and copper (refer Table 2). Overall, both LSM and MMYA contain no harmful substances, which mean they are safe for use.

**Table 2** Metal content of MMYA.

Material	Amount (ppm)
Iron (Fe)	21.4850
Silicon	10.848
Aluminium (Al)	7.187
Lead	0.9720
Manganese (Mn)	0.3673
Copper	0.1060

## Results from Tests on LSM and MMYA Mixture

### Plasticity test

Plasticity is the property that allows wet clay to be formed without cracks and to retain a consistent shape after the shaping force is removed (Perkins 1995; Andrade 2011). Plasticity is a fundamental property in the processing of clay-based materials since it defines the technique of applying pressure (Norton 1938; 1974; Moore 1963; 1965; Astbury, Moore and Lockett 1966; Singer and Singer 1979). Plasticity is also referred to as "extrudability", "ductility", "workability" or "consistency" (Händle 2007). Clay plasticity is directly related to the amount of water used (Miller et al. 2002).

In traditional clay containing ceramic materials, the amount of plasticity needed to characterise the system and to optimise the processing conditions needs to be measured and controlled (Ribeiro, Ferreira and Labrincha 2005).

The results of the plasticity test performed on the clay processed from LSM and MMYA (as shown in Photo 1) showed that the ideal mix of LSM and MMYA in terms of plasticity was 40:60. The results of the common trial of clay mixed with the composition shows no cracks. Thus it can be said that this type of soil is quite plastic and can be used as raw material for ceramics.

### **Dry and firing shrinkage test**

The shrinking of clay varies greatly in the drying process (as shown in Photo 2) according to the amount of water needed to produce its plasticity (Everett and Barritt 2014: 105; Huang, Li and Sumner 2011: 3390). The greater the shrinkage of the clay, the more water is absorbed and the greater is the dried up shrinkage (Smith 2014: 4; Volhard 2016: 42). The extent of shrinkage during the drying process can be calculated from the shrinkage of measured lines in specially prepared specimens (Reeves, Sims and Cripps 2006).

The data showed that clay composed of 60% LSM and 40% MMYA shrank by 4.88%. These results indicate that the clay can be used as a ceramic raw material, since the required shrinkage margin in the drying process is 8%–12% (McKee 1984: 5).

Another type of shrinkage that also needs to be measured is the firing shrinking of the clay. The firing shrinking of clay is a measurable quantity of the shrinking size of the object, after the firing process. This firing shrinking is not because of the vapourisation of free water, but because of changes in the chemical and physical properties of the clay into ceramics permanently. The firing tolerance of clay for the manufacture of ceramics is 8% to 12% (McKee 1984: 5).

The results of the firing shrinking test on clay made of 60% LSM and 40% MMYA at different temperatures were as follows: 900°C (5.8%), 1,000°C (6.96%),

1,100°C (8.28%) and 1,200°C (11.4%). These results indicate that the clay can be developed as a ceramic raw material.



**Photo 1** Clay plasticity test on the LSM and MMYA mixture.



**Photo 2** Drying clay test result of LSM and MMYA.

### **Vitrification test**

Vitrification is the temperature of maturity that results from the firing process in the manufacture of ceramics. It is characterised by the melting of free silica present in the clay body such that the fused product fills in part or all of the pore space (Mittal, Kaur and Sharma 1992: 299; Bengisu 2001: 447; Dewar 2002: 32). In the cooling process, the clay mass that has undergone vitrification becomes hard, solid and waterproof. The actual welding is a form of liquefaction, in which certain parts of the clay begin to melt into glass (Astuti 2008a: 17). If the time and temperature in the firing process increase, the melting parts gradually dissolve the remaining composition of the clay. This step is responsible for the hardness of the fired clay. Different degrees of maturity in relation to hardness, density, water absorption or shrinkage and firing shrinkage are required for the clay used in earthenware or stoneware. In earthenware, the maximum temperature is 1,100°C, while for stoneware, the temperature starts from 1,200°C (Barnes 2013: 101; Rice 2015: 5).

The test results showed that the maturity temperature of the clay from the mixture of LSM and MMYA was 900°C–1,100°C for the earthenware category and 1,200°C–1,300°C for the stoneware category. If the temperature is more than 1,300°C, the fired ceramics partially melt (as shown in Photo 4).



**Photo 3** Firing shrinking clay test result of LSM and MMYA.



**Photo 4** Ceramics products after the vitrification test.



### **Porosity test**

Porosity is the ability of clay bodies that have been fired to absorb water through the pores. Porosity is usually defined as the percentage of unit volume "filled" by voids and pores (Brostow and Lobland 2016: 138). The porosity rate can be calculated by boiling and immersing the specimens for a given time (Demira, Baspinara and Orhanb 2005). The porous nature of the clay results from the presence of both fine and coarse soil-forming particles. The porosity threshold for earthenware ceramics is 6%–16%, while for stoneware is 1%–3% (Brostow and Lobland 2016: 138).

The results of the porosity analysis showed that the clay mixture of LSM and MMYA at temperatures of 900°C, 1,000°C, 1,100°C and 1,200°C were 10%, 8.99%, 6.00% and 2.89%, respectively. These results indicate that the porosity of the clay falls within the required threshold.

In summary, the results of a series of tests on the mixture of LSM and MMYA show that the clay can be developed as a raw material for ceramic manufacture at both low (earthenware) and high (stoneware) temperatures.

### **Manufacturing Processes in the Production of Ceramics Using Clay Made from a Combination of LSM and MMYA**

The manufacture of ceramic items involves the processes of forming, drying and firing the clay. The forming process can use several different techniques, the basic and most difficult of which is the throwing technique (as shown Photo 5). If the clay can be thrown using this technique, it is highly likely that it can also be made using other techniques. This technique also provides more space for experimentation and creativity in relation to the shape, thickness and size of the final product.

The second step is the drying process, in which the water content is removed before the item is ready to be fired. Ready-to-fire ceramics are those with a moisture content of less than 5%. If the water content is more than 5%, the object will crack or break during the firing process. The drying process involves air-drying in a room that is not exposed to direct sunlight for five to seven days, depending on the weather and the size and thickness of the ceramics (as shown in Photo 6).

The final stage is the firing process, which differs for glazed and non-glazed ceramics. Non-glazed ceramics are only fired once, while glazed ceramics are fired twice, first by biscuit firing, then by glaze firing/glost firing. In this research, two types of firing were used: biscuit firing for earthenware ceramics at a temperature of 1,000°C and glaze firing/glost firing for stoneware ceramics at a temperature of 1,200°C (as shown in Photo 7).



**Photo 5** The process of making ceramics using the throwing technique.



**Photo 6** The drying process.



**Photo 7** The fired ceramic products.

In the manufacture of glazed stoneware ceramics, the next stage after biscuit firing is to add a layer of the desired type of glaze using various techniques, such as smearing, dipping or spraying (as shown in Photo 8).

Once this drying process is finished, the object is fired again at a high temperature of about 1,200°C (as shown in Photo 9).

Once the glaze firing process is complete and the ceramic has been left to cool, it can be examined to determine its quality (as shown in Photo 10).

Photos 11 and 12 display examples of earthenware and stoneware ceramic products, respectively, made from clay mud comprising a mix of LSM and MMYA.



**Photo 8** The glazing process for stoneware ceramics.



**Photo 9** The firing process for glazed ceramics.



**Photo 10** Removing ceramics from the oven after the firing process.



**Photo 11** Unglazed earthenware ceramics made from LSM and MMYA clay.



**Photo 12** Glazed stoneware ceramics made from LSM and MMYA clay.

## CONCLUSION

This research aimed to assess the suitability of clay made from LSM and MMYA for use as a raw material in ceramics manufacture. The clay was subjected to the following tests: drying and firing shrinkage test, plasticity test, porosity test and vitrification test. The results showed that a mix of 60% LSM and 40% MMYA was suitable for earthenware ceramics and that a 50:50 mix was suitable for stoneware ceramics. Hence, it can be concluded that ceramics can be successfully produced using mixed clay material from LSM and MMYA using various techniques, including throwing, slip casting and handbuilding.

## ACKNOWLEDGEMENTS

The authors would like to thank The Ministry of Research and Higher Education of the Republic Indonesia through the Directorate General of Higher Education of Republic Indonesia who awarded the authors a four year (2011–2016) research grant to conduct this project, some results of which are presented in this article.

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