Brick Artifacts as Trading Commodities, Quality, and Uses at Grogol Site, Trowulan, East Java

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ABSTRACT
The Grogol Site is a settlement site in the Trowulan area of Mojokerto, East Java, which is included in the cultural heritage of the Majapahit period. Various artifacts were found, and one of them is brick. Brick is a material commonly used to construct buildings and other structures related to residential. Its widespread use as a building material creates demand for bricks as a trade product. According to several written sources, many forms of baked clay were traded. As a product of industrial processing, clay-based brick combined with tempering materials certainly has a level of quality reflected in the composition of the mixture of the main ingredients and the temper used. This will affect the level of strength of the brick used to withstand the loads of building construction. This paper discusses the quality of the bricks found at the Grogol Site using mineralogical analysis to determine their physical properties, constituent compounds, and degree of combustion. By revealing the quality level of bricks at this site, it can provide an overview of the brick industry as a merchandise commodity and its use at settlement sites from the Majapahit era.

Keywords: *Brick, Settlement, Laboratory, Mineralogy, Grogol Site*

1. INTRODUCTION

The use of bricks on residential sites, especially on Majapahit sites scattered around the Trowulan area and its surroundings, identified as the central location of the Majapahit community's settlements, has a function as a building material or any other construction. Bricks can be used in residential construction or structures with a broad function, such as religious buildings, water channel systems, wells, etc.

The use of brick as a raw material for religious buildings can be seen in temples located in the Trowulan area, such as Brahu Temple, Gentong Temple, and Kedaton Temple, which are situated at the Upas Wells complex, as well as on monumental structures such as Gapura Wringin Lawang and Bajang Ratu. The bricks used in some of these structures and buildings have a larger size compared to the sizes of the bricks used in the younger days [1]. The use of large-size bricks indicates a period in the use of brick materials and the types and forms of development of the use of bricks in past societies. The use of bricks as a building material can also be found in several sites that have a characteristic of settlements in the Trowulan area.

The use of brick as a material for residential buildings during the Majapahit period has been stated in several depictions of the Majapahit residential in several canto/*pupuh* contained in the *Negarakertagama* manuscript. The description of the use of brick as the raw material for the main element of the building is described in canto 11, stanza 2, where houses are depicted using pillars standing on red color bricks decorated with sculptures of human figures [2], [3]. Many other quotations from the Negarakertagama manuscript indicate that the buildings in the center of the Majapahit royal city were solid buildings made of brick decorated with terracotta in several parts, such as roofs, pillars, and walls. One of the sites from the Majapahit era that shows the characteristics of a large settlement that massively used brick as a building material construction is the Grogol site.

The research conducted in the Grogol site, Trowulan, Mojokerto, already began in 2017 and has produced several archaeological findings, such as ceramics, pottery, and other archaeological remains. The Grogol site belongs to the Pakis hamlet area, Pakis Village, Trowulan District, Mojokerto Regency, East Java Province. Geographically, the observation location in the Grogol site is at 7° 34' 48.7" south latitude and

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112° 23' 40.6" east longitude with a height of about 49 meters above sea level and listed on the Indonesia Earth Map sheet 1508-344 (Sooko), with scale 1: 25.000. The Grogol landscape is included in the Weakly Wavy Morphological Unit (2-8%), the constituent rocks are an old Anjasmara volcanic rocks which originate from the Early Pleistocene – Middle Pleistocene [4]. This research found archaeological remains in the form of ceramics, building structures made of bricks and boulders, fragments of pottery, etc. In the Grogol site, excavations were carried out by opening 24 boxes of excavation spots. One of the findings was in the form of part of the building structure in the form of a large intact or fragmented brick [5].

Bricks are clay-based objects that are shaped to a certain size and shape, then dried using solar heat and fired at a specific temperature. Ancient Javanese society, especially the Majapahit people, is thought to have had industrial workshops making clay products. Based on written sources, the craftsmen who make pottery are called *Madyun* [6]. The types of products from the clay processing industry, apart from producing pottery items for household needs and ceremonial purposes which are often found based on evidence from archaeological excavations, such as pots, plates, jugs, decorative items such as miniature statues and houses, also produce many terracotta items that are known as the elements of buildings such as *kemuncak*, pillar casings (*selubung tiang), umpak,* waterspout to roof tiles and especially bricks [7], [8]. These clay-based processing products have an economic value, which is thought to have contributed to the material being traded as a commodity, processed clay, which was traded in place of economic activity, such as markets in ancient Javanese communities.

Clay as the main ingredient for making bricks, is a material that comes from the weathering of bedrock caused by several factors, such as chemical processes and mechanical processes. The chemical process includes several aspects that affect the weathering process based on factors such as oxidation, reduction, hydration, hydrolysis, and carbonation, which then affect the composition. While the mechanical weathering process is a weathering process without any change in the chemical composition of the rock and only affects changes in the physical form of the rock into smaller fragments, The mineral composition of the clay itself consists of three main substances, such as illite, kaolinite, and montmorillonite, where each of these mineral compositions has different characteristics from the formation process and its properties [9].

Apart from using clay as the primary material, brick also uses other materials in the manufacturing process called temper. Temper in the form of sand is an additional material for making bricks, mixed with clay as the primary material in a specific ratio. The addition of temper is intended to facilitate processing and improve the properties of the brick produced. Laboratory technology analysis of baked clay aims to obtain information or an overview of the physical and chemical properties of the brick [5], [10], [11]. Based on the data obtained from the processing process, conclusions can be drawn regarding the quality of the brick. Research on tracing mineral content in archaeological artifacts has been found in several studies. Research on the characteristics of minerals in artifacts that can be categorized as trade commodities can contribute to trace trade relations between one region and another based on the information on the mineral content, firing rate, and tempering materials used [12], [13]. This can also be applied to other processed commodities like brick artifacts.

2. OBJECTIVES

The Grogol site which is included in the Trowulan Cultural Heritage area, is evidence of settlement remains from the Majapahit Period. Based on research that has been carried out stages and continuously, it is revealed that the Grogol site area which is located to the south of the city centre of Trowulan is a large settlement that has been inhabited gradually. This article will focus on the brick artifacts originating from this site and will provide an overview of the standard quality of bricks used in residential building and other structures. The quality of the brick will be reflected in the type of material used, both the main material and the tempered material, which will be known from the mineral composition contained in each sample used. Apart from that, the quality of the firing or the level of brick firing temperature also shows the level of quality and skill of the brick craftsmen at that time. Overall, this describes the quality of a processed clay product used as a building material at the Grogol site. This quality, of course, is closely related to the economic aspect where bricks, as a product of the clay industry, have economic value as a trade commodity. This article will explain the quality of the brick from the Grogol site as one of the large sites in the Trowulan area based on the results of laboratory analysis and explain several aspects related to its position as a processed product that was traded at that time.

3. THEORETICAL REVIEW

Brick as a product made from fired clay, contains main ingredients and mixed ingredients. Clay itself is defined as soil material that has plasticity characteristics when mixed with water and is generally formed from mineral elements such as silica (SiO_2), alumina (Al_2O_3), iron, alkalies, alkaline earth, and water [14]. Meanwhile, according to Orton and Hughes, clay material is formed from the weathering process of igneous rock together with the small particles contained therein, giving clay physical and chemical properties that can be shaped and burned to obtain the shape desired by the craftsmen [15]. Its plasticine nature and ease to shape according to desires means that humans use clay to form tools that can support daily life.

Clay as the main ingredient, then mixed with another ingredient called temper. This tempering material functions as a strengthening material for clay dough, which will be crushed and integrated with the dough during the process of making clay products such as pottery [16]. In the process of making pottery, usually, the soil that has been cleaned of plant debris and roots is mixed with water in a hole and then left to sit until these two mix perfectly. But if the soil quality is good, then the mixing process can be carried out directly [16].

Bricks are included in the type of processed clay in the clay product category for construction goods. In terms of composition and burning characteristics, bricks have similar characteristics to terracotta items, which have a burning level degree below 900^0 C with a high porosity level of 30 %, a rough and porous texture, and reddish burnt characteristics [17].

If we look at the characteristics of the materials and processes as well as the firing rate, bricks can be said to have the same characteristics as pottery. However, in this case, the meaning of pottery is more aimed at clay-based products that are shaped and fired to produce household utensils to support daily life, such as containers or vessels to contain water or food. Based on the description of the materials that make up bricks and the types of clay products, it is known that the materials that make up the main materials and additional materials, known as temper, have their own characteristics according to the availability of the materials used to make them. This research aims to provide a brief overview of the quality of the production bricks produced and used at the Grogol Site. Provide a brief overview of the position of bricks as a traded commodity.

4. METHODS

The research method was carried out in several stages. The sampling process was carried out through a survey and excavation process. The sample was then examined and analyzed in the laboratory. The methods used in the laboratory analysis include a) The Physical properties of brick, including porosity, water absorption, moisture content, density, and degree of combustion; b) the chemical properties of bricks are carried out using the gravimetric method, namely the type of element to be determined is separated from its compounds whose composition is known with certainty, for example, data on the content of silicate, iron, calcium carbonate, magnesium chloride, lost of ignition (LOI), and other elements; c) Mineralogical to determine the types of minerals contained in the bricks. The analysis results are then described and categorized based on their quality level. Based on the analysis results, it is linked to patterns of human activity during the Majapahit period in relation to trade aspects.

5. FINDINGS & DISCUSSION

5.1. Bricks Sampling location

Brick sampling was conducted in six places (Table 1 and Figure 1). The sampling process was carried out at these six points to obtain precise variations in data from each type of brick sample taken. The samples taken are guaranteed to be in the same historical layer and come from different types of structural forms in order to get a more accurate data picture regarding the quality of the bricks used on this site. These are the locations where brick sampling was carried out at the Grogol site:

Table 1. Location of Brick Sample Collection

No.	Sample	Location
1.	Brick	Grogol village cemetery
2.	Brick	Garden-1 (East of the Grogol village cemetery, west Linggan-1[1]
3.	Brick	West cliff Linggan-1
4.	Brick	Excavation box-1 2017
5.	Brick	The north cliff faces the Kencana Tirta River.
6.	Bricks	The eastern cliff faces the Kencana Tirta River.

Source: Eriawati et al., 2017 reworked by author

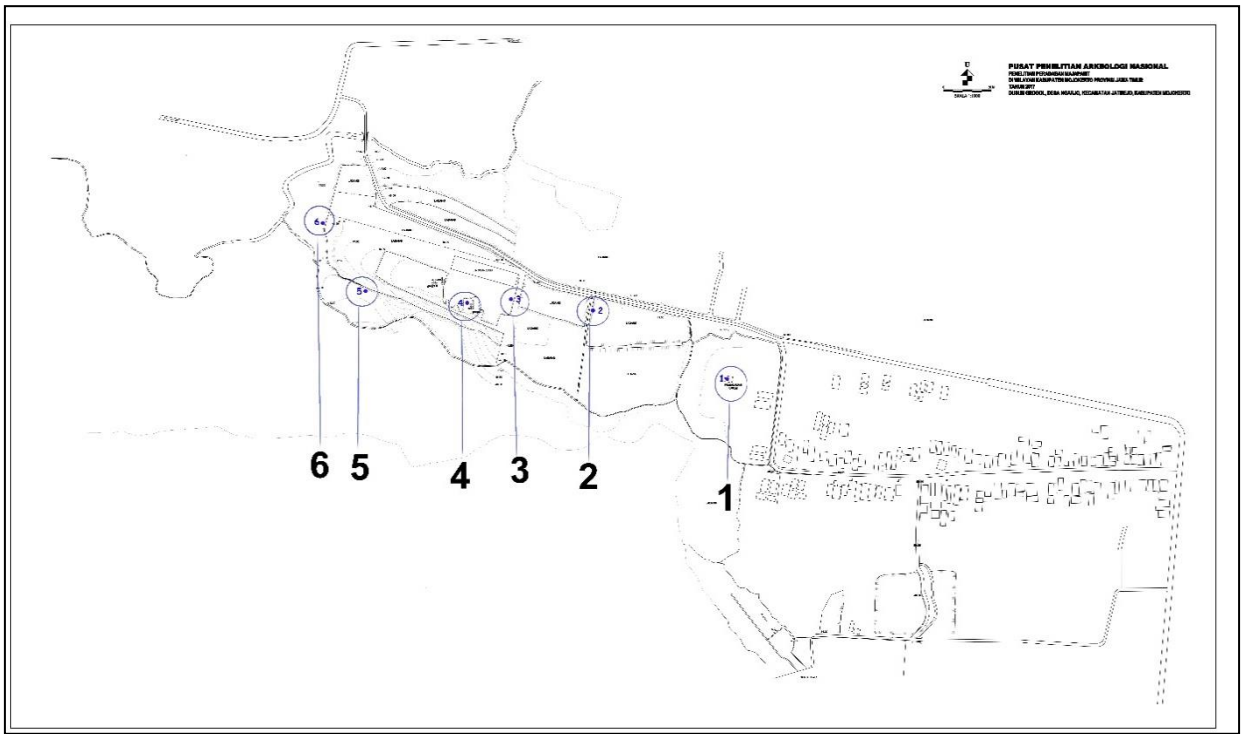

Figure 1. Location of brick sampling at the Grogol Site and its surroundings
Source: Eriawati et al., 2017 reworked by author

5.2. Physical Analysis

The results of laboratory analysis of brick artifacts using physical analysis methods include:

1. Porosity analysis, namely analysis to determine the level of porosity in the brick by immersing the sample in distilled water for 24 hours, then placing the sample in an oven and drying for 24 hours at a temperature of 90° C.
2. Water absorption analysis, namely analysis to determine the level of impermeability/ability of the material to absorb water by placing the sample in an oven and drying for several hours at 105°C - 110°C.
3. Water content analysis, namely analysis to determine the water content of brick by placing the sample in an oven and drying for 3 – 6 hours at a temperature of 105°C - 110°C.

[1] Linggan is the designation for modern temporary brick kiln made by the community to produce brick. Linggan is widespred in several places in the Trowulan area.

4. Density analysis, namely analysis to determine the weight of a sample in the air with the weight of a sample in the liquid solvent whose density is already known, by comparing the weight of the two samples.
5. Analysis of the level of combustion, which is an analysis to determine the level of heat used when bricks were fired in the past by making an experiment using a source of material that was burned with a certain level of temperature range. The same combustion product (color and hardness) between the original sample and the trial sample, which is set at a specific temperature that shows the same physical condition (color and hardness), is considered to have the same level of combustion temperature.

The resume of the results of the physical analysis is described in table 2 below:

Table 2. Results of Analysis of the physical properties of brick from the Grogol Site, Trowulan 2017

No. Sample	Porosity (%)	Water Absorption (%)	Water content (%)	Density Gr/cm^3	Combustion Temperature (0°C)
1	30,25	14,53	1,64	2,32	650
2	30,85	16,34	1,54	2,34	650
3	35,04	17,63	1,69	2,48	650
4	37,33	19.12	1,52	2,54	650
5	33,92	18,24	1,49	2,36	650
6	31,23	15.78	1,46	2,39	650

Source: Research Data Analysis, 2023

Information
Sample No.1: Grogol Village cemetery
Sample No.2: Garden-1 (East of the Grogol village cemetery, west Linggan-1
Sample No.3: West cliff Linggan-1
Sample No.4: Excavation box-1 2017
Sample No.5: The north cliff faces the Kencana Tirta River.
Sample No.6: The eastern cliff faces the Kencana Tirta River.

The results of the analysis of the physical properties of several brick samples taken have shown that all of them have varying material properties, namely porosity from 30,25 to 37,33%, water absorption from 14,35 to 19,12%, water content from 1,46 to 1,69%, density 2,32 to 2,54 Gr/cm^3, and combustion rate reaches 650° Celcius.

These results generally describe the quality of the bricks included in the excellent quality brick category. So, in researching these brick artifacts, they were found to be in good condition and intact.

5.3. Chemical Analysis

The results of laboratory analysis of brick artifacts using chemical analysis methods via gravimetric methods, focusing observations on the main chemical elements, namely silicate, iron, calcium carbonate, magnesium chloride, LOI, and other elements included in smaller levels that make up the percentage. It is necessary to know the content of the main chemical elements mentioned above because (1) silica influences the hardness level of the brick, (2) magnesium chloride in the brick influences its stability in retaining heat, (3) iron influences the production of the resulting color, a reddish color resulting from combusting indicates high iron content, (4) calcium carbonate indicates the level of the lime element which functions in the formation of brick hardness like silica, (5) the level of LOI (lost of ignition) needs to be identified to find out how much organic content in the brick has an effect on brick density level. The results of the chemical element content above can be seen in Table 3.

Table 3. Results of chemical properties analysis from the Grogol Site, Trowulan 2017

No. Sample	Silicate (SiO_2) (%)	Iron (Fe) (%)	Calcium Carbonate ($CaCO_3$) (%)	Magnesium Chloride ($MgCl_2$) (%)	LOI (%)	Other Elements (%)
1	81,4	6,14	4,1	0,8	6,53	1,03
2	81.2	6.34	4,2	0,8	6,55	0.91
3	81,3	6,49	4,3	0,9	6,29	0,72
4	81,5	6,76	4,2	0.9	6,21	0.43
5	81,4	6,83	4,3	0,9	6,32	0,25
6	81,1	6,72	4,3	0.8	6,42	0,66

Source: Research Data Analysis, 2023

Information
Sample No.1: Grogol Village cemetery
Sample No.2: Garden-1 (East of the Grogol village cemetery, west Linggan-1
Sample No.3: West cliff Linggan-1
Sample No.4: Excavation box-1 2017
Sample No.5: The north cliff faces the Kencana Tirta River.
Sample No.6: The eastern cliff faces the Kencana Tirta River.

The results of the analysis of the chemical properties of several brick samples taken showed that all of them had almost the same chemical elements, namely silicate (SiO_2) 81,1-81,5%, iron (Fe) 6,14-6,83%, calcium carbonate ($CaCO_3$) 4,1-4,3%, magnesium chloride ($MgCl_2$) 0,8-0,9%, LOI (*lost of ignition*) 6,21-6,55%, and other elements that were not detected reached 0,25-1,03%. In general, this pattern indicates that silicate is dominant (>75), followed by iron (< 10%), calcium carbonate (< 5%), other elements (<1%) and LOI (5-10%). These chemical elements indicate the quality of bricks included in the good quality category.

5.4. Mineralogical Analysis

Mineralogical analysis of brick artifacts by conducting laboratory analysis on pottery samples so that the presence of various minerals is known. The naming of minerals found in pottery samples refers to the mineral's names used by Hunt & Kraus (1959) [18] as follows:

1. Bricks from the Grogol village cemetery comprise quartz, plagioclase, pyroxene, biotite, and clay minerals. Meanwhile, the non-mineral composition is igneous rock fragments.
2. Bricks from Garden-1 contain the mineral composition of quartz, plagioclase, hornblende, pyroxene, biotite, iron oxide, and clay. Meanwhile, the non-mineral composition is igneous rock fragments and sedimentary rock fragments.
3. The bricks from the west cliff of Linggan-1 comprise the mineral quartz, plagioclase, hornblende, pyroxene, biotite, orthoclase, olivine, iron oxide, and clay. At the same time, the non-mineral composition is igneous rock fragments and sedimentary rock fragments.
4. Bricks from excavation box-1 2017 are composed of the mineral's quartz, plagioclase, pyroxene, biotite, olivine, iron oxide, and clay, while the non-mineral composition is igneous rock fragments and sedimentary rock fragments.
5. The brick from the north cliff facing the Kencana Tirta River comprises the mineral quartz, plagioclase, pyroxene, biotite, olive, iron oxide, and clay. Meanwhile, the non-mineral composition is igneous rock fragments and sedimentary rock fragments.
6. The bricks from the east cliff facing the Kencana Tirta River comprise quartz, plagioclase, hornblende, pyroxene, biotite, iron oxide, and clay minerals. Meanwhile, the non-mineral composition is igneous rock fragments and sedimentary rock fragments.

The results of mineralogical analysis on several brick samples found nine minerals: quartz, plagioclase, hornblende, pyroxene, biotite, orthoclase, olivine, iron oxide, and clay. In contrast, two non-minerals were found: igneous rock fragments and sedimentary rock fragments. The pattern of finding these minerals in the brick content means that the mineral content comes from a geological area composed of igneous rock. In connection with the location of Grogol in Trowulan, the source of the raw material for brick artifacts is

geologically located in the Trowulan-Mojokerto area. This strongly indicates that the bricks used as building materials at the Grogol Site are local products produced by brick-making industries in the Trowulan and its surrounding areas. It is estimated that the craftsmen took raw materials from around the Trowulan area and then processed them into brick products for their own use or for trade.

6. CONCLUSION

Based on the laboratory technology analysis of baked clay (brick artifacts) from the Grogol Site, Trowulan, Mojokerto, the brick artifacts used as building materials at the Grogol site have a good (high) quality. Good quality brick has the following indicators (Table 4).

Table 4. Level Quality of the Brick

Quality	**Variable**					
	Porosity	Water absorption capacity	Density	SiO_2	LoI	Combustion Temperature
Good	> 30 %	> 14 %	> 2	**>75**	**>5%**	500°-700°C
Average	30 %	10-14	2	**60-75**	**5%**	400°-500°C
Low	< 30 %	< 10 %	< 2	**<60**	**<5%**	< 400°C

Research Data Analysis, 2023

The bricks in The Grogol site have good quality as evidenced by high porosity with measurement results of 30,25% - 37,33%, water absorption capacity of 14,35% - 19,25%, density of 2,32 gr/cm^3 – 2,54 gr/cm^3, the silicate (SiO_2) content reaches 81,1% - 81,5%, the mineral element quartz content dominates. The burning rate of the brick artifact goes 650° Celcius, which means it has reached the oxidation stage.

The use of high-quality bricks illustrates that the residential buildings in Grogol were built well and not haphazardly. The description of the quality of the bricks can, of course, also provide the quality of the strength of the building structure in supporting the heavy loads on it. Based on the archaeological findings of other loose artifacts at the Grogol site, many fragments of components of roof structures such as *memolo, ukel,* roof tile, and others were found. This data also provides an idea that the buildings on the Grogol Site, both residential or any other type of building or construction in the residential area of Grogol Village in the past, are sturdy buildings and can withstand many ornamental attributes on their roofs.

The Grogol settlement, which is located a little outside the Trowulan core area, illustrates the type of brick mineral the people use to make brick with good quality. The people of Grogol processed it well using a good mixture and a good level of burning temperature, so it was suspected that the commodity could/benefits/potentially been traded in the past, both in the area and in its surroundings. It does not rule out the possibility that there are trade routes for this commodity from the city center to the residential areas around it, such as the use of burnt clay as a city wall found in Tuban [19], which is interesting to look into. Despite that potential, to what extent is the distribution of these good-quality bricks from Grogol, and who are the consumers? is still needed for further research.

7. COMPETING INTEREST STATEMENT

This article is clear of any conflicts of interest related to data collection, analysis, and publication process.

8. AUTHORS' CONTRIBUTIONS

Dimas Nugroho is the main author of this article. M. Fahlan S.I. is the second author, and Rusyanti is the third author of this research. All researchers contributed significantly to this research.

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