

Analysis on the Composition of Ancient Brick in Telagajaya Village, Batujaya Temple Complex, West Java, Indonesia

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ABSTRACT

Telagajaya Village is known as one of the rural areas that is located in the Batujaya Temple Complex, Karawang, West Java. Preliminary investigation in Telagajaya discovered that there were 16 sites which are believed to have been the construction sites of ancient temples, while an excavation revealed that there were rubbles of building surfaces and several base platforms of ancient temples. The main building material used for this temple was bricks. The present paper aims to validate whether the bricks used in the temple construction in Desa Telagajaya were made from local materials. The material composition analysis was examined using X-ray diffraction (XRD) and X-ray fluorescence (XRF) analytical technique. Scientific analysis on bricks from the temple construction is able to verify whether local raw materials were used in the construction. Scientific analysis of XRF and XRD are effective in determining chemical composition of the bricks, including minerals, major elements and trace elements. Besides soil sample, analysis of clay sample in Telagajaya Village was also conducted. According to an analysis on the mineral content, the brick samples used for temple constructions in Telagajaya Village were burned at extremely high temperatures (>800°C). Based on an analysis on major elements and trace elements, it is proven that the raw materials used to build the bricks originated from the same source. The comparison between brick elements and clay elements in Telagajaya Village demonstrates that the clay in Telagajaya Village was used as raw materials for building bricks.

Keywords: *Telagajaya Village; XRF; XRD; temple bricks*

1. INTRODUCTION

Telagajaya Village is located in Batujaya district, Karawang Regency in West Java province. This area has large paddy fields, and the Batujaya area is considered to be among the top rice producer in West Java. Since 1984, researchers in archaeology have discovered several rubbles from an ancient building, of which several parts were identified as temples that were located at paddy fields in Telagajaya Village. Studies on the temple remains in Telagajaya that were conducted by archaeologists and other scientists have been in progress since 1984 until now. There were nearly 16 sites of temple remains which have been identified in Telagajaya Village, Batujaya Temple Complex.

The remains of ancient buildings such as temples in Batujaya Temple Complex especially in the Telagajaya Village was found to be built using bricks. Nearly all of the temple buildings found were made of bricks. Hence, the aim of this research is to validate whether the bricks used to develop the temples in Telagajaya were made from local raw materials. This study was conducted by assessing and analyzing the bricks to determine if they were made from clays that originated from the temple areas or they were actually non-local materials. Bricks are known as the main architecture material that was used in temple constructions in Telagajaya Village, and one of the methods that can be applied to determine whether raw materials were used in the construction is to identify the chemical compositions of the bricks (Zuliskandar Ramli 2012, Zuliskandar Ramli et al. 2014), as what has been studied in the Asem Temple, Lingga Temple and the Serut B Temple that were located in the areas of Telagajaya Village (Muhamad

Shafiq & Zuliskandar 2015 & 2017; Muhamad Shafiq, Zuliskandar & Bambang 2016; Muhamad Shafiq, Zuliskandar, Mohd Rohaizat & Bambang 2014). Earlier studies on ancient bricks explained that the temple bricks were manufactured from local raw materials. For example, previous research on bricks that were used in temple constructions in Bujang Valley -- such as Mas River (Site 32/34), Bukit Pendiak Temple (Site 17) and Pangkalan Bujang Temple (Site 23) -- demonstrates that the temple architecture were made of local raw materials and they were from Muda River, Bujang River, Terus River and nearby area of temple site (Ramli et al., 2012; Zuliskandar et al., 2011).

2. SITE RESEARCH

This research focuses on the area of Telagajaya Village, Batujaya district, and the Karawang Regency in the West Java province. The Telagajaya Village area consists of nearly 16 construction sites which are believed to be temples. Three construction sites were selected to be scientifically analysed in order to obtain the mineral content, including trace elements and major elements of raw materials in clays which were used to make the bricks. The selected construction sites were the Serut-B Temple (TLJ I-B), the Lingga Temple (TLJ II) and the Asem Temple (TLJ V). The three construction sites were chosen, as deep excavation activities of them have been conducted. Moreover, previous researchers have excavated the whole construction site until the original structure design of building was visible.

2.1. Serut B Temple

The Serut B Temple was given a TLJ I marker, which was located at the coordinate of 107°08'50" E dan 06°03'23"N. In 1989, the National Survey and Mapping Coordinating Agency (BAKOSURTANAL), Faculty of Geography of University of Gadjah Mada and Directorate of Protection and Construction of Historical and Archaeological Relics (DITLINBINJARA) have investigated through geoarchaeology, drilling and test excavation by installing several trials in these construction sites. According to preliminary investigation, it is found that this area has temple remains at three different sites (TLJ I-A, TLJ I-B and TLJ I-C), all of which were facing towards northeast-southwest in azimuth of 46° (Djafar 2010).

In 1999, Social and Cultural Research Centre LP-PUI has collaborated with the Department of Archaeology, Faculty of Arts, Universitas Indonesia did a reinvestigation at the construction site area. The reinvestigation of the construction site was continued again in 2003 and 2004 by a group of archaeologists

from the Faculty of Cultural Sciences, Universitas Indonesia. The remains of a collapsed building were found in Serut-B Temple. The floor plan was square in shape, each side measuring 7.77 metres in length. There was only one staircase or front door which was located on the northeast side. At the platform base of the temple, there were indications of possible activity of repairing or renovation after the temple was built.

2.2. Lingga Temple

The Lingga Temple was marked with TLJ II, located at the coordinate of 107°08'48"E and 06°03'18"N, 60 × 50 m wide, measuring at 1.50 m tall from the rice field surface at the nearby area. Originally, the north platform base of the Lingga temple (TLJ II-A) had a higher ground level and was developed into an agricultural area, whereas the north side (TLJ II-B) which had a lower position was developed into housing areas by the land owner. This construction site was separated between the ones located at the north and south areas, because this site was developed into rice fields by the land owner. The bricks that were arranged longitudinally facing northwest-southeast were discovered along with fractions and rubbles of bricks at the south side of the temple base.

Apart from the rubbles and its structure, a total of five conglomerate stones that have a structure of an octagonal pillar with 80 cm height and 50 cm diameter were found. There was a hole at the centre of the stones, and it is assumed that these stones were rubbles from the top of the stupa. In 2004, the Department of Archaeology Study Program, Faculty of Cultural Sciences, Universitas Indonesia has excavated the south side of the temple and they found a temple base that measures 18×15 m, facing towards northeast-southwest in azimuth of 46°. There was a staircase at the base of the temple which located at northeast side.

This temple was constructed using the shape of a reservoir with a 2–2.5 m thick wall. At the inside of the temple reservoir was filled with compacted brick rubbles. The base platform of the temple was arranged flatly using bricks without seams decorations whereas the upper side of temple base has collapsed, hence the original structure of temple seams were unable to identify (Djafar 2010).

2.3. Asem Temple

Asem Temple with TLV J mark was located at coordinate of 107°08'41"E dan 06°03'00"N. The temple site was 90×50 m wide, has a terraced ground and shaped like a small hill, nearly 3 m high from the rice field surface. In 1989, DITLINBINJARA collaborated with National Survey and Mapping

Coordinating Agency (BAKOSURTANAL) and Faculty of Geography, Universitas Gadjah Mada (UGM) have conducted a geoelectric survey and installed several trials at this site. The survey has identified a brick building structure, positioned towards northwest-southeast. The survey also discovered parts of staircases to climb the temple building which located at southwest side of temple (Djafar 2010).

In the same year, which was in 1989, an investigation was carried out in the Asem Temple by a group of researchers from Universitas Tarumanagara. They investigated the entire upper part of the building and operated a thorough excavation at several building bases, until the complete profile of the base platform and the frame of the temple was determined. A concentric circle structure of bricks can be identified at the upper part of temple. Some brick impacts from the temple rubble can also be seen around the building site. From some of the temple rubbles, there were curved bricks with notched edges that are assumed to be fractions of a stupa-shaped building. In 1992, the site investigation was continued by the Department of Archaeology, Faculty of Arts, Universitas Indonesia in collaboration with National Research Centre of Archaeology of Indonesia and The Ceramic Society of Indonesia. The investigation discovered that the remains of the Asem temple is square shaped with 10×10 m measurement, and inclusive of two staircases. One of the staircases was positioned at southwest, while the other one was positioned at northeast. The southwest staircase was built after the yard that surrounds the temple was raised up at nearly 1 m by piling up the soil around the area. On top of the mounds of soil, the second staircase was built and was located at southwest of the building.

Two broken clay pots and a small piece of fan-shaped gold were found during the excavation of both staircases. There were no scripts on the gold piece. At some of the Asem temple base wall, there were remaining of stucco layers which were still intact on its surface. It is highlighted in this study that from a perspective on the temple construction technology in Batujaya temple site has made its first discovery of evidence of stucco layers application.

3. MATERIAL & METHOD

This study applied scientific approach to identify whether the bricks used in the temple constructions in Telagajaya Village were locally originated raw materials or foreign raw materials. A total of three sites were chosen to represent the entire Telagajaya Village site for research purposes. The Serut B Temple was marked with TLJ I, Lingga Temple was marked with TLJ II and Asem Temple with TLJ V. This marker was

applied according to the site identification that has been conducted by previous researchers. In order to prevent any confusion, identical identification and markers were maintained throughout.

Fifteen fragments of bricks were obtained from every site and they were placed in plastic bags and coded according to the site identification and marker. All of the samples were transferred to the Laboratory of Archaeology and Archaeometry, Institute of the Malay World and Civilization (ATMA), Universiti Kebangsaan Malaysia for analysis process. The samples were water-cleansed with pure water and then heated at 120°C for two days. Next, the samples were crushed into fine particles until it can be passed through a 500 µm sieve. Finally, these samples were brought to Physical Characterization Lab, Centre for Research and Instrumentation Management (CRIM), Universiti Kebangsaan Malaysia for further analysis by applying two different techniques – X-Ray Diffraction XRD to identify the mineral content in bricks and X-Ray Fluorescence (XRF) to identify the major elements and trace elements. The data obtained from both apparatuses will be compared with data analysis of clay elements from Batujaya area.

4. RESULTS & DISCUSSION

Based on the analysis results, the XRD technique is used to identify mineral content that available in the brick samples, whereas the XRF technique is used to obtain the major elements and trace elements of bricks from the Telagajaya Village site.

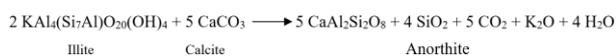
4.1. Mineral Content

According to the mineral content analysis that has been conducted on the Asem Temple, Lingga Temple and Serut B Temple in Telagajaya Village (Muhamad Shafiq & Zuliskandar 2015 & 2017; Muhamad Shafiq, Zuliskandar & Bambang 2016; Muhamad Shafiq, Zuliskandar, Mohd Rohaizat & Bambang 2014), there were a few minerals that can be found in all analysed samples. Minerals such as Quartz, Cristabolite, Albite, Anorthoclase, Andesine, Anorthite, Hematite and Labradorite were present in all three sample sites in Telagajaya Village. In addition, Mullite was found in Serut B Temple and Lingga Temple. Gismondine was present in both Lingga Temple and Asem Temple, whereas Spinel was discovered in Serut B Temple and Asem Temple. Besides that, there were minerals that can only be found in a single site only, such as Arsenopyrite, Pyroxene, Clinopyroxene, Diopside, Tealite, Bytownite, Andradite, Tremolite, Rhonite and Opal. The list of minerals from every site is shown in Table 1 below.

Table 1. Mineral content found in brick sample in the Telagajaya Village

Serut B Temple	Lingga Temple	Asem Temple
Quartz	Quartz	Quartz
Cristabolite	Cristobalite	Cristobalite
Albite	Albite	Albite
Anorthoclase	Anorthoclase	Anorthoclase
Andesine	Andesine	Andesine
Anorthite	Anorthite	Anorthite
Hematite	Hematite	Hematite
Labradorite	Labradorite	Labradorite
Mullite	Mullite	Spinel
Spinel	Pyroxene	Clinopyroxene
Arsenopyrite	Gismondine	Gismondine
Tealite	Diopside	Bytownite
		Andradite
		Tremolite
		Rhoenite
		Opal

Quartz is a mineral that can be commonly found in most clay samples. Anorthite and Hematite provide adequate proof that the bricks were heated at between 850oC to 900oC. These minerals that originated from illite were baked at extremely hot temperatures with high Calcium content (Cardiano, P et al. 2004). The presence of anorthite in all samples suggests that all samples were fired at temperature range 850°C–900°C. Amount of hematite increases with increased firing temperature. This is due to the Fe+ content that trapped in calcium silicate and aluminosilicate will turn into hematite with increased temperature (Miniatis et al. 19821; Cultrone G. et al. 2005).



Graphs of comparative minerals in bricks from every site are illustrated in Figure 1 (Serut B Temple), Figure 2 (Lingga Temple) and Figure 3 (Asem Temple).

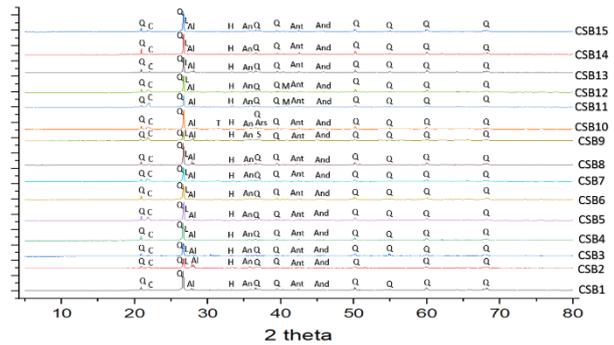


Figure 1. Comparison of mineral content sample from Serut B Temple

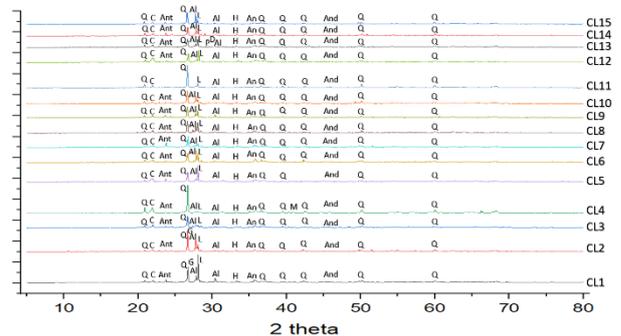


Figure 2. Comparison of mineral content sample from Lingga Temple

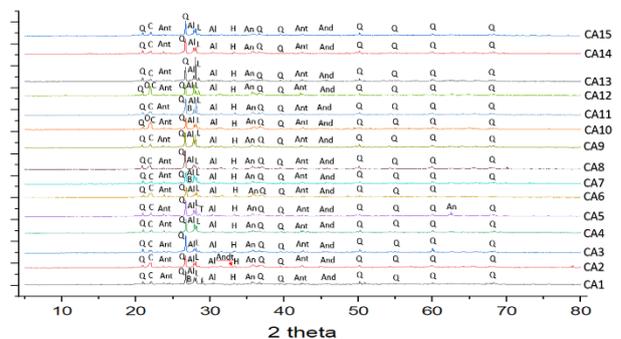


Figure 3. Comparison of mineral content sample from Asem Temple

Key: Q=quartz; C=cristobalite; H=hematite; Ant=anorthoclase; Al=albite; An=anorthite; And=andesine; L=labradorite; M=mullite; S=spinel; As=Arsenopyrite; T=tealite; P=pyroxene; G=gismondine; D=diopside; B=bytownite; Andt=andradite; Tr=tremolite; O=opal

4.2. Major Element Content

Table 2 below demonstrates the percentage of major elements in brick samples from Serut B Temple. The dry weight value of silica features by the highest

value, ranging from 50.85 to 55.75%, followed by aluminium ranging at 15.89 to 21.95%, iron (7.71–10.62%), magnesium (0.95–1.79%), calcium (0.92–2.35%), calium (0.85–1.18%), titanium (0.83–1.07%), natrium (0.47–1.29%), phosphorus (0.21–0.67%), manganese (0.14–0.25%) and sulphur (0.03–0.16%).

Table 2. Major element content in bricks from Serut Temple (%)

Formula	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃
CSB 1	55.75	0.92	20.54	8.47	0.18	1.26	0.92	0.47	0.93	0.23	0.05
CSB 2	52.58	0.98	18.52	9.42	0.14	1.79	2.35	1.29	1.18	0.67	0.07
CSB 3	55.62	0.96	17.26	8.30	0.17	1.07	1.50	0.75	1.18	0.26	0.05
CSB 4	54.41	0.92	19.91	8.07	0.14	1.36	1.48	0.69	0.97	0.36	0.04
CSB 5	54.09	0.92	18.09	8.48	0.19	1.19	1.09	0.55	1.12	0.66	0.05
CSB 6	55.31	0.92	19.66	8.45	0.17	1.14	1.12	0.57	1.07	0.50	0.06
CSB 7	53.84	0.95	15.89	8.38	0.17	0.96	1.13	0.62	1.04	0.23	0.03
CSB 8	55.21	0.97	18.96	8.52	0.19	1.24	1.18	0.61	1.00	0.21	0.06
CSB 9	50.85	1.07	21.11	10.62	0.20	1.47	1.10	0.49	0.85	0.25	0.05
CSB 10	53.67	0.97	17.96	8.70	0.17	1.13	1.02	0.51	0.97	0.54	0.05
CSB 11	55.28	1.02	19.19	8.83	0.16	1.24	1.35	0.79	1.02	0.46	0.04
CSB 12	53.30	0.98	17.93	8.76	0.17	1.11	0.98	0.51	0.98	0.63	0.05
CSB 13	53.64	1.01	21.95	9.11	0.16	1.12	1.27	0.51	1.09	0.53	0.07
CSB 14	54.93	0.83	17.61	7.71	0.23	0.95	1.37	1.28	1.17	0.36	0.16
CSB 15	54.54	0.97	19.48	8.66	0.25	1.18	1.09	0.63	1.02	0.52	0.06
Average	54.20	0.96	18.94	8.70	0.18	1.21	1.26	0.68	1.04	0.43	0.06
SD	1.31	0.06	1.58	0.67	0.03	0.21	0.35	0.26	0.10	0.17	0.03
Max Value	55.75	1.07	21.95	10.62	0.25	1.79	2.35	1.29	1.18	0.67	0.16

The percentage of major elements in brick samples from the Lingga Temple is shown in Table 3. Silica demonstrates the highest level of dry weight, ranging at 50.14–56.38, followed by aluminium (17.13–20.59%), iron (8.04–10.48%), calcium (1.48–3.02%), magnesium (1.08–1.92%), calium (0.95–1.40%), titanium (0.86–1.04%), natrium (0.60–1.61%), phosphorus (0.15–0.83%), manganese (0.10–0.38%), and sulphur (0.03–0.06%).

Table 3. Major element content in bricks from Lingga Temple (%)

Formula	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃
CL 1	50.14	0.90	18.48	10.10	0.32	1.69	3.00	1.37	1.15	0.80	0.04
CL 2	54.62	0.89	19.23	8.90	0.10	1.49	2.79	1.61	1.28	0.61	0.06
CL 3	55.07	0.95	19.52	9.45	0.16	1.86	2.60	1.39	1.14	0.17	0.04
CL 4	54.72	0.94	17.13	8.04	0.19	1.08	1.48	0.60	0.95	0.83	0.06
CL 5	52.38	1.04	19.26	10.48	0.14	1.93	2.71	1.34	1.03	0.18	0.04
CL 6	53.80	0.93	17.87	9.89	0.12	1.74	2.66	1.47	1.40	0.34	0.05
CL 7	56.05	0.92	18.42	9.09	0.13	1.62	2.84	1.61	1.28	0.18	0.05
CL 8	54.95	0.95	19.19	9.04	0.11	1.32	2.89	1.48	1.12	0.19	0.04
CL 9	53.96	0.96	17.66	9.19	0.17	1.38	2.82	1.42	1.38	0.45	0.06
CL 10	54.24	0.87	17.22	9.10	0.38	1.86	3.02	1.42	1.12	0.43	0.05
CL 11	56.38	1.01	20.59	8.92	0.13	1.34	1.64	0.91	1.16	0.25	0.04
CL 12	53.91	1.04	19.23	10.13	0.10	1.81	2.35	1.17	1.07	0.15	0.03
CL 13	53.75	1.02	19.49	10.11	0.18	1.92	2.73	1.37	1.11	0.18	0.05
CL 14	53.90	0.86	20.36	9.82	0.18	1.75	2.56	1.37	1.10	0.17	0.04
CL 15	55.36	0.97	18.56	9.36	0.15	1.59	2.73	1.38	1.26	0.27	0.04
Average	54.22	0.95	18.81	9.44	0.17	1.63	2.59	1.33	1.17	0.35	0.05
SD	1.50	0.06	1.04	0.64	0.08	0.25	0.45	0.26	0.13	0.23	0.01
Max Value	56.38	1.04	20.59	10.48	0.38	1.93	3.02	1.61	1.40	0.83	0.06

Table 4 represents the percentage of major elements in ancient bricks from Asem Temple. Silica has the highest percentage, ranging between 49.23 to 54.89%, followed by aluminium (16.28–19.70%), iron (8.91–10.95%), calcium (1.92–2.67%), titanium (0.91–1.12%), natrium (0.89–1.41%), magnesium (0.88–1.79%),

calium (0.81–1.20%), natrium (0.11–0.34%), manganese (0.10–0.29%) and phosphorus (0.03–0.06%).

Table 4. Major element content in bricks from Asem Temple (%)

Formula	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃
CA 1	52.23	0.91	18.05	9.22	0.29	1.12	2.39	1.09	1.06	0.14	0.06
CA 2	51.33	0.98	17.46	9.91	0.11	1.79	2.27	1.13	1.07	0.13	0.05
CA 3	54.89	1.00	18.55	8.91	0.10	1.41	1.92	1.07	1.13	0.17	0.05
CA 4	51.02	1.04	18.27	9.42	0.11	0.88	2.12	0.86	1.00	0.16	0.06
CA 5	52.31	1.01	18.74	9.33	0.11	1.26	2.34	1.22	1.07	0.11	0.05
CA 6	49.23	1.04	16.99	10.55	0.11	1.70	2.60	1.26	1.14	0.13	0.04
CA 7	51.99	1.00	17.65	9.57	0.11	1.60	2.61	1.32	1.20	0.34	0.06
CA 8	52.93	1.03	19.70	9.66	0.13	1.68	1.93	0.95	0.87	0.11	0.04
CA 9	49.63	1.01	19.03	10.14	0.17	1.58	2.49	1.34	0.99	0.19	0.06
CA 10	50.63	1.02	16.28	9.74	0.12	1.56	2.35	1.15	1.16	0.15	0.04
CA 11	52.40	0.98	18.60	9.86	0.10	1.76	2.12	1.03	1.13	0.13	0.03
CA 12	49.29	1.12	16.57	10.95	0.19	1.60	2.52	1.18	0.81	0.13	0.03
CA 13	53.28	0.94	19.52	9.43	0.12	1.33	2.00	0.98	1.19	0.17	0.06
CA 14	53.22	0.98	18.16	9.54	0.16	1.77	2.67	1.41	1.15	0.23	0.04
CA 15	51.78	0.95	18.23	9.30	0.11	0.92	2.36	0.92	1.00	0.16	0.05
Average	51.74	1.00	18.12	9.70	0.14	1.46	2.31	1.13	1.06	0.16	0.05
SD	1.60	0.05	0.99	0.53	0.05	0.30	0.25	0.16	0.11	0.06	0.01
Max Value	54.89	1.12	19.70	10.95	0.29	1.79	2.67	1.41	1.20	0.34	0.06
Min Value	49.23	0.91	16.28	8.91	0.10	0.88	1.92	0.86	0.81	0.11	0.03

Figure 4 exhibits the dry weight percentage of SiO₂ and Al₂O₃ in brick samples obtained from Telagajaya. Bricks with high silica content is characterized by presence of silica and aluminium. Furthermore, samples in Telagajaya also indicate a uniformed distribution of SiO₂ and Al₂O₃. This suggests that similar source of raw materials was used in Telagajaya temple bricks.

Dry weight percentage of MgO and TiO₂ in brick samples in Telagajaya is provided in Figure 5. The figure proves a grouped distribution of samples, and this means that the bricks used in the Telagajaya temple construction were made from raw materials or clay that originated from the local environment.

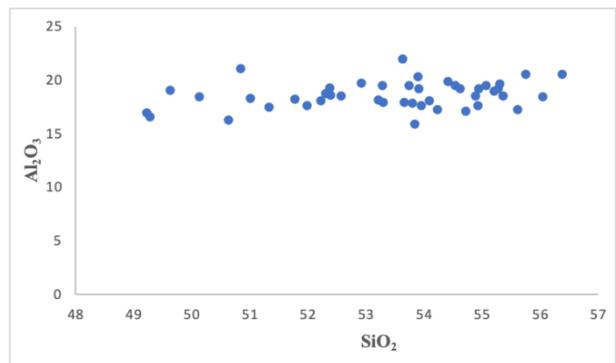


Figure 4. Dry weight percentage (%) of SiO₂ and Al₂O₃ in brick samples from Telagajaya

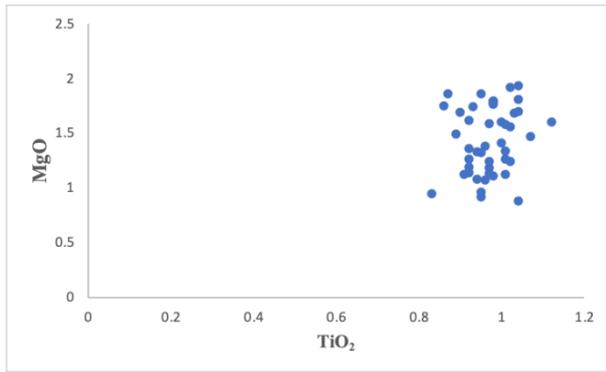


Figure 5. Dry weight percentage (%) of MgO dan TiO2 in brick samples from Telagajaya

4.3. Trace element content

The trace element that available in the brick samples from Serut Temple are barium, chromium, copper, nickel, rubidium, strontium, zinc, chlorin and zirconium. Table 5 shows the trace element of each brick sample from the Serut B Temple, and only trace elements of rubidium, strontium, zinc and zirconium were present in every sample. Barium content in brick samples appears in the range 200–600 ppm, chromium (50–100 ppm), copper (54–87 ppm), nickel (38–61 ppm), rubidium (32–54 ppm), strontium (100–400 ppm), zinc (100–1100 ppm), zirconium (100–400 ppm), chlorin (100–2800 ppm).

Table 5. Trace element content in ancient bricks from Serut B Temple (ppm)

Formula	BaO	Cr ₂ O ₃	CuO	NiO	Rb ₂ O	SrO	ZnO	ZrO ₂	Cl
CSB 1	300	71	61	57	38	100	200	200	100
CSB 2	400	86	63	61	48	200	100	100	700
CSB 3	400	BDL	56	BDL	54	200	200	200	BDL
CSB 4	300	BDL	62	BDL	37	100	200	400	BDL
CSB 5	200	93	66	38	43	100	200	200	100
CSB 6	600	BDL	76	BDL	42	100	200	200	200
CSB 7	BDL	53	67	BDL	46	100	1100	200	BDL
CSB 8	BDL	50	54	BDL	41	100	200	200	500
CSB 9	BDL	100	87	41	38	100	200	200	BDL
CSB 10	400	BDL	73	51	49	100	200	200	100
CSB 11	BDL	BDL	BDL	48	44	400	200	200	400
CSB 12	300	BDL	58	49	38	100	200	200	BDL
CSB 13	500	91	71	BDL	32	100	200	200	BDL
CSB 14	400	81	69	49	51	200	100	200	2800
CSB 15	BDL	88	67	58	32	100	200	200	200

The studied bricks in the Lingga Temple contain trace elements of barium, chromium, copper, nickel, rubidium, strontium, zinc, chlorine and zirconium (Table 6). Only trace elements of copper, rubidium, strontium, zinc and zirconium were found in every sample. Barium element in bricks fell within the range of 0.03–0.06%, chromium (56 ppm, 0.01%), copper (49–86 ppm), nickel (39–67ppm), rubidium (29–52ppm), strontium (0.01–0.03%), zinc (83 ppm, 0.02%), zirconium (0.01–0.02%), chlorin (92 ppm, 0.01%).

Table 6. Trace element content in ancient bricks from Lingga Temple

Formula	BaO	Cr ₂ O ₃	CuO	NiO	Rb ₂ O	SrO	ZnO	ZrO ₂	Cl
CL 1		91 ppm	72 ppm	51 ppm	38 ppm	0.03%	0.02%	0.01%	0.01%
CL 2	0.03%		72 ppm		45 ppm	0.03%	0.01%	0.01%	0.01%
CL 3	0.06%	76 ppm	64 ppm	56 ppm	34 ppm	0.02%	0.02%	0.01%	0.01%
CL 4	0.03%	0.01%	74 ppm	43 ppm	43 ppm	0.02%	83 ppm	0.02%	0.01%
CL 5			61 ppm		43 ppm	0.02%	0.02%	0.01%	0.01%
CL 6	0.04%	69 ppm	84 ppm	39 ppm	47 ppm	0.02%	0.02%	0.01%	0.02%
CL 7	0.03%		74 ppm		42 ppm	0.02%	0.01%	0.01%	
CL 8	0.03%		73 ppm	45 ppm	40 ppm	0.03%	0.02%	0.01%	
CL 9	0.06%	96 ppm	55 ppm	47 ppm	49 ppm	0.03%	0.01%	0.01%	99 ppm
CL 10	0.06%	0.01%	86 ppm	40 ppm	47 ppm	0.03%	0.01%	0.01%	0.01%
CL 11	0.05%		85 ppm	67 ppm	41 ppm	0.01%	0.02%	0.02%	
CL 12	0.04%	95 ppm	49 ppm		52 ppm	0.02%	0.01%	0.02%	
CL 13	0.03%		54 ppm	52 ppm	29 ppm	0.02%	0.02%	0.01%	0.08%
CL 14	0.03%	56 ppm	84 ppm	62 ppm	43 ppm	0.02%	0.01%	0.01%	92 ppm
CL 15	0.04%	0.01%	64 ppm		40 ppm	0.02%	0.01%	0.01%	

Barium, chromium, copper, nickel, rubidium, strontium, tungsten, zinc and zirconium are among the trace elements that were present in studied bricks from the Asem Temple (Table 7). Barium lies within the range of 0.02–0.08%, chromium (45ppm, 0.01%), copper (46–74 ppm), nickel (29–67 ppm), rubidium (28–56 ppm), strontium (0.02–0.03%), zinc (0.01–0.02%), zirconium (97 ppm–0.03%), tungsten (0.02–0.07%).

Table 7. Trace element content in ancient bricks from Asem Temple

Formula	BaO	Cr ₂ O ₃	CuO	NiO	Rb ₂ O	SrO	WO ₃	ZnO	ZrO ₂
CA 1	0.06%	45 ppm	64 ppm	47 ppm	40 ppm		0.04%	0.02%	0.01%
CA 2	0.03%	82 ppm	66 ppm	43 ppm	52 ppm	0.02%	0.07%	0.01%	0.02%
CA 3	0.03%	92 ppm	68 ppm	43 ppm	52 ppm	0.02%	0.07%	0.01%	0.02%
CA 4	0.08%		70 ppm	49 ppm	33 ppm	0.02%		0.02%	0.01%
CA 5	0.05%		62 ppm	47 ppm	43 ppm	0.03%		0.01%	0.01%
CA 6	0.03%		71 ppm	41 ppm	56 ppm	0.02%	0.04%	0.02%	0.01%
CA 7	0.04%	95 ppm	46 ppm	41 ppm	34 ppm	0.02%	0.05%	0.02%	0.01%
CA 8		0.01%	55 ppm	51 ppm	28 ppm	0.02%	0.02%	0.02%	0.02%
CA 9	0.06%		72 ppm	50 ppm	37 ppm	0.02%		0.02%	0.01%
CA 10		0.01%	54 ppm	29 ppm		0.02%	0.04%	0.02%	0.01%
CA 11					61 ppm	0.02%	0.02%	0.02%	0.02%
CA 12	0.02%		74 ppm	65 ppm	36 ppm	0.03%	0.03%	0.01%	0.02%
CA 13	0.04%	88 ppm	65 ppm	67 ppm	48 ppm	0.02%	0.02%	0.02%	0.01%
CA 14			63 ppm	67 ppm	34 ppm	0.02%	0.03%	0.01%	97 ppm
CA 15	0.07%	0.01%	68 ppm	41 ppm	39 ppm	0.02%		0.01%	0.01%

4.4. Comparison with Local Sources

It is crucial to conduct a comparative analysis between elements from the Telagajaya temple bricks and elements that were available in clays around the Telagajaya area. This is to prove whether the bricks used to build the temples originated from raw clay that was geographically available from the Telagajaya area or brought from different local sources.

There were three different areas to obtain the clay source around Telagajaya to analytically compare the samples. The three areas were abandoned clay resource sites; clay in the Citarum River flooded areas; and clay mixture for brick manufacturing by locals (Muhamad Shafiq 2018).

As shown in Figures 6 and 7, there was an overlap between the contents of brick samples and clay samples

from Telagajaya temple areas. The overlapping result from both brick sample contents and clay samples signifies that the raw material (clay) to make bricks were picked from the Telagaya localities. This finding also suggests that the local communities used raw materials available from their common geological source to make bricks for temple buildings.

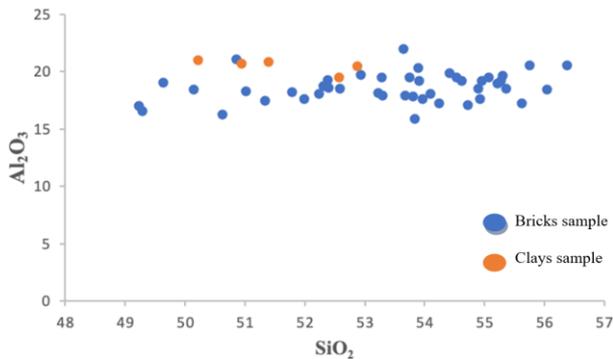


Figure 6. Dry weight percentage (%) of SiO₂ dan Al₂O₃ in brick samples and clay samples from Telagajaya Village

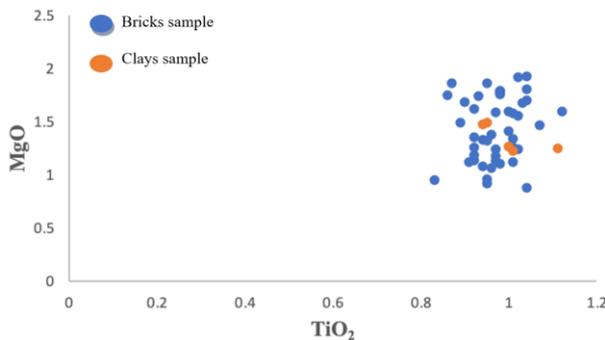


Figure 7. Dry weight percentage (%) of MgO dan TiO₂ in brick samples and clay samples from Telagajaya Village

5. CONCLUSION

Mineral content analysis and elements in studied bricks from Telagajaya Village demonstrated that the analyzed samples were derived from the same raw material source. Based on the mineral content analysis, the brick samples used to construct temple building in Telagajaya Village were baked at high firing temperature, exceeding 800oC. According to the major element and trace element content analysis, it is suggested that the raw materials used to make bricks were originated from the same source. The comparative analysis between brick element content and clay element content that available from Telagajaya Village area also signifies that the clay from Telagajaya Village was used as raw materials to make bricks. The comparative results also demonstrated that the local communities has contributed in the construction of temple buildings in Telagajaya Village by utilizing the

raw materials in their local geological source to make bricks. Hence, the finding of this study support the idea that the temple buildings in Batujaya Temple Complex, specifically in Telagajaya Village were built by local communities and this can be regarded as the knowledge and local wisdom of the local community. It can be concluded as well that between fifth to seventh century, the locals in this particular area has the literacy to produce and bake bricks, as well as build their own worship buildings.

AUTHORS' CONTRIBUTIONS

The contributions of each author are as follows conceived and designed the analysis, collect the data, contributed data or analysis tools, performed the analysis and wrote the paper.

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