

Compositional Analysis O Ancient Bricks From The Seg-II Temple (Unur Lempeng), Batujaya, Indonesia

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ABSTRACT

The aim of this study is to determine whether the ancient bricks from Candi SEG II (Lempeng) are made from local raw material or otherwise. Candi SEG II is located in a cultivation area which has unearthed various interesting artefacts like fragments of pottery, rouletted pottery, glass beads, animal bones, skeletons and inscriptions with Palava characters. The main construction materials used to build the temple consisted of bricks, while limestone was used as the mortar. The upper part of the temple is believed to have been built using wooden structures and the roof using palm leaves. Scientific analysis on the bricks shows that local raw material was used to produce these bricks. Scientific analysis using the X-ray fluorescence technique and X-ray diffraction technique can determine the chemical composition of the bricks; among others the mineral content of the bricks as well as the major element and trace element content. The usage of local raw material also demonstrated the local wisdom in temple construction technology and also the technique in producing bricks that had existed.

Keywords: Candi Segaran II, X-ray fluorescence, X-ray diffraction, ancient bricks, archaeometry

INTRODUCTION

Candi SEG II is located at coordinate 107°08'58"E and 06°03'24"N, and is approximately 100 X 100 m, with an average height of 0.5 m. This area was land which was cultivated for crops and now it is an area of rice cultivation. This area then divided into five sectors named SEG II-A, SEG II-B (SEG II-B1 & SEG II-B2), SEG II-C and SEG II-D. In 1985 and 1986, archaeological team from Faculty of Arts, University of Indonesia conducted research advances in this area in the form of surface survey and carried out test trenches around the area. This preliminary study resulted in a number of findings in the form of pottery shards, glass beads, bone and animal teeth and Arikamedu pottery shards. Finding of Arikamedu pottery shards is an important one. This is not only because it is the first time findings of this kind have been found in Batujaya, but more importantly, these findings indirectly indicate early relationship with the Indian culture (Djafar 2010). From the excavation of test boxes and surface stripping in the region, remains of brick structures of four sectors were obtained that stretched within the northwest-southeast direction (Jurusan Arkeologi FSUI 1986; Djafar 2000). In September 1999, *Pusat Penelitian Kemasyarakatan dan Budaya* funded and conducted archaeological research at this site. The research was carried out in SEG II-A and SEG II-B1 sectors. A test box at SEG II-A was

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excavated to a depth of 180 cm, generating data about the stratigraphic layering of the ground with the findings in the form of broken pottery, beads and bones from the late prehistoric period. Excavations at SEG II-B1 uncovered the rest of the foot portion of a brick building with a southwest-northeast direction. The leg seam composition in the form of seam (*patta*), semicircle seam (*kumuda*) and jagged seam was visible from the other part of the building (Djafar 2000).

In the month of Jun-July 2005, archaeological teams led by the Deputy Assistant of the National Archaeological Affairs with EFEQ conducted archaeological excavations in all the sectors of the SEG II site, and managed to find the remaining four structures, including the remains of a brick building in the groundwork of sectors SEG II-A, SEG II-B2, SEG II-C and SEG II-D. From the excavation was also found a variety of other findings in the form of broken pottery of the Buni, and the Arikamedu pottery type, glass and stones beads, ornate stucco fragments and seven individual human skeletons. The human skeleton was found buried together with artefacts in the form of stock pot with a lid, iron tools and a gold bracelet (Budi Utomo & Manguin, 2004; 2005). Human skeleton and grave provision were found in the Buni cultural layer located below the temple's cultural layer (Hindu-Buddhist cultural layer). From the ruins of the buildings in sector SEG II-A, a small gold plate inscribed with letters containing Palava script was found. Study on SEG II site by the Centre for Research and Development of the National Archaeological Affairs together EFEQ resumed in 2006 to obtain additional data and to attain clarity on some constraints that were faced in the previous research (Djafar 2010).

Therefore, the main objective of this research is to determine whether the bricks used for construction of Candi SEG II were made from local clay or otherwise. Bricks were the major construction material used to build Candi SEG II (Unur Lempeng) and one of the methods to determine whether the raw material used to produce these bricks was local raw material or otherwise is by determining the chemical composition of the bricks (Zuliskandar Ramli 2012, Zuliskandar Ramli et al. 2014). Research carried out previously on the ancient bricks showed that the bricks were produced by using local raw material and not using raw materials from the outside. For example, the research carried out on the bricks that were used to build Sungai Mas Temple (site 32/34), Bukit Pendiak Temple (Site 17) and Pengkalan Bujang Temple (Site 23) revealed that the raw material used to build the temples was obtained from the basin of Muda River, Bujang River, Terus River and the areas surrounding the sites (Ramli et al., 2012; Zuliskandar et al., 2011).

MATERIALS & METHODS

This study used the scientific approach in determining whether the bricks in the site of SEG II used local raw materials or not. A total of 15 fragments of ancient bricks were taken from the site of Candi SEG II (Lempeng) and placed into plastic bags and recorded. These samples were taken to the laboratory for sample treatment where each sample was cleaned using water and later dried at a temperature of 120°C for 2 days. These samples were then ground into very fine powder and once again dried at a temperature of 120°C for 1 day. These samples were then sent for analysis where the two techniques used were the X-ray Diffraction

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Technique to determine the mineral content in the brick samples and the X-ray Fluorescence Technique to determine the major element content. The data obtained were later compared with the data analysis of the clay around Batujaya that was carried out previously.

RESULT & DISCUSSION

Material composition analysis of the ancient bricks of Batujaya's Candi SEG II was performed to determine the mineral content of the bricks and the major element and trace element content. Material composition of the bricks will be able to determine whether the raw material used was local clay or otherwise. Hence, the analysis can support the hypothesis that the candi at Batujaya were built by the local people using sources of local raw material.

The mineral content contained in the ancient brick samples of Candi SEG II showed the presence of minerals such as quartz, cristobalite, anorthite, labradorite, mullite, gismondine, albite, hematite and several other minerals that can be found in Table 1. The result shows that the raw material used for making the bricks was clay mixed with volcanic ash.

Table 1. Mineral content of ancient bricks from Batujaya SEG II

| Location | Sample | Mineral content |
|-----------------|---|---|
| Batujaya SEG II | CLE 1 | SiO ₂ - Quartz |
| | | (Ca,Na)(Al,Si) ₂ Si ₂ O ₈ - Anorthite, sodian, ordered |
| | | Fe ₂ O ₃ - Hematite |
| | | (Na,Ca)Al(Si,Al) ₃ O ₈ - Albite, calcian, ordered |
| | CLE 2 | Ca _{0.68} Na _{0.30} (Al _{1.66} Si _{2.34} O ₈) - Labradorite |
| | | Na _{0.622} Ca _{0.368} Al _{1.29} Si _{2.71} O ₈ - Andesine |
| | | SiO ₂ Quartz |
| | | SiO ₂ Cristobalite |
| | CLE 3 | Ca _{0.68} Na _{0.30} (Al _{1.66} Si _{2.34} O ₈) Labradorite |
| | | Al(Al _{1.272} Si _{0.728} O _{4.864}) Mullite |
| | | CaAl ₂ Si ₂ O ₈ Anorthite |
| | | Fe ₂ O ₃ Hematite |
| | CLE 4 | SiO ₂ Quartz |
| | | SiO ₂ Cristobalite |
| | | Al _{4.59} Si _{1.41} O _{9.7} Mullite |
| | | Fe ₂ O ₃ hematite |
| CLE 4 | SiO ₂ quartz | |
| | SiO ₂ cristobalite | |
| | Ca _{0.68} Na _{0.30} (Al _{1.66} Si _{2.34} O ₈) Labradorite | |



| | |
|--------|--|
| | (Na _{0.75} Ca _{0.25})(Al _{1.26} Si _{2.74} O ₈) Albite calcian CaAl ₂ Si ₂ O ₈ Anorthite Fe ₂ O ₃ hematite |
| CLE 5 | SiO ₂ quartz SiO ₂ cristobalite Al(Al _{1.27} Si _{0.728} O _{4.864}) Mullite SiO ₂ -x-H ₂ O Opal |
| CLE 6 | (Na _{0.45} Ca _{0.55})(Al _{1.55} Si _{2.45} O ₈) Anorthite (Na _{0.5} Ca _{0.5})(Al _{1.5} Si _{2.5} O ₈) Labradorite SiO ₂ quartz CaAl ₂ Si ₂ O _{8.4} H ₂ O Gismondine Na _{0.499} Ca _{0.491} (Al _{1.488} Si _{2.506} O ₈) Andesine (Na,Ca)Al(Si,Al) ₃ O ₈ Albite, calcian (Mg _{3.78} Al _{4.22})(Si _{1.91} Al _{4.09} O ₂₀) Sapphirine Al ₂ (Al _{2.8} Si _{1.2})O _{9.6} Mullite |
| CLE 7 | SiO ₂ quartz CaAl ₂ Si ₂ O _{8.4} H ₂ O Gismondine Fe ₂ O ₃ hematite (Na _{0.85} K _{0.14})(AlSi ₃ O ₈) Anorthoclase AlPO ₄ Berlinite KAl ₃ Si ₃ O ₁₀ (OH) ₂ Muscovite |
| CLE 8 | SiO ₂ quartz (Na,Ca)Al(Si,Al) ₃ O ₈ Albite, calcian SiO ₂ Cristobalite CaAl ₂ Si ₂ O ₈ Anorthite Al _{4.54} Si _{1.46} O _{9.73} Mullite Fe ₂ O ₃ hematite |
| CLE 9 | SiO ₂ quartz Na(AlSi ₃ O ₈) Albite Na _{0.685} Ca _{0.347} Al _{1.46} Si _{2.54} O ₈ Andesine (Ca,Na)(Si,Al) ₄ O ₈ Anorthite, sodian Ca _{0.68} Na _{0.30} (Al _{1.66} Si _{2.34} O ₈) Labradorite Fe ₂ O ₃ hematite |
| CLE 10 | SiO ₂ Quartz CaAl ₂ Si ₂ O _{8.4} H ₂ O Gismondine Al _{4.56} Si _{1.44} O _{9.72} Mullite (Na,Ca)Al(Si,Al) ₃ O ₈ Albite, calcian SiO ₂ Cristobalite SiO ₂ -x-H ₂ O Opal |
| CLE 11 | SiO ₂ Quartz low |

| | |
|--------|--|
| | C Graphite |
| | CaAl ₂ Si ₂ O ₈ .4H ₂ O Gismondine |
| | SiO ₂ Cristobalite |
| | Na _{0.499} Ca _{0.491} (Al _{1.488} Si _{2.506} O ₈) Andesine |
| | (Al ₄ SiO ₈) _{1.2} Mullite |
| CLE 12 | SiO ₂ quartz low |
| | AlPO ₄ Berlinite |
| | (K _{0.22} Na _{0.078})(AlSi ₃ O ₈) Albite high |
| | (Na _{0.75} K _{0.25})(AlSi ₃ O ₈) Anorthoclase |
| | Fe ₂ O ₃ hematite |
| CLE 13 | SiO ₂ Quartz |
| | AlPO ₄ Berlinite |
| | CaAl ₂ Si ₂ O ₈ Anorthite |
| | CaAl ₂ Si ₂ O ₈ .H ₂ O Gismondine |
| | (Na,Ca)Al(Si,Al) ₃ O ₈ Albite, calcian |
| | Na _{0.85} K _{0.14})(AlSi ₃ O ₈) Anorthoclase |
| CLE 14 | SiO ₂ Quartz |
| | CaAl ₂ Si ₂ O ₈ .4H ₂ O Gismondine |
| | Na _{0.685} Ca _{0.347} Al _{1.46} Si _{2.54} O ₈ Andesine |
| | Ca _{0.66} Na _{0.34} Al _{1.66} Si _{2.34} O ₈ Labradorite |
| | CaAl ₂ Si ₂ O ₈ Anorthite |
| | Na(AlSi ₃ O ₈) Albite high |
| CLE 15 | SiO ₂ Quartz low |
| | CaAl ₂ Si ₂ O ₈ .4H ₂ O Gismondine |
| | SiO ₂ -xH ₂ O Opal |
| | (Na,Ca)Al(Si,Al) ₃ O ₈ Albite, calcian |
| | SiO ₂ Crisobalite |
| | Cu _{0.28} Mg ₂ (Al _{4.5} Si _{4.5} O ₁₈) Cordierite |

Major element content in the ancient brick samples of Candi SEG II can be referred to in detail in Table 2. The analysis showed that the brick samples contained dry weight percentage of silica element of between 50.18 to 55.81%. Percentage of dry weight for the titanium element was between 0.88 to 1.27%. Percentage of dry weight for the aluminium element was between 14.73 to 19.42%. The iron element contained dry weight percentage that was between 7.55 to 10.89%. Manganese element had dry weight percentage between 0.13 to 0.25%. For the magnesium element, the dry weight percentage was between 0.83 to 1.54% while calcium element contained dry weight percentage of between 1.00 to 1.76%. The dry weight percentage for the sodium and potassium element was 0.43 to 0.72% and 0.87 to 1.22% respectively. Phosphorus and sulphite elements contained dry weight percentage of between 0.21 to 1.14% and 0.03 to 0.07 respectively.

Table 2: Major element content of the ancient bricks of Candi SEG II (Lempeng)

| 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 |
|---------|------------------|------------------|--------------------------------|--------------------------------|------|------|------|-------------------|------------------|-------------------------------|-----------------|
| CLE 1 | 51.76 | 1.27 | 19.21 | 10.89 | 0.23 | 1.53 | 1.56 | 0.72 | 0.96 | 0.35 | 0.05 |
| CLE 2 | 51.85 | 0.90 | 15.20 | 8.31 | 0.20 | 0.89 | 1.40 | 0.66 | 1.00 | 0.37 | 0.04 |
| CLE 3 | 52.51 | 0.91 | 14.73 | 8.33 | 0.25 | 0.87 | 1.76 | 0.65 | 1.01 | 0.39 | 0.04 |
| CLE 4 | 50.18 | 0.98 | 19.42 | 9.79 | 0.20 | 1.54 | 1.49 | 0.63 | 1.08 | 0.55 | 0.05 |
| CLE 5 | 53.95 | 1.03 | 19.32 | 9.44 | 0.17 | 1.45 | 1.19 | 0.53 | 1.01 | 0.29 | 0.04 |
| CLE 6 | 54.86 | 0.98 | 17.77 | 8.66 | 0.21 | 1.17 | 1.12 | 0.47 | 0.98 | 0.35 | 0.03 |
| CLE 7 | 53.68 | 0.91 | 17.94 | 8.75 | 0.19 | 1.20 | 1.27 | 0.57 | 0.87 | 0.60 | 0.05 |
| CLE 8 | 52.91 | 0.99 | 17.55 | 8.85 | 0.20 | 1.20 | 1.17 | 0.54 | 0.94 | 0.21 | 0.04 |
| CLE 9 | 54.60 | 0.91 | 16.20 | 8.27 | 0.14 | 1.08 | 1.24 | 0.68 | 1.09 | 0.29 | 0.04 |
| CLE 10 | 54.38 | 0.93 | 18.11 | 8.70 | 0.16 | 1.19 | 1.00 | 0.43 | 0.99 | 0.23 | 0.04 |
| CLE 11 | 54.12 | 10.4 | 15.85 | 8.50 | 0.14 | 1.03 | 1.09 | 0.65 | 1.01 | 0.20 | 0.03 |
| CLE 12 | 55.81 | 0.89 | 16.39 | 7.55 | 0.13 | 0.83 | 1.47 | 0.60 | 1.18 | 0.47 | 0.03 |
| CLE 13 | 53.60 | 0.88 | 15.30 | 8.01 | 0.14 | 1.01 | 1.29 | 0.62 | 1.09 | 0.43 | 0.03 |
| CLE 14 | 51.18 | 0.95 | 18.06 | 8.52 | 0.15 | 0.93 | 1.32 | 0.51 | 1.22 | 1.14 | 0.07 |
| CLE 15 | 53.02 | 0.96 | 15.49 | 8.04 | 0.15 | 0.83 | 1.27 | 0.62 | 1.04 | 0.25 | 0.03 |

The trace element content of the brick samples of Candi SEG II showed element content such as chromium, copper, nickel, rubidium, strontium, zinc, zirconium and chlorine. The trace element can be seen in Table 3. From the table, we can see only copper, strontium, and zirconium were present in all the samples. Chromium element content was between 82 ppm to 0.01% while copper element was between 50 to 83 ppm. Nickel element content was between 38 to 70 ppm while rubidium element was between 36 to 54 ppm. Strontium and zinc element was between 0.01 to 0.02% and 88 ppm to 0.02% respectively while zirconium and chlorine element was between 0.02 to 0.03% and 0.01 to 0.02% respectively.

Table 3. Trace element content of the ancient bricks of Candi SEG II (Lempeng)

| Sample | Cr ₂ O ₃ | CuO | NiO | Rb ₂ O | SrO | ZnO | ZrO ₂ | Cl |
|--------|--------------------------------|--------|--------|-------------------|-------|--------|------------------|-------|
| CLE 1 | 0.01% | 50 ppm | 41 ppm | 44 ppm | 0.02% | 0.02% | 0.03% | 0.01% |
| CLE 2 | | 63 ppm | | | 0.02% | 0.01% | 0.03% | 0.02% |
| CLE 3 | 0.01% | 71 ppm | 70 ppm | 39 ppm | 0.02% | 88 ppm | 0.03% | |
| CLE 4 | 95 ppm | 64 ppm | 48 ppm | 45 ppm | 0.02% | 0.02% | 0.02% | 0.02% |
| CLE 5 | 85 ppm | 83 ppm | 38 ppm | 48 ppm | 0.01% | 0.02% | 0.02% | |
| CLE 6 | 86 ppm | 61 ppm | 62 ppm | 45 ppm | 0.01% | 0.02% | 0.02% | |
| CLE 7 | 82 ppm | 56 ppm | 41 ppm | 39 ppm | 0.01% | 0.02% | 0.03% | 0.01% |
| CLE 8 | 96 ppm | 75 ppm | 49 ppm | 45 ppm | 0.01% | 0.02% | 0.03% | 0.02% |
| CLE 9 | 98 ppm | 65 ppm | 56 ppm | 49 ppm | 0.02% | | 0.03% | 0.01% |



| | | | | | | | | |
|--------|-------|--------|--------|--------|-------|-------|-------|-------|
| CLE 10 | | 59 ppm | 45 ppm | 47 ppm | 0.02% | | 0.03% | 0.01% |
| CLE 11 | 0.01% | 55 ppm | 47 ppm | 36 ppm | 0.01% | 0.01% | 0.03% | 0.01% |
| CLE 12 | | 58 ppm | 47 ppm | 47 ppm | 0.02% | 0.01% | 0.03% | |
| CLE 13 | | 60 ppm | 47 ppm | 54 ppm | 0.02% | 0.01% | 0.03% | |
| CLE 14 | | 65 ppm | 46 ppm | 50 ppm | 0.02% | 0.01% | 0.02% | |
| CLE 15 | | 57 ppm | 46 ppm | 52 ppm | 0.02% | 0.01% | 0.03% | 0.01% |

Dry weight percentage of SiO₂ and Al₂O₃ elements for the brick samples of Candi SEG II is shown in Figure 1. The silica and aluminium content showed that the bricks have high silica content. Dry weight percentage of MgO and TiO₂ elements for the brick samples of Candi SEG II is shown in Figure 2. From Figure 2, it can be seen that in making the bricks for Candi SEG II, local materials were used and it is suggested that the bricks are made from local materials.

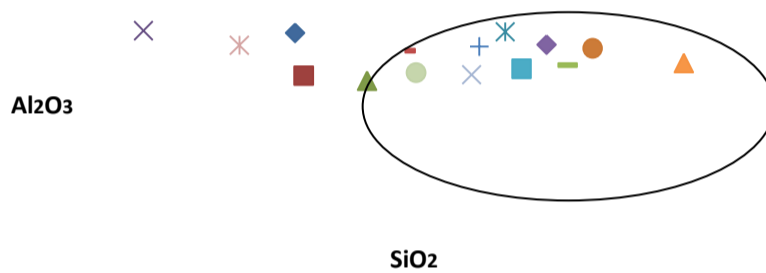


Fig 1: Dry weight percentage (%) of SiO₂ and Al₂O₃ elements for the brick samples of Candi SEG II

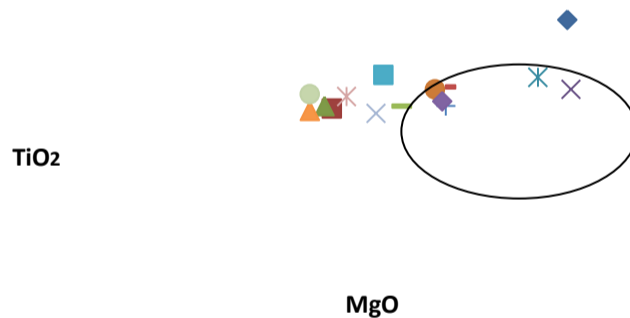


Fig 2: Dry weight percentage (%) of MgO and TiO₂ elements for the bricks samples of Candi SEG II

CONCLUSION

Compositional analysis on the ancient bricks from Candi SEG II shows that most of the samples analyzed used the same local material. Several major minerals occur in the bricks suggesting that the raw materials were taken from clay mixed with volcanic ash. Based on the major and trace element analysis, it has been shown that the raw material used to make the bricks was taken from the same location and it can be suggested that the raw material used was local material. It can be suggested also that the local people were involved in the process of making the bricks for the purpose of building their temples.

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