WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.13 (2): 197-200. 2015 *www.world-food.net*

X-ray fluorescence and X-ray diffraction analysis of ancient bricks from the temple SEG-II (Ubur Lempeng), Batujaya, Indonesia

Muhamad Shafiq Mohd Ali [1], Zuliskandar Ramli [1]*, Nik Hassan Shuhaimi Nik Abdul Rahman [1], Abdul Latif Samian [1], Muhammad Rizal Razman [2] and Bambang Budi Utomo [3]

*[1]Institute of Malay World and Civilization (ATMA), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia. [2] Research Centre for Sustainability Science and Governance (SGK), Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600, UKM Bangi, Selangor, Malaysia. [3]Pusat Penelitian Arkeologi Nasional, Jl. Raya Condet Pejaten No. 4 (Gedung A), Jakarta, DKI Jakarta, Indonesia. *e-mail: ziskandar2109@gmail.com*

Received 10 January 2015, accepted 20 March 2015.

Abstract

The aim of this study was to determine whether the ancient bricks from Candi SEG II (Lempeng) are made from local raw material or otherwise. Candi SEG II located in cultivation area has unearthed various interesting artefacts like fragment 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 and limestone was used as a mortar. The upper part of the temple is believed to have been built using wooden structures and the roof used 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 contents. The usage of local raw material also demonstrated the local wisdom in temple construction technology and also technique in producing bricks that had existed.

Key words: Candi Segaran II, X-ray fluorescence, X-ray diffraction, ancient bricks, archaeometry.

Introduction

Candi SEG II located at coordinate 107°08'58''E and 06°03'24''N, approximately 100 m x 100 m, with an average height 0.5 m. This area was land cultivated for crops and now this area is an area of rice cultivation. This area became agitated and 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 form of surface survey and made 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 important. This is due to his deep not for sake only the first time the findings of this kind are found in the Batujaya, but more importantly these findings indicate an early relationship with the Indian culture indirectly [1].

From the excavation of test boxes and surface stripping in the region gained four sector remains of brick structures that are stretched with a northwest-southeast direction [2, 3]. In September 1999 archeological research was funded and conducted by Pusat Penelitian Kemasyarakatan dan Budaya at this site. The research was carried out in the sector SEG II-A and SEG II-B1. A test box at SEG II-A were excavated to a depth of 180 cm, generating data about the stratigraphic layering the ground with the findings in the form of broken pottery, beads and bones from the late prehistoric period. Excavations at SEG II-B1 found the rest of the foot portion of a brick building with a southwest-northeast direction. From the rest of the building is still visible leg seam composition in the form of seam (*patta*), semicircle seam (*kumuda*) and jagged seam. The rest of the building is the rest of the foot portion of a temple could no longer form known size [3].

During Jun-July 2005, the archeological teams from the Deputy Assistant National Archeological Affairs with EFEO conducted archeological excavation team in all sectors SEG II site, and managed to find the remaining four structures, including the remains of a brick building foundation sector SEG II-A, SEG II-B2, SEG II-C and SEG II-D. A variety of other findings in the form of broken pottery Buni types and Arikamedu pottery types, glass and stones beads, ornate stucco fragments and seven individual human frame were also found from the excavation. The human skeleton was found buried together in the form of stock pot with a lid, the tools of iron and a gold bracelet [4, 5]. Human skeleton and grave provision was found in the Buni cultural layer located below the temple cultural layer (Hindu-Buddhist cultural layer). A small gold plate inscribed with letters containing Palava script was found from the ruins of the buildings in the sector SEG II-A. Study on SEG II site resumed in 2006 by the Centre for Research and

Development of the National Archeological together EFEO to obtain additional data and clarity on some constraint has been obtained through the previous research [1].

The main objective of this research was to determine whether the bricks used for construction of the Candi SEG II were made from local clay or otherwise. Bricks were 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 was by determining the chemical composition of the bricks and then compared with clay taken from surrounding area [6-8]. The research carried out previously on the ancient bricks from ancient temples from Malaysia showed that the bricks were produced by using local raw material and not using raw materials from outside. For example, the research carried out on the bricks that were used to build Sungai Mas Temple (site 32/34), Bukit Pendiat Temple (site 17) and Pengkalan Bujang Temple (sites 18, 19, 21/22, 23 and 2211) and Bukit Kechil Site revealed that the raw material used was obtained from the basin of Muda River, Bujang River, Terus River and the areas surrounding the sites [9-13].

Material and Methods

This study used the scientific approach in determining whether the bricks in site SEG II used local raw materials or not. A total of 15 fractions 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 samples were cleaned using water and later dried at a temperature of 120°C for 2 days. These samples were ground up 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 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.

Results and Discussion

Material composition analysis of the ancient bricks of Batujaya Candi SEG II was performed to determine the mineral content of the bricks and the major element and trace element contents. 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 was built by the local people using sources of local raw material. The mineral content contained in the ancient bricks 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 results show that the raw materials used for making the bricks was clay mixed with volcanic ash.

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 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 aluminum element was between 14.73 to 19.42%.The iron element contained dry weight percentage was between 7.55 to 10.89%. Manganese element had dry weight percentage between 0.13 to 0.25%. For the magnesium, dry weight percentage was between 0.83 to 1.54% while calcium contained dry weight percentage between 1.00 to 1.76%. The dry weight percentage for the sodium and potassium element were 0.43 to 0.72% and 0.87 to 1.22%, respectively. Phosphorus and sulphur elements contained dry weight percentage of between 0.21 to 1.14% and 0.03 to 0.07%, respectively.

The trace element contents of the brick samples of Candi SEG II showed elements such as chromium, copper, nickel, rubidium, strontium, zinc, zirconium and chlorine. The trace element contents

Table 1. Mineral composition of Batujaya SEG II location.

Sample	Mineral content	Sample	Mineral content
CLE 1	SiO_2 - Quartz	CLE 9	SiO_2 quartz
	$(Ca,Na)(Al,Si)_2Si_2O_8$ - Anorthite, sodian, ordered		$Na(AlSi_3O_8)$ Albite
	Fe_2O_3 - Hematite		$Na_{0.685}Ca_{0.347}Al_{1.46}Si_{2.54}O_8$ Andesine
	$(Na,Ca)Al(Si,Al)_3O_8$ - Albite, calcian, ordered		$(Ca,Na)(Si,Al)_4O_8$ Anorthite, sodian
	$Ca_{0.68}Na_{0.30}(Al_{1.66}Si_{2.34}O_8)$ - Labradorite		$Ca_{0.68}Na_{0.30}(Al_{1.66}Si_{2.34}O_8)$ Labradorite
	$Na_{0.622}Ca_{0.368}Al_{1.29}Si_{2.71}O_8$ - Andesine		Fe_2O_3 hematite
CLE 2	SiO_2 Quartz	CLE 10	SiO_2 Quartz
	SiO_2 Cristobalite		$CaAl_2Si_2O_8.4H_2O$ Gismondine
	$Ca_{0.68}Na_{0.30}(Al_{1.66}Si_{2.34}O_8)$ Labradorite		$Al_{4.56}Si_{1.44}O_{9.72}$ Mullite
	$Al(Al_{1.272}Si_{0.728}O_{4.864})$ Mullite		$(Na,Ca)Al(Si,Al)_3O_8$ Albite, calcian
	$CaAl_2Si_2O_8$ Anorthite		SiO_2 Cristobalite
	Fe_2O_3 Hematite		SiO_2-x-H_2O Opal
CLE 3	SiO_2 Quartz	CLE 11	SiO_2 Quartz low
	SiO_2 Cristobalite		C Graphite
	$Al_{4.59}Si_{1.41}O_{9.7}$ Mullite		$CaAl_2Si_2O_{8.4}H_2O$ Gismondine
	Fe_2O_3 hematite		SiO_2 Cristobalite
CLE 4	SiO_2 quartz		$Na_{.499}Ca_{.491}(Al_{1.488}Si_{2.506}O_8)$ Andesine
	SiO_2 cristobalite		$(Al_4SiO_8)_{1.2}$ Mullite
	$Ca_{0.68}Na_{0.30}(Al_{1.66}Si_{2.34}O_8)$ Labradorite	CLE 12	SiO_2 quartz low
	$(Na_{0.75}Ca_{0.25})(Al_{1.26}Si_{2.74}O_8)$ Albite calcian		$AlPO_4$ Berlinite
	$CaAl_2Si_2O_8$ Anorthite		$(K0_{.22}Na_{.078})(AlSi_3O_8)$ Albite high
	Fe_2O_3 hematite		$(Na_{0.75}K_{0.25})(AlSi_3O_8)$ Anorthoclase
CLE 5	SiO_2 quartz		Fe_2O_3 hematite
	SiO_2 cristobalite	CLE 13	SiO_2 Quartz
	$Al(Al_{1.27}Si_{0.728}O_{4.864})$ Mullite		$AlPO_4$ Berlinite
	SiO_2-x-H_2O Opal		$CaAl_2Si_2O_8$ Anorthite
	$(Na_{.45}Ca_{.55})(Al_{1.55}Si_{2.45}O_8)$ Anorthite		$CaAl_2Si_2O_8.H_2O$ Gismondine
	$(Na_{.5}Ca_{.5})(Al_{1.5}Si_{2.5}O_8)$ Labradorite		$(Na,Ca)Al(Si,Al)_3O_8$ Albite, calcian
CLE 6	SiO_2 quartz		$Na_{0.85}K_{0.14})(AlSi_3O_8)$ Anorthoclase
	$CaAl_2Si_2O_{8.4}H_2O$ Gismondine	CLE 14	SiO_2 Quartz
	$Na_{.499}Ca_{.491}(Al_{1.488}Si_{2.506}O_8)$ Andesine		$CaAl_2Si_2O_8.4H_2O$ Gismondine
	$(Na.Ca)Al(Si,Al)_3O_8$ Albite, calcian		$Na_{0.685}Ca_{0.347}Al_{1.46}Si_{2.54}O_8$ Andesine
	$(Mg_{3.78}Al_{4.22})((Si_{1.91}Al_{4.09})O_20)$ Sapphirine		$Ca_{.66}Na_{.34}Al_{1.66}Si_{2.34}O_8$ Labradorite
	$Al_2(Al_{2.8}Si_{1.2})O_{9.6}$ Mullite		$CaAl_2Si_2O_8$ Anorthite
CLE 7	SiO_2 quartz		$Na(AlSi_3O_8)$ Albite high
	$CaAl_2Si_2O_{8.4}H_2O$ Gismondine	CLE 15	SiO_2 Quartz low
	Fe_2O_3 hematite		$CaAl_2Si_2O_8.4H_2O$ Gismondine
	$(Na_{0.85}K_{0.14})(AlSi_3O_8)$ Anorthoclase		SiO_2-xH_2O Opal
	$AlPO_4$ Berlinite		$(Na,Ca)Al(Si,Al)_3O_8$ Albite, calcian
	$KAl_3Si_3O_{10}(OH)_2$ Muscovite		SiO_2 Crisobalite
CLE 8	SiO_2 quartz		$Cu_{0.28}Mg_2(Al_{4.5}Si_{4.5}O_{18})$ Cordierite
	$(Na.Ca)Al(Si,Al)_3O_8$ Albite, calcian		
	SiO_2 Cristobalite		
	$CaAl_2Si_2O_8$ Anorthite		
	$Al_{4.54}Si_{1.46}O_{9.73}$ Mullite		
	Fe_2O_3 hematite		

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

Formula	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_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

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

Sample	Cr_2O_3	CuO	NiO	Rb_2O	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	N.D	63 ppm	N.D	N.D	0.02%	0.01%	0.03%	0.02%
CLE 3	0.01%	71 ppm	70 ppm	39 ppm	0.02%	88 ppm	0.03%	N.D
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%	N.D
CLE 6	86 ppm	61 ppm	62 ppm	45 ppm	0.01%	0.02%	0.02%	N.D
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%	N.D	0.03%	0.01%
CLE 10	N.D	59 ppm	45 ppm	47 ppm	0.02%	N.D	0.03%	0.01%
CLE 11	0.01%	55 ppm	N.D	36 ppm	0.01%	0.01%	0.03%	0.01%
CLE 12	N.D	58 ppm	N.D	47 ppm	0.02%	0.01%	0.03%	N.D
CLE 13	N.D	60 ppm	47 ppm	54 ppm	0.02%	0.01%	0.03%	N.D
CLE 14	N.D	65 ppm	N.D	50 ppm	0.02%	0.01%.	0.02%	N.D
CLE 15	N.D	57 ppm	46 ppm	52 ppm	0.02%	0.01%	0.03%	0.01%

N.D = Not Detected

are in Table 3. Only copper, strontium, and zirconium were present in all samples. Chromium content was between 82 ppm to 0.01% while copper was between 50 to 83 ppm. Nickel content was between 38 and 70 ppm while rubidium was between 36 to 54 ppm. Strontium and zinc were between 0.01 to 0.02% and 88 ppm to 0.02%, respectively, while zirconium and chlorine between 0.02 to 0.03% and 0.01 to 0.02%, respectively.

Dry weight percentage of SiO_2 and Al_2O3 for the brick samples of Candi SEG II are shown in Fig. 1. The bricks have high silica content. Dry weight percentage of MgO and TiO_2 for the brick samples of Candi SEG II are in Fig. 2. In making bricks in Candi SEG II local materials were used.

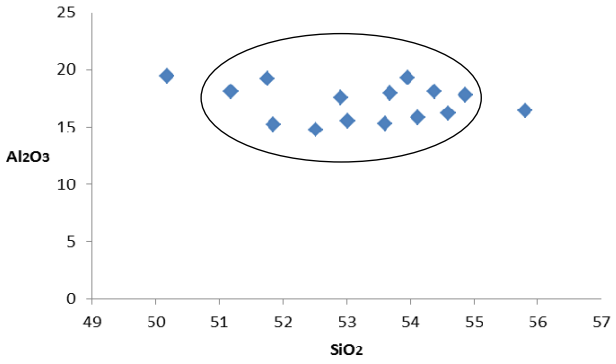

Figure 1. Dry weight percentage (%) of SiO_2 and Al_2O_3 elements for the brick samples of Candi SEG II.

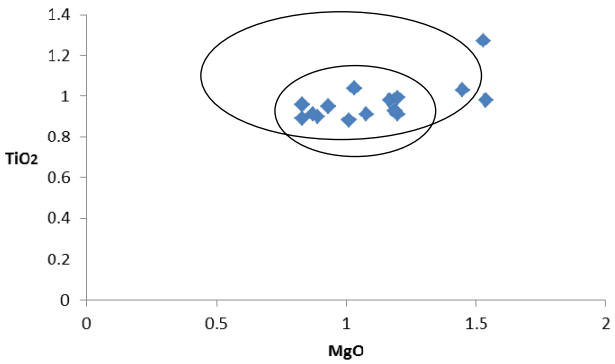

Figure 2. Dry weight percentage (%) of MgO and TiO_2 elements for the bricks samples of Candi SEG II.

Conclusions

Compositional analysis on ancient bricks from Candi SEG II shows that most of the samples analyzed included same local material. Several major minerals in the bricks suggest that the raw materials were taken from clay mixed with volcanic ash. Major and trace element contents show 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 suggest also that the local peoples were involved in the process of making the bricks for purpose of building their temples.

Acknowledgments

This research was conducted using the II/004/2012 and DPP-2014-069 grant; and therefore, we would like to express our gratitude to the Ministry of Higher Education and The National University of Malaysia (UKM) for the research grants awarded.

References

[1]Djafar, H. 2010. Kompleks Percandian Batujaya: Rekonstruksi Sejarah Kebudayaan Daerah Pantai Barat Utara Jawa Barat. Bandung. Penerbit Kiblat Buku Utama.

[2]Jurusan Arkeologi FSUI 1986. Laporan Sementara Penggalian Purbakala di Desa Segaran, Kecamatan Batujaya, Kabupaten Karawang, Propinsi Jawa Barat (Not Published)

[3]Djafar, H. 2000. Percandian di Situs Batujaya, Kerawang: Kajian Arsitektur, Kronologi dan Sistemnya. [Laporan Penelitian Hibah Bersaing VII Perguruan Tinggi Tahun Ajaran 1998/1999-1999/2000], Depok: Lembaga Penelitian Kemasyarakatan dan Budaya, Lembaga Penelitian Universitas Indonesia.

[4]Budi, U., Bambang and Manguin, P.-Y. 2004. Ringkasan Laporan Penelitian Kerjasama Ecole francaise d'Extreme-Orient & Asisten Deputi Urusan Arkeologi Nasional, Batujaya, 26 Juni-15 Juli 2004. Jakarta. Asdep Urusan Arkeologi Nasional/EFEO.

[5]Budi, U., Bambang and Manguin, P.-Y. 2004. Laporan Sementara Penelitian Kerjasama Ecole francaise d'Extreme-Orient & Asisten Deputi Urusan Arkeologi Nasional, Batujaya, 18 Juni-25 Juli 2005. Jakarta. Asdep Urusan Arkeologi Nasional/EFEO.

[6]Ramli, Z., Rahman, N.H.S.N.A., Jahi, J.M., Razman, M.R., Syed Zakaria, S.Z. and Dadian, H.S. 2014a. X-ray diffraction and X-ray fluorescence of clay and soil samples in sub district of Bujang and Merbok, Kedah. Journal of Food, Agriculture and Environment **12**(2): 1061-1065.

[7]Ramli, Z., Rahman, N.H.S.N.A., Jahi, J.M., Razman, M.R., Syed Zakaria, S.Z. and Dadian, H.S. 2014b. X-ray diffraction (XRD) and X-ray fluorescence (XRF) analysis of ancient bricks from Sungai Batu Temple (site SB1), Bujang Valley, Kedah. Journal of Food, Agriculture and Environment **12**(3-4):360-364.

[8]Ramli, Z., Rahman, N.H.S.N.A., Samian, A.L., Razman, M.R., Syed Zakaria, S.Z. and Yusof, A.R.M. 2014c. Usage of local raw material in the construction of Candi Pengkalan Bujang (Site 18), Bujang Valley, Kedah. Research Journal of Applied Sciences, Engineering and Technology **7**(9):1779-1786.

[9]Ramli, Z., Rahman, N.H.S.N.A., Jusoh, A. and Hussein, M.Z. 2012. Compositional analysis on ancient bricks from Candi Sungai Mas (Site 32/34), Bujang Valley, Kedah. Am. J. Appl. Sci. **9**:196-201.

[10]Ramli, Z., Rahman, N.H.S.N.A., Samian, A.L., Noor, S. M. and Yarmo, M.A. 2011. Scientific analysis of ancient bricks at Bukit Pendiat Temple (Site 17) and Pengkalan Bujang Temple (Site 23): A comparative study. Res. J. Appl. Sci. **6**:473-478.

[11]Ramli, Z., Rahman, N.H.S.N.A., Jusoh, A., Sauman,Y., Samian, A. L. and Yatim, O.M. 2013. Compositional analysis of ancient bricks at site 2211, Candi Pengkalan Bujang, Kedah. Research Journal of Applied Sciences, Engineering and Technology **6**(16):3027-3033.

[12]Ramli, Z. and Rahman, N.H.S.N.A. 2013. Composition analysis of ancient bricks, Candi Bukit Kechil, Bujang Valley, Kedah. Research Journal of Applied Sciences, Engineering and Technology **6**(5):924-930.

[13]Ramli, Z., Rahman, N.H.S.N.A., Samian, A. L. and Yarmo, M.A. 2013. X-ray diffraction and X-ray fluorescence of ancient bricks of Candi Bukit Pendiat (Site 17), Bujang Valley, Kedah. Research Journal of Applied Sciences, Engineering and Technology **6**(6):1094-1100.