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Research Article

Usage of Local Raw Material in the Construction of Candi Pengkalan Bujang (Site 18), Bujang Valley, Kedah

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Abstract: The aim of this study is to determine whether the ancient bricks from Candi Pengkalan Bujang (Site 18) are made from local raw material or not. Candi Pengkalan Bujang (Site 18) which is located in the cemetery area of Pengkalan Bujang Mosque, Kedah has unearthed various interesting artefacts; among them are the Sung Dynasty celadon findings and also *kala* carvings made from granite. The main construction materials used to build the temple consisted of laterite, slates, bricks and also granite. Laterite and bricks were used to build the lower part (foot) of the temple while granite stones were used as the pillar bases, door sills, stone hem and also *kala*. The upper part of the temple is believed to have been built using wooden structures and the roof used palm leaves. Natural rock resources used to build this temple were local resources based on the distribution of the rocks that are aplenty in Bujang Valley. Scientific analysis on the bricks also showed 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 analysis showed that open burning technique was used in the process of producing the bricks while the major and trace element content analysis showed the clay used was obtained from the Muda River and Bujang River basin. This usage of local raw material also demonstrated the local wisdom in temple construction technology and also technique in producing bricks that had existed since the 5th century AD.

Keywords: Bujang valley, Candi Pengkalan Bujang (site 18), local wisdom, X-ray diffraction, X-ray fluorescence

INTRODUCTION

Pengkalan Bujang Temple (Site 18) is located in the cemetery area of Pengkalan Bujang Mosque, Kedah. The areas around the fence of the mosque site was found to contain many piles of temple construction materials made from laterite, granite and bricks which were the main materials used to build the lower part or foot of this temple. The findings of the foundation of the pillar bases showed that this temple used wooden pillars. Quaritch Wales (1940) had carried out his own excavation at this site and in his report he mentioned about the findings of the local villagers of granite stones that resembled lintels and door sills.

This site is located about 40 yards from the river bank of Bujang River and the excavation carried out revealed the construction structure where the lower part of the temple was made of laterite while on top of the laterite, bricks were stacked. Several foundations of pillar bases made from granite were also found (Quaritch Wales, 1940). The lower part of the temple construction was built by stacking three layers of laterite while the next part used bricks (Fig. 1).

Fig. 1: Pengkalan Bujang temple's (site 18) construction structure (Jacq-Hergoualc'h, 1992)

The excavation carried out by Quaritch-Wales has unearthed important artefacts that can be linked to the site. Among them are the Chinese ceramics of the Age of the Song Dynasty particularly the Lungchuan

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Fig. 2: Celadon bowls from the age of the sung dynasty (Jacq-Hergoualc'h, 1992)

Fig. 3: Laterite slabs and bricks at site 18

Fig. 4: Photo of a *kala* found at site 18

Fig. 5: Sill made from granite

celadon that were produced around the 11th to the 12th century AD (Fig. 2). Also found were the Chinese-made spoons that were made of material resembling pearls. Apart from that, iron nails as well as bronze materials that are believed to be coins were also found in addition to carnelian stones in the shape of hexagonal bi-cone and crystal stone beads in the shape of spheres (Quaritch Wales, 1940).

A lot of glass fragments in brown, green and amber that are believed to originate from the Middle East were also found at this site. Two fragments of Arab oil lamp were also found. These lamp fragments were re-constructed and the result was that the shape of the lamp can be clearly seen. The glass is a mixture of green with the edge of the lamp coloured black. This Arab lamp has similarities with the findings at Site 11. Based on the architecture of the temple and the artefact findings that are associated with the site, it is believed that this site was built in the 11th or 12th century AD (Quaritch Wales, 1940). This site has important functions based on the discoveries of the construction materials that comprised of bricks, laterite, sculpture or pillar bases, a *kala*, door sills and wedges (Fig. 3 to 5).

Excavation at the Pengkalan Bujang Temple (Site 18) has revealed the construction materials that are comprised of various types of natural rocks and also bricks. The main construction material that was used to build the lower part or foot structure of the temple comprised of laterite and bricks. Other parts comprised of pillar bases, kala, door sills and wedges produced using granite. The usage of pillar bases and wooden structures for the upper part of the temple showed local characteristics in temple construction and rejected the opinion that the temples in Bujang Valley were built by traders (Jacq-Hergoualc'h, 2002; Sullivan, 1958; Wheatley, 1964).

The temple built by the traders from India was also said to have been built by bringing bricks from the areas outside of Bujang Valley. Therefore, material composition analysis of the bricks should certainly be carried out to prove that the raw material used which was clay, was local raw material. Indirectly, this can prove the involvement of the local people in the production of the bricks, in addition to having the knowledge in construction of temples. Cultural acculturation and knowledge transformation of the Malay community of Old Kedah since the 4th or 5th century AD had enabled the civilisation at Bujang Valley to develop and prosper with characteristics of Indian civilisation applied and adapted to the local culture.

The excavation carried out by Quaritch-Wales at the end of the 1930s has revealed the construction structure that was made from laterite slabs and also bricks. The lower part (foundation) of the temple structure particularly the foundation was built using laterite while the bricks were stacked on the laterite slabs to build the following temple structure (Quaritch Wales, 1940).

Other parts, for example the pillar bases, door sills, wedges and also *kala* were produced by using granite. The discovery of door sills, wedges and also the *kala* showed that this temple was one of the important temples in Pengkalan Bujang in the 11th to the 12th century AD. The temple's upper structural part was made of wood based on the findings of the pillar bases. The temple's roof was either made of tiles or palm leaves but based on the fact that there were no findings of tiled roof at the site, hence it is more likely that palm fronds were used for the roof.

The structure of the temple's upper part that used wood and palm leave roof, supported by the pillar bases showed the construction characteristics of the local people. The raw materials used in particular the laterite and granite were obtained from the surrounding areas where many of this laterite can be found at the bottom of the Bujang River while a lot of granite can be found

at the base of Jerai Mountain and traces of the granite slabs can be seen at Batu Pahat Hill.

The main objective of this research is to determine whether the bricks used for construction of the temple were made from local clay or otherwise. Bricks were the major construction material used to build Site 18 (Candi Pengkalan Bujang) 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. The 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 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 (Site 23) revealed that the raw material used 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). Analysis on Sungai Mas monochrome glass beads also reveal that local community involved in glass beads industry (Zuliskandar *et al*., 2009; Ramli *et al*., 2011).

MATERIALS AND METHODS

This study used the scientific approach in determining whether the bricks in Site 18 used local raw materials or not. A total of 18 fractions of ancient bricks were taken from the site of Pengkalan Bujang (Site 18) 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 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 Fluorescence Technique and the X-ray Diffraction Technique. The X-ray Fluorescence Technique was used to determine the major element content while the X-ray Diffraction Technique was used to determine the mineral content in the brick samples. The data obtained were later compared with the data analysis of the clay around Bujang Valley that was carried out previously.

RESULTS AND DISCUSSION

Material composition analysis of the ancient bricks of Pengkalan Bujang Temple (Site 18) 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 temples at Bujang Valley were built by the local people using sources of local raw material.

Table 1: The mineral content of the ancient bricks of Pengkalan Bujang temple (site 18)

Location	Sample	Mineral content
Pengkalan Bujang (site 18)	TM 1	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
		$KAlSi_3O_8$ microcline
	TM 2	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	TM 3	SiO_2 quartz
		$KAlSi_3O_8$ microcline
	TM 4	SiO_2 quartz
		$KAlSi_3O_8$ microcline
	TM 5	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$Mg_2Al_3(Si_3Al)O1_0(O)_8$ chlorite
	TM 6	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$Al_2Si_2O_5(OH)_4$ kaolinite 1Md
	TM 7	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
	TM 8	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$Mg_2Al_3(Si_3Al)O1_0(O)_8$ chlorite
	TM 9	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
		$KAlSi_3O_8$ microcline
	TM 10	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
		$KAlSi_3O_8$ microcline
	TM 11	SiO_2 quartz
		$KAlSi_3O_8$ microcline
	TM 12	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 1M
		$KAlSi_3O_8$ microcline
	TM 13	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$KAlSi_3O_8$ microcline
	TM 14	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$KAlSi_3O_8$ microcline
	TM 15	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$KAlSi_3O_8$ microcline
	TM 16	SiO_2 quartz
		$K_2O.Al_2O_{3\text{-}6}SiO_2$ microline
	TM 17	SiO_2 quartz
		$KAlSi_3O_8$ microcline
	TM 18	SiO_2 quartz
		$KAl_2Si_3AlO_{10}(OH)_2$ muscovite 2M1
		$KAlSi_3O_8$ microcline

The mineral content contained in the ancient brick samples of Pengkalan Bujang Temple (Site 18) showed the presence of minerals such as quartz, muscovite, microcline, kaolinite and chlorite (Table 1). Kaolinite mineral that was present in the TM (ii) and TM (iv) samples showed that there are samples that were baked at temperatures less that 550°C. This is because of the way the bricks were arranged when carrying out the baking of the bricks where there were bricks that did not have direct contact with the temperature. Clearly, open firing technique was used to produce the bricks at this site, similar to the technique used at other sites. The mineral content of chlorite was present in the TM (viii) and TM (v) samples and this type of mineral is in the clay of Bujang River basin. The pattern of X-ray diffraction can be referred to in Fig. 6 and 7.

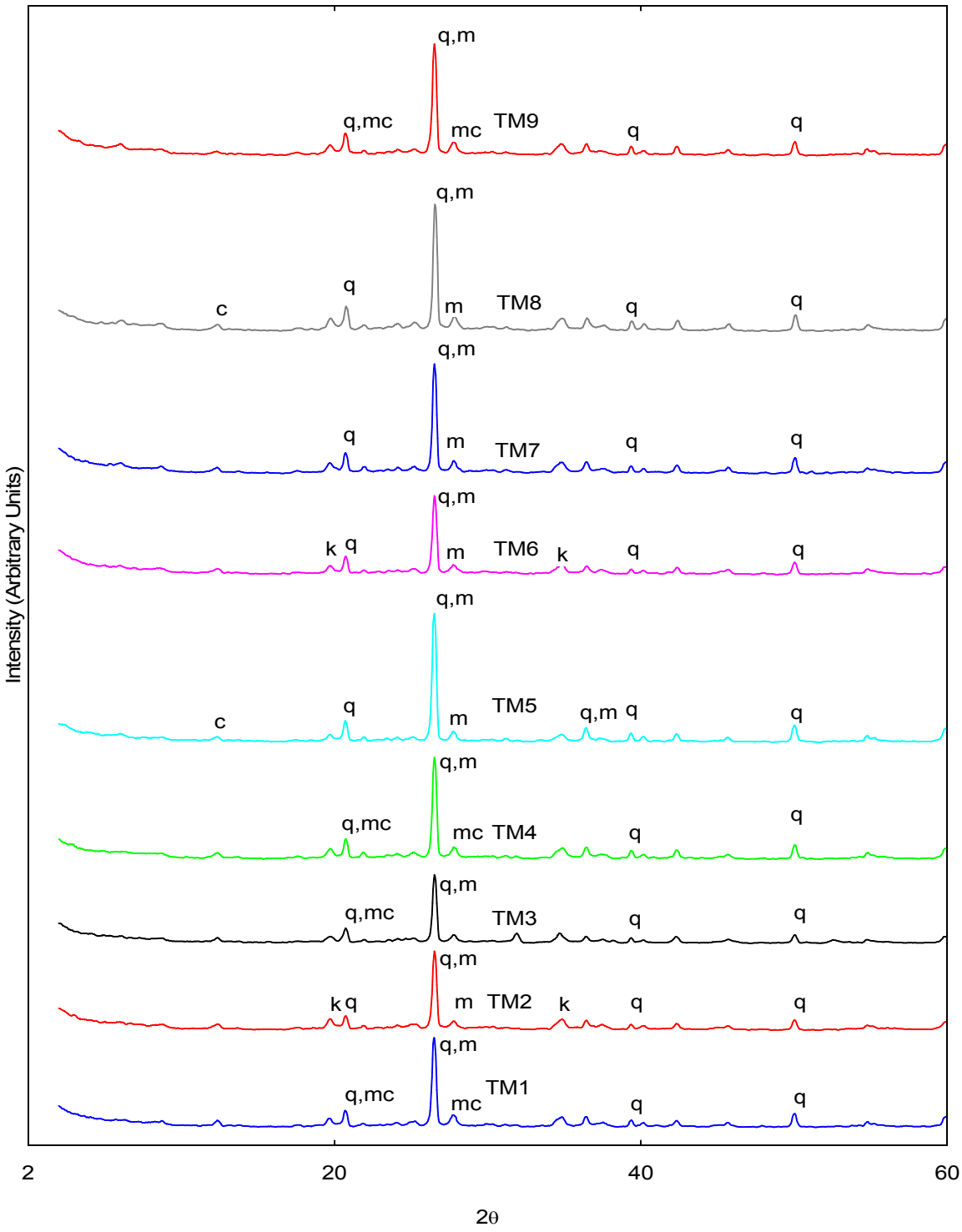

Fig. 6: XRD diffraction pattern of bricks from Pengkalan Bujang temple (site 18)
q: Quartz; m: Muscovite; mc: Microcline

Major element content in the ancient brick samples of Pengkalan Bujang (Site 18) can be referred to in detail in Table 2. The analysis showed that the brick samples contained dry weigh percentage of silica element of between 60.12 to 79.82%. Percentage of dry weight for the titanium element was between 0.53 to 0.77%. The iron element contained dry weigh percentage of between 3.06 to 4.59%. Dry weigh percentage for aluminium element was between 12.52 to 25.30%. Manganese element had dry weight

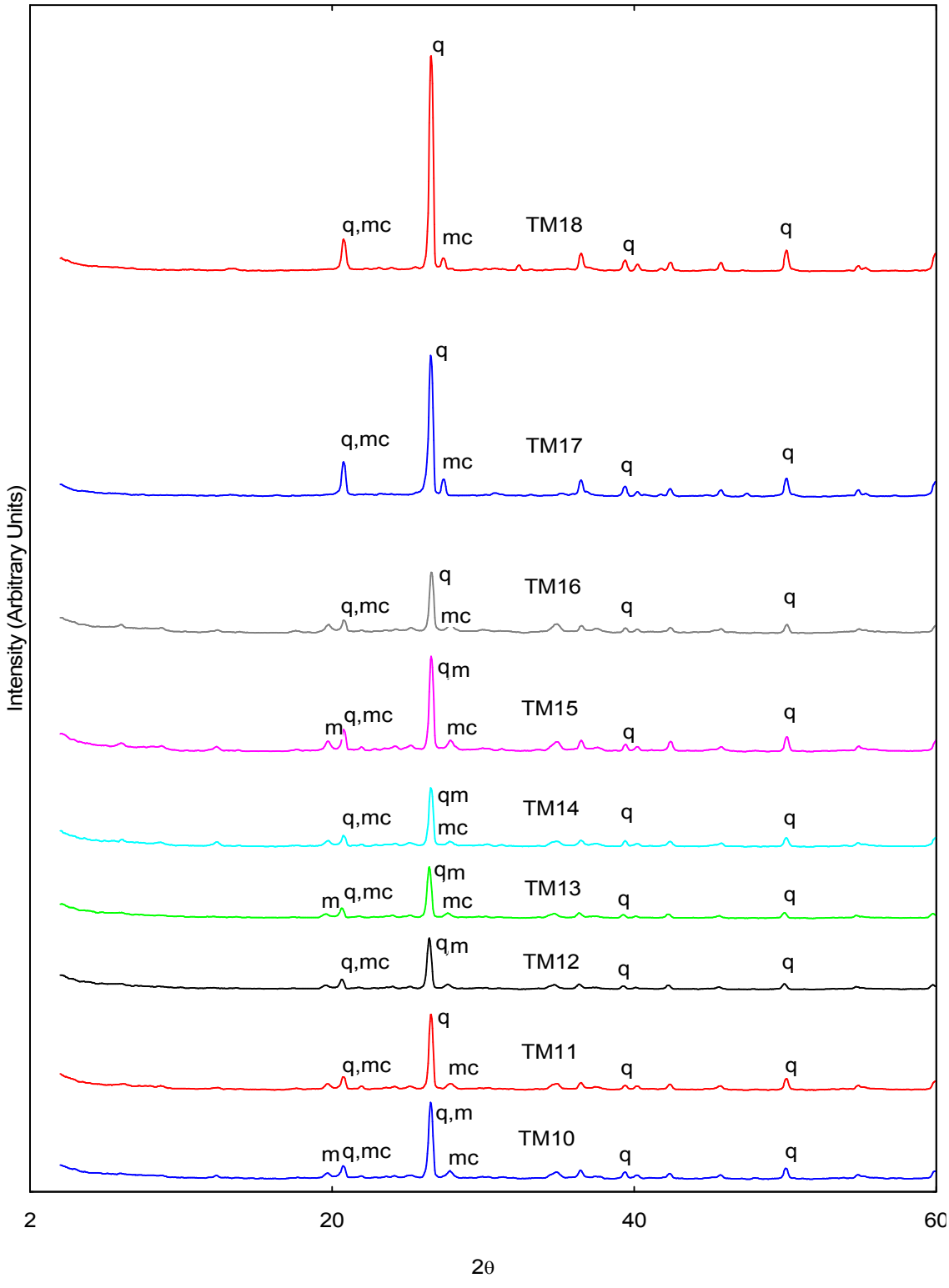

Fig. 7: XRD diffraction pattern of bricks from Pengkalan Bujang temple (site 18)
q: Quartz; m: Muscovite; mc: Microcline

percentage of between 0.02 to 0.08% while calcium element contained dry weight percentage of between 0.05 to 1.13%. The dry weight percentage for the magnesium and sodium element was between 0.31 to 1.30% and 0.01 to 0.04%, respectively. Potassium and phosphorus elements contained dry weight percentage

Table 2: Major element content of ancient bricks of Pengkalan Bujang temple (site 18)

	Dry weight (%)									
Sample	Si	Ti	Fe	Al	Mn	Ca	Mg	Na	K	P_2O_3
TM 1	75.47	0.69	3.99	15.65	0.05	0.32	1.00	0.04	2.62	0.05
TM 2	79.82	0.57	3.07	12.52	0.05	0.24	1.07	0.03	2.01	0.03
TM 3	78.87	0.53	3.23	12.97	0.08	0.43	0.85	0.04	2.46	0.06
TM 4	78.76	0.62	3.06	14.23	0.04	0.21	0.60	0.02	1.99	0.04
TM 5	76.86	0.66	4.03	15.18	0.04	0.27	0.80	0.03	2.12	0.05
TM 6	78.56	0.77	3.59	14.98	0.06	0.05	0.07	0.03	1.85	0.07
TM 7	60.12	0.62	3.76	25.30	0.05	0.35	0.79	0.03	2.86	0.06
TM 8	79.48	0.55	3.07	13.51	0.04	0.25	0.60	0.03	2.31	0.08
TM 9	76.51	0.73	4.06	14.76	0.05	0.26	1.16	0.04	2.16	0.04
TM 10	78.37	0.56	3.17	13.82	0.04	0.35	0.82	0.03	2.61	0.06
TM 11	78.16	0.56	3.12	13.83	0.03	0.22	0.93	0.03	2.48	0.05
TM 12	75.68	0.64	3.97	15.24	0.05	0.29	1.30	0.04	2.43	0.03
TM 13	77.67	0.53	3.20	14.30	0.03	0.15	1.03	0.03	2.65	0.03
TM 14	77.66	0.57	3.60	14.30	0.08	0.39	0.95	0.03	2.34	0.04
TM 15	76.32	0.69	4.40	15.62	0.02	0.31	0.94	0.01	1.58	0.06
TM 16	76.49	0.65	3.73	15.26	0.06	1.10	0.31	0.02	1.79	0.04
TM 17	77.30	0.53	3.69	14.01	0.06	1.13	0.31	0.03	2.48	0.03

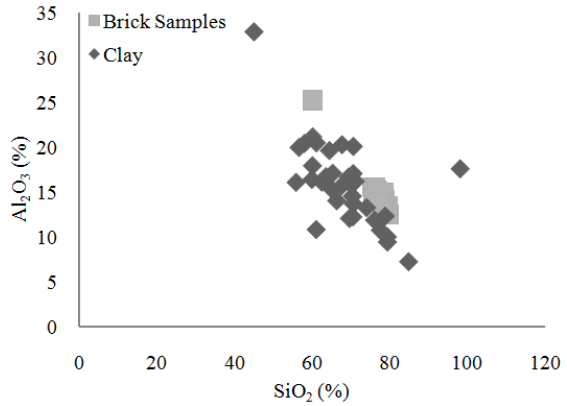

Fig. 8: Dry weight percentage (%) of SiO_2 and Al_2O_3 elements for the brick samples of Pengkalan Bujang temple (site 18) and clay of Bujang valley

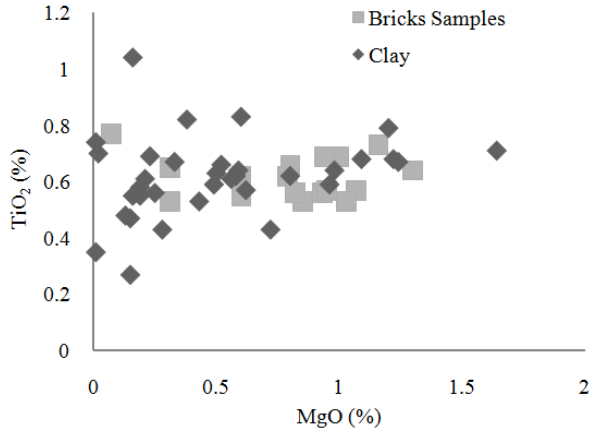

Fig. 9: Dry weight percentage (%) of MgO and TiO_2 elements for the bricks samples of Pengkalan Bujang temple (site 18) and clay of Bujang valley

of between 1.58 to 2.86% and 0.03 to 0.07%, respectively.

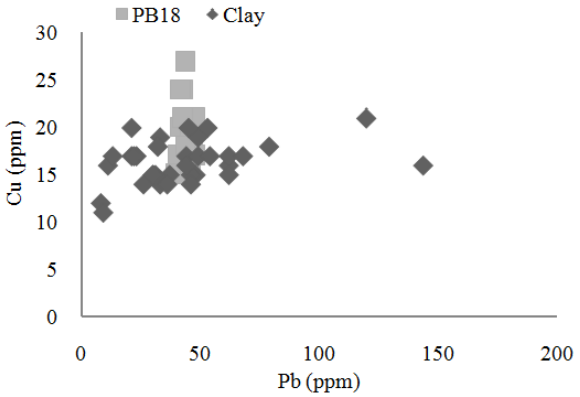

Fig. 10: Graph of lead and copper element concentration in the brick samples of Pengkalan Bujang temple (site 18) and clay of Bujang valley

The silica and aluminium content showed that the bricks have high silica content compared to clay. The dry weight percentage graph for the elements of SiO_2 and Al_2O_3 (Fig. 8) as well as the dry weight percentage graph of MgO and TiO_2 elements (Fig. 9) for the brick samples of Pengkalan Bujang Temple (Site 18) and clay of Bujang Valley were plotted to see the result of the comparison between the brick and clay samples based on their major elements. Based on the graphs, it was found that the major element composition of the bricks samples of Site 18 was found to be the same as the major composition of clay in Bujang Valley. Figure 9 also shows that most of the raw material used to produce the bricks at this site was obtained in the areas around the Muda River basin.

The trace element content of the brick samples of Pengkalan Bujang Temple (Site 18) (Table 3 and 4) showed content beyond 100 ppm for the elements such as barium, cerium, rubidium and zircon. Other elements were at the lower concentration level that is less than 100 ppm. Barium element content was between 725 to

Table 3: Trace element content of ancient bricks from Pengkalan Bujang temple (site 18)

Elements	Sample								
(ppm)	TM 1	TM 2	TM 3	TM 4	TM 5	TM 6	TM 7	TM 8	TM 9
As	17	13	18	15	17	18	18	16	15
Ba	725	733	802	760	747	766	738	772	725
Ce	552	588	550	516	581	554	574	549	545
Co	13	19	17	22	14	15	15	14	18
Cr	77	62	63	65	77	68	68	59	84
Cu	17	20	19	17	17	19	21	17	16
Ga	20	15	15	18	17	17	36	15	22
Hf	7	7	7	7	7	7	7	7	7
La	28	29	29	29	29	29	28	29	29
Nb	27	31	29	29	29	29	30	30	26
Ni	27	29	29	28	32	28	32	28	29
Pb	45	42	47	45	46	46	48	48	41
Rb	204	147	190	160	153	189	283	173	180
Sr	54	41	56	62	41	50	30	41	54
U	9	9	9	9	9	9	10	9	9
Th	26	17	19	22	24	20	27	19	30
V	93	79	78	87	91	83	90	80	97
Y	34	18	28	20	26	28	46	26	35
Zn	71	99	82	65	86	69	69	80	78
Zr	246	220	187	225	256	182	256	207	253

Table 4: Trace element content of ancient bricks from Pengkalan Bujang temple (site 18)

Elements	Sample								
(ppm)	TM 10	TM 11	TM 12	TM 13	TM 14	TM 15	TM 16	TM 17	TM 18
As	16	13	13	14	16	15	15	14	15
Ba	773	727	767	763	849	806	764	731	756
Ce	563	500	537	551	584	560	543	558	576
Co	14	15	17	15	14	14	14	17	18
Cr	63	64	76	62	68	86	84	74	63
Cu	17	17	15	18	16	21	27	24	24
Ga	15	17	19	16	14	19	19	19	16
Hf	7	7	7	7	7	7	7	7	7
La	29	28	29	29	30	29	28	29	29
Nb	30	30	30	32	31	31	30	31	28
Ni	28	27	29	28	30	30	30	33	28
Pb	46	41	40	44	46	43	44	43	42
Rb	194	194	175	191	177	136	134	140	168
Sr	48	48	49	42	46	36	34	39	45
U	9	9	9	9	9	9	9	9	9
Th	18	21	25	16	16	23	25	25	21
V	79	81	88	77	80	99	98	89	78
Y	30	27	24	22	25	16	15	15	23
Zn	67	74	78	72	70	84	84	106	74
Zr	225	193	242	169	210	221	216	200	215

849 ppm while the cerium element was between 516 to 588 ppm. Rubidium element content was between 134 to 283 ppm while zircon element had concentration of between 169 to 256 ppm.

Figure 10 is the graph plotted to see the distribution of copper element versus lead for the brick samples of Site 18 where the concentration of both the elements was between 15 to 17 ppm and 41 to 48 ppm, respectively. The result showed that copper and lead element composition at this site is almost similar to the clay composition at Bujang Valley, Kedah.

CONCLUSION

Based on the survey at the site, it clearly shows that the main construction material at the Pengkalan Bujang Temple (Site 18) site used construction materials from natural rocks such as laterite, granite and also bricks. Laterite and bricks were used to build the lower part or foot of the temple and also its foundation while granite was used to produce the pillar bases, door sills and *kala*. Material composition analysis of the bricks showed that the method used to bake the bricks was the open burning technique while the major element and trace element analysis showed that the raw material used to produce the bricks at this site was obtained from the basin of Muda River and Bujang River.

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REFERENCES

Jacq-Hergoualc'h, M., 2002. The Malay Peninsula: Crossroads of the Maritime Silk Road (100BC-1300AD). Translation by Victoria Hobson Koninklijke Brill N.V., Leiden.

Quaritch Wales, H.G., 1940. Archaeological research on ancient Indian colonization in Malaya. J. Malayan Branch Roy. Asiatic Soc., 18(1): 1-85.

Ramli, Z., N.H.S.N. Abdul Rahman and A.L. Samian, 2011. X-ray fluorescent analysis on Indo-Pacific glass beads from Sungai Mas archaeological sites, Kedah, Malaysia. J. Radioanal. Nucl. Ch., 287: 741-747.

Ramli, Z., N.H.S.N.A. Rahman, A. Jusoh and M.Z. Hussein, 2012. Compositional analysis on ancient bricks from *Candi Sungai Mas* (Site 32/34), Bujang Valley, Kedah. Am. J. Appl. Sci., 9: 196-201, Doi: 10.3844/ajassp.2012.196.201.

Sullivan, M., 1958. Excavations in kedah and province wellesley. J. Malays. Branch Roy. Asiatic Soc., 31(1): 188-219.

Wheatley, P., 1964. The Golden Khersonese. University of Malaya Press, Kuala Lumpur.

Zuliskandar, R., H.S. Nik and A.R. Nik, 2009. Beads trade in Peninsula Malaysia: Based on archaeological evidences. Eur. J. Soc. Sci., 10(4): 585-593.

Zuliskandar, R., H.S. Nik, A.R. Nik, L.S. Abdul, M.N. Suhaini and A.M. Mohd, 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, Doi: 10.3923/rjasci.2011.473.478.