III.20
Conservation of an Amun Temple in the Sudan

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Abstract Excavation of a 2000-year old Amun temple at Dangeil began in 2000 under the directorship of Drs Salah Mohamed Ahmed and Julie R. Anderson of the National Corporation for Antiquities and Museums (NCAM), Sudan and the British Museum, UK, respectively. Dangeil is located south of the 5th Nile cataract in Sudan. In 2007, it was decided to assess and explore the options available for long term site preservation. In 2008, a preliminary visit was organised to initiate a number of trials on various aspects of the architectural fabric of the site. The materials used in the temple’s construction include mud brick, fired brick, lime plaster and sandstone. During the 2009 field season, the previous year’s tests were evaluated and other areas of the site were selected for further trials.

1 The Dangeil Amun Temple – Goals and Objectives

Dangeil is situated in northern Sudan on the right bank of the Nile, roughly 350 km north of Khartoum. The site consists of several mounds covered with fragments of red brick, sandstone, ceramics, plaster, etc. Excavations have focused on the central part of the site where a large, well-preserved Amun temple has been discovered. Much of the ancient built environment at Dangeil has survived and as such the site represents an important and unique part of Sudan’s cultural heritage. The mission’s major goals are to preserve, conserve and protect the site for the future using affordable locally-sourced materials and a trained local labour force, to promote understanding of the site’s cultural significance, and ultimately to make the temple accessible to visitors. To assist in achieving these goals, a capacity building programme has been initiated wherein personnel from NCAM, students from the University of Khartoum and local Dangeil personnel are trained in excavation and conservation techniques and materials.
2 Temple Description

The temple (48.5 x 33.5 m) is orientated east-west, in the desert on the edge of the cultivation, with the entrance facing the Nile. Most walls are a metre wide and preserved to a standing height between 1.5 and 3 metres. The basic unit of measurement used in construction was the Egyptian cubit (c. 52.3 cm) and it is evident that the structure was laid out precisely. The measurements reveal clear harmonic proportions, symmetry and regular architectural planning principles.

A mixture of materials including sandstone (quartz arenite), fired red brick and sundried mud brick were used in the temple’s construction. Most walls have red brick foundations with the upper parts consisting of a mud brick core, faced on the exterior with red bricks. Column drums in the courts were created from red brick quarter circles or thirds sandwiched together with mud mortar. The floor surfaces, sanctuary columns and wall facings are of sandstone. Fine chisel marks on the external surfaces of the sandstone indicate that many blocks had been prepared for a finishing layer of painted lime plaster. The wall surfaces had been covered with a white-washed mud plaster which was painted yellow, red, robins’ egg blue or some combination thereof. The pigments used have been identified by Raman spectroscopy with the red and yellow being hematite and a highly crystalline goethite respectively and the blue, a calcium copper silicate (CaCuSi₄O₁₀) commonly known as Egyptian blue.

The temple was destroyed by fire and Accelerator Mass Spectrometry (AMS) and C14 dating of the charred roof beams have placed construction of the most recent incarnation of the temple in the 1st century AD. This date is further confirmed by the associated ceramics and inscriptions. Following its destruction, the temple gradually decayed and collapsed.

3 Conservation of the Archaeology

3.1 Establishing Principles and Assessing Options

An initial working visit to Dangeil was conducted in November 2008 (Fig. 1).

In discussion with the site directors, the conservation principles and goals for the site were established. The decay mechanisms affecting the architectural elements of the site were identified as: the inherent fragility of the building materials; the extreme temperatures; the short seasonal period of heavy rainfall and the physical damage due to human activity.

This first visit in 2008 was intended to establish the locations and extent of the trials, the materials to be used and to discuss the aesthetic appearance of the finished work. It was agreed that: the main aim of the project was to preserve the
site’s long term future; any materials used in the site’s conservation or maintenance must not confuse the ancient archaeology; all materials used must be sympathetic to the original structures and be sourced locally; and that the conservation work would be continued and executed by a local work force in the future, after appropriate training. It was also important that any work could be removed easily without compromising the archaeology and essential to find a solution to prevent the continuing cycle of loss of original material due to environmental factors and human footfall impact. The materials to be conserved were the brick, stone and lime plaster elements of the temple.

Fig. 1 Aerial view of Dangeil

A capping system of a sacrificial lime mortar, combined with local building materials was proposed as protection against the various decay mechanisms. This practice has been used successfully by English Heritage on exposed architectural ruins in England and by conservators on archaeological sites in Europe; this was considered to be an appropriate system for this site. An alternative approach of soft capping using earth and shallow-rooted plants was considered, but dismissed because neither the climatic conditions nor the indigenous plants suit this method of protection.

3.2 Conservation

The initial days were devoted to sourcing suitable materials for the conservation project. Sand and bricks posed no problem. There is a plethora of sand in Sudan and an abundance of fired bricks. The lime, however, caused some issues due to the confusion in product labelling, local Arabic names and to its wide variety of local uses. It was only after several explanations and purchases, including the acquisition of casting plaster, that these issues were clarified. As the work proceeded, the working characteristics of the lime mortar mixes indicated that the lime varied in quality.
Test samples were prepared to determine the most appropriate mix of sand and lime for the mortar. Finally, a mix of 3:1 (sand:lime) was decided on. These proportions appeared to be sympathetic in colour and hardness to the historic material. A sharp sand was used in the preparation of the bedding mortars and scratch coats while a fine sand was used for the finish coats and pointing.

3.2.1 Test Areas 2008

The areas selected covered a range of the site’s architectural elements; an area of the missing sandstone floor; the lime-plastered sandstone walls; the capping and rendering of the exposed fired brick walls and the plaster-rendered brick columns (Fig. 2).

![Fig. 2 Plan of the temple](image)

With a small team of workmen to train, a missing section of sandstone floor was the first area selected. The intention was to fill the missing area with fired bricks. Sand and soil were removed and the area levelled to allow for a bedding mix and a brick depth to be laid. The area was well-damped and the bricks soaked to avoid rapid drying of the bedding mortar. It was imperative to plan the activities of the day. When possible, work was carried out in shady areas and in the coolness of the early morning. It was important to avoid working in areas directly under the midday sun and it was essential to keep the lime mortar work covered with tarpaulins. This allowed the mortar to cure slowly and in a controlled way. Retaining the moisture in the bricks and mortar assisted the pointing (Figs. 3, 4). Other trial areas followed a similar practice and approach; bedding with combinations of lime mortars; raking out and removal of excess soil; pointing. For the wall capping and brick column, a render was applied to cover the top of the new bricks (Figs. 5, 6).
3.3 Evaluation of Test Areas 2008 and Further Test Areas 2009

In November 2009, a two-week visit allowed for the evaluation of the previous year’s work, to continue the trial areas and to adjust, if necessary, the methods and treatments. Regrettably, there had been some failure of the previous year’s trial areas. The lime renders to the brick wall capping and the brick column had been washed away by seasonal rains (Figs. 7, 8).

The two areas of brick infill to the temple floor were successful and had withstood the rain of the previous season. Perplexed by the failure of the lime mortar, a sample from each of the various limes purchased in 2009 was retained to be analysed on return to the British Museum. It was hoped these analyses would give an indication of the lime content in the mortars being used. As in the preceding season, purchasing lime appeared to be a lottery, when one bag transpired to be a casting plaster. Three further areas were chosen to continue the work of the previous season; a larger, missing area of the temple’s sandstone floor; a staircase; and another area of wall capping (Figs. 9-12).

Fig. 3 Laying bricks in a missing area of floor
Fig. 4 Pointing the bedded bricks
Fig. 5 Applying lime render to brick capping
Fig. 6 Finished lime render on column
The same methods were used as in 2008. Whilst it was felt that the workmen required more training in building with and using lime, it was not the key reason for failure. The foremost reason was the weakness and absence of lime in the mortars as shown by the scientific analyses of the mortars (see below). The work completed in the season of 2009 will be re-evaluated in 2010.
4 Scientific Analyses

On return to the British Museum the samples of mortars prepared in Dangeil were analysed. The recipes were not specified and the samples were identified by number only. A sample of the archaeological lime plaster was also analysed. The samples were imaged using a Centaurus backscattered electron detector in an Hitachi S-3700N variable pressure scanning electron microscopy (VP-SEM: 20 kV, 30 Pa). Energy dispersive X-ray (EDX) microanalysis was conducted on all the uncoated cross-sections to analyse and map their elemental compositions. The analyses revealed that the lime content, as indicated by the calcium (Ca) peak, was negligible in the two mortar samples prepared in Sudan (samples II & IV, Figs. 13, 14).

In contrast, EDX analysis of sample VI indicated a level of calcium (in the form of calcium carbonate) typical of a good lime mortar (Fig. 15).

![Fig. 13 Elemental composition of sample II prepared at Dangeil](image)

![Fig. 14 Elemental composition of sample IV prepared at Dangeil](image)

![Fig. 15 Elemental composition of sample VI prepared at Dangeil](image)
This can be compared with mortars prepared at the British Museum using the same recipes as in Sudan, but replacing the Sudanese lime with an hydraulic lime (Fig. 16, British Museum sample X) or a lime putty (Fig. 17, British Museum sample IX). These spectra show comparable levels of calcium to Sudanese mortar sample VI shown in Fig. 15.

5 Conclusion

The trials carried out are actual illustrations of what can be achieved with the restricted resources available at this remote site in Sudan. The following seasons will help the team understand what is practical to accomplish in this environment, and where there is failure, what adaptations are necessary. All the materials used in this project are readily reversible and will cause no future problems to the architectural elements. These trials have helped the site directors visualise the conservation possibilities and what alterations might be essential in future. Generally, the work carried out was successful; the local workmen had the manual dexterity to use the materials and were quick to learn their application. Scientific analyses have shown that the purchase of good quality lime is essential for the success of the capping. A great deal has been accomplished within the programme and with the limited choice of resources. If there has been one criticism of the project, it is that the aesthetics of the modern work might be confused with some
of the original archaeology. This is a debate for NCAM and the site directors. There are options for alterations of the methods and materials which will not compromise the conservation of the archaeology.