The Archaeological Site of Konar Sandal, Jiroft, Iran: Conservation of Earthen Architecture

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Abstract: *New discoveries from five seasons of excavations at the archaeological site of Konar Sandal in southeastern Iran (2003–7) have revealed evidence of a civilization dating to the third millennium* B.C.E.*, one of the oldest civilizations in the East. The principal deterioration mechanisms on the site are rapid erosion of the earthen remains after excavation, extensive washout from heavy rains, creation of deep ridges and waterways, and soluble salt efflorescences. Based on the results gained from scientific studies, we recommend that the earthen structures be preserved by coating the exposed surfaces with earthen materials to protect against rainwater washout and to decrease the moisture evaporation rate. Creating suitable drainage systems and sloping would also help decrease erosion and deterioration.*

Résumé : *À la suite de cinq saisons de fouilles sur le site archéologique de Konar Sandal dans le sud-est de l'Iran (2003–2007), des témoignages d'une des plus anciennes civilisations de l'Orient au III*e *millénaire avant notre ère ont été mis au jour. Les principaux mécanismes de détérioration qui affectent le site sont l'érosion rapide des vestiges en terre après les fouilles, le ravinement après les fortes pluies, la création de gorges profondes et de cours d'eau, et des efflorescences de sels solubles. Sur la base des résultats des études scientifiques, nous recommandons de préserver les structures en terre en appliquant un revêtement en terre sur les surfaces exposées pour les protéger contre les effets de la pluie et diminuer le taux d'évaporation et d'humidité. L'aménagement d'un système de drainage adapté en créant des pentes permettrait aussi de ralentir l'érosion et la détérioration.*

The Jiroft plain is situated south of the province of Kerman in southeastern Iran. It is located in a flat, low-lying region that is surrounded on the north, west, and east by relatively high elevations. The plain slopes down from north to south. It has a 60 kilometer north-south length and a 10 to 15 kilometer east-west breadth. The Konar Sandal region lies 30 kilometers outside and to the south of the city of Jiroft on the banks of the Halil Rood River. The majority of the region's orchards, farms, and villages are located in this area, which is agriculturally rich and fertile from the extensive layers of alluvial topsoil left behind from repeated overflowing of the river.

The artifacts recovered from Konar Sandal's northern and southern archaeological sites belong to an ancient civilization dating to the third millennium B.C.E. (fig. 1). Five seasons of excavations at the two sites have produced a wealth of archaeological finds, as well as remnants of adobe architecture that include two huge structures and both residential and industrial (metalwork) units.

The conservation of ancient architecture is of utmost importance. Immediately after the start of the project in 2002, we approached and later collaborated with the Research Center for the Conservation of Cultural Relics to conduct preliminary studies on the composition and physical/mechanical characteristics of the adobe structures. In addition, we asked them to determine the type and extent of damage and the best methods to conserve and restore the buildings.

Decay and Damage

Some of the damage to the structures may have occurred in the interim period between the two seasons of excavations and even during excavation when the walls were not adequately protected. Factors contributing to the rapid erosion of exposed adobe walls are the local soil's extraordinary ability to absorb

FIGURE 1 Northern main hill of Konar Sandal. Photo: Nader Soleimani, Archaeological Research Base, Halil Rood region

FIGURE 2 Rapid erosion of exposed adobe. Photo: Manijeh Hadian, RCCCR

FIGURE 3 The use of adobe plaster on jute textile. Photo: Manijeh Hadian, RCCCR

water (hygroscopicity), extensive water runoff that has caused soil erosion and the formation of deep furrows and water conduits, and the efflorescence and dissolution of soluble salts on and just below the wall surfaces (fig. 2).

Previous Conservation Methods

In the first and second seasons of excavation, archaeologists experimented with various methods to protect the architecture found in multiple layers. These methods included covering the walls with adobe plaster on jute textile (fig. 3), constructing new brick walls covered with adobe plaster to protect the original fabric, and applying temporary plastic sheathing over the exposed areas (figs. 4, 5). Each of these methods suffered certain shortcomings and disadvantages that made them incapable of fully preventing damage to the structures. A critical problem was insufficient adhesion between the new and old materials, a lack of adequate protective covering, and high moisture permeability in the old walls.

Studies and Results

Geology and Climate of the Region

Geological studies indicate that the Jiroft plain consists of clay and newly formed streams on river plains. The clay layers have caused the formation of aquifers in the region. Based on the climate tables, Jiroft is classified as hot and semiarid. Though the

FIGURE 4 The raising of brick walls covered with adobe plaster as a means of protecting the main walls. Photo: Manijeh Hadian, RCCCR

average annual temperature is 25°C, there are wide differences between summer and winter temperatures. The area is characterized as having high humidity and frequent morning fog, and the average annual evaporation rate is 2,468.9 millimeters.

Analysis of Soil and Water

Chemical tests of the region's ground and surface water revealed high levels of chlorine, sulfate, sodium, and magnesium (table 1). Mineralogical studies of the soil indicated the presence of quartz, albite, and muscovite. Montmorillonite and illite were found in the mud bricks from the northern and southern hills of Konar Sandal (table 2). Chemical tests of these samples showed lesser amounts of calcium and higher amounts of sodium, chlorine, and sulfur, as compared with the soil of western Iran (tables 3, 4). The region's soil may be classified into two categories: clay-sand and clay.

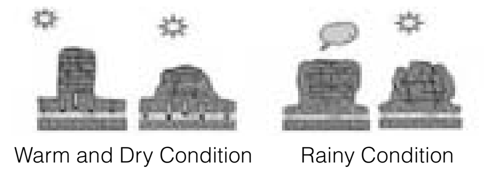

FIGURE 5 Schematic form of the decay process of mud bricks. Photo and drawing: Manijeh Hadian, RCCCR

Table 2 Mineralogical studies of Konar Sandal mud bricks

Sample	Mineral
Konar Sandal north mud brick	Quartz, albite, calcite, montmorillonite, chlorite, muscovite, gypsum
Konar Sandal north mud brick	Quartz, albite, calcite, montmorillonite, chlorite, muscovite, gypsum

Table 1 Chemical analysis of the ground and surface waters of the Konar Sandal region. Samples were taken from a local well and at different locations along the Halil Rood River.

Row	Water Source	pH	Cation and Anion Concentration (mEv/lit)							
			K^+	Na^+	Mg^{+2}	Ca^{+2}	SO_4^{-2}	Cl^-	HCO_3	CO_3^{-2}
1	Well	7.3	—	28	12.8	4.8	25	13.6	6.6	—
2	River (Halil)	7.9	—	5.4	2.3	2.6	5.2	2.4	2.4	—
3	River (Halil)	7.9	—	3	1.5	2.3	2.8	1.2	2.7	—
4	River (Halil)	8	—	4.2	1.0	2.3	3.0	1.5	3.1	—
5	River (Halil)	7.8	—	25.8	3.6	8.8	22.8	11	4.1	—
6	River (Halil)	7.8	—	26.5	4.8	8/0	24	11	3.8	—
7	River (Halil)	8	—	4.8	1.4	2.2	2.5	2.4	3.7	—

Table 3 Chemical analysis of Konar Sandal mud bricks

Sample	% SiO_2	% Fe_2O_3	% Al_2O_3	% CaO	% MgO	% K_2O	% Na_2O	ppm S	ppm Cl
Konar Sandal north mud brick	49.20	6.19	9.54	10.96	4.42	2.89	2.04	5291	4989
Konar Sandal north mud brick	48.27	7.29	11.15	12.27	4.58	1.75	1.43	4461	426

Table 4 Chemical analysis of Chogha Zanbil mud bricks in western Iran

Sample	% SiO_2	% Fe_2O_3	% Al_2O_3	% CaO	% MgO	% SO_3
Chogha Zanbil mud brick 1	35.79	2.6	9.83	22.75	2.97	5.12
Chogha Zanbil mud brick 2	25.47	3.77	6.123	22.59	3.43	9.07

Decay Process

Our studies indicate that the erosion of adobe structures is partially attributed to montmorillonite minerals and chlorine and sodium sulfate salts in the soil. These expandable clays and soluble salts accelerate disintegration of the adobe, especially at the wall tops and bases, which are exposed to rain and high groundwater levels respectively. In dry weather a high degree of surface evaporation transports soluble salts through the earthen wall, leaving efflorescences on and just below the adobe surface.

Conservation Strategy

The following measures are recommended to minimize erosion and protect the earthen structures:

- Insulate the structures against moisture and temperature fluctuations and reduce surface evaporation by protecting the exposed surfaces with materials such as geotextiles, soil, mud brick, and adobe plaster.
- Regrade the site to eliminate standing water and divert surface water runoff.
- Reduce groundwater levels by drilling wells in the vicinity of the site (this method requires detailed geological studies).

Conservation Operation

A work area was set up on-site to make mud bricks. Prior to mass production, bricks made from locally available soil were assessed for suitability, and the most important factors were determined to be cohesion, wet and dry strength, water permeability, and shrinkage. Their dimensions were half the size of the original bricks, nominally measuring 10 × 20 × 40 centimeters. The smaller size and composition of the replacement bricks was chosen for the following reasons: (1) physical compatibility between the original and the restored sections; (2) sufficient thickness of the new adobe to protect the originals from erosion; (3) increased pace of bricklaying; and (4) distinction between the original and replacement building materials.

Conservation work on the six archaeological trenches of Konar Sandal proceeded in the following stages:

1. Leveling and sloping of the ground and diversion of surface water away from the site.
2. Creation of protective layers for the floors and walls.
3. Covering of all surfaces with adobe plaster (*kah gel*).

These activities were carried out by teams that completed all stages of the work, including acquiring the materials, transporting them to the site, preparing the trenches, and conducting the actual construction and conservation work.

Walls

Conservation of the walls within the trenches began with new mud bricks set in mud mortar laid approximately 5 centimeters from the original wall. The space between the new and the original walls was filled with compressed earth (fig. 6). It should be noted that the soft nature of the adobe bricks enables the mason to cut them to the required dimensions as the work proceeds. The tops of the walls were covered with a layer of geotextile and a layer of compressed earth 10 centimeters thick, followed by another layer of mud bricks and compressed earth. This was covered with adobe plaster sloped at an incline to shed water.

FIGURE 6 The conservation method of treating the walls within the trenches. Photo: Manijeh Hadian, RCCCR

Brick Floors

The same materials and methods were used to protect the brick floors (fig. 7). First, the surface of the floors was leveled using compressed earth. This was covered with a layer of geotextile and an additional layer of bricks. A thin layer of soil was used to fill the gaps and create the required slope for the adobe plaster. One-centimeter-diameter holes were pierced through the geotextile material to allow airflow and reduce condensation.

FIGURE 7 The conservation method of treating the brick floors. Photo: Manijeh Hadian, RCCCR

Floors of the Trenches

The trenches were leveled with compressed earth to protect them. When possible, positive slopes were created to divert surface water; otherwise, the floors were leveled flat. Geotextiles were sandwiched between two layers of compressed earth and covered with adobe plaster. The plaster was applied to prevent the edges of the trenches from collapsing and to divert surface water flow away from them.

Monitoring

Close monitoring of the repairs over a three-year period showed some success. Important factors contributing to this were (1) careful application of plaster to the adobe and (2) precise leveling of the surfaces to shed water. Other treatments were also tested and monitored. These included laying new bricks at the wall corners to increase structural stability. Differences in settlement between the compressed earth and the bricks resulted in cracks on the upper surfaces of the walls. In addition, the walls of some trenches were unstable and collapsed owing to poor adhesion of the adobe plaster. To address this, the walls were covered in geotextile prior to being covered with earthen plaster. The outcome of this method is yet to be determined.

Conclusion

In conclusion, the following points are worthy of note:

- Both stabilization and restoration measures taken on the trenches have been accomplished using traditional materials such as adobe and earthen plaster to reduce the rate of erosion and with minimal intervention to retain the architectural characteristics of the structures. Treatment measures were designed to be reversible and retreatable. Considering the environmental conditions of the region—high groundwater levels, soluble salt–rich soils, and rapid surface evaporation, together with related wet/dry and salt phase cycling (efflorescence/deliquescence) that rapidly disintegrates adobe bricks—geotextiles are recommended to help reduce surface evaporation and moisture absorption.

- Conservation and restoration materials and methods adopted at Konar Sandal differ based on the condition of the buildings and the site, as well as the physical environment. The treatments adopted at one site may prove destructive for another that has a different climate and deterioration conditions.
- There are many issues that drive conservation and restoration activities on archaeological sites. Some of the environmental complications at Konar Sandal are the high levels of salinity in the water and the prevalence of expandable clay minerals in the soil. These conditions cannot be eliminated and require considerable research to mitigate on a sitewide basis. In some cases new and high-tech treatment solutions that address these issues are prohibitive due to insufficient resources, and the prospect of their potential success can cause delays in carrying out critical and often simple emergency conservation work. Therefore, our best course of action is to continue using traditional and practical repair materials and methods while advanced analysis and treatment testing continue. A critical part of the process, though, is the ability to distinguish between the issues that are compelling and immediate and those that can be addressed over time as the necessary research and resources are acquired.

The complex environmental conditions of Konar Sandal, as well as its extensive size and archaeological importance, require development and implementation of a carefully considered, long-term conservation and management plan. In the interim, our recent conservation and restoration activities at Konar Sandal have helped reduce the extent of erosion, and our efforts to increase public awareness, train locally stationed staff, and vigilantly guard the site have helped prevent serious damage.

References

Ashurst, J., and N. Ashurst. 2001. *Practical Building Conservation.* Vol. 2: *Brick, Terracotta and Earth.* Aldershot: Ashgate.

Croci, G. 2000. *The Conservation and Structural Restoration of Architectural Heritage.* Southampton, UK, and Boston: Computational Mechanics Publications/WITPress.

Fakher, A., and F. Askari. 1993. *Swelling and Dispersivity of Soils, from a Geotechnical Engineering Point of View.* Tehran: Tehran University Press.

Feilden, B. M. 2001. *Conservation of Historic Buildings.* Oxford: Architectural Press.

Houben, H., and H. Guillaud. 1994. *Earth Construction: A Comprehensive Guide.* London: CRATerre-EAG, Intermediate Technology Publications.

Warren, J. 1999. *Conservation of Earth Structures.* Oxford: Butterworth-Heinemann.