Nile's Earth 2023 International Conference : study and conservation of earthen archaeological sites in ancient Egyt and Sudan, 4-5-6 July 2023. Proceedings

Joffroy Thierry, Crosby Anthony, Gandreau David, Hubert Alix, Marchi Séverine, Spencer Jeffrey

Construction details against moisture in ancient Babylon and its surroundings

THEME 3 - Conservation, Valorisation and Management
3.1 - Threats, circumstances, and processes of decay; impact of climatic change

Maddalena Achenza, DICAAR - Università di Cagliari, ICOMOS-ISCEAH.
Ammar Al-Taee, Iraq State Board of Antiquity, World Monuments Fund.

Summary
Babylon lays in a semi-desertic environment characterized by high temperatures and elevated thermal excursions during winter, with differences of 30 °C or more. This difficult climate is co-existing with a very elevated presence of humidity showing in various forms: atmospheric moisture, rain- and ground water condensation. Moreover, a high presence of salts is evident in the whole region where during dry seasons flat surfaces become white.
Temperature oscillation, moisture and salts together determine severe physical and chemical reactions and biological growth on and in adobe walls, resulting in a varied range of deterioration patterns. Historical constructors have evidently faced these concerns in ancient times and developed strategies to contain, when not eliminate, such threats.
An accurate observation of the archaeological remains unveils the peculiar know-how of ancient builders, who put up skilled strategies to contain effects of the raising moisture and presence of salts on earthen walls.
Examples have been investigated in different settlements in the Babil region, in Babylon, Borsippa and Kish. The ancient technological strategies observed are considered to be a great source of inspiration for the development of solutions for new construction.
This contribution is a first compilation of case studies and analysis gathered in the frame of the conservation works of the Ninmakh Temple in Babylon, a project coordinated by World Monuments Fund and the Iraqi State Board of Antiquities and Heritage (SBAH).

1 INTRODUCTION

This contribution reports some observations done during the assessment studies for the conservation of the Ninmakh Temple in Babylon, in the period January 2021 until now.
These observations have been registered in the archaeological sites of Babylon, Kish and Borsippa (the remains of these sites date to the new Babylonian period, 604–562 BC). The first ones have been done in the Temple of Ninmakh in Babylon, of which a more meticulous record of details is being kept so far.
What is visible today of the temple of the mother goddess Ninmakh (E2.MAḪ, which means "magnificent Temple") was mostly built during Nebuchadnezzar II reign (604–562 BC) even if there are very few remains that have been dated older (old Babylonian period 1700 BC - Assurian period 626 BC). Due to the repeated raising of the level of the nearby Processional Way and the Ishtar Gate, the temple was rebuilt on higher levels several times during Nebuchadnezzar's reign. The first recorded excavation of a few rooms of the temple occurred in 1880 by Hormuzd Rassam working for the British Museum, and then later, starting in the year 1900, by the German archaeologist Robert Koldewey.
In 1961-1962, Iraqi archaeologists undertook excavations to a deeper level and reconstructed the temple on the standing original walls with newly produced earth bricks. No documentation was left to witness these works. The addition of an incoherent heavy concrete roof resulted later in its partial collapse leading to successive rebuilding of the exterior walls and roof during the following decades. After 2003, the lack of maintenance has led in the collapse of large areas of the roof and consequently also of some walls.
A recent activity of consolidation and restoration has been started by World Monuments Fund under the supervision of the Iraqi State Board of Antiquities – SBAH.

The preliminary studies of the temple, of its building elements and techniques, and especially the comparison with significant buildings at other sites nearby, highlighted a very interesting collection of historical strategies to address the presence of humidity in buildings. The buildings considered for this article are the temples of Ninmakh, Nabûšaḫarê and Ishtar in Babylon, the Ishtar Gate in Babylon, the ziggurat in Borsippa and the temple of Kish.
Unfortunately, at this stage we cannot yet provide laboratory test results of the materials cited in this contribution, as the procedures for getting permission are still ongoing, but we are confident that we will be able to integrate them in the next future.

2 THE SITE

The Babil region, on which our investigation is focused, is located in ancient Mesopotamia, considered since early times the area between the Euphrates and the Tigris. In reality, over time, the use of this definition became broader, indicating Iraq, but also including partial areas of Turkey, Syria, Iran, Saudi Arabia and Kuwait.
The Babil region is located by the southern sections of the Euphrates carrying waters that come predominantly from the Turkish mountains. Due to the low precipitation, people who settled on the Mesopotamian floodplain are dependent on water from the rivers and on very well-organized irrigation.
The plain is also collecting groundwater from all surrounding areas. Heavy evaporation of the near-surface saline groundwater leads to salt accumulation on the surface, producing sometimes impressive effects on the landscape (Fig. 1).

Figure 1. Tell Bander, Kish archaeological site. Credits: Maddalena Achenza

Groundwater near the rivers may sometimes be useable for irrigation purposes, having a lower level of salinity (1–5 g/l), but not as drinking water, as the salt content is too high for this use. Because of this, the water of the Euphrates is traditionally preferred[1].
The area is also affected by a critical climate, with a dramatic oscillation of temperature which can be, according to the annual period, both cold (-5°C) and extremely hot (+54°C). In the same way, dry seasons alternate with humid ones, determining a quite hard condition for human activities such as agriculture and herding. That also includes building practices.

[1] PEDERSÉN 2014

Temperature fluctuation, moisture and salts together determine severe physical and chemical reactions and biological growth on, and in, adobe walls, resulting in a varied range of deterioration patterns. Historical constructors have evidently faced these concerns in ancient times and developed strategies to contain when not eliminate such threats.
Some techniques of prevention of moisture rise on earthen walls have been observed during the preliminary studies and data collection for the works of the conservation at the Ninmakh Temple and the Ishtar Gate in Babylon and in some other buildings of nearby sites: Kish and Borsippa.
The strategies observed are described in the following paragraphs.

3 STRATEGIES FOR PREVENTING MOISTURE CAPILLARY RISE

3.1 Positioning of buildings

Commonly, as it happens to witness in settlements of any age and everywhere in the world, earth buildings are positioned in areas that are some meters higher than their surroundings. In Mesopotamia, too, iconic and representative buildings such as the ziggurat in Kish and Borsippa (Fig. 2), are located on barely perceived hills, well visible even from far. Though these sites are not yet fully excavated, we can still assume by logic that they were chosen to dominate the landscape. Experience from other similar sites informs us that this is a very common strategy to slow the capillary rise of humidity and keep sites safe from floods.

Figure 2. Borsippa. Credits: Maddalena Achenza

3.2 Sloping floor levels inside temples

Temples in the Babylon area have recurrent shape and internal distribution. They are built in paralepidid form, with an inner courtyard that serves as a connection to various chambers. At the opposite side of the main entrance crossing the courtyard is the *cella*.
In Babylon, some temples have been rebuilt on their archaeological remains, in what has been called the new Babylonian style, following the original floor shape. Although no reports nor scientific documentation of the methodology that has been followed for their reconstruction is existing, thanks to some on-site surveys, we are quite sure that the historical ground level has been kept as a reference.

In all three temples analyzed in Babylon, Ninmakh, Nabûšaḫarê, and Ishtar, the *cella* and the other chambers are reached through a sloping floor that rises about 5 cm from the courtyard level. This difference in level is covered either with a step, to avoid water from heavy rains to come from the courtyard towards the sacred spaces. Supporting this, Koldewey reports: "*… at the gate (of the cella, editor's note) there's a channel which carried off the rainwater from the building*" [2].

3.3 Use of lime as a protection for surfaces

The use of lime plasters for external walls is recurrent in almost all significant buildings. Lime could be used mixed with earth, sand and ashes[3].
Lime, *noura* in Iraqi, used in Babylon was traditionally produced in the area of Karbala and it is still, even if its use in construction has decreased drastically in favor of cement. Nowadays lime is rarely used, due to its slow hardening and presumed lack of durability. After the experience of some builders interviewed, mixes are usually done with the following ratios of *noura* (lime) / sand:
1 / 6, mix preferred by less wealthy users;
2 / 9, it is the most common percentage used for building;
1 / 4, mix of higher quality, it is preferred in the case of expectation of frost;

Lime plasters that can be dated back to Nebuchadnezzar II have been found in Babylon at Ishtar Gate and in the Ninmakh Temple. White plastered walls were found and reported by Koldewey during one of the first excavations at Ninmakh Temple and are well visible in some photos of his reports: *"The temple, like all others hitherto found by us, is composed of mud brick, but we must not judge of its original appearance by the present condition of the ruins; its walls were covered with a white plaster that gave it the appearance of marble"*.[4]
In the temple, lime plasters were found, according to Pedersén during an interview with the authors, on the external façade next to the north entrance, on the walls of the courtyard, and in the *cella*. In February 2023, during reparation works, traces of this type of plaster were found also at the base of the external eastern wall (Fig. 3).

Figure 3. Babylon Ninmakh temple. Lime plaster. Credits: Ammar Al Taee

[2] KOLDEWEY 1914. P. 57
[3] LANGENEGGER 1911
[4] KOLDEWEY 1914, P. 55

In January 2023, at Ishtar Gate, part of a squared masonry pillar was unearthed during the construction works of the new staircase accessing the site. The pillar is part of the entrance gate to town from the processional way. The fired brick pillar is covered with the same type of lime plaster found at Ninmakh Temple on earthen bricks.
At a preliminary analysis, the plaster, very similar in both cases, appears mixed just with soil and with no pigment added. The result is a pale coating, 1 cm thick in average.
According to these observations, lime plaster has likely been used as finish for the most significative buildings, such as temples and the inner sides of the defensive walls. Further tests on samples of the plaster at the Ishtar Gate have been carried out by ZRS Ingenieure GmbH in Berlin (Germany) in August 2023, confirming that the composition of the binder of the plaster mortar consists of lime with very low gypsum content. [5]

3.4 Interposition of layers of bitumen and earth-bitumen mixes in masonry

The use of bitumen for building purposes dates back to more than 8,000 years ago[6], confirming the highly sophisticated building culture in ancient Mesopotamia. The use of bitumen appears to have been common since prehistoric times and continued in following ages. Bitumen has been regularly used for many purposes, but especially in building practices, as adhesive and protecting bond, and to prevent the infiltration of moisture and water into buildings. It was appreciated due to its broad availability, qualities of impermeability and elasticity, and ease of employ.[7]
Actually, this mineral oil can be found almost everywhere in the country in different forms: liquid, dense or solid. When liquid or dense, it can be used straight to obtain a composite water-resistant mixture, able to stop or at least slow the rise of moisture in the walls. When more solid, it needs to be melted by heating to be brought to a more liquid state. It can then applied as mortar in between bricks, both fired or not fired, or used, in thin layers, as coating. This is a practice that is often observed in many buildings in Babylon, such as the South Palace, and the Ishtar Gate.
Bitumen was also used as waterproof barrier in between bricks for the construction of rainwater drainage channels, as observed in the Ezida Temple in Borsippa, rebuilt during the new Babylonian era. Although the temple is mostly built with mud bricks, waterways were built with fired bricks laid with a bitumen/soil mix in the form of vertical channels, extending from the top of the roof to the base of the walls (Fig. 5).
Other materials such as lime and soil were sometimes added to bitumen to reduce its fluidity, as found in some ziggurats masonry such as Dorcoricalzo from the middle Babylonian era (c. 1595 – c. 1155 BC), and Borsippa. This type of mix has been used for the construction of walls made both with raw earth and fired bricks.[8] In Borsippa, layers of bitumen mixed with earth or sand have been found in many walls of the ziggurat (Fig. 6). Bitumen layers recur on walls every 5-7 bricks. The bitumen is easily recognizable because of the smell, still very strong and well identifiable. At Ninmakh Temple there are perfectly preserved layers of pure bitumen in between earthen bricks. The better-preserved ones are at the lower part of the wall facing the north entrance (Fig. 7). Here, at a height of 16 cm from the floor, two layers of bitumen about 2 cm thick are placed between earthen bricks. Many other walls built with earthen and fired bricks have been laid with bitumen in Babylon, confirming how common this practice has been through time.

---

[5] This information is included in the WMF documentation of the works ongoing at present at Ishtar Gate
[6] Al-Khatib 2003
[7] Bahr 1997, p. 170.
[8] Al-Jumaili 1971, p. 70

Figure 4. Water drainage in the Ezida Temple. Credits: Ammar Al Taee

Figure 5. Bitumen mix found in Ezida Temple. Credits: Maddalena Achenza

Figure 6. Layers of bitumen in earth masonry at the Ninmakh Temple in Babylon. Credits: M. Achenza

Sometimes fluid bitumen was applied on reed mats. Reed mats, as better explained in the following paragraph, were laid at regular intervals in the earthen masonry. Supposedly, bitumen served as further protection to a system that was evidently used as a barrier for moisture.
Earlier studies[9] concluded that the presence of a high percentage of sulfur in bitumen assures good quality and durability. The bitumen used in Babylon was coming from the city of Hit and its surrounding areas where the percentage of sulfur and bitumen ranges between 7.6 - 9.31% for sulfur and 21 - 28.5% for asphalt. According to both cuneiform texts and Herodotus, the city of Hit was the main center for supplying bitumen to the city of Babylon. Some cuneiform texts refer to Hit also providing the city of Ur with bitumen by transporting it by ship.[10]

3.5 Interposition of reed mats

Reeds are widely spread in Mesopotamia along the Tigris and Euphrates rivers, which provide a perfect environment for these plants. Reeds were easily available to everyone, so the people of Mesopotamia employed them since ancient times for their various daily needs. In the south of Mesopotamia, in the Marshes, they have been used for centuries to build robust houses and furniture.
Earthen houses included reeds as a basic construction material, as a Sumerian proverb indicates[11], "*a lot of building works use bricks, reeds and reed mats, and beams*".
Due to the importance of reeds in the daily life of Mesopotamia, various jobs and specializations emerged related to the harvest and transformation of reeds, employing both men and women.

[9] AL-ADHAMI 1989
[10] ABDUL-HALIM 1983
[11] AL-SHAMMARI 2019

Reeds were used raw for construction of fences and thin walls, or cut in the form of long strips, which get then waived by women in form of mats, and then used for different purposes.
Mats were interposed in between earth-brick courses, in one or, most probably depending on the quantity of moisture present. They were interposed at 7-9 bricklayers or even more, as can still be observed at the Summer Palace in Babylon: *"on the north and south-west remains of walls of very considerable height are still standing, with courses of mud brick held together by layers of well-preserved reed stems. They date from a later period and may have belonged to a fort which was erected in Sassanide or Arabic times on the already ruined Babylonian building"*[12] *(Fig. 8-9).*

Figure 8. Summer Palace in Babylon. Credits: Maddalena Achenza

Figure 9. Borsippa: reed mats and bitumen layers in brick masonry. Credits: Ammar Al Taee

[12] KOLDEWEY 1914, P. 10

Transformed through time, these layers appear now often as a bright white layer. Their presence was reported already by Koldewey in his early excavations: "*After every 9 or 10 layers, a cane or reed mat is inserted into the clay joint to protect the wall from vertical splitting. These inlays of mat, which have deteriorated to a white ash over time, are noticeable throughout the exterior of the walls as white horizontal lines" (Fig. 10).*[13]

Figure 10. Borsippa: reed mats in earth masonry. Credits: Ammar Al Taee

4 STRATEGIES FOR KEEPING WALLS DRY

4.1 Ventilation conduits

The remains of the ziggurat in Borsippa show an interesting system of conduits built in the masonry that looks like a well-thought arrangement to provide ventilation and thus, dryness to walls. The whole section of the walls is crossed by 18 X 18 cm straight conduits obtained through a specific bonding pattern. These conduits are positioned at a distance of about 2 m one from each other (Fig. 11).
These conduits are visible in all types of masonry used for the fabrication of the monument, made both with half-baked- and fired bricks, and are not coated on their sides. The direction of the conduits is crossed perpendicularly on the different heights of the walls and goes from one surface to the opposite one across the whole thickness of the walls, in a way that it is easily possible to look through.

[13] KOLDEWEY 1911, P. 25

W. Allinger Csollich[14] reports a quite detailed description of the fabric of this system, accompanying the design of each layer unearthed. He proposes many hypotheses for the function of these conduits, not coming to a definitive conclusion. Among these hypotheses is the possibility that they could have served as a mean to help the structure dry faster during construction, and to ventilate the core of the building. Something similar was also observed in the ziggurat of Ur whereconduits with a similar pattern were also considered as ventilator ducts.
Even though little literature was found by the authors on this subject, and apparently no in-depth investigation has been undertaken recently on this topic so far, it reamins difficult to attribute to these conduits a different function than ventilation, given that the ziggurat is a massively built object, with no rooms or empty spaces inside.
It will be therefore convenient that deeper survey and further research be made to survey these particular construction practices and to better understand their function.

Figure 11. Ventilation channels in brick masonry. Credits: Ammar Al Taee

4.2 Bitumen plasters, floors and roofs

Fired brick walls were sometimes waterproofed with bitumen if exposed to weathering, as in open courtyards, or if in direct contact with water, such as for gutter canals[15]. Some bitumen plasters are still visible in many buildings, such as is the North Palace in Babylon. Here, a layer of this building material is observed, 1-2 cm thick.

[14] ALLINGER-CSOLLICH 1991
[15] AL-ADHAMI 1989

Figure 7. Babylon, bitumen plaster on the South Palace. Credits: Ammar Al Taee

Floors were also commonly covered with bitumen as described in Koldewey's report: "*Between them (two walls, editor's note) is a broad street or roadway, which leads directly to the Ishtar Gate, made by Nebuchadnezzar as a processional road for the God Marduk, to whose temple of Esagila it eventually leads. It still possesses the brick pavement covered with asphalt which formed a substratum for the immense flagged pavement*" and again about the Ninmakh temple with the following: "*The floor of the courtyard and of the rooms was laid on asphalt and covered with asphalt too*". [16]
The protection of the roof from the permeation of moisture was assured by a layer of reeds and asphalt placed over a strong wooden roofing and, above this, rested two courses of bricks laid in mortar.[17] As described by old masons interviewed, â layer of soil is placed on on top structural elements, making possible to plant barley. This practice has been used traditionally in the Babil region until some decades ago. According to the same people interviewed, the barley roots help to consolidate the soil layer and absorb all the water brought by rains. It is a fascinating practice, that brings the thought back to the famous Babylonian hanging gardens.

5. CONCLUSIONS

This contribution describes the first results of a general analysis of the archaeological sites of the Babil region, focusing on the strategies of ancient builders to protect monuments and civil buildings from the aggression of capillary rise and pathologies caused by the action of rain. All descriptions are the result of research at a very initial stage, not supported by scientific test analysis as those have not yet been authorized. Nevertheless, a recurrent practice can be observed of using certain materials in a repeated manner, confirmed by literature produced by archaeologists in the early years of the XX century.

[16] KOLDEWEY 1911, PP. 4-6
[17] KOLDEWEY 1911, P. 26

The skilled use of different materials and technologies to address the presence of moisture and water in buildings has led to the development of creative strategies to contain, when not eliminate the problem.
Lime, bitumen, and reed mats have been used alone or combined to assure the best result for waterproof walls and external surfaces. Their excellent quality has survived through centuries and today represent a very inspiring testimony of an ancient, sophisticated building culture.
Amazing technologies such as the channels of the ziggurat in Borsippa and the roofs planted with barley deserve consideration and scientific in-depth studies to verify their real function and eventually allow us to achieve new useful knowledge for our future practice.
What was observed until now has just opened the path to broader research on building practices and construction skills that just confirm, if ever necessary, why Iraqi architecture has been kept in such high consideration throughout history.

AUTHORS' BIOGRAPHICAL NOTICES

Ammar Al Taee
Archaeologist, MA in Sumerology, Researcher in archaeology, works at Inspectorate of Antiquities and Heritage of Babylon, Department of Archaeological Buildings Maintenance, SBAH - Iraqi State Board of Antiquities and Heritage (Iraq)

Maddalena Achenza
Associate Professor at DICAAR of building design, Department of Civil and Environmental Engineering, and Architecture, Università degli Studi di Cagliari (Italy).
Architect, PhD in Architecture, her academic research focuses on conservation strategies of earthen and vernacular heritage, sustainable innovation of building systems and processes.

BIBLIOGRAPHY

Abdul-Halim 1983
Abdul-Halim, A.K., Mohammed & Kariem A.,Mohammed, *The effect of distillation temperature on the Sulphur Compounds Stability of Some Iraqi Crude Oils*. Journal of Petroleum Research, Baghdad Vol. 2, No.2,1983, P.45-46

Al-Adhami 1989
Al-Adhami, K., Sabiha K., Yamomah M., *Bituminous materials and their fields of use in Mesopotamia buildings*, Sumer, 46, 1989-1990, pp. 45-46

Al-Jumaili 1971
Al-Jumaili, Abdullah Abd al-Razzaq, *Results of maintenance, investigations and excavations in the ziggurat of Aqraquf, the tenth, eleventh, twelfth and thirteenth seasons*, Sumer, 27, 1971

Al-Khatib 2003
Al-Khatib R., *Hit in its ancient and modern framework*, Alf Baa Magazine, Baghdad 2003

Al-Shammari 2019
Al-Shammari , T. M., Al-Fatlawi A. H., *Lark for Philosophy, Linguistics and Social Sciences*, Wasit University, 2019

Allinger-Csollich 1991

Allinger-Csollich, Wilfrid, *Die Baukörper der Ziqqurrat von Borsippa. Ein Vorbericht,* in Baghdader Mittailungen, Band 22 – 1991, Gebr. Mann Verlag, Berlin 1991

Bahr 1997
Bahr, Osam, *The ziggurat, a distinctive civilizational phenomenon in ancient Iraq,* University of Baghdad, College of Arts, Department of Archeology, unpublished master's thesis, 1997

Koldewey 1911
Koldewey R., *Die Tempel von Babylon und Borsippa*, J.C. Hinrichs'sche Buchhandlung, Leipzig 1911

Koldewey 1914
Koldewey R., *The excavations at Babylon,* Macmillan and co. limited, London 1914.

Langenegger 1911
Langenegger F., *Die Baukunst des Iraq (Heutiges Babylonien),* Gerhard Kuethmann, Dresden 1911.

Pedersén 2021
Pedersén O., *Babylon: The Great City,* ed Zaphon, Münster 2021.

Pedersén 2014
Pedersén O., *Waters at Babylon,* In: Water and urbanization, Terje Tvedt and Terje Oestigaard (editor), London: I.B. Tauris. 107-129, 2014.

Pedersén 2010
Pedersén O., Sinclair, P., Hein, I., Andersson, J., *Cities and Urban Landscapes in the Ancient Near East and Egypt with Special Focus on the City of Babylon,* In: The Urban Mind: Cultural and Environmental Dynamics, Paul J.J. Sinclair, Gullög Nordquist, Frands Herschend & Christian Isendahl (editor), Uppsala: Department of Archaeology and Ancient History, Uppsala University. 113-147, 2010.