Antonio Almagro
Escuela de Estudios Arabes
C.S.I.C. Granada
Spain

Antonio Almagro

Remarks on Building Techniques During Umayyad Times

Architecture, just like any form of culture, cannot be improvised, nor can it emerge from nowhere. The architecture of Umayyad times inherited both forms and building layouts from previous cultures, taking into consideration the limited architectural tradition that existed in Arabia prior to the arrival of the Islamic culture. The first architectural constructions under Islamic rule were to a certain extent adaptations of those observed in other cultures, even though their own characteristics soon developed, particularly in those buildings destined to house the new functions specific to the new culture.

A similar process of assimilation occurred with respect to the building techniques, although obviously there was no innovation motivated by the adaptation to new needs, since the purpose was in fact the construction of the buildings themselves. Therefore there was no question of being conditioned to new functions. In the region of Bilād ash-Shām we can observe a distinct continuity in almost all the forms of building and in decoration, although innovations are soon to be seen, owing to the influence of building traditions of other cultures integrated into the Umayyad empire.

My proposal here is to analyze some specific aspects related to the construction techniques used in buildings in the Umayyad period in Jordan. I would like to emphasize the fact that this is no more than an elementary and restricted study of the subject.

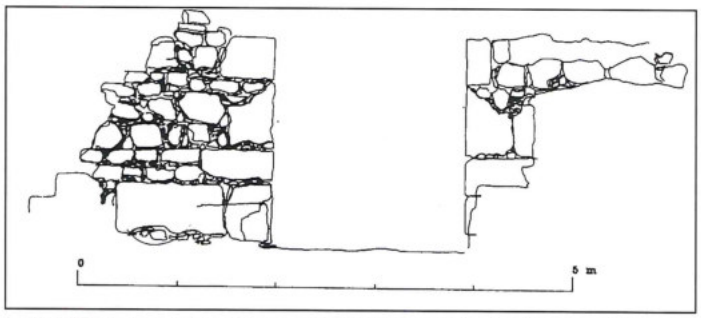
Construction Materials

The building traditions of Roman and Byzantine times continue to prevail in almost all of the Umayyad buildings in Jordan. The use of local building materials necessarily meant following the same methods. The stone found locally is limestone in the central region and basalt in the north, and these are the materials used predominantly, and to a great extent they condition the manner of building.

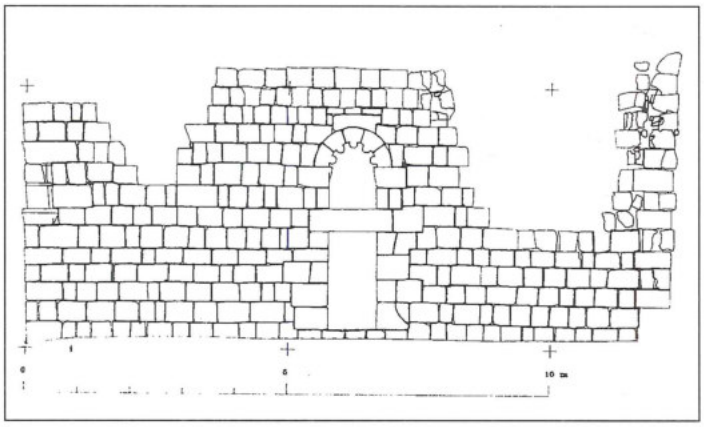
Stone is used, both in roughly-squared rubble masonry and in ashlar masonry. In rubble masonry the irregular stone is accompanied by numerous small fragments, which in the jointuring made with plentiful quantities of mortar become incorporated into the jointuring material (FIG. 1). This system eliminates both the need for dressing the stones and for pre-selecting the stones in order to ensure their correct placement in the structure of the wall, since this can be left to the smaller stones. However, walls constructed in this way are not particularly stable, especially if the mortar filling the joints and the inside of the wall is scant or lacking in resistance, and any slipping of this rubble may result in partial collapse of the wall. When limestone is used in these structures, one can rarely find stones connecting both faces of the wall, while on the other hand in constructions using basalt, the availability of longer stones favoured the use of these types of bonding.

In structures of ashlar masonry, when limestone is used, there continues to be a characteristic absence of connecting stones joining the two faces of the wall. The inner side usually consists of a mixture of mortar that is lacking in consistency and has small rubble stones. These characteristics can be observed in the walls of the mosque in Qaṣr al-Ḥallābāt (FIG. 2), in the entrance hall of the Qaṣr of ʿAmmān, in the palace walls at al-Qasṭal, etc.

Another feature in some of these ashlar structures is the presence of stone slabs that are higher than they are long, and that do not correspond to transversal connecting ashlars, as can be found in the constructions at al-Qasṭal (Carlier 1984: FIGS. 57-66) and ʿAmmān.



1. Rubble masonry in the door of building F in the Qaṣr in ʿAmmān.



2. Ashlar masonry in the mosque of Qaṣr al-Ḥallābāt.

The introduction of brickwork was one of the outstanding features adopted from the Mesopotamian culture. Although it was a well-used material in Roman and Byzantine times, it was scarcely used in the construction of walls in the region of Syria. In Umayyad times, and in two buildings in particular, bricks were used for the construction of arches and vaults. The most remarkable thing about the use of this material in Qaṣr al-Mushatta and Qaṣr aṭ-Ṭūba is its combination with a particular building technique that allows for the construction of arches and vaults without centering, and therefore eliminates the large amounts of wood usually necessary in such cases.

Mortar

The conglomerates used in mortar are particularly interesting. This is one aspect where innovative influences can be appreciated with respect to the prevailing Roman and Byzantine traditions in the region. Throughout our research on the Qaṣr of ʻAmmān we observed different types of mortar, some of which appeared to be different from the traditional lime mortar, and which instead made use of gypsum as a binding substance. This led to our subsequent analysis of some other Umayyad buildings, such as Quṣayr ʻAmra and Kharrāna (TABLE 1).

The results of these studies demonstrated that mortar with a greater or lesser proportion of gypsum as agglomerate was used in some buildings, and within these buildings in specific structures and for particular purposes. This shows that in addition to the traditional techniques found locally, others of a more oriental origin from Persia and Mesopotamia soon appeared. The use of gypsum was almost unknown in Roman and Byzantine times, as far as we know. Only in Hispania, where gypsum is an abundant natural resource, can we find examples of gypsum used in decoration and relief work.

Gypsum had been known in Egypt since ancient times and was subsequently used in Mesopotamia and Iran, and was later the material commonly used in Parthian

Table 1. Results of the analysis of mortars from some Umayyad buildings.

Sample No.	Origin of Sample of Mortar	Lime %$CaCO_3$	Clay %	Gypsum %	Type of Mortar
1	Qaṣr of ʻAmmān. Main wall on the area of Zayadine's excavation	76.0	6.3	15.4	gypsum and lime
2	Qaṣr of ʻAmmān. Interior of south wall of the vestibule	86.0	6.7	2.1	lime
3	Qaṣr of ʻAmmān. Plaster of the pipe on the east facade of the vestibule	84.0	5.6	8.2	lime
4	Qaṣr of ʻAmmān. Interior of wall of the big cistern	75.0	8.5	12.7	gypsum and lime
5	Qaṣr of ʻAmmān. Plaster of the south side of the big cistern	77.0	6.2	14.0	gypsum and lime
6	Qaṣr of ʻAmmān. Wall of room on the east of the vestibule	91.0	3.0	1.8	lime
7	Qaṣr of ʻAmmān. Central column of the south īwān of building A	60.0	8.3	27.4	gypsum
8	Qaṣr of ʻAmmān. Plaster of room beside the west door of the complex	94.0	1.0	2.2	lime
9	Qaṣr of ʻAmmān. Foundation of wall of building B	90.0	2.1	4.9	lime
10	Qaṣr of ʻAmmān. Interior of wall of building B	97.5	0.2	0.5	lime
11	Qaṣr of ʻAmmān. Column in front of the east īwān of building B	58.0	9.3	27.0	gypsum
12	Qaṣr of ʻAmmān. Foundation of column of courtyard 3	59.0	5.4	31.0	gypsum
13	Qaṣr of ʻAmmān. Interior of north īwān vault	92.0	2.7	2.0	lime
14	Kharrāna. Interior of wall	49.0	10.8	36.5	gypsum
15	Kharrāna. Plaster of wall	70.0	6.5	18.5	gypsum and lime
16	Kharrāna. Vault of staircase	68.0	5.9	23.4	gypsum
17	Quṣayr ʻAmra. Interior of wall	89.0	4.0	3.5	lime
18	Quṣayr ʻAmra. Plaster of wall	92.0	2.2	2.6	lime

and Sasanian architecture. No doubt Islam spread its use because after the Muslim conquest of al-Andalus, it became a highly-used material, and in fact it was used almost exclusively in certain areas and times. This widespread use of gypsum as a building material must have stemmed from Umayyad times, after the Sasanian empire became absorbed into the territories of Islam.

It is particularly significant that the buildings in Jordan from which we have taken analyses of the mortar and found gypsum as a building material, are the ones that show the greatest oriental influence. The most obvious example can be observed in Qaṣr al-Kharrāna. Three samples were analyzed: one of mortar from inside the walls, another from the plastering on the surface of the walls, and another from inside a vault, and all of them were found to contain quite a high proportion of gypsum. If we take into account that the most abundant stone in the area is limestone, and that therefore the arids (sand and gravel) have similar characteristics, we should consider that an important part of the calcium carbonate found in the samples comes from the arids. Taking for granted that the proportion between the mixing agent and the arids is about 1 to 3 (Vitruvius, Book 11, chapter 5), we must suppose that mortar with 25 and 30% gypsum is a gypsum mortar. Such mortar usually has a greater clay content than lime mortar, because this material forms part of the impurities of gypsum, and therefore part of this clay should be considered an integral part of the conglomerate.

The proportion of gypsum in the three samples from Kharrāna were the following: 36.5% from the inside walls and 23.5% from the vault, showing that they are obviously gypsum mortars. The analysis of the layer of plastering on the wall contained only 18.5% gypsum. This proportion should be interpreted in light of a technique used even until recently in some areas of Spain, and specified in some building manuals, which consists of mixing the gypsum with the lime, usually lime dissolved in water (lime water). The proportion of lime used in these cases is usually 25% of the gypsum, which in the case of Kharrāna would again mean that the proportion of arids and conglomerates is 1 to 3.

I would like to insist on the fact that it was in a building that has until very recently been widely acclaimed as Sasanian, that gypsum was used as almost the only material for making the mortar. This mortar technique, together with the structural systems in the arches and vaults and the decoration show the marked influence of Sasanian architecture in the planning and carrying out of this building.

The opposite occurs in the case of a building such as the baths at Quṣayr ʻAmra, where all the signs point to Roman and Byzantine architectural influence. Two samples were analyzed, one from the interior of the wall, and another from the plastering, and they both undoubtedly point to the use of a high quality lime mortar, maybe even higher in the mortar of the fine wall plastering, but which in no case has a combined proportion of clay and gypsum exceeding 8%. The construction technique in this case corroborates the continuity of the classical Roman tradition in this building.

The analysis of various samples of mortars coming from different structures in the Qaṣr of ʻAmmān is of particular interest. Within this palace are three different types of mortars. One type that clearly corresponds to the lime mortars contains about 90% or more calcium carbonate. Another group of samples corresponds to gypsum mortars, with a proportion of about 30% gypsum. Last of all, there is another group of mortars with a gypsum content of approximately 15%, which we may conclude is a mortar combining gypsum and lime, with a percentage of the latter of about 50% of the gypsum.

It is also fascinating to analyze the sources of each of these types of mortars. The lime mortars, which generally contain wood-ash, were used systematically on the inside of the walls and for plastering throughout the palace. The presence of ash is frequent in other types of mortar, as it is in the bedding layer of mosaics and paving. Although in the latter case there may be technical reasons for its presence, since this mortar would be more porous and protect against damp, this is not justified in the case of mortar on the inside of the walls unless it were the manner of baking the lime together that resulted in it becoming mixed with the ash in the kiln. Another reason for this presence of ash could be the experience that it sometimes gives slight hydraulic characteristics and strength to the mortar, in the same way as crushed bricks do.

Gypsum mortar is used in very specific structures when necessary because of the structural forms. It is used specifically in the columns in the courtyards of different residential buildings belonging to the palace, and in the lintels of the doors of these buildings. In these cases construction would have been difficult to carry out with lime mortar, because of the length of time it takes to set, and this would have meant a slow building process to avoid crumbling. In these cases the builders resorted to building techniques that were completely alien to local and traditional methods but that were linked to elements of an obviously Sasanian origin. Such is the case of the columns in the patios mentioned previously, and the formation of door lintels using irregular stones instead of monolithic slabs. There is no doubt that these elements were contemporary with the rest of the palace. It is sufficient to analyze the union of the lintels with the rest of the construction of the walls to realize that it was carried out as a whole. The fact that the gypsum was used as a material for delicate elements from the very beginning is

confirmed by the fact that the columns of carved stone in the northernmost patio of the Amīr's residence are built on a foundation of small stones and gypsum mortar (Almagro 1983: 184, sample 12).

Finally, mortars with a mixture of lime and gypsum are to be found in the southeastern area of the building complex, around the large reservoir. This origin is remarkable, since the use of gypsum in hydraulic construction does not seem to be entirely suitable, although the mixture of gypsum with lime does increase its impermeability and resistance to damp.

It is my opinion that a study of the composition of the different mortars could prove to be an interesting field of research that might enable us to determine with greater certainty technical influences on architecture in different periods, and it might allow us in the future to place some of the buildings of uncertain date in their correct chronological period.

Covering Systems: Arches and Vaulting

Arches and vaults are both common in Roman-Byzantine and Sasanian architecture. The Syrian tradition of using well-carved stonework still prevailed in Umayyad times in the construction of vaults. In the Qaṣr of 'Ammān, in particular, the most significant and at the same time the largest areas were covered with well-carved ashlar stonework vaulting. On the other hand, simultaneous work in other smaller areas of the palace show the use of vaulting with rubble masonry (Almagro 1983: 108). This system of construction was widely used in other buildings, such as in Quṣayr 'Amra (Almagro 1975: 34) and, according to Butler (1909: 76), in the mosque of Qaṣr al-Ḥallābāt. In the nearby baths of Ḥammām aṣ-Ṣarāḥ, vaulting with well-carved stonework is combined with other uncarved stone (Creswell 1969: 499-501). All of these building systems may be considered as a continuity of local tradition, and do not offer any innovations with respect to preceding systems of construction.

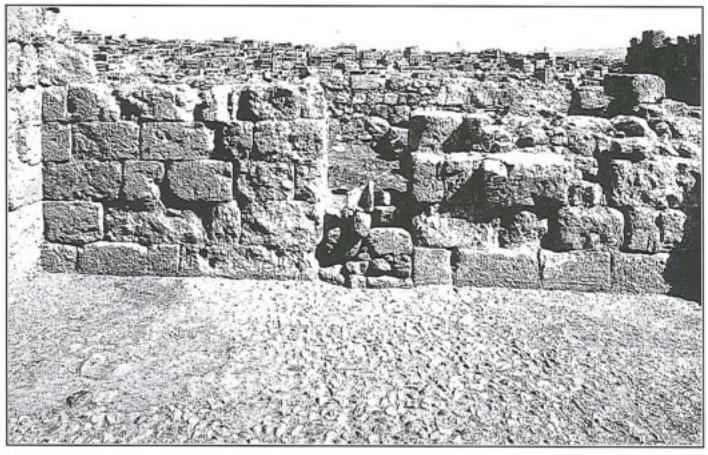
In Qaṣr al-Mushatta and Qaṣr aṭ-Ṭūba, however, there is an obvious alien influence in the vaulting (Creswell 1969: 588-590) because it was built of brick, using a technique that undoubtedly came from Iraq, where the Sasanians used bricks in constructions such as the great vaulting in the īwān of Ctesiphon (Creswell 1969: FIGS. 17D, 19D). Those vaults are constructed without the use of centering or any other supporting system, since the bricks, joined with gypsum mortar, have been laid from the edge of the wall, in such a way that the widest surface of the brick is laid first with its face to the wall, and the successive rings to each previous one. Thanks to the binding qualities of gypsum and to the wide surface of the brick used to join it to the bricks already laid, no supplementary structure is necessary as a provisional support for the vaulting once the mortar hardens.

This system dates back to ancient Egypt and Mesopotamia, and from there it extended under Muslim rule to the west, where we can observe vaults built in a similar way in al-Andalus in different periods, and particularly in the Nasrid times, in both the Alhambra and other contemporary buildings (Almagro 1991: 21-22).

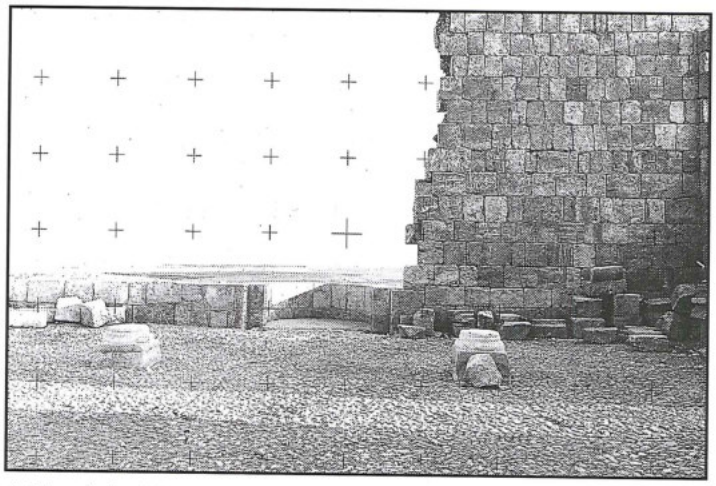
Mosaic Pavements

Excavations carried out by the Spanish Archaeological Mission in the northern area of the Qaṣr of 'Ammān show quite clearly that the two main rooms in that area, the īwān and the cruciform hall, had mosaic floors. Remains of this flooring appeared on the west side of the cruciform hall where it was possible to appreciate the composition of the different layers of preparation and setting of the flooring. The cubes remained fixed and set with a grouting of about 2 cm. Underneath this, there is another layer formed by lime mortar with wood-ash and gravel, and beneath this yet another layer of paving stones of 5-10 cm diameter, with lime mortar and wood-ash. This latter layer lies on another one of limestone sand and gravel without lime, which levels out the terrain and facilitates the drainage (Olávarri-Giocoechea 1985: 51). This arrangement can be observed in the īwān where the mosaics and the layer immediately below have disappeared, and the small stone paving has been exposed (FIG. 3). Remains of this paving also appear in some corners of the great cruciform audience hall, which leads us to suppose that this building also had a mosaic floor. The same disposition in preparing the flooring has been observed in the mosque of Qaṣr al-Ḥallābāt, where the only remaining layer is the stone paving characteristic of the sub-base of a mosaic (FIG. 4). The nearby palace has beautiful mosaics, the setting of which we have been unable to analyze, but which we can imagine to be similar.

This technique proves to be similar to the one used in the Byzantine mosaics in the area (Barogi and Giorgi 1991: 92), which maintained the continuity of a technique practically unchanged over centuries.



3. Mosaic bedding in the north īwān of the Qaṣr in 'Ammān.



4. Mosaic bedding in the mosque of Qaṣr al-Ḥallābāt.

Plastering

We can find the same continuity in the plaster that covers the faces of both interior and exterior walls. This plastering is usually done with a base of lime mortar and done generally in two or sometimes three successive layers. The surface of the first layer generally has V-shaped incisions hacked by the builder's trowel. This technique can be seen in the intrados of the arches in the entry of the well at Quṣayr 'Amra. A similar disposition is found in the plastering in the palace at Qaṣr al-Ḥallābāt, in this case the plaster over the basalt slabs, and on the rubble masonry walls in the Qaṣr of 'Ammān (Almagro 1983: PL. 53). On top of this lower layer that fills up the joints of the rubble masonry and levels out the surface of the wall with a thickness of several centimetres, there is another finer layer, just a few millimetres thick and a completely smooth finishing, which constituted the base for wall decoration. Similar techniques have been described in Byzantine buildings at Umm al-Jimāl (Marino 1991: note 8) and do not vary a great deal from the Roman type of construction.

It is worth pointing out that the technique of V-shaped incisions with a trowel was used in the mortar covering the pendentives supporting the dome of the caldarium of the Quṣayr 'Amra baths. However, there are clear signs that lead us to believe that these pendentives were decorated with mosaics, to judge from the large amount of cubes that appeared in the excavation of the hypocaust, and that could only come from that part, since the dome is painted and the walls were covered with marble panels (Almagro *et al.* 1975: 38). It can therefore be deduced that such an arrangement was also used in the initial layer of the wall mosaics.

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