BAUTECHNIK IM ANTIKEN UND VORANTIKEN KLEINASIEN

Internationale Konferenz
13.-16. Juni 2007 in Istanbul

Herausgegeben von
Martin Bachmann

(OFFPRINT/AYRIBASIM)

Bautechnik im antiken und vorantiken Kleinasien

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BYZAS 9
Veröffentlichungen des Deutschen Archäologischen Instituts Istanbul

ISBN 978-975-807-223-1

Umschlaggestaltung
Martin Bachmann
(Aufnahme: Mauerwerkspartie der hell. Stadtmauer von Oinoanda 2007)

Redaktion
Martin Bachmann, Celine Wawruschka, Lena Kühne

Druck
Graphis Matbaa

Produktion und Vertrieb
Zero Prod. Ltd.
Abdullah Sokak. No: 17 Taksim 34433 Istanbul-Turkey
Tel: +90 (212) 244 75 21 Fax: +90 (212) 244 32 09
info@zerobooksonline.com
www.zerobooksonline.com/eng/

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M. Bachmann (Hrsg.), Bautechnik im antiken und vorantiken Kleinasien, BYZAS 9 (2009) 371-391

Early Examples of So–Called Pitched Brick Barrel Vaulting in Roman Greece and Asia Minor: A Question of Origin and Intention

Lynne C. LANCASTER

Abstract

I examine the early examples of the so–called pitched brick vaulting technique in barrel vaults in Greece and Asia Minor. I make the distinction between bricks set vertically and those that are truly pitched because the distinction can shed light on both the use and origin of the technique in the Roman world. Particular attention is given to the earliest and largest example known, Bath A at Argos, Greece, and then examples from 2nd – 3rd-century Asia Minor are presented. I argue that the large spanned examples were intended not to reduce the amount of wood used for centering as commonly assumed but rather as a means of reinforcing the crown of the vaults by making them less susceptible to cracking. I suggest that the inspiration for the Roman use of the technique comes directly from Mesopotamia, as opposed to Egypt, through contact via military interventions against the Parthians and Sassanids in the 1st – 3rd centuries AD.

In this paper I examine early examples of what has been called »pitched brick« barrel vaulting in Greece and Asia Minor. Traditionally the term »pitched brick« vaulting refers to a method of laying bricks in which they are placed side-by-side rather than radially and they are slightly inclined, hence the term »pitched«. The term was coined originally to describe a type of vaulting that developed in mud brick in Egypt and Mesopotamia as early as the 3rd millennium BC. However, in the examples that began to appear in fired brick in the 2nd and 3rd century AD in Roman architecture, the bricks are, in fact, *not* pitched but rather are set vertically (Fig. 1); therefore, in what follows, I refer to three different methods of laying the bricks: radial, vertical, and pitched. The fact that the same term has been used to describe both the vertical and the pitched methods of setting the bricks has obscured an important distinction that provides clues regarding the transmission of the technique to Greece and Asia Minor. It has also led to the assumption that both methods were used for the same reason, which is not necessarily the case. The two goals of the present study are to determine where the source of inspiration for vertical fired brick barrel vaults

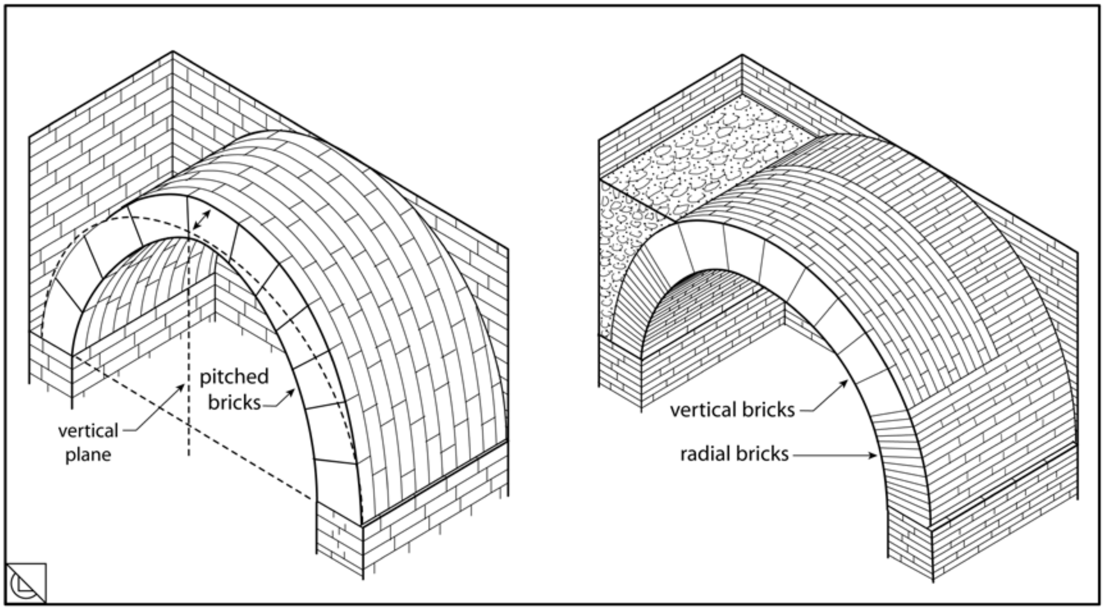


Fig. 1 Illustration of vaults with pitched bricks and with vertical bricks.

originated and why the Roman builders adopted the technique. I focus specifically on barrel vaulting because the vertically laid bricks only occur in barrel vaults and because the construction and structural properties of barrel vaults are different from cross vaults and domes and thus raise different questions regarding intention of this building technique.

Before examining the Roman monuments, I look briefly at the reason for the early pitched brick vault construction in Egypt and Mesopotamia. The technique is generally agreed to have been developed as a means of avoiding or reducing the use of wooden centering in areas where wood was scarce. The materials used were mud bricks and mortar made from gypsum, which required a much lower temperature (200° C) for firing than the limestone (900° C) for lime mortar, thus requiring less fuel. Gypsum mortar also sets much faster (in minutes) than does lime mortar (3–4 hours). The vault was built by effectively »gluing« the first layer of bricks against a wall in the appropriate curved shape with the quick setting mortar and then »gluing« each successive ring to the previous one so that little or no wooden formwork was needed. The bricks were pitched at an incline to reduce the force of gravity and help prevent them from sliding down as the mortar set. Both regions were rich in gypsum deposits and had plenty of clay supplied by their respective river systems, the Nile in Egypt and the Tigris and Euphrates in Mesopotamia, so the building technique developed in response to the natural resources of the regions.

Argos

The earliest known example of a Roman barrel vault built of vertical fired bricks occurs in a building at Argos, Greece, known as Bath A, which was one of the largest structures in the city[1]. The vault (10.7 m span) covered the main room, A1, of a cult complex into

[1] The structure has unfortunately only been published in a series of excavation reports in BCH from 1973–1990. A monograph on the building is promised.

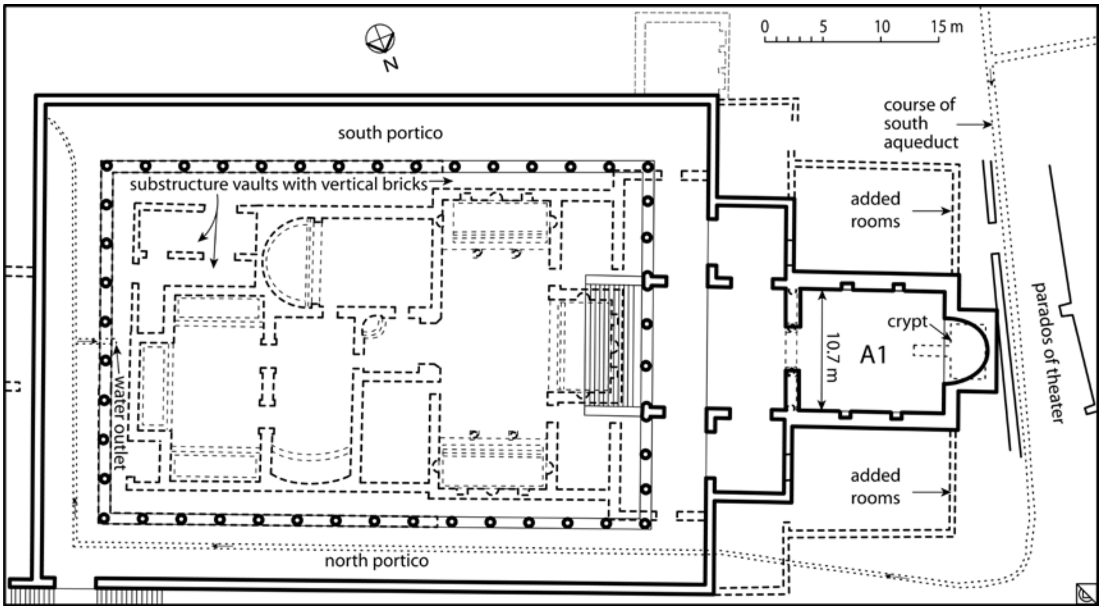


Fig. 2 Argos. Plan of cult building later turned into the bath complex known today as Bath A. Dashed lines indicate bath complex built into courtyard of cult building.

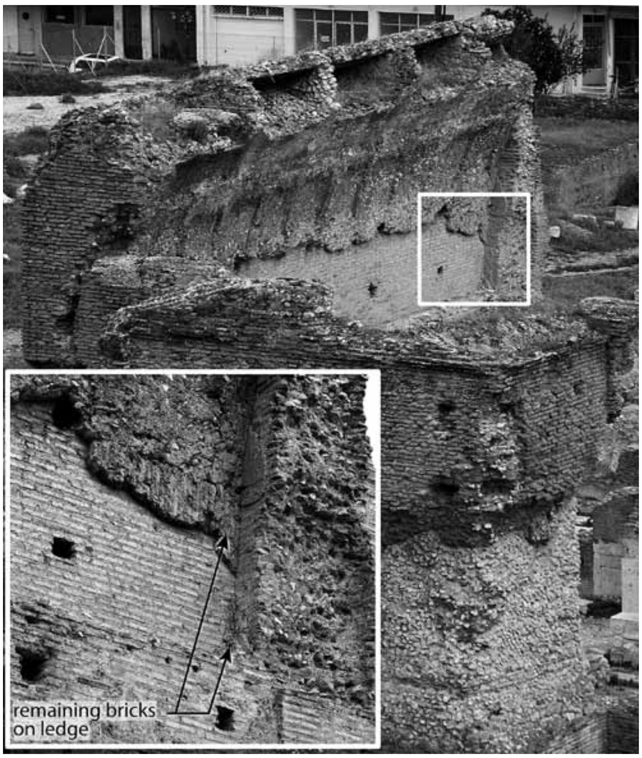


Fig. 3 Argos. Bath A. View of remaining roof structure of main hall A1 from above. Inset shows detail of remains of vertical bricks.

which was later incorporated a bath complex (Fig. 2). The vaulted room was approached by a wide stair case leading into an entry vestibule from a sunken, porticoed courtyard and entered through a door in the front wall. The rear wall of the room contains a large apsed niche with a crypt below.

The construction of the vault of A1 is unique in Roman architecture. The intrados was formed by a semicircular vaulted shell of vertical bricks (ca. 41 cm thick[2]), which sprang from a recessed ledge at the top of the brick faced supporting walls. Most of the bricks have been removed, but a few original ones remain in the northeast corner, and impressions can be seen where others were removed (Fig. 3). The vault of the crypt (4.8 m

2 The thickness is estimated based on photographs and the measured 41 cm thickness of the crypt vault.

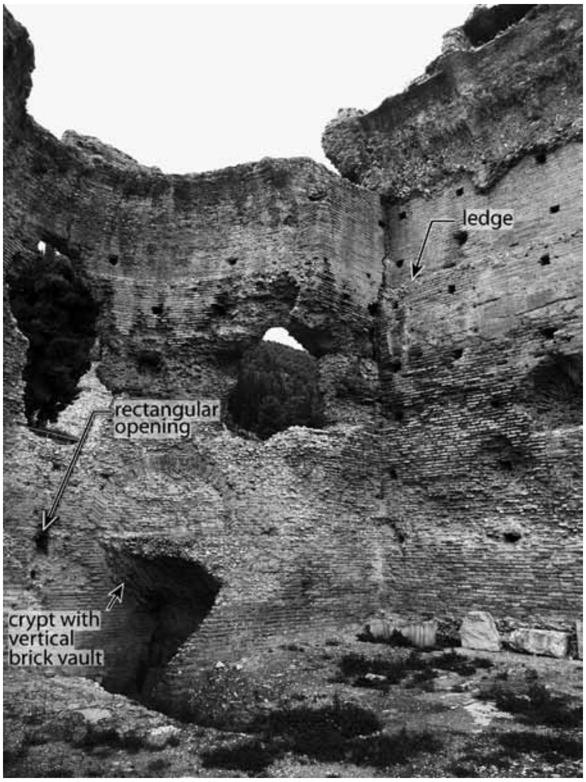
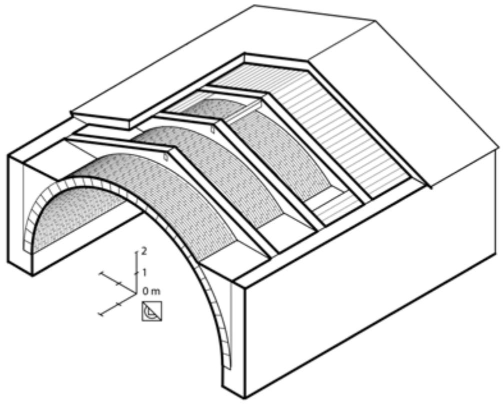


Fig. 4
Argos. Bath A. View into main hall A1 showing crypt and ledge that supported vertical brick vault.

Fig. 5
Argos. Bath A. room A1. Author's reconstruction of roof structure.



span) was built using the same technique of vertical bricks (Fig. 4). In both vaults, the area above the haunch of the brick shell was filled with mortared rubble. The upper haunches of the large vault, however, display a singular feature. About four meters above the spring of the vault the mortared rubble fill ended, and four walls continued up over the brick shell to divide the roof into five sections, each of which was filled with a wooden structure that acted as the formwork for the concrete roof (Fig. 5)[3]. The impressions of the boards are still visible in the hollows left by the wooden structure (Fig. 6)[4], which must have been left in place and ultimately sealed within the concrete as a permanent structure, as there was no way to remove it once the concrete was laid.

A curious feature visible along the intrados of the vault is what appears to be coffers that align with the dividing walls of hollows above (Fig. 6). Close inspection reveals that the indentations are in the form of a shallow arc and are more likely to have been the result of the extraction of bricks for building material at a later date. The remains of some vertical bricks in the fabric of the haunch fill can still be seen. Their purpose is unclear.

The original building has been dated to around 100 AD based on pottery that was found in excavated fill of the north portico[5]. According to this dating, this vault thus represents the earliest known examples of the Roman use of vertical brick vaulting. Later, when the

[3] My reconstruction of the roof structure (Fig. 5) is slightly different from the one published by Aupert – Ginouvès 1989, Pl. 58, fig. 52.

[4] Aupert 1984, 850.

[5] Sève 1977, 671; Aupert 1982, 639; Aupert 1986, 767. I have some reservations about this dating.

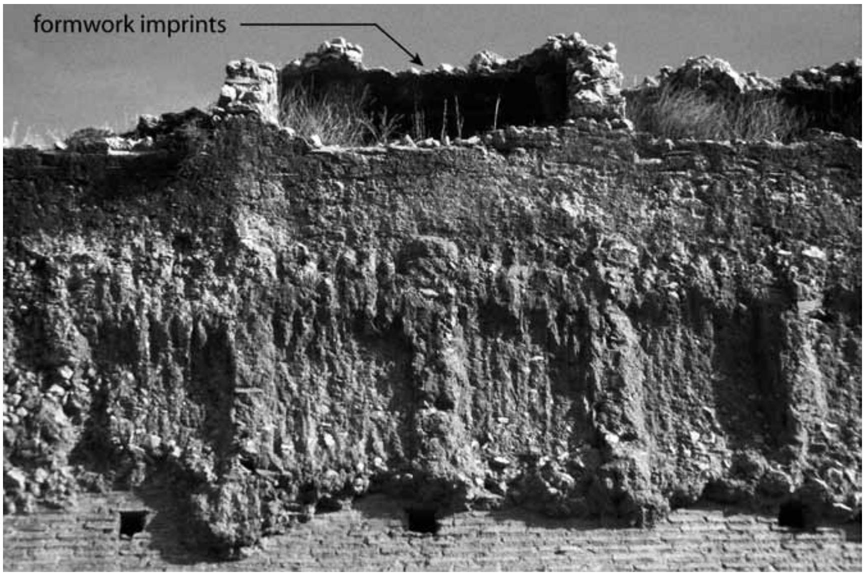


Fig. 6
Argos. Bath A. View of remains of roof structure in room A1 showing formwork imprints and remains of partially removed bricks in the »coffers«.

sunken courtyard of the complex was converted into a bath, the vaulted room (A1) was integrated into the new design by opening the front wall and replacing it with an open colonnade[6]. The excavations give a *terminus post quem* for the date of the addition of the bath based on by fragments of an inscription, probably a dedication, found in the excavations. In the first line are the letters ΩΡΚ (12.5 cm high), which has been reconstructed as [ΑΥΤΟΚΡΑΤ]ΩΡ Κ[ΑΙΣΑΡ], »Autokrator Kaisar« and on the second line ΘΙΚΟ, which has been reconstructed as [ΠΑΡ]ΘΙΚΟ[Υ], »Parthicou«[7]. These two phrases, the latter in the genitive, would refer to an emperor who associated himself with Trajan, who adopted the title »Parthicus« after his Parthian victory. The most likely candidates are Hadrian or Antoninus Pius, which would date the inscription to the mid 2nd century. In addition rooms covered by a wooden roof structure were added to either side of A1[8], and the two rows of holes (ca. 60 cm high) for the wooden beams of the roof of the northern room are still visible in the north wall of A1. At some point in the early Christian period, the complex was transformed into a monastery[9]. A destruction layer throughout the area dates to the 6th century[10].

The use of the vertical bricks at Argos is unlikely to have been to avoid the use of wooden centering given the 10.7 m span of the vault. The pitched mud brick vaults of Egypt and Mesopotamia were built with gypsum mortar, which hardens much quicker than lime mortar, so that the bricks could be placed without the use of wooden centering. These early mud brick vaults were much smaller than the Argos vault, usually less than 5 m. Moreover, the mortar used at Argos was lime based rather than the quick drying gypsum mortar (tested by the application of hydrochloric acid (HCI), which produced fizzing as it

6 Aupert 1984, 850.

7 Piérart 1974, 779.

8 Aupert 1986, 767; Aupert 2001, 445 n. 421. believes they date to the time of Gordion III.

9 Piérart 1974, 782; Aupert 2001, 445 n. 419.

10 Aupert 1983, 851.

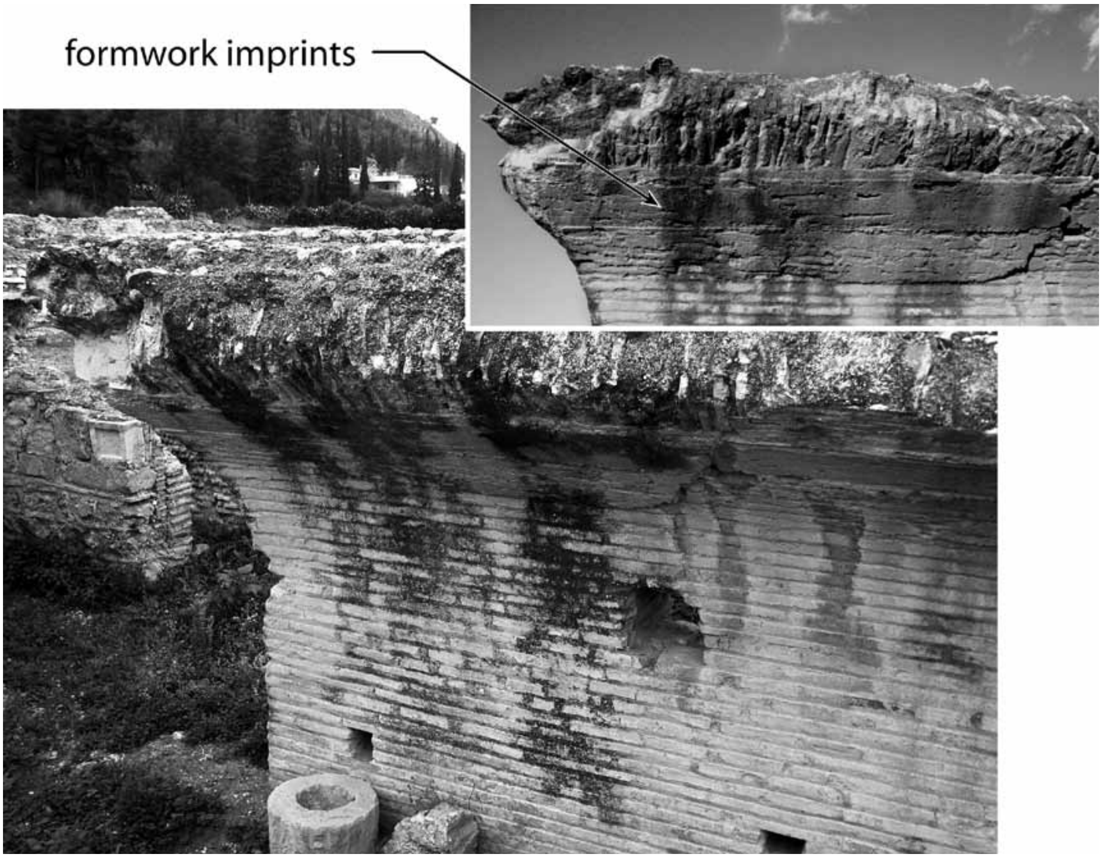


Fig. 7 Argos. Bath A. Substructure vault of bath showing centering hole and vertical bricks. Inset shows formwork imprints.

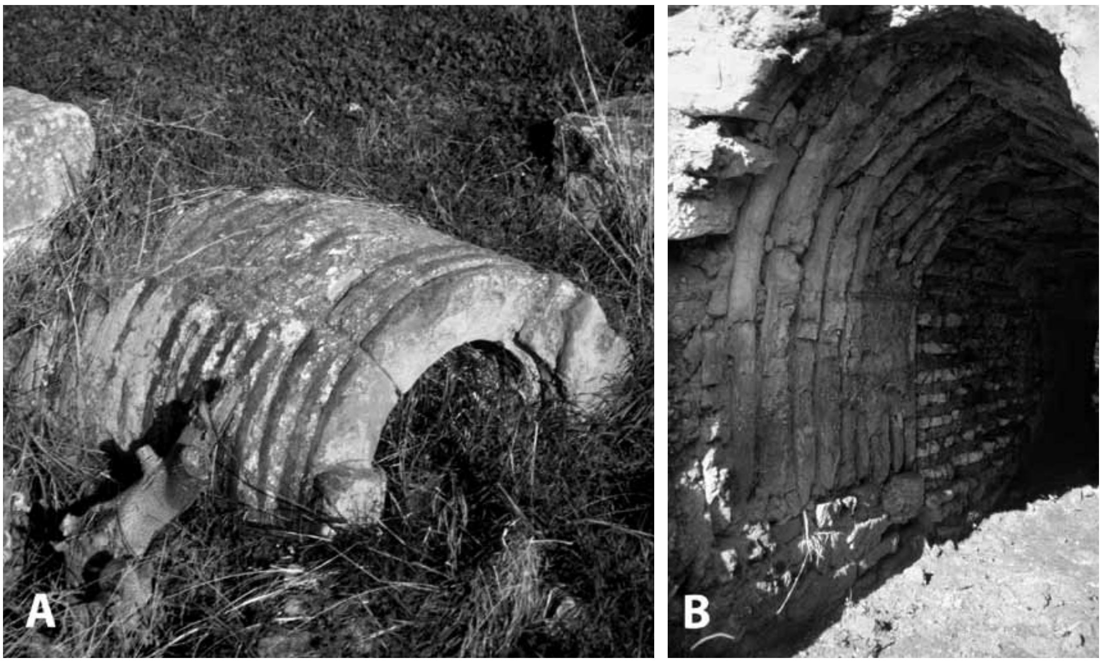


Fig. 8 Small vaults employing vertical bricks at Eleusis (A) and the baths at Isthmia (B).

reacted with the calcium carbonate of the lime). If the purpose of the vertical bricks was not to eliminate the use of wooden centering, why then did the builders use them? This is a question to which I will return after examining other examples of the use of this vaulting technique.

Within Greece, the vaults of vertical bricks are not limited to Argos nor to this building within Argos. The bath substructures that were built into the original sunken court were built using vertical bricks albeit only at the crown of the vaults (Fig. 7). In fact these vaults were clearly built using wooden centering because the formwork imprints are still visible in the mortar into which the vertical bricks were laid. Large drains (1.15–1.20 m span) in the agora at Argos also employ the same technique[11]. On the other hand, examples of the vertical brick vaults in small structures, such as the drains at Eleusis (0.64 m span, 2nd century AD), a praefurnium of a bath building in Isthmia (2nd century AD), and a tunnel in Athens (2nd century AD)[12], would suggest that the technique was also used as a means of building small vaults where centering would have been difficult to construct and remove (Fig. 8).

Ephesus

The use of the vertical brick vaults also occurs in Asia Minor, the earliest securely datable example occurring in room 8, the so-called basilica, of Unit 6 in Terrace House 2 at Ephesus, which is covered by a barrel vault of nearly 8 m. Parts of the vault have been reconstructed, but the original construction is still visible in places not covered by plaster, revealing that a small section of the crown was built with vertical bricks while the haunches were built with typical radial construction (Fig. 9). A view of the rear of the room from the exterior shows, however, that the vertical bricks at the crown did not continue through the back wall, as the arch defining the end of the vault consists only of radial bricks (Fig. 10). The rear of the intrados is covered with plaster so where the transition from vertical to radial bricks takes place is not known.

Room 8, the »basilica«, was built during phase 3 of the complex, which has been dated to the 3rd quarter of the 2nd century AD. An inscription found in a nearby room provides the name of the owner of the house during this phase, C. Flavius Furius Aptus, a priest of the cult of Dionysus and a member of a well known family in Ephesus[13]. The barrel vault of room 8 is not the only example of the use of vertical bricks in vaults at Ephesus (they can also be seen in the so-called brothel across the street), but it is the largest and the earliest datable example in Asia Minor.

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11 Thalmann 1983, 842–844.

12 Leigh 2001, Fig. 6.6.; Shear 1973, 159 f. pl. 132b.

13 IvE 4, 1267; Thür 2002, 61 f.

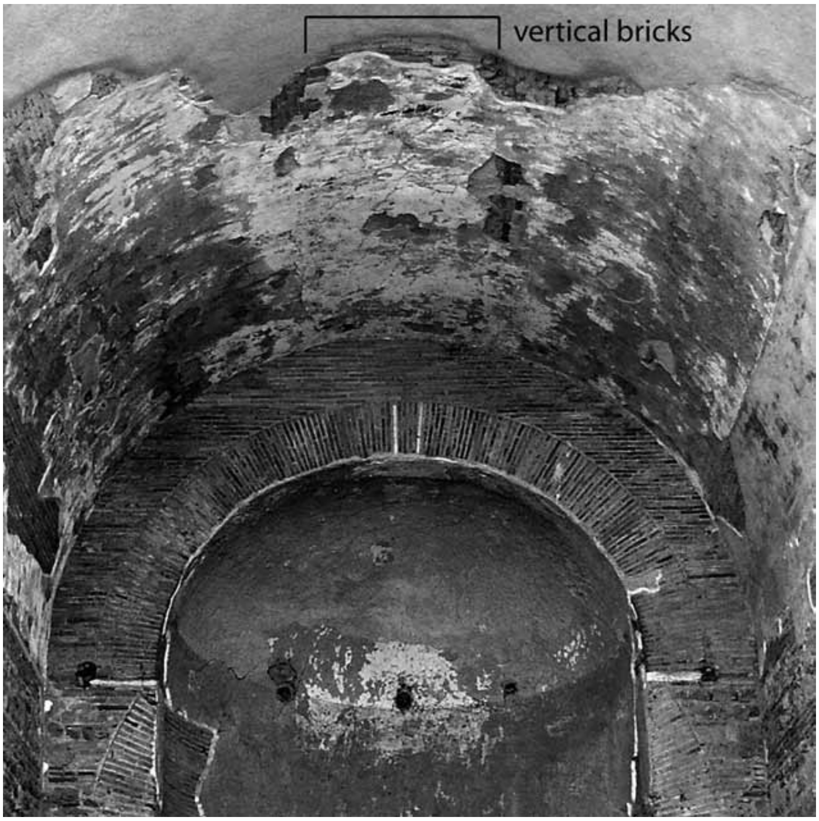

Fig. 9
Ephesus. Terrace House 2 Unit 6. View into room 8 showing vertical bricks at crown of vault.

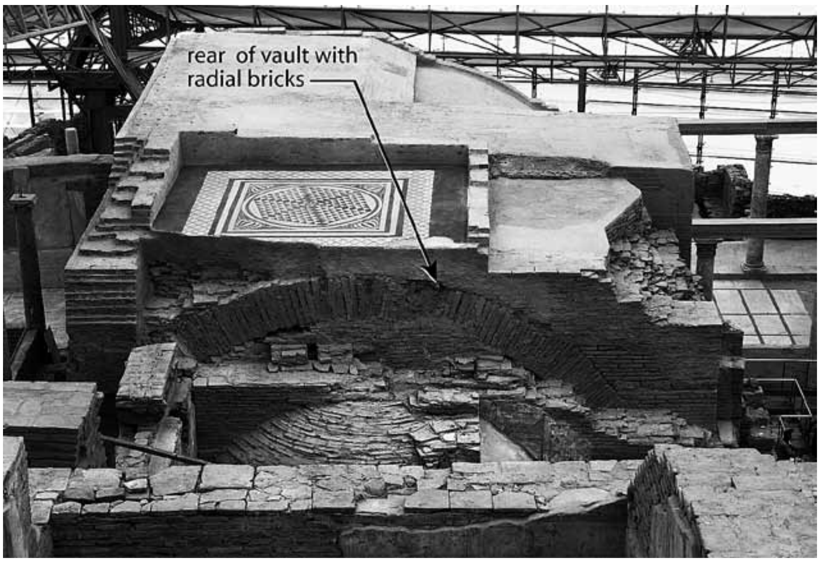

Fig. 10
Ephesus. Terrace House 2 Unit 6. View showing radial bricks at rear of vault of room 8.

Smyrna

A similar construction was used in some of the substructure vaults of the basilica at the Agora of Smyrna. The original construction of the basilica substructures consisted of a series of parallel arches with limestone slabs spanning between them to create the floor of the level above (Fig. 11). When some of these slabs were damaged, they were replaced with very shallow brick vaults (ca. 1.85 m span) with haunches of radial bricks and crowns of

Fig. 11
Smyrna (modern Izmir). Basilica. View showing stone arches of substructure supporting flat slabs of flooring.

Fig. 12
Smyrna. Basilica. View shallow brick vault with vertical brick crown that replaced the stone slabs.

vertical bricks (Fig. 12). As at Ephesus, the ends of some of the vaults were built completely of radially laid bricks with the vertical bricks only used in the central section. The radial bricks in these shallow vaults are unlikely to have been built without centering as they do not appear to have possibly been self supporting (Fig. 13).

The Agora is presently being excavated and reassessed, and the results are not yet finalized. In preliminary reports the excavators have dated the original slab structure of the basilica to the 1st half of the 2nd century AD based on stylistic analysis of some of the composite capitals. The reconstruction is assumed to have occurred after the severe earthquake in 177 or 178[14], and stylistic analysis of elements of the superstructure places the reconstruction at this time or possibly extending into the 3rd century. The earthquake damage is subject of a number of letters

14 Taslialan – Drew-Bear 2005, 304; Taslialan – Drew-Bear 2006, 316.

Fig. 13
Smyrna. Basilica. Detail of construction of partially fallen vault.

of Aelius Aristides[15], according to whom, the rebuilding effort was apparently well underway in 178 and was nearing completion in 179. If these brick vaults date to the building campaign immediately after the earthquake, they would date only shortly after the one in Terrace House 2 at Ephesus.

Aspendos

Another example of the use of vertical bricks occurs in the substructures of the basilica at Aspendos. The 131m long basilica was built on a plateau such that its central section spanned a gulley and had to be supported on substructures, which were also used as cisterns as shown by the calcium deposits remaining on the walls. The southeast aisle facing the gulley was supported on large (7.75 m) cut stone arches, three of which remain. These gave access through doors into the narrower brick vaulted substructure rooms that support the nave floor[16]. These vaults (3.2–3.4 m span) consist of radial bricks at the haunches and vertical bricks at the crowns (Fig. 14). The ends of each vault were built exclusively of radial bricks (34 × 34 × 7.5 cm)[17]. Given the projection from the wall of the radial brick haunches and the use of radial brick at the end, these vaults were probably built using wooden centering that could have been supported by the projecting course of impost blocks at the tops of the supporting walls. The basilica likely dates between the mid 2nd to early 3rd century AD given the urban development of the area, but specific dating criteria are lacking[18].

15 Aristid. 18-21. The earthquake is usually typically dated to 178, but for an earlier date in 177, see Behr 1968, 112 n. 168; Behr 1981 with notes.

16 Cüppers 1961, 29 n. 29.

17 Ward-Perkins 1958, 96.

18 Ward-Perkins 1955, 122 f.; Ward-Perkins 1958, 96; Lauter 1970, 84 f.

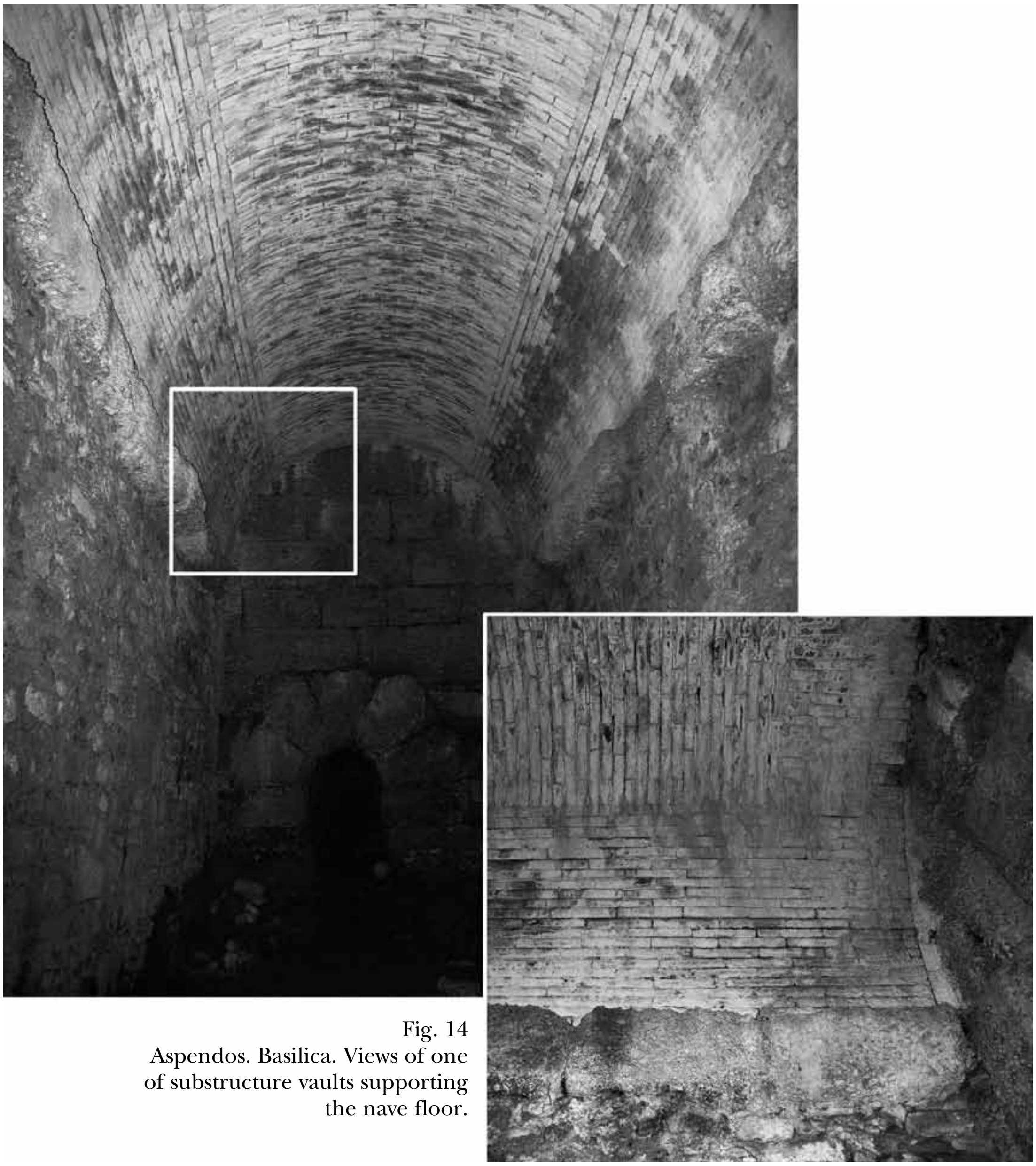

Fig. 14
Aspendos. Basilica. Views of one of substructure vaults supporting the nave floor.

Elaeussa Sebaste

An undated cistern on what was once the island of Elaeussa Sebaste has a partially preserved vault (6.68 m span) with radial bricks at the haunch and the beginnings of bricks that are somewhat pitched above. It is unusual in that the pitched bricks do not spring from a horizontal plane but are arranged in stepped fashion (Fig. 15). In spite of the angle of the bricks, the existence of holes for centering frames at the impost implies that the vault was constructed with formwork[19]. Another fragmentary and undated example of vertical brick vaulting can be seen in a later addition to the Reticulate Baths.

19 Spanu 1999, 92–95.

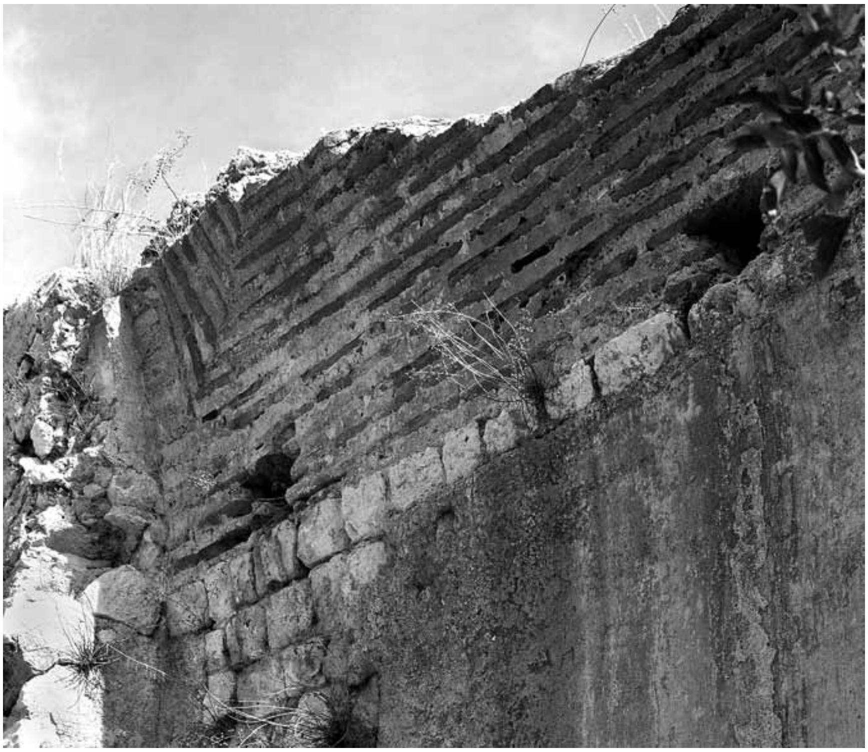

Fig. 15
Elaeussa Sebaste. Island cistern. Detail of remains of vault showing pitched brick and centering holes at impost. Note that the stepped pattern for the transition from radial to pitched brick is similar to the transition seen in fig. 20 (below) at the royal Palace at Assur.

Anamurium

A unique example of the use of vertical brick vaulting occurs in Bath III 2 B in Anamurium. This is the closest parallel to the vault at Argos because all the vaults were built of vertical bricks without the radial courses in the haunch (with the exception of a few courses to establish a base on which to lay the vertical bricks and a band of radial brick at each end of Room E). Only a few bricks remain in situ, but the impressions of the vertical bricks are clearly visible in all remaining vaults (Fig. 16). The span of the largest vault of this bath (Room D) rivals the Argos vault at 10.10 m, but the building is much later, having been generally dated to the mid 3rd century AD[20]. This bath represents the only structure in Anamurium built with brick vaults of any type; the typical building method for vaults here was radially laid shale.

Intention

The three earliest examples from Ephesus, Smyrna, and Aspendos, as well as the examples from Argos in the bath substructure and the agora drains, employ the vertical bricks only at the crown, so the primary intention in these examples seems unlikely to have been to avoid the use of centering and indeed the formwork imprints remain along some of the vaults of the bath substructure at Argos (Fig. 7). So, why did they choose to build in this manner? A barrel vault employing a different construction method may shed some light on the question. At Cremna in Pisidia, some of the barrel vaults that once covered the 16 chambers of a large cistern underneath the forum still remain. These vaults supported the

20 Rosenbaum et al 1967, 11–14. 75–77.

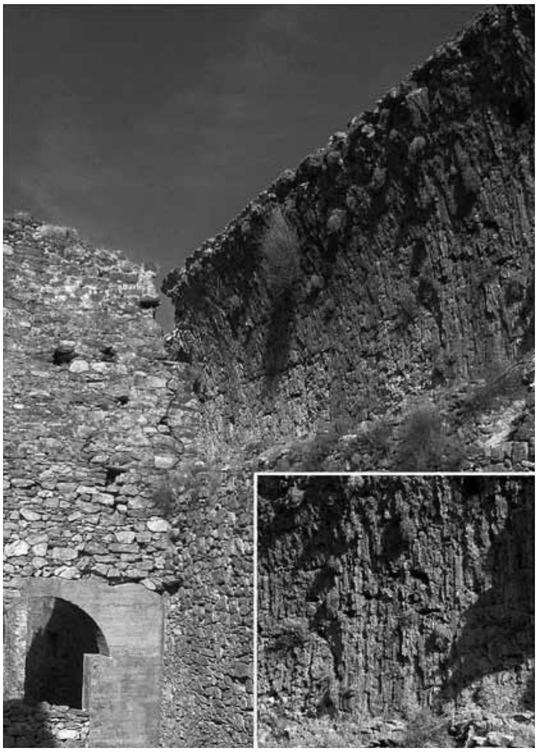

Fig. 16 Anamurium. Baths III 2 B. View of room G with inset showing detail of impressions in mortared fill of vault left by vertical bricks.

Fig. 17 Cremna. Agora Cistern. View of interior of one chamber showing the cut stone voussoirs at crown.

forum paving, some slabs of which are still visible. Each vault was built using two methods of construction. The haunches consist of mortared rubble whereas the crown was built with cut stone voussoirs (Fig. 17). One explanation for the use of the cut stone, which is a more labor intensive building method, at the crown is that the builders intended them to reinforce the most vulnerable part of the vault by controlling where the cracks could occur.

The crown of a barrel vault is commonly the first place that a crack develops. The typical failure mechanism for a barrel vault is shown in figure 18. Cracking is not a problem for stability as long as the supports at the side of the barrel vault do not give way. The vault will remain perfectly stable with the two halves of the arch propped against each other. This is known as a »three-hinged arch«[21]. Indeed, building an arch of cut stone is a means of controlling the location of the cracks so that they only occur at the joints. An example of a vault from the Outer Baths at Hierapolis demonstrates the typical failure pattern of arch with spreading abutments (Fig. 18). The builders would have observed this behavior at the crown, which would naturally have been perceived as the weak point in a barrel vault, so an attempt to reinforce the crown would have been an understandable response. However, in most cases the cracking is a cosmetic concern that does not necessarily signify that the building is in danger of collapse.

21 For an explanation of arch and vault failure mechanisms, see Block et al. 2006.

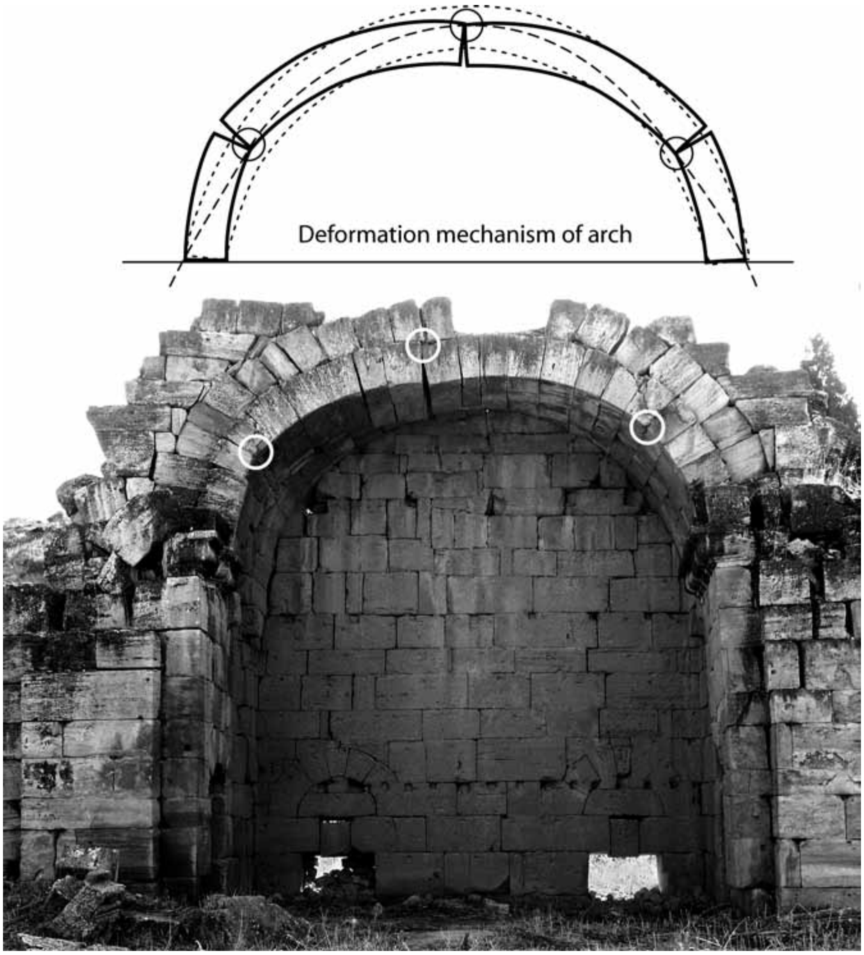

Fig.18 Hierapolis, Deformed arch in Baths out side city wall with diagram of deformation mechanism of arch.

Like the Cremna vaults, the examples from Asia Minor with vertical bricks at the crown formed floors for levels above, but the use of vertical bricks represents a somewhat different response than the Cremna vault. By building the crown in this manner, the builders eliminated the mortar joints that would naturally run along the crown of a radial brick vault. The interleaved bricks created a »zipper« effect that would have made the vault more crack resistant because the crack would have to cross through both brick and mortar rather than forming within a mortar joint between two bricks. Analysis on the bricks and mortar at the Hagia Sophia, for example, indicate that the bricks had a tensile strength of 30 kg/cm^2 whereas the mortar had only 4–6 kg/cm^2 [22]. In effect, the vertical bricks would have provided some additional resistance to tensile stresses and thus would have reinforced the vault to some extent; however, if the abutments began to spread, the levels of tension at the crown could easily have surpassed even the tensile strength of the brick.

The vault of room A1 at Argos is different from the others in that it has the unusual concrete and wooden superstructure above and it has virtually no buttressing. The builders were clearly concerned about the stability of the Argos structure when they developed

[22] Mark – Çakmak 1994, 277–279.

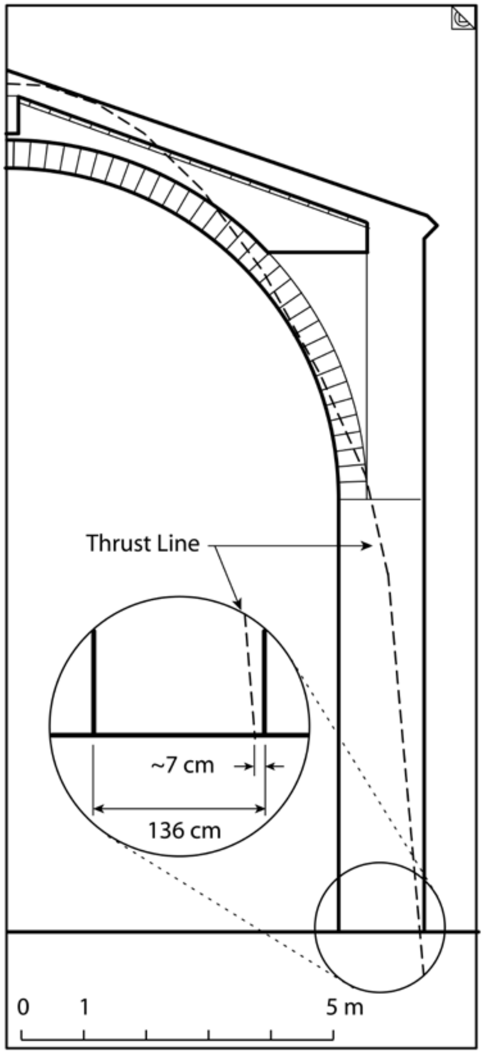

Fig. 19 Argos. Bath A, Room A1. Thrust line analysis through vault as reconstructed in figure 5.

such an innovative roof design that integrated the hollow spaces within the concrete with the use of a shell of vertical bricks. I suggest that this early use of the upright bricks in this very unusual vault was an attempt by the builders to provide it with additional tensile resistance to prevent it from cracking given the precariously thin supporting walls.

A question that arises is the degree to which such innovations actually contributed to the stability of the structure, which evidently stood for over four centuries. This is a question that can be answered by the application of thrust line analysis, a method of determining the amount of lateral thrust in structure under a given set of conditions[23]. The line of thrust in a vault is graphic representation of the internal line of force vectors within the structure. As long as the thrust line remains within the structure it is stable. Places where the thrust line touches the boundaries of the walls or vaults are where cracks may develop and threaten stability.

The upper part of the roof structure of A1 is missing, but an informed reconstruction can be made based on the standing remains,[24] which provide enough information to determine the ultimate height of the walls, the amount of fill and the basic outline of the pedimental roof. There are an infinite number of thrust lines possible for an uncracked structure, but by calculating the thrust line so that it touches the crown of the vault and the inside of the haunches (Fig. 19) in this experiment, I am assuming that cracks develop in these places and I am calculating the minimum thrust to test if the thrust line remains within the wall all the way to the ground. Given a density of 1650 kg/m^3 for the brick and 2100 kg/m^3 for the mortared rubble, the analysis shown in figure 19 reveals that the thrust line of the reconstructed roof configuration would remain within the supporting walls, but barely. This analysis provides the following information about the structure as reconstructed:

23 For an explanation of the principles behind this type of structural analysis and the method for applying it, see Lancaster 2005, 149–156. 225–229. For an interactive demonstration of thrust lines in arches, see http://web.mit.edu/masonry/interactiveThrust/examples.html.

24 This reconstruction is based on published plans, on my own photographs and measurements from the site and on observations offered by P. Vitti. The heights were determined by counting brick courses and using an average of 62.5 cm per 10 courses, which also corresponds to the average of 62–64 cm published by Ginouvès 1972, 233.

1) the fact that the thrust line remains within the wall confirms that the structure as reconstructed could stand, but the fact that the line comes so close to the outer edge of the wall illustrates that structure was in a precarious state right from the beginning.
2) given such a precarious state, the use of voids above the crown of the brick shell were critical in establishing stability.
3) the fact that the analysis allows for cracking in the vault demonstrates that structure would have stood even if the brick shell had been constructed of radial bricks. The use of vertical bricks to create the »zipper« effect to resist tension would have aided in the prevention of cracking, though given the precarious nature of the structure a crack at the crown was still likely to have developed at some point.

Origins

Finally, I want to address the question of the origins of the use of the vertical brick vaulting technique in Roman structures. P. Aupert and R. Ginouvès proposed that the use of the vertical brick vaulting at Argos is due to Egyptian influence, because they have argued that the original cult complex was dedicated to the Egyptian god Serapis[25]. As no votive offerings or inscriptions have been found, the evidence in favor of Serapis as the dedicatee is circumstantial and consists of a number of factors including the architectural form of the complex, sculpture and inscriptions found in elsewhere at Argos with Egyptian elements, and the provision of water for the complex. Indeed, remains of a 2nd-century AD aqueduct ran along the east wall of the south parados of the theater and could have supplied water to the tower courtyard[26]. A further argument for the Serapis attribution involves the conflation of a temple of Aesclepius at Argos mentioned by Pausanius[27] with this complex based on syncretism between Aesclepius and Serapis. The conversion of the cult complex into a bath is explained as part of its integration into a healing sanctuary in which the Aesclepius persona became the more dominant one[28].

Aupert and Ginouvès acknowledge that the technique of laying bricks »par tranches« was used in both Mesopotamia and Egypt, but in the course of mounting evidence in favor of the Serapis attribution, the vault at Argos becomes the »voûte egyptienne« and any possible Mesopotamian influence is left aside. In terms of examining the origins of the vaulting technique, the argument quickly becomes circular: the building demonstrates Egyptian influence because it is constructed with an Egyptian vaulting method, which is not Mesopotamian because it occurs in a building dedicated to an Egyptian deity. My intention here is not to determine the dedicatee of the original cult building but rather to look at the evidence for the origins of this vaulting technique without the preconceptions inherent in their argument.

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25 Aupert – Ginouvès 1989, 151–155.

26 Aupert 1986, 769; Aupert 1994, 195 f. also suggests that the crypt was a basin for water, but the pattern of encrustations suggest that they accumulated after it was no longer in use.

27 Paus. 2.21.1.

28 Aupert 1985, 172–174; Aupert – Ginouvès 1989, 151; Aupert 1994, 193–200.

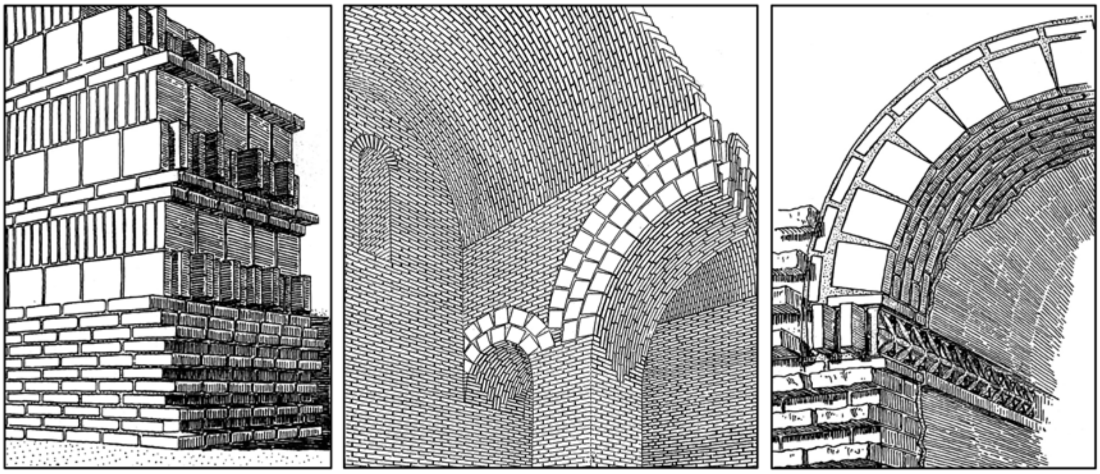

Fig. 20 Assur, Royal Place. Details of construction.

The characteristics that distinguish the Roman vaults are that they are made of fired bricks instead of mud bricks and that the bricks are laid vertically instead of pitched, and that radial and vertical bricks are often combined in the same vault. These characteristics are, in fact, found in the Parthian architecture of the 1st century AD in Mesopotamia, where builders of the royal palaces were experimenting with new uses of this old technique, undoubtedly inspired by examples from the Roman west. The palace at Assur (1st century AD) was built using fired brick with gypsum mortar, and the vaults were combined in a complex manner such that a series of arched openings supported a second series of barrel vaults above (3.5–5.0 m span; Fig. 20). There, the bricks were all laid vertically instead pitched, in part because they actually formed part of the facade of the wall. These vaults no longer remain standing, but the excavators in the 1930s found the fallen pieces of vaulting and the springings on the support piers[29], so a reconstruction is possible[30]. The vertical bricks were also used to form the imposts of vaults at the palace (Fig. 20). The idea of setting the bricks vertically so that vaults could be combined in this way may have been influenced by a method of wall construction peculiar to Mesopotamia in which courses of brick were alternated between flat and upright (Fig. 20). Moreover, there are Parthian examples elsewhere of vaults that combine either pitched or vertical bricks at the crown with radial brick haunches. At a burial chamber in Seleucia-on-the-Tigris, the vault (3.2 m span) consists of radial brick haunches and a pitched brick crown[31]. Another Parthian example at Qal' eh Zohak, in Azerbaijan displays all these techniques together in one facade: an arch of radial brick at the haunches, vertical bricks in the crown and alternating horizontal and vertical bricks in the surrounding walling[32]. The builders in Roman Egypt during the 1st century A. D., on the other hand, continued the tradition of using pitched

29 Andrae – Lenzen 1933, 27, 43 f. Taf. 10.

30 Reuther 1938, 423 f.

31 Hopkins 1972, 68; Yeivan 1933, fig. 9. Pl. 20.

32 Besenval 1984, 162; pls. 85 b; 85 c; 86 a.

mud brick, with the arches often forming parabolas instead of semicircles, and they are usually found in fairly simple domestic or utilitarian structures[33].

A number of possible modes of transmission for Parthian building techniques into the Roman world are possible including traders, soldiers, and captives. The last two are more likely than the first because we know that they both belong to classes of people involved in the building trade. From as early as the Augustan period Parthian archers formed ala of auxiliary units in the Roman army[34]. During the 1st century AD when the more advanced techniques appear in Parthian architecture, Roman legionaries would have come into contact with Parthians and with the structures they were building during campaigns under Nero in Armenia. Moreover, enemy captives were regularly taken as a natural part of warfare as Tacitus describes in Corbulus's taking and auctioning off of the non combatants captured at Volandum in AD 58[35]. The result of such activities is even recorded in a 1st century AD tombstone found at Ravenna, of C. Iulius Mygdonius who describes his plight[36]:

»Caius Julius Mygdonius, born a free man in Parthia, was captured in his youth and sold as a slave in Roman territory. Once I became a freedman and Roman citizen, thanks to kind fate, I saved up a nest egg for when I reached fifty. Ever since my youth I have been traveling toward old age, so now, O grave stone receive me willingly; in your care I will be released from my worries«[37].

Mygdonius's life story is somewhat similar to, though less illustrious than, the more famous imperial freedman, Zoilos, at Aphrodisias[38], but such stories of capture, displacement, and manumission must have been quite a common occurrence in the Roman world, and no doubt some of these slaves and freedmen ended up in the building trade throughout the empire.

The examples from Asia Minor of vaulting with the vertical bricks occur both along military transport routes and in coastal locations[39], making them prime locations for soldiers and captives to find themselves. The southern coast of Asia Minor provided important military way stations during the eastern campaigns. For example, Elaeussa Sebaste and nearby Korykos both minted coins calling themselves »mistress of the fleet« (NAVAPXIC)[40]. In the case of Ephesus, an inscription even places troops of Lucius

33 Ward-Perkins 1958, 91–93. fig. 20.

34 Kennedy 1977, 521–531.

35 Tac. Ann. 13.39.

36 CIL 11, 137=ILS 1980: C · IVL · MYGDONIVS/GENERI · PARTHVS/NATVS · INGENVVS · CAPT/PVBIS · AETATE · DAT · IN · TERRA/ROMANA · QVI · DVM · FACTVS/CIVES · R · IVVENTE · FATO · CO/LOCAVI · ARKAM · DVM · ESSE/ANNOR · L PETI · USQ · A PVB/ERTATE · SENECTAE · MEAE · PERVENI/RE · NVNC · RECIPE · ME · SAXE · LIBENS/TECVM · CVRA · SOLVTVS · ERO.

37 Translation from Aldrete 2004, 87.

38 For Mygdonius, see Gardthausen 1906, 848 f.; for Zoilos, see Smith 1993, 4–10.

39 Mitchell 1993, 120 map 127.

40 Hill 1900, 69 f. (Korykos- Valerian and Salonina wife of Gallienus), 235 f. (Elaeussa Sebaste- Comodus and Geta).

Verus, who were returning from their victorious Parthian campaign, in Ephesus for 13 months from AD 166[41], which falls in the same period when the barrel vault at Terrace House 2 has been dated.

The bath at Anamurium, which is built almost exclusively with vertical bricks, is quite unique for its context since brick was used sparingly in this city (usually for praefurnia and hypocausts in bath buildings) and rarely, if ever, for vaults. The mid 3rd century date of this bath roughly corresponds with Sassanid invasion of Cilicia by Shapur in AD 260, during which time Anamurium was captured and under Sassanid control. The Sassanid dynasty deposed the Parthians earlier in the 3rd century and continued the tradition both of building vaults using vertical and pitched bricks and of fighting the Romans[42]. These events may help explain why this unusual technique was used at this site; however, the dating of the building is not specific enough to make a direct link between the two.

For the example at Argos in Greece, which was a less militarized area of the Empire, such connections are more difficult to trace; however, we know that military personnel were often sent to oversee building projects. For example, under Hadrian military experts were sent to supervise a project at Lake Copais in Boeotia. Likewise, a frumentarius from Legio I Italica, which had fought in Trajan's Parthian campaigns, was sent from Moesia Inferior to Delphi to supervise Hadrianic projects and was awarded citizenship there[43]. Admittedly, there were many Egyptians recruited into the Roman army, so Egyptian building expertise could be spread in a similar manner. Nevertheless, the fact remains that the details of the construction at both Argos and the examples from Asia Minor share more with Parthian models than with Egyptian ones. The vault of room A1 at Argos is extraordinary both for its strikingly unusual and daring roof structure and for being both the largest and among the earliest examples of the technique of using vertical bricks in barrel vaults. Alas, unless more information comes to light, we will probably never know exactly how or why it took the form it did.

41 FiE no. 80; Mitchell 1993, 252.

42 Another example of this type of construction can be seen in the Museum Baths at Side. They have been dated much later, in the 5th century AD, but the evidence for dating is not definitive: Mansel 1963, 148–155.

43 Mitchell 1987, 338 f.; Robert 1937, 88 f.; Fossey 1982, 44–59.

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