

CURRENT INTERDISCIPLINARY STUDIES IN TECHNOLOGY IN THE ARCHAEOLOGY OF THE SOUTH-EAST EUROPE  
AKTUELNA INTERDISCIPLINARNA ISTRAŽIVANJA TEHNOLOGIJE U ARHEOLOGIJI JUGOISTOČNE EVROPE



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## **CURRENT INTERDISCIPLINARY STUDIES IN TECHNOLOGY IN THE ARCHAEOLOGY OF THE SOUTH-EAST EUROPE**

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# CONSTRUCTING LATE ANTIQUE BARREL BRICK VAULTS WITHOUT FORMWORK ON THE TERRITORY OF TODAY'S SERBIA

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**Keywords:** *building technique, Late Antique vaults, bricks, Serbia*

## **Introduction**

The use of wooden formworks has certainly been one of the basic principles in the techniques of constructing brick and mortar vaults throughout the centuries. The primary reason for the use of formworks is the fact that, during the construction, brick rows with too large an inclination angle may start sliding. This occurrence is especially conspicuous when the mortar of the vault is still in a liquid state. Therefore, the scientific and expert public is often under the impression that vaults cannot be made without the use of formworks.

Throughout the development of architecture, special forms of building processes can be noted in which formworks had obviously not been used. This paper will deal with first such examples on the territory of Serbia, in the form of the simplest barrel vaults and a similar, conoid type of vaults. When it comes to barrel vaults, the centre of the curvature is stretching along the same horizontal line, and the radius of the curvature has a constant value. When it comes to conoid vaults, aside from the fact that the centre can be stretching along a line with a certain slope, there is also a decrease of the radius of the curve toward one end of the vault.

The stability of the vault is an essential problem during the construction. When it comes to vaults and arches, the greatest problem with their stability is the transfer of their own load and the load of the mass above them onto sufficiently stable supports. During the construction of vaults, there is also the question of stability of unfinished structures, and the load is usually transferred onto wooden formworks.

## **Vaulting techniques without formwork**

However, one of the more specific manners of constructing vaults is the one without the use of formworks. In all types of vaults, the need for a wooden formwork depends on the manner in which bricks are placed within the surface of the vault. Auguste Choisy was one of the first to notice this circumstance in barrel vaults, providing adequate illustrations of building techniques (Karydis 2012: 7–8, Choisy 1883: 21–48).

The first type of building pitched bricks vaults had been known in Egypt and Mesopotamia in the 3<sup>rd</sup> millennium BC (Lancaster 2015: 39–40). Barrel and conoid vaults made in this technique were formed from brick rows leaning

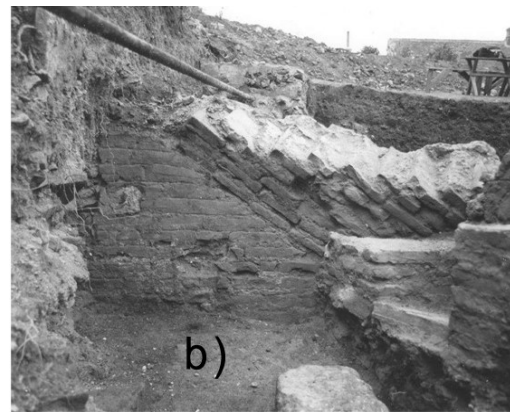
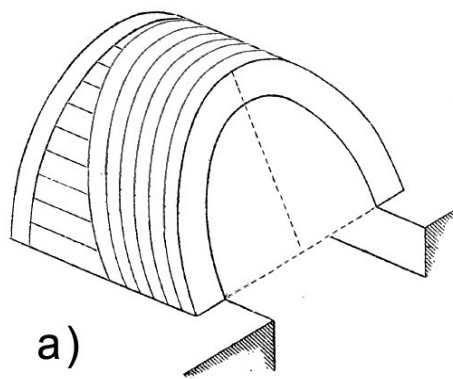


at an angle, with every following row leaning onto the previous one (Fig. 1a). A series of these rows forms the curved surfaces of the barrel type of vaults. In order to achieve this type of slope, it is necessary to form a safe support for the first row of the vault which is being built. Most commonly, the support for the first row is a front wall, which closes the transverse diaphragm arch (barrel opening) of the vault, i.e. the lunette, and in some cases the walls between the first leaning row and the diaphragm.

Built arches and vaults appear on the territory of today's Serbia for

of the canal wasn't demanding in itself, since constructions of this type did not require large spans. Here, however, we will describe an older example instead, where the spans of the vaults were such that the area under them could have been used as a useful surface.

The method of building by arranging rows of bricks under a constant inclination angle is present in the conoid and barrel vaults of the Hippodrome of *Sirmium* (Јерemiћ 2016, 248-252, fig. 180) (Fig. 1b). The Hippodrome originates from the second or the third

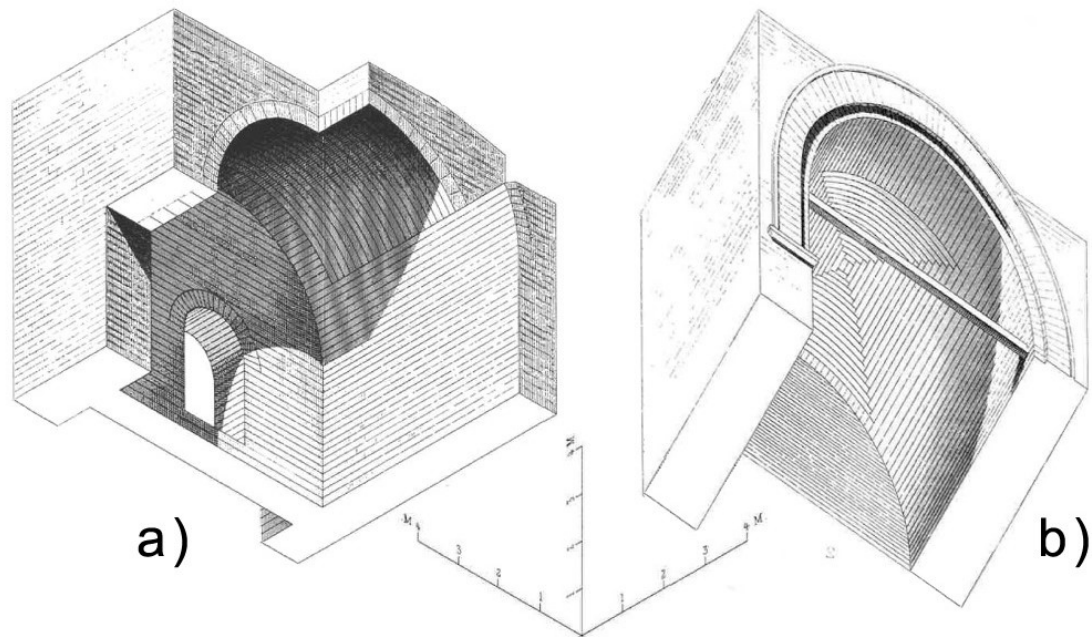


**Fig. 1** a) A method of building barrel vaults with rows leaning at an angle (Choisy 1883, fig. 42); b) Remains of conoid vaults of the Hippodrome of *Sirmium* built with brick rows leaning at an angle (photo by N. Borić, according to M. Jeremić 2016, 180).

the first time during the period of the Roman dominion. In terms of the history of architecture, it was Miroslav Jeremić who studied built Roman vaults made without formwork (Jeremić 2006). Certain segments of his work dealing with the topic of barrel vaults can be supplemented today. Namely, in the work of M. Jeremić there is only one example listed of barrel vaults built with this technique, and it comes from the 6<sup>th</sup> century – the example of the drainage sewer system from Caričin Grad (Jeremić 2006: Fig. 9). The building

quarter of the 4<sup>th</sup> century (Поповић, Ochenschlager 1976: 64). In the area of the turning point of the Hippodrome of *Sirmium*, more specifically, under the seating tiers there, conoid vaults were made, while barrel inclined vaults were constructed under the seating tiers which were in parallel with the axis of the Hippodrome. The spans of the barrel and conoid vaults above them vary from 2.30 m to 4.00 m (Јерemiћ 2016: 249).

The other type of building technique for barrel vaults without temporary formworks comprehended



**Fig. 2** a) The technique of building barrel vaults without formworks, with a combination of radial rows of bricks in the lower part and vertical rows in the upper part; b) A subtype of the previous type, where horizontal and vertical brick rows are combined in the upper part as well.

a slightly more complex geometrical approach in arranging brick rows. Essentially, two different manners of arranging brick rows would be alternated (Fig. 2a). The first of them was the usual manner, in which the rows were laid radially, so that the bed joints of bricks would be on the radial line of the curvature of the arch, i.e. the vault. This method was applied in the lower part of the vault, which was closer to the support points. The other method was applied in the upper part of the vault – the brick surface was built in a manner similar to the previous one we described while reviewing the first type of technique of building vaults without formworks – with vertical rows within which every single brick was placed at a certain angle. With the set angle, every brick of the following vertical row would lean onto the bricks from the previous vertical row.

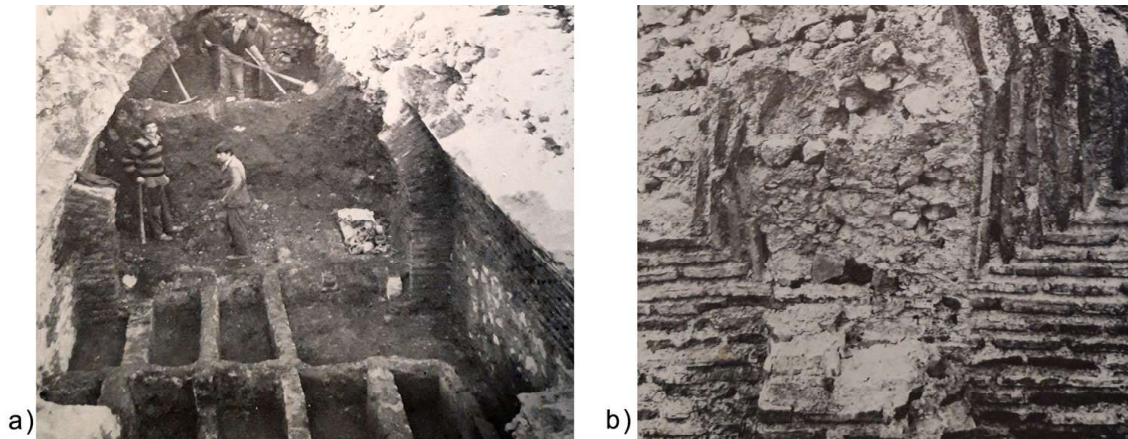
Many of the Late Antique vaults of this type were made precisely in

the previously described manner – by applying one building technique in the lower part, and another one in the upper part of the vault (crown) (Lancaster: 40). However, within this type of building, one subtype of the mentioned technique stands out, in which a slightly different combination of described techniques was used in the upper part; namely, the length of the vertical rows would gradually decrease from the protruding ends towards the top of the vault, from the end of the vault towards its centre. This subtype of this building technique has been initially registered on Byzantine monuments (Fig. 2b), but it is also present on older Roman monuments in Argos and Ephesus, from the 2<sup>nd</sup> and the 3<sup>rd</sup> century (Lancaster 2010: 456, Lancaster 2015: 39-69; Vitti 2013: 58, 60, 71) and on the triumphal Arch of Galerius in Thessaloniki (Lancaster 2015: Fig. 39).

On the territory of today's Serbia there is only one registered example of

barrel vaults made with a combination of radial and vertical rows of bricks without using formwork. It is located in a Late Antiquity tomb intended for group burials, within the church yard of the Monastery of the Mother of God

uncovered so far, the building of the tomb at the Monastery of the Mother of God in Hvosno could be dated into the 5<sup>th</sup> century. The span of the barrel vaults within the grave construction is 4.40 m.



**Fig. 3** a) A Late Antique tomb intended for group burials, discovered at the Monastery of the Mother of God in Hvosno (Kopaň 1976, Сл. 108); b) Remains of a supporting arch between two compartments in the central part of the grave construction; remains of the vaults' quoins are visible on the left and the right (Kopaň 1976, Сл. 110).

in Hvosno (*Bogorodica Hvosnanska / Studenica Hvosnanska*) (Kopaň 1976: 34). Researches have unequivocally established that the medieval monastery had been built on an older Late Antique, i.e. Early Christian cult place (Kopaň 1976: 17). Even though the tomb was dated into the 6<sup>th</sup> century on the basis of the building technique, according to V. Korać, and based on Byzantine analogies, the date of construction can actually be changed to the previous century. Namely, Korać was unaware of the previously mentioned considerably earlier examples of this building technique for making vaults from cities of the Aegean Sea region. The burial method from this tomb is identical to examples noted so far in *Naissus*, *Viminacium* from the 4<sup>th</sup> or the 5<sup>th</sup> century (Мирковић 1954-1955: 53-54; Зотовић 1994: 62-63). According to examples

## Conclusion

The appearance of barrel and conoid vaults for which building technique was used that didn't require formworks is so remarkable that it is necessary to establish, in the first place, the reasons it appeared at all, or, more importantly, why it was used to such a limited extent. The territory of Serbia could hardly be described as lacking in wood material necessary for making formworks. This circumstance certainly explains the small number of examples of techniques for building vaults without the use of formworks, which comprehend the few examples of barrel vaults made in this manner. The reasons for opting to use this technique in places where it was registered were certainly of a different nature.

Aside from the expenses for

the material (the amount of material, preparations and transfer) required to construct formworks for barrel and conoid vaults, skilful carpenters were necessary. Reasons for applying the building techniques we just described had been of predominantly economic nature, because a whole series of processes and unnecessary expenses would have been avoided that way. This specific building technique also guaranteed a greater speed of performing the construction, because, in this manner, the making and also disassembling of the formwork would have been avoided. A special quality of the technique described was its static reliability. Craftsmen of foreign provenance are the only possibility that can explain the appearance of the few, and thus exceptional examples of the building technique without formworks on the territory of Serbia. The technique of building barrel vaults without formworks in the Hippodrome complex in *Sirmium* is the first known example of these specific techniques, and it is certain that it was a part of the building activity initiated by Roman emperors. Namely, it is certain that the building of the monumental imperial Hippodrome in the vicinity of the imperial palace conditioned certain specific traits of the construction as well. One of them was the size of compartments under the seating tiers (with a 4 m span). In this sense, some of the prominent builders of monumental structures would also have had to be hired for the imperial Hippodrome, and the closest ones among the best were certainly those from the shores of the Aegean. According to their solutions, the load due to the pressure of the vault and construction above it was distributed on neighbouring walls as well, upon which sloping rows of the

vaults were partially leaning.

The second example of barrel vaults comes from a somewhat later period. It can be found in an Early Christian tomb at the Monastery of the Mother of God of Hvosno. The span of the vault is almost identical to the one from the previous example, however, progress in building techniques for barrel vaults can be seen in the manner in which the vault of this Early Christian tomb was made. The stability of the vault was provided through specific self-supportive vertical slices within this technique, which enabled them to avoid load transfer onto any of the neighbouring walls except for the ones that the vault was actually leaning onto in the lower part.

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