The Basilica of Maxentius in Rome: Innovative Solutions in the Organisation of Construction Process

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The Basilica of Maxentius (which was constructed in the early 4th century A.D.) was one of largest concrete structures built in ancient Rome and featured both cross and barrel vaults that spanned over 20 metres., it therefore represents one of the most advanced buildings of the time (fig.1; See AAVV 2005 for general details on the construction and structural behaviour of the Basilica).

Figure 1. Basilica of Maxentius. Reconstructed image of the interior of the Basilica, entering the nave from main entrance.

Studying important and highly original buildings like the Basilica Maxentius can reveal innovative construction techniques that more modest buildings (which are usually constructed following traditional techniques) do not show. The use of scaffolding in recent restoration work at the Basilica has allowed a more detailed analysis of the wall surfaces; this has revealed some unique building techniques which also shed light on the organization of the construction process.

A sophisticated technique was to build a continuous wall that supported different loads in different sections, but always connected to the vaults above, and therefore experiencing different stresses from one part to another. Each section, which experiences a different loading condition, was built separately with a construction joint in between. This shows a clear understanding of the structural problem. The segments of wall subject to different loading conditions were purposely left without any type of toothing at points corresponding to construction joints. When each section settled at different rates, controlled cracks developed along these pre-determined joints. The designers preferred not to interfere with the likely differences in compressive loads that would take place during settlement. Rather than allow uncontrolled cracking they counted on the strength of the massive walls to allow for "planned cracking" (figs. 2-3).

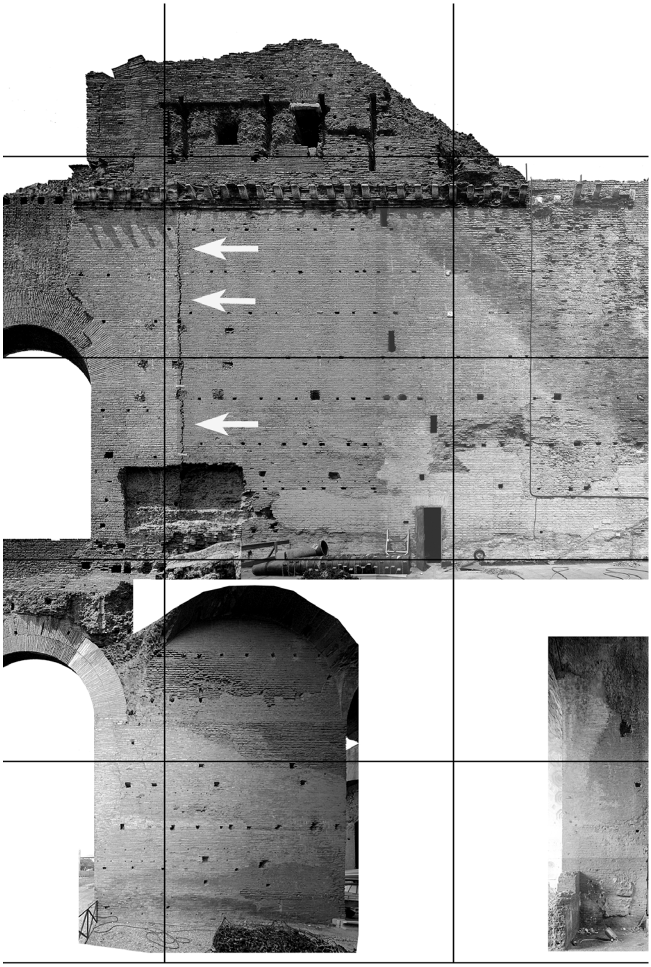

Figure 2. East perimeter wall, exterior. Construction joint between the section of the wall supporting the barrel vault, which was subject to enormous loads in part due to the thrust of the adjacent cross vault over the central nave, and the windowed infill section of the wall, which was subject to only minor loads. During a second phase, a large ribbed buttressing arch has been constructed against it to ensure the stability of the wall, leaving clear traces in the original wall.

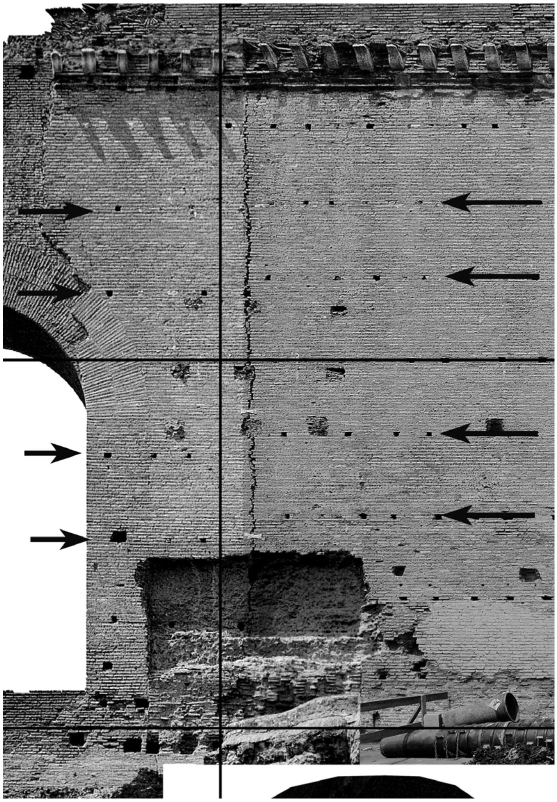

Figure 3a. The arrows show the different alignments of the putlog holes on each section of the wall, clearly built as two different part; the resulting joint purposively has no toothing.

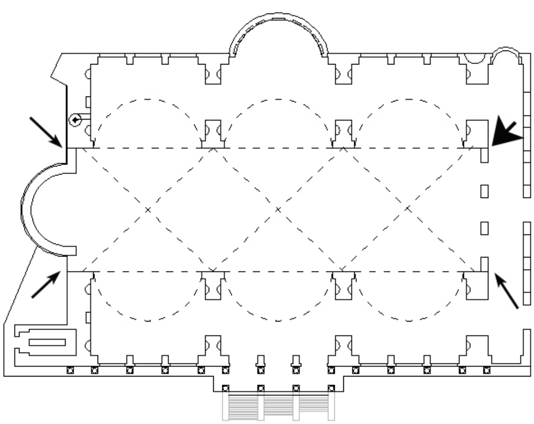

Figure 3b. Position of the four major free joints of the Basilica; the enlarged arrow indicates the wall shown above.

The same system was used to build the upper part of the supporting wall of each pair of barrel vaults, to which was attached one of the columns supporting the cross vaults over the central nave; structurally, this is the key point in the design of the roof system of the Basilica.

Analysis of the composition of the brick facing reveals that the concrete in the barrel vaults over the lateral aisles was placed seamlessly up to the planned height of the capital of the supporting column. From here upward construction continued on all the vaults at the same time (though each was built separately and with its own extrados) leaving the in-between spaces to be put built later at the back of the entablature (figs. 4, 5).

While the marble decoration was being applied to the face of the wall, the column was raised and put into position, and the entablature was inserted into the cavity reserved for it. Only later was the wall completed, creating the horizontal plane that acted as the abutment for the cross vaults. Yet again the wall segment below the inserted entablature was built separately and without toothing, (which would support the spring of the two cross vaults and a much greater load than those of the lateral segments).

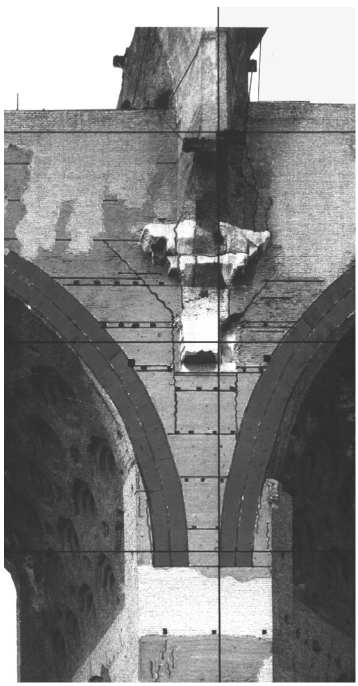

Figure 4. Photogrammetric image. Central nave: face of the upper part of the supporting wall of a pair of barrel vaults, to which was attached one of the columns supporting the cross vaults over the central nave. The compression loads on the part of the brick-faced walls supporting the cross vaults (under the entablature) were proportionally much greater than those of the lateral segments. This clearly differentiated treatment, designed to avoid uncontrolled structural cracking, reveals a remarkable amount of experience gained in the design and construction of vaulting systems.

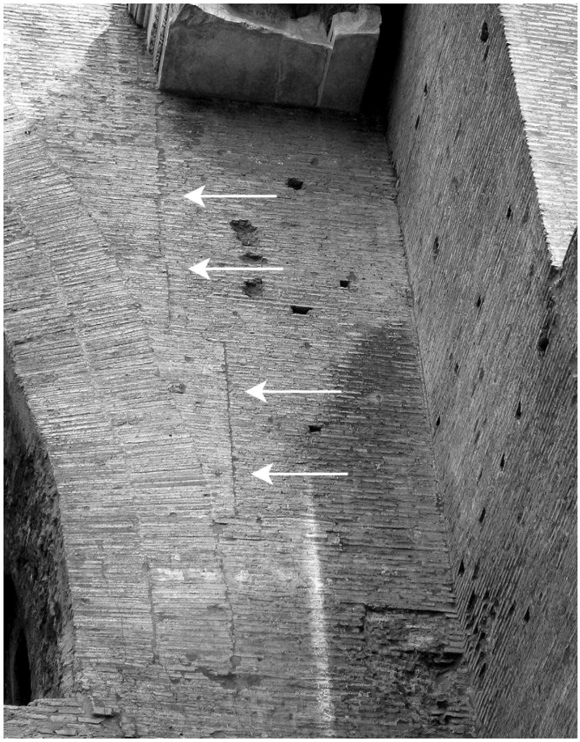

Figure 5a. Northeast supporting wall. Construction joint with no toothing between the section of the wall supporting the barrel vault and part support of the spring cross vault located on top of the entablature.

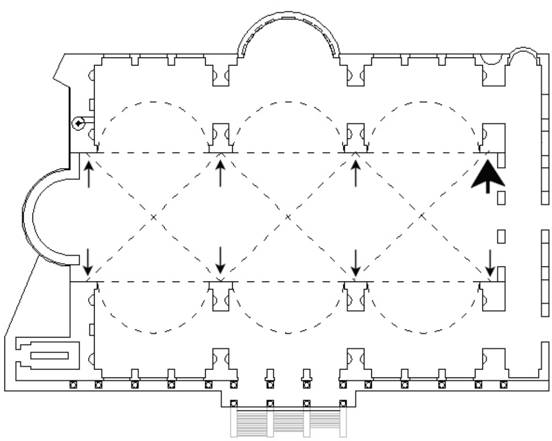

Figure 5b. Position of the eight supporting piers of the Basilica; the enlarged arrow indicates the pier shown above.

This construction worked mainly thanks to the use of lattice ribbing, a technique employing bricks inserted into the concrete in a carefully arranged pattern so that it provided a means of stiffening vaults and a way to optimise load distribution (for a clear discussion on the use and the meaning of the ribs inserted in the concrete of the vaults see Lancaster 2005, pp. 86-112). The barrel vaults in the nave of the Basilica have two layers of ribbing for each vault, which can be seen in the façade as two concentric arches of *bipedales* and were completed before the haunches were filled.

The outcome was a sort of strong ribbed shell over the centering that hardened well before the filling of the spandrels and the insertion of the blocks of the entablature. The vaults were then finished with several horizontal layers of concrete. This complex procedure allowed the use of an innovative method of constructing using strong supporting walls in connection with huge barrel and cross vaults.

A less complicated and more flexible method was used to ensure that the vaults were built to the proper thickness and the upper walls were built plumb over the lower walls. During the construction of the cross vaults over the east porch, terracotta tubes of about two-thirds of a Roman foot in diameter (around 20 centimetres) were positioned vertically over the centering against the exterior face of the piers before the concrete was placed (figs.6,7,8).

Figure 6. East end. Remains of terracotta tubes used as reference devices on the face of the walls and along the edge of the cross vaults.

Figure 7. Porch, north end. Remains of a well-preserved terracotta tube at the spring of a cross vault placed perpendicularly to the exterior limit of the upper wall.

Thus the tubes could be used to determine from the extrados of each vault the exact thickness of the concrete by means of a measuring stick. The tubes also made it possible by the use of a plumb line to determine the correct position of the walls built over the piers above the level of the vault. They were hidden from above by the floor of the terrace, and from below (once the formwork and the centering had been removed) by the painted plaster and stucco mouldings.

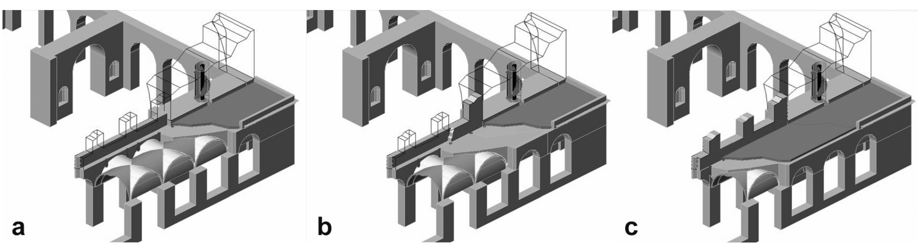

Figure 8. Reconstruction of the building sequence of the east porch. a) arranging the terracotta tubes on the extrados of the centering, marking the correct positioning of the upper piers; b) laying out of the cross vaults in parallel layers up to the upper end of the tubes; c) layout of the floor of the terrace which obscures the tubes.

An analogous but necessarily more complex strategy was used during the construction of the large barrel vaults over the aisles to precisely position the large buttressing arches that support the cross vaults over the nave. These buttressing arches have been correctly designed with a reduced width with respect to the walls on which they stand and, because of this, required careful measurement to position them.

Three horizontal cavities running through the thickness of the wall were created along the springing line of each barrel vault before the installation of the centering and are marked by a line of bipedales in a strip of wall approximately 90 centimetres high (fig.9).

Figure 9. Southwest perimeter wall, interior. The rectangular holes are clearly visible and are built along the spring line of the vault. They are marked by a course of *bipedales*, connected with the reference tubes. Each cavity is 45 centimetres wide, 35 centimetres high and 124 centimetres deep and have *bipedales* on top.

A terracotta tube was then placed vertically so that it intersected each of them at the end (figs. 10-11); cavity depth is exactly the thickness of the two concentric rings of lattice ribbing forming the shell of the barrel vault, and allows a series of tubes to be built into the vaults.

The rectangular holes provided support to the main beams of the centering frame that probably also had ground supports. The holes are regularly positioned along the perimeter wall. Once the centering was removed it was possible to again use the cavities to check the conformity to the vertical line of the tubes; and also use them as reference points on the extrados of the vaults to identify the exact position of the face of the buttressing arches, and finally to check the thickness of the concrete.

Figure 10. Remains of a series of vertical terracotta tubes with a 25 centimetre diameter and 250 centimetre height buried in the remains of the vault. Concrete above the ribbed sections of the vault was made lighter by the use of *tufo giallo* and grey pumice.

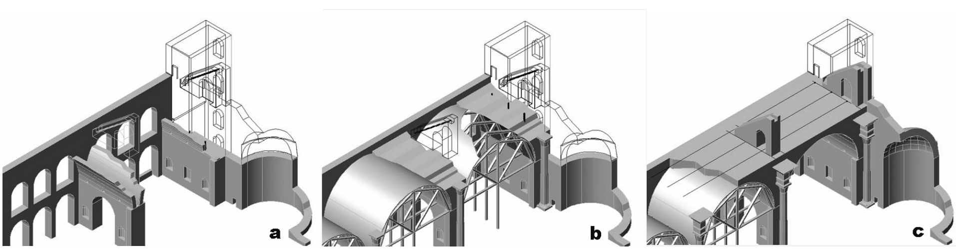

Figure 11 Reconstruction of the building sequence of the south-west aisle. a) arrangement of the terracotta tubes at the spring of the two concentric rings of lattice ribbing forming the shell of the barrel vault. Also shown is the locations of the main beams of the centering, marking the correct positioning of the buttressing arch; b) layout of the vault arrangement, in parallel layers up to the upper end of the tubes; c) removal of the centering, checking of the thickness of the concrete and of the vertical line of the tubes (which are used to fix the exact position of the buttressing arches). The floor of the terrace eventually hides the tubes.

A close examination of the wall at the springing line of the corresponding barrel vault on the north-west end has confirmed an identical situation: the holes are closed off at the face of the wall with mortar and brick fragments, and the resulting surface plastered over to create a continuous intrados.

To fully appreciate the advantage of having rapid access to the reference points for checking during construction, it should be pointed out that the barrel vaults over the aisles (which have a span of 23.5 metres and total length of approximately 86 metres and width of about 17 metres) were all built at the same time. Furthermore, the construction of the four buttressing arches on each side was done without interruption and before the placement of the floor mortar over the terrace; this ensured maximum cohesion with the vaulting system below and provided a stable support at the springing of the cross vaults.

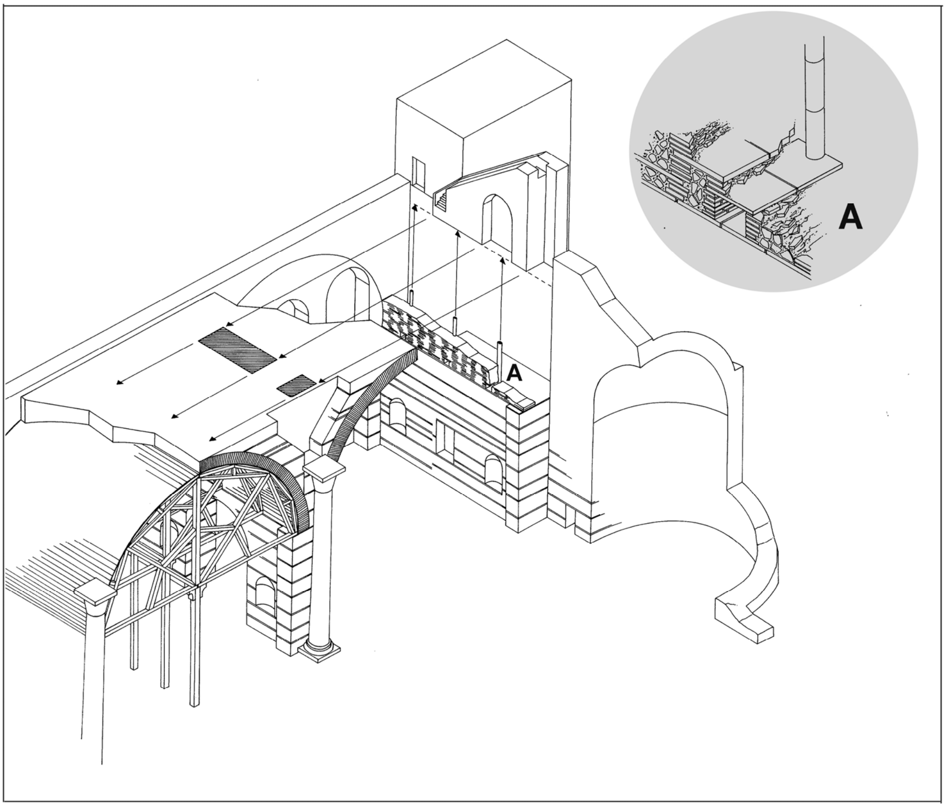

Figure 12. South-west aisle, axonometric sketch. The insertion of terracotta tubes at both ends of the aisles allows for easy and accurate positioning of the buttress arches. The insertion of the rectangular holes at the spring of the barrel vault is carefully made out of the intricate network of the lattice ribbing.

This technique – while not unique to the Basilica – appears not to have been used elsewhere in such a carefully planned manner. Other more obscure examples of the technique can be found in several of the side rooms of the so-called Basilica of Trajan Market and in the substructures of the Severian Bath on the Palatine (fig.13).

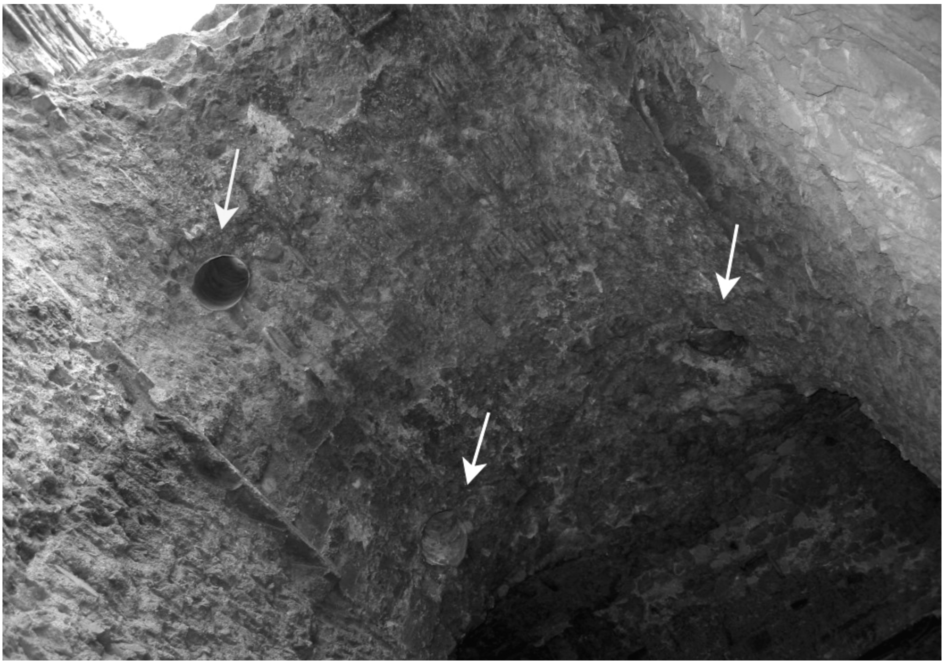

Figure 13. Palatine, substructures of the Severian Bath. Barrel vault built on brick linings of bipedales and bessales, with lattice ribs and reference tubes embedded in the concrete.

Both techniques come about through an understanding of loading conditions (tensile stresses, lateral thrusts and load distribution) acquired over six centuries of building and the need for temporary formwork to support the building of huge vaults. The use of the techniques allowed savings in construction time but required careful planning to sequence the work. Not only was it necessary to consider the architectural style of a building like the Basilica of Maxentius, but also how such a huge building was to be constructed. The use of sophisticated construction techniques raises interesting questions on the role and responsibilities of the architect and/or builder on a Roman building project. (See Daguet-Gagey1997; Rea 2002; Martin 2004 for details on the organization of the building industry in imperial Rome).

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