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

(Carla Maria Amici)

The Basilica of Maxentius, constructed in the early 4th century A.D., was one of largest concrete structures built in ancient Rome with cross and barrel vaults that spanned over 20 m., and therefore represents the most advanced building methods of the times (fig.1; AAVV 2005 for general details on the construction and the structural behaviour of the Basilica).

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

As is so often the case in the practical achievement of important and highly original architectural projects, a careful analysis of the construction of the Basilica unveiled a dynamic architecture that featured a number of innovative elements. Some of these were special solutions and clever expedients developed within the context of construction practices that were by then well-established, after the amazing feats of the Trajanic-Hadrianic period; clearly showing that to find true innovations that can provide insight into the art of building, one must analyse large and noteworthy structures that have made an architectural impact on their environment. More modest structures, even if they can offer original insights, rarely modify the building techniques developed within a particular culture and very seldom are able to have an influence on later constructions.

The availability of extensive scaffolding in recent restoration work at the Basilica has allowed for a detailed documentation of the wall surfaces and has revealed some very unique building techniques that shed light on the organization of the construction process.

A sophisticated expedient has been used to build a continuous wall that supported different weights in different sections, always in connection with vaults above, and, therefore, underwent different stresses from one part to another. Each section undergoing a different load was built separately with a construction joint in between, showing a clear understanding of the structural problem. The segments of wall subject to differing structural 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. In fact, the designers preferred not to interfere with the probable 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).

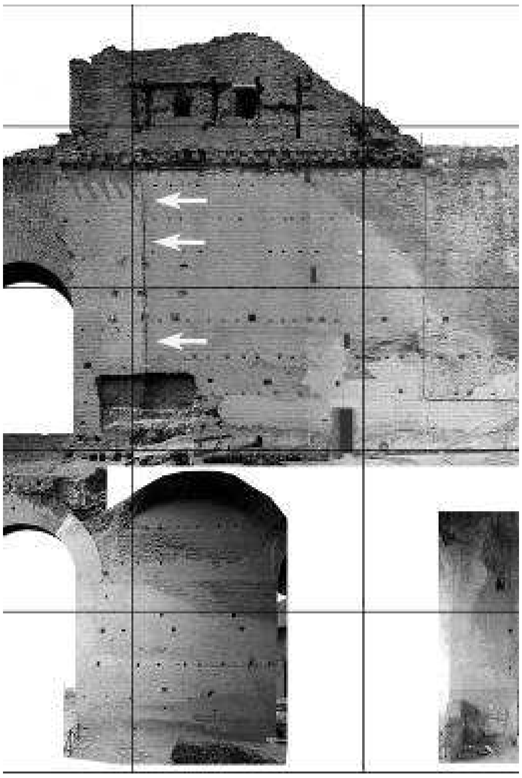


Figure 2. East perimeter wall, exterior. Construction joint between the section of the wall supporting the barrel vault, which was subject to enormous loads in part due to the thrust of the adjacent cross vault over the central nave, and the windowed infill section of the wall, which was subject to only 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.

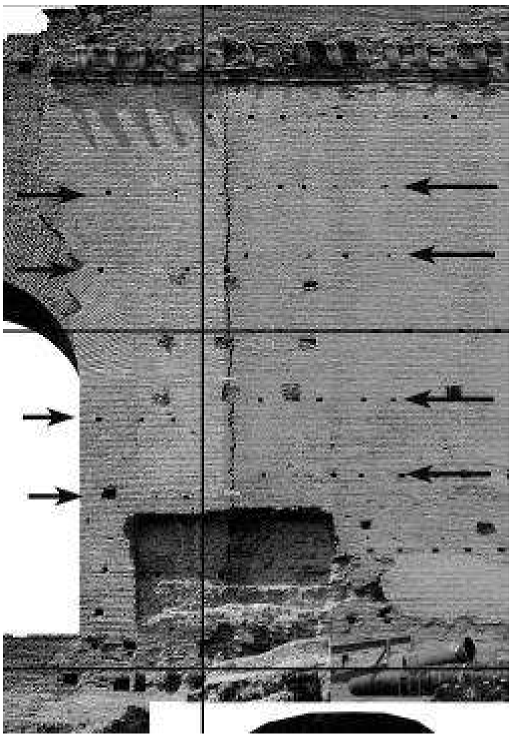
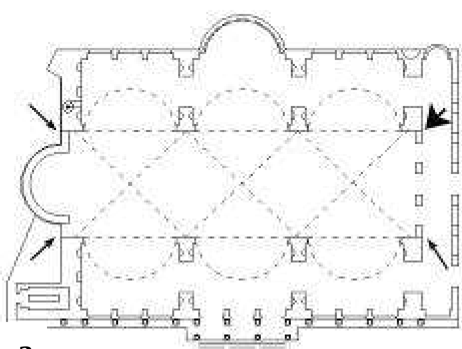


Figure 3. The arrows show the different the alignment of the putlog holes on each section of the wall, clearly built as two different part; on purpose the resulting joint intentionally has no toothing.
a) Position of the four major free joints of the Basilica; the enlarged arrow indicates the wall showed beside.



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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.

The analysis of the composition of the brick facing reveals that the concrete of the barrel vaults over the lateral aisles was placed seamlessly up to the planned height of the capital of the engaged column. From there on up, construction continued on all of the vaults at the same time, though each was built separately and with its own extrados, leaving in between the space to put later in place later the back side of the entablature (Fig.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. Here again the wall segment below the inserted entablature, which would support the spring of two cross vaults, and therefore a much greater load than those of the lateral segments, was built separately and without toothing.

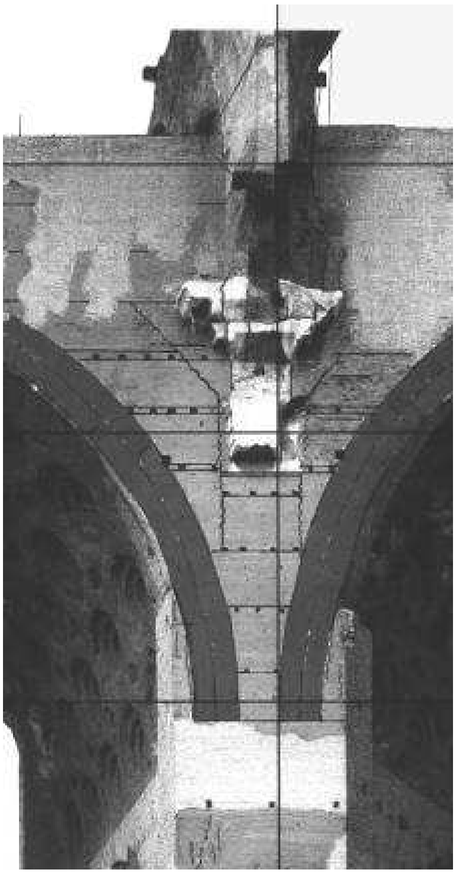


Figure 4. Photogrammetric image. Central nave, face of the upper part of the supporting wall of a pair of barrel vaults, to which was attached one of the columns supporting the cross vaults over the central nave.

The compression loads of the part of the brick-faced walls supporting the cross vaults, under the entablature, were proportionally much greater than those of the lateral segments. Their clearly differentiated treatment, designed to avoid uncontrolled structural cracking, reveals a remarkable amount of experience gained in the design and construction management of vaulting systems.

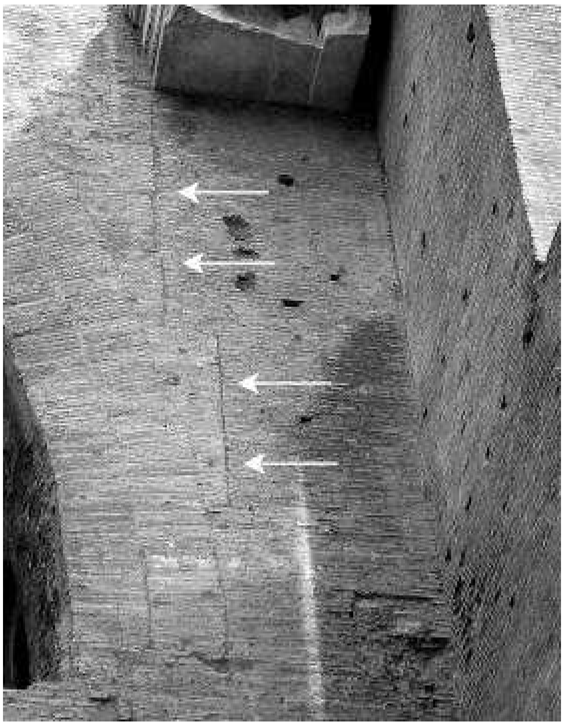
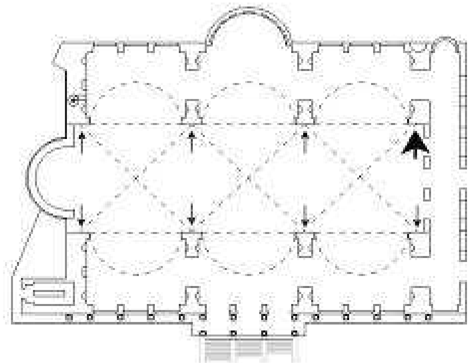


Figure 5. North east supporting wall. Construction joint, with no toothing, between the section of the wall supporting the barrel vault, and the part supporting the spring of the cross vault, on top of the entablature.
a) Position of the eight supporting piers of the Basilica; the enlarged arrow indicates the one showed beside.



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This construction system 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 cfr LANCASTER 2005, pp. 86-112). In the construction of the barrel vaults covering the naves of the Basilica two layers of ribbing for each vault, shown in the façade by two concentric arches of *bipedales*, were completed before the fill at the haunches was gradually added. The outcome was a sort of strong ribbed shell over the centering, that hardened well before filling in the spandrels, inserting the blocks of the entablature and concluding the building of the vaults with several horizontal layers of concrete.

Technically, this complex procedure allowed the use of an innovative method of constructing strong supporting walls in connection with huge barrel and cross vaults.

A less complicated and more flexible method was used to guarantee that the vaults were built to the proper thickness, and that the upper walls were built in plumb over the lower walls, hidden from above . During the construction of the cross vaults over the east porch, before the concrete was placed, terracotta tubes of about 2/3 of a Roman foot in diameter, around 20 cm, were positioned vertically over the centering, against the exterior face of the piers (Figs.6,7,8).

Figure 6. East end. Traces left by the 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. Traces and remains of a terracotta tube, still well preserved, 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 as it was being placed by means of a measuring stick. The tubes also made it possible to determine the correct position of the walls built over the piers above the level of the vault, by means of a plumb line. They were hidden from above by the floor of the terrace, and from below, once the formwork and the centering was removed, by the painted plaster and stucco mouldings.

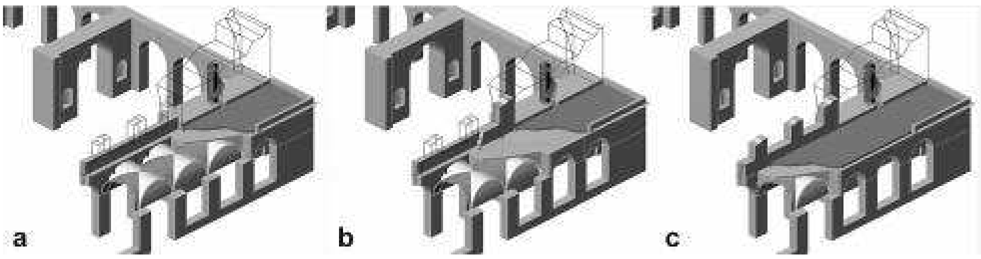

Figure 8. Reconstruction of the building sequence of the east porch. a) arranging the terracotta tubes on the extrados of the centering, marking the correct positioning of the upper piers; b) lay out of the cross vault conglomerate, in parallel layers up to the upper end of the tubes; c) lay out of the floor of the terrace, definitely hiding the tubes.

An analogous but necessarily more complex strategy was used during the construction of the large barrel vaults over the aisles, in order to position precisely the large buttressing arches that support the cross vaults over the nave. In fact, these buttressing arches had been correctly designed with a reduced width with respect to the walls on which they stand, therefore requiring a careful measurement to place them correctly.

Three horizontal cavities running through the thickness of the wall were created along the springing line of each barrel vault, marked by a line of bipedales, in a strip of wall approximately 90 cm high (Fig.9) built before installing the centering.

Figure 9. South-west perimeter wall, interior. Clearly visible the rectangular holes created along the springing line of the vault, marked by a course of *bipedales*, connected with the reference tubes. Each cavity is cm. 45 large, cm. 35 high, cm. 124 deep, with *bipedales* on top.

A terracotta tube was then placed vertically so that it intersected each of them at the end (Figs. 10-11); and as the depth of the cavities meets exactly the thickness of the two concentric rings of lattice ribbing forming the shell of the barrel vault, it has been possible to position a series of tubes one on the other going along with the construction of the vault.

Figure 10. Remains of a series of vertical terracotta tubes, diameter cm 25, h preserved cm. 250, buried in the remains of the vault. Above the ribbed sections of the vault, the weight of the concrete was adapted to need using *tufo giallo* and gray pumice.

The rectangular holes provided lodging to the main beams of the centering frame, surely in connection with ground supports, considering the large span of the barrel vault; they are regularly positioned along the perimeter wall, whose face toward the central nave has been designed to offer a similar support at exactly the same level. Once the centering was removed, it was possible to use again the cavities to check the conformity to the vertical line of the tubes; and then to use those as reference points on the extrados of the vaults to identify the exact position of the face of the buttressing arches, and to check the thickness of the concrete.

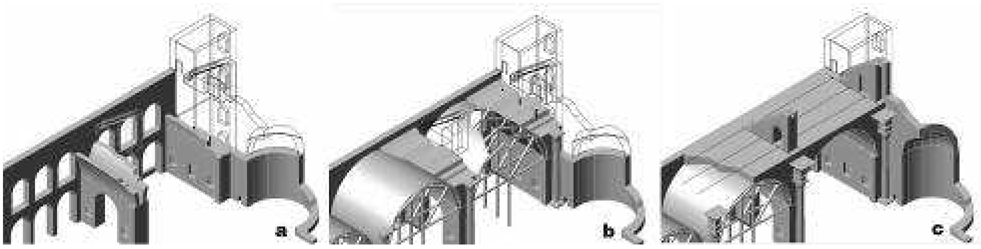

Figure 11 Reconstruction of the building sequence of the south-west aisle. a) arrangement of the terracotta tubes at the spring of the two concentric rings of lattice ribbing forming the shell of the barrel vault, in connection with the lodging of the main beams of the centering, marking the correct positioning of the buttressing arch; b) lay out of the vault conglomerate, in parallel layers up to the upper end of the tubes; c) removal of the centering, check of the thickness of the concrete and of the vertical line of the tubes, using them to fix the exact position of the buttressing arches. The floor of the terrace will eventually hide 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 appreciate fully the advantage of having rapid access to the reference points necessary for checking the construction process, it should be considered that the barrel vaults over the aisles, each with a span of 23.5 m, were all built at the same time, for a total length of approximately 86 m and a width of approximately 17 m, with the height of the extrados at approximately 26 m above floor level. Furthermore, the construction of the four buttressing arches per side was carried out without interruption and before the placement of the floor mortar over the terrace, in order to ensure maximum cohesion with the vaulting system below and to provide a stable support at the springing of the cross vaults.

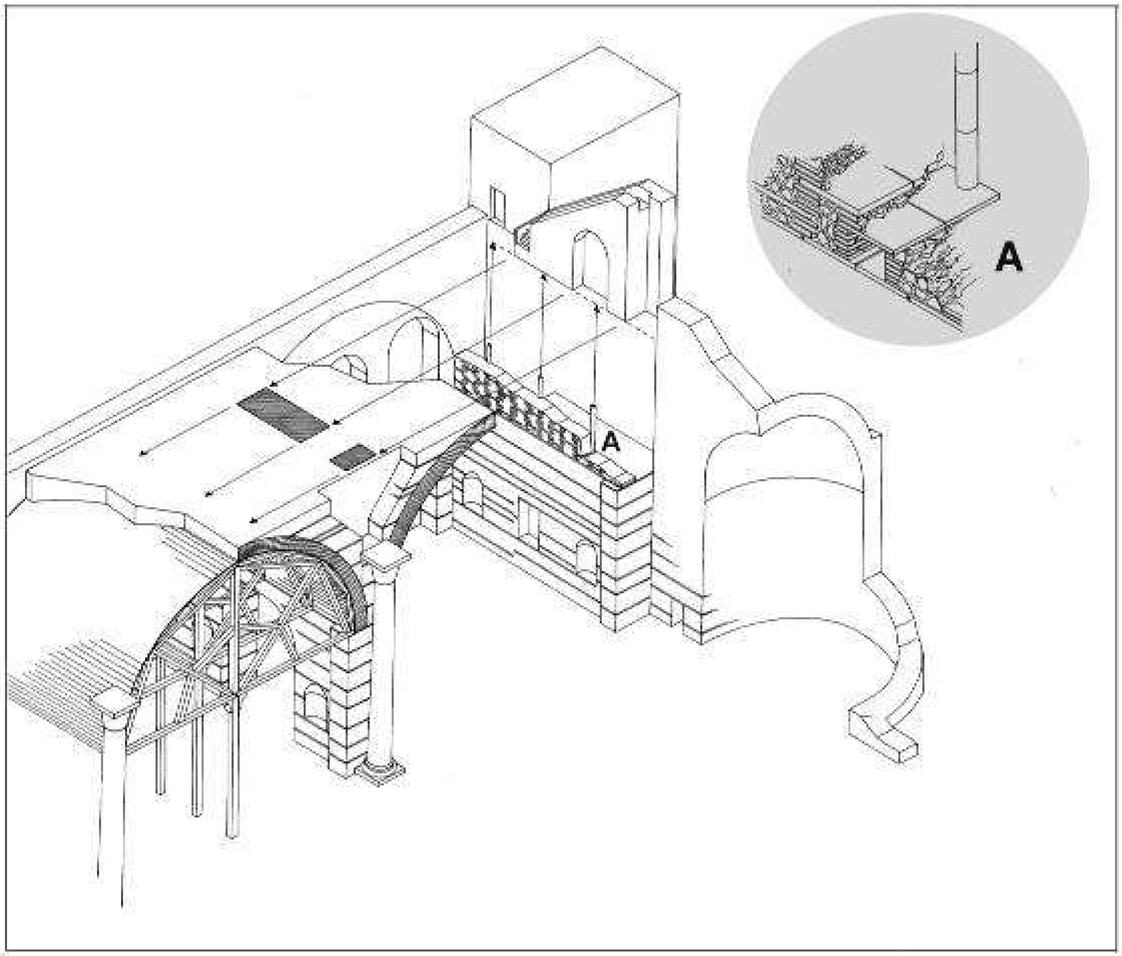

Figure 12. South west aisle, axonometric sketch. The insertion of terracotta tubes at both end of the aisles allow for easy and accurate positioning of the buttress arches. The insertion of the rectangular holes at the spring of the barrel vault is carefully made out of the intricate network of the lattice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

Though not innovative, at least at the state of present knowledge this method was not applied elsewhere in such a carefully planned manner. Examples of similar techniques, not always easy to detect and not accounted for, can be found in several of the side rooms of the so-called Basilica of the Trajan Markets, and in the substructures of the Severian Bath on the Palatine (Fig.13).

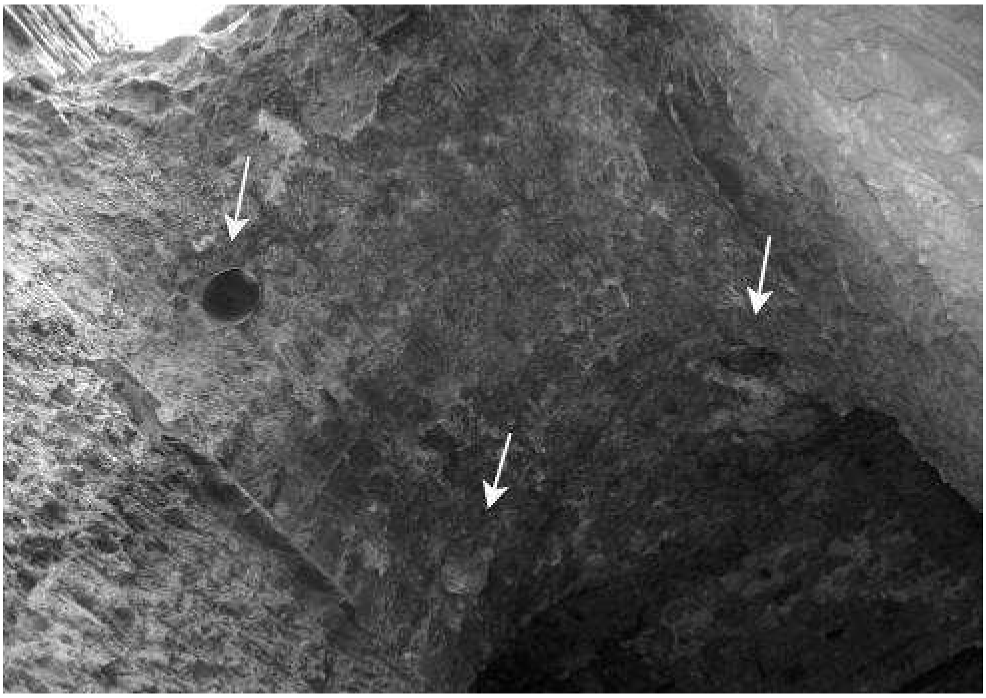

Figure 13. Palatine, substructures of the Severian Bath. Barrel vault built on brick linings of bipedales and bessales, with lattice ribs and reference tubes embedded in the concrete.

Both expedients, complex but very effective, arise from a very dynamic construction context , characterized by a highly specialized skill to design, build and use ambitious centerings, a clear understanding of the effect of form and mass on vault behaviour, and a knowledge acquired over more than six centuries experience about to cope with tensile stress, lateral thrusts and different load distribution.

Though allowing to save time and affording several crews to work together, the use of such methods requires a perfect coordination of schedule times and activities during the building process, making the construction phase of the project similar to mounting a mechanical device, in which each element requires the preceding one and is a prerequisite to the following one.

Therefore, in addition to the architectonical project itself, a carefully planned administrative project was necessary to account for each progressive stage of the construction and to secure the necessary general coordination; at least in the Basilica of Maxentius, such sophisticated coordination suggests that the same person, or group of people, were responsible for both. This raises the question, far from fully answered, of the real range of responsibilities and involvement of the architect and/or the builder in the practical achievement of a Roman building project.

(DAGUET-GAGEY 1997; REA 2002; MARTIN 2004 for details about the operative organization of the building industry in imperial Rome).

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