PANTHEON 1.0 or: Reflections and Speculations on the Roman Construction and Casting of the Pantheon Dome

How the casting of the dome was executed without massive formwork

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Introduction

During medieval times, the execution of the Florence Cathedral came to a halt because there was not enough wood in all of Italy to create the scaffolding to complete the dome. It was first in the Renaissance that architect Fillipo Brunelleschi devised a system to execute a dome using brick, without any scaffolding. By contrast the Florence Cathedral dome is slightly larger than the Pantheon in Rome, where the dome was cast in concrete. Even after 1900 years, the Pantheon remains the largest unreinforced cast in-situ concrete dome ever made. But how was it executed without deforesting the entire Mediterranean region to construct the mold required to cast such a project?

Fig. 1. Detail of the coffer system inside the rotunda of the Pantheon in Rome, Italy.

This writing revisits speculative drawings and ideas by various architects and scholars of the construction of the Pantheon and suggests an alternative methodology negating the need of massive scaffolding structures. While all original specifications have been lost, there have been multiple speculative suggestions since the Renaissance time for how the formwork was implemented to cast the dome of the Pantheon.

• This paper refers to drawings from Renaissance and modern time that suggests a massive centering system, with trusses for scaffolding and formwork, in the casting of the dome of the Pantheon, and evaluates the feasibility of those proposals.

• The authors of this paper considered the possibility that no scaffolding was needed, if the designers required the drum of the Pantheon to be filled with clay providing a mold to cast the dome. Such effort would have been time consuming and considering stress on the walls of the drum this idea is judged unrealistic (see addendum).

• This paper explores a third concept where the Pantheon builders implemented minimal scaffolding, similar to Brunelleschi's method, by focusing on the construction of a mold for each of the columns set between the waffle-like depressions called coffers (see Fig. 1). This can be done if the purpose of the seven outer rings on the roof of the Pantheon is reconsidered. Furthermore, a central tower must be created to complete the part of the dome that has no coffers. The authors find this combination of methods easier to execute and more economical than all previous scholarly speculations.

The presentation reflects briefly on geometry, history, brick and Roman concrete, but the focus is on the workflow, casting, and execution of the dome and the formwork that had to be constructed to create a span of 150 Roman feet (about 142 imperial feet) or 43 meters.

500 Years of Speculative Drawings

It was probably Emperor Hadrian who initiated the construction of the Pantheon that was executed from year 118 to 128. Construction was probably continued until year 140 for the full completion under Emperor Antoninus Pius. The Pantheon is considered a joint work of Emperor Hadrian and architect Apollodorus of Damascus, but no record can confirm that.

It is assumed that the Pantheon is a replacement of two previous monuments that originally occupied this site. Today there is only the portico, and the rotunda left of the Pantheon monument. The forecourt to the north with its colonnade has been lost and the adjoining building to the south of the rotunda has been lost as well.

There are unfortunately no surviving original drawings or specifications for the construction of the Pantheon. However, there are drawings that have been crafted since Renaissance time. One of the most informative drawings that reflects the general structure within the walls of the rotunda (and casting of the dome) was done in the 16th century by Venetian architect Andrea Palladio. This drawing is useful even if the outer supportive ring system on the dome is placed somewhat too high in the upper coffer area. The drawing is embedded in a collage in Fig. 2, and in Fig. 4, 5, 6, and 7 in this paper.

The authors revisited drawings and writings by architects and scholars such as Mark Wilson Jones, Rabun Taylor, George R. H. Wright, Friedrich Rakob, Eugène Viollet-le-Duc, and the artists and visualizers Helen Leacroft in collaboration with Richard Leacroft. All suggests that a massive centering system or mold, either standing or suspended, or a combination thereof, had to be used to execute the casting of the dome of the Pantheon. The authors question if a standing or flying centering system was needed in the area of the dome that was executed with the 140 coffers and suggests a more economical solution in the casting of the dome 1900 years ago.

In 2015 Mark Wilson Jones published the idea that a doughnut shaped tower must have been constructed to execute a major part of the dome. This aligns to some degree with the thesis in this research. The doughnut shaped tower, as presented by Mark Wilson Jones, included the support of the top 48 coffers. However, the authors of this paper suggest building a tower and a mold only below the area of the dome that has no coffers. We suggest the most efficient shape would have been an octagon shaped tower (see notation).

Two Experts on a Scaffolding in 1925

One of the authors of this paper stumbled over a photo that perhaps was published in 1925. In the photo one can see two people standing on a scaffolding that has been constructed within the rotunda of the Pantheon to do some repair work. The large scaffolding is reaching up to the 2nd or 3rd coffer area of the dome. The two people are probably archeologists. They are inspecting a crack in the springing area of the dome.

The architects of the Pantheon designed the walls that carry the dome to be about 20 feet thick. This was needed because 1900 yeas ago it was not possible to produce rebar and include that into the structure during casting. Therefore, the only other option was to hold the vertical and lateral forces at play by expanding the walls to this extreme dimension.

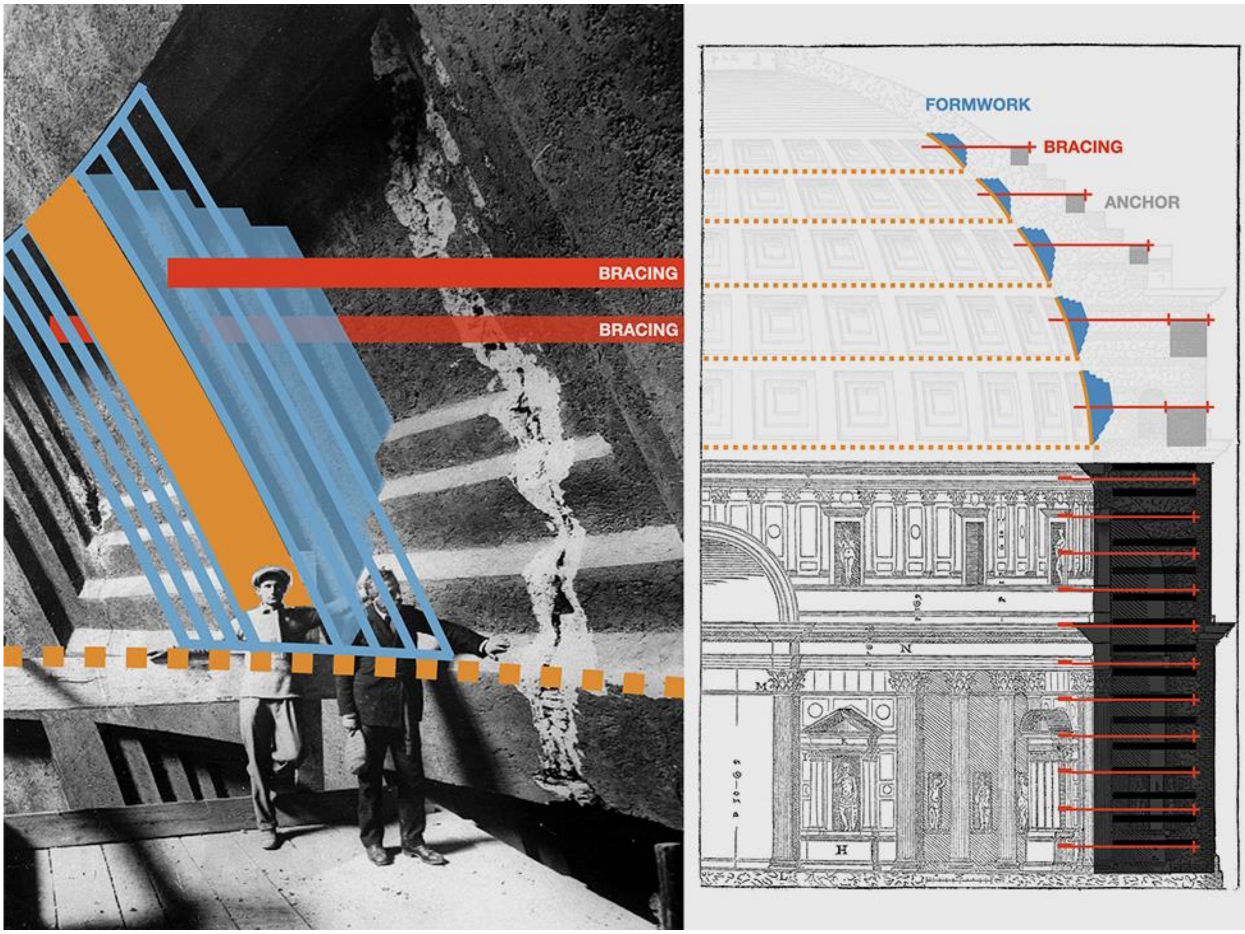

Fig. 2. The person with the hat is stretching out his arms indicating that this is how each coffer was cast using formwork placed in the space between each coffer. Each mold was stepped and then braced backwards using the outer wall as counterweight/anchor.

Today it would not be needed to execute a wall that thick as compression and tension forces can be controlled with use of reinforced concrete. Still, the Pantheon is exceptional as the largest unreinforced concrete dome ever made. The cast structure is a remarkable feat of engineering and architectural space from the time of the Roman Empire. The contractors knew that cracks would emerge in the springing area of the dome. This can be confirmed as one can find bricks that have been inserted into the cracks. That repair was executed within decades, not centuries after the construction. This observation can be validated by identifying the seal from various successors that ruled the Roman Empire stamped into the bricks. However, there is far more to be discovered from the 1925 photo.

Notice that the person with the hat is stretching out his arms and that the other person is resting his hand on the horizontal area of a coffer. The scale of the coffer took the authors by surprise. When visiting the monument and looking up it is difficult to comprehend the scale. The springing of the dome is at 75 feet and the 30 feet wide oculus is 150 feet above the floor. When examining the photo from 1925 it was a surprise to discover that the vertical lines are perfect and that the horizontal lines are uneven. Notice that all horizontal layers of the coffer behind the two visitors are uneven as are those of the second coffer in the photo (see Fig. 2). The vertical blue lines inserted into the photo helps the unexperienced eye manifest that all vertical lines within the cast of the coffer are parallel. This difference is typical for a cast that was executed with formwork that was left partly open while casting. This evidence is key to understanding how most of the dome was executed in a very efficient way.

The Concrete is Placed and not Poured

There are writings by scholars such as Kjeld de Fine Licht that elaborate on the difference in executing a cast by placing concrete and by pouring concrete. Understanding the difference of placing or pouring is critical for casting a large-scale monument like the Pantheon.

Since the industrial revolution it has become common to pour concrete into a form to execute a cast. The mixture of cement and aggregate must flow to fill a void, and it does not matter if the mold is made of wood, or steel-ply formwork. However, cement and aggregate can also be mixed to a consistency that allows the concrete to be placed within the form. The basic casting technique has not changed since Roman time. Craftsmen in any field manipulate and modify the application of their chosen medium to achieve a desired result. To place concrete in a mold is often a better controlled interaction. Placing concrete can be more efficient than pouring when considering workflow, time, and temperature.

One of the authors of this paper has cast large scale prefabricated concrete ferro-cement objects. The use of this reinforcement approach is not relevant for the thesis of this paper, but the mold is key for this research (see bottom Fig. 3). This mold was constructed with variable geometry so that the inner formwork could be removed to place concrete in a particular area. To control a casting, cement and aggregate was mixed to such consistency so craftsmen could place the concrete and not pour the concrete. This was important during casting and to transition from horizontal to vertical. This hands on experience results from placing concrete in a mold, as opposed to pouring, suggest the coffered portion of the dome of the Pantheon must have been accomplished with a similar manner. The author learned that all vertical cast areas are perfectly parallel but horizontal areas can be difficult to control and often emerge uneven. Gravity, time, temperature and workflow are important factors for any cast as it cures but there is a difference. Concrete that is placed is difficult to control horizontally, but if concrete is poured the horizontal layers emerge just as perfect as vertical elements of a cast.

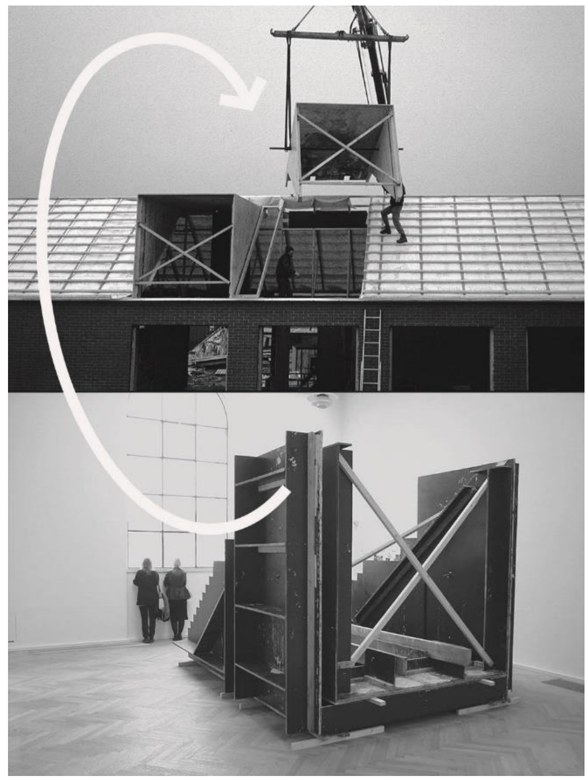

Fig. 3. Mold with variable geometry. Craftsmen can walk in and out of the mold and access the casting area to place concrete.

The formwork in the coffer area of the dome of the rotunda was therefore not a closed system but must have been semi-open. Parts of the mold were perhaps only a wooden frame that could be recycled and modified to the correct geometry while casting the 5 bands of 28 coffers. This would allow placing strings to the frame to install a matrix with the correct circle segment and then align bricks as formwork for the concrete that had to be placed within the 20 feet thick wall. If executed as described, those frames are then the primary objective for the craftsmen when casting the dome. It is not the coffer area but the column (indicated in orange color in Fig. 2) that should have our focus in how to cast the dome. A semi-open formwork in the coffer area allows for controlled bracing and installing secure anchor points (see red lines in Fig. 2) that provide easy access to place bricks in offsetting successive horizontal courses that eventually is backfilled with concrete and aggregate.

The formwork that was constructed to cast ferro-cement objects (Fig. 3) is too complex for the coffer system in the Pantheon. However, this formwork is an important key for the authors' idea of how the mold for the columns would have been braced. All formwork in each band would have been linked together in the arch coffer area. The vertical frames would have been stepped, base plated and then braced. After removing the formwork from each column, the coffer was finished by parging from top to bottom.

How to Cast a Dome Without a Centering System

The man with the hat in the photo from 1925 is spreading out his arms. He is leaning against the railing of a temporary scaffolding. Serendipitously he is simulating how the formwork was installed: Step the mold at the bottom and then brace backwards. If anchoring to the floor was compromised craftsmen could brace across to the perimeter of the outside walls and, if needed, to the rings on the roof of the dome (see Fig. 2 and Fig. 4).

Installing the very first mold on top of the drum of the Pantheon is to some degree easy. At this position the mold must be braced and secured to the back. Casting the first 28 columns and the arch in the first 28 coffers can best be described as a balancing act. Each mold is approximately 12 feet tall at this level. As craftsmen proceed further and further up and away from the springing of the dome, technically at that distance the gravitational pull differences would be negligible for each of the five bands of all braced formwork. The brickwork backfilled with concrete placed and cast along the outside perimeter of the drum are excellent anchor points for bracing. This allows craftsmen to gradually tilt the top of each mold into the void of the rotunda on the base plated edge of the interior wall. By doing so the contractor could control the angle of each mold to the exact position.

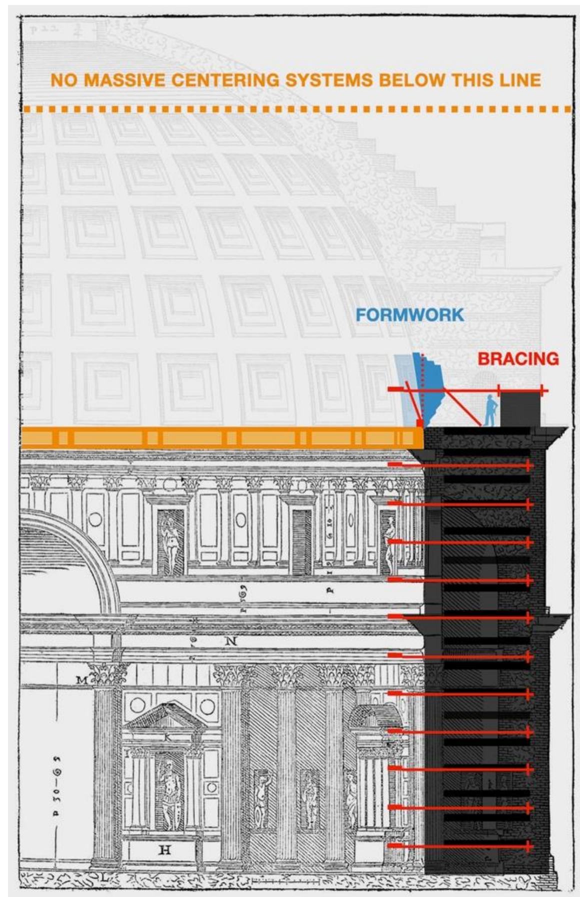

Fig. 4. Diagram of how to cast the first coffer area on top of the 75 feet tall and 20 feet wide wall in the springing of the dome.

Insert the Putlog Scaffolding in Walls and Dome

There is no need for a standing scaffolding as one can use the wall that is being constructed as a scaffolding. This can be done by executing the putlog system and then attach guardrails and boards to the ledgers. Any contractor would like to have an easy workflow, and the safety inspector was very likely a nonexistent factor during the Roman Empire.

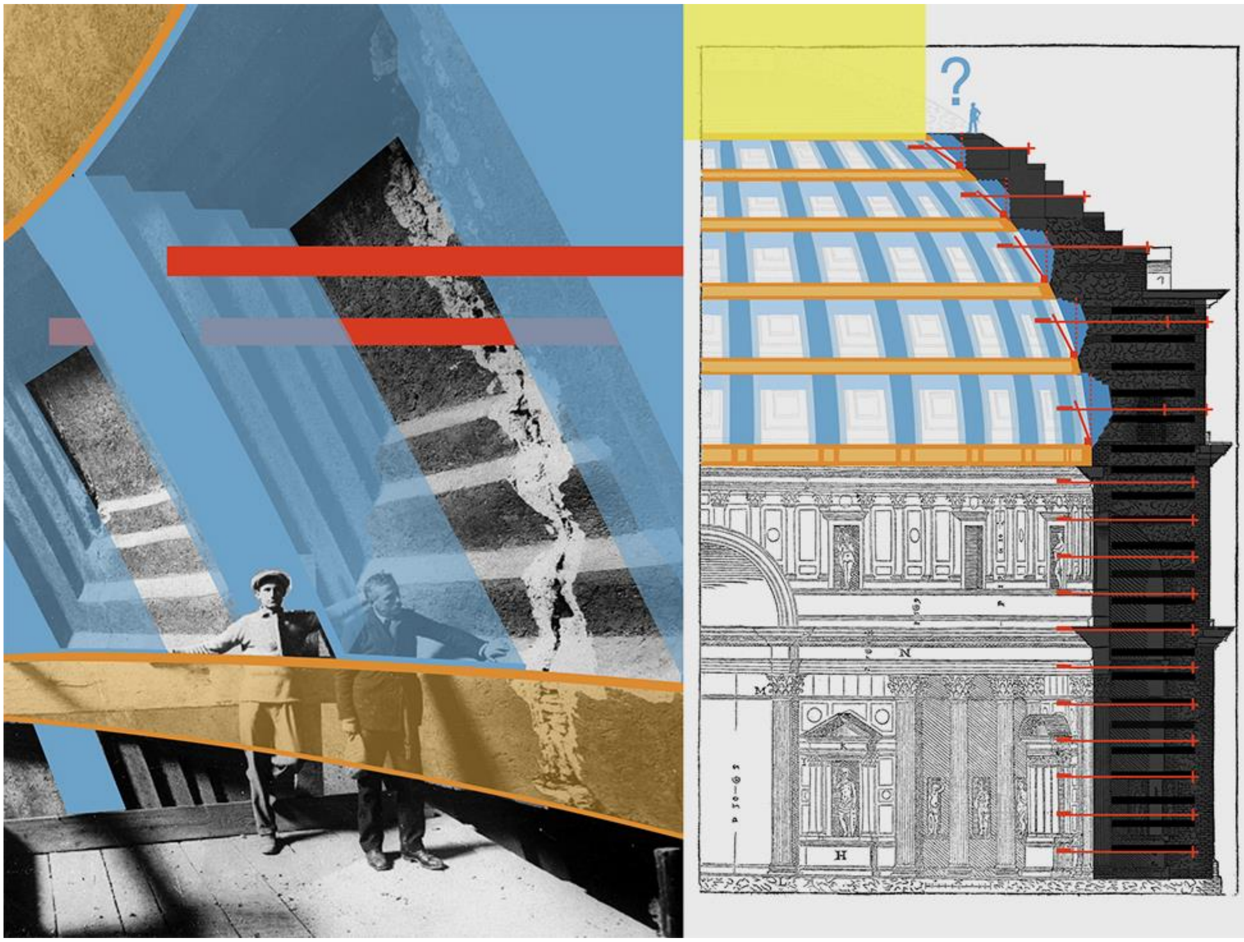

Fig. 5. If using the putlog system craftsmen can cast the entire coffer area of the dome of the Pantheon without any standing or flying centering system. Notice that the vertical edges are cast perfectly but horizontal surfaces are not, indicating that the mold was open.

When visiting the Pantheon, and other buildings from that time, it is evident that one is looking at brick and not concrete. All the brick is formwork for the cement and aggregate, so the mold is therefore still in place today. It is well known that the Roman contractor will parge buildings with a cement and mortar mixture and do so from top down. The putlog system was removed in stages while parging and finishing the surface of the walls.

Furthermore, there is a technology used within the walls of the drum and the coffer area of the dome that is known as the Bi-Pedalis system. The contractor included plates of Travertine that would close the cement and aggregate mixture into sections (that can be compared to a box with a lid) and was carried out at each 28th bond. The plates of Travertine reach from the front of the wall all the way across to the back of the wall in an interlocking pattern. When casting concrete today, one could compare the Travertine to the tie-rod system that is being used in modern formwork. However, the Travertine was never removed and is still in place within the walls and the coffer area of the dome of the Pantheon (see Fig. 5).

Voids in the Springing of the Dome is a Factory

The authors of this paper examined a plan drawing at the 80-foot level that has been crafted by Francesco Piranesi around 1790 and concluded that voids or rooms within the springing area of the dome is a carefully arranged factory for mixing water, cement, and aggregate.

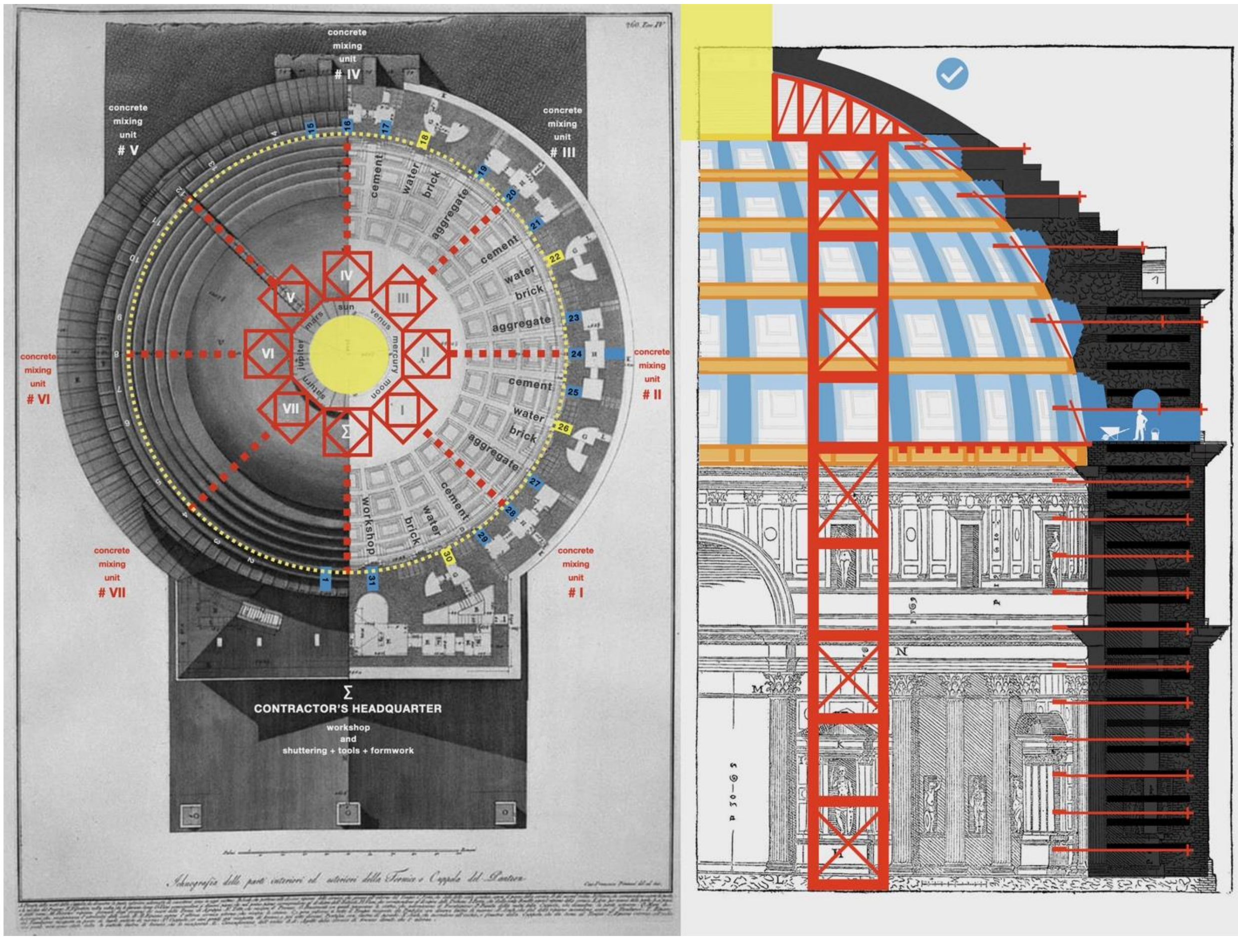

Fig. 6. To complete the casting of the dome a different approach was needed to execute the top with no coffers. By interlocking 8 or perhaps only 4 individual towers a top mold could be installed and each void in the springing of the dome could be utilized for mixing concrete. Notice that rooms in the springing of the dome and that stairs top roof line up with the towers. It is a factory for casting.

The authors translated the text attached to the drawing from 1790 but found only general descriptions of the rooms within the springing of the dome. We spelled out the functions for each room in how we speculate them being used. The rooms and the workflow for the crew line up with 4 or perhaps 8 individual towers that we suggest craftsmen constructed to install the formwork beyond the coffer area top dome. The many embedded arches within the springing of the dome are not only an elegant structural component harnessing all forces at play but is also evidence of corridors that would have allowed craftsmen to walk from outer cornice to inner cornice on top of the drum of the monument. Those corridors were then closed with brick before parging. We superimposed the corridors in blue or yellow color into the drawing of the springing area of the dome (see Fig 6).

Mixing Cement and Aggregate under the sun in Rome

Not only were the towers interlinked to hold the mold in place to cast the top dome area, but we assume that the structure was used to haul material from the floor of the interior of the monument to the ceiling as well.

Architects and contractors know that a building site is a restricted performance area when executing large scale buildings and that was not different when building the Pantheon. Huge amounts of brick, aggregate, cement, and water had to be stored. Especially the cement had to be protected to not accidentally cure before needed. The floor of the dome can only hold that much material that all must be organized for a proper workflow. The putlog scaffolding must be placed at the same time as the walls are constructed and there must be a timely workflow for carpenters and crew that would mix and place concrete. When casting concrete all contractors understand that temperature and timing is an important factor. The voids in the springing of the dome are therefore not only structural engineering but could have aided the workflow for a well-organized crew. With rooms in the springing of the dome the crew did not have to run the additional 75 feet down to the ground. Mixing cement and aggregate as close to the area in need is preferred. Craftsmen were perhaps assigned to 7 crews at 75 feet in the dome. Perhaps there was a headquarter in the portico at 75 feet as well. If 4 towers were placed in the center, notice the surviving staircase top roof (leading from outer cornice to oculus) perfectly lines up with the southeast tower within the rotunda. The crew would not only have used the putlog scaffolding system, but also the towers, as both systems must have been interconnected (see Fig. 7).

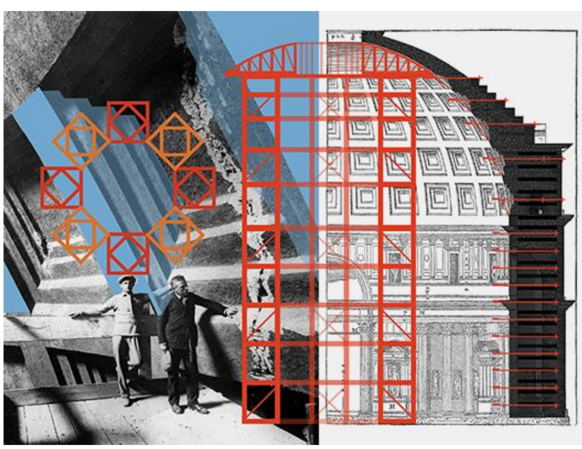

Fig 7. Conceptual plan + section of tower and formwork that had to be constructed to cast the top dome area without any coffers.

The Walls of the Drum are as Wide as an Interstate

Placing bricks and casting a 20 feet wide wall during Roman time is a huge undertaking and it is easy to forget that there are no trucks, pumps, or machines that can mix or deliver concrete where needed. Instead, everything was done by humans. If you are driving a car on the Interstate in the United States or perhaps are driving on the Autostrada on your way to visit Rome, you might realize that two lanes combined are just as wide as the widest part of the walls in the drum/dome area of the Pantheon. Imagine now that you are the contractor and that you are organizing several crews to place the concrete. The walls reach to 75 feet, and you are installing the first frames for the first cast in the springing of the dome, or perhaps you are casting coffer 29 to 56 in the second band. Craftsmen are laying brick along the inner and outer perimeter of the wall and now the concrete and additional aggregate must be placed within. You must cast 470 feet along the inner perimeter of the rotunda and the surface is in many places 20 feet wide. With a crew as large as you can imagine you will work from sunrise to sunset and still it was only possible to cast 1” or 2” of concrete before the day was over. You are guiding a crew that is casting by hand (using buckets and shovels) a two-lane wide Interstate. There is simply no more room, additional crew, or time in the day to cast more. The scale is huge, and most architects and scholars forgot this when elaborating on how the dome in the Pantheon was executed. This is why the concrete would set so easily behind the brickwork that hold back the placed mixture. This is why no massive mold or centering systems are needed in the coffer area. When you return the next day with your crew the concrete has already cured to be walkable.

Homogenous verses Heterogenous

When many perceive The Pantheon, it is in a romantic way. They typically look at the highlight of the building, being the dome, as a homogenous structure. Similar to that of Tadao Ando, many expect this to not only be comprised of a singular material, concrete, but also constructed from a minimal series of concrete pours. The expectations are that these few concrete pours would be placed into a grandiose formwork. The authors of this paper believe just the opposite, that the Pantheon is not a homogenous structure, nor it was formwork ever fully complete that had to be enclosed with boards regarding the shape and execution of the dome. If the dome were cast in two to three massive pours the loads of these pours would require extraordinary standing or flying centering/formwork as suggested by other scholars.

Throughout the majority of the dome construction craftsmen placed bricks that are essentially actings of the formwork, which we believe the concrete pour lifts would only be around a height of 1” to 2”, equivalent to the height of a Roman brick. Furthermore, there was stone slabs in the form of Travertine, that often has a fibrous appearance and surface, that acted in regard to the perpendicular tension of the structure. Once a substantial portion of the construction, or possibly all, was completed then the interior would be parged with concrete. The parging was applied in the reversed order, from the occulus to the bottom of the monument.

Coffer as Control Joint

In modern day construction we utilize the control joint as a means to deal with expansion and contraction. While the Pantheon has no control joints, it is possible that coffers were the elements in which the designers intended cracking and movement to happen. We understand that the coffer is a multivalent architectural element, not only reducing the weight of the dome as it ascends to the oculus but also is designed to provide calculated perspective to the human eye from the center of the floor. The concept of the coffer as a control joint, implies that the ribs running vertically at the left and right of each coffer are acting as columns, and there is a greater importance of these elements not fracturing (see Fig. 8 and notation). While there have been significant developments in the use of lime in modern concrete technology, it is possible that the designers and craftsmen of the Pantheon were knowledgeable of the self-healing properties of lime. Thus, they saw little need for control joints; perhaps expecting movement and cracking to emerge in the coffer area, waiting for the lime to do its job.

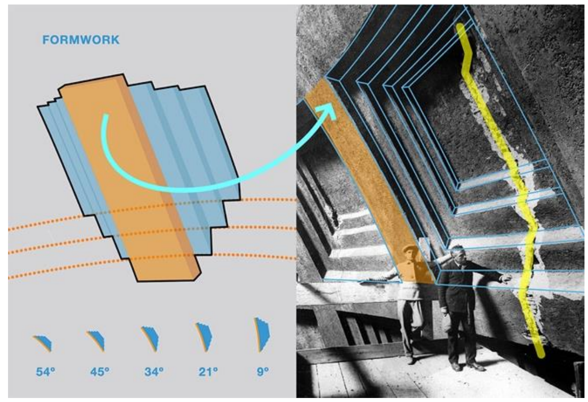

Fig. 8. The formwork for the dome was executed for each column and not the coffer area. This way the control joint for the cast was guided away from primary or more important elements.

Experiencing the Pantheon Monument

Today the Pantheon monument has lost its original urban context, but architects and scholars can reconstruct how a visitor in Rome would have perceived the building. The following text has been *extracted from ‘The Rotunda in Rome’ by Kjeld de Fine Licht (page 14-16):*

“… If we just imagine ourselves back in Hadrian's time, we can try to picture the new Pantheon endowed with a splendid magnificence by its pure, shining polychrome materials. Anyone who then approached the rotunda in a suitable manner went first through the forecourt with its surrounding porticos and finally reached the pronaos of the temple. The columns here and the marble-faced façade of the intermediate block which - apart from the two niches - are reminiscent of other temple fronts, betrayed nothing of the unique interior to be found beyond the portal. Only an observant specialist would have noticed on his way across the forecourt that behind the traditional arrangement of the front there was something which was essentially

different. Once this knowledgeable Roman had reached the other side of the door and stood under the mighty cupola, no doubt he would in the first instance be struck by the technical achievement in the temple's construction. From other buildings he was not unacquainted with the simple calculations used for the basic proportions of the hall: the radius of the cupola equaling the height of the cylinder; the lighting through a hole in the middle of the cupola he already knew, because this was general, and under the previous emperors had been repeatedly used with happy results. If we further try to imagine this man's reflections during his visit to the Pantheon, it cannot be considered entirely unlikely that he found it correct and relaxing, but at the same time possibly something of a shock that here the cylindrical domed rotunda served as a temple. With this object in mind it was only reasonable that the building had been given a traditional front, but the whole thing was a strange composition as a result. However, he might ask himself if there had been any other way of arriving at a dignified solution…".

Conclusion

To design a dome with 140 coffers (arranged in 5 bands) is not only a decorative, cultural or mathematical matter (see notation). It is the result of casting to the maximum height without using a centering system. Then, when gravity made it impossible to proceed beyond the 140 singular and in-situ formwork installations, the casting approach changed. Therefore, the top of the dome has no coffers.

References (writing, drawings, photography)

Kjeld de Fine Licht: The Rotunda in Rome. Jutland Archeological Society Publisher. Copenhagen, 1968.

George R. H. Wright: Ancient building technology. Vol 1, 2, and 3 part I and part II. Leiden, Boston, Köln. Brill, 2000.

The Pantheon, From Antiquity to the Present, Edited by Tod A. Marder and Mark Wilson Jones. Cambridge University Press. Cambridge U. K. 2015.

Andrea Palladio, 'Quattro libri dell´architettura', Il Pantheon di Roma (Libro IV). Domenico de'Franceschi. Venice 1570.

Drawing crafted by Francesco Piranesi in 1790. Raccolta de' tempj antichi, tav. 3-IV. Opere di Giovanni Battista Piranesi, Francesco Piranesi e d'altri. Firmin Didot Freres, Paris 1839.

Professor and archeologist Giacomo Boni inspecting a fracture in the Pantheon. Photo extracted from the Austrian Archives / Brandstätter images / Picturedesk.com. See Fig 2, 5, 7, 8, & 9.

Photos in Fig. 1 and 3 and drawing in Fig. 8 are by the authors and collages in Fig. 2, 4, 5, and 6 are by the authors.

Addendum

The quote "…To support the skeleton he had the Pantheon filled with earth, it is said, mixed with gold coins and, once the work was finished, I invited the Roman citizens to take away the earth and keep the coins. Imagine how many people ran to empty the Pantheon: A real crowd, attracted more by the coins than by the duty of citizens, and so the Pantheon was emptied in the blink of an eye…" is attributed to Giovanni Battista Piranesi.

Notation

140 coffers are the sum of 1×1+2×2+3×3+4×4+5×5+6×6+7×7 or the sum of the squares of the first seven integers. This aspect of the dome is fascinating. Please look for our follow-up paper Pantheon – 2.0, as presented in the *Double* publication in the Collection Of Texts About Architecture (COTAA) where the authors will reflect upon how they found the original contractor drawings that depicts how to execute the structure for the formwork to cast the apex of the dome of the Pantheon.

Drawings that record damage to the coffer area in the springing of the dome is documented by Alberto Terenzio in 1932.

All feet mentioned in this paper are Roman feet. The diameter in the rotunda is 150 Roman feet or 142 imperial feet or 43 meters.

Contributions

Special thanks to Joel Davy, FAIA; Lisa Eggebraaten, MLS; Susan Schaefer Kliman, Ph. D., FAIA; Lucas Laskow, GTA; Samuel Newman Ph. D; Giacomo Pirazzoli, Ph. D., iCad; David Swenson, MFA and all the students in Regin Schwaen's 2024 concrete seminar.

Post Scriptum – replace figure 6 and 7 by figure 10 and 11

All research is a journey. When we created this paper, it was mostly crafted in Keynote and PowerPoint by Regin Schwaen. He was too busy to fetch a proper application and craft better drawings. The diagrams would hopefully be sufficient in the communication of the idea and premise. Then in conversation with Nick Wickersham it became clear that there was much more to bring forward. There was no other way than to start all over when we realized that our findings made information surface that we never could imagine. Not only was there a sea of information but also challenges in the beginning of this journey. We had a hunch that the tower was too narrow as presented in this paper.

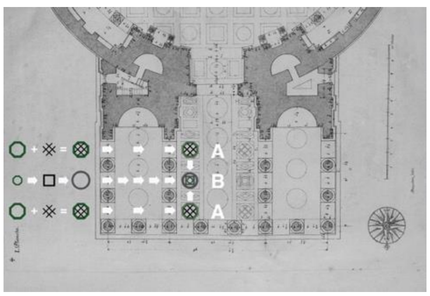

Fig. 9. Drawing by Antoine Desgodetz. Les Edifices Antiques De Rome: Dessinés Et Mesurés Très. Paris. 1682. Ornamentation overlay by the authors.

We perhaps had crafted diagrams for the temporary tower that had more to do with the 21st century than towers executed 1900 years ago. However, this paper trained our eyes, but then we had a moment of serendipity. When we looked at the carefully crafted recordings done by Antoine Desgodetz in 1682, we came to new conclusions and findings. We could see that the ornamentation that was implemented in the portico of the Pantheon had something to do with our proposition in this paper; that the rotunda at one point in time had a temporary tower installed to cast and finish the very top of the dome of the Pantheon. However, we could see that our suggestion to construct eight individual towers probably was not correct, but that perhaps only four was needed. This conclusion is based on our discussion of a better and more solid structural framework for the form that was placed about 150 feet above the floor of the rotunda and is perhaps the correct interpretation of the information that was published by Antoine Desgodetz in 1682. Then we found the same ornamentations again, now recorded with slight variations by Francesco Piranesi and published in 1790. After that we accessed Adobe Illustrator and other applications and crafted new elaborations in drawings and text. We had excellent architectural models crafted by Lucas Laskow as well, who became our Graduate Research Assistant.

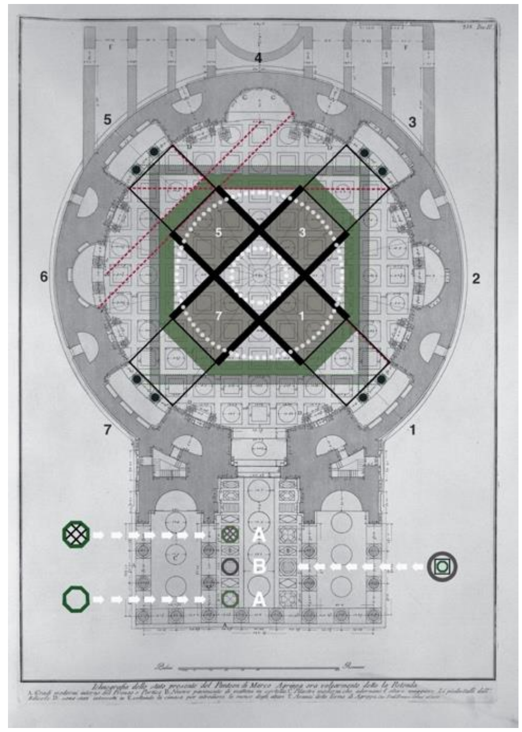

Fig. 10. Drawing by Francesco Piranesi. Published in 1790. Extracted from the Kamei Collection and the U-Tokyo Digital Archive Portal. Superimposition by the authors.

Fig. 11. Overlay of two drawings by Francesco Piranesi and then superimposed by our speculations for implementation of a temporary tower and ramp for transportation of concrete.

Our findings that were based on the conclusions as presented at the BTES conference in Chicago evolved into a new publication that is pending in a second peer-review at the international journal Collection Of Texts About Architecture [COTAA]. Look for the print *Double* and *PANTHEON 2.0 or: Finding a Copy of the Original Drawings for the Formwork of the Dome and then Rediscovering them Again*. We extract a few paragraphs [*text in italic*] and three drawings from the COTAA publication that should be available in November 2025.

Finding a copy of the original drawings for the formwork of the dome and then rediscovering them again

"…the authors explored the idea that the formwork for the dome was done without using a centering system when casting the dome. Architects and scholars since renaissance time have speculated about various formwork that all require exceptional large-scale support systems to cast the dome. We show how all the 140 perspective coffers in the dome instead can be cast by using a putlog system in combination with bracing. We crafted drawings that show how the outer rings on the roof are efficient anchoring points for the bracing of each formwork for each perspective coffer and columns, but we discovered that [after casting all the 140 coffers] the contractor was forced to install a temporary tower to cast the top area of the dome that has no coffers. We concluded that the formwork for the very top of the dome was supported by eight individual towers that must have been linked together. After crafting the drawings in section and plan for such a tower and publishing our findings we stumbled over a drawing from 1682 that shows ornamentation in the floor of the portico that was surprisingly similar to the drawings that we had just crafted.

Then we found the ornamentation a second time in a drawing from 1790 with slight alterations. This ornamentation could be a codex to the construction of forgotten and lost formwork and scaffolding. We realised that the ornamentations on the floor of the portico might be architectural construction drawings. They explain the fundamental geometry of the Pantheon and show how to construct a temporary tower. We realised that we were mistaken in our first publication. Not eight but four towers were made to support the formwork to cast the area of the dome that has no coffers…".

Overlay and superimposition to drawings by Antoine Desgodetz published in 1682 and Francesco Piranesi published in 1790 [see previous page] were the *"…towers are shown as ornament next to shape A. The drum of the Pantheon is represented as a circle in shape B. It is also the principal geometry: An octagon inside a square inside a circle. The square is implemented by extending strings from the eight columns…"* and we found that *"...an octagon within unfolds a hashtag figuration as recorded by Antoine Desgodetz. This hashtag can be extracted from the edges of niches 1, 3, 5, and 7 that then form the footprint for four towers. The towers can then support the formwork to cast the very top of the dome as outlined by dotted circles…".*

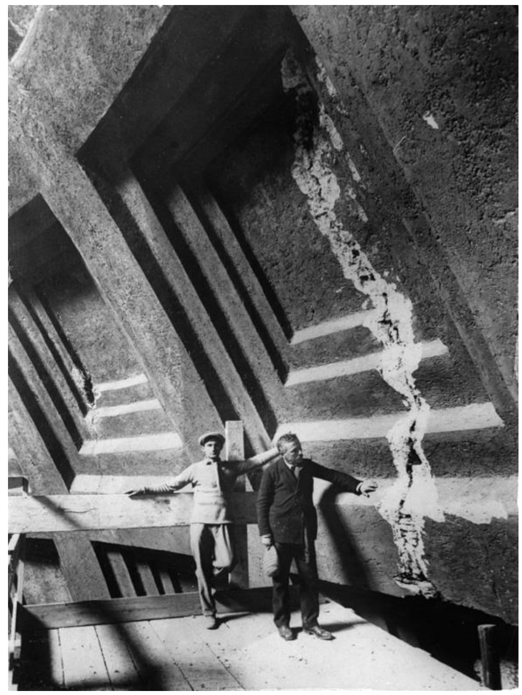

Fig. 12. Professor and archeologist Giacomo Boni inspecting a fracture in the Pantheon (Austrian Archives - Chr. Brandstätter).

Additional conclusion

The follow up publication to this paper - *PANTHEON 2.0 or: Finding a Copy of the Original Drawings for the Formwork of the Dome and then Rediscovering them Again*, added new research that allowed the authors to rethink some of the concepts in this paper. Based on our findings, a temporary central structure was likely used to carry a mold, enabling craftsmen to cast the dome's apex (from top coffer area to the oculus). The design is concluded to have involved only four towers, and not eight interlocking ones. Correct therefore our previous drawings by replacing figure 6 and 7 by figure 10 and 11 in this paper.