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Technologies for Architectural Restoration Works in Eighteenth Century Rome: The Birth of the Modern Scaffolding Practice

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ABSTRACT

In 17th and 18th century Rome, building site technology depended on a consolidated empiricism rather than on formalized cognitive processes. Technologies inherited from the Imperial Rome continued to prevail, renewed by the experience of the greatest Renaissance and Baroque architects, and, above all, by of the colossal building site of the new St. Peter's. Starting from the second half of 17th century, the design of restoration scaffolding became indispensable for the conservation of the Vatican Basilica and its precious decorations, as well as for the conservation of the Pantheon, the Basilica of St. John in Lateran, and for other important monuments' maintenance, in Italy but also in some European nations. However, the development of scaffolding went almost unnoticed by the principal treatises on architecture, nor did it even find its way into technical handbooks. There are just a few exceptions in the contemporary literature on artistic techniques in 18th century. These works fit into the general context of the lavishly illustrated machine books, which had flourished during the 16th and 17th centuries, a genre, which gradually ended in the early 18th century, due to the changing attitude towards technology.

This paper clarifies the origins and the gradual improvement of scaffolding for restoration, indispensable for the maintenance of the architectural heritage. The scaffoldings designed in the early 18th century and their progressive improvement are analyzed. Among them, scaffolds used for the restoration of the domes of St. Peter's and the Pantheon assumed model authority in Italian and European restoration practice, and was celebrated in European carpentry manuals until the early twentieth century.

1. INTRODUCTION

In the mid-17th century Rome, building practice was finally perfected. This was due, among other things, to the development of an effective system for the economic and technical management of great Papal building sites and of a myriad of private new architectural constructions. This improvement took place at the same time as the slow progress of the new St Peter's Basilica in the Vatican's construction and thanks to the experimentation, it induced in the roman building "industry", both in the technical and administrative spheres. At the same time, building techniques and technologies expressed the unique specificity of the Roman context and its congenital relationship with antiquity, finding fruitful development in the many construction sites opened in the city. They became the major experimental laboratories for architects and workers of different origins. At the same time, the proven experience of the masters from Tuscany and Lombardy, and the fruitful cooperation between papal and private building sites were decisive in the early 17th century, and turned the Roman building practice into a recognized and appreciated model for construction techniques, material procurement, and organization of the workers and development of building technology. One of the fastest growing sectors is that of scaffolding for restoration, which is indispensable for the ordinary and extraordinary maintenance of Christianity's first Basilica.

Between 1700 and 1800, thanks to the inventions of a group of skillful carpenters from St. Peter's, scaffolding

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for restoration was perfected and made effective for works also outside the Vatican. Their proven functionality extinguished in the first decades of the 20th century, when metal scaffolding came into use. Some of these, however, still carry the memory and characteristics of the wooden scaffolding used for the restoration of St. Peter's and the Pantheon, celebrated in European treatises and manuals until the 1920s.

From a methodological point of view, the information taken from the technical literature of the 18th and 19th centuries was compared with that found in the Vatican archives. These clearly illustrate the various types of scaffolding, their components, measurements, wood species used, as well as construction, assembly and dismantling techniques. Clear indications are also given on how scaffolding was used for restoration, both in large and small Roman buildings, from which it is now possible to trace the line of their gradual improvement and critical fortune in the European context.

2. The Restoration Scaffolding in the History of Construction and Building Technology

Construction machines, supporting beams and scaffolding in use in Italian Renaissance and Baroque construction sites have been widely investigated by scientific literature, as well as work organization, production and transport of materials and construction techniques. Although widely practiced in the modern age and documented in literature for only a few authoritative interventions in Roman buildings, scaffolding for ordinary and extraordinary maintenance remained undocumented for a long time, and they were only rarely the subject of architectural treatises.

This was because the knowledge of mathematics and the emergence of modern science have long been inevitable dividers between the intellectual and operational components of the construction profession. The only exception was the construction machinery, already included by Vitruvius in Book X of *De Architectura* and subsequently described by all the major Renaissance treatise writers. The correct execution of scaffolding is of fundamental importance for the good execution of the construction work, as well as restoration. Nevertheless, it was overlooked by Vitruvius and Leon Battista Alberti, but also by Andrea Palladio, Vincenzo Scamozzi and even by Philibert de l'Orme (De l'Orme 1570), which deals extensively with the subject of structural carpentry, as well as the characteristics and mechanical properties of the various wood species. There is a glaring gap in the illustration of the practice of building even in the famous *Encyclopédie* by Denis Diderot and Jean-Baptiste Le Rond d'Alembert (Diderot, D'Alembert 1751-1780). This may have been because in all building sites of the early modern age the construction of scaffolding was entrusted to the experience of artisans like bricklayers and carpenters. They were responsible for inventing new platforms, perfecting the ones already in use, and adapting each work of scaffolding to the specific needs of the construction, and later for restoration as well. Yet this important work did not deserve to be included in the intellectual treatment of architectural work, at least until the technical manuals became widespread. The importance of scaffolding for the success of the work was also well known to the supporters of the theoretical-intellectual component of the construction profession. In the mid-19th century, the French architect Emmanuel Eugéne Viollet-le-Duc (1814-1879) stated that «a well-designed scaffolding is one of the elements of the art of construction that best shows the intelligence and the good leadership of the project. One can judge the science of the builder by the manner in which he sets up the scaffolding. Well-built platforms save time and, by ensuring the workers' safety, permit them to work with greater regularity, method, and care». In 1871, the Milanese engineer Luigi Mazzocchi dedicated an entire treatise to wooden constructions, in which he included an extensive chapter on provisional works and an authentic tribute to the scaffolding designed by Nicola Zabaglia (1667–1750) (Mazzocchi 1871). He was a master carpenter of the of St. Peter's Fabric (the Papal institution in charge since 1506 for the construction and maintenance of the Vatican Basilica) and his astonishing inventions, as well as those of his successors, were considered virtuous examples of operational empiricism for a long time. Some of them were included in the main European treatises on construction up until the early 20th century. The long-lasting fortune of the Zabaglia's scaffolding shows that the scientific method did not make the empirical approach obsolete, but a gradual incorporation of theoretical precepts sanctioned the successful qualitative transition in the relationship between theory and practice even on the construction site. Zabaglia's activity includes a series of important interventions carried out among his forty-year service at the Vatican Institution, during the first half of the eighteenth century. At that time, the oral transmission of technical knowledge and operational empiricism progressively entered a crisis due to the rapid progress of scientific methods. The inventions of Zabaglia represented an authoritative model of cohesion between architectural theory, construction site experience, applied mechanics and restoration practices. Thanks to the Zabaglia's experience, scaffolding could be adapting to the specific requirements of restoration or maintenance works, also in the immense and variously articulated interior space of the St. Peter's. During the second half of 18th and all the 19th century, Zabaglia's partners and collaborators, still perfecting restoration scaffolding, ferried his inventions to the threshold of the 20th century, earning the celebration in the most important European carpentry treaties.

The numerous maintenance operations carried out in St. Peter's Basilica from the late 17th century until the early decades of the 20th century were formidable vehicles of development for the design of restoration scaffolding. They testify to the long-standing and never-discussed adherence to traditional operational practice. Reliable and safe, this practice made use - in construction as in restoration - of traditional materials, techniques and technologies tested by centuries of experimentation. The use of traditional building practices is documented in both routine maintenance and more demanding consolidation, rehabilitation and restoration works

The intuitive and perfect control of "contrast and balance of forces" allowed Nicola Zabaglia to test provisional apparatus and machines "well connected, strong and safe to work on any higher and more difficult site". Therefore, his work represents a turning point for the development of construction technology: thanks to it, "there was no longer any need for Engineers and artists to direct and work on a scaffold, which cost the *Fabbrica* (St.Peter's) a lot of money, and carpenters [...] became perfect in all works of mechanical engineering". Moreover, Zabaglia's prodigious technical inventions have the potential for interesting adaptations to current construction and restoration practice.

The restoration work carried out in St Peter's between the eighteenth and early twentieth centuries is characterised by a substantial uniformity of procedures and practices. They derive from the widespread practice of "ripristino" (restore), not yet contaminated by the theoretical speculations of the mid-twentieth century, and entrusted to the operative wisdom of several generations of highly qualified building craftsmen, carpenters and masons, capable of assembling daring mobile scaffolding at the dizzying heights of the Basilica. The integration of fallen portions of stucco decorations, the replacement of stone elements, the reintroduction of some parts of cornices, the displacement of statues and furnishings, the replacement of columns, the restoration of the great Dome, including the consolidation with iron hoops (Marconi 2009; Dubourg Glatigny 2017), and the mounting of statues were possible thanks to the ingenious dexterity of skilled "sanpietrini" [of St. Peter's] carpenters.

Traditional practices and techniques are therefore responsible not only for the material survival of St. Peter's and for its impressive decorations, but also for the authoritative role played by the St. Peter's Fabric in Roman construction field, at list until the middle 19th century (Marconi 2004). Its extraordinary efficiency in the organization of work force and its influence on the improvement of building techniques are strongly connected to the development of scaffolding, and related working spaces. The Vatican Basilica's precious architectural space imposed severe restrictions to the design and functionality of restoration scaffoldings that had to be assembled and used without interfering with liturgical uses.

The temporary works employed by Nicola Zabaglia at St. Peter's in Rome were published in the two editions of the *Castelli e Ponti* (literally "scaffolds and platforms") (*Castelli e Ponti* 1743; 1824). The publications dates of the two editions neatly mark the end of the "old world" of show-off presentation books on technology, and the rise of the new scientific word of mechanical engineering. Zabaglia's inventions have been described as the masterwork of a genius with innate and miraculous talents. However, a correct evaluation of his work is possible only through an in-depth analysis of his biography and the technical features of the scaffoldings conceived by him. Furthermore, the reasons that motivated the St. Peter's Fabric to produce two editions of the book need to be analyzed. If in the 17th century, an "engineer" was defined as a person who could practice *ars* and *technè* (arts and sciences) with ability and keen intelligence, this title could have been assigned to the simple master carpenter Zabaglia, thanks to his uncommon professional ability, and to the importance of his inventions.

Zabaglia's uncommon ability allowed him to achieve the exemption from the daily incumbencies on other workers and the privilege to use as own office. This was a private workspace, where he experimented mechanical prototypes from his inventive through models in scale, perfectly working, built with wooden sticks, production wastes of carpenters. The knowledge and the insightful control of the "contrast and balance of forces control" allowed Zabaglia to conceive and improve standing and flying scaffoldings, permanent or mobile, cheap, strong, safe and suitable for both routine maintenance, and extraordinary restoration procedures. During his long career, Zabaglia successfully completed several technical undertakings, characterized by the use of scaffolds composed of simple wooden elements that could be controlled by means of a network of ropes, driven by hoists. Thanks to his incredible intuition and with apparent ease, Zabaglia brought to perfection these devices, improving their components, simplifying their warp and turning them into movable devices that could be quickly placed where they were needed. Consequently, the St. Peter's Fabric was able to reduce execution cost and time; moreover, downtime was also shortened, as it was no longer necessary to dismantle and reassemble all the components. Thus, shoring, scaffolds and machines became more effective, and even complex interventions could be carried out in a short time, saving many materials, as well as ensuring the successful completion of the work.

Among the most relevant works done by Zabaglia in the Vatican Basilica since 1686, and celebrated in the *Castelli e Ponti* book, are the scaffolding used for the restoration of the porch vault's stuccoes (pl. XXI_fig.1), those for maintenance of the minor domes and for the main dome's pendentives, and the one settled on the molding of the main dome for the mosaic restoration (*Castelli e Ponti* 1743, pl. XXVI). From the constructional and functional point of view, the devices built for the restoration of the main nave's vault (pl. XXV_fig.3), and the multi-levels platforms so-called "Ponti Reali" (*Castelli e Ponti* 1743, pl. XXVIII) are not less interesting.

Comparable attention characterizes the project for scaffolding to clean the 30 meters high Berninian baldachin, and the installation of the fifty statues on the straight wings of Saint Peter's Square. For this work, in 1703, Zabaglia experimented a perfected version of the "antenna", a big wooden tower crane equipped with a mobile platform, which allowed him to reduce costs and times of work, closed in just three months. Zabaglia was also a protagonist of the well-known consolidation of the main Dome under the supervision of Giovanni Poleni and Luigi Vanvitelli since 1743, the same year of the *Castelli e Ponti* first edition.

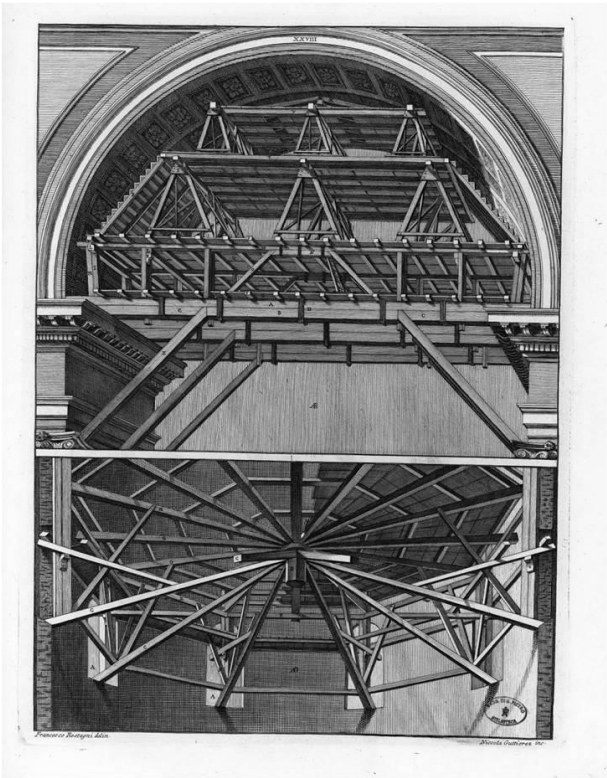

Figure 1. Scaffolding (so called "Ponti Reali") by Nicola Zabaglia for restoration works at the domes of St. Sebastiano and St. Michele in St. Peter's. 1721(*Castelli e Ponti* 1743, pl. XXVIII).

Zabaglia's talent, which revived the ancient operative pragmatism in face of the young and ongoing scientific advancement, legitimated by the celebrate volume dedicated to him, and his achievement was turned into a myth. His scaffolding share a constant care for the conservation of wall surfaces, the safety of workers and the reuse of materials. They represented such a remarkable progress in comparison with the usual building mechanical devices that they would be used without interruption up to the first half of the 20th century and abandoned only following the introduction of modern metal scaffolding. This celebratory publication and user manual at the same time, ordered by St. Peter's Fabric was inspired by the contemporary French and German manuals, in order not to lose its memory and to keep it for the next artisans generations. However, Renaissance treatises' influences still affected this volume, as the dual Italian and Latin text proves. *Castelli e Ponti* was responsible for transmitting ancient technical knowledge and for renovating the centuries-old supremacy of the Church, made weak by radical political and social changes. Thanks to this well-known compendium, Zabaglia's fame crossed the Italian borders and his inventions were recognized in carpentry treatises all over Europe. As far as the representations of the scaffoldings are concerned, the scenographic perspective tools were used to increase the magnificence of the machines and to impress the reader, as in the classical presentation books of the Renaissance age. Nevertheless, the plates excel by minute detail, enabling the reconstruction of the devices from their perspective depictions. In order to put Zabaglia's inventions in a dignified and worthy context, the editors of *Castelli e Ponti* enriched the publication by a selection of plates representing the famous translation of the Vatican obelisk, carried out in 1586 by Domenico Fontana (Fontana 1590).

Castelli e Ponti was a concrete proof of the Vatican building authority and of the great intellectual, technical and economical sources exerted in the construction and conservation of the St. Peter's, but also in defense of the Christian doctrine. Thus, technics spread, and political propaganda subtended to the promotion of Zabaglia's masterpiece, as an emblem of traditional but unfading know-how, comparable with the most advanced science's developments. The volume is divided into three parts. In the first one, tools, machines and work utensils ordinarily used by masonry workers and carpenters are illustrated (*Castelli e ponti* 1743. pls. I-XVII). The second section explains the scaffoldings designed by Zabaglia for maintenance and restoration practices (*Castelli e ponti* 1743. pls. XVIII-XXXVI). In its turn, this part is arranged in two clearly distinct partitions: the first (*Castelli e Ponti* 1743. pls. XVIII-XXX) includes scaffoldings for painters, plasterers and mosaicists, then also the ones necessary to bricklayers, carpenters and stonecutters. The second partition (*Castelli e Ponti* 1743. pls. XXXI-XXXVI) embraces scaffolds and platforms for diverse interventions, outside the Vatican also. The third and last section re-proposes the correct sequence of the plates illustrating the Vatican obelisk's transportation (*Castelli e Ponti* 1743. pls. XXXVII-LIV). The picture of the scaffolding built by Tommaso Albertini (*Castelli e Ponti* 1743. pl. LV), a skillful Zabaglia's assistant, to replace a similar structure previously made by Zabaglia for the restoration of Sts. Simeone and Giuda's tribune, concludes the volume. The sequence of the plates supports both the understanding of the individual device, and the promotion of the publication's general aims. The first plates are devoted to the tools for wooden works, connection devices and ropes knotting. These plates, through the graphic composition and the frameworks depicted, evoke some French compendia, edited in the previous century, as those by Mathurin Jousse (Jousse 1627), republished in 1702 in Paris. The accuracy of work tools, ropes, wooden grafts, and lifting machines illustrations (*Castelli e Ponti* 1743. pls I-VI) shows their consistency and typology, underlining their origins in the traditional equipment of masonry workers, stonecutters and carpenters. The detailed description of the specific techniques is also extended to materials, measures and weight, with the evident aim at demonstrating the practical aspects. The order of devices and tools, remarked in the illustrating captions sequences, follows a criterion based on the employment context.

Castelli e Ponti was conceived as a celebrative treatise as well as an operative handbook, destined to perpetuate the precious work of the carpenter masters and restoration techniques carried out by the St. Peter's Fabric and by its highly qualified technicians. Indeed, Zabaglia became the progenitor of a valuable group of St Peter's craftsmen. Due to their indubitable technical supremacy, they were even committed to solve difficult technical issues in worksites outside the Vatican, during the whole next century.

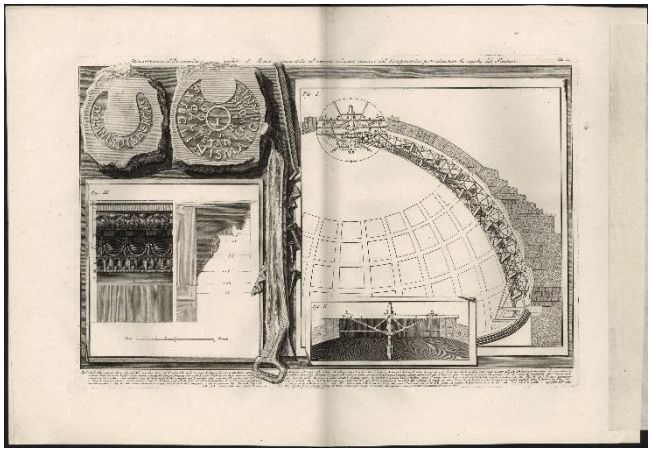

Figure 2. Scaffold designed by Giovanni Corsini and Tommaso Albertini for the Pantheon's dome restoration. 1756 (Piranesi 1790, pl. 29).

Among them, the rotating scaffolding design in 1756 by Giovanni Corsini and Tommaso Albertini (both contributors to Zabaglia) for the Pantheon's dome restoration is undoubtedly the most relevant. It is a mobile scaffold, operated by winches, and sliding on the Dome's frame. The scaffolding's structure was in the form of a spherical segment, anchored to a mechanical joint mounted in the free space of the dome's "oculus".

The followers of Zabaglia never formed a real school, but his teaching to some of the most brilliant laborers of the *Fabbrica* effectively guaranteed the transmission of his valuable technical knowledge. Notably, Giovanni Corsini, Angelo Paraccini and Tommaso Albertini contributed to the enhancement of the building practice and technology, so that some of their scaffoldings were included in the second edition of *Castelli e Ponti*, published in 1824. Tommaso Albertini, supervisor of the St. Peter's Fabric from 1773 until 1787, built the scaffolding for the restoration of the secondary dome of St. Gregory's (*Castelli e Ponti* 1824. pl. LVI), as well as the scaffold built for the restoration of the barrel vaults of the nave, replacing Zabaglia's solution (*Castelli e Ponti* 1824. pl. LV) Fig.3.

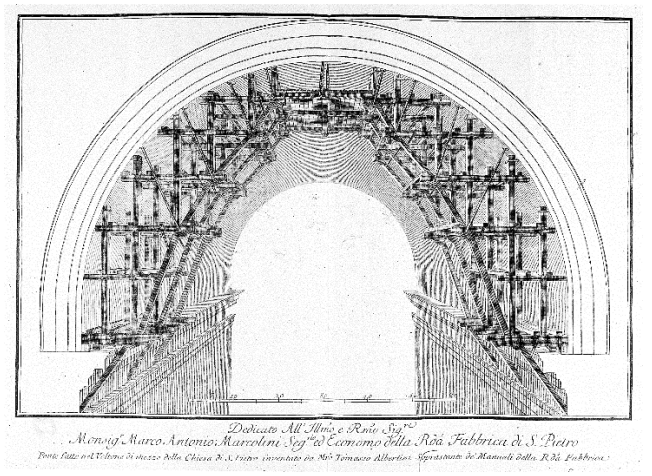

Figure 3. *Castelli e Ponti* 1743, pl. LV. Scaffolding by Tommaso Albertini for the restoration of the nave of St. Peter's, Rome.

The flying scaffolding for the restoration of the inner shell of the main dome of St Peter's, built by Tommaso Albertini, is equally interesting. Its profile designed to match the shape of the dome by the overlapping of different working platform; at its upper end it is anchored to three long poles fixed on the lantern's basis, which is connected with long inclined scissor braces (*Castelli e Ponti* 1824. pl. LVII) Fig.4.

During the French invasion of Rome (1798-1799) and the following occupation of the Church State in 1808-1812, papal authority and Vatican secular tradition entered a deep crisis. The challenge to establish a modern technical education, founded on scientific principles, endangered the technical primacy of the of St Peter's Fabric. New teaching criteria were imposed on all training sectors, including the professional and the craft ones. It was demanded to reorganize these according to the exemplar French model of the Schools of Arts and Crafts, enforcing openness towards the scientific progress that the Church could no longer postpone.

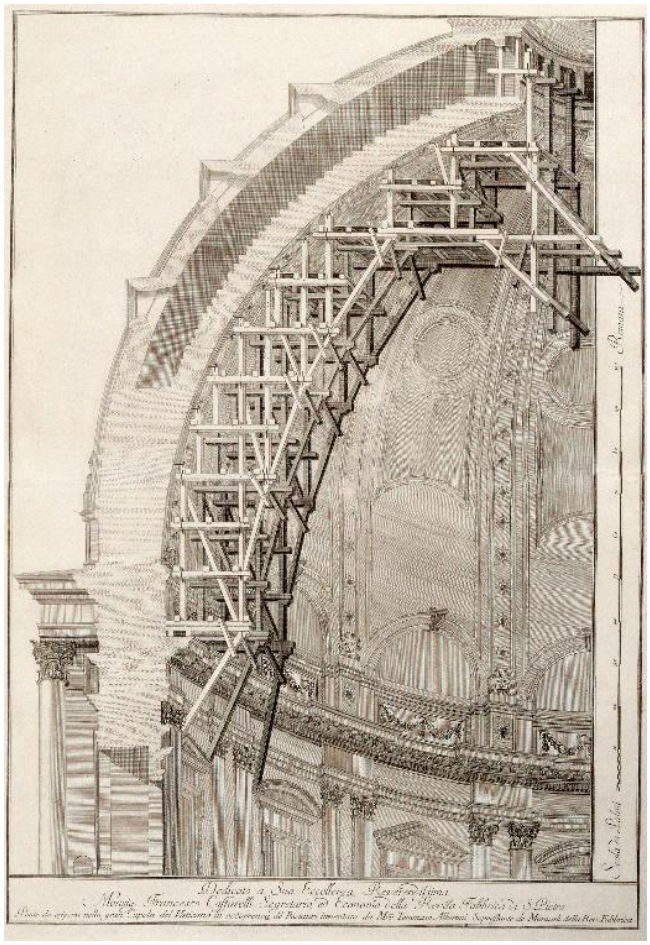

Figure 4. *Castelli e Ponti* 1824, pl. LVII. Scaffolding for restoration work of interior decoration of St. Peter's dome by Tommaso Albertini.

The second edition of the oeuvre concerning the work of the master carpenter Nicola Zabaglia saw the light at the end of this dark period. It was published in 1824 and includes 62 engraved copperplates and 48 pages with explanatory texts. A dedication to Pope Leo XII, an introduction by the treasurer of the St Peter's Fabric, bishop Castruccio Castracane, and a biography of Nicola

Zabaglia by the lawyer Filippo Maria Renazzi (1745-1808) accompany the work.

Among the new plates, some interesting technical inventions appear. Pietro Albertini, Tommaso's son, designed the great scaffolding used to restore the stuccos in the main nave of St Peter's Basilica (*Castelli e Ponti* 1824. pls. LVIII-LX). The impressive scaffold lifted to the nave's cornice with six winches on 26 November 1773. This framework, acknowledged for its reliability, safety and respect for masonries, floors and ornamentations, stands out among the most brilliant mobile scaffoldings. The plates show not only the massive and safe structure, but also the method and the equipment for its installation, like the iron crowbars used to assure the anchoring. This framework was composed of eleven shelves, covering a whole sector of the vault.

Figure 5. *Castelli e Ponti* 1824, pl. LX. Installation of a moving restoration scaffolding designed by Pietro Albertini in the nave of St. Peter's in 1773.

The flying scaffolding for the restoration of the inner shell of the main dome of St Peter's, built by Tommaso Albertini, is equally interesting (*Castelli e Ponti* 1824. pl. LVII) Fig. 4. Its profile is designed to match the shape of the dome by the overlapping of different working platform; at its upper end it is anchored to three long poles fixed on the lantern's basis, which is connected with long inclined scissor braces.

During the 19th century, other experts from the St Peter's Fabric and Roman technicians continued to perfect the design and structure of the scaffolding for the restoration. The greater attention paid to the safety of the workers, the adaptability to the complex spatial geometry of Roman architecture of different periods and types, the speed of assembly and disassembly, the economy and reuse of the various components, whether wooden or metal, were the main lines of improvement.

The St Peter's Fabric continued to be a fertile laboratory for experimentation, given the Basilica's pressing maintenance needs and its extraordinary uniqueness in terms of size, function and space.

The scaffolding designed at the end of the 19th century by St. Peter's superintendents, Enrico Donnini and Ercole Scarpellini, for the restoration of the main nave and the great dome, attest a substantial continuity with 18th-century practice (Fig. 6). At the same time, they introduced a design methodology that would lead to the invention of joint tube scaffolding. The scaffolding built in 1863 by Enrico Celso Donnini for the restoration of the gilded decorations in the Vatican dome perfected the one designed between 1816 and 1818 by Angelo Paraccini, later also used for the replacement of the lead sheet covering.

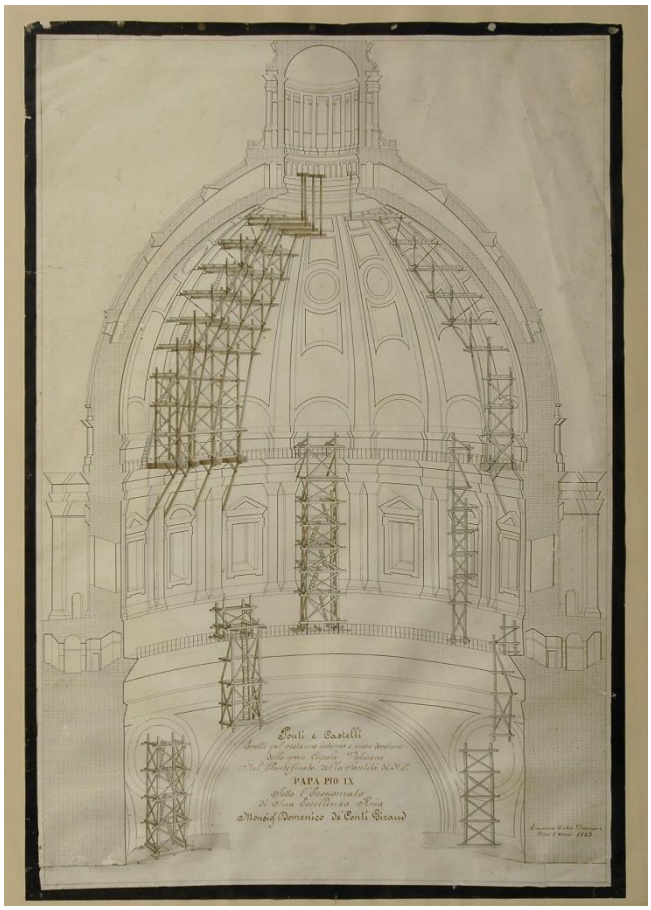

Figure 6. Enrico Celso Donnini, Scaffolding for restoration and new gilding work of St. Peter's Dome. 1863. (Vatican City. @St. Peter's Archives).

At the end of the 19th century, Ercole Scarpellini designed a colossal, multi-shelf, light and strong aerial scaffold with a span of 26 meters and a weight of approximately 9 tons (Fig. 7). This scaffolding was used to restore the stucco and gilding on the vault of the nave, damaged by a powder keg explosion in 1891 and the earthquake of 1895. On 16 November 1897, in just one-hour's work and with the help of three winches, ropes

and hand-pulls, the colossal scaffolding was erected on the big cornice of the main nave of St Peter's, some 30 metres above the ground. From the vault's setting two diagonal components supported the upper deck of the scaffolding, to which, in turn, the floorboard was fixed. Four levels of scaffolding allowed workers and artists to work comfortably and safely. The scaffold was stabilized by strong iron brackets and stiffening wooden elements placed on the diagonals. No invasive anchoring to the wall structure was required. As the previous prototype designed by Zabaglia, and later perfected by his successors, Scarpellini's "arched castle" could slide along the cornice thanks to soap-smeared slides, pulls and pulleys. It was described by contemporaries as a "bold work of art so well-conceived, worthy indeed of the artistic traditions of the first temple of Christianity" (Marconi 2015. 49-65).

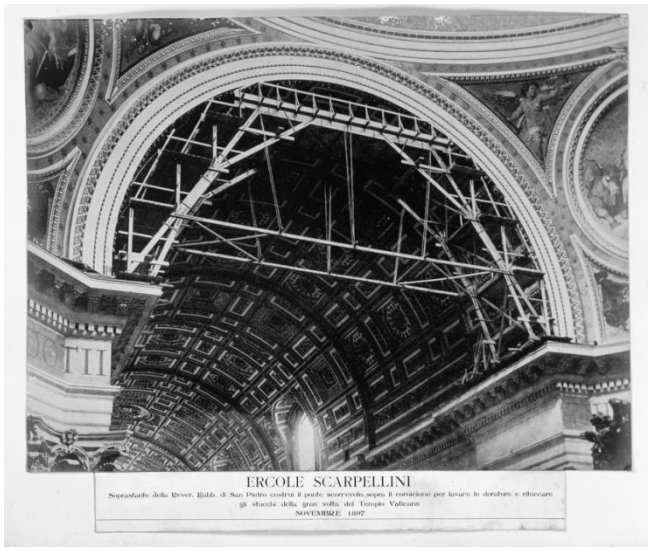

Figure 7. Scaffold design by Ercole Scalpellini in 1897 for the restoration work in the vault of the main nave of St. Peter's (@St. Peter's Archives)

From the point of view of critical acclaim, Zabaglia's teaching, developed and perfected by his collaborators and epigones, reached European treatises and manuals during the 19th century. In particular, technical literature and northern European carpentry manuals celebrated, the provisional apparatuses designed for the restoration and maintenance of the great Roman edifices, primarily the Pantheon and St. Peter's, re-proposing their shapes and constructional characteristics also in the explanatory graphic tables.

The first echoes of Zabaglia's work in later publications appears in the sumptuous treatise by Giuseppe Antonio Borgnis (Borgnis 1818-1820). References to Zabaglia's work and to the volume Castelli e Ponti appear in the two most influential Italian textbooks on construction and technology from the first half of the nineteenth century by Nicola Cavalieri San-Bertolo (Cavalieri San-Bertolo 1826-27) and Giuseppe Valadier (Valadier 1828-39).

Stefan Holzer affirms that Cavalieri San-Bertolo refers passingly to Zabaglia in his chapter on construction machinery and architectural procedures, and Valadier, in his turn, relied on the layout of some Zabaglia's plates as a model for his plates. Beyond these early Italian references to the first edition of Zabaglia, "the work received virtually no acclaim". References to scaffolding designed in the St Peter's Fabric do not appear in the works of Jean-Baptiste Rondelet (Rondelet 1802-1810) and Jean-Charles Krafft (Krafft 1805). According to Holzer, this is probably due not to his ignorance of Zabaglia, but rather might be attributed to the fact that all material referring to temporary works such as scaffolding, centers and lifting gear was excluded from his specialized *Traité des échafaudages*, which was printed only posthumously (Krafft 1856).

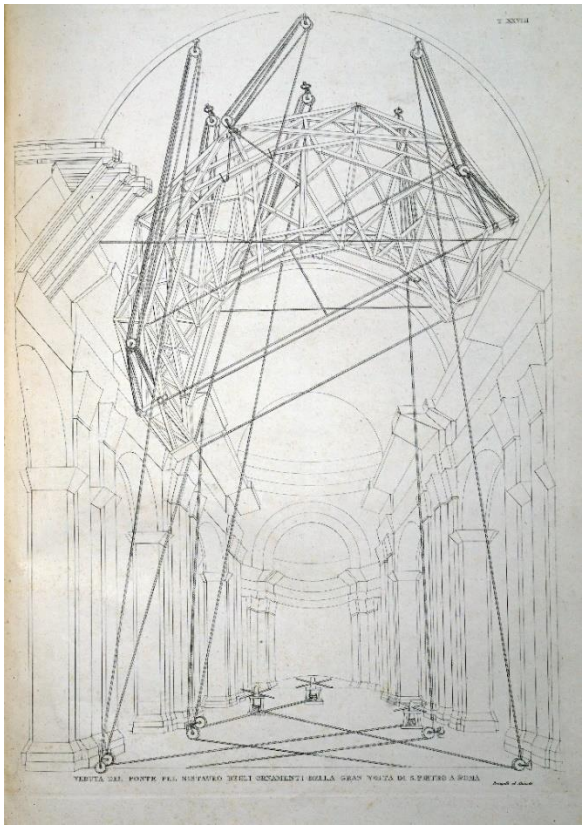

Figure 8. Pizzagalli & Aluisetti 1827, pl. XXVIII, showing the installation of the 18th century scaffolding by Pietro Albertini in the nave of St. Peter's, from Zabaglia 1824, pl. LX (here in Fig. 4).

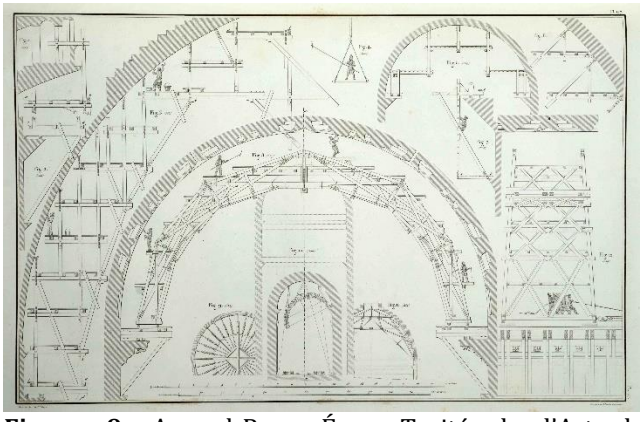

Figure 9. Amand-Rose Émy, Traité de l'Art du Charpentier (1837–41). Plate 127, showing scaffoldings for the restoration of the dome and the nave of St. Peter's, Rome, after Zabaglia 1824

However, it should not be ignored one fact decisive in understanding the reasons for the lack of success of the first edition of *Castelli e Ponti* in the treatise, whereas the operational success was immediate and prolonged: the first edition of the volume was published in 1743 in a small number of copies and they soon sold out. For a long time no copies were available for sale. The second edition, published in 1824, was reprinted from a rare 1743 copy that the *Fabbrica* itself was forced to buy at auction (Marconi 2015. 67-92). The circulation of the first edition in Europe was therefore very limited and could not influence the drafting of the carpentry and construction manuals of the time. However, there are some exceptions. The scaffolding for the restoration of the great dome of St Peter's, for example, had been included into the series of engravings by Gabriel-Martin Dumont (Dumont 1763).

3. CRITICAL FORTUNE AND RELEVANCE OF 18TH-19TH CENTURY WOODEN SCAFFOLDING

The second edition of *Castelli e Ponti*, by contrast, garnered much greater attention and was rapidly exploited in other publications; its critical fortune was conveyed by affirmation of technical schools and by the spread of scientific research achievements and its applications to the building site. Outside Italy, Amand-Rose Émy (Émy 1837-1841) introduced Zabaglia's work into the scope of the principal textbooks on carpentry. This publication was soon to become the reference text for the French-speaking world. Émy was most impressed by the Albertini scaffoldings for the St. Peter's nave and dome. He calls the scaffolding for the dome of St. Peter's "the most remarkable flying scaffolding", and depicting it, together with the scaffolding for the nave. The Albertini scaffoldings reappear in the carpentry treatise by Jean-Charles Krafft (Krafft 1856), but without any reference to the source. Later, some Zabaglia scaffolds were taken up again in another English carpentry manual, published by Edward Lance Tarbuck (Tarbuck 1857-1859). Here, with explicit reference to Zabaglia, Albertini's scaffolding for the nave of St. Peter's and Campanarino's rotating scaffolding for the Pantheon are again united in a single plate, both in orthonormal projection.

The last trace of Zabaglia within later technical literature is included a comprehensive collection of loose plates showing the Albertini's scaffolds, published by the Viennese contractor and carpenter Andreas Baudouin in 1908. When Baudouin's collection was reprinted in an abridged version in 1926, this plate was omitted, and the reception of Zabaglia came to a close (Baudouin 1908).

In the first half of the 20th century, the history of large wooden scaffolding gradually came to end. After the Second World War, the first metal scaffolding appeared in St Peter's too, which was lighter, reusable, flexible, cheap, safe and easier to maintain.

4. CONCLUSION

The inventions of Italian and European carpenters, which have made the history of modern technology, finally gave way to tube-joint scaffolding with prefabricated frames, and multidirectional or multi-storey scaffolding with prefabricated uprights and transoms. They were also adapted to restoration work. These require technical, formal and functional specifications for the protection of historical masonry and decorations. They must also be able to be suspended so as not to burden the structure and at the same time guarantee the usability of the building, specifications already known to the St.Peter's carpenters. The validity of their ideas has filtered into the current version of the devices they invented. A mention may be made of the special scaffolding built by EuroEdile (scaffold builders company) in 2005 for the conservation restoration of the Pantheon's dome. The scaffold adopts the spherical wedge shape already used in the 18th century and in the restorations of the 1920s, but updated in terms of components and technical specifications: 53,000 kg in weight for 43 m in height, 35 quintals of girders for the base, 500 m2 of worktops, 20 m3 of wooden boards, 48 dampened reinforced wheels, 6 of which are motorised and controlled by software. With this scaffolding, it was possible to leave about 70 % of the dome's surface free to allow visitors to enjoy the monument. These characteristics are similar to those of the scaffolding designed by Corsini and Albertini in the mid-eighteenth century. It would be interesting to try to adapt them to contemporary regulations and technology in order to verify their relevance and the possibility of new, certainly effective, and use potentialities.

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Conflicts of interest

There is no conflict of interest between the authors.

REFERENCES

Baudouin A (1908). Der Zimmerer-Meister. Ein Überblick über die gesamten Zimmerungen und ihre Vorbedingungen in vier serien. Wien.

Borgnis G A (1818-1820). Traité complet de mécanique appliquée aux Arts: Mouvement des Fardeaux. Paris.

Castelli e Ponti (1743). Castelli e Ponti di Maestro Niccola Zabaglia: con alcune ingegnose pratiche e con la descrizione del Trasporto dell'Obelisco Vaticano e di altri del Cavaliere Domenico Fontana (*Castles and Platforms by Maestro Niccola Zabaglia: with some ingenious practices and a description of the Transport of the Vatican Obelisk and others by Domenico Fontana*). Roma.

Castelli e Ponti (1824). Castelli e Ponti di Maestro Niccola Zabaglia […], coll'aggiunta di macchine posteriori e premesse le notizie storiche della vita e delle opere dello stesso Zabaglia (*Castles and Platforms by Maestro Niccola Zabaglia […] with the addition of later machines and historical information on the life and works of Zabaglia himself*). Roma.

Cavalieri San-Bertolo N (1827). Istituzioni di architettura statica e idraulica (*Institutions of static and hydraulic architecture*). Bologna.

De la Hire G P (1702). L'Art de charpenterie de Mathurin Jousse. Corrigé and augmenté de ce qu'il y a de plus curieux dans cet Art, and des machines les plus necessaires à un Charpentier. Paris.

Diderot D & Le Rond d'Alembert J B (1751-1780). Encyclopédie. Paris.

Dubourg Glatigny P (2017). L'architecture morte ou vive. Les infortunes de la coupole de Saint- Pierre de Rome au XVIII siecle, École française de Rome. Rome.

Dumont G M (1763). Détails des plus intéressantes parties d'architecture de la Basilique de St. Pierre de Rome. Paris.

Émy A R (1841). Traité de l'art de la charpenterie. Paris.

Fontana D (1590). Della Trasportatione dell'Obelisco Vaticano et delle Fabriche di Nostro Signore Papa Sisto V (*The Transportation of the Vatican Obelisk and the Fabrics of Our Lord Pope Sixtus V*). Roma.

Holzer S M & Marconi N (in press). Nicola Zabaglia's Scaffoldings for the Maintenance of Architectural Space in St. Peter's Basilica and throughout Europe in the Seventeenth to Nineteenth Centuries. Creating place in early Modern European Architecture, ed. by E. Merrill. Amsterdam. 95-127.

Holzer S M (2015). Statische Beurteilung historischer Tragwerke. Band 2: Holzkonstruktionen. Berlin.

Jousse M (1627). Le theater de l'art de la charpenterie, Griveau. Paris.

Krafft J C (1805). Plans, coupes et élévations de diverses productions de l'art de la charpente. Paris.

Krafft J C (1856). Traité des échafuadages ou choix des meilleurs modeles de charpentes. Paris.

Marconi N (2004). Edificando Roma barocca. Macchine, apparati, maestranze e cantieri tra XVI e XVIII secolo [*Building Baroque Rome. Machines, equipment, workers and construction sites between the 16th and 18th centuries*]. Città di Castello.

Marconi N (2006). Tradition and technological innovation on Roman building sites from the 16th to the 18th century: construction machines, building practice and the diffusion of technical knowledge. Practice and Science in Early Modern Italian Building. Toward an Epistemic History of Architecture, ed. by H. Schlimme. Milan. 137-152.

Marconi N (2009). Technicians and master builders for restoration of the Dome of St. Peter's in Vatican in the 18th Century: the contribution of Nicola Zabaglia (1664-1750). Proceedings of Third International Congress on Construction History. Cottbus (Germany), May 20-24, 2009, Cottbus 2009, vol. 2, pp. 991-1000.

Marconi N (2015). Castelli e Ponti di maestro Nicola Zabaglia. Apparati per il restauro nell'opera di mastro Nicola Zabaglia per la Fabbrica di San Pietro in Vaticano [*Castles and Platforms by Master Nicola Zabaglia. Restoration equipment in the work of master Nicola Zabaglia for the Fabbrica di San Pietro in the Vatican*]. Foligno.

Mazzocchi L (1872-1879). Trattato su le costruzioni in legno (*Treatise on wooden constructions*). Milan.

Piranesi F (1790). Raccolta de' templi antichi (*Collection of Ancient Temples*). Roma.

Pizzagalli F & Aluisetti G (1827). L'arte pratica del carpentiere (*The practical art of carpentry*). Milan.

Rondelet J B (1802-1810). Traité théorique et pratique de l'art de bâtir. Paris.

Tarbuck E L (1857-59). The Encyclopaedia of practical carpentry and joinery. Leipzig.

Valadier G (1828-33). L'architettura pratica (*The practical architecture*). Rome.

Viollet Le Duc E E (1858-1868). Dictionnaire raisonné de l'architecture français du XIème au XVIème siècle, 10 voll. Paris. V. 115-116