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Technology and repairs in *Castelli e ponti di mastro Nicola Zabaglia* (Rome, 1743)

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Abstract

The construction of St. Peter's in Rome can be considered as having been completed at the end of the XVII century. Concurrently, with the closing of the Vatican building yard, a number of important actions to maintain the Basilica were started and continued for a long time up to the XIX century, on the vault and the dome first, on the porch and the obelisk later. Both editions dated 1743 and 1824 of the treatise *Castelli e Ponti* written by Nicola Zabaglia (1664-1750), the "sampietrino" building foreman, are an excellent compendium of technical and mechanical achievements of the Roman Baroque in the field of building construction. Due to the technical and operational difficulties encountered to carry out most of these repairs, it was necessary at that time to design and erect suspension scaffolds, either fixed or moving, as well as special machines and temporary structures which were really innovative. The instruments and techniques of repairs developed in Rome in the XVIII century can be highlighted through analysis of the Zabaglia treatise *Castelli e Ponti*. There are so clearly detailed pictures of these techniques shown in this document that their understanding and use has been possible up to the beginning of the XX century. Even today, the works of Zabaglia can provide the specialists with new elements to be used for developing a more comprehensive and realistic history of repairs.

1 Introduction

In 1693, in the course of several initiatives aimed at the embellishment of St. Peter's Basilica, pope Innocenzo XII Pignatelli (1691-1700) approves the project presented by Carlo Fontana (1634-1714) for retraining of the Baptismal chapel. The project foresees the installation of a spectacular baptismal font, derived from an enormous boulder of porphyry, originally covering the sepulchre of emperor Ottone II. This boulder had been moved from the atrium of the Costantino's Basilica, where it was originally located, to the Vatican caves in 1610, at the time of construction of the portico and the façade, and must be now transferred from the caves to the foundry of St. Peter's, located in the southern area of the apse, to be sculpted, modified to the new use, and decorated with precious metallic friezes. It seems from historical records, that during transport, coordinated by an inexperienced worker of the Fabbrica of St. Peter's, Giuseppe Davini, the block was seriously damaged and broken into several pieces (*Castelli e ponti*, 1824, pg. IV). This failure aroused such a great clamour and the anger of the pope, that a lawsuit was brought against Davini. Davini was accused of negligence, malpractice, and incautiousness, then convicted and imprisoned. The severity of this conviction highlights dramatically the operational situation of this period, substantially based on the intuitive talent of only a few technicians.

The problem is solved in 1696, thanks to the extraordinary ability of another worker of the Fabbrica, Nicola Zabaglia (1664-1750), a man unaware of mechanical theories but endowed with innate practical sense and powers of observation, who was capable of designing machines and instruments suitable for this specific exigency. By use of his apparatus, it was possible to move, raise and position in place not only the baptismal font, but also statues, bas-relieves, and bronze adornments, with "easiness, rapidity, and pleasure".

Who is master Nicola Zabaglia? The title page carved by Pier Leone Ghezzi for the Zabaglia treatise *Castelli e Ponti* (Rome 1743), depicts Zabaglia in his study, busy verifying a hoisting machine (**Fig.1**).

Fig. 1- P. L. Ghezzi, Portrait of Nicola Zabaglia, in *Castelli e ponti di mastro Nicola Zabaglia*, Roma 1743.

Enrolled among the workers of the Fabbrica at a very early age, Zabaglia is soon impressed by the hoisting machines and the intricate wooden structure of the scaffolds used for maintenance of the Basilica, to dedicate himself to the experimental study of their function, with particular attention to operational safety aspects.

Most of these mechanical devices are made by assembling minor simpler elements, made of wood or metal, and are operated by ropes. The knowledge they represent is more based on the most intuitive and practical aspects of the human wits rather than the theory of Mechanics.

Two pulleys are represented in the picture, beside the wooden wedge in the foreground, at Zabaglia's feet. Not far from them, below the table, there is a *curlo* used for transport of heavy loads. It is a large cylinder of strong wood, with holes at the ends where poles are inserted to make it roll in the manner of a wheel. Zabaglia, facing the observer, has a carpenter's square fixed to the belt, while an *archipendolo* - a wooden square with a plumb line in the middle -, a hank of ropes and a tackle with two pulleys are stuck on the wall behind him. In the background, long wooden boards and a mallet complete his working kit. In the drawing, Zabaglia is represented in the act of verifying operation of a hoisting machine largely used in the building yards of Renaissance and Baroque, the *antenna*. This is a sort of wooden crane, either fixed to ground or mounted on a moving platform on four wheels, whose invention is attributed to Zabaglia himself (*Castelli e*

ponti, 1824, pg.VII). Although this theory is denied by the iconography and documentation of the building yard of Renaissance and Baroque, it was due to Zabaglia that technical characteristics and method of use of the *antenna* could be improved considerably.

The *antenna* is connected to a winch, operated by twelve workers, and laterally stabilized by means of three or four *ventole*, which are ropes of big diameter, tied to the top of the structure and fixed to wooden stakes sticked in the ground. The stone blocks are lifted by means of a hoist composed of two tackles with four turns of rope. The *antenna* shown in Tables II and VII of *Castelli e Ponti* is similar to that made and used by Zabaglia himself in 1703, to position the 50 travertine statues on the balustrade of the portico of St. Peter's, during works commissioned by Clemente XI Albani (1700-1721). This work was completed in three months with only the help of some young workers. The machine used to hoist and position the statues, each high 3 meters, up to a height of 17 meters, is a sort of big vertical mast composed of a number of minor beams, made of chestnut wood and linked together by metallic stirrups and ropes. On the top of the mast is connected the *falcone*, a strong beam positioned horizontally supporting the hoisting tackle. The *falcone* allows the balustrade to be easily accessed as it climbs over the portico, and the statues can be exactly centered on their pedestals. The *antenna* is installed on a wooden platform moving on *curli*, which allow the antenna's base to move from a pedestal to the other by rolling on the ground. The use of such device permits to reduce the costs involved considerably. It avoids the assembly and disassembly of the traditional scaffolds, otherwise required for installation of the statues, thus reduces the need for provisioning the lumber, which in Rome is very difficult to be found and therefore very expensive.

The portrait of Zabaglia also gives evidence of his operational method, which is not based on theoretical calculation and analysis of the opposition and balance of forces, but on preparation of scale models perfectly working of hoisting machines and scaffolds, made of straws, square tablets, and small pieces of wood cut to measure, with which he can verify the validity of his own intuitions.

However, Zabaglia is famous not only for having improved the existing hoisting machines, but also for the new devices he designed for restoration of the Vatican Basilica. In particular, his internal service scaffolds represent a real progress with respect to the other devices commonly in use for building construction, as they reveal a special attention addressed not only to preservation of the Basilica walls, but also to safety conditions of workers.

The traditional scaffolds, as described in the treatises of Renaissance and Baroque, remain substantially unchanged up to introduction of the metal, in

the XX century. Up to the XVII century, the traditional scaffolds are composed of a main structure of *candele*, or *ritti*, uprights of around 16 cm of thickness, usually consisting of two beams linked together with iron stirrups and ropes. The *ritti* are positioned in pairs, at a distance of 2 meters one from the other, connected each other at different heights by means of stringers, and coupled at the top to horizontal joists, to form a sort of trestle. Horizontal boardings are placed on the joists, representing the walkway surface. This same structure is then repeated to form more levels, up to a distance of about 1,90 meters - the average height of a man - from the ceiling. When the width of the span exceeds 4 meters, the joists are strenghtened in the middle section of the span by additional transverse beams. In order to support the stress caused during hoisting of materials, the scaffolds are anchored to short beams of chestnut wood, stuck into the side walls and fixed by wedges.

2 Examples

The same characteristics of essentiality, reversibility and strength, as found in the traditional scaffolds, like those used to raise the Vatican obelisk and represented in the treatise *Della Trasportazione dell'Obelisco Vaticano* (Roma 1590) of Domenico Fontana (1543-1607), revive in the scaffolds designed by Zabaglia (**Fig. 2**). The two most significant scaffolds of Zabaglia are those used for cleaning of the Berninian baldachin in St. Peter's (*Castelli e ponti*, 1743, table XXXIV) and for restoration of the bronze globe and the cross of the Vatican obelisk (*Castelli e ponti*, 1743, table XXVI). In the last one, erroneously attributed to Carlo Fontana by Francesco Milizia in the biography of Luigi Vanvitelli (Milizia, *Memorie,* 1785, pg.266), the obelisk itself is used by Zabaglia as the main supporting structure, around which he positions ten tiers of boarding and associated stairs (*Castelli e ponti*, 1824, table XVIII).

When the height to reach is such that it's not possible to install the scaffold on ground, it is recommended to use suspension scaffolds. Common suspension scaffolds are either fix or movable, normally held by ropes, or supported by short wooden beams, stuck into the wall, or propped against jutting elements, or inserted in the windows openings. The construction technology of these scaffolds still follows that conceived by Filippo Brunelleschi (1377-1446) for those used during construction of the dome of Santa Maria del Fiore in Florence, installed at a height of 55 meters from ground.

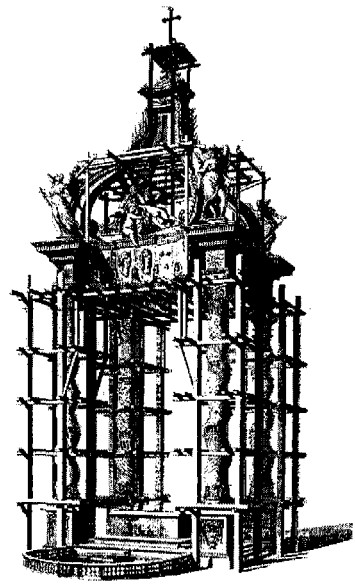

Fig. 2- Scaffolding for repair the *Confessione dei SS. Apostoli* in San Pietro, in *Castelli e ponti di mastro Nicola Zabaglia*, Roma 1743, tav. XXXIV.

The suspension scaffolds designed by Zabaglia for the several works of restoration of the Vatican Basilica will improve this technology. An example is the scaffold conceived by Zabaglia for restoration of the spherical pendentives of the minor domes of St. Peter's (*Castelli e ponti,* 1743, table XXIII). In this structure, the vertical elements (*candele*) are connected to the main horizontal beams (*falconi*), supported by the cornice of the trabeation, by means of stirrups and wooden pins. Three other tiers of horizontal beams are connected to the *candele*; they are supported by the cornice, by vertical props and are held up by ropes, respectively. The base of the *candele* is stabilized by transverse beams fixed with pins (**Fig.3**). Various versions exist for this scheme, depending, as obvious, on the different situations to solve. One is the scaffold installed for restoration of the St. Peter's chair (*Castelli e ponti,* 1743, table XXVII). The system of connection between *candele* and *falconi*, consisting of iron stirrups and pins, keeps the scaffold separate from the wall and the associated ornamentation, and allows the different tiers of beams to be spaced out according to overhang of the cornices.

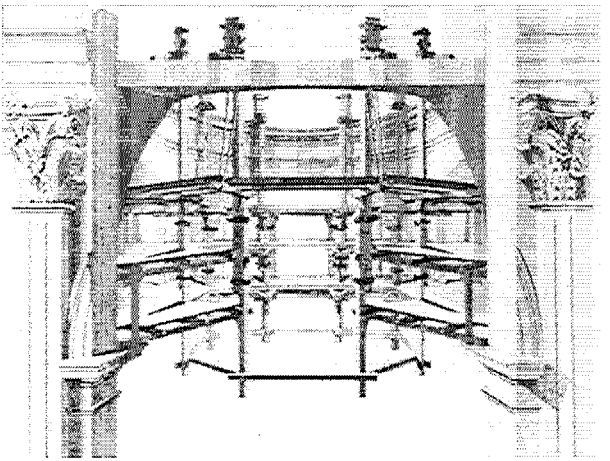

Fig. 3- Scaffolding for repair the small domes in San Pietro, in *Castelli e ponti di mastro Nicola Zabaglia*, Roma 1743, tav. XXIII.

A recurring term in the treatise of Zabaglia is "simplicity" of execution. "Simplicity" characterizes the scaffolds commissioned by pope Innocenzo XII Pignatelli (1691-1700) for the execution of stuccos and mosaics in the dome of the Baptistry's chapel, towards the end of the XVII century. The scaffold designed by Zabaglia is in this case so essential and safe in its forms to result not only appropriate for the need ("*tanto adatto al bisogno*"), but also surprisingly economical. Its joint connections, fixed with metallic stirrups and ropes, do not require the use of nails, and permit to save large amounts of expensive lumber (*Castelli e ponti*, 1824, pg.V).

"Simplicity" also characterizes the structure of the scaffold used for restoring the vault of the tribune of St. Paul's Basilica (*Castelli e ponti,* 1743, table XX). This structure is composed of three tiers of trestles, installed up to a height of 60 *palmi* (around 13,5 mt), with a height of each level decreasing upwards. Nailed and embedded transverse beams are used to stabilize the trestles each other and with the side walls, respectively. They also support the three levels of boarding, easily accessed by use of stairs and intermediate floors.

The excellence of this structure is that there is no need to damage the walls or the floor to fix the supporting beams. This special attention to preservation of the building, which must be restored without be defaced and with no damage of its ornaments, is particularly evident in the case of the scaffold designed by Zabaglia for restoration of an arch in St. Peter's Basilica (*Castelli e ponti,* 1743, table XXII). This scaffold, similarly to the other works of Zabaglia reveals his continuous research for the simplicity of execution, solidity and strength of the structure, as well as the exigency of saving lumber. For Zabaglia, nothing in his scaffolds is in excess, as every wooden component is to "support, connect, and strengthen" the

whole structure.
At the same manner, he pays particular attention to the safety of workers. Tables VIII (*Carriolo per i festaioli*) and IX (*Modo di allungare le scale per i Festaioli*) of *Castelli e Ponti* give evidence of the risks run by workers in keeping their balance to access the high levels of the building; especially workers in charge of the ornament of the walls (*festaroli*) are forced to work in hard and uncomfortable positions on extremely long stairs. The high risk taken by workers is proved by several accidents occurred during works and reported by the relatives of workers involved (D'Amelio-Marconi,1999, pg.323-324).
Other operational aspects are also involved in the design of a scaffold, first of all is the functionality of the basilica, which must continue be used without any interruption of its functions caused by works. Thus, the scaffold must be made so as to cause no obstruction on the floor.
A very clarifying example in this sense is the scaffold used for restoring the vault of the portico of St. Peter's (*Castelli e ponti,* 1743, table XXI) **(Fig. 4)**.

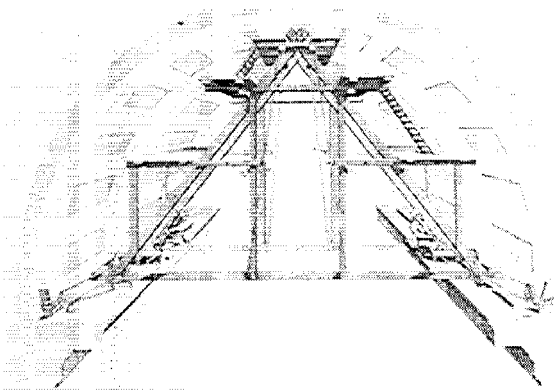

Fig. 4- Scaffolding for repair of portico's vault in San Pietro, in *Castelli e ponti di mastro Nicola Zabaglia,* Roma 1743, tav. XXI.

To accomplish this work, either a complex scaffold, installed all along the portico and starting from ground, or a suspension scaffold, starting from the height of the vault and eventually installed in correspondence of just a section of the portico, would have normally been required. In the second case, it would have been also necessary to install, dismantle and re-assemble the scaffold according to progression of the works, to cover the whole length of the portico, and the scaffold should have foreseen at least two walkway surfaces, to access both the intrados and the ridge of the vault.
On the contrary, the solution developed by Zabaglia aims to use less lumber, save money and reduce the time of execution. It foresees a movable suspension scaffold, which can be moved all along the portico at

the height of the cornice, by the strength of just a few men, without being continuously dismantled and re-installed. In this structure, the four main vertical tie-beams are linked at the lower end to the four elements positioned at 45° (*capre*) by means of two horizontal beams, fixed in pairs by iron or wooden pins (*cavicchie*) and ropes. In this way, the span of the horizontal beams is reduced, and the use of props and *saettoni*, a sort of wooden props of large section, avoided. Other ropes contribute to connect the top of the *capre* to the four tie-beams. The other transverse beams, connecting the tie-beams to the *capre*, are also used to support the walkway surfaces. Additional minor elements concur to stabilize the whole structure. A rope each side of the structure is connected to two pulleys, one secured to a big prop stuck into the cornice, the other secured to the scaffold itself, and to a winch positioned at the bottom of the structure. The scaffold is moved by synchronously pulling these ropes. A solution to facilitate sliding of the structure is to position two big soapy boards at its ends.

One of the most ingenious developments of this system will be the scaffold built in 1773 by Pietro Albertini, one of the best follower of Zabaglia, for restoration of the vault of St. Peter's (*Castelli e ponti,* 1824, tables LVII-LX) **(Fig. 5)**.

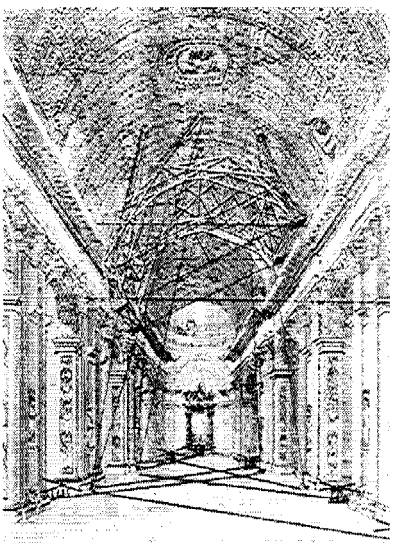

Fig. 5- P. Albertini, Raising of the scaffolding for repair basilica's vault in San Pietro (1773), in *Castelli e ponti di mastro Nicola Zabaglia,* Roma 1824, tav. LVII.

At the same manner of Zabaglia, Albertini resorts to a movable structure, sliding along a overhanging boarding positioned on the cornice, to prevent the scaffold be continuously installed and dismantled with progression of the works. This scaffold has a base large around 30 *palmi* (6.50 meters) and eleven floors; it is initially assembled on ground, then raised slantwise over the cornice, by use of six winches synchronously operated. Once erected, it

can be slid all along the vault by manual operation of winches; it is definitively dismantled only at the end of the works (**Fig. 6**).

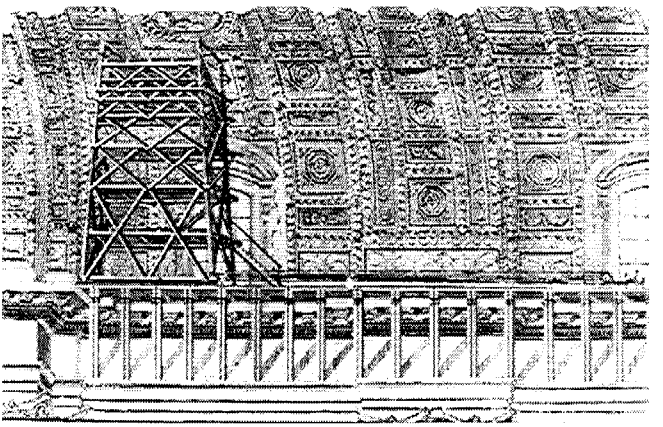

Fig. 6- P. Albertini, Sliding of the scaffolding for repair basilica's vault in San Pietro (1773), in *Castelli e ponti di mastro Nicola Zabaglia*, Roma 1824, tav. LX.

The characteristic of fast reversibility common to all the designs of Zabaglia, intended as a way to save material, and thus money, is also evident in the drawing of the small hut (*casotto*) in Table XXX of *Castelli e ponti*. The wooden elements composing the hut are secured without the use of nails or screws, but only by means of transverse slats fixed with wedges, perfectly joined together without gaps or slits, "like it happens in the hooped barrels" ("*come appunto succede nelle botti strette da cerchi*"). Thus, the structure can be easily moved, and easily assembled or dismantled, as needed.
Thanks to a perfect knowledge and masterly use of the "opposition and balance of forces", Zabaglia is able to invent and test new models of scaffolds and hoisting machines, "stable, strong and safe" structures which allow working "in whichever location, also the highest and most difficult" (*Castelli e ponti*, 1824, p.IX).

3 Conclusions

The treatise of Zabaglia *Castelli e ponti* is an extraordinary compendium of techniques and mechanical knowledge applied to the building science; it will represent an undisputed model of technological perfection for a very long time. Zabaglia machines will be used up to the second half of the XIX century; reference to their drawings can be found in the treatises and manuals of architecture and engineering up to the Twenties of the XX century (Donghi, 1925, pg.138-145; Musso-Copperi, 1890, pg.126).
It will be only the introduction of steel with the tubular scaffolding, in the first postwar of the XX century, to start the progressive overcoming of the

Zabaglia's ideas, and then cause the definitive abandonment of his machines.

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**This paper is the result of a common research of the authors. Nevertheless, M.G.D'Amelio wrote the first part, up to "dome of Santa Maria del Fiore in Florence", and N.Marconi the second one.*

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