Know how to restore: construction techniques in Baroque Rome – practices, devices and "secrets"

N. Marconi
Department of Civil Engineering, University of Rome Tor Vergata, Italy

Abstract

In the 17th Century, Roman construction techniques attained unrivalled results, derived from experimentation carried out in the greatest building sites of the Renaissance. Such was the success that the so-called "Roman construction system" became an effective, fast and technologically advanced working method that lasted, basically unchanged, up to the 20th Century. Baroque building practices hide a number of secrets and devices which not only represent an extraordinary preview of some present construction techniques, but also contribute to clarify the reason for the lasting effectiveness of these traditional construction methods. Among the most popular techniques of the Roman Baroque building practices, we have the methods used to lengthen the setting time of masonry mortar, strongly recommended by Francesco Borromini; the use of special mechanical devices; the stratagems introduced in brick manufacture and laying; the special procedures followed in the supply and the working of lime, plaster and freestone.
Keywords: building site, construction techniques, masonry, building materials.

1 Introduction

The organisational, operational and technical mechanisms of Roman Baroque building sites allow us to retrace the history of single buildings and their materials, but also to identify the factors that determined the image of modern Rome. The latter began to take shape as of the 16th Century when a series of important building projects were undertaken. Initially, they belonged to major, wide-ranging urban plans such as the ones announced by Pope Sixtus V Peretti (1585-1590), but then other single projects for new buildings or the modernisation of existing buildings appeared. Roman building sites were conditioned by the lack of working space, but they also had to overcome the problem of underground water springs and above all the problem of ancient ruins. These factors conditioned not only the type and the construction of some parts of the buildings, but also the location of the new buildings, which are constructed on existing ancient buildings thus saving on foundation work. This trend lead to an increase in the number of private construction contracts and to shorter construction time. The quality of execution remained extremely high also thanks to the wise use of construction materials and to a lucky combination of technical and financial factors.

From the purely technical point of view, the Baroque construction practice was achieved thanks to a much improved design stage, but above all to much improved organisation of the work of the Lombardy and Ticino masons, who in the 16th Century, took over from the Tuscany masons who had reconstructed Rome in the late 15th Century. Indeed, the *ars aedificatoria* of the Lombardy masters combined wise workmanship with futuristic entrepreneurial spirit intent on optimizing working time. Its trademark was a pragmatic approach to construction problems, borrowed from the Gothic tradition, but also a wise use of machinery and a labour organisation based on autonomous teams, which cut working time considerably. This is the context within which the Fabbrica di San Pietro took on a decisive role, as the institution in charge of the financial and the technical management of the new basilica building site as well as the best training institution for masons. Thanks to an ingenious system for the hire and the sale of material and equipment developed between the 16th and the 17th Centuries, collaboration between the Fabbrica di San Pietro and the other Roman building sites turned into a wonderful vehicle for the transmission and the improvement of building practices [1].

2 Construction techniques - practices, devices and "secrets"

Roman Renaissance and Baroque construction practices made use of a series of expedients that were on the one hand extraordinary previews of some current practices, but also contributed to clarify the reasons for the lasting effectiveness of these traditional construction methods. Indeed, in Rome, they remained unchanged until the 19th Century when reinforced concrete techniques were introduced and took their place. However, in the context of the evolution of construction techniques in Italy, Rome is a special case: ancient architectural ruins, especially those from the Imperial age, were an incredible formal repertoire for the architects of all eras, but they were also an embarrassing element of comparison that prompted emulation. Masons of different nationalities and traditions were obliged to use ancient materials and techniques so they made their own contribution and added their knowledge to the so-called "Roman construction system": an example of this is the wise use of stone, brick and stucco, which is a good example of osmosis and integration of different working traditions. Over the centuries, therefore, working practices, construction techniques and building technology were adapted to the specificity of Rome and to the cumbersome presence of the ancient remains, thus transforming each building site into a fertile construction research laboratory. This includes secrets that relate to the whole construction process: from labour organisation and the supply of material, from the design of scaffolding and building machinery, to building site safety measures and even technical stratagems.

Although the latter are related more to the management aspect than to construction as such, they are decisive for the general economics of the building industry. Indeed, the many works open in the city and the incredible construction turmoil of the Jubilee years promoted the gradual development of an absolutely extraordinary organizational, managerial and technical setup. This turns Roman building sites into true models of efficiency, speed and high-quality workmanship; however they still had problems linked to the supply of machinery, hemp rope, metallic instruments, rare stone materials and out-of-the-ordinary wood. Indeed, this kind of equipment was often too expensive for the "minor" building sites, however it became possible to reduce this cost considerably thanks to the hire system offered by the Fabbrica di San Pietro. It is to this system that we owe the completion of much of the Roman architecture built up to the first half of the 19th Century. It is particularly interesting for the construction machinery that was developed or specially designed to reconstruct the Vatican basilica, and was then easily adapted to normal, routine work. A majority of these devices have become emblems of a knowledge based on the more intuitive and pragmatic aspects of human intelligence, praised by Nicola Zabaglia (1664-1750) on the front page of his *Castelli e Ponti* (*Castles and Bridges*) of 1743. This text is a compendium of 16th - 18th Century Roman construction technology and it illustrates the temporary apparatus contrived by Zabaglia himself for maintenance work on the basilica of Saint Peter. These devices had in common a great simplicity as well as reversibility and a considerable degree of safety, they are wonderful examples of technological innovation and perfection, so much so that many of them were then hired out to other building sites up until the end of the 18th Century. Among the many, we remember the mobile scaffolding used for maintenance work on the nave, the scaffolding built to cover the main dome with sheets of lead and to do mosaic-like work on the minor domes. Within the context of this same construction technology, building site documents mention stratagems for the protection of wood scaffolding and iron equipment: for example, machinery and scaffolding were sheltered from the rain with large cloths coated with wax in order to make them waterproof, while at night, to avoid the frequent theft of tools, the scaffolding was lit up with oil lamps.

In the documentation of the various buildings, we find information on the secrets pertaining to the construction itself, which were often omitted by the writers of the *Capitoli*, contracts undersigned by the clients and the buildings contractors prior to the job being assigned, and the *Stime*, the final reports on the work carried out, even though they were very familiar with building site practices. They give us information on building methods, the nature and the type of materials, the specialization of the masons, the quantity and the quality of the work carried out.

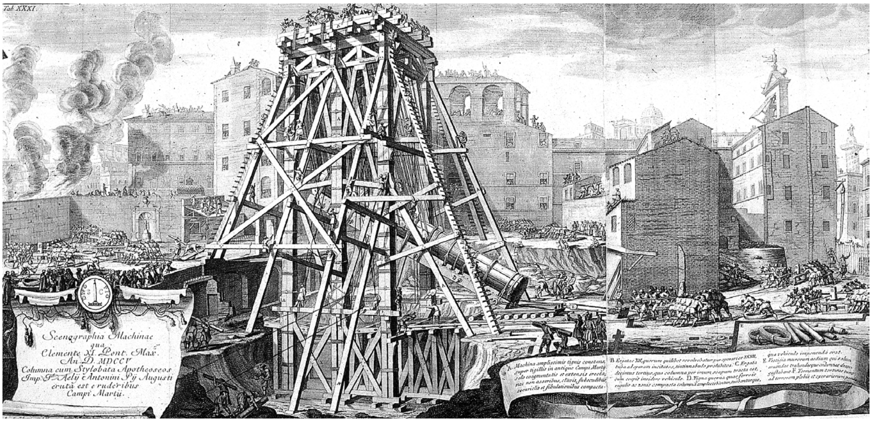

Figure 1: The raising of Antonino Pio’s Column, by G.B. Piranesi, *Il Campo Marzio nell’AnticaRoma*, Rome, 1762, XXXI.

In this latter case, the documents also reveal less well-known construction aspects, such as the different uses of materials, the tricks used to delay the setting of mortar, the manufacture and the laying of bricks as well as some details about the construction of domes.

Throughout the 16th Century, dome construction was in the hands of few, specialised masonry firms that the most famous architects fought over. We are still far from the theoretical systematization of the 17th Century, and the construction of the domes with slender outlines such as St. Carlo ai Catinari, St. Andrea della Valle, St. Agnese in Agone and Saints Ambrogio and Carlo were built following a method based mainly on geometry and experience gained in centuries of trials and by studying the great models of antiquity and of the Renaissance. From these, architects have drawn indications concerning also the choice of materials and techniques: the combined use of stone, brick and concrete has been deduced from detailed analyses of collapsed sections of masonry. Classical architecture is an undeniable reference point also for the very design of vaulted structures: throughout the 17th Century, it was based on whole number ratios and on the mutual proportional ratio of certain basic measurements, such as diameter and calotte thickness. It is only at the end of the century that some writers attempt to systematize the dome theory in treatises that remain however overtly empirical, and only reveal some of the “secrets of the rule of art” [2]. This is the legacy of Medieval construction practices that led master masons and craftsmen to refrain from revealing techniques and construction stages even when drawing up job estimates. Indeed, right up to the first half of the 17th Century, domes were paid for in a lump sum, in other words, a total amount that included the supply of material and labour costs, was agreed prior to work commencing. There were standard prices based on the estimates of recurrent models (Jesus, St. Andrea della Valle, St. Giovanni dei Fiorentini, etc.), which were considered examples of workmanship and technical perfection. This is how the specialized firms were able to ensure continued contracts and profits for themselves. It was only between the end of the 17th Century and the mid 18th Century, with the systematization of the static of buildings and the publication of numerous treatises on the subject, that the secret of dome construction was revealed. The most widely used technique was the mixed one, which combined the use of mortar and pozzolana concrete, inherited from ancient Rome, with the wise use of bricks borrowed from the experiments of the 15th Century Florentines and from the Lombardy masons. The brick masonry structure of the calotte, with a wood centering substructure, was covered with a layer of concrete made of pozzolana mortar mixed with chips of tufa and brick fragments, this entailed increased thickness in the more delicate points of the structure, which also limited deformations in the shell once it had set.

The Sistine and the Paoline Chapel building sites in the St. Maria Maggiore basilica, which symbolize 16th Century Rome architecture, were forerunners of the mature Baroque construction technique and dome construction. They were built respectively by Domenico Fontana (1543-1607) for Sixtus V Peretti between 1585 and 1587 and by Flaminio Ponzio (1560-1613) for Paul V Borghese between 1607 and 1611, and their construction is documented by the statement of expenses [3]. The *Mesura et stima* for the work carried out in the Sistine Chapel, for example, offers a detailed illustration of the various construction stages, of the material and the equipment used and also reveals some of the practical tricks of the trade. One of these is Fontana's decision to proceed to explorative drillings before undertaking work on the foundations of the four main pillars. On the one hand Fontana took up the request of the Renaissance experts to go back to ancient foundation techniques, on the other he revealed a caution, which was the result of his practical experience [4]. On the basis of the result of these tests, he decided that the dome foundations were to be built on pillars made of tufa rubble bound with hydraulic mortar, linked together by brick arches.

The use of tufa in Roman construction goes back to very ancient times. It was extracted from Latium volcanoes or from open-air quarries in the city, tufa is used as freestone, as an inert component for foundation work and is sometimes cast, or else ground with pozzolana and used to make up mortar and concrete that then has excellent hydraulic properties. More generally, in Roman building sites of all times, stone – travertine, peperino and tufa – was used for the elements that must sustain the greatest stresses, such as foundations, arches and vaults. For all other masonry sections, bricks were used, bricks made of white and red clay from the Tiber, which is what gives Roman brickwork its characteristic straw colour.

In the Sistine Chapel, the masonry work of the arches, the pendentives, the great arches that support the dome and sometimes of the side vaults too is made with the so-called *tevolozze*, bricks, whole or hewn, recovered from the demolition of old buildings. Theoreticians as well as technicians recommended the use of crushed *tevolozze* as *coementa* for concrete used for foundations, arches and vaults, but also as inert material in hydraulic mortar. This is due to the excellent hydraulic properties and the high resistance to compression that prolonged seasoning confers to it. Indeed the results are similar to those obtained through slow and uniform baking, since the natural porosity of the bricks is countered thus making the slurry compact and solid. This is why the *tevolozza,* whole or crushed, was used in all Roman factories especially when the presence of underground water makes it necessary to add protection against seepage. This was very frequent in Rome, as can be deduced for example from the records that describe the construction of the church of St. Agnese in Agone during the 1654-1657 period; here seepage of rain water as well as water from the Tiber when it broke its banks, were stemmed by Francesco Borromini with a *tevolozza* and crushed stone fill, well compacted and bound by pozzolana-base hydraulic mortar, right up to floor level [5]. The trench-like foundations of the Filippini's Oratorio were also made of *tevolozze* and tufa during the construction stage overseen by Borromini himself (1637-1643).

The foundation masonry of the Paoline Chapel is made of tufa and *tevolozze*; the latter was also used in the foundations of the pylon of the gallery encircling the Sforza Chapel. An entire chapter of the *Misura* of the work carried out in the Paoline Chapel written by Marc'Antonio Fontana, a relative of Domenico [6] describes the tufa foundations: here too there is mention of *tevolozza*, peperino (in the two arches of the underground vault) and tufa (in the foundations of the pillars supporting the four arches of the chapel). In both chapels the dome drum is made of a double layer of *tevolozze*, one internal and one external, duly scarfed and fixed. The masonry structure of the dome, resting on wood centering, is made of a 3,5 x 26 x 13 cm ordinary brick calotte. This was then covered with cast concrete made of pozzolana mortar and crushed tufa and brick. The masonry of the Paoline Chapel, made of *tevolozza* and high quality brick are marked by very accurate workmanship that includes numerous scarfs between the old and the new walls. The resistance of the bricks was increased by alternating squared blocks of tufa, peperino and *sperone* stone, a peperino originating from lava. All the supporting vaults are made of stone and brick – peperino, *tevolozza* and tufa - , as well as the pillar overhangs – brick and *tevolozza* – and the vaults of the secondary chapels made of *tevolozza* with buttresses all the way to the key section. The perfect walls of the curtain, made of thin polished and plastered bricks, are bound by lime and pozzolana mortar; the surface finish is a layer of lime with a travertine powder finish that goes well with the stone sections. The stone sections are laid with thin lime, they are well connected and fixed to the wall with iron rods welded with molten lead. The dome has a 12,5 meter diameter approximately, it is made of brick and *tevolozza* and rests on centerings; the outside was made water-tight thanks to a layer of *cocciopesto*, a mortar mix of lime and *tevolozza* fragments to which sand, gravel, cooked linen oil or pozzolana were added and which has excellent hydraulic properties and is highly resistant to compression. The extradoses of the dome are covered with sheets of lead. The stability of the dome is ensured by two circular chains made of iron beams, poles and wedges, whereas the frames of the drum are shaped with bricks that follow the lines of the travertine guides that are placed in the recesses in the wall. Indeed, in these chapels too, the elements made of travertine clearly show the superiority of the structural frame as well as the stresses borne by capitals, bases, cornices, door and window casings, wainscots and architraves;

whereas staircase steps and the lanterns of the smaller side domes were sculpted out of peperino instead.

Often the travertine elements were combined with stucco elements that, thanks to clever finishing, match the stone perfectly. Stucco is a fine mortar that can be modelled and polished perfectly, it is made by mixing a binder with inert elements in a water solution made more or less liquid according to its end use. The most widely-used binders are lime and gypsum, the inert elements are marble powder, sand and brick. Because it sets so rapidly, stucco is suitable for elaborate motifs that, when smoothed and polished, acquire the compactness and the gloss typical of stone materials [7, 8]. However, making stucco elements for outdoors requires more elaborate work. A description of this can be found in a note written by Francesco Borromini for Virgilio Spada dated September 1654. According to Borromini, in order to obtain stuccos that stand up well to water and frost, it is necessary to use building lime, which, though more difficult to clean, is more resistant and lasting. Borromini also claims that once the work has been completed, it is a good idea to protect it with a layer of *brodata* lime, which is white, rather fluid lime, mixed with finely crushed travertine powder that must be brushed on and patted down. This allows it to adhere better and the result is a travertine granite stucco, similar in all ways to Tivoli stone, such as that which is documented by some external elements of St. Ivo alla Sapienza [9, 10].

One rather curious habit of Renaissance Rome is the use of darker bricks, known as *ferrioli*. Baking in ovens confers resistance and durability to these bricks that then turn varying shades ranging from light yellow (the so-called *albasi*), to dark red (*ferrioli)*, according to their position in the oven, their distance from the flames and the time they remain in the oven. The *ferrioli*, that contain ferrous oxides, are extremely hard and difficult to work with but are very resistant; therefore they were usually used to build the outer walls that are adjacent to window casings and corner pillar strips. In some cases, brick facings have *ferrioli* inserts in incomprehensible patterns, the aim of which is still uncertain. This combination of bricks of varying colours was already common in ancient Roman times, as proved by the studies on ancient walls carried out by Leon Battista Alberti and Vincenzo Scamozzi. The two experts acknowledge the obvious practical purpose, but they insist on the aesthetic intention, supported by the perfection of the cut and polished curtains that makes it difficult for the plaster to adhere [11, 12]. At the beginning of the 16th Century, geometrical patterns made with dark bricks on a yellow background livened the splendid facades of Palazzo Farnese (1541-1546), the Villa of Pope Julius III on via Flaminia (1551-1555), Palazzo Mattei Caetani (post 1548) and even those of Palazzo Farnese in Caprarola (1562-1568) [13]. However, I believe it is reductive to link this technique to purely visual considerations and I cannot share this theory, nonetheless because of the frequently random positioning of these decorations. Since the existing documents report the purchase of only small quantities of dark bricks, it is possible that the masons were given some creative freedom in their use – except for their compulsory use in vertical strips near window casings – which would explain sudden changes and interruptions in pattern and the essentially random positioning, which we can hardly ascribe to artists of the calibre of Sangallo or Vignola.

On the other hand, the secrets used throughout the 18th Century to make lime are more obvious and easy to understand. Lime was obtained by cooking limestone at very high temperatures that, according to the teachings of the experts, should vary according to the uses to which the lime is put. For example, for construction lime, Vitruvius and his disciples suggest using pure limestone, which is white and compact, and is appreciated because it sets slowly, which allows the wall structure to settle gradually and produces a homogeneous distribution of loads; whereas for plaster and stucco lime, the use of porous stone was allowed [14]. On the other hand, Alberti, recommends that white limestone from fresh and damp lime-pits be used in all cases, in order to make the cooking process longer and more effective, while other theoreticians prefer the use of marble limestone that goes hard even under water [12]. In the specific case of Rome, the enormous quantities of residue from travertine work and the large availability of marble taken from ancient monuments made it superfluous to look for alternatives. Many limekilns were built in the Fori or even next to the most important monuments, there are documents that explicitly mention marble and travertine "quarries" in the centre of the city throughout the 17th Century. Moreover, the lime production process that is described in detail in architecture treatises is not always confirmed by practice, especially when it comes to the timing. The hydration process called "slaking" consisted in immersing clods of quicklime produced by burning lime, into tanks full of water that are set up in the quarries or even in the building sites. When quicklime comes into contact with water, it dissolves slowly turning into slaked lime, which is a malleable mixture that can be mixed with water, sand or other inert elements to produce ordinary mortar that hardens by absorbing the carbon dioxide in the atmosphere. Ancient theoreticians such as Pliny the Younger recommend very long hydrating times, two to three years even [15]. In practice however, techniques and times for lime hydration did not follow set rules, they were defined on the spot by the master mason according to site needs and could be reduced to as little as two weeks. To speed up the slaking process, the Roman masters used to dilute the lime in two adjacent tanks with strong, plastered walls, set one higher than the other. Then the lime was left to cool for a few days, protected by a layer of sand of pozzolana if it was not to be used immediately.

Water conditions not only the handling of materials but also the planning of the entire construction process. Indeed, it is possible to manage and combine the various products of each working day by controlling the setting and the carbonation process of the various mortars and mixes. This was done by dampening the wall surfaces with techniques like that used by Borromini in the St. Agnese in Agone site, where there was a large supply of water thanks to the Vergine aqueduct.

This solution, maybe inspired by a technique already used by Filippo Brunelleschi in the florentine St. Maria del Fiore dome site (1420-1436), consisted in setting up so-called "little tanks", that is small containers moulded out of mortar paste and filled with water, which were left on top of the wall that was being built every night, so that the slow trickle of water would slow down the setting of the mortar. On the eve of a holiday, when the work stoppage was longer, the containers were made of four bricks bound together with lime so as to slow down the water seepage and prolong the effects on the wall below, so it would last until work resumed [16]. This technique is recommended in the *Patti e convenzioni dell'Opera de Muratori* for the factory of the Paoline Chapel in St. Maria Maggiore [17], it was then revised at the beginning of the 18th Century by the *Manuale ad uso di muratori,* which suggests not to build a wall on top of the completed foundations immediately, but rather to surround the foundations with a sort of lime case that will retain the water, and leave it there for about eight days. This makes the mortar set more slowly thus allowing it to follow the inevitable movements of the wall as it settles [18].

Figure 2: Limekiln by G.B. Amico, *L'architetto prattico*, Palermo, 1726, tav. 9.

Despite the existence of obvious discrepancies between the teachings in the manuals and the actual practices, the methods and the techniques used in Roman building sites at the beginning of the 20th Century vary only marginally from the traditional ones of the 16th and 17th Centuries, which only goes to prove the efficacy and the validity of these practices perfected over centuries of practice, and which became obsolete only when alternative forms of energy and authentically revolutionary materials such as reinforced concrete were introduced.

References

[1] Marconi, N., *Edificando Roma barocca. Macchine, apparati, maestranze e cantieri tra XVI e XVIII secolo*, Edimond: Città di Castello, 2004.

[2] Marconi, N., La teoria delle cupole nei trattati di architettura tra Seicento e Settecento. *Lo specchio del cielo. Forme, significati, tecniche e funzioni della cupola dal Pantheon al Novecento*, ed. C. Conforti, Electa: Milano, pp. 231-243, 1997.

[3] State Archives of Rome, *Camerale I*, *Fabbriche,* b. 1527, pp. 87-106.

[4] Marconi, N., Le fondazioni nella trattatistica e nelle applicazioni rinascimentali e barocche. *Rassegna di Architettura e Urbanistica*, 84/85, pp. 59-75, 1995.

[5] Montalto, L., Il drammatico licenziamento di Francesco Borromini dalla fabbrica di Sant'Agnese in Agone. *Palladio*, VIII, p. 144, 1958.

[6] State Archives of Rome, *Camerale I, Giustificazioni di Tesoreria*, 32, p.5.

[7] Bellini, F., Lo stucco. Con note alle tecniche di Vitruvio, Vasari e Giocondo Albertolli, *Rassegna di Architettura e Urbanistica*, 103/104**,** pp. 91-103, 2001.

[8] Arcolao, C., *Le ricette del restauro. Malte, intonaci, stucchi dal XV al XIX secolo*, Venezia: Marsilio, 1998.

[9] Pallottino, E., Stucchi in esterno: la nuova scabrosità delle superfici nell'architettura del Seicento romano; precedenti di una tecnica borrominiana tra Como, Genova e Roma. *Il giovane Borromini dagli esordi a San Carlo alle Quattro Fontane,* eds M. Kahn-Rossi & M. Francioli, Milano: Skira, pp. 315-321, 1999.

[10] Cirielli, E. & Marino, A., Il complesso della Sapienza: le fasi del cantiere, gli interventi successivi al Borromini, la manutenzione. *Ricerche di Storia dell'Arte*, 20, pp.39-64, 1983.

[11] Scamozzi, V., *L'idea dell'Architettura universale*, Venezia, 1615, II/VIII, p. 300.

[12] Alberti, L.B., *L'architettura (De Re Aedificatoria),* eds G. Orlandi & P. Portoghesi, Milano: Il Polifilo, I/III, pp. 150-153, 220, 1966.

[13] Montelli, E., Note su alcune tecniche costruttive impiegate per l'esecuzione di accurati paramenti laterizi nel cantiere romano del Cinquecento. *Quaderni dell'Istituto di Storia dell'Architettura*, 25/30, pp. 85-88, 1995/1997**.**

[14] Vitruvio, M.P., *I dieci libri dell'architettura,* eds M. Tafuri & M. Morresi, Milano: Il Polifilo, II/V, p. 79, 1987.

[15] Adam, J.P., *L'arte di costruire presso i Romani*, Milano: Longanesi, 1988.

[16] Doria-Pamphilj Archives (Rome), 94/ 4-6, pp. 111-114.

[17] State Archives of Rome, *Segretari e Cancellieri della Reverenda Camera Apostolica*, 358/32, pp. 501-503.

[18] Vatican Library, ms. *Vaticanus Latinus*, 14070, p. 8.