Helicoidal Construction Geometry and Oblique Architectural Arrangement. The Spiral Staircase of the Belvedere and the Argument between de l'Orme and Bramante: Digital Models Compared

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Until the first quarter of the Sixteenth Century Italy still dictated the aesthetic canons of European art but after the sack of Rome (1527), nothing was ever the same again, starting from the conscience of the artists. Even if in architecture the Italian hegemony would last much longer, at least until the voyage in 1665 of Bernini (1598-1680) to France, with the rejection of his project for the Louvre symbolically marking the end of this supremacy.

In reality the struggle for hegemony was started much earlier. In different forms, often not consciously (all however deriving from the progressive movement of the centre of European politics to the nation states of the North, hence away from Italy), the battle began to substitute the idea of the universality of the Roman classicism of Bramante and Raffaello with that of the national styles.

In particular the contrast became clearer between *drawn* architecture, that theorized by Vasari (1511-1574), which in Italy had its strongest legitimacy in the extraordinary ability of the skilled workmen in some ways autonomous of the architects, and *built* architecture (on paper even before in reality) which found in the development of stereotomy its most coherent practice. This became firmly established in the great royal building sites, where metric-estimated computations required exact executive elaborations: de l'Orme (1510-1570) was the *Architecte du Roi* (Henri II), but this applied equally to Juan de Herrera (1530-1597) *Arquitecto de Su Magestad* (Felipe II) and the construction of the Escorial.

In Italian architectonic culture, dominated by the theories of Leon Battista Alberti (1404-1472), the capacity of the architect for design was evaluated mainly on the basis of technical drawing; the attempt of Brunelleschi (1377-1446) to unify, in the single person of the architect, the competencies of planning and construction was not taken up in Italy. For Leon Battista Alberti the project was essentially a product of the intellect: visualization and representation of the idea in the finished drawing, imposed by the use of the metric scale, the measurability of which conferred on the work a mathematical-scientific character.

On the contrary, the design process as it became defined in France meant that the translation of an idea into visible and completely structured form had to go through various levels of abstraction, of which stereotomy was the fundamental part. The practice of stereotomy, elevated to the speculative level by de l'Orme, favoured the birth of the new French Renaissance architect, profoundly different in culture and training from his Italian counterpart. Along with a sensitivity that combined classical aesthetics and the theoretical revolution of the rules of perspective, French architects innervated in the national style the secret language of construction and the *coupe des pierres* (stone cutting).

De l'Orme in the first book of his treatise, warned those who knew how to make beautiful drawings to captivate the client, and said:

> I advise the Architect and all those who work in the construction industry, to study how to recognise the nature of sites rather than make many beautiful ornaments that very often serve only as bait to catch that which men have in their wallets […]
>
> (de l'Orme 1567, Book I, p. 19-20)

While the Italians by using perspective were able to determine the exact relationship between bodies in space, the French using stereotomy determined the exact relationship between and the exact form of the stones in the body of the building. In this way stereotomy, codified for the first time by de l'Orme became - first with the superior theoretical treatment of Desargues (1591-1661) on projective geometry, and then with the admirable summary of Frezier (1682-1773) - the art of investigating the intersections between bodies in space (D'Amato, 2005).

This paper deals with a particularly significant episode, demonstrating this contrast between these approaches at the beginning of the modern epoch that saw a greater distance developing between architectonic research in Italy and France. It involved the indirect argument that de l'Orme conducted against Bramante (1444-1514) about the Belvedere spiral staircase. It was an argument that was not only ideological, but also concrete and practical, and which lay at the crossroads between two ways of thinking about and constructing architecture, destined to become ever more irreconcilable.

Mathurin Jousse (1575-1645), in 1642, in the introduction to his *Le Secret d'Architecture*, honouring the great Italian architects from Leon Battista Alberti, to Andrea Palladio, Sebastiano Serlio and Vignola, stated the following concerning stereotomy, or the art of *traits géométriques* (geometric layout):

> You will see that these Great Men have told us not one word on the way to draw the Geometric layout necessary for stone cutting: thus I will say that I have never seen a single Author who has talked of it, apart from Maestro Philibert de l'Orme, who has

> left us, in his third and fourth books, some demonstration that I do not judge to be wrong, but with text and images comprehensible only to Scholars […]
>
> (Jousse 1642 - *Privilège* del 1635)

The art of *trait géométrique* is for de l'Orme the most astute means to modernise the old Gothic style, and stereotomy is presented thus as the most effective means of moving into to the *regular* modern world. The third book of *Le Premier Tome de l'Architecture* by de l'Orme*,* is dedicated to the roles of the people who preside over the art of construction, that is to say the architect, the master builder and the stonemasons, who must all know their geometry well. The last chapters of the third book, from the fifth to the eighteenth, deal with an inherent problem with barrel vaults, with a series of solutions for special stereotomic vaults. The fourth book of the treatise is dedicated to geometry and the demonstration of *l'art du trait géométrique* applied to the construction of the most complex elements of stereotomic architecture. Among these, the following stand out for their ingenuity and virtuosity: the *trompe* d'Anet, the spherical vaults with helicoidal-bond and the re-proposal of the famous spiral staircase, the original model of which is situated in a half destroyed fragment of the Priory of Saint Gilles in Languedoc.

> This rampant vault is called by the workmen *vis Saint Gilles*, given that there is a similar one in the Priory of Saint Gilles in Languedoc. When I was young I saw that the workmen greatly esteemed one of their group who knew how to draw that type of vault very well; and they said that he had great understanding of the *traits géométriques*, and that he knew well the *vis di Saint Gilles*.
>
> (de l'Orme 1567, Book IV, p. 123v)

In the nineteenth chapter of the fourth book, de l'Orme, after having described the manner in which to construct the *trait* of the *vis Saint Gilles*, goes on to talk about the staircase of the Belvedere in Rome by Bramante (who he never cites directly), appreciating and at the same time criticising it:

> I have seen a spiral staircase very similar to the one I have described, in a place called the Belvedere situated in the *Palazzo del Papa* (Pope's Palace) in Rome, where his holiness retires from time to time to restore his strength and spirit. It is a place with an infinite wealth of ancient works of art and marble statues, including a Lacoon and an Apollo divinely made and beautiful to behold. There is also a Hercules, a Venus, and many other ancient marble statues, set into niches: and around which there are beautiful fountains, orange and lemon trees, and infinite other excellent greatly pleasing things […among which] a very large round spiral staircase, illuminated all around by windows, open in the centre, and at this part supported by columns, and the other side by walls. It does not have steps and rises around the columns very gently with a ramp

> paved in bricks, as is usual in Rome. Beneath the ramp there is a barrel vault realised in brick […] and the work is very fine in appearance and well made.
>
> (de l'Orme 1567, Book IV, p. 124r)

The spiral staircase that connects the Belvedere to the gardens below, was conceived, perhaps in 1507, by Bramante when the need arose for an external access to the Courtyard of the Statue, and it was concluded about forty years later by Pirro Ligorio.

This is how Vasari describes it in *Le Vite*:

> In Bramante's Belvedere there are different kinds of steps varying, depending on the rise and fall of the land, a beautiful sight with Doric, Ionic and Corinthian orders, work carried out with total grace. And he had made a model of it all, that they say was a marvellous thing, as can still be seen in the principle of such unfinished work. In addition to this he made a spiral staircase on columns that rise, which it is possible to ride up on horseback: the Doric order leads to the Ionic one and then to the Corinthian, and one leads on to the next: a thing carried out gracefully and with certain excellent artifice; […]
>
> (Vasari, 1550)

It consists of a circular ramp with an open stairwell, supported by a helicoidal barrel vault: the following description derives from our verification of Letarouilly's (1795-1855) survey (edited in 1882) that we carried out on 24th November 2005 **(fig. 1)**.

This is inserted in a tower flanking the body of the Octagonal Courtyard building, on a square plan with sides of 11.44 metres (equal to 52 *Roman palms*: 1 *Roman palm* equal to a 0.2234 metre) and a height equal to approximately 25 metres (equal to 114 *Roman palms*), excluding the roof, with a series of 8 grand apertures that are arched at the top. The ramp, 2.2 metres wide (equal to 10 *Roman palms*), is contained between an external circumference of diameter equal to 8.9 metres (equal to a 40 *Roman palms*), and an internal circumference, that delimits the stairwell, of diameter equal to 3 metres (equal to 13 *Roman palms*). This is supported by a helicoidal barrel vault, geometrically defined as a rotation-translation surface, the generator of which (vertical section of the barrel vault) is a semi-oval that belongs to the plane of the axis. The geometry of the oval is given by the composition of four tangential arcs: two circumferences with a radius equal to 0.77 metre (equal to 3.5 *Roman palms*) and two circumferences with a radius equal to 1.54 metre (equal to 7 *Roman palms*) **(fig. 2)**.

On one side the vault rests on the continuous wall of the tower and on the other side on continuous cornice supported by a series of 36 columns. In plan the columns are positioned, on the side of the stairwell, on a circular corona 0.77 metre wide (equal to 3.5 *Roman palms*) divided into 8 sectors.

To reach the top, at a height of approximately 21 metres (equal to 95 *Roman palms*), the helix makes 4.5 complete turns. The columns were arranged vertically with the superimposing of four orders, respectively from the base upwards: Tuscan, Doric, Ionic, and composite. Very probably the theoretical plan included the composition of five orders and thus the sequence is: Tuscan, Doric, Ionic, Corinthian and composite, even if it must be remembered that in Bramante's day the theory of the superimposing of orders was not yet well defined.

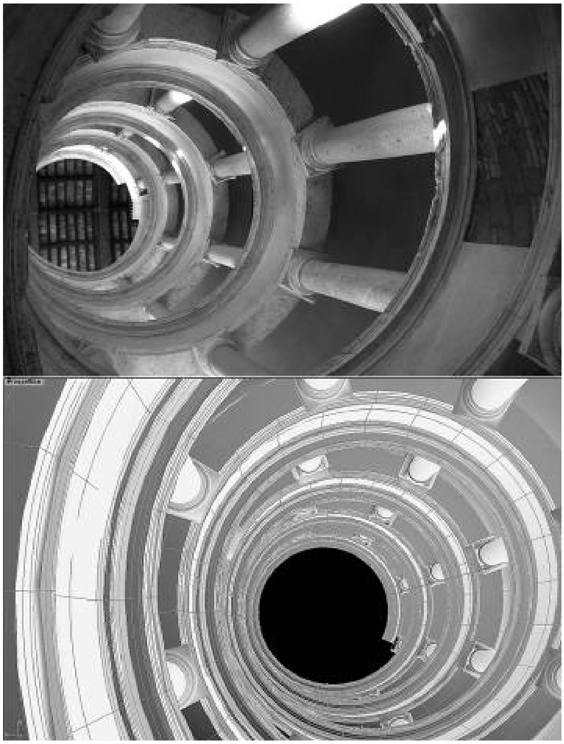

Figure 1. Interior views (real and virtual) of Bramante's staircase-tower from the bottom.

The sequence of the columns, lining the ramp from the base upwards, has eight Tuscan columns, eight Doric, eight Ionic and twelve composite. The difference in height between two flanking columns is approximately 0.44 metre (equal to 2 *Roman palms*) that gives the ramp its gentle slope. The orders follow each other separated by a frieze 1.1 metre high (equal to 5 *Roman palms*), consisting of two cornices, above and below, in stone and an intermediate plastered fascia built from horizontal layers of bricks. The upper cornice is aligned with the plane of the upper surface of the ramp, thus between the tops of the cornices or between two levels of pavement on the ramp one directly above the other the difference in height is equal to 3.75 metres (equal to 17 *Roman palms*); whereas between the level of the pavement of the ramp and the intrados of the vault measured at the keystone, the distance is equal to 3.52 metres (16 *Roman palms*). The distance between the intrados of the frieze and the plane of the pavement is constant along the length of the helix and is equal to 2.66 metres (equal to12 *Roman palms*). This consideration leads us to reflect on the principle of *proportions* of the columns according to which (all being inserted into the same height between floors), they become narrower proportional to the change in height and relative to the change in architectonic class. This makes it possible to measure the columns with a base diameter corresponding to the diameter at the top of the column below, after establishing the dimensions of the first Tuscan column positioned at the beginning of the ramp.

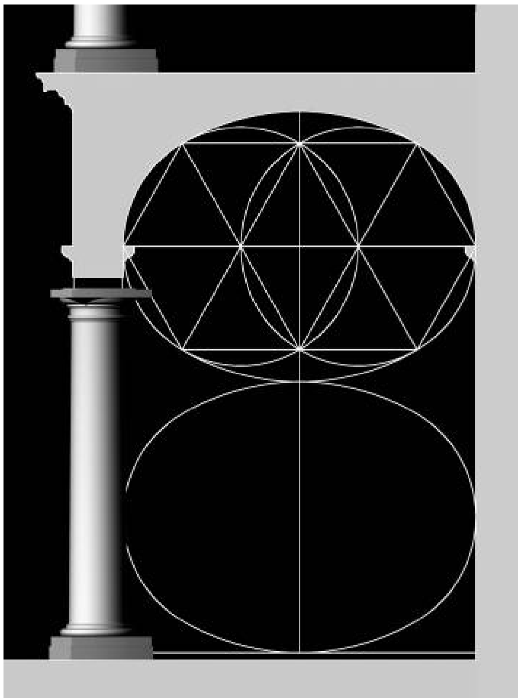

Figure 2. Vertical section and geometrical proportions of Bramante's staircase-tower.

The entire work is made from brick, apart from the cornices described and the 36 columns, the bases and capitals of which are in light travertine and the shafts in grey granite (with the exception of the thirty-second column, the shaft of which is in grey marble) **(fig. 3, 4, 5)**.

The criticism of de l'Orme was to be added to all the rest provoked by the revolutionary work of Bramante, at the beginning not understood in a professional environment and not yet culturally ready to receive the new universal concept of a rediscovered classic antiquity. This criticism was the first aimed at Vitruvian classicism regarding the theory of proportion of architectural orders; and struck at the heart of Italian Renaissance classical conception, even if its nature was technical rather than ideological.

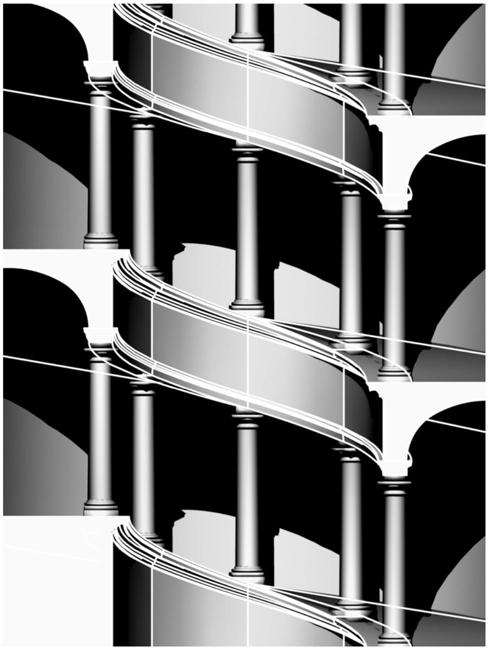

Figure 3. Part of vertical section of Bramante's staircase-tower.

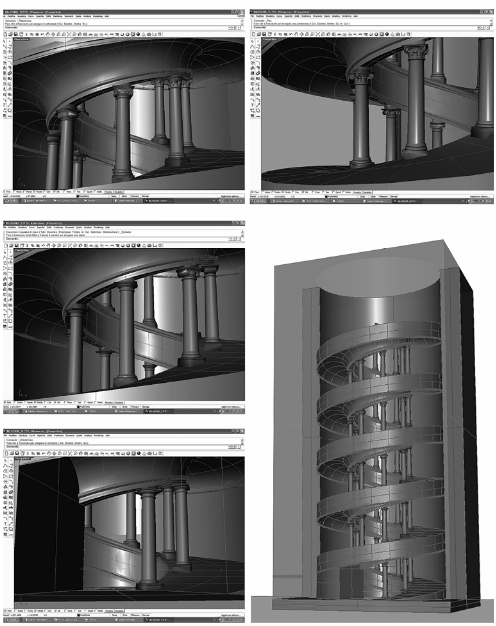

Figure 4. Virtual interior views of Bramante's staircase-tower.

De l'Orme admired the invention of the continuous ramp, with the barrel vault suspended between the walls and the free-standing columns, but noted that if the Architect had known the *traits* of geometry, which he spoke of in his writings, he would have made all the orders inclined, even the bases and the capitals, instead of having designed it orthogonally, as if he had to form a rectilinear and linear portico, and therefore having to resort to the use of suitable stone wedges inserted below the bases and above the capitals.

Figure 5. Virtual interior views of Bramante's staircase-tower with Composite columns.

Contrary to the theory of Alberti, which always associated columns with architraves and pillars with arches, de l'Orme foresaw the use of arches on columns that, in virtue of the oblique to the inclined plane, were transformed into rampant arches obviously in cut stone. Arranged opportunely these would have represented, according to de l'Orme, the best solution for the spiral staircase both from an aesthetic and static point of view.

The slanting of the orders in the theory of de l'Orme was therefore a consequence of perfecting the art of stereotomy rather than considerations of perspective such as those that would be made by Caramuel in the following century in the Berninian project for Piazza San Pietro. The complete geometric-constructive mastery of architecture was thus at the base of Delormian criticism; mastery acquired through an extremely intense apprenticeship that he had in Italy at the centre of excellence.

One of the very first works of the young de l’Orme, the *Galerie de l'hôtel Bullioud 8 rue Juiverie*, built in Lyon in 1536, was the first Gothic-Renaissance hybrid that benefited from Italian influence.

We can get a concrete idea of the counter solution hypothesised by de l’Orme for the spiral staircase of the Belvedere by referring to two examples in which the *deformed* architectural order appears: first, the two spiral staircases that he realised in *le Jubé* in Saint-Etienne-du-Mont in Paris; second, in the design for a helicoidal staircase kept in the Louvre, and attributed to him **(fig. 6)**.

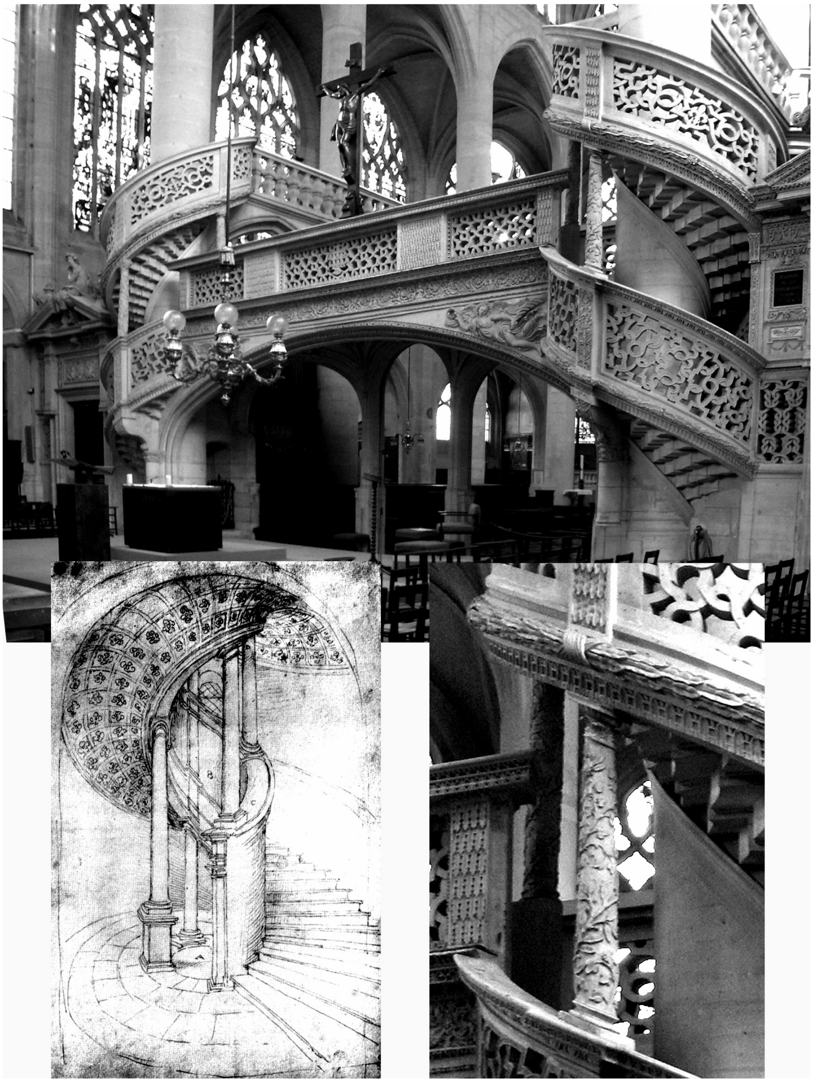

Figure 6. Interiors views and details of staircase at Saint-Etienne-du-Mont in Paris.

This obviously means that there were two ways - the Italian and the French - of seeing and understanding the statics and aesthetics of architecture, which were moving ever further apart. It is interesting to remember that Vignola made a precise distinction between that which was only ornament and could freely follow geometric design; and that which was structure and had to maintain, also visually, its static function. For the Italians therefore the vertical plumb line had to be set against the horizontal line of the earth - a distinction that evidently did not enter into the logic of de l'Orme, who by his cultural training was used to reading oblique deformation as a peculiarity and not a defect of architecture. A peculiarity that enabled him to confront all difficulties as a virtuoso:

> [The spiral staircase of the Belvedere] would have been a beautiful opportunity to make a vault, not only similar to that of Saint Gilles, but even more surprising, accompanied by ornaments and mouldings all rampant, and it would have been a thing without parallel: seeing its turns and contortions, I think the work would have shown itself to be superb and extremely difficult to realize.
>
> (de l'Orme 1567, Book IV, p. 124r)

Thus the aesthetic value of the work, according to de l'Orme, was directly correlated to the complexity and to the crystalline geometric resolution of the same. The technique by which the constructive solution is completed punctually is dictated by the art of geometric layout: "*digne d'y considerer comme la nature du trait conduit ce degauchissement si estrange*" (able to make one think how the nature of the *trait* can lead to such a strange treatment, de l'Orme, Book IV, p. 88v).

According to de l'Orme the more difficult a work was to construct, the more it deserved to be admired. On this point it is interesting to recall what he wrote about the constructive virtuosity of the *trompe* of the *Cabinet du Roi* in Anet: "*le quel i'ay voulu faire de forme estrange pour rendre la trompe de la voute plus difficile, & belle à voir*" (which I wanted to make in a strange form to render the *trompe* more difficult and beautiful to behold, de l'Orme, Book IV, p. 89v).

On the basis of these considerations it is easy to understand why de l'Orme criticised the Bramante spiral staircase, and why it hurt him that many of the beautiful French works, in which it was possible to encounter correct use of the *trait*, were completely ignored: "*Nous avons une infinité de beaux traits en France, desquels on ne tient aucune compte, pour ne les entendre, & qui pis est, l'on ne se soucie gueres de chercher l'excellence & beauté des œuvres*" (we have an infinity of *traits* in France, which we do not take into account in any way, not understanding them, and what is worse, we do not worry at all about seeking the perfection and beauty of the work, de l'Orme 1567, Book IV, p. 124r). This scale of aesthetic values was clearly typical of a circle of architects strictly linked to construction (mainly French) and did not correspond to the ideals of Italian culture, where stereotomy remained practically unknown, until the appearance on the scene of Guarino Guarini who usually operated osmotically with the French world.

The art of geometric layout or stereotomy developed by de l'Orme is in substance an orthogonal projection applied to the elements of architecture. The cases in which this projective technique became necessary were those that involved the realization of specific elements in stone with high volumetric complexity. These elements were frequent in radiocentric structures, in oblique junctions between two differently orientated bodies and especially in stairs. All of which are cases where the architectonic difficulty should be dealt with according to de l'Orme with the due geometric logic: a real architectural apparatus capable of resolving, with aesthetic/constructive dignity, complex design problems.

> What makes the art of cutting stones difficult, is the skill of producing them in different shapes with generally non parallel faces, so they fit together perfectly
>
> (de l'Orme 1567, Book IV, p. 124r)

The subtle yet substantial difference between proper stereotomic work and general stone work consists of at least two critical substantial nodes: the perfect *geometric control of the work,* both in the planning phase and in the execution of the elements, and the *strong adherence to geometric canons* that reaches the absolute category of the planning thought process. If we apply these concepts to the spiral staircase of Bramante we note that the *executive control of the work* is lacking in some of its critical points, for example the realization of the helicoidal ramp. Such an architectonic element in "torsion", in stereotomic logic, is realized with a succession of hewn stones using the *calibre rallongé* method that involves the cutting of the stones checking the double spatial curvature by means of development panels of the same and not, as in the case of the Bramante spiral staircase, with a succession of simply curved cornices, arranged on inclined planes.

The graphic technique for the determination of architectonic elements of high spatial complexity was to enter Italian technical culture much later thanks to the work of Guarini, who in his Treatise IV of *Architettura Civile* under the title *Dell'ortografia gettata* (1737) affirmed the necessity for the architect to know the theoretical and technical rules of the stereotomic discipline, so as to determine the development of the surfaces for the *panneaux* that envelop the hewn stones, essential to the stone mason in order to cut the stone blocks exactly.

Secondly, in stereotomic logic, the *strong adherence to geometric canons* requires that the oblique and radial architectural order corresponds to the inclined plane of a circular structure as stated above. In the Bramante spiral staircase the convergence at the centre of the architectonic class is respected (the bases and the abacus of the columns converge at the centre), the obliqueness of the architectonic order was not even taken into consideration, nor could it have been, since this greater geometric "coherence" would have given the work an unbearable instability to his eye, educated by classical architecture **(fig. 7, 8)**.

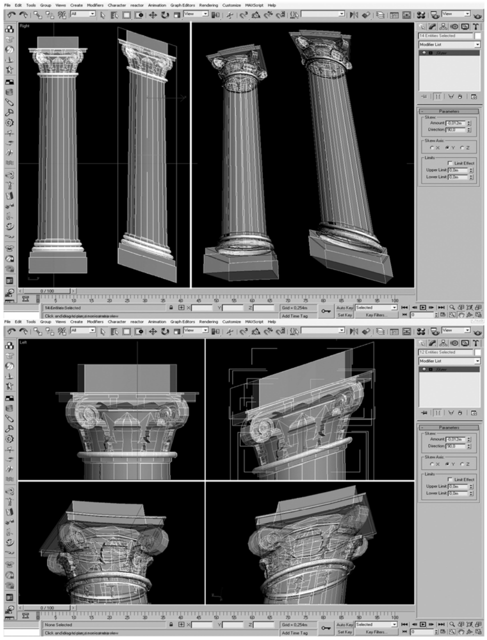

Figure 7. Skew transformations: Composite columns according to de l’Orme’s idea.

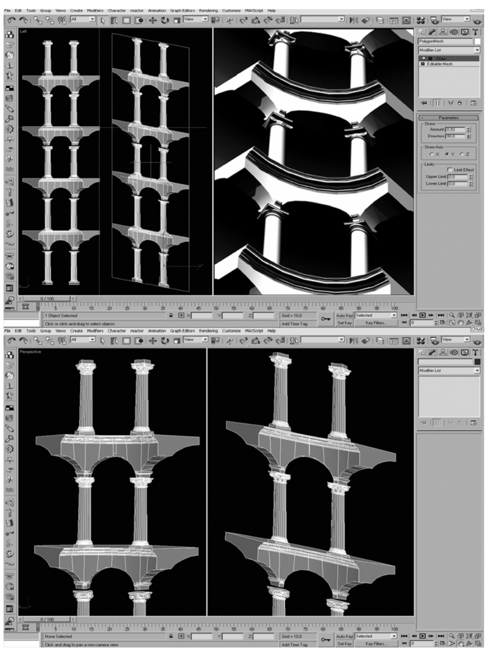

Figure 8. Skew transformations: the sequences of columns and arches according to de l’Orme.

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