Architecture and Stereotomy. The Relation Between the "Construction Apparatus" and the "Decorative Apparatus" of the Cut-Stone Vaults and Domes of Philibert de l'Orme and Andrés de Vandelvira

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> From an in-depth study of ancient monuments comes the enlightened truth that architecture, in the noblest sense, is not so much decorated construction as constructed decoration.
>
> (Charles Blanc 1867)

Cut-stone architecture, conceived and built according to the principles and techniques of stereotomy, is characterised by the correspondence between form and structure. Indeed, the task of representing the figurative and expressive values of architectonic form is entrusted directly to the structure and to its "technical form". In cut-stone architecture, structure thus has a double role: fulfilling a static function and defining an aesthetic character. In other words, *supporting* and *decorating*.

The contemporary dialectical opposition between structure and *revêtement*, technical-constructive aspects and figurative-representative aspects, has no place in a discourse on cut-stone architecture, for which load-bearing structure and enclosing shell are actually one and the same thing, *organic* and *indivisible*. Thus any analysis of the processes of the definition of form in such architecture must inevitably begin with an understanding of the complex and close relation between tectonics and architecture; in other words, with the way in which technical form, as defined by the construction system, is "translated" into architectonic form.

The construction system is not "expressive" in itself; its immediate forms are essentially technical forms, which refer exclusively to their own static function and are devoid of aesthetic intentionality. Even though tectonics, as a syntax of construction elements, can be interpreted as an "art of connection" (Frampton 1999, p. 22) and so be more pertinent to the field of aesthetics than to that of technology, it remains substantially "conformation and not form" (Brandi 1992, p. 159). The question thus needs to be dealt with, not so much with regard to the syntax of construction elements, which expresses relations of congruence and necessity inherent in the construction system, as with regard to the form of the construction elements themselves. In other words, it is a matter of the formal identity of these elements in relation to their value within construction and to the general characteristics of a building.

Indeed, the translation of technical form into architectonic form comes about through "a process of formal identification of the construction elements" (Monestiroli 2002, p. 84). And the principle that determines this identification is the Vitruvian principle of "décor" (meaning both "decorum" and "decoration"), according to which each construction element assumes the form that best "identifies" it in relation to "convenience, custom and nature" (Vitruvio 1987, p. 14). It is through "décor" that technical form, as defined by the application of a given construction system, is translated into architectonic form; it is through decoration that the construction elements assume a formal and figurative identity and become architectonic elements.

The principle of "décor" is thus a necessary and immanent principle within the process of the definition of architectonic form; it is the "genesis of [architectonic] form" (Brandi 1992, pp. 163-164), its constituent principle. In order for this process to take place, however, there must be *aesthetic intentionality*, which in architecture is expressed through the "will to representation" of a value. This "value", identified in the moment of invention of the architectural work, coincides with the concept of *venustas* (beauty, comeliness). It consists in the aesthetic information necessary for the identification of the general *character* the work must have in order for it to be an architectural "whole", and suited to the purpose for which it was created. The construction system, through which the work comes into being, must not contradict this character, but enhance it, through its translation into a decorative system.

In architecture the quest for appropriate forms to express this value is undertaken with the use of the conceptual tools of *analogy* and *metaphor*. The system of reference to which analogy and metaphor are applied, both for architecture in general and for cut-stone architecture in particular, now needs to be examined. Quatremère de Quincy, when speaking of "necessary decoration" in his dictionary (see the entry, "Décoration"), states that analogy may be applied not only to nature and its forms but to construction as well: decoration can be derived "from the analogy with objects necessary to construction" (1985, p. 185). And in order to describe this principle of the application of analogy to construction he uses the paradigm of the Greek temple, stating that

> An important part of architectural decoration originates in this imitation by analogy; thus art benefited from the primitive forms of construction. Indeed, there is no architecture, the imitative and decorative system of which is more visibly imprinted with the primitive nature of things than Greek architecture.
>
> (Quatremère de Quincy 1985, p. 185)

In the formal definition of the elements comprising the architectural orders, decoration is applied as analogous to construction. That is, the construction system is represented *analogously* by decoration, which formally defines its elements. This is the principle of the formal and expressive genesis of the Doric order, for instance, in which the support (or post) is transformed into a column;

and it is this same principle, albeit using different forms and modes, which confers formal identity on construction elements in cut stone.

Decoration, applied analogously to the construction system and its fundamental principles, translates technical forms into forms representative of the act of construction itself. This representative intention, a prerogative of architecture, is what gives meaning and character to the different architectonic elements. Schelling's definition of architecture as a "metaphor of construction" (when speaking of Greek temple architecture) would seem to confirm this process of formal characterisation as representative of the *act of construction*.

As in Greek temple architecture, in cut-stone architecture the relation between construction and decoration in the definition of form is based primarily on the *visibility* of the material and the *legibility* of the construction principle informing its use. Durand confirms this when he writes, "the true decoration of a wall is the evidence [or visibility] of its construction" (Durand, 1986, p. 34). The form of the cut-stone blocks and their disposition in the wall assemblage thus constitute the essential decoration of cut-stone architecture in that they express the principle of construction. The plastic articulation of the wall surfaces, from the surface treatment of the stone to the mouldings, being of a structural nature, reinforces analogously the *raison d'être* of the different construction elements and defines their character.

An important role in the formal definition of construction elements in cut-stone architecture is played by *proportion*, that is, by the system of geometric relations established in connection with the general characteristics of a given work. Proportion as a decorative principle is vital to cut-stone architecture. It is linked to the essential role played by geometry in the pursuit of the exactness of forms, which in turn is vital not only to the construction process, but also to the "firmness" (*firmitas*) of a building. Through geometry, every single element is studied and proportioned beforehand in relation to its specific static and figurative function. A bare stone pillar can be decorated and so manifest its formal identity through the visibility of the material used, the way in which it is assembled and its proportions.

Perret's definition of architecture as "built decoration" (Gargiani 1993, p. 52) is particularly germane to cut-stone architecture, since it expresses the simultaneous nature of construction and decoration as a fundamental condition of the definition of its forms. This, is also confirmed by Julien Guadet in his introductory lesson on masonry vaulting:

> […] construction, decoration, all that is the same thing: it is architecture. In speaking of vaults can we perhaps separate these two principles? Is the coffering of Roman vaults just construction or just decoration? Is medieval ribbed vaulting just construction or just decoration? Each of these principles on its own is as inadequate as the other. Once built, we can say that these vaults are already decorated. And in no other case is this more

> apparent than in medieval vaulting. We find these vaults expressive, ingenious, fascinating, and clearly the decorative intent appears obvious to us […]. Yet it is decoration expressed through construction, since this decoration is the ribbed vaulting, the arches, in other words, the construction itself. And it is construction conceived with a double purpose, in relation to firmness and in relation to decoration. After that, what still remains to be done in terms of decoration? Nothing: once the scaffolding has been removed, the vault already appears fully decorated by its construction elements. If there were indeed something still to be done, then that would be painting, in other words, embellishing, but more often than not ruining. In any case the decorative *apparatus* resides wholly in the construction *apparatus*.
>
> (Guadet 1929, pp. 556-557)

The impossibility, to which Guadet refers, of separating the moment of construction from the moment of decoration, the technical from the representative, is even more apparent in cut-stone architecture, for which we may speak of an "expressiveness" of construction.

"DECOR" IN CUT-STONE ARCHITECTURE: WALL TEXTURE AND STRUCTURAL MOULDINGS

The wall assemblage as an expressive means: the wall texture.

In masonry architecture the term "texture" indicates the design generated by the assemblage of stone blocks on the wall surfaces. This design, the simultaneous expression of a constructive principle and an aesthetic choice, has a *decorative value* in cut-stone architecture. There is a conceptual difference between the terms "assemblage" and "texture". Assemblage refers to the strictly technical aspects of masonry work and expresses the strategy used to put together the cut-stone material in keeping with the project choices. On the other hand, texture (in Italian "tessitura" or "orditura" from the lexis of weaving and textiles) is inherent in its expressive effects, which are linked to the visibility of the design, or pattern, of the assembled blocks.

Assemblage in horizontal layers, reproducing the geological principle of stratification and complying with the principles of gravity, may be considered "natural". This type of assemblage is used both for masonry walls and for the simplest kinds of vaults and domes. A cylindrical barrel vault, assembled in horizontal rows parallel to its geometric directrix, may be read as a curved wall following the curve of the intrados. Projected in plan, the continuous joint seams are represented by lines running parallel to the directrix of the vault. A spherical dome, assembled according to the same principles, is formed by horizontal rows arranged along the parallels of the spherical surface, from which the dome itself originates. Projected in plan, the continuous joint seams generate concentric circles.

This type of assemblage in horizontal rows is by far the most common in the construction history of vaulted architecture, though it is not the only one. Consolidated types of assemblage are closely linked to the geometric form of vaults, since such types are naturally suggested by the geometric principles that shape the surfaces of the intrados (by translation, rotation and so on). For instance, in the case of a barrel vault, the surface of the intrados can originate either from the translation of a straight generatrix along a curved directrix or from the translation of a curved generatrix along a straight directrix. This consideration of a geometric nature leads directly to two different criteria in erecting a barrel vault. The first suggests the solution of horizontal rows arranged according to the generating lines; the second, that of "transverse elements" in which the rows are arches arranged according to the direction of the generating curves.

Nevertheless there are types of assemblage that do not seem to have such a direct relation to the geometric principles that shape the surfaces of the intrados and this happens not only for technical reasons – as in the case of "composite" vaults and linking elements (for example, groin vaults and pendentives) – but also for aesthetic reasons. An example is that of the "spherical dome on a square plan" in which, for aesthetic reasons, the typical construction model of the dome is transformed, through a topological operation, into a decorative model without radically changing the construction process (Potié 1996, pp. 120-123).

Through subtle topological operations, which reveal an extraordinary control of solid bodies and their geometric matrices, the quest for form in the art of stereotomy has elaborated a great variety of assemblage "figures", most of which have been assayed and described in the literature on the subject. The choice, or refinement, of a certain type of assemblage does not therefore belong exclusively to the technical field, but is also determined by an aesthetic intentionality in virtue of the expressive result produced.

The texture (or "weave"), as a *visible design*, or pattern, generated by the assemblage of cut-stone blocks on the surface of a masonry construction, thus constitutes the *main form of decoration* in cut-stone architecture. The construction system and its principles are described by this texture, which is illustrative of the whole production process of the stereotomic work and thus gives character and expressiveness to its elements. The pattern of masonry joints, representative of the nature of stereotomic architecture – of the fact that it is composed of discrete pieces held together by their own gravitational force – becomes a decorative motif, since it is the *conscious result* of an aesthetic intentionality.

The analogy between the art of weaving, which Semper recognised as the origin of tectonic and decorative forms, and the art of stereotomic assemblage well illustrates the relation between the construction order, expressed by the wall assemblage, and the formal, decorative order, expressed by its design or texture (Potié 1996, pp. 107-123). Just as in a carpet the warp and the weft, generated by the (topological) geometric operation of weaving and knotting, constitute both the

material structure and its decorative motif, so in a cut-stone vault "la nudité de l'appareil avec ses lignes de joints constituent dejà des éléments du dècor" (the visibility of the assemblage, with its joint seams, already constitutes the elements of decoration) (Lalbat, Margueritte and Martin 1987, p. 32).

The wall mass as an expressive means: the structural mouldings.

Texture can be considered as a primary form of decoration in stereotomic architecture. This form of decoration is expressed by the design belonging to the geometric surface of the stone masonry and does not invest the plastic nature of its mass, the representation of which is by means of another type of decoration: the mouldings. Obtained by the removal of layers of material, by carving into the stone mass, mouldings (rib vaults, or any other element that projects from the wall surface) model the wall surfaces, enhancing their *plastic essence*. As Panofsky writes, this "three-dimensional projection of form [with regard to the unity and continuity of the wall surface] constitutes a direct expression of the building mass" (1961, pp. 58-59).

Since mouldings of this kind are conceived as a plastic elaboration of the wall mass and not as something applied to it afterwards, they are an integral part of the load-bearing section of the structural element that they decorate, and so have a structural value. In recognising the structural role of ribbing in gothic vaults, Henry Focillon posits the question of their true nature, as in some way linked to the will to represent the construction principle formally, and as such, he affirms, they have a pre-eminently decorative value. He thus maintains that

> […] ribbing gives body, visibility and especially strength to 'places' of great pressure […]. It replaced an apparently compact system, balanced by its weight and mass, with the evidence of a nervous complexity.
>
> (Focillon 1965, pp. 128-132)

An emblematic case is the Pantheon dome, in which the system of coffering not only has the function of lightening and strengthening, but decorates the dome and identifies it formally with regard to the space it covers, in the same way that the triglyphs formally identify the trabeation of a Greek temple. So, too, the role of mouldings in the formal identification of the structural element of which they are part.

In stereotomic architecture we can recognise two distinct ways of decorating construction elements using mouldings. This distinction is due to the different relation of the mouldings, on both a technical and a figurative level, to the constructive geometry of the masonry work and to the type of assemblage. In the first case the mouldings are conceived in accordance with the geometric configuration of the vault, or else with its assemblage, *emphasising* the arrises and plastically *marking* the texture of the wall surface. They have a direct and explicit relation to the construction

system and its tectonic logic, which they both represent and describe. Coffered or ribbed domes and vaults are the most obvious examples of this type of moulding. From a technical point of view they are usually composed of specially cut stone blocks, the complex forms of which are dictated both by their disposition in the wall assemblage and the general figurative motifs adopted.

In the second case the mouldings are conceived as an *autonomous* design, independent of the geometric-constructional and figurative matrix, which consequently "disappears" behind it. In this case the design of the mouldings, in theory, does not set up any relation, either technically or aesthetically, with the wall assemblage and its surface texture. With a sculptural approach, the stone masonry is seen as a uniform surface to carve or model with the chosen type of decoration. In the design phase these mouldings are segmented in relation to the construction pattern and are then sculpted on the visible surface of the stone blocks. This type of decoration, while conserving its structural nature, can have an "ornamental" value, as a secondary and independent formal system that is able to influence the general character of the building – for instance, by setting up a metaphorical or symbolic relation with it – but does not determine it at all.

The gothic cathedral is an example of the co-presence of both types of mouldings and their clear division into a main decorative system, to which is entrusted the formal identification of the construction elements, and a secondary decorative system, with an ornamental value, like a great text narrating "histories" connected to the building type and its uses.

A critical point common to both types of moulding, regarding their conception and execution, is the relation between the design in plan and its projection onto the curved surface of a vault; in other words, the conscious control of the deformation (anamorphosis) produced by the passage from a flat surface to a curved one and vice versa. In stereotomic architecture this aspect can have a strategic value, given the importance of projective geometry in its invention and production processes.

A CASE STUDY: THE DOME OF THE CHAPEL OF SALVADOR AT ÚBEDA BY ANDRÈS DE VANDELVIRA AND THE DOME OF THE CHAPEL AT ANET BY PHILIBERT DE L'ORME

In the light of the above, the work by two sixteenth century masters of stereotomic architecture – the Spanish architect Andrés de Vandelvira (1505-1575) and the French architect Philibert De l'Orme (1515-1570) – is paradigmatic. Their cut-stone vaults and domes are an expression of the quest for the formal identification and definition of construction elements in keeping with the technical know-how and aesthetic canons of stereotomy. A comparison of two of their works is particularly interesting: the dome of the chapel of Salvador at Úbeda by Andrés de Vandelvira, built between 1536 and 1542, and the dome of the chapel at Anet by Philibert De l'Orme, built between 1548 and 1553 **(fig.1)**.

A comparative reading of these two cut-stone domes, stripped of their ornament, reveals two distinct ways of conceiving the relation between "constructive apparatus" and "decorative apparatus", linked to two different principles in the definition of architectonic form.

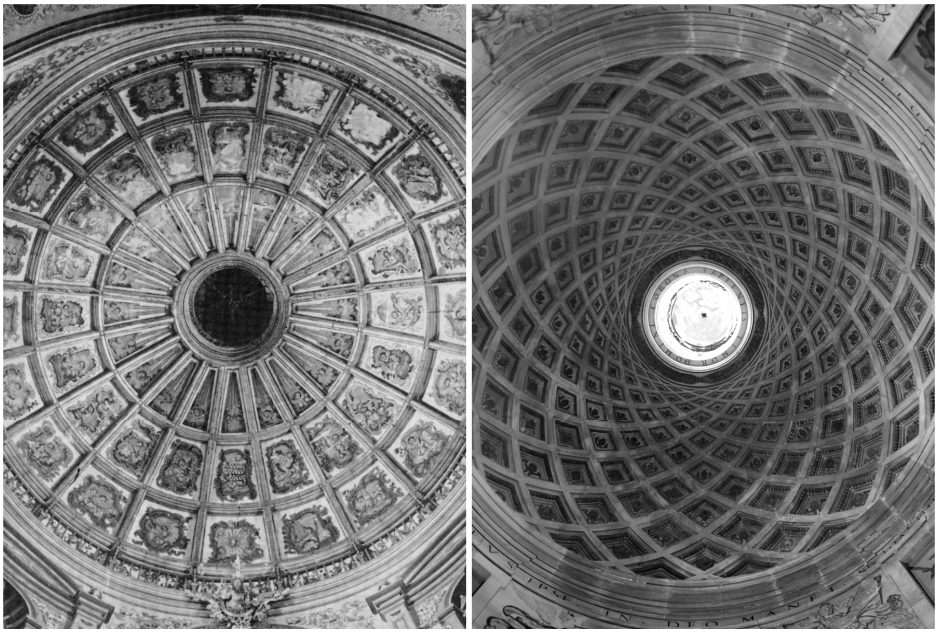

Figure 1. Intrados of the domes of the Salvador chapel at Úbeda and the chapel at Anet

The two domes have the same basic geometric and construction matrix: they are both spherical domes raised on a circular plan, composed of cut-stone blocks arranged in concentric horizontal rows. As is well known in construction processes for this type of dome the difficulty of determining the exact geometric development of the curved intrados surface of the voussoirs is compensated for by the fact that, thanks to the radial symmetry, all those in the same row have the same shape. Thus the number of "panneaux" needed to cut the stone blocks is, in theory, equivalent to the number of rows. Onto this common model, however, are applied two distinct decorative systems, based on two different ways of conceiving the relation between the construction pattern defined by the techniques of assemblage ("texture") and the figurative pattern generated by the design of the mouldings.

According to Spanish architectural treatises, the Úbeda dome belongs to the category of domes and vaults "por cruceros" (Palacios 1992, pp. 66-68), in reference to the cross-like shape of the stone blocks that define the structural system of the mouldings **(fig. 2)**. The dome is actually composed of two types of cut-stone blocks: the standard ones, which here coincide with the base of the coffers, and the cross-shaped ones of the ribbing. To the latter is entrusted the task of clenching and securing the wall assemblage. Since all the blocks in the same row have the same shape, eight

"panneaux" were needed for the construction, four for the coffers and four for the cross-ribbing **(fig.3)**.

From a formal point of view this is a coffered dome, on the model of the Pantheon, the ribbing of which, comprised of special blocks sculpted in relief, creates a decorative pattern that is perfectly inscribed within the construction pattern, emphasising and describing it plastically more than the wall texture alone could do.

In Vandelvira's dome the "quest for form" thus takes place *within* the construction system; the decorative apparatus refers directly to its principles and manifests itself as their explication. The aesthetic model of Roman coffered domes, interpreted stereotomically, is here translated into a construction model that is capable of generating new representative forms in keeping with the Renaissance conception of space.

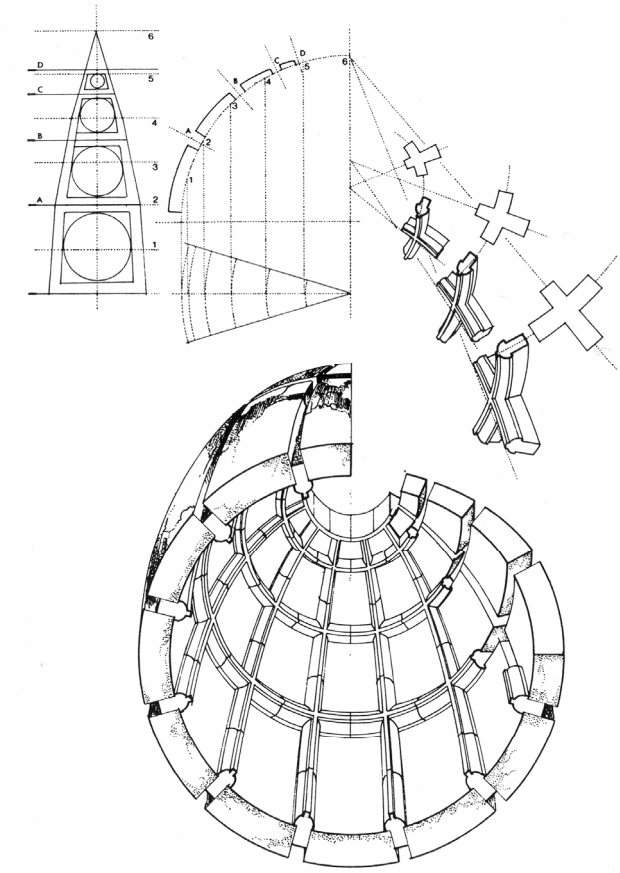

Figure 2. Geometrical development of the "cúpula por cruceros" (Palacios 1992, fig. 9)

Within the Spanish tradition of stereotomic domes the construction of the Úbeda dome sanctioned the beginning of a technical and formal experimentation with the "bovedas por cruceros" type that would reach its zenith in the coffered sail vaults in the church of Nuestra Señora de la Consolacìon at Cazalla de la Sierra, attributed to a pupil of Vandelvira (Palacios 1992, pp. 66-68).

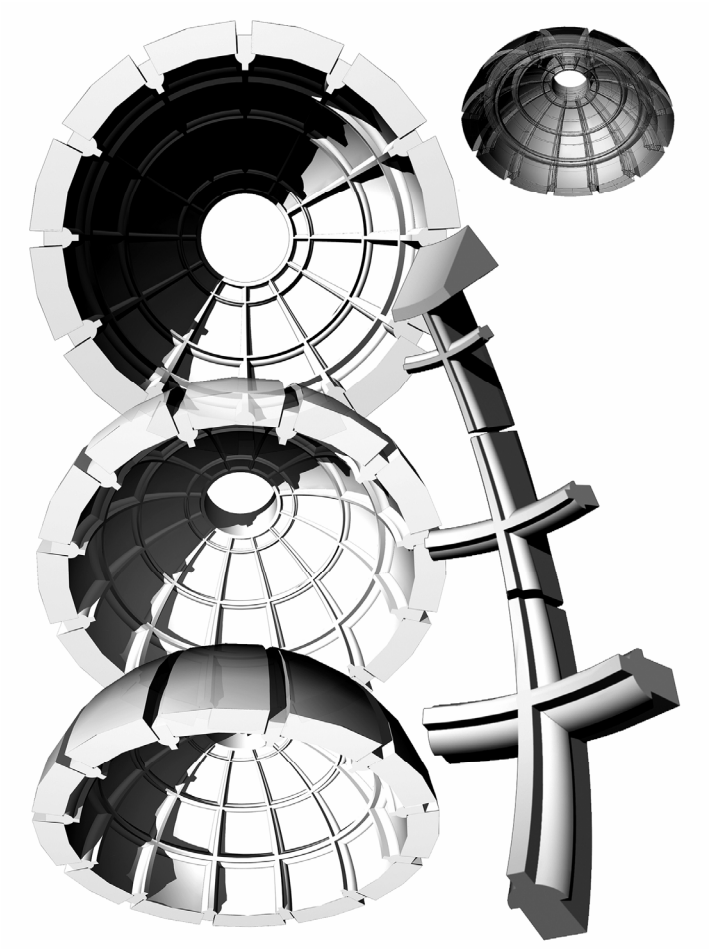

Figure 3. Three-dimensional computer model of the Úbeda dome: analysis of the geometric-construction process (G. Fallacara 2005)

The Anet dome, on the other hand, represents a unique case in the French repertory of cut-stone domes and vaults. Indeed, the architect's intention was to create an unusual type of ribbed dome of extraordinary beauty, rediscovering and updating, with the new techniques of stone-cutting, the construction traditions of the ribbed gothic vault and the Roman coffered vault **(fig. 4)**.

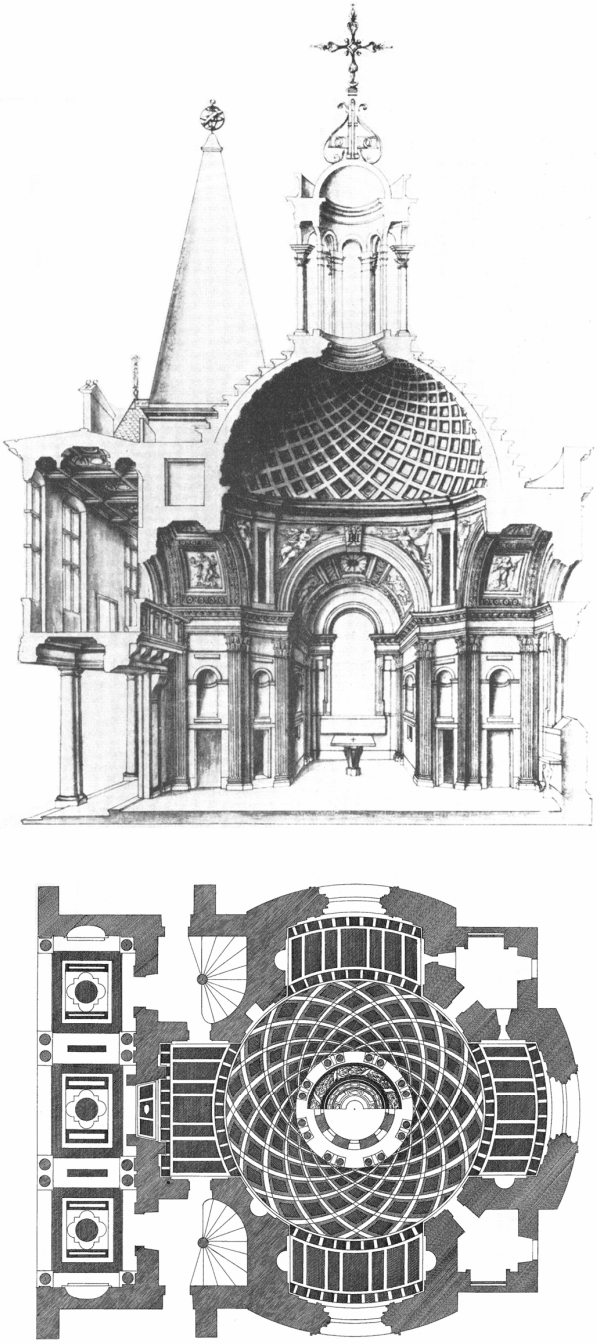

Figure 4. Plan and perspective section of the chapel at Anet (J. A. Du Cerceau 1576-1579)

At first glance, the figurative solution adopted by De l'Orme seem dictated by a virtuoso and ornamental approach to the problem of the definition of form. Oblique coffering, obtained by intersecting two specular bands of helicoidal ribs, is superimposed on the construction pattern of the dome, which is assembled on a standard circular plan with concentric horizontal rows of masonry blocks. So at first it seems that there is no relation between construction and decoration. The system of interlacing ribs seems to be an independent one applied to the intrados of the dome, without any relation to its construction.

Actually a more careful reading disproves this hypothesis and reveals a sophisticated strategy in the definition of form, in which a relation with the masonry construction is established on two distinct, yet complementary levels: metaphorical-representative on the one hand, technical-constructional on the other.

On a metaphorical level, the interlacing motif was chosen by De l'Orme as a *figurative system* that would represent analogously the principle of masonry assemblage, on the basis of its above-mentioned relation to weaving. Rather than denying or ignoring the wall texture behind, the decorative motif exalts it and renders it "convenient" – in the Vitruvian sense – to the spatial value of the dome and the character of the building **(fig. 5)**.

On a technical level, the juxtaposition of the decorative and the construction pattern is not casual, but geometrically controlled in order to optimise the production of the voussoirs by reducing to a minimum the number of "panneaux" needed to cut them. The system of ribbing, conceived according to the logic of this production process, is commensurate with the "metre" used in the wall assemblage and is consequently segmented in strict relation to the shape and dimension of the curved surface of the voussoirs that define the intrados of the dome.

The result is that for every row there are two types of voussoir with the same dimensions, yet distinct because of the fragment of moulding carved on the curved surface. In other words, two "panneaux" were needed to cut all the voussoirs in the same row and 28 for the whole dome. Conceived as a module, the stone block is thus expressive of both the construction and the decorative model, since it is an element that goes to create both patterns simultaneously (Potié 1996, pp. 108-118) **(fig. 6)**.

Another interesting aspect of the definition of form in the Anet dome is the relation between the design of the mouldings and that of the pavement below. Some architectural historians maintain that the pavement is a "petrification" of the "épures"; in other words, a geometric development in plan, on the same scale, of the oblique coffering above (Pérouse de Montclos 2000, p. 118).

Like a mirror, the pavement seems to reproduce the design obtained by the orthogonal projection (*ichnographia*) of the decorative motif above. This design is composed of two series of 18 sections

of circles with the same radius, which rotate around a central circle (a projection of the oculus in the dome) while remaining tangential to it. The intersections between the cylindrical surfaces, generated by the orthogonal projection of these sections, and the spherical dome determine the open spatial curves (fourth order curves) that generate the geometric matrix of the mouldings (Gava and Trintinaglia 2004, pp. 188-193) **(fig. 7)**.

Figure 5. Three-dimensional computer model of the Anet dome: analysis of the geometric-construction process (G. Fallacara 2005)

Within this anamorphic play, connected to the method of projection, lies the secret of the Anet dome (and of Philbert de l'Orme's work in general). Not so much with regard to the hypothetical formal models adopted – the semi-dome in the apse of the Temple of Venus in Rome, the apsidal semi-domes in the frescoes of the Stanza della Segnatura in the Vatican or the mosaic in the Museo delle Terme in Rome – as to the two-dimensional or three-dimensional context within which the invention of form takes place, and to the instruments of control and representation adopted. More specifically, it would be interesting to know whether De l'Orme began with the two-dimensional model of the pavement or the spatial model inscribed on the spherical dome **(fig. 8)**.

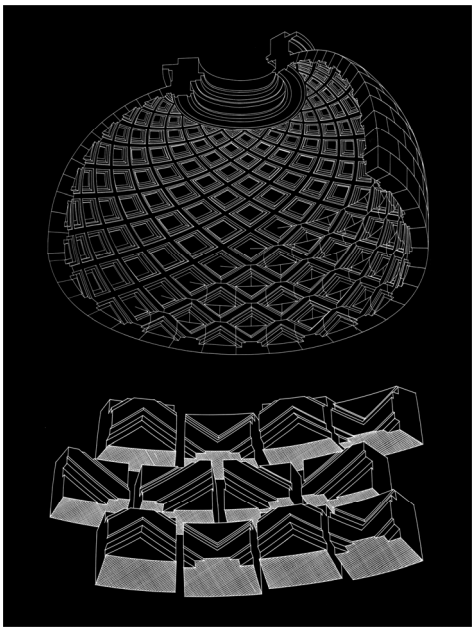

Figure 6. Axonometric section and detail of the voussoirs of Anet dome (Potié 1996, pagg. 116-117)

Figure 7. Perspective section of the chapel at Anet: projective correspondence between the design of the mouldings and that of the pavement below (Gava and Trintinaglia 2004, fig.33)

Certainly the geometric relation between the two decorative patterns expresses a fundamental principle of stereotomic art: the principle of projections, which was scientifically tested and codified in the theory and practice of De l'Orme himself.

CONCLUSION

This paper, a reworking from a fresh perspective on the findings of other scholars, is an attempt to contribute to the research on contemporary forms in cut-stone architecture. It is based on the assumption that forms in architecture are "complete" only when they are representative of a value connected with their construction. In this sense, the domes of Úbeda and Anet are exemplary cases, as the concrete expression of this principle.

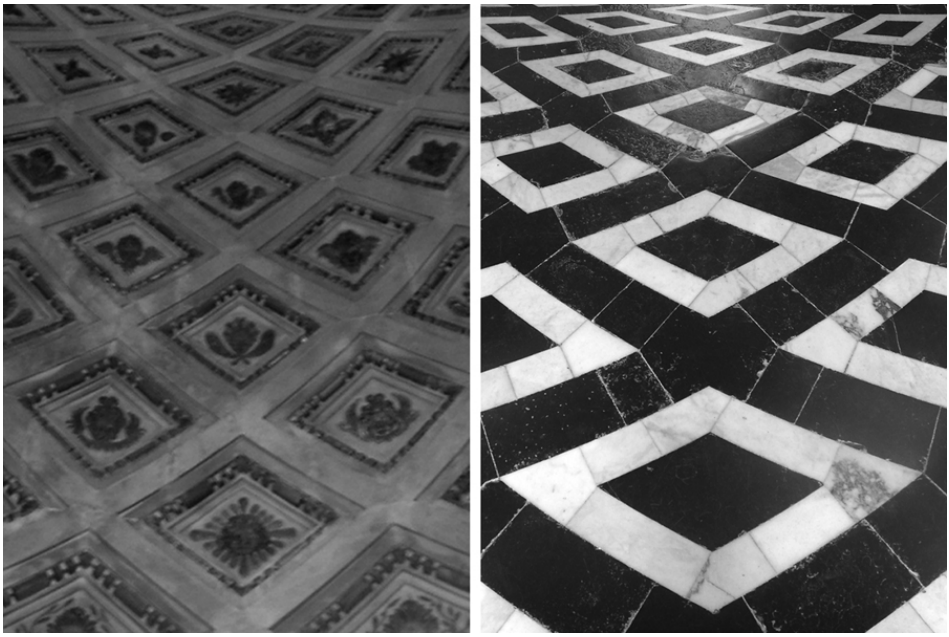

Figure 8. Anet chapel: decorative patterns of the dome and pavement

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