Ornament in Hellenistic architecture: Standardization in construction processes and the birth of the artistic industry. Hypotheses of updating, using CAD/CAM processes

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The main treatises about Classical Architecture and Stereotomy consider the Architectural Orders with their related elements, as a model for stone construction, in which principals of Composition and Construction are given as a result of exact proportional correspondence and numerical relations.

In the Hellenistic period, the relationship between Geometry and the principals of construction became very strong, as new rationalistic ideas of beauty as a product of mathematical relations replaced the aesthetic conception of Art as a product of God’s inspiration, codified according to the canons of harmony and rhythm, like Music and Poetry.

Rigour in geometrical models is the fundamental characteristic of the main Hellenistic monuments, both in the planning of the Order and in the planning of ornament too.

Geometrical and Construction rules, according to tectonic and stereotomy principals, become essential, given that the elements of architectural decoration of the temple gained meaning in the use of repetition in series and in the device of mutual combination, which followed the passage from multiplicity to unity. The formal iteration process intrinsic to the Hellenistic aesthetic and to the principals of decoration, characterize the whole building structure. In the trilith building, in fact, each element is submitted to the rule of the series. Each element is conceived of not as unique and unrepeatable, but as a characteristic of reproduction, to emerge as a model for composition and technical principles.

The passage from the unique sculptural model (the original) to the serial, simplified model (the copy)

Figure 1
Drawing of Temple, archaeological survey made by George Nieman in 1912 for the DAI in Berlin (supplied by the DAI, Deutsche Archaeological Institut, Rome)
takes place through a process of stylised methods that are to be considered fundamental to grand architecture (see the Temple of Apollo in Didyma) and civil architecture (the stoa and the Colonnate strips of the Syrian town).

This paper intends to analyse the artistic production of the «special piece» and the methods and proceedings of serial production in order to discuss the birth of the artistic industry.

HELENISM AND THE BIRTH OF THE ARTISTIC INDUSTRY

Art collection and copy industry

The enlightened rationalism that characterizes Hellenistic culture determined the organization of scientific and artistic activity through the creation of research centres, museums and libraries and operated according to the principals of the division of labour in the intellectual field.

Artistic production was employed in the creation of complete Art Collections. Princely and private collections already existed but only during this period is the collection systematically organized according to a plan: collections representing the evolution of Greek art, characterized by the search for ancient masterpieces, was begun.

It is very important to notice that this process, regarding the acquisition of classical art, is achieved also through the birth of artisan workshops engaged in the production of copies.

In this way the copyist craftsman compensated for gaps in the artistic heritage and became involved in a kind of rhetoric or exercise that provides, first of all, for an enrichment of the formal repertory and secondarily increases the spread of new technical knowledge in proto-industrial serial production and process.3

In the passage from the original artistic object to the series of replicas and copies, it is possible to recognize the beginnings of standardization in production methods: the geometrical model and the Original, numerical model and the Copy.

The principal characteristic of the artistic object, the special unique piece, is that only the author who conceived it masters the geometrical model. The original is followed by replicas4 made by the same author, or by another one, who reproduces the original geometrical model and becomes adept at reproducing replicas, creating thus new, unique objects. Following this logic, the last steps in the sequence is the creation of copies, realized by hand or by machine, similar to pantographs without any plan. Selecting points from the original, the craftsman develops a kind of mathematical model that becomes the basis of the copy. Mathematical models were often very similar to the originals, the difference between the original and the copy being technical.

When these copies were produced on a large scale for the art trade, this kind of technical difference began to be codified using stylised methods.

Design and building: construction enterprise organization and the architect’s role

Works of Classical theory of Architecture were focused on the aesthetic principals of Proportions and Relations between elements of Order, according to the principals of rhythm and harmony, fine refinement and perfect execution, which were the principal topics of such works.

Hellenistic works on architecture speak about mechanics and engineering5 showing the change in attitudes to a research in architecture and building. The search for new aesthetic reference models ceased and models were taken directly from classical tradition. The aims of Hellenistic theory were the invention of new civil and religious building typologies, conceived to be grand and to give resonance to the expansionist politics of Greece.

Architectural theory was divided into problems of Aesthetics and Practice. Formal decoration became eclectic with a contemporary use of subjects consolidated and codified in the Classical and Ionian periods, and new subjects taken from Asiatic traditions (for example decoration in Didymaion is characterized by the use of actical profiles in mouldings and samic subjects in the decoration). On the technical side, more rationalized processes in stonework took place, based on the specialization of work phases and on the creation of an artisan dimension in serial production.

This kind of specialized organization was based on the use of different workers for the same building and for each carved stone, the aim of skilled work was
speed of execution and a good finish. However, in Greece the reunification of different areas in a single, large enterprise was never realized.

The Temple of Apollo at Didyma is an example of the grand Hellenistic Ionian building in which many different classes of worker were employed for a very long time (the construction started around 334 B.C. and went on slowly for 600 years—it was never finally finished) creating a structure made of 108 columns. Greek workers were used at the beginning and Roman workers at the end. According to H. Lauter (1986) workers assigned to the Didymeion were a sort of stately slave. There were four main categories of worker: the latomai assigned to the quarry phases, the leukorgoi who transported the handmade stone blocks from the quarry to the Temple yard, the egemon, a supervisor who directed the activities of the other two classes of worker, and finally the skilled craftsmen, responsible for the yard phase. The Latomai quarried stone blocks congruent in dimension to the planned architectonic elements and gave the essential geometrical shape to the stone. The Leukorgoi transferred the pre-manufactured blocks to the temple site and then began the process of shaping and refining them (anathyrosis). The architectural stone element was situated according to the codified position of Order. In the last phase, the skilled craftsmen carved this element following the ornament design made by the architect of the temple, copying a model for capitals; for the column entasis, for the moulding profiles and the architectural decoration they utilized a guide-plane, as well as with strips sculpted on the blocks of the wall of the cellar and the stylobate. These are the blueprints (fig 2) for the temple discovered by Lothar Haselberger in 1979.

The architects Daphnis of Mileto and Paionios of Ephesus designed Didymeon. In the Greek practice of planning the construction phases of the temple, there was an architekon and a hyparchitekon. The first was essential to the life of the building, he was familiar with the complete architectural plan, directly involved in part of it and directing the work in progress. In the building yard he was responsible for the technical direction of all activities and, completely independently, could plan and approve small interventions in the immediate building area. The hyparchitekon, on the other hand, was committed to the direct supervision of each individual block production. In this kind of organization seems to be very clear the strong relationship between design and construction.

**Morphological development of elements pertaining to the Orders through the process of standardization**

In the wake of evolution in building types and large scale production processes, elements pertaining to the classical orders have undergone a series of noticeable changes regarding formal details as well as involving substantial modifications to the morphological characteristics of blocks, both due to the diminishment of the original structural role. These changes effect, above all, elements of moulding and entablature.

What initially might appear as a new form or as an added form to the ornamentation, is, in reality, evidence of how the tectonic quality of building elements have lost their original strength.

With regard to moulding, the most substantial variations can be seen in the Doric triglyphon, an eminently tectonic element in which it is possible to witness a noticeable loss of the sense of alternation between metope and triglyph. The metope, which
originally represented an interruption in the pattern of the wooden beams, increases in size, giving space to the secondary plastic. This expedient was aimed at creating a plastic effect of *chiaroscuro*, eliminating for the most part the structural differences between *metope* and *triglyph*; the represented objects, in this way, have a structural role, upsetting the tectonic sense.

The manipulation of building elements such as entablature (or frontals) reveals not only a clear variation of the structural role but the whole traditional system, based on a clear relationship between single blocks and the organic structure, is called into question. Even blocks used in the cornice reveal a progressive deconstruction of the original monolithic aspect.

In this way, compositional processes are born based on the concept of series repetition and to which completely new formal qualities are associated, with new proportional relationships between the various elements.

In general, these morphological and tectonic changes are most evident in the reduction in thickness of the blocks, an aspect that responds directly to the economic obligations imposed by primary materials, and to the increase in production speed and assembly necessary in the construction of civic buildings, for example the *stoà* and the colonnades of commercial Syrian cities.

**The Ornament in Architecture**

**Mouldings and decoration**

The analysis of architectural ornament begins with the distinction between *mouldings*, pertaining to the architectural field and *decoration*, pertaining to figurative one. During the archaic age the association between decoration and profile was rigidly controlled, while Hellenistic culture was open to new combinations. Indeed, during the Hellenist period an enrichment of the formal repertory, made up of different styles and traditions, takes place.

Mouldings are serial architectonic elements set in a Greek Order and their sequence and combination generates the language of stone trilithic architecture.

According to the archaeological tradition, they are represented by two-dimensional sections, representing combinations of circular arcs filled to create the *listello*, *cavetto*, *gola rovescia* and so on.

From an architectural point of view they are parallel-piped stone blocks, characterized by three planar and orthogonal faces and one sculpted surface, extruded to cast a linear or a curved path.

Indeed, each face of the block is precisely refined: the contact side of the block is scored to create the *anathyrosis*. This kind of finishing allows for the perfect assembling of the block and, most importantly, functions as a device to pass from the single block to the organic structure of the building as a whole (from the unique to the multiple).

According to Karl Böttier (10) this kind of morphological envelope corresponds to the Tectonic needs. He says that Tectonic referring to Greek architecture means exact and congruent functions of the members into the Order’s system according to their structural role.

In the Doric Order, ornament represents the *stone* evolution of the archaic wood temple and mouldings were scantily decorated. The Ionic tradition allowed for more decorative themes, often inspired by natural subjects or of a textile derivation. Leaves, weavings and meanderings are the most characteristic decorative themes from the Archaic period to Hellenism. Those natural or fictile subjects were processed by geometrical and stylised methods to become repeatable in succession, in the same moulding or the same building and beyond.

Decoration was applied to painted or sculpted moulding profiles.

**Standardization in Hellenistic ornament production**

Stone architectural element production has always been dominated by a series of rationalized proceedings that are to be intended as a series of operations organized to create a finished product, and methods that are models for specific action.

The first operative stages in ancient stone working, followed standardized procedures and methods in the quarry itself and included quarrying and squaring. These two operations were regulated by standardized measures congruent with the architectural element to be realized. The stone blocks
are first worked in the quarry where they are squared. The quarrying of the stone was performed following the precise economic need of limiting off-cuts. The stone blocks were thus quarried according to the required size and type of architectural element to be fashioned. The second operation performed in the quarry was the squaring of the block, a task performed with great care as an ill-squared or imperfect face could compromise successive work phases. The next phase includes the rough-shaping of the block, using dime and hages and subbias, before the successive, final finishing. The process of ornamentation is only partly realized before the block is put into position, or until the process of moulding is begun. (Tav. I)

These initial work phases saw at least two classes of specialized workmen working on the same block and it is probable that different workmen worked at the same task. In such cases, it was essential that the work proceeded according to standardized methods, given that the various sculptors involved worked towards finishing a single block. Mouldings or capitals for example had to reveal the same pattern on different sides.

At Didyma, general information about the shape of the moulding sections, the size of the enthasis of columns etc., is still visible on the cell walls and on the stylobate blocks because, as this Temple was never finished, such graffiti, which represents the Greek working methods, was never smoothed off or cancelled.

The mouldings were sculpted with stylised decorative sketches, which functioned as a guide for the artisans who decorated the stone. Following this method of directing work by architectural sculptors, the final surface is sculpted before them. The sculptors were required, above all, to produce a faithful copy of the original. Finishing of blocks with flat surfaces was performed once the block had been positioned in the wall. The sculpting of contact surfaces (anthyrosis) had to be performed with great care as they were the principal elements of formal juncture between surfaces that had to be perfectly flat and those which continued the decoration. Evidently, the façade had to be sculpted once all the blocks were in position.

The development of the idea and its development before and during the work phases, constitute the technique of stone working.

Decorative patterns: planar curve to surface (TAV.II, III)

Decoration could be developed following a process of either direct or indirect design.

In the first case the artistic component of the sculptor, who develops his own design directly on the stone, prevails. This methodology is contrary to the principles of standardization, and its the final product is a «special piece», that is difficult to produce and reproduce in faithful copies for the team of stone masons.

Indirect design implies characteristics of repetition, and the decorative pattern corresponds to precise geometrical rules, which prevail over the purely figurative components.

The method of direct design in Hellenistic architecture was predominantly used in the production of «special pieces» to be inserted into buildings as representative of a certain monumental spirit. The indirect method was more commonly used in the serial production.
Moulding’s surfaces are always being developable in planar surfaces: this means that it is possible to study the decorative patterns in their planar configuration, and to project the planar curve to surfaces. In this way starting from the original configuration of the decoration is possible to achieve different kinds of 3D patterns, according to the development surfaces, both linear and/or generated by revolution, on which it had been projected.

In this light the Decoration design could be divided in two main phases:

— The first regard definition of two-dimensional pattern.
— The second pertain to the study of the three-dimensional moulding’s surfaces and their related planar development.

The two-dimensional decoration is proportioned to the planar envelop of moulding’s surface and then projected on the three-dimensional surface. This method is based on the geometrical principle of congruence between surfaces and planar curve developed.

In the ancient methods this theory was applied in the determination of stylised guide line sculpted in the first work of the row block.

**Figure 4**

Synoptic plate II, Apollo Temple at Didyma: development of the planar pattern to the curved surfaces of the astragal, and stylised decorative sketches sculpted on the moulding’s surfaces. Drawing by the author (September 2002)

**Figure 5**

Synoptic plate III Apollo Temple at Didyma: development of the planar decoration pattern on the entablature moulding’s surfaces. Drawing by the author (September 2002)

**STANDARDIZATION IN CAD-CAM PROCESSING.**

**Cad/cam methods and processes**

The hypothesis of updating stone architectural ornament design and production processes is based on the possibility of applying modern stone cutting technologies through the use of cad-cam. The aim of such a research hypothesis is the development of contemporary architectural forms to be used mainly in restoration sites.

Electronic Design replicas, referred to ancient Orders and Ornaments, allowed us to comprehend the complexity of classical geometrical models and technical knowledge in sketching and finishing surfaces.

Starting from the study of the single special element, the reflection led to the methods that are to
be consider valid for replicas and copies’ serial production.\textsuperscript{11}

On the basis of the archaeological survey’s data, the Cad design allowed us to reproduce the original geometric model and to make a virtual three-dimensional replica, that could be considered likely identical to the original.

Cam processing concerns the planning of work-phases in making replicas.

The first step is to import cad project files (dwg, iges and so on) and then to choose the number and the kind of processes, the number and the kind of tools.

Work cycles are divided into two main categories, rough-shaping and finishing. These two phases of work in progress correspond to a growing approach to the form, from the parallelepiped block to the final ornamental element.

The second step is the tools’ choice, the number and kind of which depend on row-block dimension, final element morphology and the kind of sketching and surface finishing. In the tools repertory we distinguished two main categories: those which use their form to reproduce predisposed form and those with a cylindrical or spherical form. The first kind of tool is generally used to make contours and incisions, the second type in rough shaping and finishing. The variables to be decided on in choosing tools include rotation speed and progress speed, depending on the characteristics of the stone and the shape to be achieved.

The last steps in a CAM project is the generation of CN files\textsuperscript{12} made by a cam software. This file contains all the information about labour, finishing and tools changes.

Sketched and finished surfaces in the ancient age and in Cad-Cam production

The tools choice and the techniques of rough-shaping and finishing are important for any research project that intends to recover the expressive nature of stone, since certain plastic outcomes of the period are to be

Figure 6
Synoptic plate IV Apollo Temple at Didyma: the 3D virtual model of the naikos wall base’s moulding, and CNC Work phases for the prototype’s realization (Laboratorio Cad-cam, Dipartimento ICAR, Scienze dell’Ingegneria Civile e dell’Architettura, Politecnico di Bari, June 2002)
evaluated as the result of the tools which were used for the percussion.

The study of the artisan ornamental techniques used in Hellenistic building sites permits a comparison of the similarities and differences between a manual production system and a mechanical system using numerical controlled machines.

In ancient building sites the constructions of finished elements necessitated a series of work phases (often performed by different specialists) analogous with mechanized systems in which the number of jobs to do depended on the nature of the object to construct and on the type of ornament.

A decorated surface would be subject to at least three work phases, which would increase in relation to the morphological characteristics and to the number and type of tools necessary to the stone-cutting. In the ancient period the production of different blocks was often the responsibility of various workers and the result was a slight difference between the pieces. The production of a series of elements entirely produced with mechanical processes, on the contrary, guarantees absolute similarity.¹⁴

In the ancient period the first work phase after the squaring of the block was the redesigning of the orthogonal surface of the moulding. The pattern was accomplished using dime and boring tools. The dime were generally made in wood and appear as the negative of the mouldings, they permitted the control of the required shape during the sculpting process. The circulation of templates and pattern cards throughout the building sites was associated with the mobility of artisans and allowed for the rapid execution of similar elements. Only in the final surface finishing phase were abrasive tools used.

The mechanized processes employed by computerized numerically controlled machines use mills and rotating drums which need materials with different characteristics to those required by scraping off tools. Certain processes (including "bush hammering", which is typical of the surfaces between the blocks and the drums) do not appear to be reproducible with off-cut techniques. Thus it is necessary to establish a priori both the type of tools necessary to create the desired effect and the right type of operation (wholly mechanical, partially manual etc.). This problem is more complex in the study of decorative pieces, in which the finished product reveals both intaglio and, sometimes, fretwork.¹³

NOTES

1. The philosopher Platone in the Res Publica expresses the conception of beauty as a strong relationship between geometrical shapes and mathematical proportion.
2. Doric Order was exactly ruled in the VI B.C.c. and only few changes in decoration and proportion appear during the following centuries. The architects of the Asia Minor codified ionic Order later in IV B.C.
3. «Accanto alle botteghe dei ceramisti, che in parte lavorano già con sistemi industriali, comincia la produzioni su vasta scala di copie dei capolavori della scultura. Senza dubbio le stesse botteghe e le stesse persone producevano anche opere originali ma è naturale che gli scultori, esercitando quel mestiere di copisti, si lasciassero facilmente sedurre dal puro virtuosismo stilistico». (Hauser, 1986)
4. Kugler (1972) gives a precisely distinction between original object and copies according with aesthetics’ principles. The formal class is expressed «da oggetti primi o da cose dotate di grande potenza generativa, quali ad esempio il Partendone [...]. Anche se parte del loro splendore è andato perduto col tempo, la loro qualità di oggetti primi resta indiscutibile».
6. Building’s enterprises were generally managed by private organization.
7. Lothar Haselberger (1985) discovered in October ‘79 many etched line on some of walls of the Temple. Then he realized that those strips should have been the construction plans for the temple of Apollo at Didyma.
8. Trevor Hodge (1960) makes an interesting comparison between the cornice’s blocks of the main temple from the Archaic to Hellenistic age.
9. According to Giorgio Rocco (1994), Greeks inherited from Egyptian Architecture the two main moulding: the cavetto or gola egizia and the semicrcho. Hellenic culture taken this two forms and developed five new form. The semicerchio was used in his linear and original form and became the toro for the columns’ bases. The becco di civita and the gola rovescia were typically used in the Doric Order and gola rovescia and the ovoli in Ionical Order.
10. Karl Bötticher, neoclassic architect and architecture’s theorist.
11. Prof. D’Amato (2002) speaks about the replica of the 9A Doric Capital of the Temple of Apollo Epicurio at Bassai. He makes a comparison between an artistic replica and an architectural one.
12. A CN file is written in an ISO-normalized format and adapted to characteristic of the Numeric Controller.
Machine by the CAM-software. The file elaborated by the author was processes by the cam software of the Easy 11 CNC machining centre of the Laboratorio Cadcam at the Politecnico di Bari for the realization of a first moulding prototype with the imbricate leaves, presented during the Study Seminar «ARCHITETTURA E STEREOTOMIA: TRADIZIONE E INNOVAZIONE. Giornata di studi sull’Architettura in Pietra da Taglio», 3–4 June 2002).

13. The paper summarises some aspects of the on-going Doctorate dissertation the author is carrying out at the Politecnico di Bari, and titled La decorazione Architettonica ellenistica: dal pezzo singolo artigianale alla produzione in serie. Tutor: Prof. Claudio D’Amato Guerrieri. Politecnico di Bari, PhD Course in Progettazione Architettonica per i Paesi del Mediterraneo, ciclo XVI.

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