THE NECESSARY PROCEDURES FOR THE RENDERING OF A MONUMENT. THE CASE OF THE HOLY SHROUD CHAPEL IN TURIN (1657-1694).

Vincenzo Borasi, Maurizio Aiello
Polytechnic of Turin

Abstract

A work of complete survey, suitable to define a geometric model of a building, becomes absolutely unavoidable when we have to face the project of restoration of a monument. As a matter of fact, the survey permits to point out the geometrical characters of the building as much as its evolution in time. In this way it is possible to investigate the original morphology of the building, describing at the same time its present condition.

In order to achieve these targets, the survey has to go further the mere (but indispensable) assessment of the visible surface and must cover a range of inspections from the examination of historical documents to the analysis of connections between different elements.

1. Introduction

The potentially useful documents are those about the examined building: projects, book-keeping and surveys. It is possible, if these documents are missing or incomplete, to take into account those ones concerning other buildings with similar characters, especially if belonging to the same author. The research of this material can be directed towards historical and modern building archives of Cities and other institutions. It is possible, through the analysis of book- keeping of works, to acquire the quantity, quality and origin of the materials employed in the building, the succession of laying operations and the professionals involved. It is furthermore possible to get the chronology of all the events concerning the construction (interruptions, variations, etc.).

The comparison between this material and the available graphic documents (project drawings, sketches, laying schemes) can give veritable information about the making of the monument and the nature of its constitutive elements.

Any other document concerning the following period is useful to detect the occurrences which have happened up to the present age: enlargements, reconstruction, demolition and anything that have altered the monument's original characters, as the natural decay of materials due to weather, use and time. In particular, it is indispensable to identify previous restorations or consolidations. If interventions of this kind are discovered, the original projects must be found, together with the specifications of the employed materials, in order to evaluate the full compatibility with new designed works.

The knowledge of the stylistic and building characters of the examined monument may be improved by the information coming from another source: the treatises and the handbooks of that age. Through the treatises, most of which come from 17th and 18th century, it is possible to identify, by means of direct references to the monument or by analogies, the architectonic principles that inspired the designer and the structural typologies that have been chosen; in the handbooks, which began to spread during 19th century, the techniques of laying, that before were transmitted orally, are codified and explained in detail.

The methods of geometric survey, as well as those of its graphic rendering, depend on several factors. In first place, the objectives: if the study works as a basis to a project of maintenance, restoration or consolidation the requested information can be different, as well as their detail scale. The accessibility of the various parts of the building is another determining factor and may be improved if maintenance passages or scaffolds exist. In the end, the methods depend on the amount of human, instrumental and economic resources that have been granted for the survey.

Generally, the measurements can be topographic or photogrammetric. An accurate survey has to exploit the advantages of the different techniques and integrate them in order to achieve the requested precision with the least expense of resources. Moreover, the use of non-destructive investigations may be necessary to get information about the internal composition of massive or inaccessible structures.

In order to complete the framework that can be obtained with geometric measures and historical documents, it is useful to make surveys of other characteristics of the monument, which are the disposition and continuity of structural elements, the chemical and physical composition of employed materials, the distribution and use of the light (shades, patinas, reflections), the state of decay and the speed of ageing of the different parts.

The rendering, likewise, is a function of the targets of the project. It can be done through graphic representations of plants, sections and elevations or through a virtual reconstruction that can be managed with three-dimension

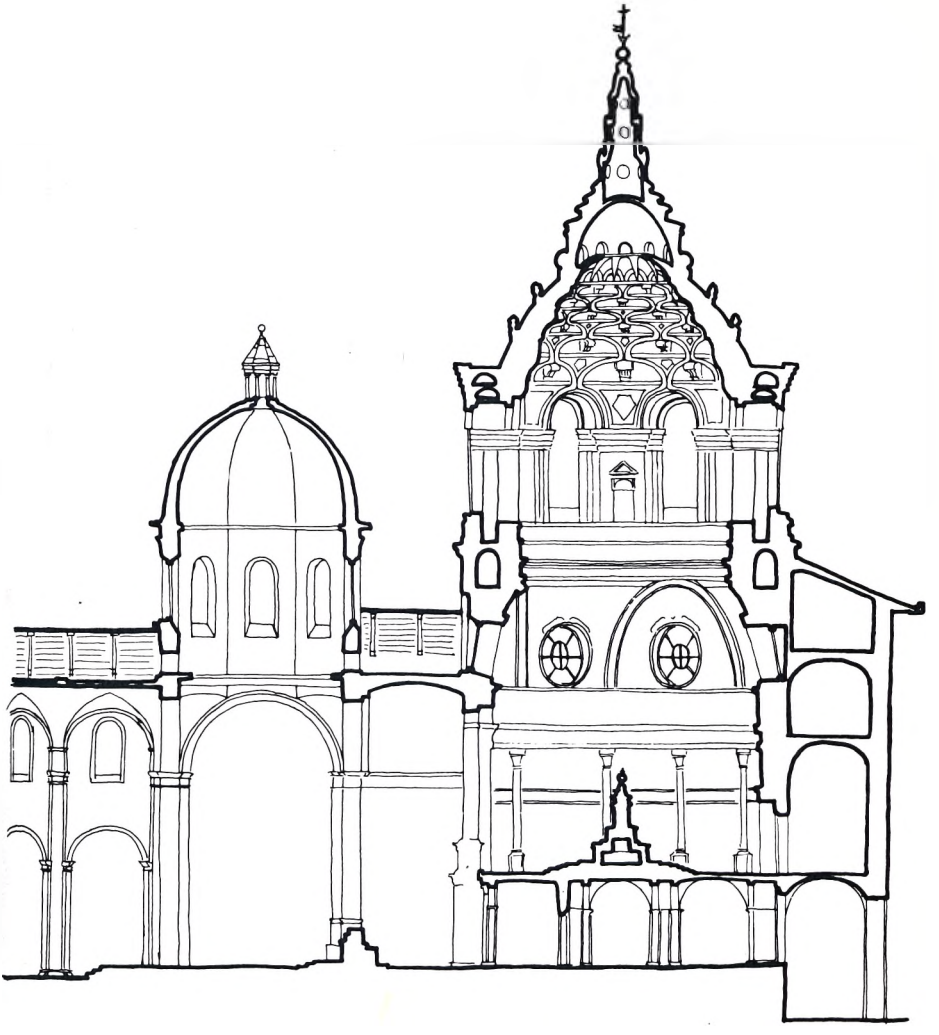


Fig. 1 - Section of the Holy Shroud Chapel

modelling software, as well as any other kind of graphic, descriptive or photographic information that permits the full understanding of the building.

The making of a reliable geometric model leads to obtain information about the original project of the monument pointing out the latent geometry, the proportioning criteria and the stylistic choices. A model of this kind, besides, is necessary when we try to understand the mechanical behaviour of the building,

either through simple structural schemes or through a more refined computer-supported analysis. By means of the proportions of the structures and assuming a substantial homogeneity of materials (or, at least, of the function imposed by the designer), it is possible to determine the position of the resulting forces. In this way, through considerations of equilibrium, we can recognise the behaviour of the structures, and discriminate between domes, reticular vaults, buttresses, etc. According to the results of this analysis, we can therefore make suppositions about the laying techniques: it is possible to verify whether the construction needed centerings and props or it proceeded by tight, self-supporting successive layers.

The survey operations, anyway, should be always be leaded, if not directly done, by the subjects responsible of the restoration project. Assumed that the quantity of measurements is strongly limited by the amount of granted resources, it will be necessary to discriminate with great care the indispensable, useful or just interesting information from the useless or otherwise obtainable one.

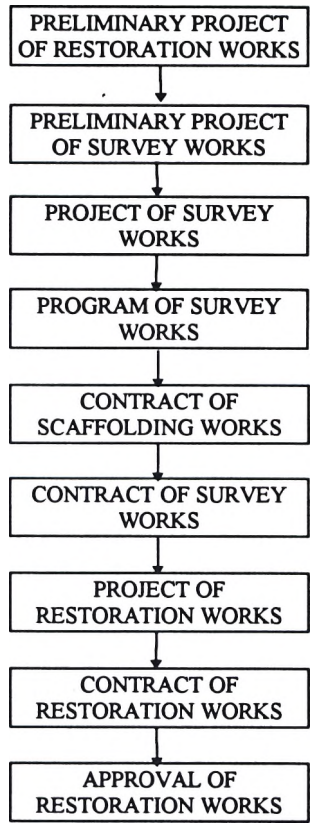
The program and the project of the survey should take in account these factors:

1. Time necessary for site survey (hours per person);
2. Time necessary for information rendering (hours per person);
3. Cost of necessary survey equipment;
4. Cost of necessary rendering equipment;
5. Compatibility with site work and necessary technical assistance (scaffolding, lighting etc.).

In order to evaluate the importance of these elements, the project and the program of the survey should follow a preliminary project, in which some considerations are compulsory:

1. Individuating the aim of the survey: historical and stylistic analysis of the monument, structural verification, project of restoration works, book-keeping of works, monitoring);
2. Evaluating the existence and the reliability of previous measurements (project drawings, as built drawings, surveys). To accomplish this it may be useful to investigate at building and historical archives of Cities and Institutions.

Afterwards, it will be possible to design and to let out on contract the scaffolding works necessary to execute all the measures and the site diagnostic tests. The best operation succession, in the case of a monument's restoration works, is described hereafter.



The geometric survey must be done through successive approximations, converging to the full comprehension of the monument. The necessary stages should be:

- urban scale survey (according to Italian rule UNI 7310);
- architectural survey (from scale 1:500 to scale 1:1, if necessary).

The geometric survey, besides improving the figurative, stylistic, decorative and technical knowledge of the building, must be aimed at allowing the structural survey of the building skeleton and its decorative elements.

The structural survey should consist, at least, in measures of:

- density;
- elastic module;
- viscosity state;
- resistance to compression;
- resistance to traction;

- materials forming the skeleton (bricks, mortar, stone, iron, etc.).

Only a survey of building details, however, permits the calculation of tensions. This survey should tend towards the univocal comprehension of:

- contact surfaces finishing;
- laying methods;
- defects of materials (detectable by chemical, physical and mineralogical analysis).

Following the adoption of such cognitive measures, the survey can be completed with a series of non-destructive or quasi-destructive investigations.

2. The case of the Holy Shroud Chapel in Turin

The restoration works in the Holy Shroud Chapel in Turin (1657-1694) have offered the unique possibility to study Guarino Guarini's masterpiece from a closer point of view. These works could not have been postponed after some fragments of the marble covering, falling from an height of over thirty meters, threatened the safety of employees and visitors. The urgency of these works has been made even greater by the approaching of next Ostension of the Shroud in 1988.

2.1. Guarino Guarini: mathematician, geometer and architect

The Modenese architect Guarino Guarini, like many intellectuals of the 16th and 17th century, had a many-sided range of interests, which included Philosophy, Mathematics, Theology, Astronomy, Geometry and Architecture.

After having taught Philosophy in Modena (1650) and Messina (1660), he spent the years from 1662 to 1666 in Paris, where he published the *Placita Philosophica*. Most of his works, however, were printed in Turin, where Guarini worked as the Duke's Architect for twenty years. Overlooking the treatises on Theology and Astronomy, we can mention *Euclides Adauctus* (1676), the *Trattato di fortificazione* (1676), the *Modo di misurare le fabbriche* (1674), the *Disegni di Architettura civile ed ecclesiastica* (1686-posthumous), the *Architettura civile* (1737-posthumous).

In *Euclides Adauctus* (Euclides enlarged), in particular, Guarini sets the theoretical basis for his following treatises, basis that will permit him to demonstrate in his works an absolute mastery of stereotomy. The complex geometric constructions necessary to individuate double-curvature surfaces and intersections of solids in space are the same that he used to design buildings, from the general outline of the edifice to the shape of single stone ashlars. As a matter of fact, in the *Trattato di fortificazione* he writes that Architecture is closely depending on "Euclides' elements, as necessary to every mathematical science".

The first charge of Guarini in Turin was, in 1666, the new project for the Chapel of the Holy Shroud. The construction of this monument, begun in 1657 under the direction of architect Bernardino Quadri, had been suspended, because of growing doubts about the structure's stability. The first concern of Guarini was to reinforce extensively the existing foundations. Having in this way obtained a firm base, he continued the edification (1668-1682), raising, from the level left by Quadri, a masterpiece of architectonic daring, in which he showed the whole of his knowledge.

2.2. The apparent geometry of the Chapel

The Chapel is placed between the Dome (15th century) and the Royal Palace (built a few years before) so that it represents an ideal link between these two poles of attraction (or repulsion). From the Dome it is possible, climbing two long and dismal stairways, to reach the floor of the Chapel, which is at the same level as the first story of the Royal Palace (fig.1).

Going upwards from the floor to the summit of the dome, the structural geometry of the Chapel seems to go under a continuous change, with a succession of different divisions of vertical surfaces, always based on the multiples of three. At the floor level, the perimeter is divided by columns in nine equal parts; three of them correspond to the entrances (one from the Palace and two from the stairways), four are occupied by niches while the last two ones give place to the great window (1826) that separates the Chapel from the Dome.

At the top of this level, which is the limit of Quadri's construction, Guarini springs a hemispherical dome, early truncated to give way to a tall tambour. The dome is marked by three great arches that cross the space below to sustain the tambour. Even if they are perfectly vertical, they seem to loom precariously on the observer. With the design of these arches, Guarini can change the division in nine parts of the base, inherited from Quadri, to another in six parts of the tambour above. As a matter of fact, the arches, skipping every time a column, divide the dome in six parts: three of them lying under the arches and three pendentives springing between them. The scenic result is that of a singular vault with only three (instead of four) pendentives sustaining the tambour, which rest on the dome like a huge lantern.

The cadence of solid and empty parts of this vault, due to the presence of six great circular windows placed in the centres of pendentives and arches, is reprised in the tambour, where we find six tall windows in the same position as those below. The division in six parts becomes, hereafter, definitive, and will be always repeated in the superior part of the dome. This partition, anyway, respects the initial one, through the passage from nine parts to eighteen and then to six. From the keystones of the six arched windows of the tambour, springs the framework of small arches that constitutes the upper part of the dome: six orders of six arches each, that grow flatter as they approach the summit, in order to alter the perspective effect and to create the illusion of a high spire em-

broidered by daylight. Looking up we have the final effect of a distant and shining three-dimensional rose, suspended over three huge arches whose origins fade in the dark space beyond the field of vision.

2.3. The surveys made in the Chapel

The only survey, that had been made before present restoration works, was that done by Mario Passanti in the '30s of this century. Even without scaffolds, he managed to draw a reasonably precise geometric survey of the interior of the Chapel, revealing the extraordinary optical effects displayed by Guarini.

In occasion of the current project of restoration, a preliminary photogrammetric survey of the internal surface has been made, in order to grant a basis for the book-keeping of works. For this purpose, the rendering has been made developing the fuses of the dome on a plan, in order to keep the areas unaltered. Yet, as this survey is not sufficient to achieve a detailed three-dimensional model of the building, a systematic series of photographs, taken from two different points, is being made, with the purpose of obtaining the spatial position of the internal surface of the Chapel.

Beside this kind of surveys, which permit to describe the general geometry of the Chapel, local measurements have been made in order to study the building details of the structure. In particular, it has been investigated the connection between the marble covering and the masonry, aiming to understand its mechanical behaviour (fig.2). The symmetry of the dome has been checked, looking for signs of possible settlements. The measurement of the external surface, up to now rather neglected, gives great help to individuate the bearing structures of the Chapel.

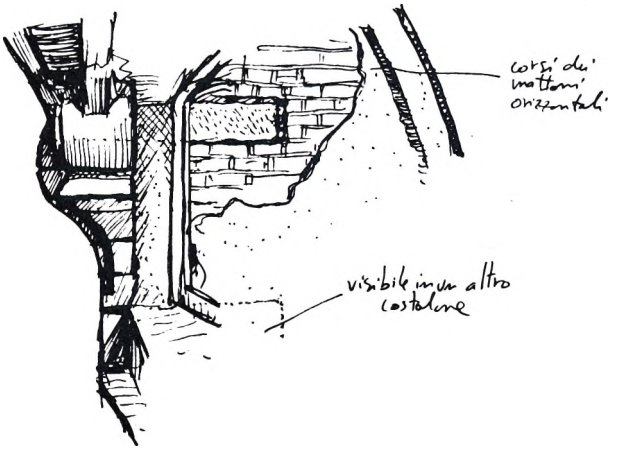


Fig. 2 - Junction between keystone and buttress

Finally, in order to point out the presence and the position of breaks in the continuity of materials inside the wall masses (like the contact between marble and masonry, iron cramps, hollows), non destructive investigation techniques have been used, like metal detector, radar, termography.

2.4. The latent geometry and the structural solutions

The peculiar quality of Guarino Guarini is, with no doubt, the ability in leaving the observer puzzled and bewildered in front of the structural paradoxes that are found often in his works: which elements are bearing, and which are borne? The answer to this question is sometimes simple and obvious, but Guarini often makes use of all his art to deceive the onlooker. In this case, especially, the structure is even more hidden, because the thick covering of black marble conceals the whole Chapel, from the base to the nail crown placed at forty meters of height.

In order to clear the mechanical behaviour of the building it is therefore necessary to ignore the artifices put on by the designer and to follow step by step the flow of forces, from the vertex of the dome to the foundations.

The upper dome, far from behaving like a proper dome, is actually more similar to a space frame, in which forces are transmitted along longitudinal elements. In this case there are six orders of arches and, in every order, each arch springs from the keystone of those of the lower level. This scheme is repeated as far as the lower order, where the arches impost upon the keystones of the arched windows of the tambour. In fact every keystone rests upon a cantilever inserted in a buttress, which is able, in this way, to bear the vertical weight transmitted from the impost of the overhanging arches. Every arch has only to bear the weight of its own ashlars and of the loading covering. The horizontal components produced by the arches are absorbed by the ribs, which work as the buttresses of Gothic architecture. The presence of a series of iron chains, one or two per level, confirms the necessity, in phase of construction, to bear those forces at stage in which the weight of the buttresses was not enough to contrast them. The scheme of the marble arches in the internal covering repeats itself in the same way on the outside, producing correspondent masonry arches. The joining elements between the two structures are the marble cantilevers placed below the keystones of the arches, which insert themselves deeply into the buttresses.

The transmission of loads to the tambour below occurs through a system of arches, partially hidden. While the marble arches load directly the six internal pilasters, the weight of six of the twelve buttresses is shared between the internal and the external pilasters, thanks to masonry arches that climb the space between them, connecting alternatively the internal pillars to their correspondent on the outside. So, a certain part of the weight is driven away from the centre of the dome, relieving the pressure upon the ring that closes the truncated vault below.

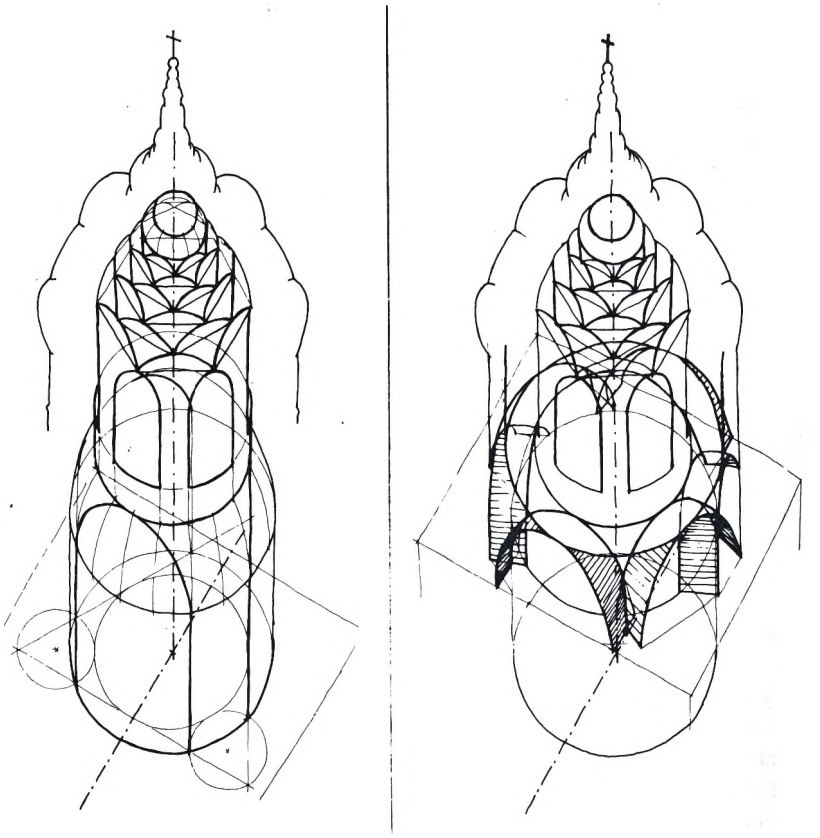


Fig. 3 - Apparent geometry (left) and structural geometry (right) of the Chapel

The fact that a great part of the weight of the tambour is still encumbering on the hollow, has turned to be a unique case in the scene of ancient buildings. Actually, the base ring of the tambour, which seems to be supported by the great marble arches and pendentives, rests upon six huge masonry arches, as it is clear from the survey of the external structures (fig.3). These arches, keeping themselves tangent to the internal ring, transfer the loads to the more external areas of the walls (fig.4), clambering over the six circular windows that pierce the surface of the vault. Due to their exceptional span (more than ten meters), the arches cross next to the supports, reproducing a motif that Guarini had already used in Sainte Anne La Royale project (1662) in Paris and that he proposed again afterwards in the San Lorenzo dome. In the latter building, he left this motif within sight of all, furthermore underlining its structural mechanism.

Having solved in this way the difficult problem of the truncated dome, Guarini leaves the forces running down vertically along the walls as far as the foundations, that he had previously reinforced.

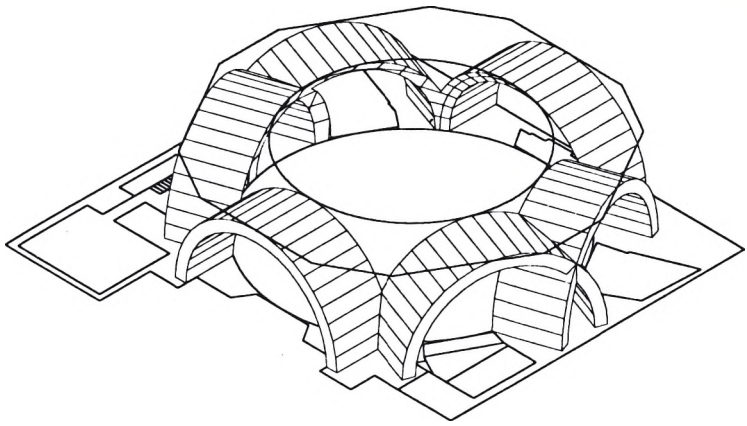


Fig. 4 - Scheme of the masonry arches supporting the truncated dome

As a consequence of the use of stone and masonry structures, Guarini have often been compared to the builders of the Gothic period. As a matter of fact, he defended the Gothic architecture of which "nobody has ever given principles and proportions, but, born without Master, in this way it has spread". Even after some decades (1736), Frezier, in his famous treaty about stereotomy, which signed the apex (and the beginning of the decline) of this science so dear to Guarini, states that Gothic style, already abolished because of its unpleasant forms, should be considered better than the modern way of building as a result of its lighter and cheaper structures. Guarini's skill is just the same, attributed to Gothic architecture by the English writer Samuel Ware (1809): "reducing each force, both lateral or vertical, to certain principal supports, and reducing all the vaults, that modern architect would build cylindrical, to domes".

3. Conclusions

The building of a virtual model which enables to understand and foresee the behaviour of a monument is an unavoidable operation in a case similar to the Holy Shroud Chapel. As a matter of fact, it is not possible to reason upon the structural scheme of the building without previously studying its morphology and building nature.

Meanwhile, whoever has the chance to study this monument must free himself from previous logical schemes and trust totally Guarini's genius and geometrical skill, as the builders of the Chapel did for fifteen years. Despite the behaviour of the military engineers of his time, the Modenese architect solved the structural and design problem trusting exclusively his genius, not minding the rules established by tradition and treatises. We can imagine that this freedom created relevant difficulties in the execution of the building works, as Guarini had to explain to the craftsmen, even skilled, absolutely particular building solutions. It should be satisfactory to remind the example of the marble covering, so

thick to be considered a wall itself, whose ashlars had to be manufactured so precisely to allow the three-dimensional framework in sight today.

The task of directing such a difficult work could have been given only to Guarini himself, who, thanks to his mastery of geometry, was able both in creating forms in the space of his mind and in describing how to realise them.

References

(1) CENTO G., *Rilievo edilizio architettonico*, Genova, 1959.
(2) DOCCI M., MAESTRI D., *Manuale di rilevamento architettonico e urbano*, Bari, 1994.
(3) FREZIER J., *La theorie et la pratique de la coupe de pierres et des bois pour le construction des voutes*, Paris, 1737.
(4) GUARINI G., *Architettura civile*, Torino, 1734.
(5) GUARINI G., *Euclides Adauctus*, Torino, 1676.
(6) GUARINI G., *Modo di misurare le fabbriche*, Torino, 1674.
(7) GUARINI G., *Trattato di fortificazione*, Torino, 1676.
(8) ISTITUTO CENTRALE DEL RESTAURO, *Carta del Restauro 1972* in BRANDI C., *Teoria del restauro*, Torino, 1977.
(9) MEEK H.A., *Guarino Guarini*, Yale, 1988.
(10) PASSANTI M., *Nel mondo magico di Guarino Guarini*, Torino, 1963
(11) ROBISON E.C., *Optics and Mathematics in the Domed Churches of Guarino Guarini*, in JSAH L:384-401, December 1991.