PLAN, EXECUTION AND RAPRESETATION OF AN ARCHITECTONIC SURVEY: THE TORRAZZO OF CREMONA, ITALY

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Abstract

The Torrazzo di Cremona results in being an example of a particularly interesting survey both for its uniqueness and for its complexity.
The survey, inserted in a static and conservation restoration project, had to provide for the shape of the tower in its external and internal parts, through profiles of the vertical development, horizontal sections at different heights, in order to construct a structural model of finished elements.
The survey data constitute a numeric model of the monument, obtained by the determination of a significant set of topographical points surveyed with different instrument, some innovations in the survey of architecture. The work done has provided the possibility of effecting a series of technological experiments both for that which concerns methods and instruments, and for the approach itself to the understanding and representation of an architecture such as the subject of this paper.

The Torrazzo, which makes up the monumental complex of the Duomo of Cremona, is made up of a tower-bell spire (12th century) on which an octagonal steeple is imposed, called "Ghirlandina," and reaching a height of approximately 113 meters (112.27m). The structure of the Roman tower is pipe shaped in masonry, inside which are found six tall rooms and barrel-vaulted covered stairs that turn round the four sides of the tower.
The problem with the survey, a problem which is set on a conservative and static restoration plan, is to be able to provide the geometrical obstruction of the tower in its internal and external parts, through profiles of the vertical development, horizontal sections at various heights, vertical sections in order to construct a structural model of finished elements.
The phases of the job are charted in:
- topographical and photogrammetrical survey: from the plan and simulation of the principle net, to the execution of the nets, the photographic settings and the survey of topographical detail points;
- restitution of the survey data through the representation of the plans, sections, and façades in orthogonal projection;
- three-dimensional construction of a solid model simplified by the subdivision in finished elements and construction of a model architectonically more detailed to the integration of the representation of the survey data.

View of the Torrazzo and the Duomo of Cremona

Three-dimensional scheme of the principle net

THE TOPOGRAPHIC SURVEY

The nets

Given the difficulty of setting the tower on a net exclusively from the ground level, seeing the particular height of the Torazzo and its location in a dense urban environment, it became necessary to develop the principle net at elevated heights, using the two civic towers of the Palazzo Comunale nearby, and various pinnacles of the 12th century Duomo of Cremona, of which the Torazzo is the bell tower.

It became evident right from the simulation phase how the visuals nevertheless inclined required a three-dimensional adjustment for the weight that even the zenith bearing assumed in the determination of the planimetric position of the setting points.

The principle net, which determines the system of coordinates to which every measurement operation is referred, is composed of 21 vertices surveyed with a total station of the first order.

Beyond the principle setting net, a secondary net within the Torazzo was done as a support for the survey of the interior. Profiles and sections need a correspondence between extrados and intrados of the walls in order to render it possible to reconstruct the thicknesses with an uncertainty of the same order of that of the indefiniteness of the bricks making up the walls. The secondary net is made up of a polygon that follows the development of the stairs on the four sides up to the impost of the Ghirlandina. Its particular geometric configuration, highly developed in the vertical direction, required a large number of connections, through the windows of the tower, to the principle external net in order to reduce the uncertainty of the position of the points.

Topographic detail points

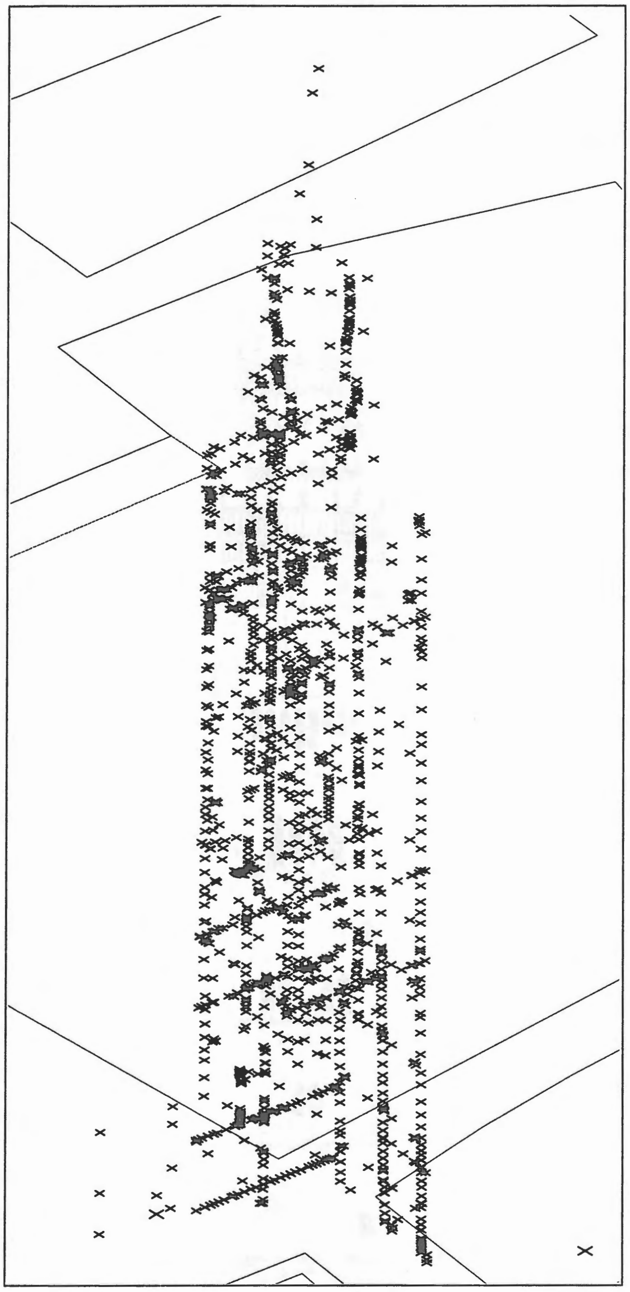
The configuration of the net and the characteristics of the object to survey have made the use of topographic instruments, which do not require reflecting prisms for the determination of the distances. The vertical profiles and the horizontal exterior of the Torazzo and the control points of the photogrammetric restitution have been surveyed topographically by polar coorinates, using TC1600 - DIOR, an instrument widely tested in the field of architectonic survey.

The DIOR allows for measurements up to distances of almost 200 meters with an accurancy of between 5 and 10 mm. The range depends on the luminosity of the environment and the reflection of the target; the intensity of the reflected line depends on the structure of the surface, the material that it is made up of, and the angle between the surface and the laser beam.

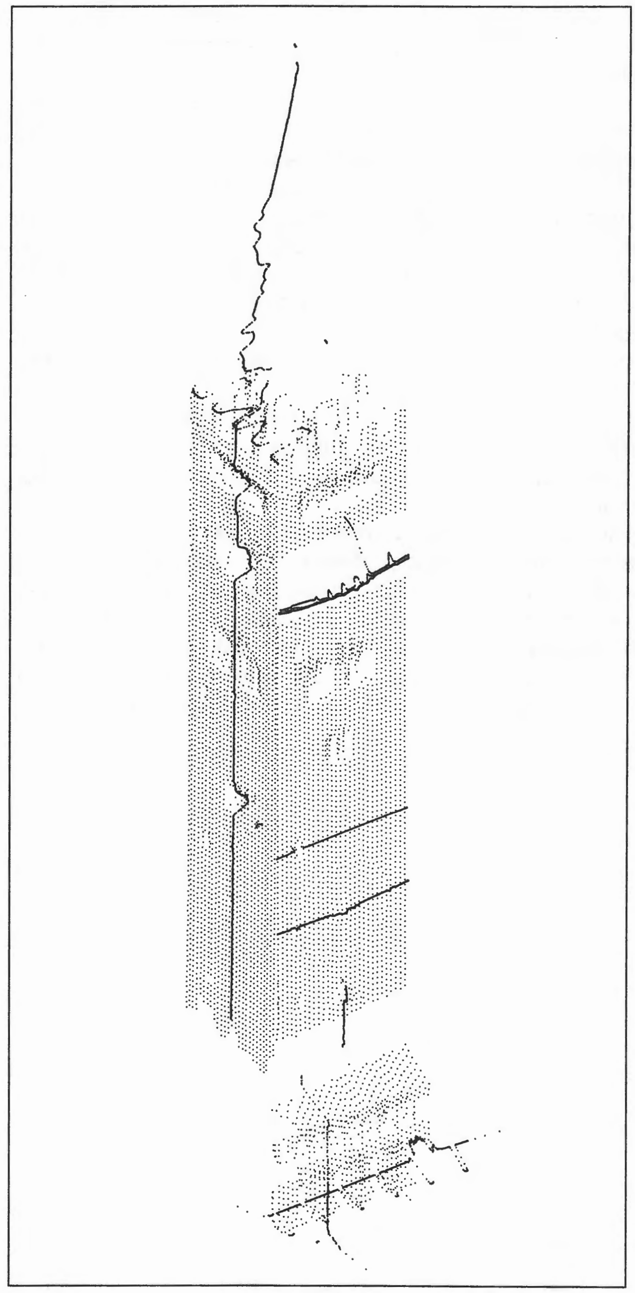
Approximately 1200 points were determined in this way: 800 for the construction of the profiles and 400 for the photogrammetric support.

The use of the Autoscanning Laser System MDL results experimental in the survey of architecture in so far as the instrument comes from the survey of quarries and mines. It is an impulse instrument that determines with polar coordinates grids of points with a predefined pass within an area. The scanning grid is fixed defining either the angle of the movement in azimuth and zenith or the horizontal and vertical distance, calculated on a cord starting from the last surveyed point.

The Autoscanning Laser System MDL, which does not have a very high precision for an architectonic survey (2-3cm), is however able to survey automatically some thousands of



Topographic detail points surveyed by TC1600-DIOR



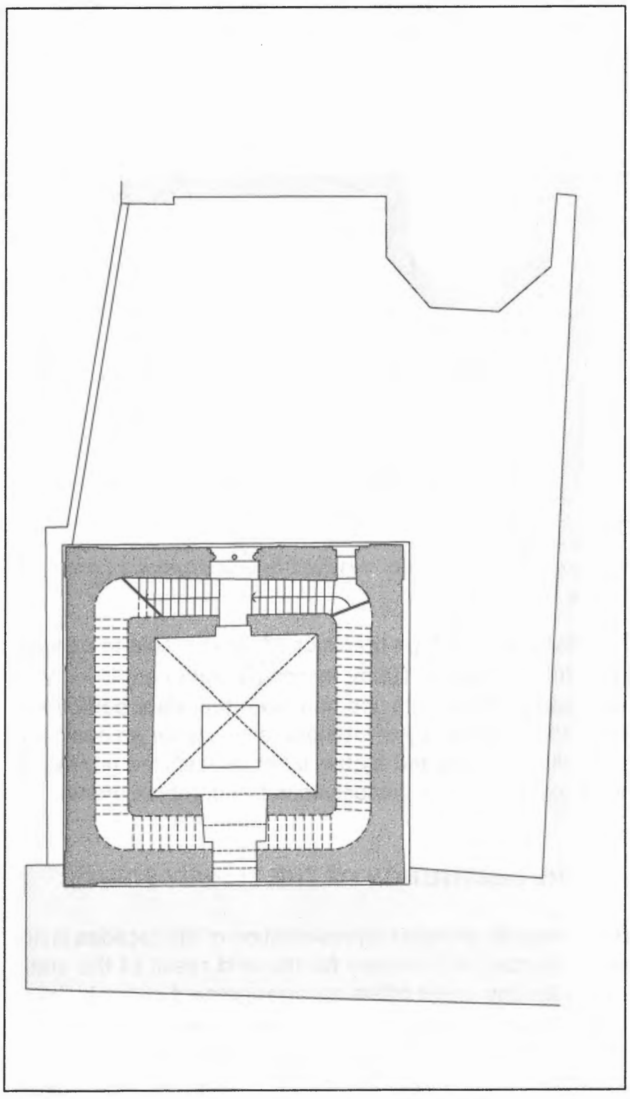
Topographic detail points surveyed by Autoscanning Laser System MDL

points in an hour of use, up to a distance of about 600m. In this case, tens of thousands of points have been surveyed: their formulation, among other things rather complex, allows for the valuation of the utility of similar instruments in the point survey of architecture. The interpolation of such a high number of data makes up for the scanty precision intrinsic to the instrument and can provide information that up till now only precise analytic photogrammetry was able to give, but as in this case, at inaccessible costs.
By interpolation of the almost 20,000 points determined, a DTM of the masonry structure of the four façades is used. Starting from the points of the secondary internal net, positioned in correspondence to the landings of the stairs, the detail points for drawing up the plans and sections and the support for the direct survey have been determined using polar coordinates, using a third type of distanceometer specific for architectonic survey, the T460+Disto by Leica. The Disto permits high precision (± 3mm), able to operate from 20cm to about 100m, in optimal light conditions and reflection surfaces. Its use has been therefore particularly adapted to the survey of interiors, allowing for an easy and fast collimation guided by the laser pointer, the geometric point construction of inaccessible and complex areas.

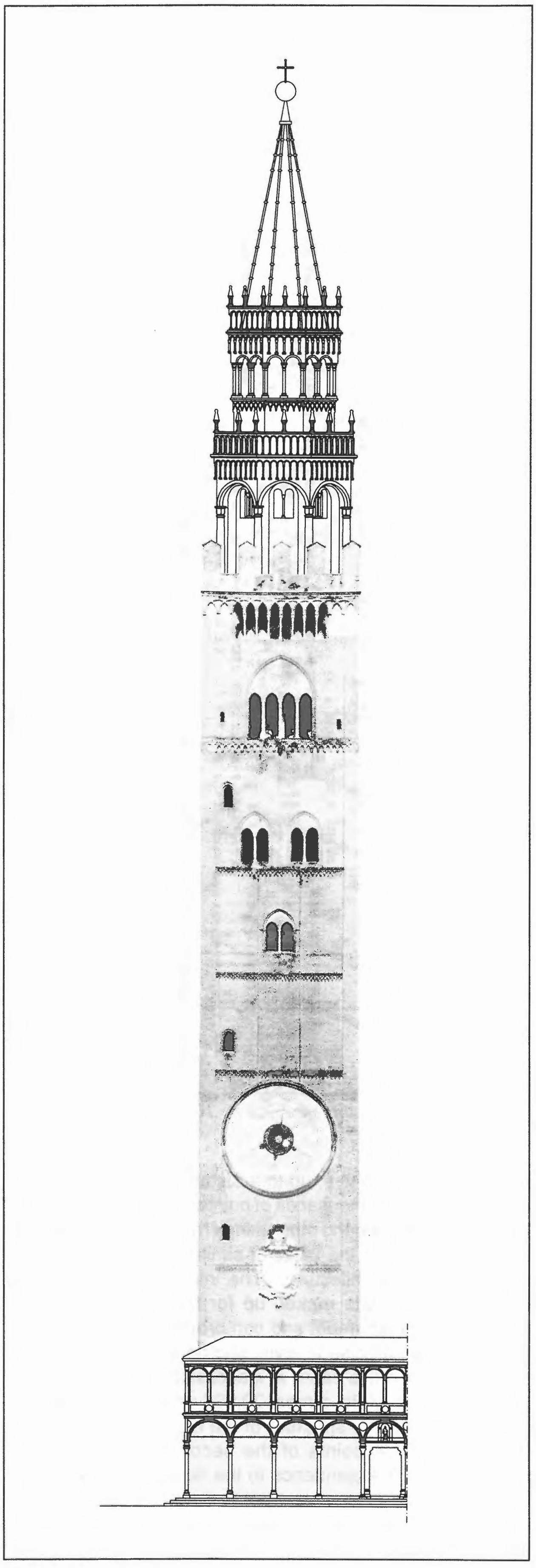
THE RESTITUTION OF THE SURVEY POINTS

The survey as an exact representation of the façades is not very important in this case for the end result of the static understanding, but it offers an arrangement of the building of the masonry right up to the corner edges.
The façades of the tower, with the exclusion of the Ghirlandina, and on the western side, of the Loggia Bertazzola, have been surveyed with the photogrammetric

method named rectification: this method consents the obtaining of a orthogonal projection representation of a plane object, or the ability to be assimilated with a good approximation of a plane, beginning with a single photographic image (in a central projection). The choice was motivated by the notable planeness of the façades of the Torazzo, also by the evident qualitative and quantitative content of the images that are obtained: discontinuity of the masonry fiber, crack summary, etc. For every façade about 8 photograms have been rectified, then mosaicated. Given the closure of the tower with the urban nucleus and its height, photos with non-metrical and semi-metrical cameras were applied, the cameras equipped with long focus objectives.
The rectification software used is the Rollei MSR, for which the input data are the coordinate control points and the photographic images, made numerical by scanning (300dpi resolution).
The raster façades have been integrated successively with external topographical profiles in vector format and with the vectorial insertion of the Ghirlandina and for the western side of the Loggia Bertazzola, both obtained by the digitalization of the existing surveys checked topographically. Plans and sections have been restituted according to a representation to the orthogonal projection tract.



Plan of the Clock room (elevation: 30m)

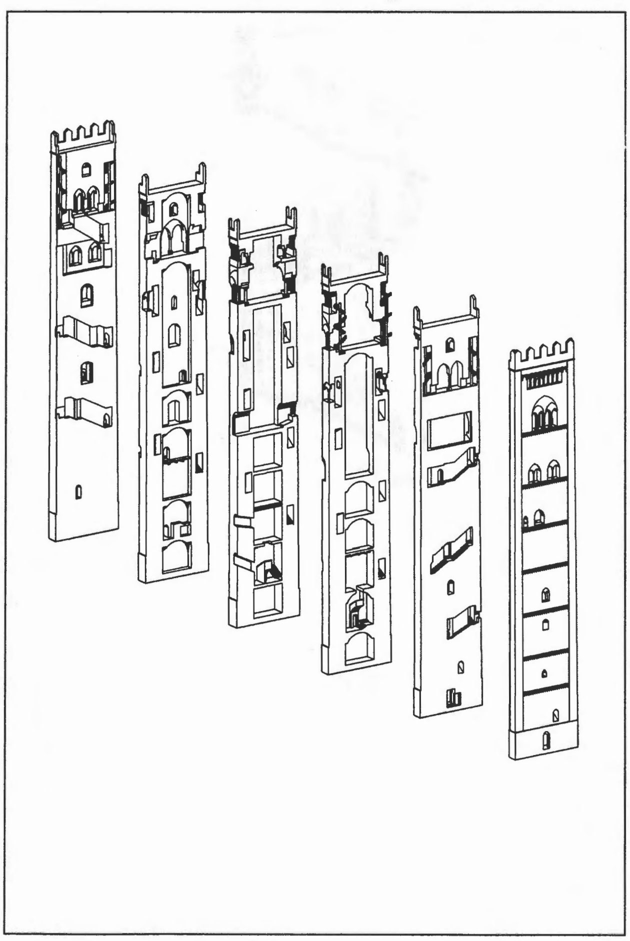


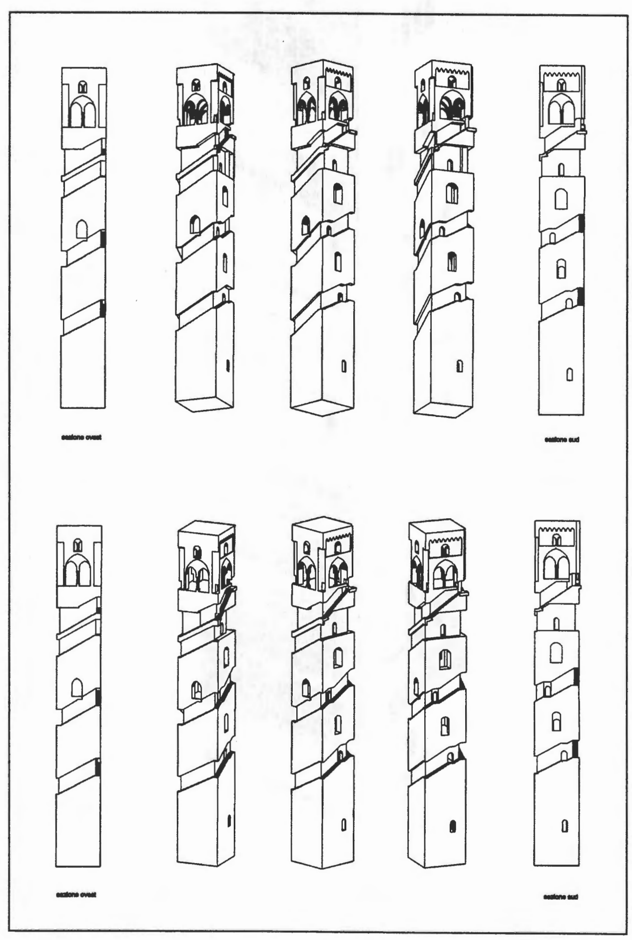
Integration raster-vector of the west façades

From the analysis of the topographically obtained horizontal and vertical profiles, an incline of the tower in the north-east direction as noted and quantified.

THE MODEL

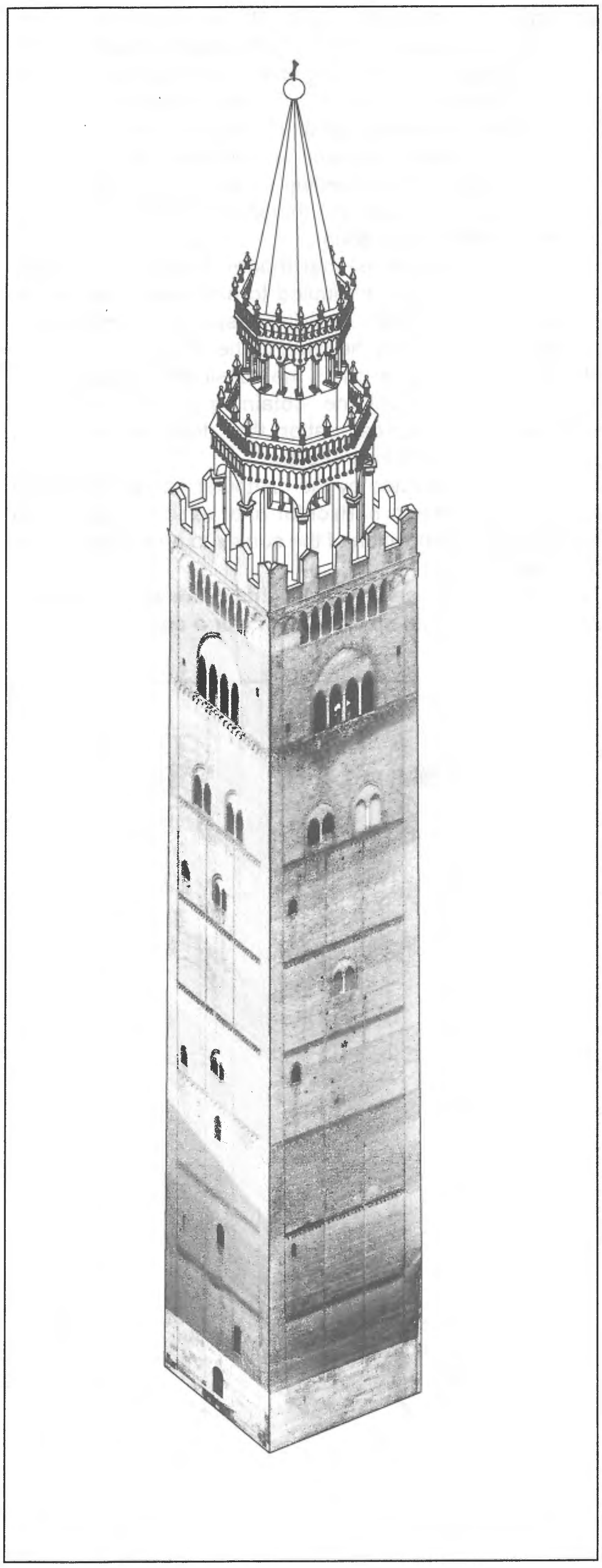
The three-dimensional modelization and the documentation of the images determine a radical change in the codes of the representation and in the ways of analyzing architecture. Today the object is reproduced three-dimensionally in a three-dimensional model and not just on the two dimensional support like in a paper design.
The ease of use of the third dimension has already modified the approach to the planning: many architects illustrate their plans with façades and assonometries and study the modifications that will affect the surrounding environment, showing their insertion into the environmental context. In this paper the applied modelization was explored and valued for surveyed architecture.
The decision to use a solid model as place for the information derived by the survey permits us to arrive at levels of understanding more and more in depth: the deepening of the information is always more up-to-date through the acquisition of ulterior details inherent to the understanding of the edifice.
In the construction of the model, the realty is simplified, in order to allow for the easy examination of the particular aspects and documentation of trustworthy responses (for example, the verification of the structure through the course of the forces.)
The modelization, in order to be valid, must on the one hand be based on a profound understanding of the work and on the other hand must be finalized to a clearly defined objective: from the geometric understanding of the manufactured article to the study of the static difficulties.
For this reason two solid models have been constructed with different content information. The first simplified in order to undergo a subdivision of the finished elements; this method allows for the control of the static comportment of complex structures beginning with the properties of certain fundamental elements such as rectangles and triangles.
The second model has been constructed with the same formal content of the preceding survey documents (plans, sections, façades), useful to the understanding of aspects otherwise difficult to explain.
Having a three-dimensional model means a complete reconstruction no longer limited to a façade or a precise plane section. It means studying in space the relationship between the parts and the parts to the whole.
The solid modelization offers the possibility to question an area, a surface, a volume, obtaining a whole series of information and representation that don't require being defined during the survey project.
The model constructed by the computer can be sectioned according to infinite horizontal and vertical planes that highlight the composition of the surveyed architecture in all of its elements.
The study is focused on highlighting the solids and the vacuums that make up the Torazzo for a complete



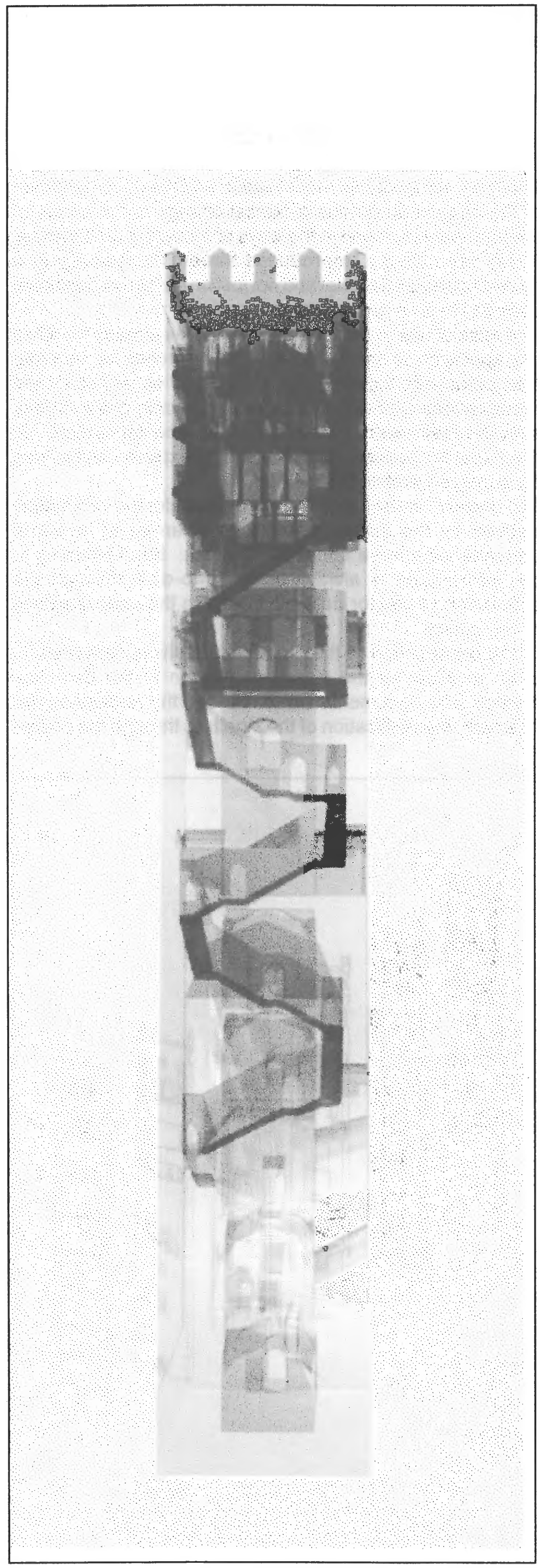


Sections of the 3D-model

understanding and visualization of its structure relying on the model, in the phases of rendering, a transparent material that permits a concurrent reading of the internal spaces and the external volumes.



3D-model with the rectified images mapping



Rendering of 3D-model with a transparent material