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RUBRICHE

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The Sala Grande of Palazzo Vecchio, Firenze: an insight into its walls by non-destructive analysis

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Figure 1. Firenze, The Sala Grande of Palazzo Vecchio.

Keywords: Palazzo Vecchio, Sala Grande, Masonry, Thermo-camera, GPR

Abastract

The Sala Grande or Salone dei Cinquecento in Palazzo Vecchio in Firenze is one of the most remarkable and larger space in an historical public palace. The Sala Grande was realized in its first configuration by Simone del Pollaiolo named il Cronaca (1495-1498) and then, from the Fifties of XVI Century, Cosimo I and his architects, among which Vasari, developed a great program of renovation of the entire Palazzo Vecchio comprising the raising of the ceiling of the Sala Grande.

The architectural structure of the Sala Grande has been never analyzed into detail; therefore no information

is available regarding the masonry equipment and its distribution on the walls, also in respect to all the changes occurred during the centuries.
Thus, a scientific interdisciplinary research group set up in order to promote and execute extensive survey of all the structural components of the Sala Grande. The Research Group considers essential to combine investigation of written and iconographic documents with a non-destructive *in situ* test of the east wall, as thermo-camera and GPR (Georadar).
In this paper, we present the results of our preliminary thermo-camera and GPR survey compared to previous data coming from diffuse unplasters in the lower east wall executed in the early 1970s and archive documents.
Thermo-camera and GPR very clearly shows the masonry structure behind the plaster, also evidencing windows and doors now covered, which appears to be coherent with what deriving from the documents.

1. Introduction

The Sala Grande of Palazzo Vecchio in Firenze, also known as "Salone dei Cinquecento", is one of the most famous pieces of architecture in the Renaissance city because of its connection to Leonardo and Michelangelo, its extraordinary dimensions, and the rich decoration realized by Giorgio Vasari (fig. 1). Such great hall has always aroused the interest of experts and of the general public; nonetheless, no thorough scientific publication provides general information about the constructional features of the walls and the transformation that these have undergone through the centuries, as the Sala has been subject to many changes, following the political and institutional evolution of the government of Florence. There is also a lack of sure data about the disposition of doors and windows, the original horizontal and vertical connections of the Sala, and their evolution through the centuries. This is extremely relevant in light of a full grasp of the structure, which cannot be separated from the configuration of Palazzo Vecchio as a whole.
This paper presents the results of diagnostic surveys, carried out at the end of 2016, as part of scientific interdisciplinary studies on the Sala Grande of Palazzo Vecchio. To this aim, a research group set up in order to improve the knowledge of the architectural structure and changes occurred, providing an important contribution to the investigation of the decorative apparatus. The specific reports of the researches are collected, and now published, in FERRETTI *et al.* 2019.

2. The Sala Grande: history and evolution

The Sala Grande has a trapezoidal plan (circa 23 by 50 meters); it was built between 1494 and 1498 by a group of Florentine architects-carpenters: Simone del Pollaiolo also known as il Cronaca, Antonio da Sangallo the Elder, Giuliano da Sangallo and Baccio d'Agnolo. An extraordinary structure of wooden roof trusses with a span of 22 meters supported the mighty roofing; at the same time, a vast wooden lacunar roofing of over 1000 square meters was attached to the structure. There were five arch windows on the long walls – three on the west side, and two on the east side – and three windows on each short wall[1].
The Sala was built in a partially undeveloped area of the huge medieval building, thus connecting the two different units of Palazzo Vecchio. Since the foundation of the palace at the end of the 13th century, this space had partly been left unoccupied, thus showing an incoherent architecture. During the first years after the realization of the structure, Leonardo da Vinci and Michelangelo were invited by the Florentine government to decorate the long walls of the hall (1503-1506) with scenes from the *Battle of Anghiari* and the *Battle of Cascina* respectively. However, the project was never finished: Leonardo prepared the cartoon for the fresco and started working on the wall, but the experimental technique employed turned out to be a failure. Michelangelo, for his part, only prepared the cartoon, but never started to work on the fresco. Between 1563 and 1574 the Sala Grande underwent a huge transformation thanks to Giorgio Vasari: the walls were raised 7 meters, the huge roof trusses were disassembled and reassembled again, and a new lacunar roofing was attached to the structure. This time it was decorated by precious paintings fixed to the structure by an ingenious system devised by Vasari himself. The east and west walls were partially covered with bricks so as to provide space for Vasari's frescoes, framed by monumental frames in pietra serena. The short walls were partially regularized, thus transforming the original trapezoidal plan. Vasari's works also affected the number and type of windows both on the long walls (where these were eliminated) and the short ones. In addition, the entrances were modified (both in dimension and position), and the outer corridors and entrance staircases were adjusted in position and morphology[2]. Later, Sala Grande underwent modifications and restorations, first in 1860s and then in 1930s. Those interventions partially modified the architectural structure, especially in south-eastern part[3].

3. Fundamental problems and aims

Leonardo's part in the history of the Sala Grande raised an almost greedy interest for this piece of architecture, which proved even dangerous for the integrity of the structure. As a matter of fact, from the 1960s to 2012 expensive research was carried out in order to locate the supposed remains of Leonardo's fresco, sometimes on the west wall, sometimes on the east one. The fact that Vasari's frescoes were realized on a layer of bricks set against

1 For historiographical investigation on the hall's original configuration see WILDE 1944; MICHELI 1971; ALLEGRI, CECCHI 1980; NEWTON, SPENCER 1982.
2 On Vasari's renovation program see CONFORTI 1993 and FUNIS 2019.
3 A synthesis and cronology of Sala Grande's trasformations, among which the most recent ones, are published in FERRETTI 2019.

the original wall led some to believe in the existence of a cavity that would provide enough space to protect the remains of Leonardo's work. Nearly fifty years of research did not pay off, and the only effect was to endanger the preservation of Vasari's frescoes. Furthermore, the method employed has proven faulty: the structure of the Sala has not been inspected as a whole, and the relation with its pre-existent features has been neglected. There is no reference in the literature to the section of the long walls that might shed light on the masonry structure, or on the relationship between Vasari's brick covering and the pre-existent masonry[4].

All these elements have been thoroughly studied thanks to a collective enterprise coordinated by the University of Florence together with the Ufficio della Fabbrica di Palazzo Vecchio (2014-2017) and the Superintendency of Archeology for Tuscany. The research was carried out both in archives and through a non-destructive analysis of the walls, the outcomes of which we would gladly share. As a matter of fact, knowing the exact position of the doors and windows can give a decisive contribution to the history of the Sala Grande and the issue about the location of Leonardo's and Michelangelo's lost paintings. This way one might also prevent Vasari's frescoes from being put in danger by unreasonable and scientifically unreliable research stirred up by facile enthusiasm surrounding Leonardo and his works.

4. Methodology

In the field of Cultural Heritage Buildings (CHBs), main aspects of the knowledge of the manufact are constructional features, mechanical properties of the materials and also changes occurred due to human actions or environmental impacts. Extensive studies on CHBs employ non-destructive tests (NDT) as fundamental tools for the analysis of structural details and qualitative judgment of constructional materials. Indeed, NDT techniques offer the benefits of wide application and indirect methods; therefore, integrated protocols for using destructive tests, semi-destructive and non-destructive tests, allow to limit invasive surveys obtaining reliable results.

Technical Standards for Construction (NTC) 2008-2018[5] provide for the use of NDT in combination with semi-destructive and destructive techniques, including them in the guidelines for the seismic vulnerability assessment of existing buildings, among which the historic ones (Ch. 8). Concerning the protected architectural heritage, "Guidelines for the evaluation and reduction of seismic risk of cultural heritage - alignment with the New Technical Standards for Construction" (MIBACT, 2011)[6] present further references, applicable in general to CHBs.

The Knowledge path – aimed at supporting the risk evaluation and/or project of intervention – provides an in-depth analysis, that comprises historical-critical research, geometrical and structural survey, mechanical properties' characterization. About this last point, the norm specifies that calibration of NDT techniques (infrared thermography, ground penetrating radar, ultrasonic testing) and destructive ones, can help to limit invasive methods for the measurement of mechanical parameters (Ch. 4).

Therefore, developing an interdisciplinary study of the Sala Grande, the Research Group consider essential to combine investigation of written and iconographic documents with a non-destructive *in situ* test of the east wall, as thermo-camera and GPR (Georadar) surveys.

4.1. GPR survey

In October 2016 an experimental GPR inspection of several sections of the east wall was carried out as part of the scientific collaboration between DST and IDS Georadar S.R.L. The inspection aimed at the following:

1. To locate and provide spatial reference for the area under inspection;
2. To position the GPR grid reference for collecting data;
3. To calibrate the equipment (one-off);
4. To acquire scan lines in vertical directions;
5. To acquire scan lines in horizontal directions.

In particular, four GPR surveys were carried out using a unipolar 16-bit TRHF 2 channel antenna, central antenna frequency of 2 GHz and pulse frequency of 400 KHz. The scan lines were obtained with a vertical and horizontal lines grid set at a distance of 5 cm, on a surface of 2x1 meters. Data were collected using IDS' K2 FastWave acquisition software.

The processing of data allowed to create a 3D tomography of the parts of walls analysed; the data collected were then processed with IDS' GRED HD for 3D and tomographic rendering by developing the following workflow:

1. Filtering data;
2. Choosing the pace of execution and calculation of timeslices according to the target under analysis;
3. Two-dimensional plan and section rendering of timeslices;
4. Selecting relevant timeslices.

In summary, the analysis of GPR data led to the conclusion that the sections of wall inspected display the following types of masonry: regular brick walls and walls of bricks and stones.

4.2. Thermal analysis

Thermal analysis of the east wall of the Sala Grande was carried out by means of a thermographic camera FLIR

4 For previous surveys on the east wall's masonry structure see Pieraccini *et al.* 2005; Pieraccini *et al.* 2006; Pieraccini 2008. See also Seracini 2011, pp. 193-194: no detailed images are available except the thermal image of the entire east wall on the front and back book covers.

5 Technical Standards for Construction, NTC 2008-2018 (M.D. 14/01/2008 updated with M.D. 17/01/2018) and their respective Instructions for application.

6 Guidelines for the evaluation and reduction of seismic risk of cultural heritage - alignment with the New Technical Standards for Construction (DPCM 9/02/2011).

Figure 2. GIS project with thermal images showing masonry structure and the existing infilled openings.

Figure 3. GIS project with Micheli's drawing (1971) and sections of the wall inspected with GPR survey.

SC660, which measures temperature in a range from -40 °C to +1500 °C, with precision of ±1 °C or ±1%, and a resolution of 3.2 Megapixel.

The thermal monitoring was carried out between the end of October and November 2016; the cold temperatures of the Sala, and the wall that was still releasing the heat accumulated during summer facilitated the analysis of the masonry structure. In particular, the section of wall under the frame of the frescoes was methodically inspected; the relative thermal images were loaded in a GIS system so as to provide direct comparison with other data surveyed (fig. 2).

4.3. GIS implementation

A GIS project of the east wall of the Sala Grande was developed for managing the data collected so far. Geographic Information Systems (GIS) are by now renowned for their potentialities, which have been widely proven. Unlike other systems, GIS allow to handle a wider set of spatial data and the respective attribute data, integrating the two within a single software environment. The advantages of this process can be discerned especially in projects involving a vast number of spatial and chronological analyses, like the different construction stages of masonry works.

Nowadays, GIS approach is one of the main systems in documentation and management of CHBs' data. The core principle - linking data to a territorial area - is basically applied to the characterization of architectonical surface, by georeferencing a wide typology of information (among which results of diagnostic investigations), in order to obtain a multithematic informative model. Applications of GIS platforms are reported in scientific literature, and more recently these systems have been extended to 3D geometric models[7].

In this case, the GIS project was developed with ArcInfo® (ESRI - Environmental Systems Research Institute, Inc.), a multi-platform GIS software to realize and handle geographic reference databases. The form and position of geographic features can thus be described following primitives of the vector data model (points, lines or polygons) that are checked against topology rules. Furthermore, georeferenced raster data (like images or photographs) can be employed as background.

In addition, by employing the functions to define the behaviour of geographic features in spatial relationship –

7 An example of GIS application is SICaR Web, a shared platform for the management of CH, officially adopted in 2012 by Ministry of Cultural Heritage and Activities (see more on http://www.sicar.beniculturali.it). An example of 3D-GIS database, is the documentation project of Insula V 1 in Pompei (DELL'UNTO *et al.* 2015, CAMPANARO *et al.* 2016).

Figure 4. Detail of the masonry emergencies and the existing infilled openings included in Micheli's drawing (Fototeca Musei Comunali, raccoglitore 8 cod 81043).

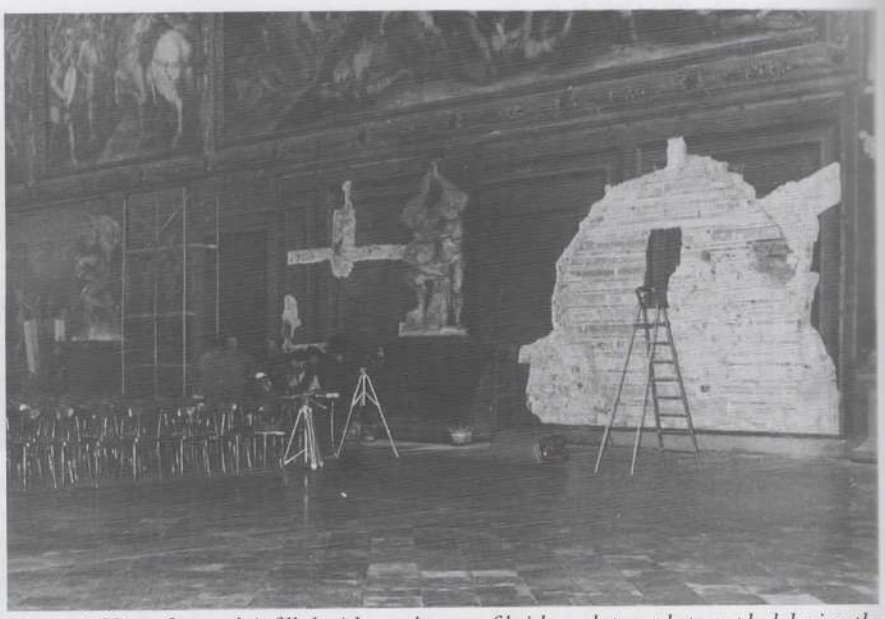

Figure 5. View of an arch infilled with regular sets of bricks and stone photographed during the removal of the plasterwork between 1970 and 1971 (Fototeca Musei Comunali, raccoglitore 8 cod 81080).

or topology – it is possible to perform the following tasks:

- To combine different databases through overlay operations (or topological combination);
- To generate buffer (for instance, minimum distance);
- To perform queries about geographical data.

In the case of the east wall of the Sala Grande, the geographic reference consists of the view of the same wall in a CAD 1:1 scale rendition that includes illustrations of Vasari's three frescoes. Subsequently, a drawing by architect Piero Micheli was georeferenced on the preliminary survey referring to the removal of the plasterwork, which took place between 1970 and 1971: the drawing shows masonry emergencies and the existing infilled openings (figg. 3-5).

5. Final remarks

According to the analyses and observations carried out, one may infer that the analysed sections of the east wall in the Sala Grande are made up as follows:

- Below the frame of the fresco in the northern part, the masonry is around 90 cm thick (1½ florentine arm) and was built using bricks arranged organically on a mortar bed (ca. 1 cm). One may also observe a former door infilled with regular sets of bricks and mortar. As shown by Micheli's drawing, brick structures can be confirmed as part of the masonry;
- Below the frame of the fresco in the southern part, the masonry is around 90 cm thick (1½ florentine arm) and was built using bricks and stone, with mortar and empty spaces. At the bottom south end of the wall there is an arch infilled with regular sets of bricks and stone combined with mortar.

The two kinds of masonry are similar to other examples of the time all around Florence. It was also possible to relate the data collected through GPR and thermographic investigation to the photographs documenting the removal in 1975 of the plasterwork in the lower part of the east wall that was covered again in plaster later on. The photographs were scanned and included in the GIS project according to their original arrangement. It was therefore possible to compare the results of our partial investigations with broader chunks of the same masonry without plasterwork (fig. 6).

The findings are no doubt satisfactory and promising: as demonstrated by the photographs collected after the removal of the plasterwork, the results obtained through non-destructive testing for the chunks examined are perfectly aligned with the corresponding masonry structure.

Moreover, the presented paper contributes to the discussion about knowledge and preservation of CHBs, by setting up an in-depth and interdisciplinary cognitive framework of the manufact. Our research thus demonstrates that positive and useful results in the field of preservation of cultural heritage can be achieved crossing historical data and evidences shown by a thorough, indirect, non-invasive study of materials.

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Figure 6. GIS implementation of photographs documenting the removal of the plasterwork in 1975.

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