About the Structural Restoration of the S. Domenico's Monastery in Naples

O. Corbi and M. Candela

Abstract— In the paper one focuses on the need of coupling the building site experience with a deep theoretical knowledge, which is of primary importance especially when dealing with masonry fabrics, and in particular with constructions with an historical or monumental relevance. The case of the monumental complex of S. Domenico Maggiore in the Campania Region is focused on, by presenting some intervention strategy adopted for increasing the seismic vulnerability of the main Chapter Hall.

Keywords— Masonry constructions, Monumental Heritage, Preservation, Refurbishment, in-situ investigations, Study case.

I. Introduction

The building site experience is of primary interest for examining some characteristic features of structural consolidation interventions on buildings of monumental and historic significance since it represents an important verification of the stage of structural design, in particular when dealing with interventions on masonry constructions.

An interesting examination of some of the structural solutions that one can take in relation to the constraints imposed by the specific characteristics of the constructions to be preserved.

Generally speaking, particular significance acquires the understanding of the behavior of masonry material in relation to its condition of damage and the ability to relate it to the causes of the damage.

Analogously it appears to be of fundamental interest the ability to distinguish what can be accounted to a purely physiological behavior mode of the material and of the structure, which tend to absorb the internal stresses through the redistribution of balances within the building masses with the development and read of fractures and cracks, from what is, on the contrary, to be considered pathological, and which must, therefore, be the starting point for any planning and design for consolidation purposes.

In this context, the structural interventions of recovery and consolidation of monumental constructions should be aimed at the acquisition of a number of selected data for the proper analysis of the operating conditions of the masonry structures under examination.

As regards the modeling stage, the structure may be modeled under the hypothesis of material Non- resistant to Tension (NT). To this regard, a wide bibliography may be referred to, developed by the research group [1]-[16].

The Limit Analysis may be then successfully employed in order to identify, through the fundamental collapse theorems for NT material, the load-bearing capacity of these structures; the acquisition of proper tools for the set up and conception of the most appropriated consolidation measures [17]-[20] or most advanced technologies and approaches [21]- [31] is, then, to be related to the on-site experiences, investigations and data in order to achieve the best results. This also in the light of future dynamic load, that may be hard to be forecasted in their properties [32]-[33].

In the following, a case study is referred to, located in the Neapolitan area, i.e. the monumental complex of San Domenico Maggiore.

II. The monumental complex of San Domenico Maggiore in Naples and the Chapter Hall

II.1. The S. Domenico Monastery

As most of the monumental constructions in the historical ancient centre of Naples, the monastery of San Domenico Maggiore is the results of centuries of stratification.

The monastery (Fig.1) forms with the S.Domenico church (Fg.2) a complex of huge proportions, dating back in its original apparatus to 1227 when a group of Dominicans were sent in Naples.

From 1272 to 1274 Thomas Aquinas lived in the monastery.

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The first restoration works aimed at the renovation of the convent started in the last decades of the XIII century.

The original body of the monastery during centuries grew up very significantly with a number of progressive extensions, turning it into an insula of considerable dimensions within the city of Naples.

These extensions were particularly contributed during the XVII century when large works were executed starting from 1669 by the prior Ruffo di Bagnara, deeply contributing to the development of the complex.

Works preserved some special areas with high historical value , such as the St Thomas's cell.

After the works' ending, the complex was characterized by some main parts: the dormitories, arranged around the garden area, and, at the first floor, the Refectory, the Chapter Hall and the Library.

During centuries until nowadays, the complex suffered a number of further transformations mainly related to changes in the final use of the different spaces of the monastery.

Different usage zones included, in recent times, a zone still used by Dominicans, as well as a gym, a school, and an entire large part hosting the classrooms of the former Court of Assizes.

Mainly the restoration works executed in the last years interested this latter part together with the security cells.

The restoration was basically aimed at recovering and restoring the original architectural apparatus and spatial characteristics.

II.2. The restoration interventions of the S.Domenico's monastery

The restoration interventions recently concluded interested a large parts of the original fabric.

In particular, restoring works interested either the decorative parts and artistic pieces, including the original cycles of paintings, the late seventeenth century stucco , the decorated St. Thomas's cell and numerous pieces of furniture, or the structural members, as well as the architectonic organization of the spaces.

Fig.1 - The S. Domenico Monastery.

Fig.2 - The S. Domenico Church.

The works were executed on an area of approximately 7000 square meters by the Superintendence for Architectural Heritage of Naples.

Starting from the first beginning on 2000 under the program Polis - Musea, with the financial support of the European Community, lasting two years, and continuing up to the conclusion on 2011 under the financial support of the Ministry of Heritage and Culture and the Campania Region, only recently the majestic complex was made accessible to visitors.

II.3. The Chapter Hall

Significant restoration works have been executed on a large part of the monumental complex of San Domenico Maggiore in Naples.

In particular, in the following one focuses on the area of the old Chapter Hall, where particular works were realized for seismic vulnerability reduction.

In the covering of this huge hall, the activation of unilateral hinges occurred inside its vaulted structure.

The phenomenon was initially attributed to the tectonic events that occurred in the Neapolitan region during 80s; further extensive researches were then developed which demonstrated that the damage was to be referred to pre-existing phenomena of instability of the masonry panels.

The chapter hall perfectly fits, as regards to its size and role, the insula of San Domenico Maggiore in Naples, which constitutes the largest building complex of the historical centre of Naples, characterized by the presence of three cloisters merged following a centuries-old compositional and evolutionary layering.(see Fig. 3).

The monumental resistant organism of the complex under consideration is characterized by long corridors, wide halls, sequences of slender piles and columns, which, along with the present voids and discontinuities, mark the significant volumetric ratios characterizing the construction.

First of all, a large and comprehensive campaign of tests, also of direct type, were executed aimed to identify in a systematic way the walls' intersections, their resistant thicknesses, often very different from their geometric shapes.

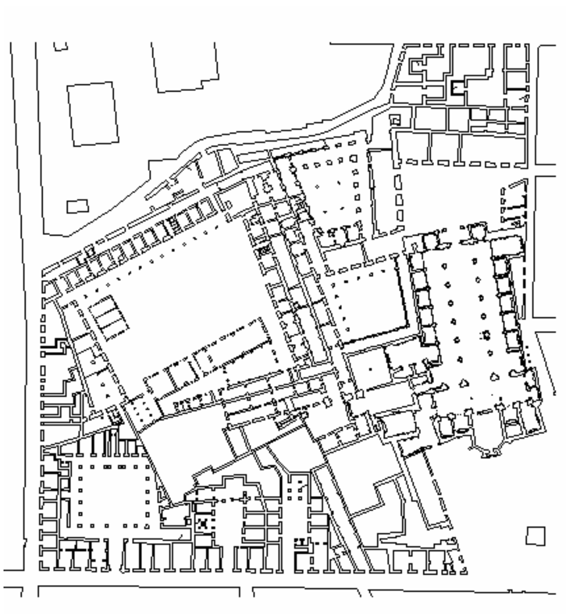

Fig. 3 - The insula of the historical centre of Naples concerning the complex of San Domenico Maggiore.

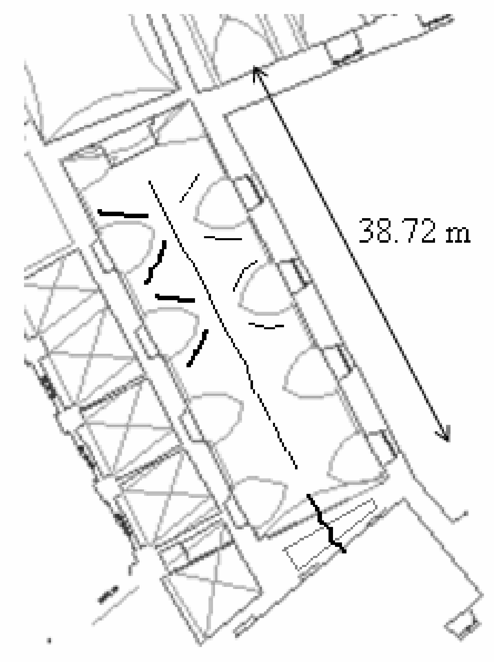

Fig. 4 - Details of the Chapter Hall with crack distribution.

Fig. 5 - The Chapter Hall plan with the main crack in the key; one may notice the resistant panels facing the main cloister with a free length of about 40 m.

Fig. 6 - The Chapter Hall consolidated vault with the metallic tie-rods during the restoration works.

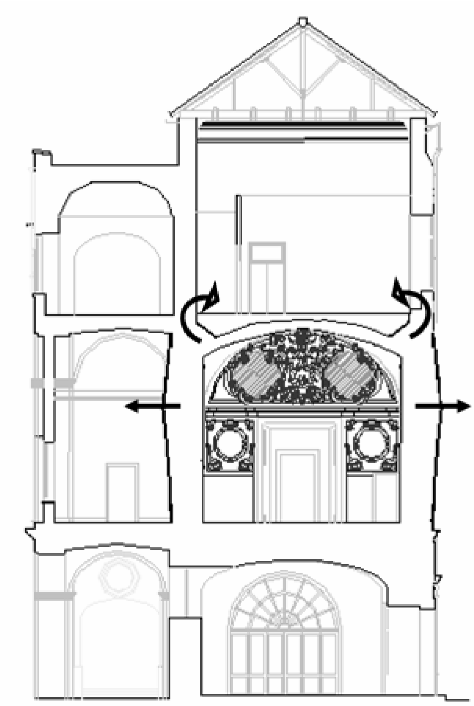

Fig. 7 - The S. Domenico Maggiore Chapter Hall – the crack pattern with the overexpansion of the wall panels and kinematic mechanism of the vault.

In the meanwhile a cataloguing of the masonry textures of the structural members and a archive of the vaults' composition, typically realized in tuff, was done, in order to capture and represent clearly the multiplicity and variety of aspects which characterise the monumental construction both under the static and historical profile.

II.2. The Chapter Hall: diagnostic features and monitoring frameworks

The representation of the crack pattern of the chapter hall is shown in Figs 4 and 5.

One traced one of the causes of instability in the absence, for over 38 mt, of transverse diaphragms, resulting in noticeable deformations of the longitudinal walls.

Moreover, the presence, at the intermediate level, of a huge barrel-vault with lunettes, constitutes, with its pushing action, a further cause of the masonry overexpansion that can be noticed in the wall, which is evident in the cross-section of Fig. 7.

From Fig. 5 the crack distributions are detected with fractures localized along the lunettes of the barrel vaults; those appear rigidly lifted up, especially on the side that faces the cloister; one may notice a large crack as well as present along the South side of the chapter hall.

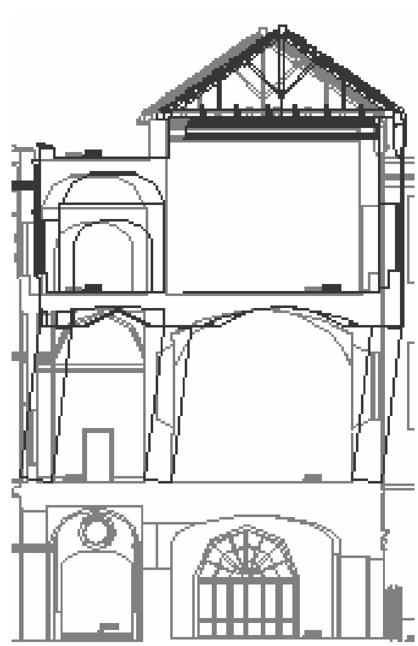

Fig. 8 - The S. Domenico Maggiore Chapter Hall – The damage mechanism activated by a collapse multiplier equal to $\lambda = 0.04$.

II.3. The intervention strategy

The constraints relevant to the monumental construction have resulted in the simple introduction of metal tie systems at the inter-plane quotas, placed inside the floor, although it was also required the construction of transverse diaphragms.

The collapse multiplier calculated for the resistant structural scheme without tie-rods in Fig. 8 is rather modest and equal to $\lambda = 0.04$, confirming the seismic vulnerability of the system. In order to increase the load-bearing capacity of structural system, were then inserted some rods arranged in the plane in a way not aligned with the resistant frames, as shown in Fig.9.

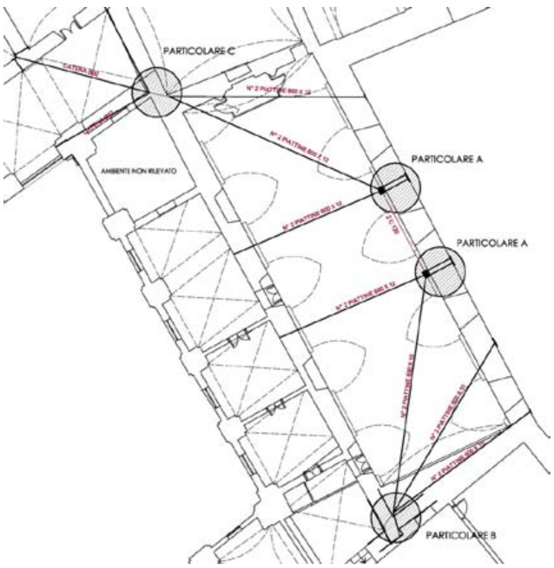

Fig. 9 -: Non-aligned brace-system in the Chapter Hall

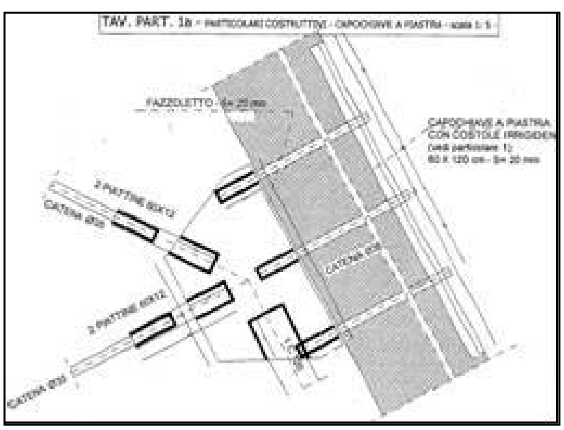

Fig. 10 - Detail of the anchoring plates.

Particular attention was paid to follow the construction work, in order to prevent that small defects, such as excesses of mortar in the anchoring plates, reduce the effectiveness of the intervention; its tensioning was verified by means of shooting tests with values proportional to the maximum ones predictable under operation service of up to 43,000 dN, which demanded the design of special plates with size of 60 x 120 cm and with three bolts (see Figs 10 and 11).

Fig. 11 - Detail of the anchoring plates.

II.4.Theoretical knowledge and on-site experience

The need of preserving the monumental and historical heritage by refurbishment techniques that are as less invasive as possible, also as regards to the impact on the fabric in the respect of the architectural and historical apparatus is really felt by the scientific community as well as in the professional practice.

Nevertheless, often traditional restoration techniques should preferred which may be more invasive than provisions based on the adoption of new technologies and materials such as composites.

The building site experience is of central importance at the stage when the intervention actions are to be planned and undertaken.

Actually, at this stage, besides the on-site visual inspections, the necessary tests and investigations may be executed for collecting data about the real status of the masonry masses and composition, level of damage, distribution of cracks, and actions may be undertaken by means of monitoring systems in order to give evaluations about the rate of development of possible still in-progress evolutionary phenomena, or to deepen the understanding of the complex interactions between localized and overall diseases of the fabric.

The collected data should represent the necessary premise for properly modelling the structure and its real damage status in the light of the theoretical knowledge, thus allowing to refer to structural models that are as much as possible reliable in capturing the behaviour of the construction under examination.

This issue is of central importance when intervening on historical fabrics, since errors that may derive from a lack of theoretical knowledge, or from poor or not enough accurate data acquired on site, from wrong convictions or misunderstanding of occurred or ongoing phenomena, may lead to misleading conclusions and, consequently, to wrong choices as regards the intervention strategy, which may also result in a further damage to the construction that may occur at once or during the life-cycle of the fabric, in the form of an evolutionary phenomenon or after an exceptional event.

In this context the case of the refurbishment, by the insertion of set of non-aligned tie-rods in the Chapter Hall of the monumental complex of S. Domenico Maggiore in Napoli, is focused on.

The intervention, which may be considered to be of traditional type, has been conceived in agreement with the above referred to issue, and has demonstrated to be respectful of the historic fabric and effective during time, as a proof of its right conception.

III. Conclusion

The paper focuses on the strict relationships among theoretical knowledge, professional/technical practice and on-site experience that should always inspire any structural restoration intervention, especially in the case of constructions with high monumental and historical value.

One refers to the restoration works executed by Superintendence for Architectural Heritage of Naples on the S.Domenico's monastery.

The works, that took almost a decade and were recently concluded allowing the re-opening in 2012 of the complex to visitors, were funded by the European Community, the Ministry of Heritage and Culture and the Campania Region, involving highly qualified consultants and technicians.

The study case of a refurbishment intervention realized in the Chapter Hall of the monumental complex of S. Domenico Maggiore in Napoli is focused on.

In this case, all of the above mentioned conditions are met, and the contribution of the on-site experience for inspiring the most proper of restoration strategies is evident as a complementary and necessary tool to be coupled to the deep theoretical knowledge of the structure.

Acknowledgement

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