STRUCTURAL ISSUES OF MONUMENTAL BUILDINGS IN STRATIFIED HISTORICAL CITIES: THE STUDY CASE OF ATENASIO PALACE IN TAORMINA, SICILY-ITALY

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Abstract
The historic cities often are characterized not only by presence of architectonic and monumental heritage of great artistic value, but also for presence of a long constructive history of site, on which it stands; this is certainly an element of great interest to scholars of historical artistic disciplines, but often this element is accompanied by on-setting of structural conservation problems of architecture. Presence of a stratified archaeological heritage in fact does not always communicate properly with above architectures, producing each other threats to their conservation. For example, most of foundation structural instability in monumental buildings and in archaeological centres find their genesis in presence of differential foundations, especially in seismic area, which had to adapt to site, where there were already existing structures in ruin conditions, creating discrepancies plans and sometimes structural damages, which are difficult to diagnose and often cannot have solution with interventions adequately respectful of archaeological remains, on which they arise. This is the case of Atenasio Palace in Taormina, one of most ancient and interesting Sicilian Greek city, thanks its artistic and landscape value. This Palace, built in the eighteenth century, is located in part on archaeological remains of old Greek Naumachie and partly on new foundations; this condition determined, since construction of building, a serious foundation instability, putting it in a worrying condition of structural conservation. The research, here proposed, describes a study, which, through a dense modelling analysis and a planned and only partially realized diagnostic investigation, determined a reliable diagnosis of this not easy problem of soil-structure interaction, without producing alteration to archaeological ruins and to Atenasio Palace.

INTRODUCTION
Taormina is one of the oldest Greek colonies in Sicily and, how a lot of them, is located in an elevated position with a direct view on sea, in order to be suitable both to defense and trade. The city was afterwards conquered by Romans, who made a lot of and improvements, above all infrastructures, including a Naumachie and a complicated system to bring water into the city, which was gradually expanding. The Taormina urban development therefore had always to take into account two elements: the rationalization of available space and the water supply; the urban history and stratigraphy of this city shows good these limits and this conflict, being it today the result of transformations, overlaps
and stratifications, which makes it a unicum with great historical and architectonic value. Therefore, the constructive and transformative events of historic buildings in this town are expression of this conflict and of the interesting solutions applied to overcome it. Among them there is Palazzo Atenasio, which was built in the centre of ancient Greek site, along the main street, now called Umberto Avenue, defined in the Middle Ages, but set on the ancient Greek scheme. A large part of the existing today buildings pertain to the eighteenth century, but were built on the ruins of the Greek-Roman city, so lots of them serve, especially in the foundations, ancient and valuable structures and architectural ruins. One of the largest of these archaeological remains is called Naumachie, which, in ancient Greek, means naval battle, because a local tradition narrated that it was place of shows and performances of naval battles. Indeed it was a huge terraced structure, consisting of fountains, a large nymphaeum and gardens. Of this impressive architecture today we have only the downstream elevation, more than a hundred meters long and built during the Roman domination; instead the upstream portions are incorporated in lots of the overlooking Umberto Avenue buildings.

Fig. 1 – Sicily, Taormina and Atenasio Palace
ANAMNESIS

Palazzo Atenasio is a vast, two-storey building, built in the eighteenth century, but expanded and modified in the twentieth century; the palace is known for having hosted in 1922 H.D. Laurence, who describes this stay in his famous letters (Laurence, H.D. (1978) Letters 1921-1924, Cambridge: Cambridge editions). The building now has numerous recent alterations, introduced in order to adapt it for tourist reuse (shops and restaurants on the ground floor, stores and offices on the first floor), although it preserve its structural and aesthetic peculiarities. However, the implementation of these new buildings led to a change of its planimetric arrangement, that was originally rectangular and now it has the shape of an irregular T. Also the oldest parts of the Palace are built on foundations, which are coincident with the area where the Naumachie stood, while the parts, made in the twentieth century, are founded on inconsistent soil and this situation produces a different structural behaviour, which can represent a relevant vulnerability for a city that has high seismic risk, considering that Taormina is located not far from Etna, one of the most active volcanoes in Europe, and on a system of particularly complicated tectonic faults, which formerly caused severe and destructive earthquakes (Fig. 1). The lack of constructive coherence of the various parts in Atenasio Palace, determined by the circumstance that they are built on different foundation systems, produces on the building a complicated series of recent and ancient structural problems (cracks, deformations, and so on), which suggest triggering of complicated displacements, difficult to be diagnosed (Fig. 2).
DIAGNOSIS
The complexity of the structural condition of Atenasio Palace has therefore become necessary to project a particularly intense investigative plan. In fact, although architectural restoration has become a very specialized practice, we still have to do much more in spreading a culture and sensitivity, aimed to invest in preliminary investigation of building, also in order to reduce costs of interventions and for their better effectiveness and durability. Preliminary investigations therefore require careful and scrupulous planning, such as the design of an intervention and, therefore, in this paper we do not want to describe the project, but we want to focus on the long and complicated diagnostic process in its different phases. The first phase of a diagnosis, for a so complicated situation, is to try to investigate its foundation system and, in this specific case, the primary step was a direct overlapping of architectonic plans of Atenasio Palace and the archaeological maps of Naumachie (Fig. 3).
This work allowed us to understand that the oldest parts in the building rationally exploit the walls of Naumachie, because they are well aligned on them, although this determined some limitations for functional articulation of the Palace, for example doing room rather narrow and long; moreover its ancient builders were aware of possible structural problems for a construction, if it is incoherent with the archaeological ruins on which it is placed. The following enlargements do not respect this principle and in fact a large part of cracks and deformations are located in the connection between the oldest parts and the latest ones or inside the most recent portions, where there is a discontinuity between foundations of the new building and archaeological ruins (Fig. 4).

However this investigation has to be considered only preliminary, because there is not a detailed map of Naumachie, both as regards their original conformation and about the current state of consistence of ruins, therefore this planimetric overlapping should be considered only preliminary. A useful tool to investigate this issue is the Ground Penetration Radar technology (GPR), which is not only able to intercept the ruins of Naumachie, but also to better understand how foundations of Atenasio Palace are placed on them.

Therefore, the diagnostic plan purposes a detailed GPR investigation, to be concentrated in specific areas, identified through the previous phase of planimetric overlap. It is useful to specify that a scrupulous historical, archaeological and stratigraphic research, preliminary to diagnostic tests, not only improves their potential applications, but also allows a reduction of costs and timing of these investigations, which are usually quite expensive, considering that they pertain to expensive technologies and specialized procedures. The next step of preliminary knowledge, about diagnostic investigations, was a technological and structural documentation of the building, enriched by a detailed and critical drawing of structural alterations, such as cracks, misalignment and so on, because every of these signs is the first element to postulate a deformation or translation mechanism, in which purposing their genesis and causes. In this case, the structure of Atenasio Palace and its numerous elements of structural stress made this passage particularly interesting and difficult; therefore were defined little macro-categories of structural problems, obtaining a rapid and at same time detailed localization of two main structural issues: an outside rotation of a slim recent of the building and an inside vertical foundation translation.

Therefore, the critical documentation of so many cracks and deformations, adequately summarized, led ultimately to highlight only two problems, both connected to the characteristics of building stratification. In these cases the diagnosis becomes quite simple, but it usually requires to know a chronological evolution of displacements, which can sometimes be slow and gradual, sometimes sudden and occasional. In the case of Palazzo Atenasio was important to understand if these mechanisms were still in progress or were exhausted, if they continuously progressed or only in defined period of the year, for example during the rainy season, considering that they are correlated to foundation problems and the soil, in this area, is not homogeneous. For this reason, in a first emergency phase some mechanical crackmeters were placed, which in the following six months did not show an evolution of cracks and deformations, suggesting a rather serious, but not more active, displacement. This condition determined the planning of a supplementary and much more intense investigative structural health monitoring program, including electronic jointmeters and inclinometers, and a detailed 3D-scan documentation to evaluate deformations (Fig. 5).
Fig. 4 – Structural issues and kinematics of Atenasio Palace
Also in this case, they are expensive technologies and procedures, but possibility to choose a few specific points, through preliminary investigations, also in this case reduces costs and improves their applicability.

All this complex of tests and investigations is more useful if it is possible to schedule them in a way capable to guarantee that a results of a test will be used to detail position and performance of subsequent investigations; for this reason, this study ends with a flow chart, which explain a step by step sequence of numerous investigative typologies, prefiguring a progressive choose, which takes account of expected results, defined during the preliminary procedure.

Finally, it should be considered that, at this time, understanding that some of the structural problems of the Palazzo Atenasio are due to ancient foundation problems and are not due to extrinsic recent causes, considering that lots of these cracks and deformations are in a quiescent phase, suggests that, although its mechanisms are extended and at first glance were really worrying, it is reasonable to assume that they now pertain to little dangerous problems. Obviously, only an effective and whole implementation of planned investigations can give confirmation of this assumption; however, this process corresponds to a quite common mechanism in the architectonic diagnostics, consisting in the fact that detailed knowledge of a building allows a better understanding of its problems and this often helps to resize initially supposed problems, which were result of a only superficial observation of issues.

**INTERVENTION CRITERIA**

The preliminary hypothesis, that the investigation could confirm, is that the kinematics occurred in a now ended phase and that the building currently has an articulated set of cracks, suggesting a no more active mechanism, though still dangerous because of the alterative effects that it has over time produced on the walls. If the diagnostic tests are able to show, as we hypothesize, that the structural problem is no longer in progress, the intervention should therefore not be intended to remove its causes, thereby avoiding the need to implement consolidation works, which are often very invasive. In this specific case in fact it would be an extensive intervention on foundations, for example with underpinning or micropiles, which would determine an irreparable alteration just of one of the most important architectural elements of the building, namely the Naumachie. In the case in which the monitoring investigation can verify the hypothesis that the instability mechanism is exhausted, the intervention could in fact limit to propose a repair of current damage, for example with local retrofitting works, as repair of cracks and the partial reconstruction of deformed floors.

This approach not only meets the minimum intervention criterion, but allows also an economic savings, which, in this specific case, by a first estimate, appears even more than 50% of an intervention cost on foundations. This saving can find a better investment for example in planning interventions aimed at reducing seismic vulnerability, considering that Taormina, as already described, is a site with high seismic risk; in fact few traditional seismic improvement work, such as application of tie-rods in the floors and the roof or rebuilding of some recently built concrete floors in timber ones, would cost not more than half of the savings; besides this form of investment is particularly advantageous, because, allowing a better seismic performance of the building in case of an earthquake, it will reduce the correlated damage, with a consequent reduction of future repair costs of the building.
Fig. 5 – Diagnostic and investigative plan for Atenasio Palace
However, this form of restoration, which we could perhaps roughly define "preventive restoration", becomes effective only if considered in a holistic perspective, namely if it is possible to correlate seismic performance of a building in urban context to which it belongs, especially in places urbanistically very dense, like most of Italian historical cities. This issue is for Taormina even more complicated, because presence of the historic city, layered on the ruins of the ancient Greek-Roman city, introduces non-negligible elements of variety and differences in seismic performance of an urban system; so reducing seismic vulnerability of a dense and stratified site should include a evaluation of vulnerability involving the urban historic site a whole, with very complicated logistical and economic implications. In addition, the need to read structural behavior of historical building of Taormina as a whole, in order to understand status of individual buildings, it is a not only seismic matter and in fact it has already been presented in evaluation of kinematics of Palazzo Atenasio; for example to investigate relation between foundations of other buildings and Naumachie, which we know were very large, could contribute to a better diagnosis of structural problems of Palazzo Atenasio. Even in this case, diagnosis is confirmed as a very good means of knowledge: widening the previously described diagnostic investigation to buildings, close to Palazzo Atenasio, it is possible to obtain a urban-scale and preventive evaluation of structural and seismic risk.

CONCLUSIONS
To classify the articulated problems of a complicated building in a few fundamental mechanisms is an effort useful for reducing necessary restoration and consolidation works, with advantages in terms of conservation and preservation of the historic building, but also in terms of reduction of risks and costs, so the experience of this research shows that an investment in knowledge and diagnosis is often rewarded in the following phase of restoration and retrofitting project. This is a warning to promote the culture of preventive diagnosis among professionals, involved in restoration, not unlike how, not more than twenty years ago, was done about the awareness for a culture of maintenance, as strategy to avoid or procrastinate need of a restoration, which, instead to be considered as an occasional and exceptional intervention, it should be understood as a in progress activity and as a constant care, where diagnostics, especially if monitoring, constitutes a valid and reliable support to obtain and serve structural safety of an ancient building.

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