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ABOUT BUILDING DATING AND THE EVALUATION OF MASONRY'S STRENGTH IN PALAZZO PIANCIANI, SPOLETO, ITALY

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ABSTRACT

It is common knowledge that restoring a building involves not only the physical rebuilding of its parts, but also the identification and conservation of the peculiarities of each building as a first stage. Therefore, the process leading to the identification of the main features becomes important and a chief part of the restoration project.

There are two fundamental aspects in this process: the dating of each part of the building, and the evaluation of the actual strength of building components (masonry, foundations, floors, etc.). Dating the building entails an evaluation of the way it stands, whilst the knowledge of forces leads to an evaluation of the level and the type of intervention required. Obviously, the more information we obtained on the actual stress, the better the restoration project we were able to conceive.

In the case of Palazzo Pianciani, for example, direct shear test on the masonry, both in its present-day state and following fluid-mortar consolidation, let us to opt for no mortar injection into the masonry, thus saving about US $1.55 million compared to a diagnostic cost of US $50,000.

The paper shows the results on an 18th-century building and what this method can offer to the designer in order to optimize restoration work.

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INTRODUCTION

Europe is witnessing an increasingly frequent restoration of historical buildings used for purposes different from their original ones. Besides the well-known controversial issues of the cultural propriety and the suitability of the project for such programmes, there are clearly problems in assessing the stability of the building, both in the overall plan and in the individual component parts of the building. To this end, a fast and useful procedure is computerized calculation with one of the various methods for the assessment of vertical loads and of seismic horizontal forces. Such methods can divide the forces acting on the different parts of masonry in relation to their size, position and the resistance capacity of the masonry.

In the assumption of a perfect knowledge of both size and masonry quality, mathematical algorithms can be process numerical data with the precision desired. However, the problem arises precisely with the two aforementioned instances (i.e. the knowledge of the exact size and quality of the masonry.) Normally this data is only approximate in terms of typology and referred to bibliographical data concerning the masonry bearing capacity.

The case discussed in this paper is significant as the aforementioned issues have been solved by means of precision topological mapping, critical surveys and endoscopic surveys with the purpose of determining the time of the construction of the masonry. This enables the identification of homogeneous masonry groups, and carrying of direct testing to assess the masonry bearing capacity (particularly, with shear strain test).

Typological mapping was effected with procedures of architectonic photogrammetry. An in-depth study of this point is not suitable here. On the contrary, we are eager to report the results we obtained through a "critical survey" as they enabled us to determine the successive construction stages of a building that today has a homogeneous 18th-century aspect. Similarly, we are eager to report the results of shear tests performed on the masonry in its present-day condition, and following fluid mortar injection.

BUILDING DATING WITH THE "CRITICAL SURVEY" METHOD

It is well known that the critical survey method is based on determination of the characteristics of the building through the knowledge of the formation/transformation processes of the building itself. In general, such transformation may be subdivided into two main categories: transformation due to substitutions entailing the destruction, either total or partial of the existing physical structures, and transformations due to addition or superposition, in which the existing physical structures survive, but undergo important interventions, such as superposition of plasters, enlargements, the making/closing of openings, etc.

Therefore the critical survey method is the identification and interpretation of transformation characteristics and traces in order to gather the fundamental data of buildings as well as the structural discontinuities and/or deficiencies determined during the formation-transformation process (Doglioni and Gabbiani, 1983).

It is a well-known fact that, in spite of the widespread appreciation of the efficiency of the results, the critical survey is considered a destructive method in relation to the tests and the removal of plaster it entails (Feiffer, 1990). In the case of Palazzo Pianciani, destructive effects were minimized by using endoscopic imaging (Fig. 1) for in-depth testing and the exfoliating scalpel removal technique for superficial tests aiming at the identification and restoration of pictorial decorations.

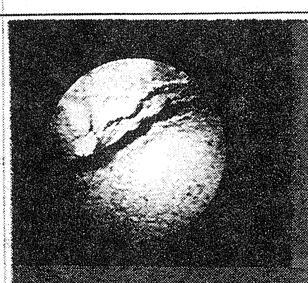
Palazzo Pianciani - Spoleto - 2° livello		
Saggio	*Riferimento in documentazione fotografica*	*Descrizione della prova*
n° 27	Foto n° 22	KIND OF TEST: endoscopic imaging into a 30 mm hole at the eight of 115 cm over floor level AIM: stratigraphy and kind of masonry RESULT: Two holes took to identify an hold fire-place pipe. Third one shows a masonry of boasted stones kept together by a very poor mortar and with internal pockets of remarkable size
Foto n° 22 Empty space inside the masonry		

Fig. 1 – Left side: endoscopic investigation into a decorated bearing vault; Right side: typical card resulting from an endoscopic investigation.

The information thus obtained was collected on cards and graphically represented in the plans. This research showed the substantially homogeneous character of the building technique in all the building bodies, independent of the time of construction. In short, the result was a masonry composed of boasted stones kept together by a very poor mortar, sometimes powdery and with internal pockets of remarkable size. A rather widespread lack of efficient toothing was also observed.

Typological variations emerged when examining an area overlooking Largo Maurizio Clementi. This area had a more regular masonry structure with stones that were boasted but placed in a less orderly manner along subhorizontal lines and kept together by a quality binder. The floor structure clearly dates back to approximately the 14th century as well.

Another important source of information was the historical analysis. The study of record office documents and of both drawings and paintings of the time provided us with information regarding the disposition of masses during the centuries.

Summing up the information led us to arrange the evolution tables illustrating, although schematically, the subsequent aggregation of the building bodies from the 15th-century to the 18th-century restoration work (Fig. 2).

EVALUATION OF MASONRY STRENGTH

With a view to the project operational choices, knowing the bearing capacities of the masonry structures in their original condition is of utmost importance. In general, given their remarkable thickness, masonry work does not have great problems in terms of vertical loads, but tends to be more exposed to the effects of horizontal seismic strains.

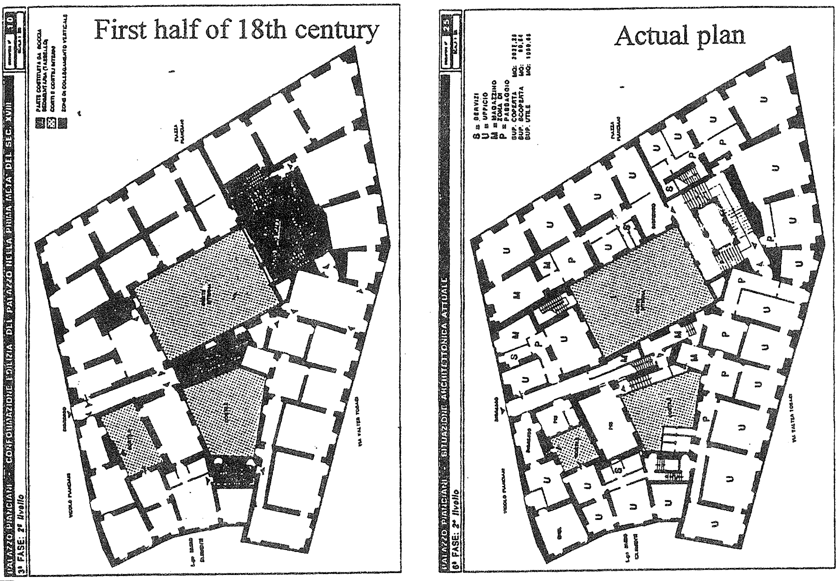
In current practice, a good interpretation of their behaviour is possible with the use of a computerized control calculation, in which shear values derive from the literature according to the typology and the degree of preservation of the masonry being examined.

In the case being treated in this article, we opted for a direct test in situ where we calculated the value of the necessary shear strain to take an ashlar to the breaking point. Such a test was conducted on two different ashlars of the building. Subsequently, the ashlars are consolidated by fluid mortar injection and, following the setting of the binder, they were taken once again to the shear breaking point.

The purpose of these instrumental tests is to measure sure values referring to the particular masonry under examination. The comparison between the values obtained in the present conditions and those after consolidating the masonry indicates the degree of efficiency of the injection of a fluid mortar with a cement binder.

The tests were carried out with the following equipment (Figs. 3 and 4):

- six hydraulic jacks, each capable of 500 KN;
- steel anchor plates and load distribution plates of S = 30 mm built for this purpose;
- electromagnetic transducers capable of signalling displacements of 10^{-6} m;
- computing exchange for the optical reading of force and displacement values and for the direct drawing of the Load-Displacement diagram.



PALAZZO PIANCIANI
plan of first floor

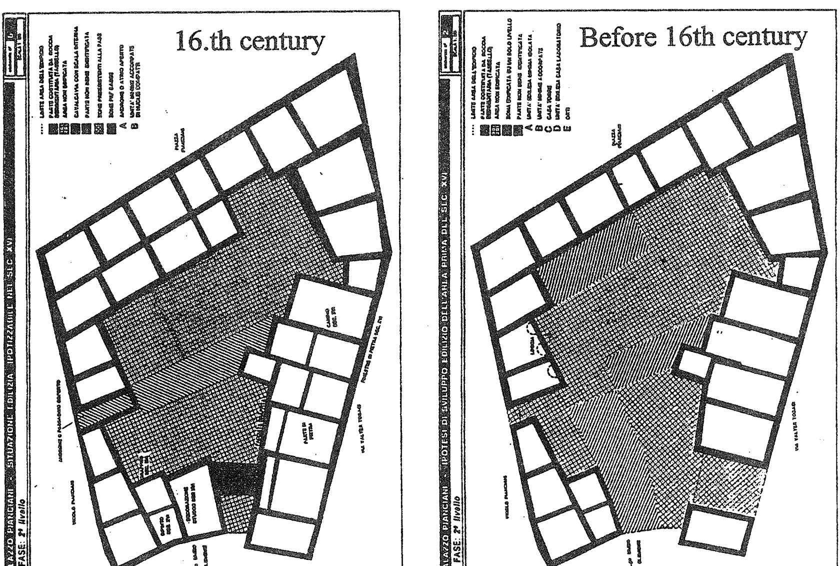


Fig. 2 — Dating the building led to recognition of different steps in the evolution of what finally became, in the 18th century, Palazzo Pianciani.

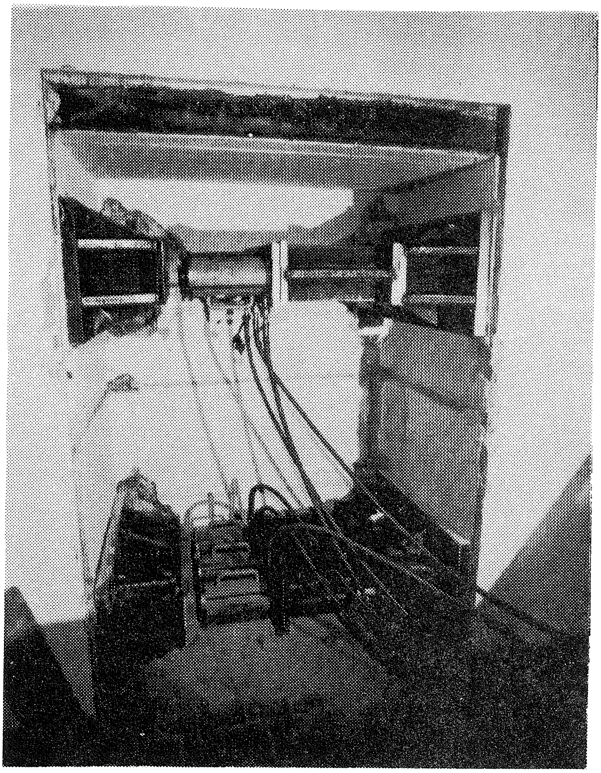


Fig. 3 – The shear test set-up.

All of the equipment was provided by the Materials and Structure Tests Laboratory of the University of Ancona.

The tests were performed with subsequent load and relief cycles so as to assess residual deformation. In each load phase, the area of masonry subjected to the pressure was 15.456 cm^2.

The study of the test graph (Fig. 5) shows that in the ashlar left undisturbed, the breaking load is a τ of about 6.6 Bar, obtained with a deformation in the order of 4.7 mm; that the τ of the 3.3 Bar corresponding to half the breaking load entails a deformation in the order of 1 mm, whereas 1.5 Bar – the value generally given in the literature for similar masonry work – corresponds to a deformation of only 0.2 mm.

Subsequently, the masonry was consolidated by injecting cement mortar at a pressure of 1.5 Bar at the rate of 120 kg of cement per m^3 of masonry.

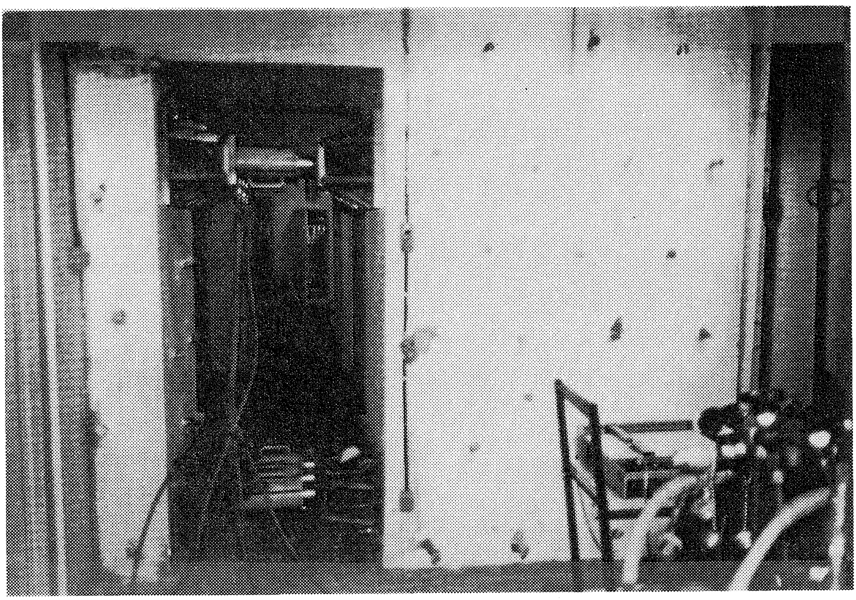


Fig. 4 — The shear test set-up on consolidated masonry.

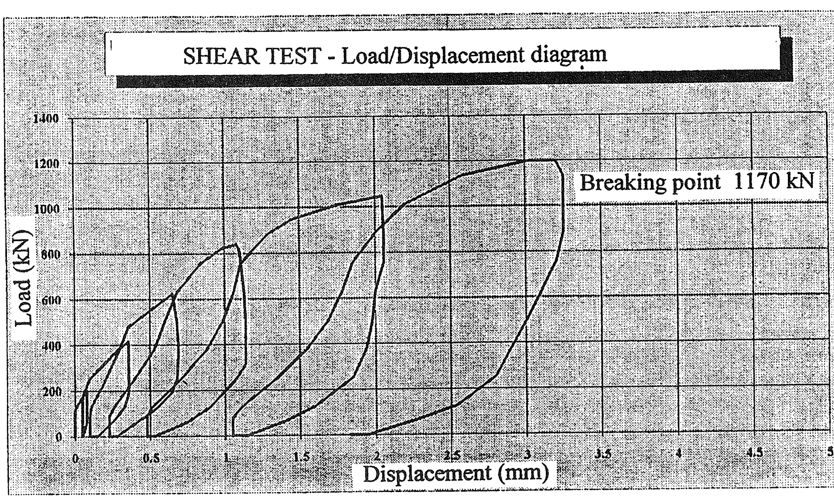


Fig. 5 — Diagrams of shear test on the historical masonry in its own status.

The graph regarding the test carried out on the unconsolidated masonry (Fig. 6) shows a slight increase of the horizontal strain (from 1021 to 1170 KN) but a remarkable decrease of deformations. The horizontal displacement equals 3.2 mm with a tension τ of 7.6 Bar, 17 mm with τ equal to 6.6 Bar, 0.3 mm with τ equal to 3.3 Bar and only 0.12 mm with τ equal to 1.5 Bar.

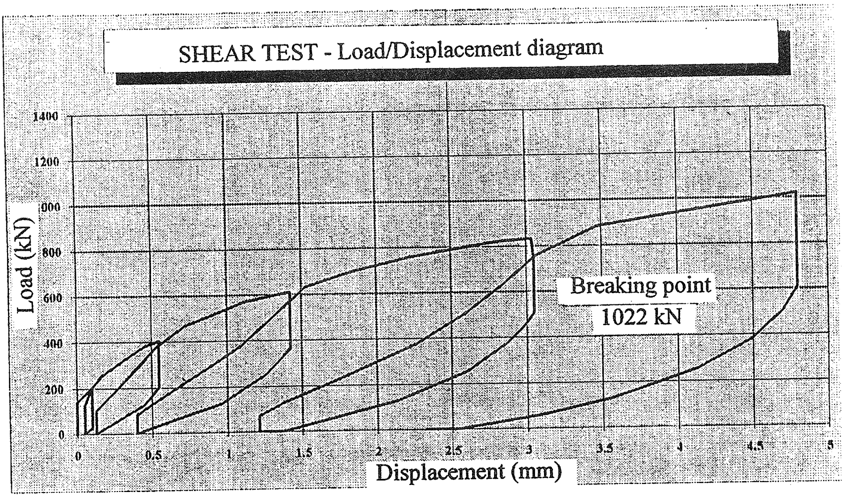


Fig. 6 – Diagrams of shear test on historical masonry consolidated by injection of fluid cement mortar (120 kg per cubic meter).

Therefore, a 32% reduction in deformations is observed with τ = 6.6 Bar (breaking point at nonconsolidated conditions), whereas with 3.3 Bar, the reduction of deformation equals 70% of the value measured in nonconsolidated masonry.

CONCLUSIONS

The tests performed lead to the following considerations:

- assuming a safety coefficient equal to 3, the value of τ for limestone masonry bound with a mortar of powdery cement lime is 2.2 Bar (as opposed to 1.5 bar, the value normally assumed);
- fluid mortar injection does not significantly improve shear resistance (breaking at 7.6 Bar instead of 6.6 Bar), but it proved suitable for restoring damaged masonry to initial conditions;

- on the basis of the experimental data, generalized mortar injection in the whole building proves unnecessary; this technique is often proposed as a method to improve total stability;
- measured τ values explain how the building in question, as well as may other similar buildings in terms of building technologies, has withstood over four centuries of earthquakes of remarkable intensity.

More generally, it can be stated that the critical survey method yields good results that help understand the building in the outlining of the restoration project. The adoption of nondestructive survey procedures, such as endoscopic examinations, provides a good level of knowledge without excessive damage of historical buildings.

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