

Original article

Metrological definition and evaluation of some mechanical properties of post-medieval Neapolitan yellow tuff masonry

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Abstract

The knowledge of the morphological and mechanical properties of masonry walls is very important for the refurbishment of ancient buildings, particularly when the requirements of both structural safety and historical preservation must be fulfilled. The masonry is not of homogenous material: its mechanical properties depend on stones, mortar, and texture which are very variable due to their dependence on the historical periods and the geographical area of the erection. For this reason, a deep knowledge of masonries built in different sites and historical periods is essential in order to evaluate both the capacities of bearing vertical load and the seismic vulnerability of the masonry structure. Three fundamental typologies of tuff masonry have been defined: they are the characteristics of different historical periods from the XVI to the XX century. The models are in full-scale in order to reproduce the three defined chronotypes. Original tuff stones quarried in the corresponding historical period, mortars similar to the original ones, reproduced according to ancient documents and original constructive techniques have been used for the construction of the specimens. Compression tests performed in displacement control have been carried out on the masonry models in order to determine the maximum resistance of the material and the corresponding strain, the ultimate strain and corresponding residual strength. In this paper, the procedure used for making the specimens and for experimentally evaluating the mechanical properties of post-medieval Neapolitan yellow tuff masonry are illustrated and the obtained results, even in terms of plastic capacity of these kinds of masonry, are reported.

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1. Research aims

Measure-chronological research carried out in the past decade in the Naples area established a definition of the metrological characteristics of yellow tuff masonry of the modern and contemporary age, so that its construction period can be defined using both morphological and dimensional [1] chronological indicators. This innovation of knowledge has led to the creation of specific categories to distinguish the characteristics of different kinds of masonry. In other words, if we recognise a given typology of masonry, this could be enough to date the building and vice versa if the date of construction is well known

(e.g. by ancient written documents), it should not be necessary to investigate on the feature of the masonry.

The present work combines the historical-critical expertise of specialists in architectonic restoration and the physical-mechanical skills of construction technique researchers to prepare macro-models of historical masonry, closely following the chronotypes present in this research area both in terms of conformation and construction procedure. Historical masonry characteristics, synthetically described afterwards, have had a prominent function in the settlement of the respective research procedure. As a matter of fact, the actual accomplishment of macro-models has been determined by the constant checking of their own correspondence to the historical model derived from the above-mentioned researches.

Subsequently, a constitutive model was defined by means of compression tests under controlled deformation and a theoretical model was developed to predict the mechanical behaviour of masonry slender elements under cyclic action in order to confirm

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and complete the results of previous experiments conducted on scale models [2].

The present paper explains the procedure used to prepare masonry panels and carry out compression tests with a short report on the results. A more detailed description of equipment, test procedures, test results and mechanical behaviour of tested masonry panels is reported in other paper [3].

2. Metrological and chronological characteristics

Metrological research carried out on Neapolitan yellow tuff masonry, constructed between the first half of the XV and early XVI centuries, identified three basic constructive types, defined by chronological, morphological and dimensional parameters:

- *cantieri* masonry widespread in the XVI and XVII centuries;
- *bozzette* masonry dating back to XVIII century;
- *blocchetti a filari* masonry used in the XIX century and first half of XX century.

The above classes can be further divided, allowing the post-medieval tuff masonry in the Neapolitan area to be dated with relative precision [4].

The typologies analysed concern a high proportion of the historical heritage of this area. Macro-models capable of representing post-medieval masonry thus provide an evaluation of vulnerability to gravitational and seismic action of a considerably large proportion of the Neapolitan architectural heritage.

Briefly, under the Spanish viceroys, yellow Neapolitan tuff masonry was mostly built according to *cantieri* type, piling up broken stone – laid on a thick bed of conglomerate made of lime mixed with rubble and small rough stones – on planes spaced about two Neapolitan palms (one Neapolitan palm = 26.37 cm) apart. Cross sectional engagement was assured by slender elements used as bondstones.

Rubble was obtained by breaking stone with a wedge and mallet, sometimes broken up using a *mannara* (a kind of axe with a rectangular head and a cutting surface parallel to the handle). The resulting elements were of variable size and shape with irregular external surfaces. The stones were called *spaccatoni*, *spaccate*, *spaccatelle* and *rustiche* depending on the shape and size. The distinctive features of Spanish-age typologies are the distance between the mortar planes (the size of *cantiere*), the characteristics and size of the stones and the criteria for arranging them on the mortar planes.

Cantieri masonry was widely used to build neighbourhoods outside the city walls and for the foundations of the *Quartieri Spagnoli* neighbourhood from the second half of the XVI century [5].

Examples of *cantieri* masonry are a part of the walls of the Church of *S. Caterina a Formiello* (1501–1514) at *vico S. Caterina* (Fig. 1) where some *spaccatoni* were included in order to stabilize the wall.

Another interesting example is *Palazzo Donn'Anna* at “Posillipo” (1642–1644): in the curtain of the gallery, on the first floor, *cantieri* with two rows may be seen, the former 40 cm and the latter 45 cm in height, associated to 30 cm-high rows made up



Fig. 1. *Cantieri* masonry wall (*S. Caterina a Formiello* Church in Naples).

of *spaccatoni*, well-worked on the horizontal face and superficially worked on the vertical faces. On these elements, thick mortar beds and small stones were arranged in order to restore the horizontal plane of the masonry.

In the last quarter of the XVII century, especially after the serious earthquake of 1688, the renewal of construction technique and structural typologies led to the introduction of masonry in which stones were arranged in rows. Hence, in the XVIII century, walls were constructed with *bozzette* stones – worked on the vertical and external faces, placed along rows of 13 cm (“half a palm”) in height. The masonry core was characterized by the use of stone elements of the same size, though roughly worked.

This technique was also used for erecting additional storeys, which were built by adopting the *bozzette* masonry in order to obtain more slender (lighter) walls compared to the ones made of *cantieri* masonry. The *filari-bozzette* technique was also used for new buildings, such as the *Albergo dei Poveri* and the *Royal Palace at Portici*. In Fig. 2, a masonry piece from the western wing of the belvedere of the *Royal Palace* (completed in 1763) is shown. It may be noticed that stones are placed in parallel



Fig. 2. *Bozzette* masonry wall (West front wall of the *Royal Palace* in Portici).

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