ARCHIVIO ISTITUZIONALE
DELLA RICERCA

Alma Mater Studiorum Università di Bologna
Archivio istituzionale della ricerca

Determination of Masonry Compressive Strength Properties by Testing Cores

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:
Ferretti, F., Incerti, A., Mazzotti, C. (2025). Determination of Masonry Compressive Strength Properties by Testing Cores. Springer Science and Business Media Deutschland GmbH [10.1007/978-3-031-73310-9_84].

Availability:
This version is available at: https://hdl.handle.net/11585/1011636 since: 2025-03-29

Published:
DOI: http://doi.org/10.1007/978-3-031-73310-9_84

Terms of use:

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (https://cris.unibo.it/).
When citing, please refer to the published version.

(Article begins on next page)

14 October 2026

Determination of masonry compressive strength properties by testing cores

Francesca Ferretti[1*[0000-0003-1484-3853]], Andrea Incerti[2[0000-0002-6431-3730]] and Claudio Mazzotti[1[0000-0002-5314-4687]]

[1] Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Viale Risorgimento 2, 40136 Bologna, Italy
[2] CIRI Buildings and Construction, University of Bologna, Via del Lazzaretto 15/5, 40131 Bologna, Italy
*francesca.ferretti10@unibo.it

Abstract. Dealing with the seismic vulnerability assessment of existing masonry constructions is not an easy task, especially concerning the difficulties in determining the masonry mechanical properties. Experimental tests, classifiable, depending on their invasiveness, as non-destructive, slightly-destructive or destructive, may be performed directly on-site or in laboratory on materials extracted on-site. Existing buildings with an historical, architectural or artistic value cannot be severely damaged by testing; therefore, there is the need of assessing the reliability of non-destructive and slightly-destructive testing methodologies for the determination of the material parameters. The goal of the present research is to evaluate the suitability of testing cores for the determination of the masonry compressive strength. Testing a masonry core in compression is not a standardized procedure and it implies the casting of high-strength mortar caps at the top and at the bottom of the samples to obtain regular surfaces on which applying the compressive load and to simulate the confinement given, on site, by the surrounding masonry. In this research, a solid clay brick masonry typology is considered, for which the compressive strength is estimated by testing cores and standard wallets. To investigate the reliability of the testing method, both single-wythe and double-wythe cores are subject to uniaxial compression tests, also considering variations in the dimensions of the high-strength mortar cap. Correlations between the results obtained by testing cores and wallets are presented in the paper, in terms of compressive strength and evolution of the crack pattern.

Keywords: Brick masonry, Slightly-destructive test, Cores, Non-standard testing, Compressive strength.

1 Introduction

For the vulnerability assessment of existing masonry buildings, one of the most important aspects is determining the mechanical properties to be used in the structural analyses and verification. With this purpose, experimental tests can be either performed on-site or in the laboratory on samples extracted on-site. In general, testing methods can be classified as non-destructive, slightly-destructive or destructive depending on the damage they cause to the construction [1,2]. Existing buildings with an historical, architectural or artistic value cannot be severely damaged by testing; therefore, slightly-destructive tests could be usually preferred to destructive tests [1].

One promising slightly-destructive technique involves extracting masonry cores from the load-bearing walls of the building under investigation. Testing a masonry core in compression is not a standardized procedure and it implies the casting of high-strength mortar caps at the top and at the bottom of the samples to obtain regular surfaces on which applying the compressive load and to simulate the confinement given, on site, by the surrounding masonry [3-5]. To evaluate the reliability of this test method, research has been conducted in recent years with the aim of comparing and correlating the results obtained from compressive tests on cores and standard compression tests performed on masonry wallets [3,6,7]. However, the research on this topic is still open, given the fact that many parameters can influence the outcomes of the tests on cores, such as the core diameter and length, the bond pattern, the dimensions and the material properties of the cap, etc. [8].

In this framework, the goal of this research is exploring the suitability of testing cores for the determination of the masonry compressive strength. A clay brick masonry typology is considered, whose compressive strength is estimated by testing cores and standard wallets. Both single-wythe and double-wythe cores are subject to uniaxial compression tests, considering variations in the dimensions of the high-strength mortar cap. Results will be discussed in the paper in the attempt of providing a contribution for a possible standardization of the testing methodology.

2 Materials and methods

2.1 Brick masonry

The masonry typology adopted in the experimental campaign was composed by fired clay bricks with dimensions equal to 250×120×55 mm^3 and natural hydraulic lime-based mortar (NHL). Through standard testing procedures [9-11], compressive and flexural strength of the materials were obtained, as reported in Table 1.

Table 1. Brick and mortar mechanical properties.

Material	Compressive strength (MPa)	Flexural strength (MPa)
Clay brick	18.7	4.6
NHL mortar	1.4	0.4

2.2 Standard compression test on masonry wallets

To provide a reference for comparison with the results of the tests on cores, four double-wythe masonry wallets were built, having dimensions of 710×790×250 mm^3 and a Flemish bond pattern, realized with the same materials previously described. They were then tested in compression according to a standard method [12], using a universal testing machine with a capacity of 6000 kN. During the tests, vertical and horizontal displacements were measured by linear potentiometers with a repeatability lower than 0.01mm and an independent linearity equal to 0.1%, positioned on the samples, on both sides, as shown in Fig. 1.

Fig. 1. Setup for standard compression tests on masonry wallets.

2.3 Compression test on masonry cores

The extraction of the cores was performed on an additional masonry wallet, built with the same characteristics of the masonry walls tested in compression. Both single-wythe and double wythe samples, all characterized by the presence of one horizontal mortar joint in the middle of the core, were extracted. Afterwards, the cores were capped with a high-strength mortar, with a compressive strength of 22 MPa, to reproduce the confinement of masonry on site and to realize regular surfaces on which the compressive load could be applied. Different cap geometries were considered to investigate the influence of the height and the width of the cap on the estimate of the compressive strength. In more detail, the following samples were extracted, prepared and tested:

- n. 5 double-wythe cores, with a diameter of 95 mm, a cap width and height of 80 mm and 30 mm, respectively (DW_HJ_D95_80×30).
- n. 3 single-wythe cores, with a diameter of 95 mm, a cap width and height of 80 mm and 30 mm, respectively (SW_HJ_D95_80×30);
- n. 3 single-wythe cores, with a diameter of 95 mm, a cap width and height of 74 mm and 30 mm, respectively (SW_HJ_D95_74×30);

- n. 6 single-wythe cores, with a diameter of 105 mm, a cap width and height of 80 mm and 30 mm, respectively (SW_HJ_D105_80×30);
- n. 3 single-wythe cores, with a diameter of 105 mm, a cap width and height of 80 mm and 50 mm, respectively (SW_HJ_D105_80×50);

The compressive tests were performed with a hydraulic actuator, having a capacity of 100 kN, with a displacement rate equal to 0.02 mm/s. The load was applied orthogonally to the longitudinal axis of the cores, i.e., the mortar joint was aligned as in the masonry panel where it was extracted from. During the tests, vertical displacements were monitored using LVDT, on one side, and Digital Image Correlation (DIC), on the other side through a black dot pattern on white painted surfaces. The test setup is shown in Fig. 2.

(a)

(b)

Fig. 2. Setup for compression tests on cores: (a) single-wythe sample, (b) double-wythe sample.

3 Experimental results

3.1 Compression test on masonry wallets

The results of the compression tests on masonry wallets are reported in Table 2, in terms of compressive strength (f_m). All the tested walls presented a similar behavior: a first vertical crack occurred at the center of the samples, visible on both sides; afterwards, several vertical cracks appeared, all over the panel surface (Fig. 3). In some cases, separation between wall wythes occurred.

Table 2. Results of the compression tests on masonry wallets.

Sample code	Compressive strength f_m (MPa)
W_CT_1	6.4
W_CT_2	6.3
W_CT_3	6.7
W_CT_4	6.1
Average value	6.4

Fig. 3. Failure mode of masonry wallets tested in compression.

3.2 Compression test on masonry cores

The results of the compression tests on masonry cores are reported in Table 3, in terms of compressive strength (f_m) for all the tested geometries. Regarding the failure mode, both single-wythe and double-wythe cores were characterized by the presence of vertical cracks, also involving the mortar cap, especially at the end of the test (Fig. 4). For double-wythe cores, in particular, damages were sometimes observed on the longitudinal sides of the cores, with partial out-of-plane detachment, probably indicating a greater deformation of the middle part of the core. The evolution of the crack pattern, visible from the strain contour plots obtained by the DIC technique, is shown in Fig. 5 and Fig. 6 for two representative samples.

By comparing the results of tests on single-wythe and double-wythe cores, it can be noticed that the average values of the compressive strength are quite similar (difference limited to the 10%). Therefore, the presence of the collar joint seems to have a small influence on the results, at least for the tested masonry cores in which it was properly filled with mortar. Therefore, it could be preferable to test single-wythe cores, since the casting procedure is easier and undesired failure modes, e.g., along the longitudinal sides, can be avoided. For this reason, the variations of the high-strength mortar cap geometry were only considered for single-wythe samples.

Considering the single-wythe cores with a diameter of 95 mm, it can be observed that by decreasing the cap width from 80 mm to 74 mm, corresponding to a cap-to-core width ratio of 0.84 and 0.78, respectively, the compressive strength value decreased due to the lower confinement given by the cap. This observation about the confinement effect provided by the cap is also supported by the fact that cores with the same cap-to-core width ratio (SW_HJ_D95_74×30 and SW_HJ_D105_80×30) were characterized by a very similar compressive strength value. Trying to increase the cap height from 30 mm to 50 mm (SW_HJ_D105_80×30 and SW_HJ_D105_80×50), a lower compressive strength was found.

In all cases, the compressive strength obtained by testing cores was higher than the one obtained from compressive tests on wallets, with correlation coefficients ranging in between 1.48 and 1.98, with an average value of 1.73, probably due to the confinement of the high-strength mortar capping.

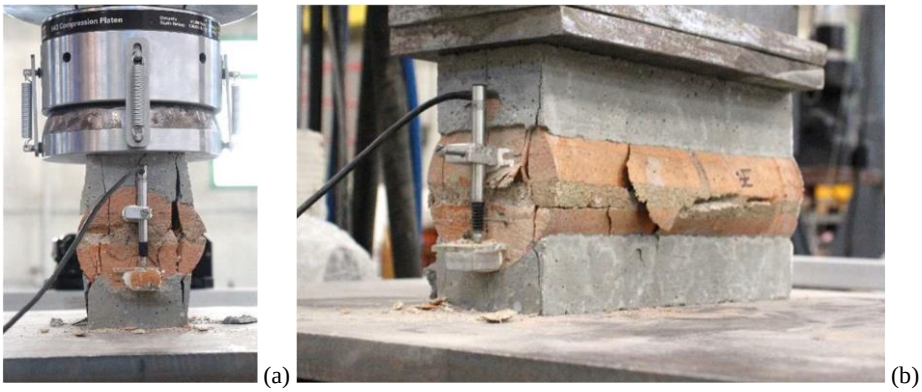

Fig. 4. Failure mode of: (a) single-wythe masonry cores, (b) double-with masonry cores.

Table 3. Results of the compression tests on masonry cores.

Sample code	Compressive strength f_m (MPa)	
	Single result	Average result
DW_HJ_D95_80×30_1	12.2	
DW_HJ_D95_80×30_2	11.8	
DW_HJ_D95_80×30_3	10.3	11.5
DW_HJ_D95_80×30_4	10.8	
DW_HJ_D95_80×30_5	12.6	
SW_HJ_D95_80×30_1	12.3	
SW_HJ_D95_80×30_2	11.0	12.7
SW_HJ_D95_80×30_3	14.9	
SW_HJ_D95_74×30_1	9.4	
SW_HJ_D95_74×30_2	10.8	11.0
SW_HJ_D95_74×30_3	12.9	
SW_HJ_D105_80×30_1	11.1	
SW_HJ_D105_80×30_2	11.2	
SW_HJ_D105_80×30_3	10.7	10.7
SW_HJ_D105_80×30_4	11.3	
SW_HJ_D105_80×30_5	9.1	
SW_HJ_D105_80×30_6	10.7	
SW_HJ_D105_80×50_1	8.8	
SW_HJ_D105_80×50_2	9.4	9.5
SW_HJ_D105_80×50_3	10.2	

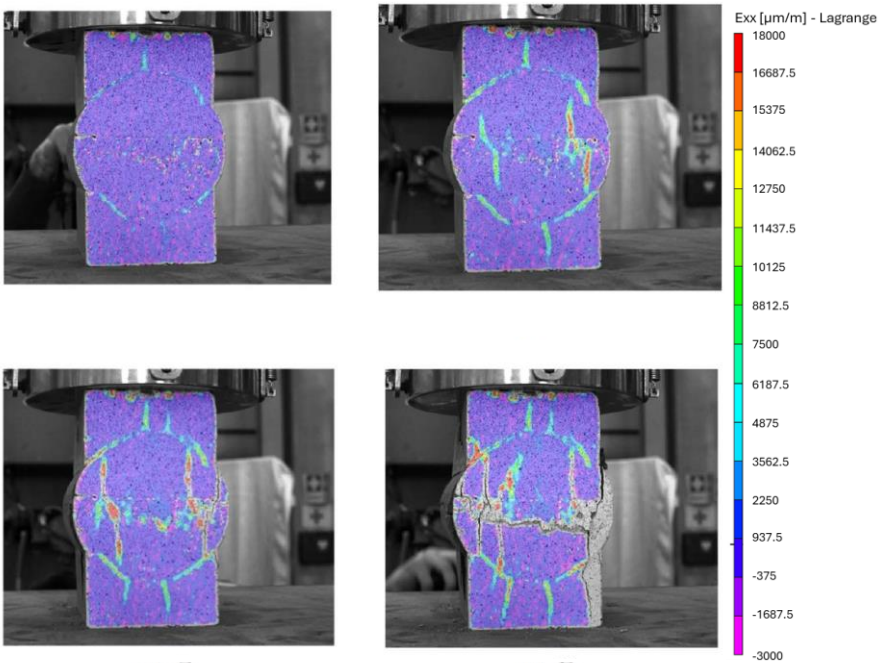

Fig. 5. Evolution of the crack pattern for single-wythe core: sample SW_HJ_D95_80x30_1.

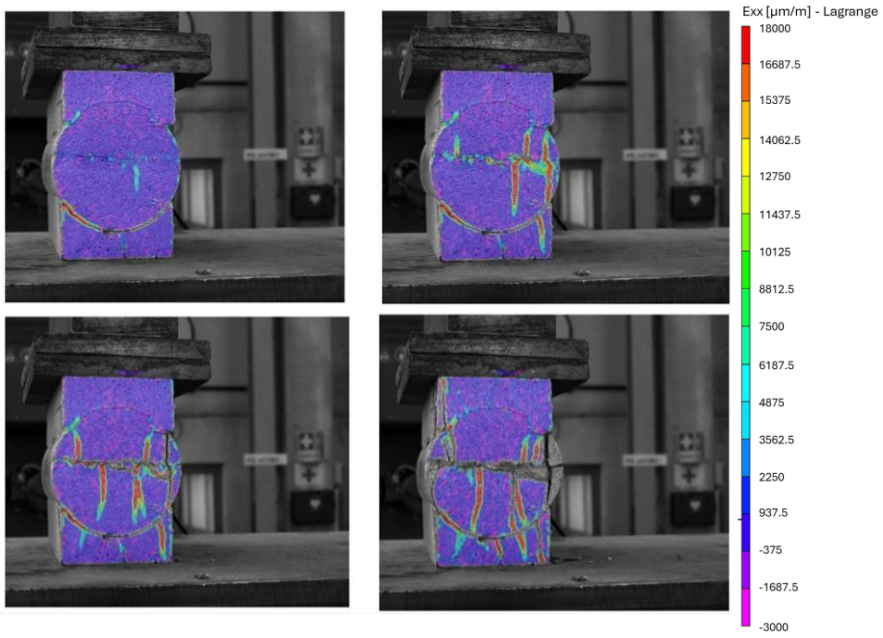

Fig. 6. Evolution of the crack pattern for double-wythe core: sample DW_HJ_D95_80x30_2.

4 Conclusions

In this research, compressive tests on masonry cores were performed to investigate the reliability of this non-standard testing methodology in estimating the masonry compressive strength. With reference to a clay brick masonry typology, both single-wythe and double-wythe core samples were extracted from wallets, capped with a high-strength mortar, and tested in compression. Different cap geometries were considered to investigate the influence of the confinement effect on the compressive strength results, which were compared to assess the impact of the geometrical variations considered. The obtained results allowed to define a correlation between the core test results and the results of standard tests on wallets, obtaining useful information, possibly contributing in the future to the standardization of the testing methodology here proposed and applied. Additionally, failure modes typical for masonry loaded in compression were obtained for both core types (single-wythe and double-wythe) without significant variations, which means the approach is consistent and reliable.

References

1. Binda A, Saisi C, Tiraboschi C. (2000) Investigation procedures for the diagnosis of historic masonries. Construction and Building Materials 14:199–233.
2. Ferretti F, Ferracuti B, Mazzotti C, Savoia M (2019) Destructive and minor destructive tests on masonry buildings: Experimental results and comparison between shear failure criteria. Construction and Building Materials 19:12-29.
3. Jafari S, Rots JG, Esposito R (2019) Core testing method to assess nonlinear behavior of brick masonry under compression: A comparative experimental study. Construction and Building Materials 218:193-205.
4. Brencich A, Sterpi E (2006) Compressive strength of solid clay brick masonry: Calibration of experimental tests and theoretical issues. In Proceedings of the 5th Structural Analysis of Historical Constructions, New Delhi, India.
5. Sassoni E, Mazzotti C (2013) The use of small diameter cores for assessing the compressive strength of clay brick masonries. Journal of Cultural Heritage 14:e95–e101. DOI: https://doi.org/10.1016/j.culher.2012.11.027.
6. Sassoni E, Mazzotti C, Pagliai G (2014) Comparison between experimental methods for evaluating the compressive strength of existing masonry buildings. Construction and Building Materials 68: 206-219.
7. Pelà L, Canella E, Aprile A, Roca P (2016) Compression test of masonry core samples extracted from existing brickwork. Construction and Building Materials 119:230–240.
8. Ferretti F, Incerti A, Mazzotti C (2020) Comparison between investigation techniques for the evaluation of the compressive properties of brick masonry structures. In Proceedings of the 12th International Conference on Structural Analysis of Historical Constructions, Eds. Roca P, Pelà, L, Molins C.
9. EN 772-1 (2011) Methods of test for masonry units - Part 1: Determination of compressive strength. European Committee for Standardization.
10. EN 12390-5 (2009) Testing hardened concrete - Part 5: Flexural strength of test specimens. European Committee for Standardization.

11. EN 1015-11:1999/A1:2006 (2006) Methods of test for mortar for masonry - Part 11: Determination of flexural and compressive strength of hardened mortar. European Committee for Standardization.
12. EN 1052-1 (1998) Methods of test for masonry - Part 1: Determination of compressive strength. European Committee for Standardization.