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RELIABILITY OF DIAGONAL TEST

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ABSTRACT

Although masonry has been widely used as building material for centuries, its behaviour is not still not completely understood. Mechanical models developed for homogeneous elastic continua cannot be suitable for such a particular material. To develop a simple mathematical model, a large number of physical parameters is needed. Among them, the masonry shear strength plays an important role. More extensive information is necessary about the evaluation of shear strength. Besides, to allow a comparison between experimental data, laboratory tests need to be performed according to fixed standards. This paper is a discussion on the effectiveness of the diagonal test and on the opportunity of realizing simpler tests. Both the results of diagonal tests reported in literature and performed by the authors are discussed.

INTRODUCTION

Many investigation have been carried out in the last twenty years on the shear strength of masonry panels, but the results are, in general, not comparable, due to the different test arrangements used to evaluate the shear strength, ranging from simple diagonal compression to widely variable combinations of horizontal and vertical loads. The effects of geometry and loading conditions in different shear panel tests have been extensively examinated (Samarasinghe et al., 1981).

Among the different laboratory tests, the diagonal test plays a fundamental role, since it is prescibed by many Code requirements. According the Italian Codes, shear strength of masonry can be determined only by means of diagonal test. A minimum number of 6 diagonal tests, performed on masonry panels is required, but size and shape of the panel, dimensions and shape of the loading shoes, number and arrangement of the bricks in the panel, and loading rate are not prescribed (D.M. 20/11/1987). More detailed information

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about the testing procedure is given by ASTM (E519, 1975) and Rilem (LUM/B6, 1990). In general, the shear strength is given by the following relation, so that:

$$\tau = 0,707 \frac{P}{A}$$

where:

τ	shear strength
P	collapse load
A = bd	b = thickness of the panel and d = side of the panel

Similar relations between the collapse load and the shear strength have been proposed during the last twenty years (Turnsěk and Cacovič,1970; Yokel and Fattal, 1976). It must be noted that the test results are not comparable because the testing procedure is not accurately described.
Besides, it must be noted that there are some difficulties in performing the diagonal test.

(a) It is necessary to rotate the panel until one of the diagonals is perfectly vertical, and then to put it into the testing machine. This series of such movements requires, for high dimensions panels, an additional arrangement, similar to that presented in the following figure:

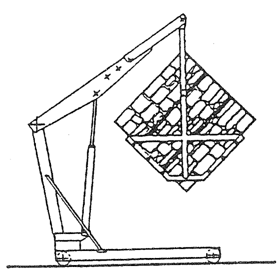

Fig. 1 Lifting of the specimen (from Vignoli, 1989)

Nevertheless, the manœuvres can produce microcrack in the panel, and the damage can invalidate the test results.

(b) Quite often the failure mode in a diagonal test is by crushing of the surface bonding material and the block near to the loading shoe. This failure appears both in hollow and normal clay brick and block panels: a reinforcement of the loaded corners of the panel, filling with mortar the block in contact with the loading shoes (Gazzola et al., 1989) or using large shoes (Vignoli et al., 1989), can modify the stress field, that is strongly influenced by the panel side/shoe length ratio (Bernardini et al., 1978). Diffent testing procedures, based on the Brazilian test, have been proposed to obviate the loading ends crushing (Bernardini et al., 1982; Drysdale et al., 1982).

LABORATORY DIAGONAL TESTS

Four diagonal tests were performed by the authors on square panels, build up with industrial clay bricks and cement mortar. The tests were performed on 53x53 mm, seven course high panels, according the scheme reported in the following figure:

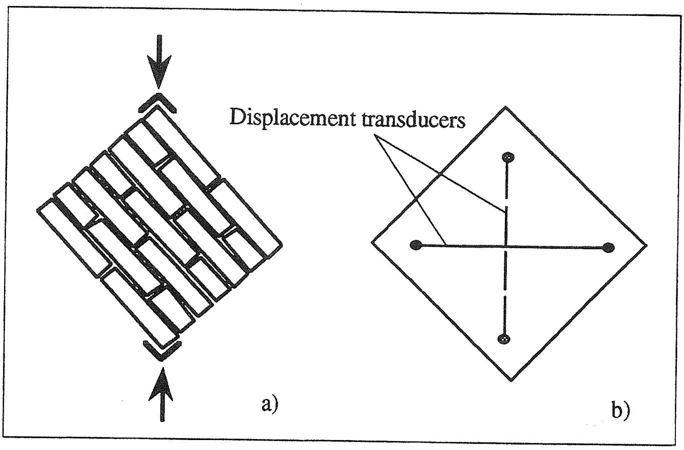

Fig. 2 Arrangement of the panel for the laboratory tests

Steel loading shoes, L-shape 60x60x6 mm, were utilized. An hydraulic servo-controlled testing machine was used to apply the compressive load to the panel. Two displacement transducers, 600 mm length, arranged as in fig. 2.b, were applied to the opposite side of the panel, in order to measure diagonal overall deformations. The mechanical properties of the bricks and the mortar employed are shown in the following table:

Brick properties	
Dimensions	55x125x260 mm
Compressive strength	45 N/mmq
Mortar properties	
Compressive strength	32 N/mmq
Indirect tensile strength	6 N/mmq

Table 1. Material properties

Fig. 4 contains the stress strain results for the four bricks panels tested.

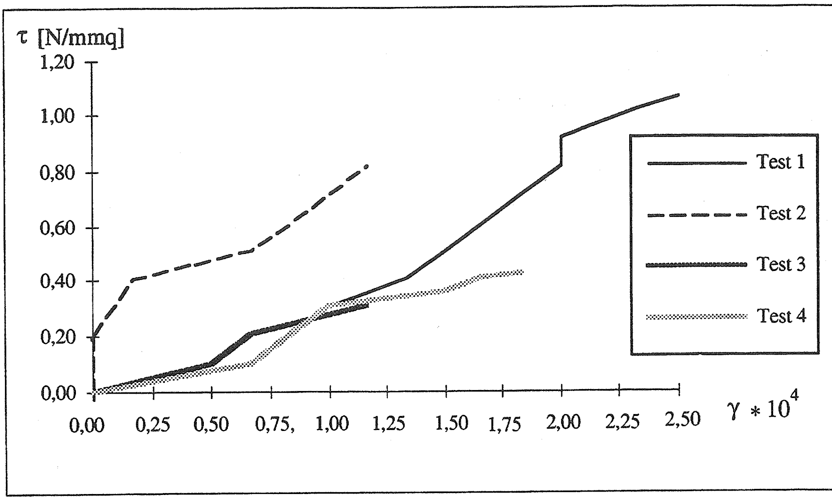

Fig. 4 Stress-strain relationship for the diagonal tests performed

The curves were drawn according to the definition of shear stress given in the introduction, while the shear strain is calculated according to the following definitions:

γ shear strain ($\gamma = \frac{h+v}{d}$)

τ shear stress

γ_u ultimate shear strain

τ_u shear strength

G shear modulus ($G = \frac{\tau_u}{\gamma_u}$)

d vertical measure base (600mm)

h horizontal strain over the 600 mm gauge length

v vertical strain over the 600 mm gauge length

A summary of the results is given below:

	γ_u	τ_u	G
Test 1	$2{,}50 \times 10^{-4}$	1,07 N/mmq	4300 N/mmq
Test 2	$1{,}17 \times 10^{-4}$	0,92 N/mmq	7800 N/mmq
Test 3	$1{,}17 \times 10^{-4}$	0,40 N/mmq	3400 N/mmq
Test 4	$1{,}83 \times 10^{-4}$	0,42 N/mmq	2300 N/mmq

Table 2. Summary of test results

DISCUSSION

The results of the laboratory tests do not provide statistically congruent results. The values of shear strength and ultimate shear strain in the four tests performed by the authors are in fact strongly different: the failure mode in the panels 3 and 4 was characterized by crushing/splitting of the bricks at the loaded ends, while the panels 1 and 2 exhibited the diagonal shear failure. The failure due to crushing at loaded end is often present: in the diagonal tests performed on hollow block panels (Gazzola et al., 1989) this failure cannot be excluded, though a better tensile behaviour can be expected because of the different bonding conditions between mortar and blocks. This result is influenced not only by the quality of the bricks or by the way of performing the test, but it is linked to the particular state of stress induced in the panel. Considering that the shear strength of masonry can be provided performing different tests, and in view of the good agreement obtaned between the results of both diagonal test and laboratory methods producing more uniform stress in the panel (Bernardini et al., 1980), *"It would better to devise a test method in which the stress field is well defined and uniform, so that the material strength is obtained rather than the shear strength of a typical wall"* (Hendry, 1987).
It must be noted that the diagonal test provides quite good results for masonry panels in which the there exist a strong difference between the mechanical properties of bricks and mortar. Simpler tests, such as uniaxial compression on panels or prisms would be preferable: suitable relations between diagonal tensile strength and strength characteristics normal and parallel to the bed joints have been proposed (Drysdale et al., 1982).

CONCLUSIONS

- The performing of the diagonal test on masonry panels involves a series of difficulties in manoœuvring the specimen and provides a wide range of different results, according to the different test arrangement an to the different materials employed;

- A more reliable laboratory test, involving uniform stress field in the masonry panel, would be necessary to evaluate shear strength of masonry;

- Code Requirements should report detailed instructions to allow a comparison between experimental data and fixed standards.

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