Mechanical Characterization of Adobe Masonry Walls

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Abstract. Many of the existing adobe constructions in Aveiro district are in the imminence of ruin, due to pronounced structural damage. This generalized negligence results, on one hand, from the lack of sensibility for the importance of preservation of this cultural and historical heritage and, on the other hand, from the limited existing knowledge concerning the mechanical behaviour and structural pathologies of these structures. In this context, it is recognised the urgency for the development of research work in the structural analysis, rehabilitation and strengthening of this important legacy.

To help filling the technical information gap concerning the structural behaviour of adobe constructions, a group of researchers from the University of Aveiro has been developing studies and tests regarding the mechanical characterization of the material components and of the adobe masonry structural elements. This article describes tests conducted on small wallets that were constructed at reduced scale (1:3) with materials representative of those found in existing constructions, and presents the principal obtained results, discussing them. These wallets have been submitted to compression tests, perpendicular and diagonal to the bed joints. The achieved results help on the structural behaviour characterization of existing adobe masonry structures, and can thus support future rehabilitation and strengthening interventions, and even support the design and execution of new edifications.

Introduction

Adobe is a construction material that possesses many attractive characteristics. It is a low cost material, locally available, biodegradable, reusable, suited to a wide range of soils, presents excellent thermal and acoustic properties, and is associated to quite simple and expeditious constructive methods that only require a small consume of energy. It is indeed an economically viable material, and its use respects the environmental equilibrium. Adobe traditional constructions, however, if not properly designed and strengthened, may present a deficient structural behaviour, namely when subjected to cyclic actions, as those induced by earthquakes, suffering severe structural damage and frequently reaching collapse.

Aveiro district possesses a vast traditional adobe constructed park, which constitutes an important architectonic and cultural heritage (Fig. 1). This constructed park, although, is not properly reinforced to resist to seismic actions, suffering of various structural anomalies and deficiencies. Structural rehabilitation of the existing adobe constructions in Aveiro district is thus demanded, and constitutes an urgent matter. To support future rehabilitation and strengthening projects, technical studies for the determination of properties and characteristics of the mechanical behaviour of the existing adobe constructions are necessary [1].

Figure 1: Examples of existing adobe constructions in Aveiro.

Mechanical Characterization of Small Wallets

Introduction. A research group of the Civil Engineering Department, from the University of Aveiro, has been developing studies and experimental tests to aid filling the technical information gap concerning the structural behaviour of existing adobe constructions. Small wallets, constructed at scale 1:3, with representative materials of those found in existing adobe constructions, were subjected to compression tests, perpendicularly and diagonally to the bed joints.

Specimens Construction and Testing. To estimate the compressive and shear strength of adobe traditional masonry walls, 13 small wallets with 17×17×10cm were constructed and submitted to compression tests, perpendicular to the bed joints and diagonally (Fig. 2).

a) b)

Figure 2: Compression tests on small wallets, a) perpendicular and b) diagonal to the bed joints.

Wallets were constructed at a reduced scale (1:3). Wallets were fabricated with prismatic adobe blocks with dimensions 17x10x5cm, extracted from adobe units taken from three existing constructions (house 5, house 10 and wall 10). The mortar used has a similar composition than the traditionally used in adobe constructions. The adobe units had an average compressive strength in the range between 0.77 and 1.72MPa, and the mortar an average compressive strength of 1.42MPa.

In the wallets, adobe blocks are disposed in three horizontal layers. The upper and lower layers are constituted by an entire block with dimensions 17x10x5cm, and the middle layer by two halves with a vertical joint in between (Fig. 2). The joints' thickness is proportional (1:3) to the joints typically found in existing adobe constructions (1cm, approximately).

Results Presentation and Interpretation. Shear and compressive strength, elasticity modulus and strain at peak strength of each wallet were estimated from the stress vs. strain curves obtained in the compression tests. The shear strength (S_S) is calculated, for each wallet, using Eq. 1 [2]:

$$S_S = \frac{0.707 \cdot P}{A_n}. \tag{1}$$

where P is the load at failure, and A_n is the net area of the specimen. A_n is calculated using Eq. 2:

$$A_n = \frac{l+h}{2} \cdot t \cdot n \,. \tag{2}$$

where t is the wallet thickness, l and h the face dimensions, and n is the solid fraction of the specimen gross area (in this case, n = 1, as the adobe blocks are solid). The compressive strength (S_C) is calculated, for each wallet, using Eq. 3:

$$S_C = P / A. \tag{3}$$

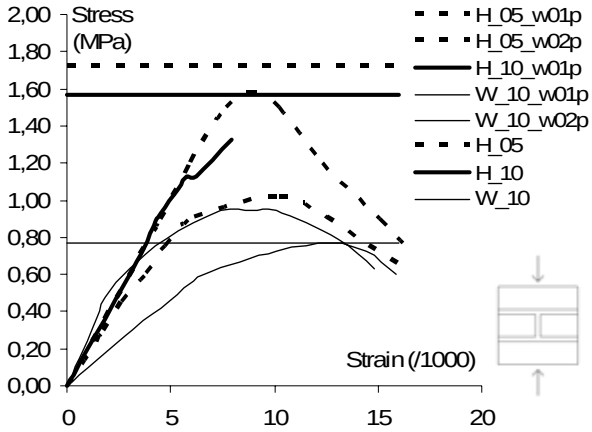
where P is the load at failure, and A is the cross sectional area of the specimen.

The values obtained in each test are summarily presented in Table 1, and the stress vs. strain relations are presented in Fig. 3. The graph with the results of the compression tests perpendicular to the bed joints also presents the compressive strength of the used adobe units.

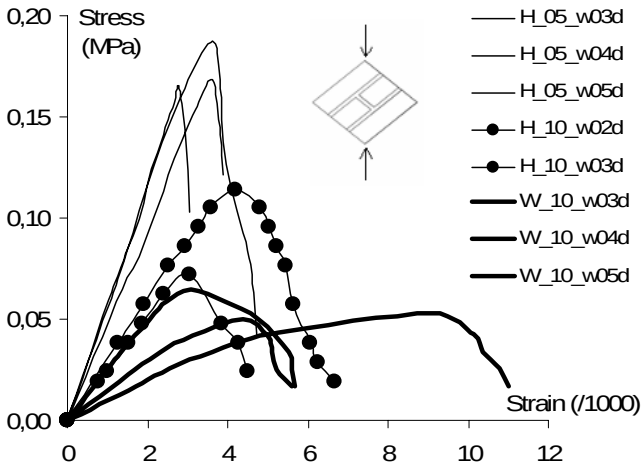
Results obtained from the tests

Specimen				Modulus of Elasticity [MPa]	Compressive Strength [MPa]	Transversal Modulus of Elasticity [MPa]	Shear Strength [MPa]	Strain at Peak Strength [‰]
House 5	Adobe		Average	448	1,72	--	--	6
	Wallet	perp.	H_05_w01p	170	1,02	--	--	17
		perp.	H_05_w02p	200	1,57	--	--	16
		diag.	H_05_w03d	--	--	47	0,17	4
		diag.	H_05_w04d	--	--	57	0,17	3
		diag.	H_05_w05d	--	--	55	0,19	5
			Average	185	1,30	53	0,18	--
House 10	Adobe		Average	334	1,57	--	--	7
	Wallet	perp.	H_10_w01p	200	1,33	--	--	8
		diag.	H_10_w02d	--	--	25	0,07	4
		diag.	H_10_w03d	--	--	30	0,11	7
			Average	200	1,33	28	0,09	--
Wall 10	Adobe		Average	127	0,77	--	--	11
	Wallet	perp.	W_10_w01p	95	0,77	--	--	16
		perp.	W_10_w02p	250	0,95	--	--	15
		diag.	W_10_w03d	--	--	25	0,06	6
		diag.	W_10_w04d	--	--	15	0,05	6
		diag.	W_10_w05d	--	--	10	0,05	11
			Average	173	0,86	17	0,05	--

Table 1: Main results obtained from the mechanical characterization tests on small wallets.



a)



b)

Figure 3: Stress vs. strain relations obtained in compression tests on small wallets, a) perpendicular; and, b) diagonal to the bed joints.

The compressive and shear strength obtained from compression tests on wallets are between 0.77 and 1.57MPa, and between 0.05 and 0.19MPa, respectively. For the wallets constituted by adobe units with a lower compressive strength, lower shear and compressive strengths were obtained. Transversal modulus of elasticity and shear strength, for each series of tested wallets, are about 1/10 of the corresponding modulus of elasticity and compressive strength evaluated in compression tests perpendicular to the bed joints.

Final Considerations

The work presented in this paper is part of a research project [3,4,5,6] that has been developed by a group at the Civil Engineering Department from the University of Aveiro and that aims to establish a basis of knowledge that can support the interpretation of observed structural pathologies, calibration of numerical models, structural safety assessment, and design of strengthening solutions adequate for existing adobe constructions, and even support the design and construction of new edifications. Even though this research is focused in adobe constructions of Aveiro district, it may have repercussions in all regions of Portugal where earth construction appears with a significant expression (namely in Beira Litoral, Algarve and Alentejo), and also in other parts of the World with similar constructive systems.

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References

[1] R.S. Hernandez, M.S. Barrios and J.M.M. Pozas: Materiales de Construcción Vol. 50(257) (2000), pp. 33–45.
[2] RILEM: *Technical Recommendations for the Testing and Use of Construction Materials* (E & FN Spon, London 1994).
[3] H. Varum, T. Martins and A. Velosa: Caracterização do adobe em construções existentes na região de Aveiro. *Proc. of IV SIACOT Seminário Ibero-Americano de Construção com terra and III Seminário Arquitectura de Terra em Portugal*, edited by ARGUMENTUM, Monsaraz (2005), pp. 233–235.
[4] H. Varum, A. Costa, H. Pereira and J. Almeida: Ensaios de caracterização do comportamento estrutural de construções existentes em adobe. *Proc. of V SIACOT Seminário Ibero-Americano de Construção com terra and I Seminario Argentino de Arquitectura y Construccion con tierra*, edited by R. Mellace, J.A. Voltan, S.A. Cirvini, G.M. Viñuales, C.M. Neves, R. Rotondaro and E. Montaña, Mendoza (2006), pp. 73–74.
[5] H. Varum, A. Costa, H. Pereira and J. Almeida: Comportamento estrutural de elementos resistentes em alvenaria de adobe. *Proc. of I Seminário Arquitetura e Construção com Terra no Brasil and IV Seminário Arquitectura de Terra em Portugal*, Ouro Preto (2006), pp. 1–8.
[6] H. Varum, A. Costa, H. Pereira, J. Almeida and H. Rodrigues: Avaliação experimental do comportamento estrutural de elementos resistentes em alvenaria de adobe. *Proc. of III Congreso Internacional de Arquitectura en Tierra*, Valladolid (2006).