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Assessment of the initial shear strength of brickwork facade – concrete slab interface

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HIGHLIGHTS

- Experimental study to assess the initial shear strength of brickwork facades.
- Experimental results differ from the provided by EC 6 for brick masonry.
- More conservative values might be considered in the EC 6 for brickwork.
- The brickwork facade - concrete slab contact plane has been studied.
- EC 6 might take into account the shear strength in the brick-concrete interface.

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ABSTRACT

Among the different existing types of current facades, the most traditional are usually built in masonry either standing on or hanging from the building's main structure. Facades must withstand not only gravitational loads but also horizontal ones, such as winds that can affect their stability. These loads must be taken into account along with those considered in seismic zones. The aim of this work is to assess the initial shear strength of brickwork facades under horizontal loads through shear tests. The interfaces studied are brick–mortar–brick and brick–mortar–concrete, the latter of which represents the support of facades on concrete slabs, a topic which is not widely dealt with in current research or standards. Several triplets and prisms, manufactured with two different configurations and using two types of mortar, were tested. Through this study a possible weak plane, constituted by the support of the brickwork facade on concrete slabs, was found, which is not contemplated in the existing standards.

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1. Introduction

1.1. Initial shear strength of brickwork

The shear strength of a wall is related to the friction stresses that generate oblique fissures or to tangential stresses that produce sliding in the mortar joints [1]. It was observed in early investigations that shear strength varied approximately linearly with precompression, a result of the application of the Mohr–Coulomb criterion, which takes into account the mortar–brick cohesion and the friction developed in the interface.

During recent years the interest in determining the shear strength has attracted great interest [2–5]. The shear strength has been determined experimentally using a wide range of tests [6,7], or it can be determined according to standards [8–12], each one with its particularities, and for specimens that range from two units laid with mortar [13–15], to tests on buildings of several floors to scale 1:1 [16]. The latter are presented as ideal, given that with them the behaviour of the brickwork of a real building can be reproduced nearly exactly. However, tests with small and medium-sized test pieces are the most widely used, due to the savings in expense, time and equipment they provide.

According to Eurocode 6 (EC6), the design value of shear strength depends not only on the geometry of the pieces used, but also on the initial shear strength and the coefficient of friction. Usually, with a test programme in accordance to UNE-EN 1052-3 [10], it is possible to characterize these parameters. In this sense, Tomazevic [3] developed an extensive study about their determination focusing on modern ceramic materials and mortar. This research was carried out using the UNE EN 1502-3 standard (procedure A), and it highlighted that the values of initial shear strength seemed not to depend greatly on the strength of the mortar used. Moreover, it was observed that there was direct correlation between the initial shear strength and the geometry (volume of holes) or the compression strength of the unit used. Zimmermann et al. [4] also carried out a programme of tests, focused on old buildings, with different mortars. Jonaitis et al. [17]

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analyzed the compatibility between the results obtained from an investigation performed on walls made of hollow blocks of calcium silicate and those found according to the technical rules of EC 6 and of Lithuania. They all found that the values of initial shear strength (f_{vko}) found in their research were below the values suggested by EC 6.

1.2. Shear performance of brickwork facades

As is well known, brickwork facades are usually found to be under the action of horizontal loads, such as wind action (pressure or suction), originating tangential stresses among the elements used for construction. Knowledge of the shear behaviour is necessary if the aim is to design a brickwork facade whose dimensions surpass what would be considered habitual; for example, windowless masonry panels with a thickness not less than 0.09 m, of up to 3.0 m in height and with length no greater than twice their height [18]. This is done to ensure the stability of the facade and the transmission of the horizontal loads which they undergo. Even so, recent works demonstrate that from values of 2.6 m in height, engineers and architects should pay special attention to the conditions for supporting the facade, both at the vertical edges (the columns of the structure) and the horizontal ones (the slabs, Fig. 1). In this sense, with the aim of bringing to light the most common levels of stress, displacements and cracking that usually occur in standard three-story brick facades under wind-induced loads, Cubel et al. [19] used finite element models to suggest a series of recommendations for design and construction of brickwork facades.

Up to now, there have been few studies in which the brickwork–concrete slab interface has been considered, so it is necessary to carry out some detailed studies in order to understand its mechanical behaviour and how this behaviour is affected by different parameters (types of mortar, preparation of the concrete surface, etc.). The interface between the brickwork and the concrete in some cases constitutes the weakest plane due to its low traction and shear strength, being susceptible to cracking under applied loads [3].

Eurocode 6 [20], when analyzing brickwork walls under lateral loads, highlights that the construction project must consider the effect of anti-humidity barriers in relation to the conditions of support and continuity of brickwork resting on them. In this sense, Mojsilovic carried out a study [21] to evaluate the influence of Damp-Proof Courses (DPC) on structural behaviour, especially shear behaviour in the plane of the unreinforced brickwork walls. Premadasa et al. [22] also carried out an experimental study with the aim of understanding the mechanical behaviour and the effect of different parameters in the brickwork–concrete slab interface.

The previous references have motivated the authors to provide information about a possible weak plane in brickwork facades under lateral loads, which was brought to light by an experimental programme carried out in laboratory. The findings could be taken into account in the design of facades made up of brickwork supported by a concrete slab (brick–mortar–concrete contact). Moreover, with the aim of optimizing the situation when the shear strength value in the brickwork–concrete support interface is not sufficient, additional tests were done improving the mortar–concrete adherence, through wire brushing or, creating a toothed joint in the masonry–concrete slab interface.

This work aims to evaluate the initial shear strength of brickwork facades made up of fired glazed clay bricks under lateral loads (wind) through shear tests. Moreover, the study will compare these values with those provided by EC 6. The EC 6 values, which are nowadays used by architects and engineers in the absence of experimental values, depend on the strength of the mortar and the type of the pieces.

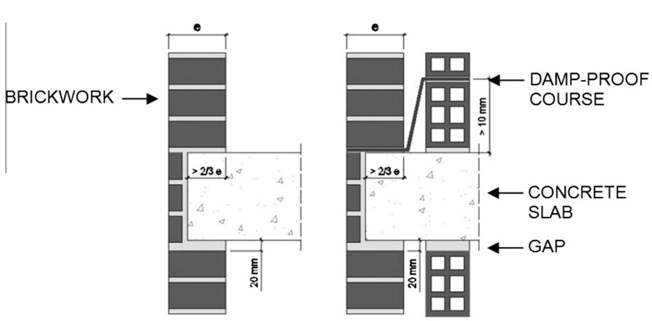

Fig. 1. Examples of brickwork exterior walls supported directly on the concrete slab [18].

2. Experimental programme

2.1. Materials

According to EC 6 [20], the bricks used in the manufacture of the specimens are clay units, category I, group 2 (approximately equivalent, in terms of net cross-sectional area, to Engineer Modular brick, H40V, Single Fired Glazed Brick exterior according to ASTM C 1405 [23]). Fig. 2(a) and Table 1 list some of their technical characteristics (the commercial name is Fired Glazed Covadonga-type brick). With the aim of finding their compressive strength, and taking into account that no breakage of full sized units occurred during the tests because the hydraulic press used did not have enough capacity, several half bricks were tested [24], Fig. 2(b). An average compressive strength of 101.6 MPa was obtained; the coefficient of variation (δ) was 9.39%.

Two types of mortar were used. The first was a general purpose M8 masonry mortar in accordance with Eurocode 6 [20] (equivalent to a type S Masonry Cement according to ASTM C270-12a [29]), habitually used in exterior facades. It was made with Portland IV-35 cement [30] and 0/2 sand [31] from the Candesa Quarry, materials that are habitually used in the region (Cantabria, Spain) where the tests were performed. With the aim of finding out their compressive strength, prismatic test-pieces were made of 160 mm × 40 mm × 40 mm, which were manufactured and stored in accordance with UNE-EN 1015-11 [32]. The mixing procedure and consistency of the mortar fulfilled UNE-EN 998-2 [33]. The samples were tested after 28 days, determining the compressive strength of the mortar after the same time as the brickwork specimens. An average compressive strength of 8.40 MPa was obtained; the coefficient of variation (δ) was 4.68%.

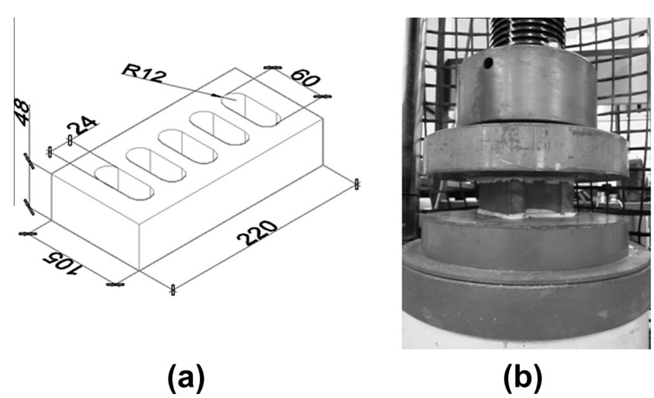

Fig. 2. (a) Dimensions in mm of the Fired Glazed Covadonga-type brick used in the tests and (b) compression test carried out on half bricks.

Table 1
Technical characteristics of the Fired Glazed-Covadonga type brick used to manufacture the specimens.

Property	Values guaranteed by the manufacturer	Values required by the corresponding Standard
Absorption of water (%) [25]	⩽5	⩽6
Suction (kg/(m^2 × min)) [26]	⩽0.40	⩽0.40
Compressive strength (MPa) [27]	⩾50.0	⩾40.0
Mass (g) [28]	⩾1600	⩾1380

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