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Structural characterisation of textile ceramic technology used as a curtain wall

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ABSTRACT

Textile Ceramic Technology (TCT) is a system composed of ceramic units installed in a grid of steel wires. TCT application as a curtain wall which allows ventilation is expected to be an inexpensive, aesthetic and sustainable solution. In order to use TCT as a curtain wall, experimental research about the mechanical response of hanged TCT panels is required. The main aim of this paper is to present the results of this experimental work. Different loading conditions corresponding to gravity and wind forces have been applied on typical TCT panels and the results point out that TCT is sufficiently mechanically competent to be used as a curtain wall. The application range and limitations are summarised.

1. Introduction

Ventilated façades, used because of their energy performance and durability, are typically composed of three layers, namely the internal building façade, an isolation material layer stuck to the internal façade and the external façade which is commonly placed leaving a gap with the insulation layer so that an air cavity is created. This multi-layered structure contributes significantly to the energetic efficiency of the building and to its thermal insulation. This advantage has been proved by López et al. [1] or Seferis et al. [2], among others, and has been specifically noted for ceramic cladding by Stazi et al. [3]. However, the use of ceramic claddings requires normally a manual procedure for placing the external façade and this is one of the main drawbacks that contribute to increase the cost of the system. Nowadays, most of the external façades are curtain walls composed of plates connected to a lightweight structure attached to the building main structure and leaving an air gap allowing the ventilation. Thus, an industrialised solution to improve the production and placement of this curtain walls is necessary. In this way, some rigid panels of bigger dimensions have been used [4]. The application of textile reinforced concrete in the panels production is also noticeable [5]. Moreover, innovative connection systems have been designed as in [6] or [7]. However, a more flexible option is herein presented, namely Textile Ceramic Technology (TCT[1]) applied as a façade.

TCT is a technical material composed of high strength steel wires and ceramic pieces specifically designed for this application. TCT consists of a mesh of steel wires that are woven to form a fabric with irregular wire density, and ceramic bricks or thin light-weight plates inserted within the voids of this steel grid. This system was developed and patented by a research group at *Escola Tècnica Superior d'Arquitectura* of *Universitat Internacional de Catalunya* (ESARQ-UIC) [8]. Fig. 1 shows a general view of TCT applied to a curtain wall. TCT elements can be folded or rolled, transported easily and suspended from the top of a building to form a ventilated façade system. For curtain wall application, stainless steel wires and lightweight ceramic pieces are used.

TCT was developed to build thin structural masonry shells like those by Eladio Dieste in South America. The mechanical behaviour of TCT when a rigid joint is casted between the pieces is similar to reinforced brick masonry as analysed in [9] or [10]. Its satisfactory results led to conceive other innovative applications of this masonry production system. So far, TCT has been successfully used to build vaulted roofs and pavements. One of the main potential applications of TCT is found in the construction of curtain walls for buildings. However, the use of the system for this application requires a previous specific research, presented in this paper, regarding the supporting and fixing conditions to the structure. It must be noted that, in its application as curtain walls, TCT is used with no mortar or any other sealing at the joints, so that its strength and stability depend exclusively of the mechanical characteristics of the steel mesh and its connection to the building structural system. For all these reasons, a detailed experimental

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Fig. 1. External TCT curtain wall (www.flexbrick.es).

campaign was necessary to characterise the behaviour of this system and to design the needed construction details. The main aim of the present paper is to present and discuss the experimental data in order to validate the use of TCT as a curtain wall.

It must be also noted that the system herein presented differs from all other commercially existing construction system for external façades due to its genuine combination of steel meshes and bricks. Thus, the result, which includes an air gap between the flexible curtain wall and the building structural façade, does not really fit to the definition of a ventilated façade.

The study followed an experimental approach involving static tests on each different component and dynamic tests on the weaker parts only. Among the specific aims of the research was the determination of the load-bearing capacity of each component and connection, characterising the global behaviour of the system and proposing some design criteria useful for real applications.

The construction of a TCT curtain wall requires a set of complementary elements. The developed system includes three main parts: the mesh connection element which is fixed at the upper horizontal edge of the TCT sheet; the hanging element which holds the mesh connection element and, thus, supports all the weight of the TCT at the upper end; and the retention element whose aim consists of restraining the out-of-plane movements of the curtain and keeps the TCT sheet at a fixed distance from the building structure. A sketch of these auxiliary elements is shown in Fig. 2. As part of the present research, each one of these elements was tested up to failure under quasi-static loading, and the weaker one was also tested under dynamic loads. The description of each test and the specimens used are presented in the subsequent sections.

Assuring a favourable behaviour of TCT when used as curtain wall may foster the use of this faster and cheaper covering system for energetic sustainable façades. The final purpose of the study is to provide useful test setups for this kind of structure components

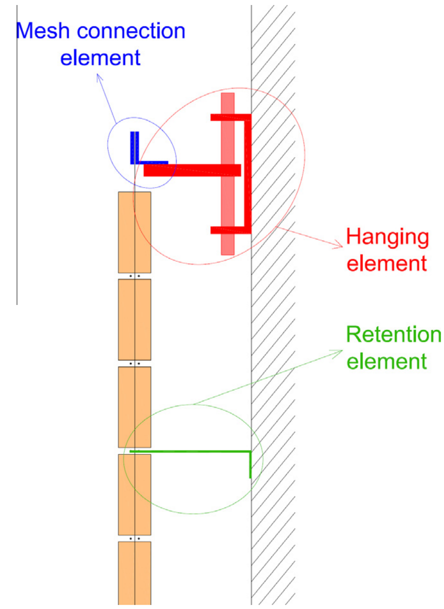

Fig. 2. Sketch of the characterised parts of a TCT curtain wall.

and, even more important, to give some design and construction guidelines in accordance with the loads that the curtain wall is expected to resist. These include the self-weight of the TCT mesh with its ceramic pieces, which is approximately 0.1 kN/m^2, and wind pressure. The seismic loading conditions are not considered in this paper because the system is oriented to be applied in non-seismic or moderately seismic areas as the ones where unreinforced brick masonry walls are commonly used as building enclosure (e.g. Spain where the system has been developed). Its application in seismic areas will require further investigation because of the large oscillations that this type of curtain wall might experience.

2. Materials and methods

The components used to fix the TCT curtain wall to the building main structure are defined in this section. The test procedure used for testing each element is also described.

2.1. Testing the mesh connection element

The mesh connection element consist of an "L" steel profile and several little steel plates which are screwed to the "L" profile by pressing the steel wires of the TCT mesh. The joint between the wires (and so the TCT mesh) and the mesh connection element fully relies on the friction between the parts.

Pull out tests were done to determine the load bearing capacity of this type of connection. Two different configurations of the mesh connection element were tested depending on the number of wires held by one plate. A common TCT sheet, of a width of approximately 1 m, includes two lateral joints and three interior ones. Each steel plate in the connections is used to fix three wires, in the case of the interior joints, and only one in the case of the lateral joints.

For the pull out test a symmetric sample configuration was used. Two equivalent mesh connection elements were simultaneously tested at the same time. No ceramic elements were placed inside the mesh during these tests. The samples can be observed in Fig. 3 and their main characteristics are summarised in Table 1. All plates had dimensions of 68 mm × 30 mm × 4 mm and the "L"