PLANKED TIMBER FLOOR SLABS WITH CERAMIC DEMOLITION WASTE

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ABSTRACT

The present work is the continuity of the research carried out by the group TEP 205, "Analysis and evaluation of construction and structural systems in Architecture", focused on domestic architecture building typologies of cities as Seville or Cordoba from the seventeenth to the twentieth centuries.
The aim of the study, mainly experimental, is to develop a new infill piece, from the reuse of ceramic waste generated in demolition works. This piece is intended to be used in the floors of this building typology.
Different test models reproducing the geometry and structural characteristics of these slabs have been developed. In these models different dosages of mortars and geometries are studied, in order to achieve the necessary strength for their use on the building site. As a result, we have developed a piece in which resistance values reaches up to 137 Kgf, higher than the values required to prefabricated concrete slabs according to regulations.

Keywords: rehabilitation, floor structures with infill between beams, recovery of ceramic waste.

1.- Introduction

The construction sector is currently enduring an environmental crisis on many levels. Constructed buildings are a direct cause of pollution in that they produce waste and consume large quantities of energy. Construction and demolition waste (CDW) is generated in the life-cycle of a building but this mainly occurs during the demolition and rehabilitation phases [1]. So, in terms of construction, any proposal for the rehabilitation of a building presumes fairly intensive building activity.

In this sense, the Spanish National Waste Plan (PNIR 2008-2015) try to promote the demand of products made with CDW, especially with recycled aggregates. The feasibility of using waste from construction and demolition has been studied in numerous research papers. These works have developed studies about concrete blocks [2, 3, 4], pieces of pavement [5] and as subbase material in road construction [6]. Also, there are currently studies on the use of demolition waste (CDW) for the manufacture of infill blocks of non-structural concrete, in which recycled aggregates replace natural ones in different percentages. [7].

The aim of the present work is to study the possibilities of reusing the demolition waste generated from the rehabilitation works of residential buildings in the historic center of cities as Seville and/or Cordoba, in southern Spain. These buildings are traditionally described as Domestic Architecture made popular between the 17^{th} and 20^{th} centuries (fig 1).

Fig. 1 “Domestic architecture façade type in the historical areas of cities as Seville or Cordoba”. Source: the authors.

In this case, the reuse of demolition waste is addressed to produce a new piece to incorporate in the slabs of these buildings (fig. 2). It is an element with a curved soffit to fill the space between the timber beams. It has the possibility of being implemented in this building typology. None of the above cited papers have studied the development of light vaults adapted to the specific characteristics of this building typology.

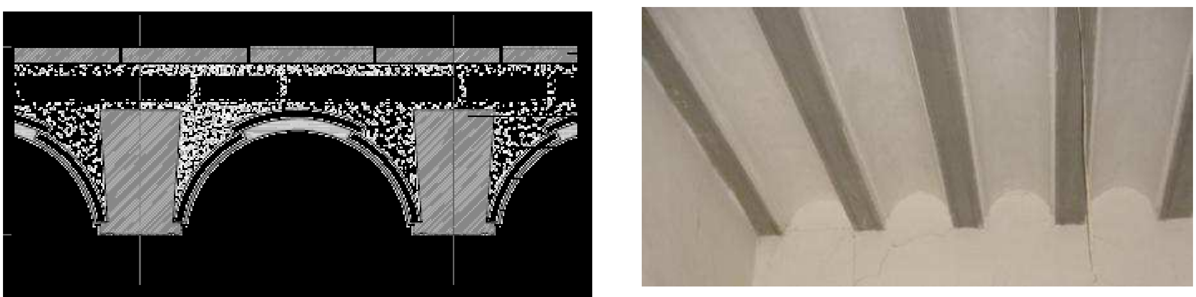


Fig. 2 “Slab systems in the form of squared beam cross-sections and filled-in space between beams”. Source: the authors.

The recovery action required for this type of floor structures is based on the traditional “trencadis” design from the late nineteenth and early twentieth centuries in the Catalan and Levantine areas of Spain. This consists of the use of leftover ceramic pieces, mainly tiles which, together with a formwork system, constitute the infill element (Fig3).

Fig. 3 “Hallway in North Station of Valencia”.

2.- Characterization of the materials used
2.1.- Ceramic waste
The small fragments of ceramic waste used for the production of the pieces mainly come from the demolition of floors and fillers used for the floor structures and slopes in the original roof coverings of this building typology. These fillers are made of “alcatifa”, a waste product composed mainly of charcoal, bits of ceramic and mortar. Ceramic fragments that pass through a 32 mm sieve from this waste are then reused.

2.2.- Mortars
White cement mortar is used to manufacture this new element. The initial mortar dosage is 1:6 (series A). In a second stage it is mixed with EPS as an additive (series B) to lighten the weight of the new element. This additive is incorporated in a ratio of 2% mass with respect to the cement mass. These mortars are characterized by taking samples size 40x40x160 mm. These specimens were then tested for bending and compression according to the procedure described in the UNE EN 1015-11:2000/A1:2007 standard [8]. The results obtained for the different dosages are shown in Table1.
As shown in Table 1, the inclusion of EPS in the dosage reduces mortar resistance considerably both in bending and compression. Furthermore, this dosage (1:6) turns the mortar into sand, so the cement content was increased by adjusting the dosage to 1:5 (series C) thereby obtaining better results, as seen in Table 1.
In the end it was decided to use a White cement mortar with a dosage 1:5 and the EPS was discarded.

Serie	Mortar dosage	**Density (Kg/m^3)** Mean value (CoV, %)	**Bending strength (N/mm^2)** Mean value (CoV, %)	**Compressive strength (N/mm^2)** Mean value (CoV, %)
Serie A	1:6	4621,23 (0,02)	1,32 (11,81)	3,44 (6,19)
Serie B	1:6 with EPS	3988,18 (0,26)	0,60 (7,69)	1,15 (13,48)
Serie C	1:5	4474,06 (0,19)	1,52 (1,01)	4,72 (23,46)

Table 1 “Results for the dosages of the mortars used”.

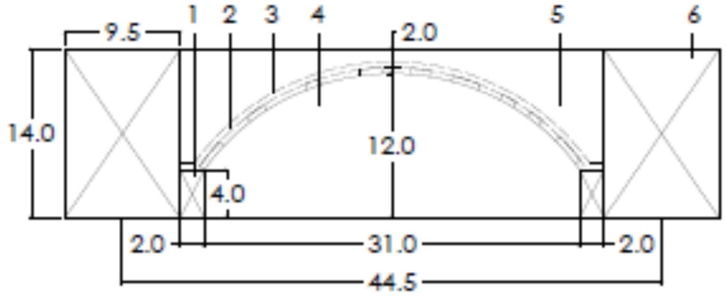
In these dosages, the mortar’s water/cement ratio is high (about 1:1) in order to facilitate workability and bonding with the reused ceramic parts. Further research could use smaller water/cement ratios by adding fluidifying additives.
Before opting for this cement mortar, lime mortar and then bastard mortar were used to manufacture the pieces in an attempt to raise the low resistance previously obtained in the lime mortar. However, the difficult workability of the lime mortar, its long setting time and the resistances in the bastard mortar being less than required led us to discard both these mortar types.

2.3.- Fiberglass

To increase the strength of the pieces we introduced a fibreglass fabric veil. Fiberglass fabric is produced by the same procedure for textile fibers, and is prepared with an anti-alkaline coating. It has a density of 300 gr/m^2 and has great tensile strength, making it suitable as structural reinforcement.

3.- Model design (geometric definition and tipologies)

The main purpose of the model design was to reproduce the real operating conditions of the pieces on site. A mould made of extruded polystyrene was wrapped in a PVC sheet on its top side to facilitate subsequent demoulding. The mould measured 31 cm wide with a height of 14-15 cm of which 12 cm corresponded to the cant height of the slope and 2-3 cm to the height of the piece on its upper side. This design is made for use in works with beams 9-10 cm in width and 14-15 cm in height. These dimensions are used as the most common example of cross-sections of this type of floor structure. However, the cross-section area of the beam was not considered in the design and in the results of the new element, only taking into account the width of the infill. In this case, we have studied the usual infill of approximately 30 cm. Figure 4 shows the model design.
To achieve a simulation of the actual conditions of this element in the building process we proceeded to strap together the piece formed by the mould and the wood pieces that function as floor beams. To test the piece, the mould was removed leaving only the piece and the exterior wooden parts wrapped in banding.



1. Wood slat.
2. “Trencadis” made of ceramic tiles 14x28 cm, reuse from a rooftop.
3. Fiberglass veil.
4. Polypropylene mould.
5. White cement mortar
6. Timber beam

Fig. 4 “Design model”. Source: the authors.

The current configuration of the model is the result of a previous test process. Different moulds with lower cant were studied (10 cm). The last model with a cant of 12 cm work structurally better acting as discharge arc.

4.- Execution process

The mould was made using extruded polystyrene as the base material. Initially the mould was vectorized in a design program and then shaped in the milling machine of the ETSA (FabLab) mock-up laboratory (fig 5).

Fig. 5 **“**Process of designing and manufacturing of the mould”. Source: the authors.

Once the mould was made, it was coated with a PVC sheet to avoid contact with the mortar and facilitate the subsequent demoulding of the piece. Then, to reproduce the work conditions, we placed two pieces of wood measuring 9x14-15x31 cm on both sides of the mould and the strapping in the form of tape was attached to simulate the conditions of the element on site (fig 6). These pieces simulate the floor beams and simultaneously act as permanent formwork.

Fig. 6 “Location of the timber pieces and the mould to reproduce a real slab”. Source: the authors.

After placing the wood pieces and the mould, the ceramic pieces to be reused were arranged. A first layer of about 2 cm mortar was poured and the fiberglass veil put in place (fig 7).

Fig. 7 “New piece production process. a. Placing the recycled ceramic demolition waste. b. Placing the fiberglass”. Source: the authors.

Then, the mould was filled to the height of the wooden beams (14-15 cm). It is very important to fill the upper surface of the slab to the top and get a flat surface in order to achieve a uniform support for the burst test (fig 8).

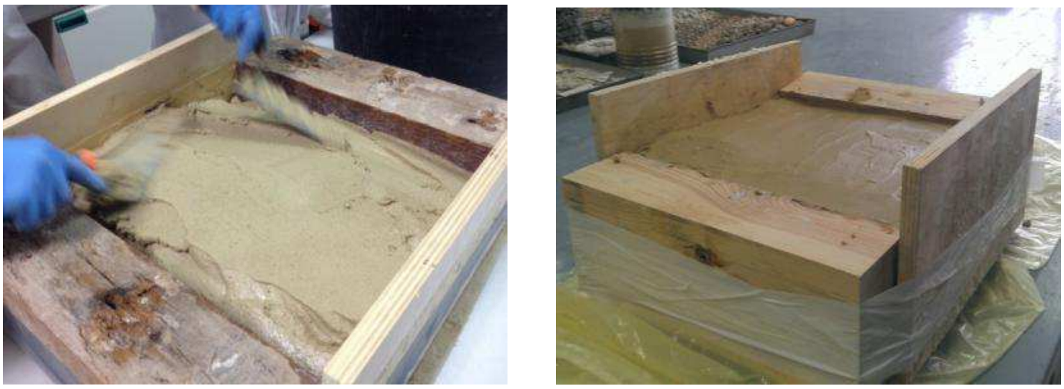


Fig. 8 “Pouring the mortar. a. Filling the upper side to the top to get a flat surface. b”. Source: the authors.

At the end of the production process a 28-day setting time is required for the mortar after which burst tests can be carried out.

Fig. 9 “Finished piece after setting, and ready for burst testing”. Source: the authors.

5.- Tests

There is no standard for testing this item since it is a new element composed of ceramic material and mortar with no specific application norms. So, the procedure followed that described in the UNE 67-042-88 standard [9] for testing large baked clay pieces as there was similarity in the shape of the elements.

This test was made using a press capable of applying the load with a speed of 5 kgf/s, and containing a plate with a two-prop patella, one fixed and the other articulated. The load was applied at the midpoint of a parallelepiped piece of wood measuring 5 cm wide and 3 cm high, and of a length equal to or greater than the width of the piece (fig 9).

According to the standard, the test result was ranked as positive when the specimen was able to withstand a load of 125 kgf without breaking.

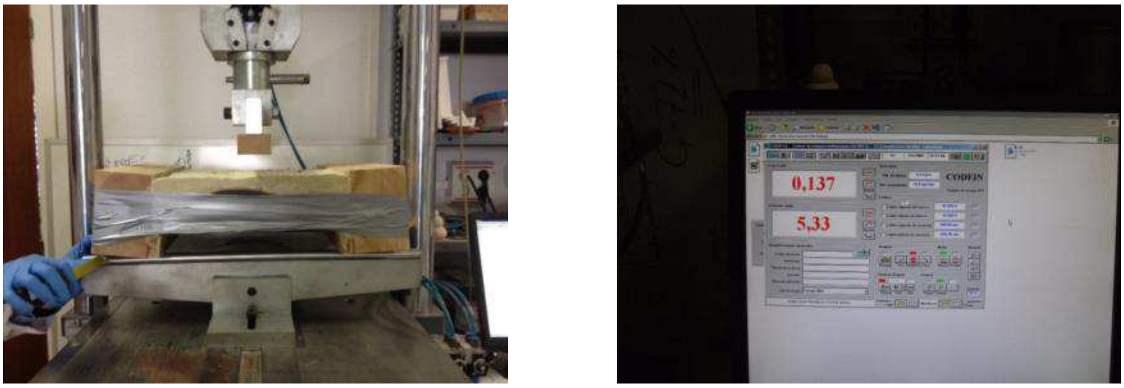


Fig. 9 “Test procedure”. Source: the authors.

Various specimen types with different top layer thicknesses were tested together with various mortar dosages (Table 2).

Piece number	Top layer thicknesses (cm)	Mortar dosage
1	2	1:6 (series A)
2	2	1:6 with EPS (series B)
3	2,58	1:5 (series C)
4	3,12	1:5 (series C)
5	3,10	1:5 (series C)

Table 2 “Types of test pieces”.

6.- Results and conclussions

Test results are shown in Table 3.

Piece number	Tensile strength (Kgf)
1	72
2	25,5
3	96
4	110
5	137

Table 3 **“**Results for the different test pieces”.

From the results shown in Tables 2 and 3 we can see that there is an increasing of resistance as the thickness of the key element is increased. Moreover, the lowest load value obtained corresponds to mortars with addition of EPS. In conclusion, it can be noted that, for the studied wheelbase and a dosage of 1: 5, the thicknesses of key under 2,58 cm don’t provide resistance values adjusted to regulations (1 KN) [10].

Future research should study the optimal keystone thickness in relation to resistance and geometry parameters, as the span of the piece to suit different caseloads that can be generated in the rehabilitation of wood slabs. Likewise, we will study the possibility of increasing the percentage of waste incorporated by the replace of commercial aggregates by recycled ones for the manufacture of mortars.

Furthermore, the difficulty in implementation should be eased by adding fluxing additives to lower the water/cement ratio and therefore increase resistance.

Another aspect to consider is the removal of the fiberglass veil and the measurement of its possible influence on the piece’s flexural strength.

In addition, the lack of a specific standard to test these elements requires the effect of the strapping on the results for the strength parameters to be studied further.

Finally, future works in this area should study the construction process on site.

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