

INNOVATIVE APPLICATIONS OF CERAMICS IN BUILDING REFURBISHMENTS

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ABSTRACT

This paper introduces some novel solutions for the refurbishment of internal and external building envelopes, in which ceramic materials play an essential role. The durability and maintenance-free properties of ceramics make them ideal for use in all weather environments. Furthermore, by suitable control of porosity in ceramic materials, their heat transmission capabilities as building enclosures is improved and greater control of their permeability is achieved. Here below, we present a number of novel ideas, firstly a system that uses large format curved ceramic pieces that enable heating and lighting installations to be integrated into the building; secondly, a system for renewing traditional tiled roofs where the top roofing tiles are replaced with porcelain tiles, thereby improving their heat transmission properties while also enhancing comfort inside the building; thirdly, a façade refurbishment system to fulfil heat transmission requirements based on a Trombe wall, where the ceramic material used renders the entire wall thermally inert; and finally, a system of ceramic roller blinds, which are easy to assemble and transport, to be used in façade refurbishments.

1. INTRODUCTION

In the Ceramics Chair at the University of Alicante, we are committed to searching for new uses of ceramic materials in Architecture. One particularly promising and currently relevant field is building refurbishments.

Spain has a pool of around 14.5 million obsolete homes (3 million of which were built in the 1930s, 3 million between 1940 and 1960, and 8.5 million between 1960 and 1980), which, together with the public areas surrounding them, are on the verge of collapse, with a high degree of deterioration and which do not meet the minimal standards of efficiency, comfort or quality of current demand. At the same time, they are inhabited by an equal number of families, the vast majority of which do not have sufficient resources to solve the problem by acquiring a new home.

In short, it seems clear that refurbishing and restoring the current list of buildings is bound to be a significant task to be dealt with from now on, especially when refurbishment is seen as something that is cyclically necessary when a building is deemed to have a service life of 25-30 years before it needs renewing. That is the time scale that we feel will be required to refurbish the 14.5 million currently obsolete homes at an assumed rate of 500,000 to 600,000 homes/year.

Thus, fully conscious of such reality and of the rate at which house refurbishment is likely to grow in coming years, we have dedicated our research to finding innovative uses for ceramic materials both for domestic and publically-owned buildings.

2. SURFING THE SPACE

The exact relationship between human illness and exposure to pollution is neither simple nor precisely understood. Nevertheless, there does exist plenty of evidence which in general indicates that high concentrations of pollutants in the air are a hazard for human (and animal) health. This project arises from the general need to find a system capable of reducing the amount of pollutants present in the air, especially nitrogen oxide (NO_x), which is so pernicious to the human respiratory system.

The system we present comprises a series of large-format ceramic pieces with a significant curvature along the edges and which are supported mechanically by means of standard metal brackets, so that when walls and ceilings are lined with them, their geometrical shape allows for indirect lighting and air conditioning systems to be fitted behind them.

The result is an image of dynamic visual continuity that is uninterrupted by louvers and grilles.

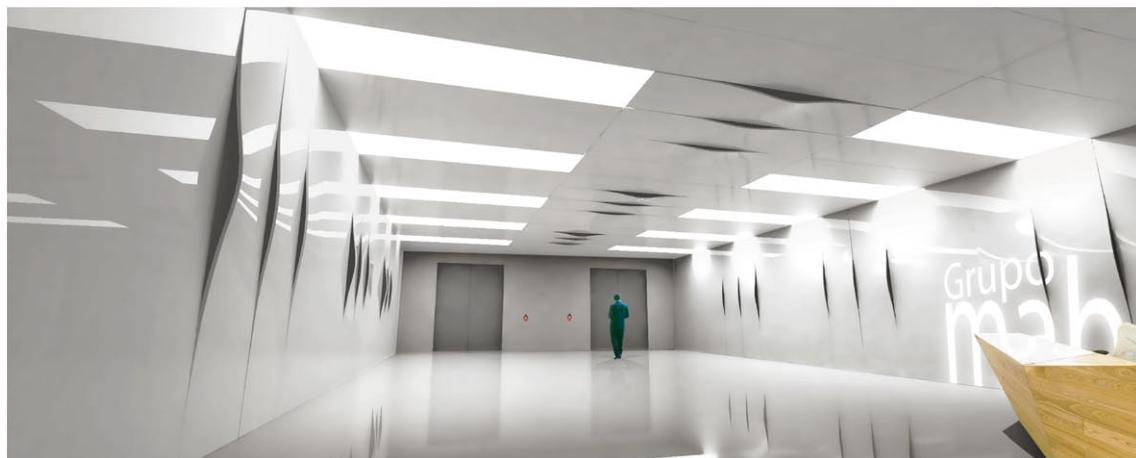


Figure 1

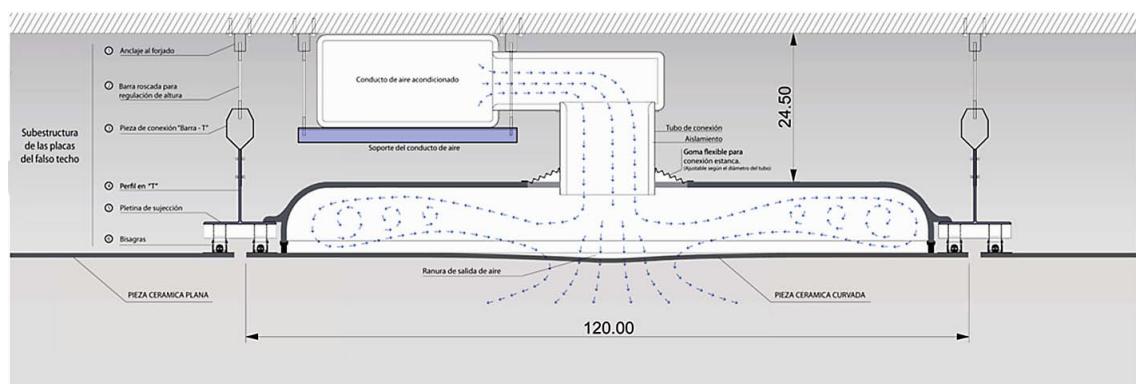


Figure 2

2.1. Special properties: "Active" additive

These ceramic tiles contain an additive known as "ACTIVE" [1]. They are able to significantly reduce the damaging effects of the main air-borne pollutants (CO-NOx-SOx-VOCs) as well as eliminating almost entirely some of the most hazardous bacteria for human health. Thanks to ACTIVE, the ceramic piece acquires the exceptional property of interacting with the environment, helping to purify the air we breathe and to lower the bacterial charge present in flooring and wall claddings in our current habitats, i.e. it becomes an active material, capable of making our surrounding environment more liveable and healthy.

It is estimated that a surface area of 1000 m² of suitably-lit ACTIVE has an equal effect on nitrogen oxide equivalent (NOxe) reduction as that produced by 20 tall trees. Furthermore, 25 m² of ACTIVE wall cladding or flooring, when properly lit, would not only eliminate the bacteria that forms on its surface almost entirely, but also could significantly reduce air-borne pollutants to the same extent as a medium-sized plant with roots growing in the middle of the floor area.



Figure 3

3. GRESPLAN

In response to conventional solutions using concave roof tiles, the system outlined here proposes replacing such conventional tiles with a well-regulated substrate, a waterproof layer, solid extruded polystyrene insulation and two 40x40 cm, 15 mm thick porcelain tiles fixed with resin and laid in such a way as to create a tongue and groove fastening system from the eaves.

The result is a new contemporary design for traditional sloping roofs, with a completely flat finish, made from glazed porcelain tiles that provide a series of additional advantages:

- Easy to clean;
- Enhanced waterproofing, thanks to the inherent characteristics of the material (glazed porcelain tile).
- Wide range of top colours (which even includes the possibility of customising pieces, printed images, etc.).

This GRESPLAN system is mainly designed for refurbishing roofs that do not meet minimal heat transmission standards and that therefore have a negative impact on heat comfort inside the building. It has been calculated to withstand wind suction forces (Spanish Building Code, CTE). Given that the system is much lighter, it would only need to be fastened at the eaves and ridge bar, where wind stress is much higher, for roofs with a tilt of 30° or higher.

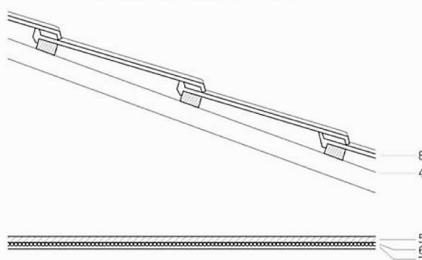
GRESPLAN



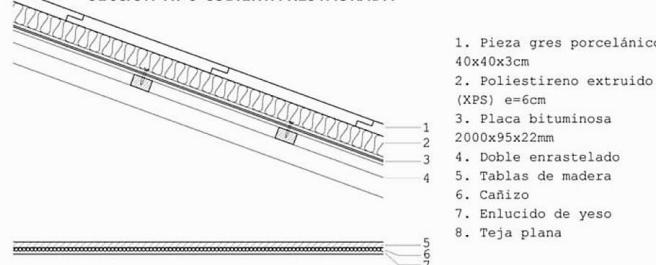
MÁS IMPERMEABLE
ACABADO PLANO
DIVERSIDAD DE COLORES
e incluso posibilidad de impresión de una imagen sobre la pieza.



SECCIÓN TIPO CUBIERTA PREVIA



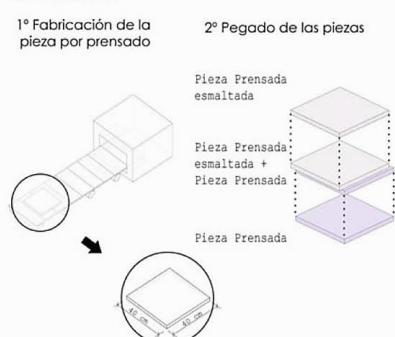
SECCIÓN TIPO CUBIERTA RESTAURADA



TIPOS DE PIEZAS

	Standard	
Medidas	Peso	
40x40x2	6 kg	
40x40x3	10 kg	
Alero		
Medidas	Peso	
40x40x2	6 kg	
40x40x3	10 kg	
Cumbreña		
Medidas	Peso	
40x40x2	6,15 kg	
40x40x3	10,10 kg	

FABRICACIÓN



CÁLCULO DE LA ACCIÓN DEL VIENTO

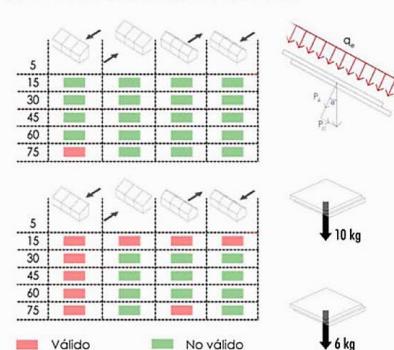
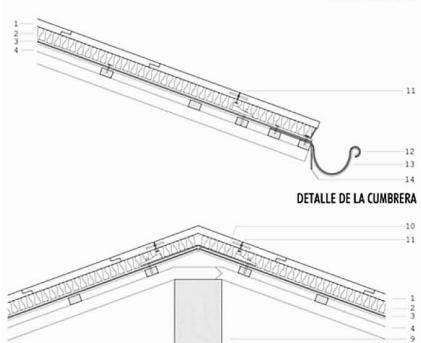


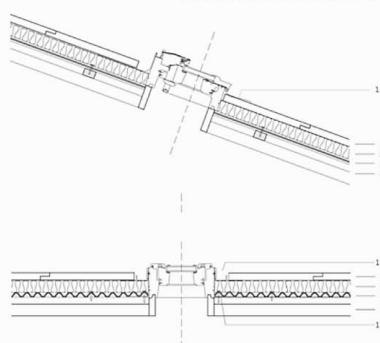
Figure 4

DETALLES CONSTRUCTIVOS



DETALLE DEL AERO

POSSIBILIDAD DE INCORPORAR LUCERNARIOS



1. Pieza gres porcelánico 40x40x3cm
2. Poliestireno extruido
3. Placa bituminosa
4. Doble enrastelado de madera
5. Tablas de madera
6. Cañizo
7. Enlucido de yeso
8. Teja plana
9. Viga madera
10. Pieza cumbreña metálica
11. Anclaje metálico
12. Canalón
13. Pieza ventilación aero
14. Sistema de soporte
15. Cerco de estanqueidad
16. Escuadras de anclaje

Figure 5

4. RYAFc

Nowadays, the vast majority of buildings erected prior to the Spanish Building Code (CTE), especially those built before the building code of 1979, do not meet the minimum conditions required for heat transmission through the envelope, thereby impacting negatively on heat comfort inside the building.

To refurbish this type of façade, we propose a Trombe wall system to be installed on blind wall panels. The system would comprise a black porcelain tile with a serrated edge. The system would capture the maximum radiant solar energy in winter and dissipate maximum energy in summer. By using a refractory ceramic tile, the maximum amount of energy would be accumulated during the day and released during the night to heat the building by means of a simple louver system.

This RYAFc system would function in the same way as a Trombe wall to optimise performance. To do so, it would use a black porcelain tile fastened to the outer face of the wall (by means of a metallic sub-frame) to enhance the selective absorption surface. To increase the total surface area capturing sunlight, the tile would be given an irregular texture that optimises sunlight reception by ensuring it strikes many points on the tile perpendicularly.

The aim of the system is to obtain maximum performance from a minimum of space and size. With the type of material described above, this would be possible with thicknesses of between 12 and 22 mm. Because porcelain tile has such low porosity, it is a material with high thermal transmittance, thereby increasing heat absorption.

To augment the wall's thermal inertia, a ceramic refractory piece (thickness = 6 cm; heat accumulating piece) would be fitted between the porcelain tile and the façade. The refractory tile provides thermal inertia for the wall with minimal thickness, storing energy on the inner face to subsequently transmit that energy into the room during the night. A colourless pressed glass would be fitted on the outer face, ($t = 6$ mm; for maximum transmittance = 0.85), which is fastened to the structure by means of a metal sub-frame, thereby forming a 10 cm cavity. An ample area would be left open at the top and bottom to allow air to circulate through the cavity when necessary.

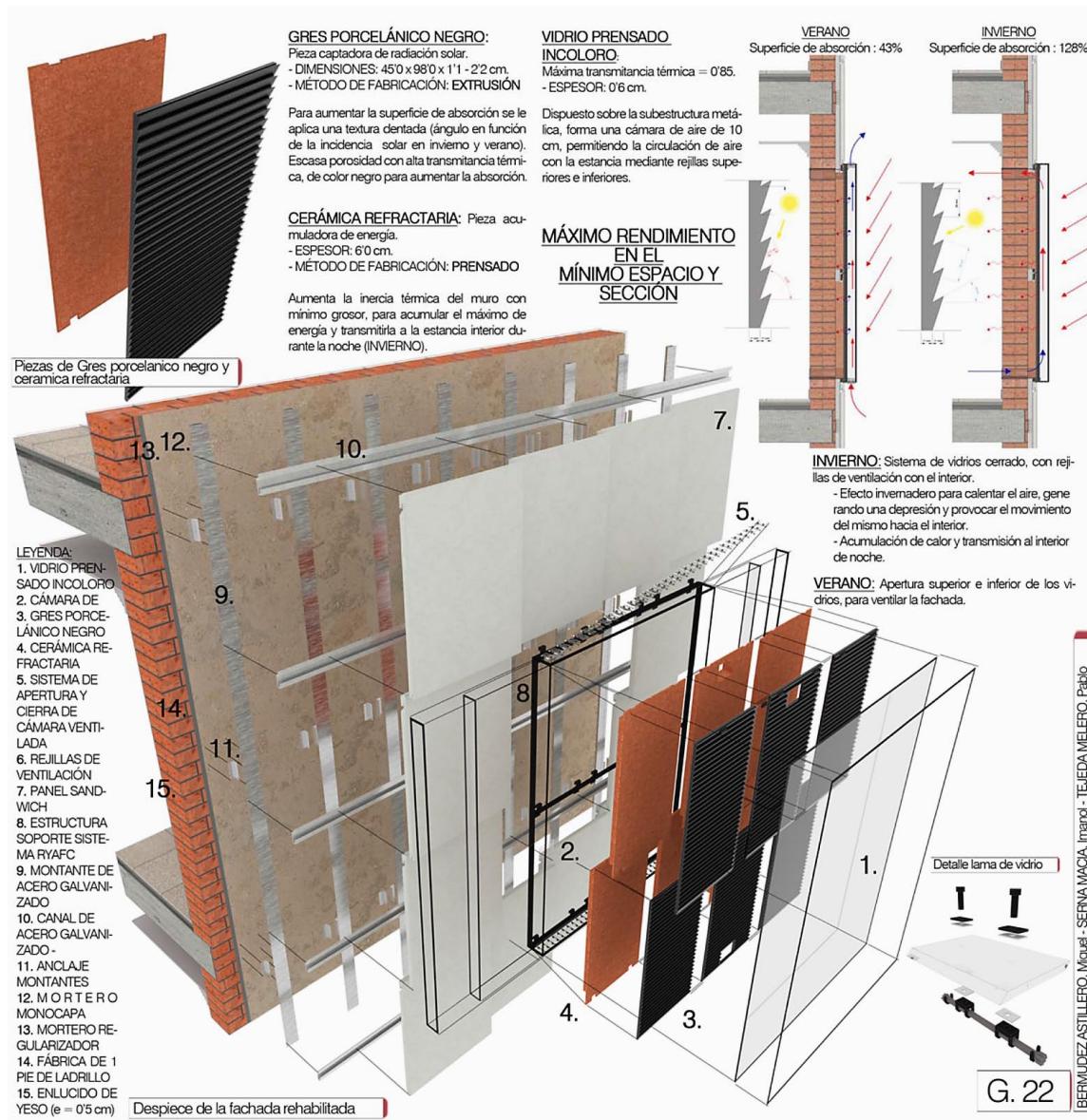


Figure 6

The way the system operates is that in the summer, the areas above and below the glass are simply left open to ventilate the facade. In winter, the glass system remains closed with ventilation louvers leading into the building. That would create a greenhouse effect that heats the air, thereby generating negative pressure that draws the air into the house.

4.1. Example of comparable performance using the RYAF system

The following table shows an example that compares a conventional Trombe wall with this new RYAF system. The example takes three standard rooms of between 8 and 14 m² each. Using the same surface area for both the Trombe wall and the RYAF system, the power generated is much greater with the latter system than with the former. The system improves the heat performance of the building skin and increases power by 20% to 30% compared to a traditional Trombe wall system.

Room	Room surface (m ²)	Façade surface (m ²)	Trombe wall surface (m ²)	Traditional Trombe wall power (W)	RYAFC power in winter (W)
1	9,1	18	5,6	11056,5	14515
2	8	10,35	4,8	9720	12441,6
3	13,7	15,3	8,22	16645,5	21306,24
Std. Enclosure	10,3	14,5	6	12150	15552

Table 1

5. CERAMIC ROLLER BLINDS

Nowadays, the visual image of outside walls on both domestic and office buildings has deteriorated due to the addition of service piping, electrical wiring, air conditioning units, drain pipes, etc., most of which were fitted after the buildings were erected. The system we propose is for the overall regeneration of such façades. It provides for a system that can be either fully or partially built into the façade, with one solution designed for blind sections of wall and another for balconies.

The objective of the system is to establish a new façade, a second skin for the building, behind which fittings and installations can be concealed. To do so, it uses a system similar to a ventilated façade that is easy to assemble and transport [2], pre-fabricated in the workshop, with a porcelain tile outer surface that not only improves the wall's original appearance and its durability but also reduces surface deterioration (compared to other stone or mortar metallic finishes). Furthermore, it works like a ventilated facade, which affords greater performance in terms of energy savings. As air circulates between the ceramic elements, it keeps the cavity well ventilated and prevents temperature from building up [3].

5.1. Solution for blind outer wall panels

The solution proposed is for a technical wall capable of housing both present and future installations and fittings. Special care is given to ensuring easy access to enable service installations to be inspected and repaired.

The chosen configuration is a multi-layer system consisting of three components:

- Ceramic piece no. 1: a porcelain tile sized 100x10x0.5 cm. It makes the whole system more rigid.
- Ceramic piece no. 2: a porcelain tile sized 100x10x0.2 cm thick as the outer layer. It delimits the rigid areas.
- A 2mm thick triple-twisting metal mesh made up of galvanised steel wire with a gap of 5 x 7 mm, as the middle layer.

The result is a roll-up panel, 3 metres long by 1 metre wide and about 40 kilograms in weight that can be wound up into a 45 cm diameter roll.

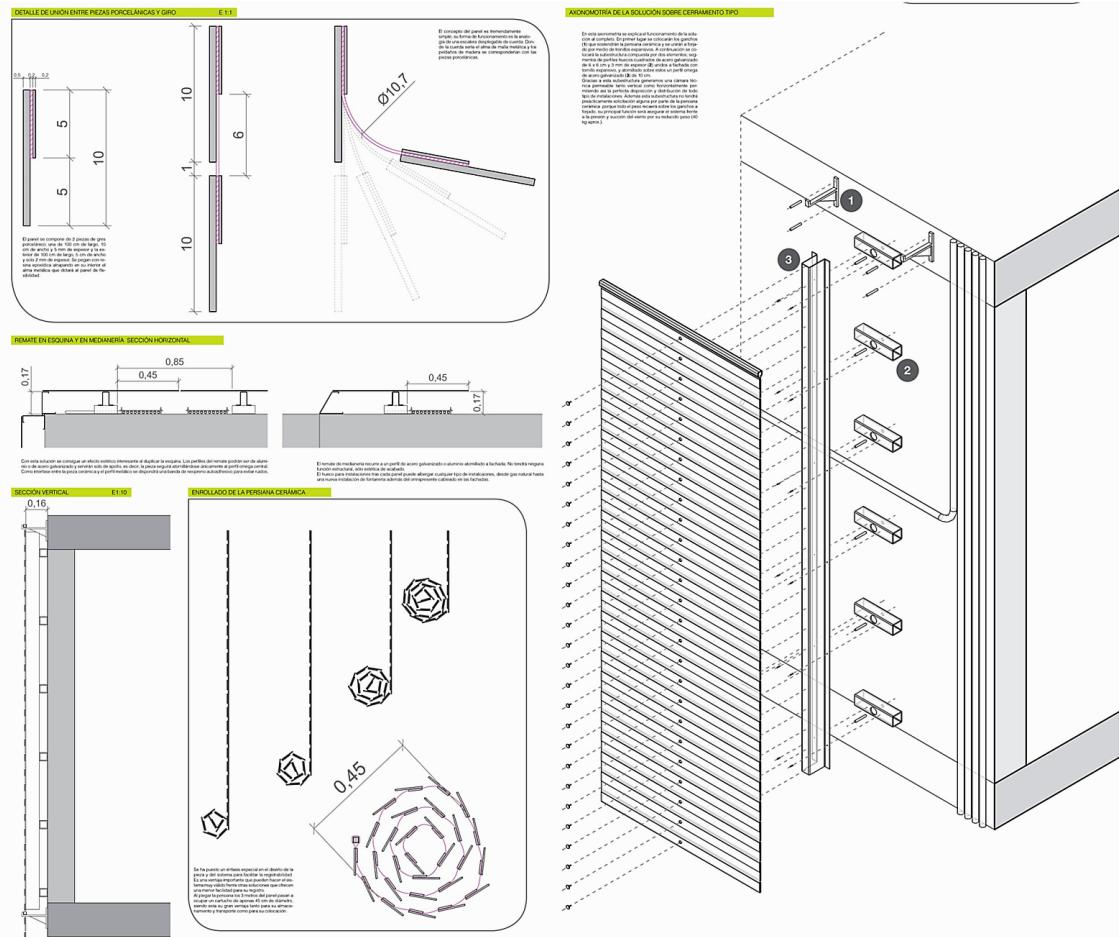


Figure 7

The system would be delivered as a roll. It would be installed from the edge of the roof by means of a sub-frame that serves as the support and anchor for the slats, thereby securing the system against the pressure and suction exerted by wind.

To ensure easy access for inspection and repair of the service installations behind it, the process can be reversed by unscrewing and rolling up the ceramic blind.

5.2. Solution for balconies

For outer walls with balconies, we propose a system of rotating slats built onto a discreet galvanised steel frame. This solution offers various alternatives:

- One face with porcelain tiles while the other with climbing plants to create the idea of a vertical garden [3].
- Same porcelain tiles on both faces.

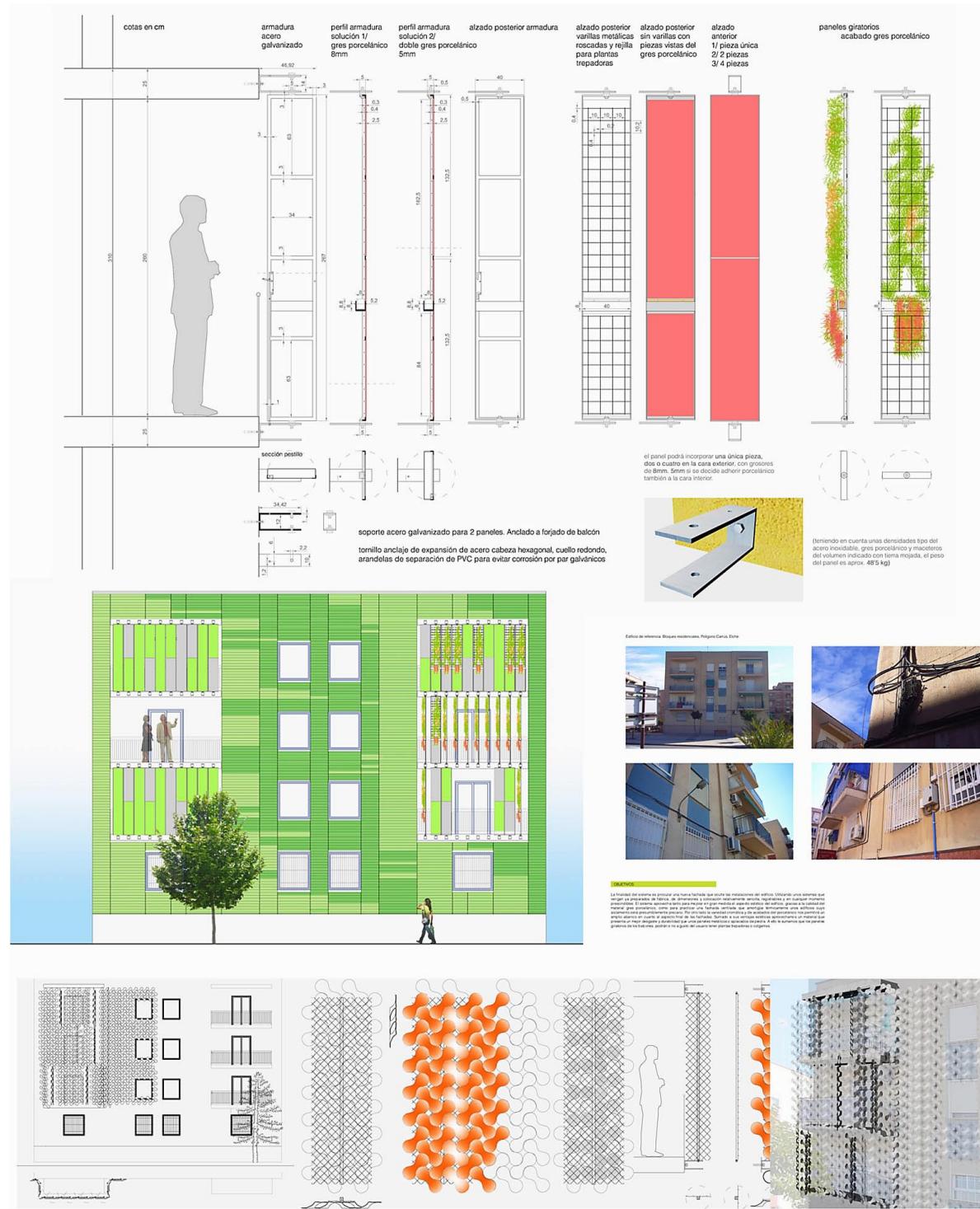


Figure 8

8. CONCLUSIONS

New generation ceramic materials have excellent properties for refurbishing buildings, both on outer walls and roofing and for indoor decoration. A large number of innovation and research projects are currently being undertaken on this matter [5]. Although the prototypes for the solutions presented here have yet to be made, i.e. the prototypes shown are still only theoretical and therefore their ac-

tual performance in terms of energy efficiency, durability, maintenance, economic costs, etc. have not yet been calculated, it is already possible to state that ceramic materials provide an efficient means of designing sustainable and energy-efficient solutions for refurbishing indoor and outdoor envelopes of older buildings, thereby contributing to creating more sustainable architecture.

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