WOVEN CERAMIC MOSAIC. PANEL FOR COMPREHENSIVE BUILDING REFURBISHMENT

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1. ABSTRACT

Many buildings in Spain today are in need of comprehensive refurbishment. In addition, it is a standard requirement that such refurbishment strategies should produce an effective reduction in annual energy demand. The solution is often to provide a new layer of thermal insulation and a new thermal seal for the building envelope. In interventions of that nature, it is crucial to implement proper control of the weight overhead added to the envelope and structure. On many occasions, this type of work is combined with strategies to reduce air infiltration. The latest developments in ceramic tiles, with thicknesses of just a few millimetres, have enabled those objectives to be achieved using ventilated façade systems.

However, buildings often need other types of work aimed at increasing their environmental compliance, overcoming building pathologies and defects, or guaranteeing human safety. In fact, numerous tall buildings along the Mediterranean coast built for residential or hotel purposes prior to Fire-Fighting standard 91 are outdated in terms of their fire protection measures. Fire escapes are undersized without adequate independent landings and evacuation routes are generally one-way – only one staircase exists instead of two, the minimum required by the relevant safety instructions in the TBC (Technical Building Code), as well as having façade walls or envelopes with insufficient fire resistance levels.

This paper looks at the research and innovation underway to design building envelopes that provide maximum flexibility, safety and energy efficiency. A pre-fabricated panel integrating porcelain tiles on a FINSA stainless steel web has been designed for either indoor or outdoor use. The large format fabric is fastened to a stainless steel frame, anchored with ease to the front edges of the existing structure. The fabric comprises thin porcelain tiles that are stuck to each other on either side of the stainless steel web using chemical adhesives. In this simple manner, a light ceramic mosaic is created that does not pose an excessive overload on current structural parts and which can be used for a multitude of applications, both indoors and out.

The research is applied in a case study, namely the Hotel Tryp Gran Sol located by the sea in the city of Alicante (Spain). It is a 31-storey building with scant fire protection measures. An assessment has been made of the comprehensive refurbishment of the building, the mainstay of which would be the addition of a specially protected staircase that fulfils the requirements of the TBC by increasing human safety standards. Installing this new staircase entails demolishing one of the city's most notorious landmarks - the emblematic mural on the north and west façades of the hotel. The idea is to apply ceramic fabrics designed to faithfully and accurately reproduce the mural using inkjet techniques while also providing continuous ventilation of the staircase through the fabric.

2. INTRODUCTION

Building refurbishment is a discipline that involves varied and complex lines of research and applications in regard to issues such as the quality of the envelopes, respect for heritage, energy consumption, cost-effective scenarios, safety in the event of a fire, etc. Such complexity increases when planning how to combine all those factors in the decisions taken both during the design stage and the actual execution of the works [1].

This paper adds to previous research carried out by the research group "Technology and Sustainability in Architecture" at the University of Alicante (Spain), as well as to the work of the "Saviarq" research group at the University of Navarre [2]. Having first analysed the main impact factors noted above, the research has been specially directed at high buildings and at solutions that effectively represent energy efficient refurbishment techniques and improve human safety in the event of fire. The research team has singled out one of the most recognisable buildings in the coastal city of Alicante, namely the Hotel Tryp Gran Sol [3]. The building, a veritable landmark of 1960s Alicante, has become the image and skyline of the city, as part of a highly interesting process in which a construction of its volume managed to be built on such a small plot of land [4]. It is precisely because of the small dimensions of the plot of land it stands on that the hotel flaunts remarkable slenderness and verticality, such that its erection did not turn out to be as traumatic for the city as it might have been [5]. Furthermore, its outer shape is backed by the clever solution of covering the outer walls with mosaics by renowned painter Manuel Baeza, of unquestionable artistic quality. The building is executed in a single volume, achieved by overlapping terraced storeys with a base and finish that employ glass surfaces within the uniformity of a curtain wall. The architect was Miguel Lopez Gonzalez [6]. It was built in 1971 and comprises a ground floor and 31 storeys above that, reaching a total height of 97 metres from the ground. Each floor has a surface area of 164 m^2, making a total floor area of 5,084 m^2. It was reformed in 1998 and 2003.

The proposed solution for adapting the building to Spanish TBC DB SI fire regulations seeks at all times to respect the uniqueness of the building. In that sense, as shown below, the application of ceramic materials in the new envelope was decisive in ensuring the deepest respect for the uniqueness and design of the building and in preserving its original and artistic physiognomy. Three-mm thick porcelain tile is ideal for integrated refurbishment solutions given its lightness and the ease with which it can combine with other materials such as stainless steel, as well as its durability, unchangeable characteristics in marine saline environments, and minimal water absorption. Furthermore, the possibility of accurately reproducing the colour range of any existing item using inkjet technology means Baeza's large murals can be replaced with ceramic mosaics, with a result that is true to the original artwork.

3. STRATEGIES AND OBJECTIVES

Although as far as integrated refurbishment is concerned, this paper only refers to the application of new ceramic materials and the evacuation of people in the event of fire through the inclusion of a new specially protected fire escape staircase, the main objectives of the refurbishment project are as follows:

1) Compliance with **Fire Protection regulations**. Given that the building dates from the late 1960s, it does not meet current evacuation and safety regulations, which is to be a prime requisite of the project. Therefore, two specially protected staircases, sufficient to achieve proper evacuation of the entire building, are proposed.
2) **Complete energy refurbishment of the building** by implementing energy efficiency measures in the design and construction, both of the rooms and services offered by the building and in the aesthetic and energy renovation of the façade, without overlooking the principles of comfort and health for humans. The building's environmental impact during its life cycle is taken into account in all aspects when choosing the type of materials and construction techniques.
3) Application of **ceramic materials on the façade**, preserving the murals that have existed since it was first built but improving the image of this urban landmark in the city of Alicante. The combined construction system consisting of parameterized ceramics and metallic mesh is seen as an ideal solution thanks to its lightness and performance, speed of execution, lack of overweight, and maximum security.
4) Preservation of as many **architectural features** and maximum respect for the current **structure of the building**, to generate minimal waste and cost and cause as little disruption as possible to the company operating this landmark building.
5) Another significant goal in terms of its sustainability is to provide the building with a **multi-purpose character** that seeks to accommodate different uses under one roof, not just accommodation and hospitality. The proposal, therefore, is for a hybrid office building that includes offices and service floors to improve user quality.
6) Further to the proposal to improve the quality of the hotel for users, it was decided to also tackle overall **Accessibility** to the building. An architectural design is being worked out that will ensure that nobody, from a disabled person

in a wheelchair to a mother with a baby's pram, comes up against any obstacle on their way into and through the hotel.

7) Performance of the building in terms of **thermal loads**. The intention is to satisfy thermal comfort and energy efficiency requirements in the building by implementing new air-conditioning (heating + VRF + air renewal) systems and defining the optimal balance between the various components.

4. PROPOSED MEASURES. COMPLIANCE WITH TBC DB-SI ON FIRE SAFETY

Our assessment of the Hotel Tryp Gran Sol has highlighted its shortcomings in terms of human safety in the event of fire. Although it barely meets the requirements of current regulations (TBC DB-SI 5) in terms of safety equipment and facilities, there are other basic requirements where it fails as a result of the age of the building, namely indoor fire propagation (DB-SI 1), evacuation of occupants (DB-SI 3), and structural fire resistance (DB-SI 6). On the other hand, due to the complexity and size of the building, other aspects such as outdoor propagation (DB-SI 2) or access for fire-fighter intervention (DB-SI 5) are nearly impossible to meet, due to its geometry and location within the city.

The current staircases in the building (Fig. 1) are very poor, in the sense that, in view of their size – over 28 metres – they should have at least two ventilated safety exits per floor. The main staircase runs through the centre of the building around the lift, with dimensions far below what is permitted (0.8m vs. 1m), without any fire door zoning or ventilation. The emergency staircase, located in the northern corner, is separated into zones and ventilated but its layout and route is confusing and it fails to meet the requirements in terms of width. The elevator shafts do not help either, because they are small (for 4 persons) and are arranged in a somewhat random fashion (Fig. 1).

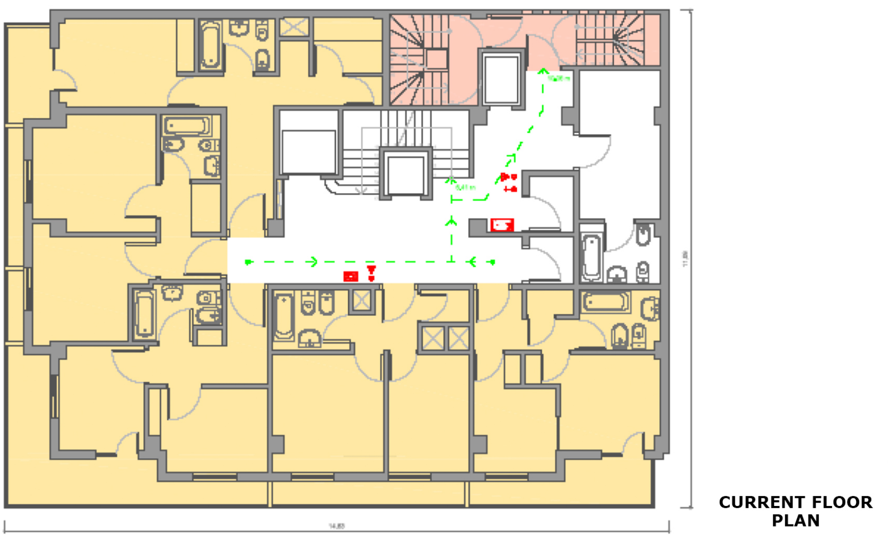

Figure 1. *Standard hotel floor – current status.*

The TBC DB-SI and DB-SUA set out all the basic requirements that need to be added in this refurbishment process in regard to human safety. By inserting various floors with different uses in the hotel to increase its diversity and possibilities, the foreseeable occupancy of each one will have to be assessed to provide it with the required zoning, bearing in mind the intended activities and uses that will simultaneously take place in the various areas of the building.

Surface area (m^2)		Per storey	Total
Built		164	5,084
Useful with safety staircase		147.6	4,575.6
Useful without safety staircase		87	2,697
Occupancy		164	
Hotel (Public residential use)	**Floors**	**m^2**	**Persons**
Accommodation floors	18	1,566.0	78.3
35 m^2 service floor	1	35.0	0
52 m^2 kitchens	1	52.0	5.2
Service floor	1	87.0	0
Meeting rooms floor	1	87.0	87
Foyer	1	87.0	43.5
Offices (Administrative use)	**Floors**	**m^2**	**Persons**
7 office floors	7	609.0	60.9
Rest (Public use)	**Floors**	**m^2**	**Persons**
Restaurant-viewing gallery	1	87	58
Breakfast room	1	87	58
	Floors	**m^2**	**Persons**
TOTAL	31	2.697,0	390,9

Table 1. *Cálculation of parameters per type of usage*

Having calculated the parameters that are most relevant to SI dimensioning, a list is made to ascertain the most favourable and unfavourable values for each type of use.

Parameters	Hotel	Offices	Catering
Zoning	**≤ 2500** m^2	**≤ 2500** m^2	**≤ 2500** m^2
Occupancy density rate	**20** m^2/person	**10** m^2/person	**1.5** m^2/person
Total density	**214**	**60,9**	**116**
Escape route length	**≤ 50** m	**≤ 50** m	**≤ 50** m
Minimum staircase width	**1.1** m	**1** m	**1.2** m

Table 2. *Comparison of sizing parameters per type of usage.*

Then the least favourable values are taken and bearing in mind the building's geometry and functions, the final sizing data for the project are worked out:

	Building dimensions
Zoning	**≤ 2500** $\mathbf{m^2}$ (and/or different uses)
Total density	**391** persons
Final occupancy rate	**≈ 6.5** m^2/person
Escape route length	**≤ 50 m** (16.32 m longest distance)
Staircase width	**≥ 1 m** (EPx1m -- EEPx1.75m)

Table 3. *Final project sizing data.*

From the outset and with an eye on energy refurbishment, the intention is to modify the structure and architectural features of the hotel as little as possible, while still guaranteeing an improvement in equipment and facilities, to meet the necessary occupancy levels for the building and to create sealed zones to avoid the spread of fire. This poses the first technical difficulty, given that two minimum-size staircases take up a great deal of surface area and could not be fitted where the original stairs are. This would have a very significant impact on the small floor space in the hotel and the idea is not to eliminate any rooms as that would reduce both profitability and guest comfort. At first, the choice is to build a single specially protected, oversized staircase (with a width of 2 m) so that the resulting total surface area is similar to two staircases and which would make for much easier installation on the floor plan (Fig. 2). However, such a solution has to be ruled out as the regulations call for two staircases, with as great a separation between them as possible for safety reasons.

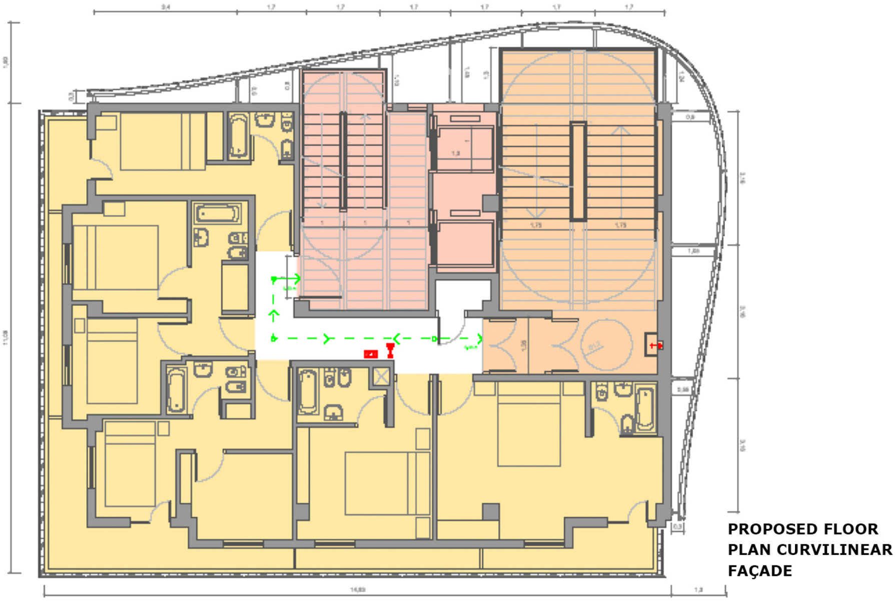

Figure 2. *Modified floor arrangement with two new fire escapes. Curved envelope.*

Another possible option is to remove one room from each floor (located in the southwest or northwest corner) and to install one of the staircases there, having opened the concrete floor on each level, while the other stairs and elevators would be tailored to the existing shafts. This solution would be highly traumatic for the building and for its business, as both economically and from the construction point of view, it would entail a loss of almost 20% of the profits. Human safety is paramount, but nobody is prepared to implement such an obligation if not compulsory. Building two protected staircases according to the requirements without changing much of the original floor plan is impossible to achieve in a conventional manner. The option that has finally been chosen is to build the staircases as overhangs outside the current structure to gain floor space (Fig. 3).

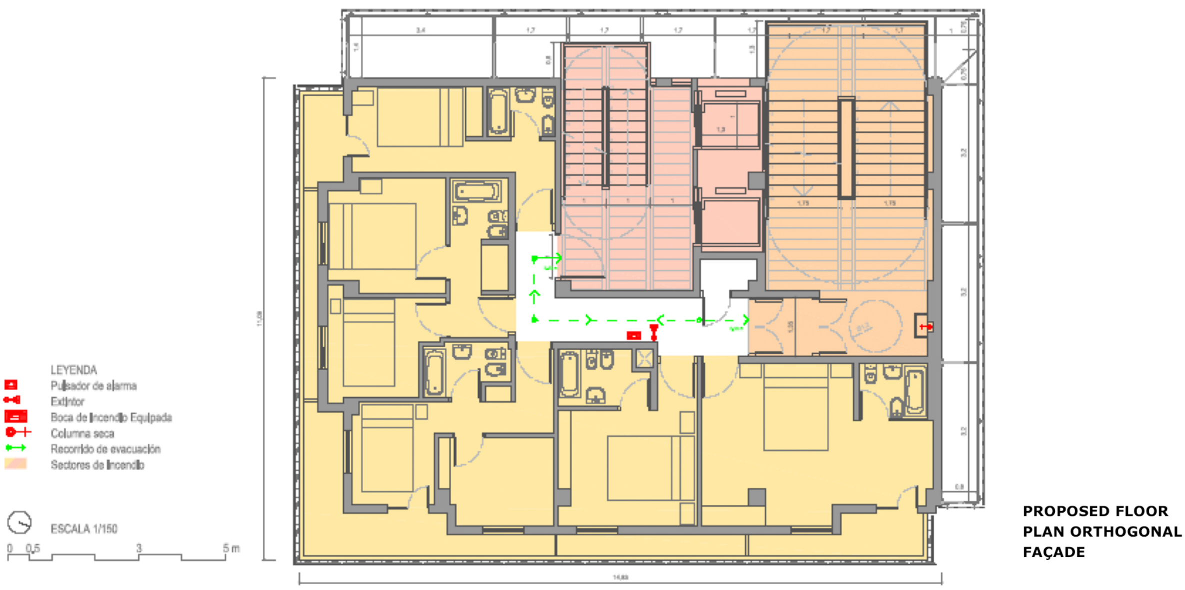

Figure 3. *Modified floor plan with two new fire escapes. Flat envelopes.*

Another primary goal is not to change the structure. Although some partition walls are altered, we adapt to the existing structure in such a way that two protected stairways are created in the north and northwest of the building - the latter includes the shaft for the elevators – thus uniting the entire block of vertical communications. The solution makes the best use of existing openings to avoid having to remove a large amount of concrete flooring. In this way, the number of rooms remains the same, although a few are made slightly smaller, and the current views over the Mediterranean Sea are preserved. Furthermore, the amount of Building and Demolition Waste (BDW) is also reduced enormously.

However, the application of this sensible solution leads to the problem of eliminating the current facade cladding, which also means removing the 900 square metre decorative mosaic of nautical and local Levantine motifs designed by artist Manuel Baeza. So the challenge now becomes to recover the mosaic at the same time as a light, ventilated envelope is built for the staircases. The final solution is described hereunder.

5. EXISTING MURAL –VENTILATED CERAMIC MOSAIC

Once the decision was taken to include a new fire escape, thus complying with DB SI, the next requirement would b to create a new outer envelope solution. We were faced with various functional restrictions. On the one hand, it would be desirable to maintain the original murals given their value as one of the city's leading artistic features. On the other hand, it would be equally desirable to ensure a high degree of ventilation for human safety and the opening of holes to allow natural light to enter. Finally, it needed to be a light envelope so as not to overload the structure. On the basis of those premises, a ceramic mosaic arrangement was proposed. With that concept in mind, V. Sarrablo's solutions for Flexbrick ceramic fabrics [7], [8], [9], [10] were carefully assessed. These solutions seemed most appropriate given their ease of installation, aesthetic quality and zero maintenance. They were perfect for providing an envelope with ventilation and natural light but the drawback was their excess weight and the difficulty of accurately reproducing the existing mosaic, given the size of the large-format tiles.

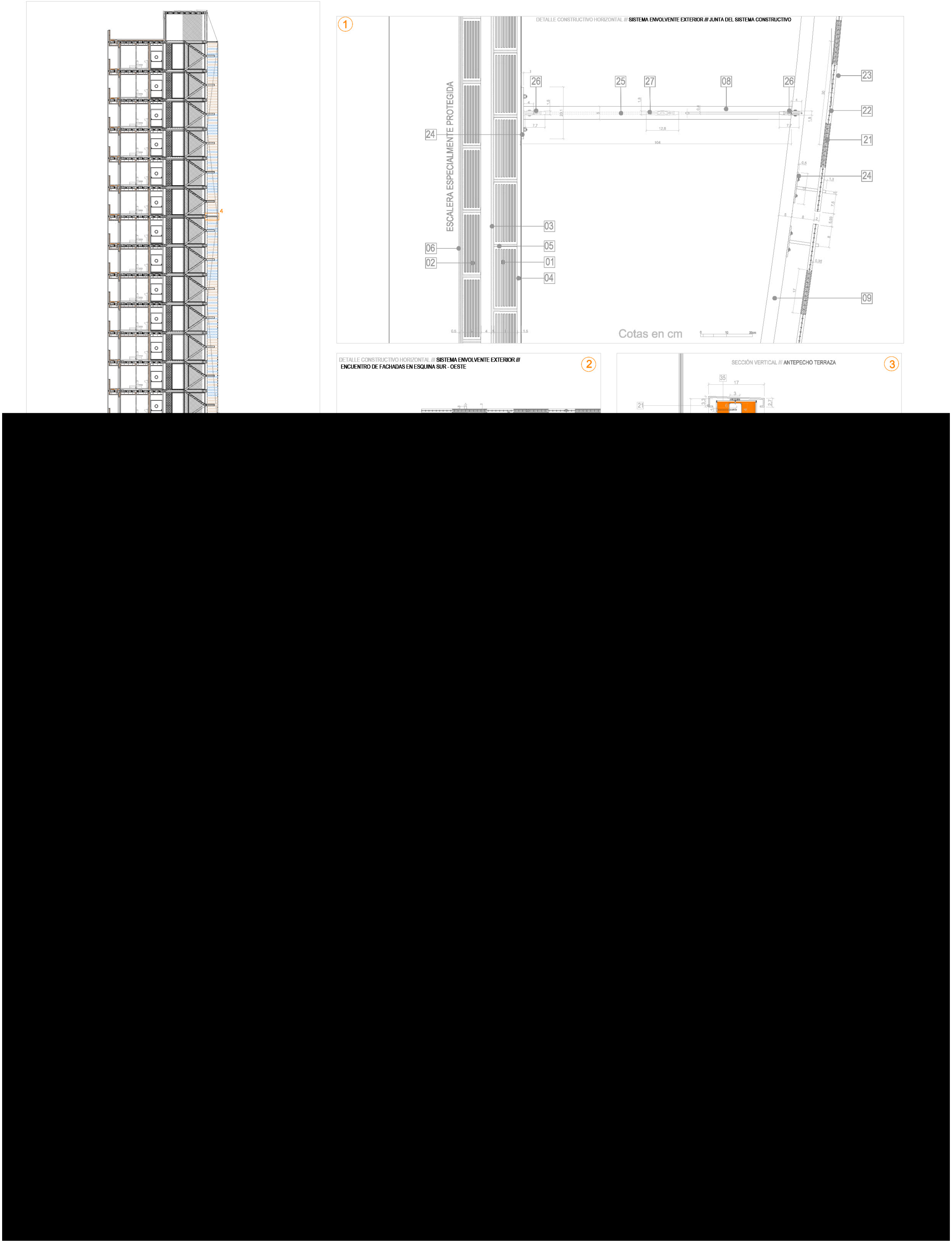

Figure 4. *Construction details of new envelope and its anchoring system.*

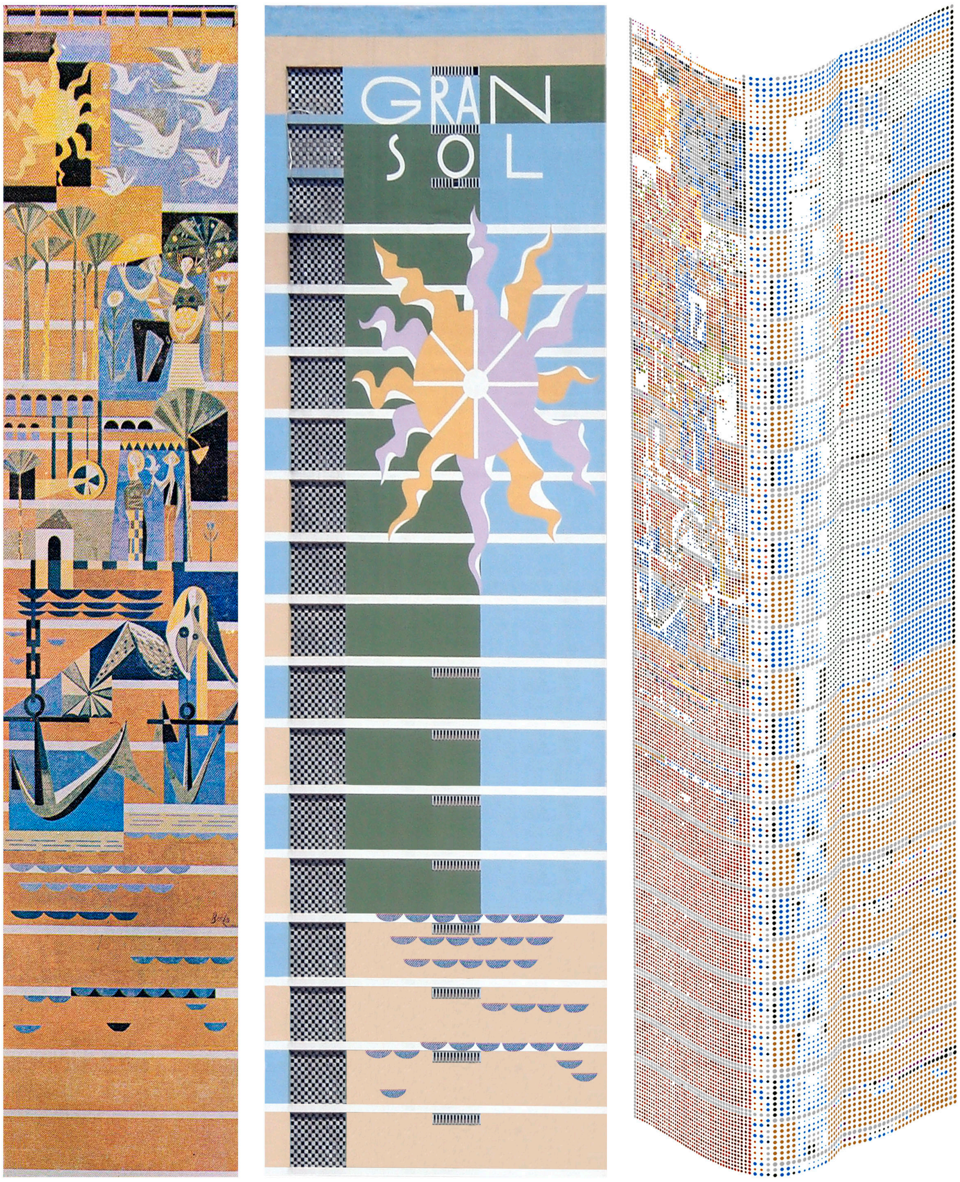

Figure 5. *Present murals and appearance of the new ceramic mosaic.*

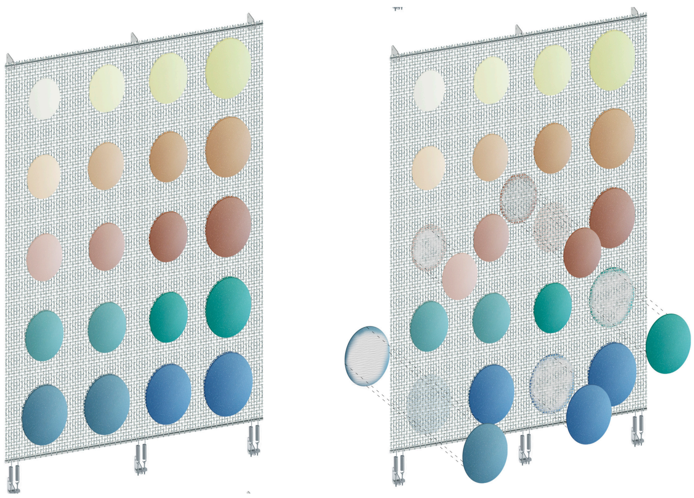

Figure 6. *Detail of the FINSA stainless Steel web with the ceramic pieces adhered to it.*

Thus, our proposal was an innovative alternative that consisted of fitting a FINSA stainless steel web [11], to which small, 3mm thick porcelain tiles are adhered. This idea enabled large fabrics of a noble material to be made that were highly resistant to adverse weather and possible corrosion in the prevailing marine environment. The ceramic tesserae needed to be round and stuck symmetrically to either side of the web. The advantages of this solution are undeniable. Because it does not seal one hundred per cent of the web surface, proper ventilation is ensured and the enveloping screen is not overly heavy. It is also less vulnerable to wind suction and thrust. The various types of fabrics available from the supplier were assessed and the 'Baltic' model selected as the best option, given its value for money and its 43% open mesh made with 2 mm steel thread. With the hotel's height, the mosaic is usually observed from a great distance and so the visual effect of the round tiles helps to re-create the original mosaic with great accuracy. Furthermore, the full colour range in the mosaics can be reproduced on the tiles using inkjet technology [12] [13].

Installation of the fabric is also seen to be quite straightforward – given that the outer wall would be completely removed in the stairwells, only the front faces of the floor structure would remain. A sub-structure could be fastened to those front faces, on which the mosaic fabric would be anchored. FINSA fabrics have a significant manufacturing advantage when attempting to produce large-sized formats, which means it would be possible to create a fabric with a maximum width of 8 metres and unlimited length. Therefore, the only restrictions when deciding the ideal size of the panels would be their transport and on-site installation on the sub-structure. Following a study of the operation taking into account that the huge mosaics were to be hung from the 10th floor to the 32nd floor and with widths of 16 metres and 8 metres, a scheme was devised using sections measuring 4m wide by 21m in length, i.e. one every 7 or 8 floors. That way, it would only be anchored to front faces 18, 17, 24 and 32 of the building structure, thus affording great formal continuity to the mosaic, which would only have two joints. To prevent wind pressure and suction, vertical tension trusses (Fig. 4) are arranged, and the fabrics fastened with threaded rods to the intermediate structure fronts.

Installation would be uncomplicated: first the stainless steel sub-structure is fitted to the four structure faces, followed by the vertical stiffening trusses, and subsequently the huge mosaics, anchored to the sub-structure, would be unfurled. Finally the intermediate threaded rods are fitted. The entire operation calls for a crane capable of working over 32 storeys to lift the 1,312 kg weight of each of the 18 sections that jointly make up the full mosaic. The sections would be held from the stainless steel frame across their top and bottom edges. The sides would not have any type of frame to avoid joints in the mosaic, thus giving it an appearance of perfect continuity.

6. CONCLUSIONS

Ceramic materials provide very reliable performance in various applications in building refurbishment. Within the wide range available, low-thickness porcelain tiles are particularly interesting as a solution for building envelopes where weight loads are an essential factor to be taken into account to avoid structural problems. Durability, resistance, fastness to weather conditions and pollution in urban areas make it a unique material, especially bearing in mind the issue of cost efficiency when undertaking such work in residential buildings.

The solution proposed in this paper is particularly suitable in the case of ventilated envelopes. FINSA stainless steel webs have a long record of applications in all kinds of buildings and uses. They also allow for other building materials to be combined with them, such as low thickness porcelain tiles. The production of ceramic tiles in these fabrics using small porcelain tiles may be multi-functional in architecture, as the example of their application in the Hotel Tryp Gran Sol Alicante shows. The colour range of ceramic tiles could faithfully reproduce existing artistic mosaics. For integrated refurbishment calling for specially protected staircases to be installed without changing the existing structure and for providing the building with maximum safety, the mosaic we have designed would be ideal, given its lightness and ease of installation, with panels of up to 4 x 21 metres. This is an interesting example of the many opportunities offered by this type of solution for building envelopes.

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