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Addressing structural issues on a 20th century office building.

Rehabilitation of floor slabs, stuccoes and decorative elements on a historic office building in Barcelona's Via Laietana.

Type of intervention

[ ] *Restoration* [X] *Rehabilitation / Renovation*

Concerned elements on the intervention project

[ ] *1. Foundations and underground structures*
[ ] *2. Vertical structures*
[X] *3. Horizontal structures and vertical connections*
[ ] *4. Roof and terraces*
[X] *5. Façade and building envelope*
[ ] *6. Finishes and completion elements*
[ ] *7. Integrate services*
[ ] *8. General strategies for building recovery*

Site	Office building, Via Laietana 4, Barcelona, Catalunya, Spain
Objectives	Rehabilitation of floor slabs made of narrow flange metal profiles; and rehabilitation of stuccoes and decorative elements of natural or artificial stone.
Property	Private
Designer	Technical Architects: . Josep Baquer and Carme Marquina
Date	2012

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Background to the intervention

At the beginning of 2009, GE Real Estate-Iberia, owner of the building located at Via Laietana Street No. 4 (VL4) in Barcelona, requested technical services to evaluate the condition of the building, which is in use by the Conselleria de Justícia del Govern de la Generalitat de Catalunya.

In a first inspection, it was found that many elements of the composition of the facades were protected with fabrics to prevent materials from falling onto the sidewalk or the roadway of both streets.

It is a building located on the corner of VL4 and Dels Agullers street, in the old town, near the seafront of the city.

The first contact with the building, before proceeding to a more thorough inspection, clearly showed that the cause of the cracks in the facade was the oxidation of the metal elements that affected the surfaces of the facades and the walls that made up the interior courtyards. Basically, the metal joists of the floor slabs supported on the load-bearing walls ("narrow flange" profiles) and the anchoring or reinforcement mechanisms of decorative elements (stone or artificial stone) or even structural elements of the façade.

The Property was informed of the need to carry out an exhaustive inspection of the building to verify the first hypotheses and to be able to proceed with a diagnosis as close as possible to reality, given that the lesions and pathologies detected in the facades and vertical walls were only the manifestation of some causes (hidden in the load-bearing walls) that could affect the structure of the building.

Description of the building

Building inaugurated in 1921, consisting of a Basement Floor, Ground Floor, 4 Typical floors, and an attic floor, each one of approximately 450 m2, making a total built area of 3375 m2.
Gravity walls on the perimeter of the basement, stone pillars in the basement and first floor. On the capitals of the pillars of the first floor, there are metal beams of composite profiles, rounded, on which the load-bearing walls of the rest of the floors are supported, consisting of solid brick masonry with lime mortar.

One-way floor slabs, with metal beams (narrow flange profiles) and ceramic hand-laid coffers, with lime mortar supported on the lower flange of the profiles.

The building, some ten years earlier (approx. in the year 2000) had been completely refurbished, according to the documentation found, in order to adapt it to the corresponding regulations for public office use. This rehabilitation was limited to updating the interior architecture to comply with the corresponding regulations, without addressing structural issues. Some beams were replaced, and the visible surfaces of the metal profiles (basically the lower wings) were fireproofed.

Fig.1: Detail of mansard windows and Agullers Street's facáde.

The diagnosis of the building (values and state)

From a first report and diagnosis that was made, with limitations since the building was in full-service activity (judicial offices of the Generalitat de Catalunya), a first basic project was drafted in order to start the administrative procedures and request the corresponding building permit (September 2009), which allowed a first assessment of the foreseeable rehabilitation of the building. It was based on the following findings and forecasts:

- The narrow flange profiles of all the slabs had reached the end of their useful-life years ago due to oxidation and exfoliation of the steel. The main injuries were almost hidden from sight since they occurred inside the walls in the recessed area of the beam. Also, in intermediate areas of the beam span, hidden under the ceramic coffers, even more so, since during the interior renovation they had primed the exposed surface with fireproof amalgam.

- The cause was due to the fact that lime mortar, contrary to what was considered years ago, does not protect the steel as is the case with Portland cement mortar, in which the lime hydroxide adheres to the steel and waterproofs its surface. In fact, lime carbonate does not waterproof the steel, and allows interstitial water transfer, whereby the alternation air/water leads to oxidation of the metal. The steel beams of the first-floor ceiling, made of large composite edge profiles, with a brick masonry core, were also affected and by the same issue.

- On the facades, almost all the structural elements of the tribunes, balconies and decorative stone elements were deteriorated in unstable equilibrium.

The Property was advised that, as soon as the building was vacated, the extent of the injuries would have to be thoroughly

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examined in phases, and that it would be necessary to proceed to open many holes in walls and floors.

In February 2010, the definitive diagnostic report was issued, confirming the first hypotheses. It was found that the pathology affected much more than initially expected:

- The slab of the first level was affected not only at the heads of the beams, but also in the rest of the section of the narrow flange profile: it was advisable to remove the entire slab and build a new roof with a mixed steel-concrete structure. In addition, many heads of the main beams had to be reworked and repaired at the points of support, either on the walls or on the capitals of the pillars.

- On all the upper floors, more than 80% of the heads of the floor beams had to be redone.

- All balcony and gallery slabs had to be repaired.

- All the facade galleries and all the medallions and decorative elements in artificial stone had to be deconstructed and rebuilt, eliminating all the metal anchoring elements that were completely rusted, swollen and out of service.

- The wooden structure of the mansard roofs was absolutely deteriorated.

In November 2010, the executive project was drafted, based on all the data collected in the previous diagnostic report, specifying the corresponding solutions and construction details:

- How to repair and/or replace the heads of the narrow flange profiles of floor slabs.

- Repair method for composite profile girders and their heads affecting the integrity of the stone capitals (cracked).

- How to repair overhanging elements, balconies, galleries, etc.

- Deconstruction and reconstruction of the mansard roofs, using a new metallic structure.

- Architectural rectification of the main staircase from the first-floor reception to the upper floor.

- New elevators, etc.

Fig.2: Heads of rusty-exfoliated profiles in support area (inside the masonry wall and lime mortar).

Fig.3-4: Rusted and swollen profiles; Fig.5: Narrow-wing profiles used in the building.

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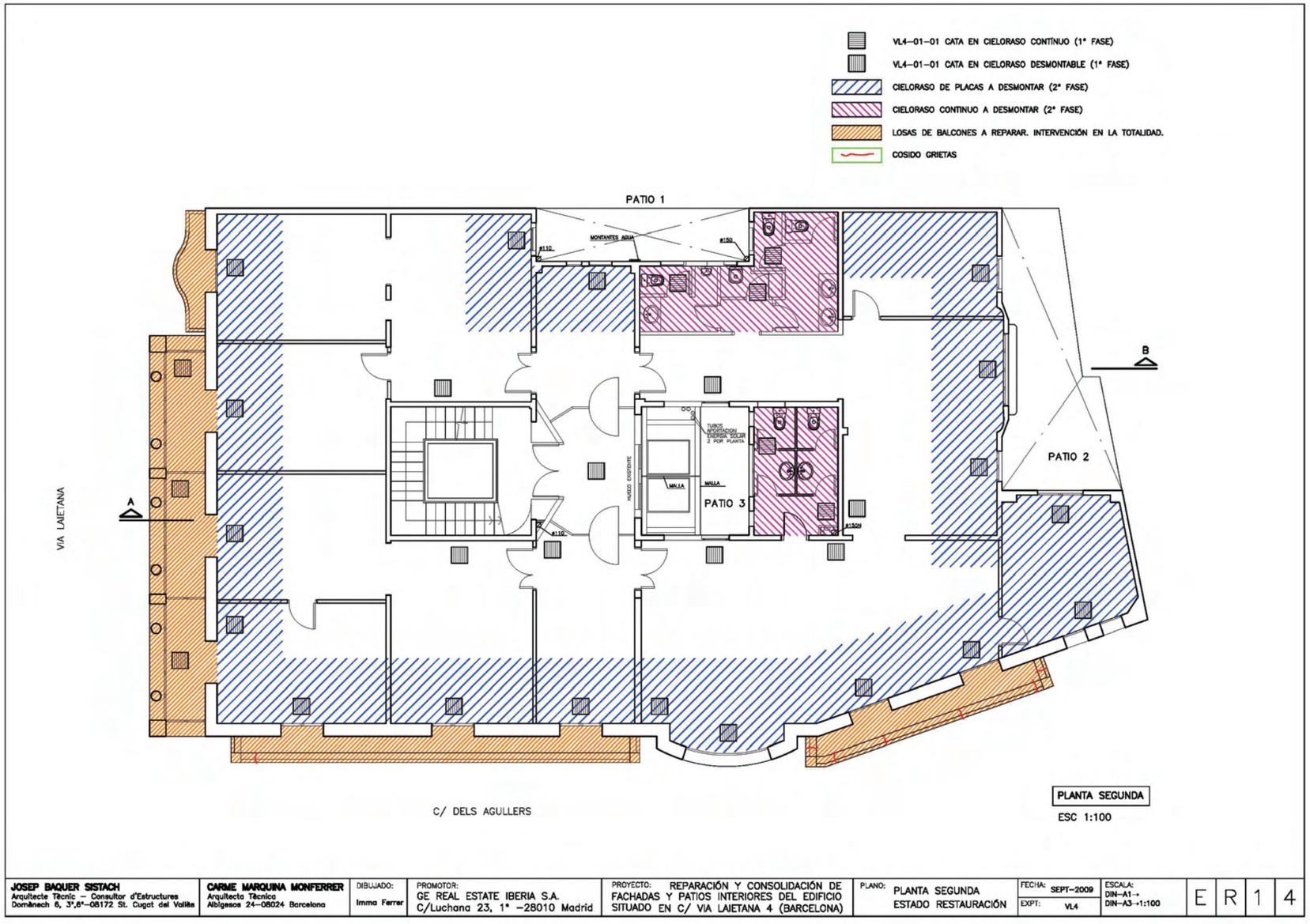

Fig.6: Typical floor plan: areas to be repaired.

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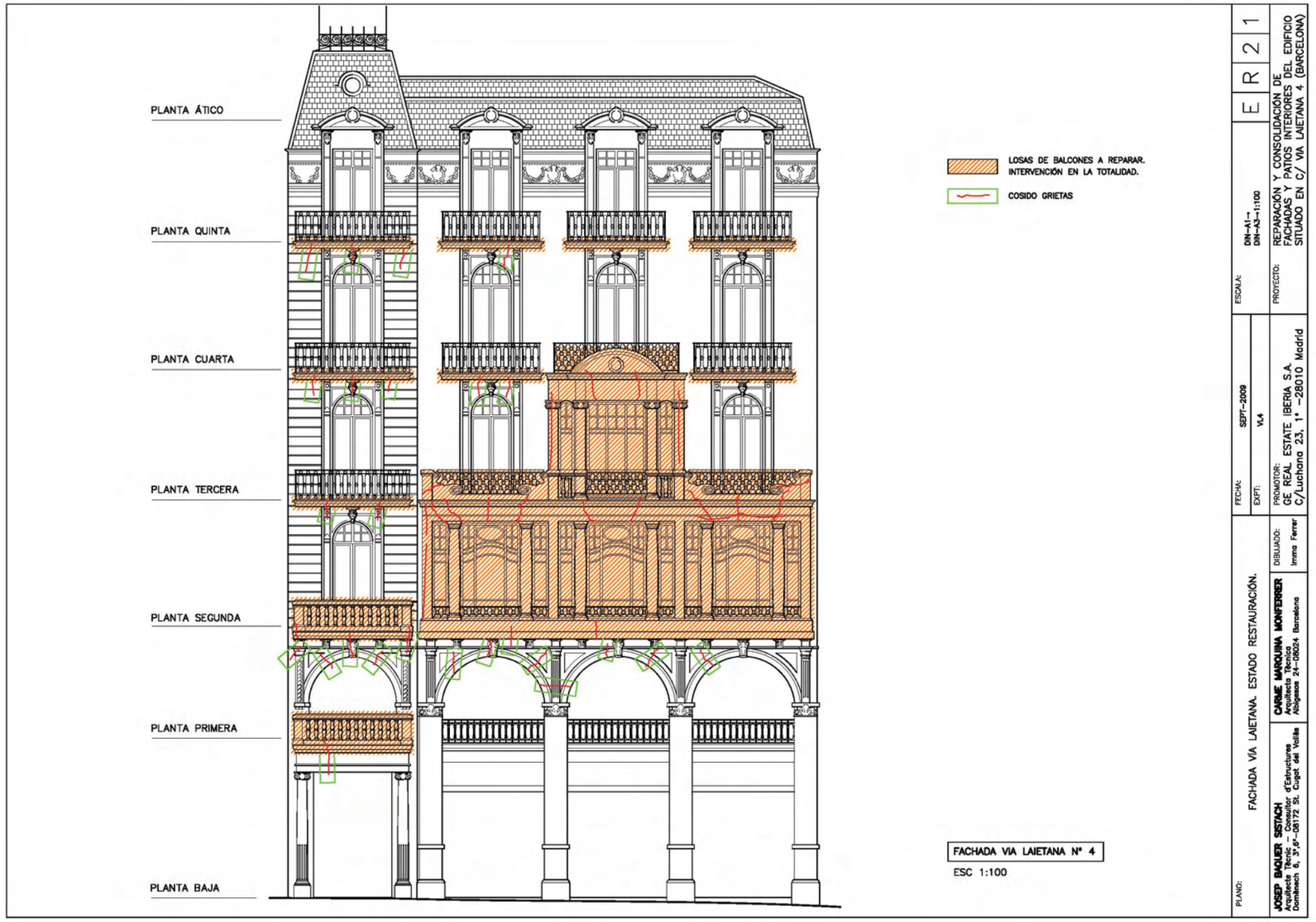

Fig.7: Via Laietana's façade: map of lesions/damages.

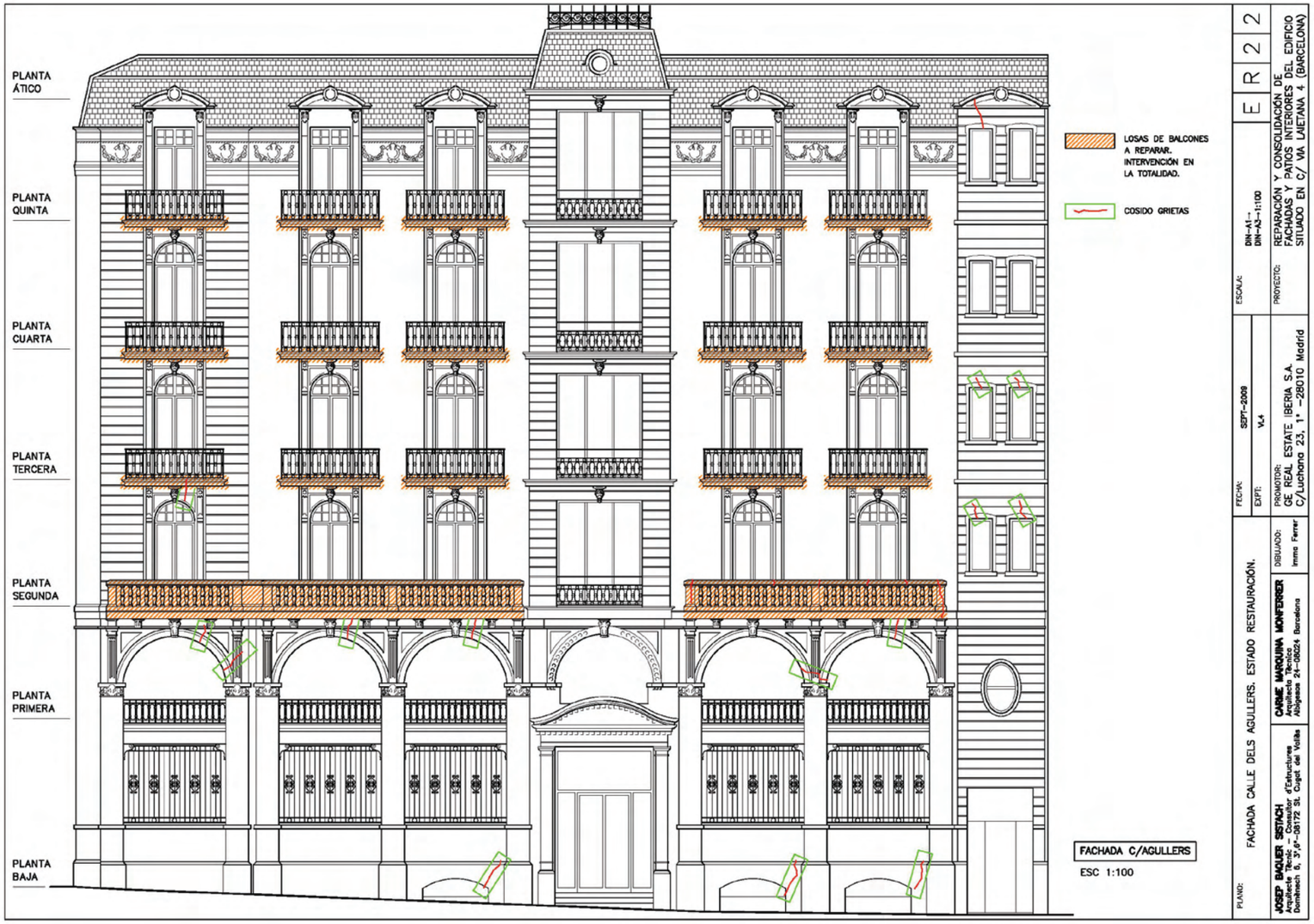

Fig.8: Agullers Street's façade: map of lesions/damages.

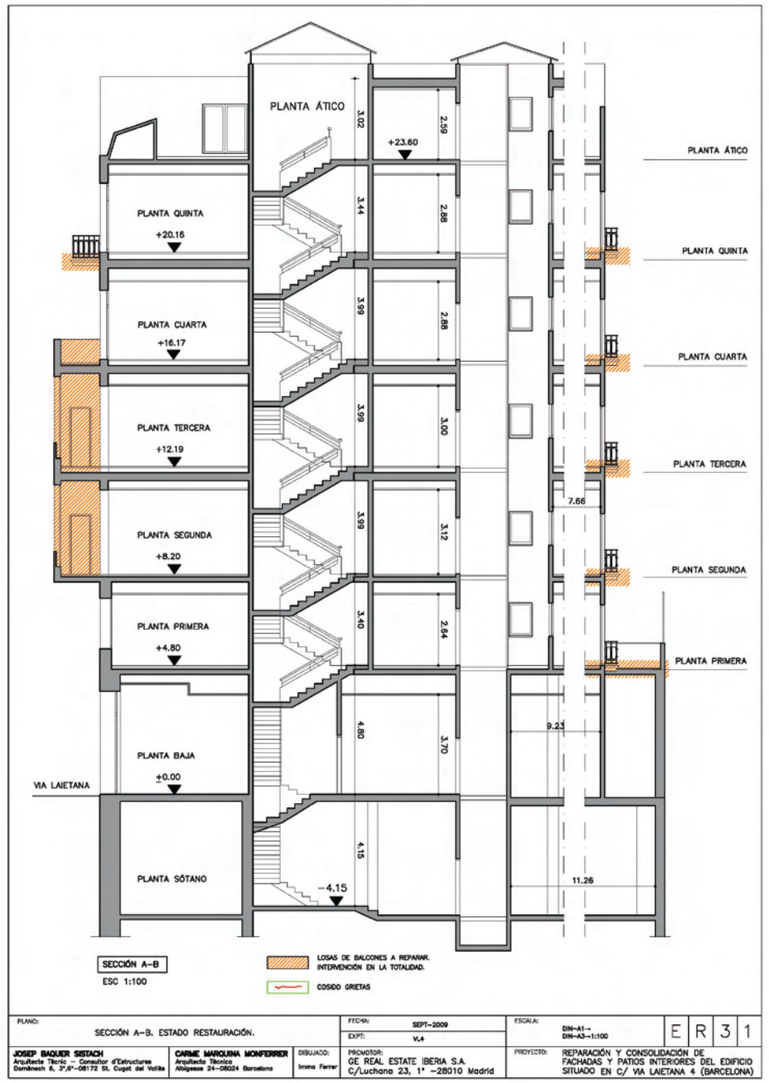

Fig.9: Section and location of areas to be repaired.

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Rehabilitation works

In this report, it only focusses on the rehabilitation works of the narrow flange profiles of the floor slabs and the overhanging elements (balconies and galleries).

The profiles that were almost completely damaged had to be replaced by new ones and the entire floor slab had to be rebuilt: mixed slabs of corrugated metal sheeting and concrete were chosen. This basically affected the basement ceiling slab, which was completely rebuilt.

The damaged profiles, when their heads had lost effective section for their function, were shored up and cut at a distance of approximately 50 cm from the vertical face. The attached images show the design and construction details, as well as their implementation.

Damaged profiles, but still with sufficient cross-section, were suitably sanded and primed with epoxy to better guarantee their durability.

In the case of cantilevered elements, the same operation had to be carried out, but obviously the cut involved removing the entire cantilever profile. In this case, the solution was analogous to that of the heads of the beams simply supported on the walls, but with the corresponding extension. In these cases, the cantilever slabs had to be completely rebuilt with reinforced concrete supported by the new profiles.

The new heads or cantilever profiles were designed with composite parts, manufactured in the workshop, and placed on site. The design of the pieces always allowed welding from above (avoiding the "roof" welding, which is always uncomfortable on site).

The dimensions of the different types of existing profiles to be "cut out" were taken to deduce the parameters of their sections. This data was attached to the project. The new sections, also with double T and unequal flanges, had parameters similar or superior to those they had to replace (original narrow flange sections of the building site).

In order to expose the head of the deteriorated profiles and to be able to relocate the new profiles, the corresponding affected area of each facing had to be repointed. These areas were filled with perforated brick and portland cement mortar.

Fig.10: Existing conditions prior to the rehabilitation of the capitel and head of the composite profile beam.

Fig.11-12: Rehabilitation of the capitel and head of the composite profile beam.

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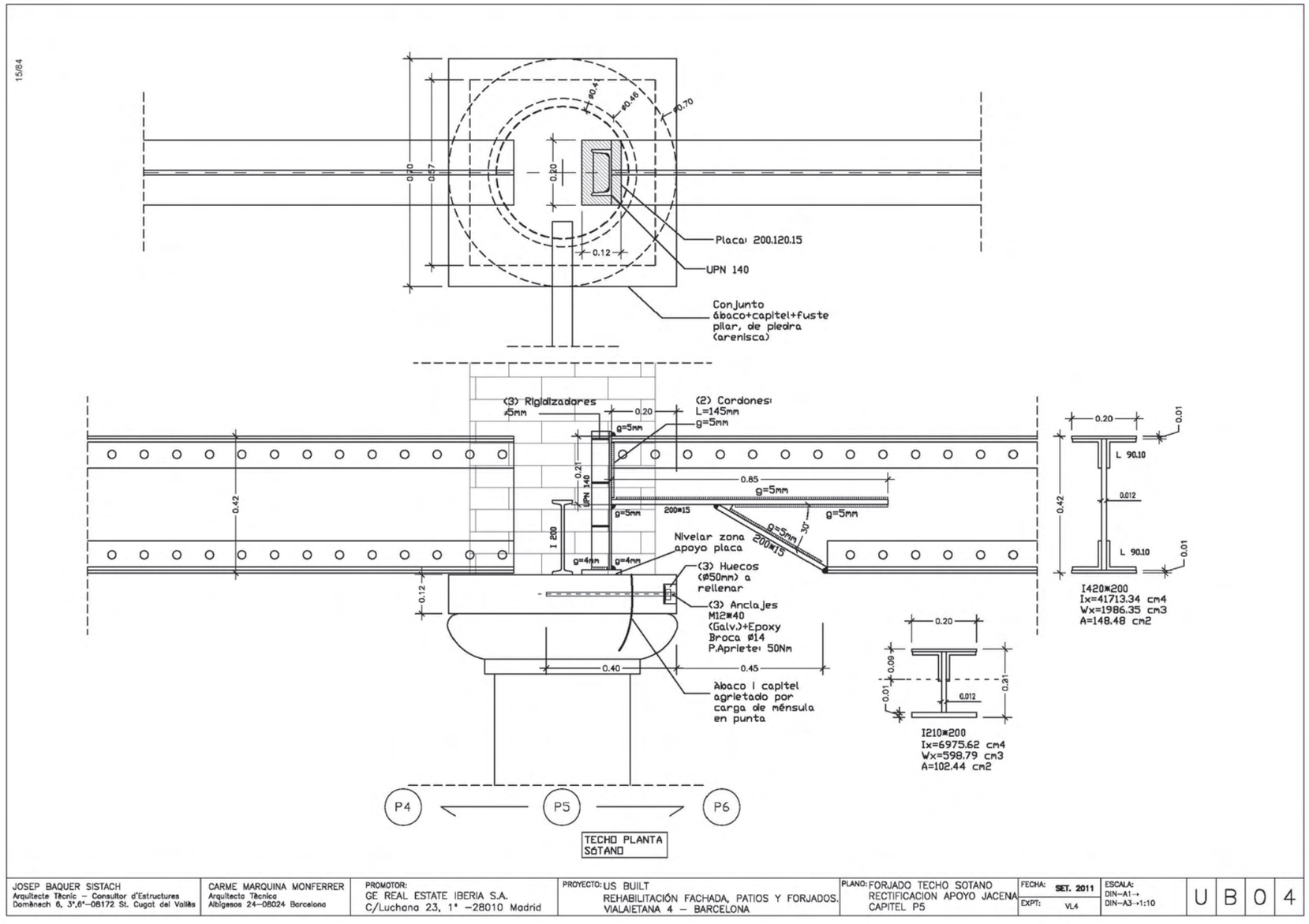

Fig.13: Detailed drawing of the intervention in the capitels and heads of beams.

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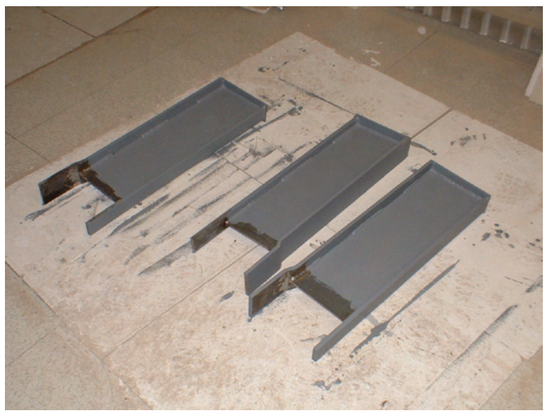

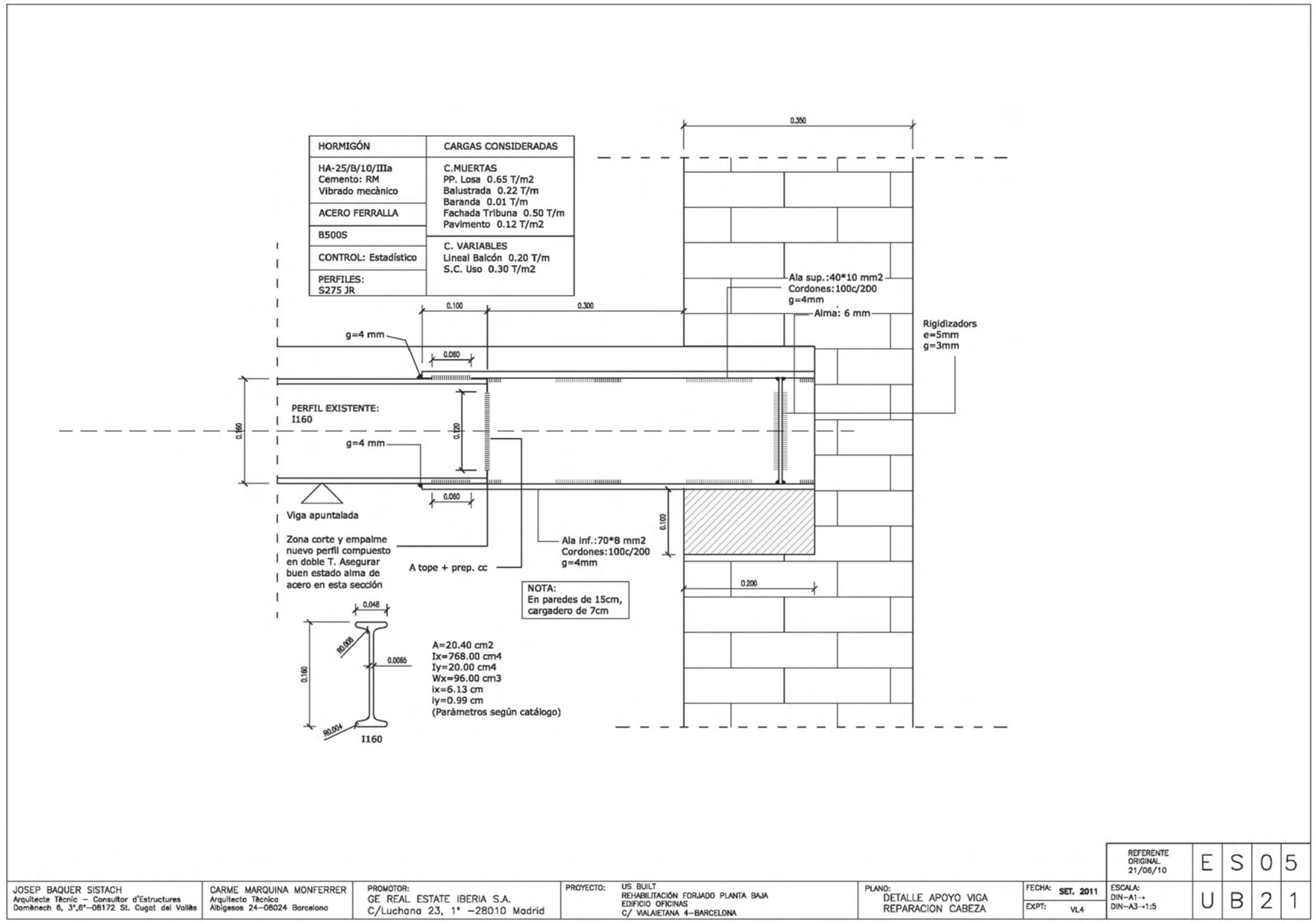

Fig.14: Rehabilitation of narrow-wing profiles; Fig.15: Detailed drawing of the rehabilitation of narrow-wing profiles.

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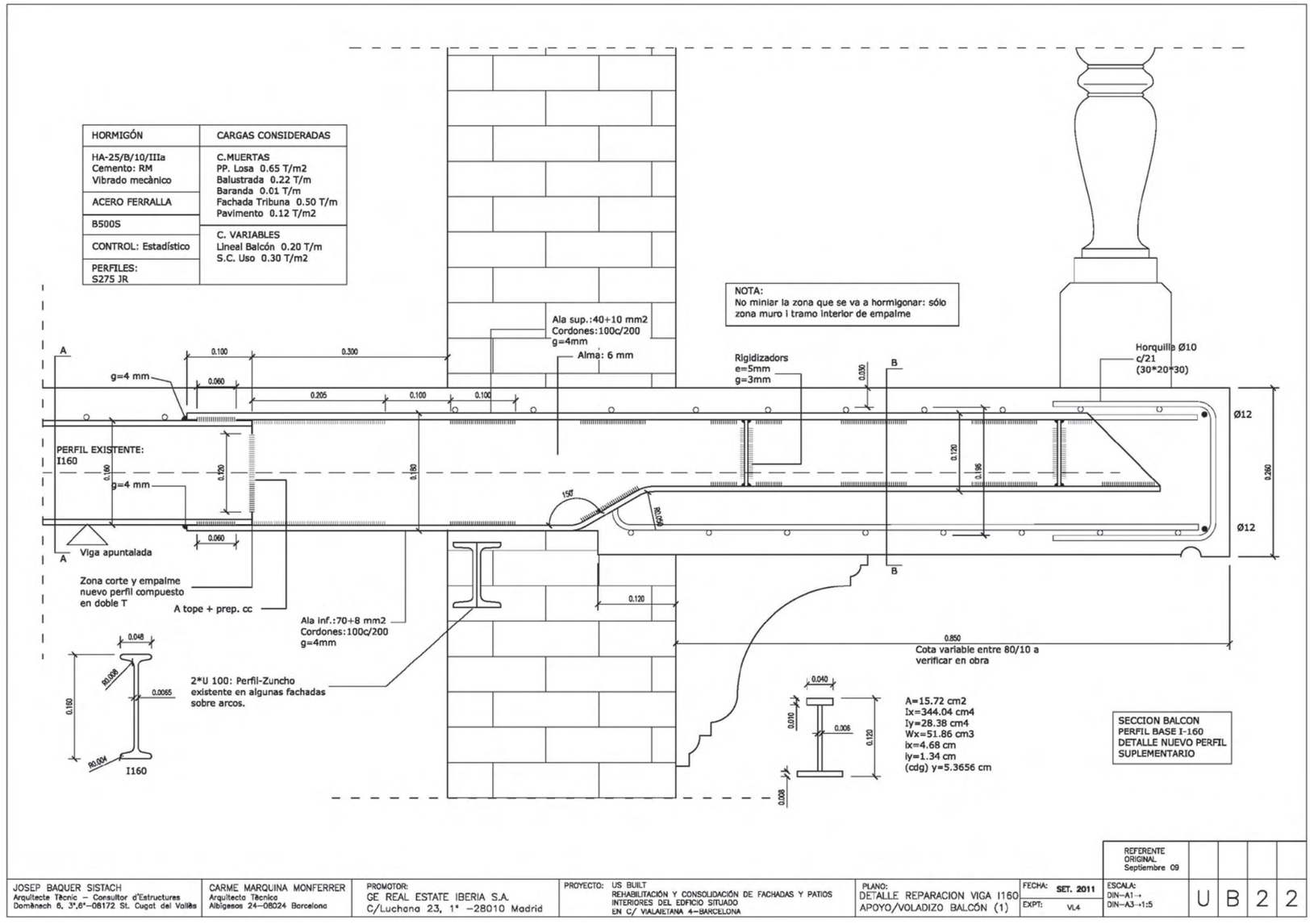

Fig.16-18: Substitution profiles in support areas and overhangs; Fig.19: Detailed drawing of the substitution profiles in overhangs.

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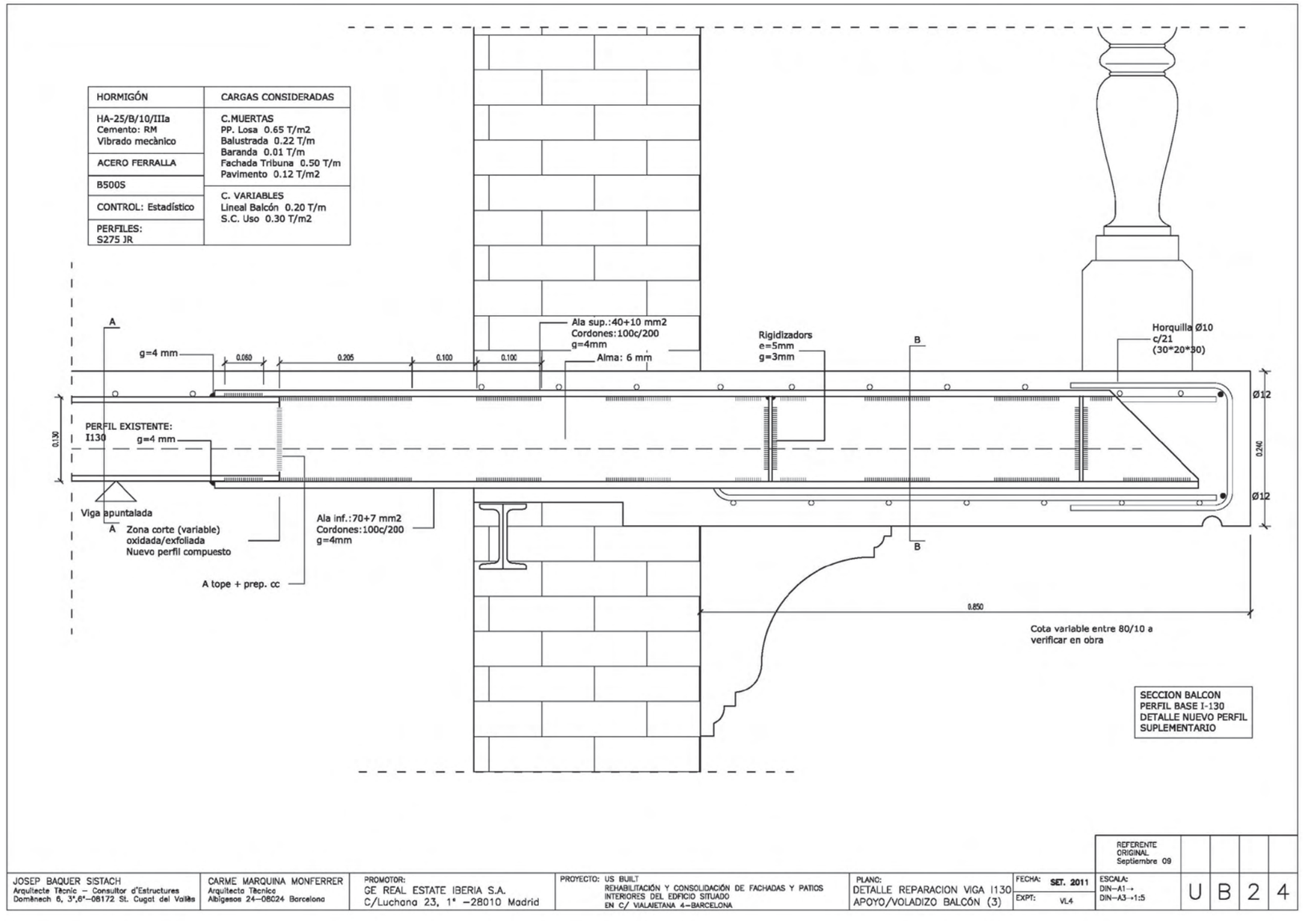

Fig.20-22: Substitution profiles in overhangs of tribunes; Fig.23: Detailed drawing of substitution profiles in overhangs.

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Fig.24-25: Restoration and rehabilitation of the ornamental elements of the tribunes.

Fig.26-27: Restoration and rehabilitation of the ornamental elements of the mansard windows.

Assessment of the results

In September 2011, the As-Built Project was drafted, and the rehabilitation of the building was completed.

Evidently, the results were as expected, since the information from the different inspections prior to the drafting of the executive project, and the final inspections during the construction phase, made it possible to locate each and every one of the deteriorated areas and elements. From the structural point of view, the building was left at "zero point", with the structure in full-service situation. In the attached figure, you can see some samples of damage location corresponding to the project plans.

Since the building did not change its use, it was not necessary to increase the design stresses of the existing ones. Only in the new slab elements or cantilevered elements.

The architectural restructuring of the first floor (staircase, services, etc., which are not contemplated in the description of this report) made it possible to comply with all the requirements for the corresponding activity license.

The Property was able to sell the building in perfect functional, architectural, and structural condition.

References

Josep Baquer: ***Perfils d'ala estreta. Final de la seva vida útil***. L'informatiu 331. February 2012.