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Haussmann Structural Floors Repairs and Strengthening Techniques

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# Haussmann Structural Floors Repairs and Strengthening Techniques

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Haussmann buildings architecture spread throughout the city of Paris. Those buildings were constructed in the 19th century, being now centenarians. However, they present several pathologies which prevent their adequate use, moreover, an update regarding users security, sound, thermal and fire requirements is, among others, urgently needed. Additionally, there is actually, in Paris, an increasing demand for hotel rooms. For those previous reasons, Haussmann buildings are nowadays submitted to heavy operations related to use change, conservation, and rehabilitation. In this paper, repair and strengthening techniques used in old timber and metallic floors and retaining a great amount of the original structure are introduced. This presentation is the result of a technical survey realized during a heavy rehabilitation operation which takes place between 2015 and 2017 in a Haussmann building complex located at *La Madeleine*. The knowledge from this study could be very useful for the development of sustainable rehabilitation and strengthening techniques, aiming to preserve this important building heritage or similar ones existing in other countries.

**Keywords:** floor rehabilitation, Haussmann buildings, strengthening, structural characterization.

## Introduction

A huge quantity of rehabilitation and strengthening works are being realized actually in Paris Haussmann buildings. In fact, those buildings being old, since built or rebuilt around the 19th century, present nowadays a very poor state of conservation and several pathologies affect their main structure. Furthermore, the environmental issue related to energy consumption for cooling and heating make them obsolete. Beyond that, the Haussmann buildings are representative of the Paris architecture, (Jombert C.A., 1764), (Froidevaux Y., 1986), (Lepoutre D., 2010), (Jordan D.P., 2015) since all the city is based on that architecture, which was used until the introduction of concrete and steel in the 20th century. It is of vital importance to preserve and protect this legacy and demolition can´t be a solution. Furthermore, there is a huge demand for hotel rooms in the city of Paris due to a growing tourism activity. All the reasons present previously justify the urgent need to realize rehabilitation and strengthening works. This scenario related to traditional building heritage state of conservation is not unique and can be found in several European countries, (Branco J. et al., 2006), (Catarig Al. and Kopenetz L., 2007), (Cardoso R. et al., 2015, 2016, 2017). This article characterizes the strengthening techniques applied to the floors of a Haussmann building complex located at *La Madeleine*, based on information gathered during the rehabilitation works that were performed between 2015 and 2017. This complex is located at *La Madeleine* near the *Saint Marie Madeleine Church*. Fig 1-a) shows an aerial view of the complex implantation and Fig 1-b) shows a front view of the existing facade.

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This article is original because the technical observations were made during the rehabilitation working stage, by the author, which was simultaneously the strengthening project designer. Proper investigations were realized in the existing superstructure, on the foundations and particularly in the floors structural elements, before and after strengthening. Complementary, an assessment of the geometric characteristics of the structural floor elements was realized. Resulting in a step description of the floors strengthening technique used.

We strongly believe this paper will allow to better understand the actual floor strengthening construction techniques which minimize the introduction of new elements, (Tuba Sari, 2017) (Akadiri P.O., 2012), allowing further studies related to numerical modelling, heritage rehabilitation and strengthening and also sustainability issues. The organization of the paper is the following: firstly the Haussmann building complex is defined, secondly, the metallic and timber floors are described and the strengthening techniques are explained. Finally, some conclusions are indicated.


a) Aerial view


b) Front view

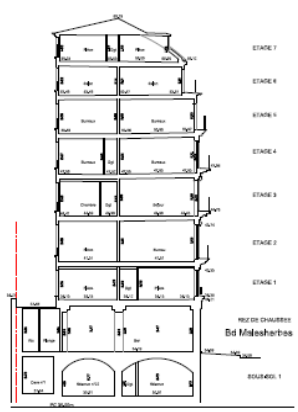
Fig. 1

The Haussmann building complex

## The Haussmann floors

The building complex is constituted by two Haussmann buildings, built between 1830 and 1841. Malhesherbe building on the left and Madeleine building on the right in **Fig. 1-a)**. Malhesherbe building as a gross floor area of 365 m$^2$ and 7 stories and Madeleine building as a gross floor area 416 m$^2$ and 6 stories. The ground floor of the two buildings has a commercial use and the basement floor is used as a storage and to the technical equipment. The other floors are used for office purposes and housing. Site observations allowed to conclude that the structure is highly composite and conceived essentially with local materials. The main Haussmann facades are made of dressed stone, excepted the two upper floors which are made with a timber frame solution. The facades located in the backside are made with a timber frame or steel frame solution. **Fig. 2-a)** shows Malhesherbe and Madeleine buildings facades viewed from *Malhesherbe boulevard*, this is a typical Haussmann facade and **Fig. 2-b)** shows an elevation along the building complex.

a) Front facade




b) Elevation

Fig. 2

Malhesherbe and Madeleine building complex

The interior walls are made with bricks or a timber structure filled with limestone. The basement walls located in the building complex perimeter are limestone rubble masonry, while the interior walls can be made with limestone rubble masonry or clay bricks. Foundation investigations revealed that the foundations of the existing walls are essentially realized extending downward the walls from 15 cm to 1 meter below the ground. Sometimes a concrete or limestone masonry strip footing or a limestone footing is placed beneath the walls. The floors structural system are of two types. The first type refers to floors made of a timber joist with floorboards attached to it and the second type is related to a floor system realized with a metallic joist and plaster interjoists. All the stories of Malhesherbe building are made with timber floors, while in Madeleine building and starting in the third floor, IAO metallic profiles, the existing metallic profiles prior to the actual IPE/IPN profiles, are the solution considered for the floors. this distribution clearly indicates a technical evolution from timber floors to metallic floors.

Fig. 3

Timber floors

a) Laths and plaster under beams

b) Laths and plaster bellow beams

## Timber floors

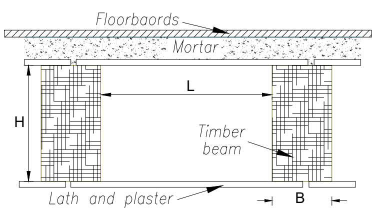
The investigations have shown that the timber floors do not have more the required resistance and stiffness to safely carry the loads. Several beams present large deformations or have extensive cracks. A weakening due to attacks by wood-eating insects and fungi is also evident. Furthermore, the floorboards are clearly deformed by the normal decay. These floors are made with resistant timber beams made of massif oak, below theme there is the floor ceiling made with laths and plaster attached and under the beams, **Fig. 3-a)**, laths and a mortar support the floorboard revetment, as shown in **Fig 3-b)**, (Cardoso R. and Pinto J., 2015).

The technical survey performed on several timber floors, **Fig. 4-a)**, allow identifying different typologies along the stories. More than sixteen type of floors were identified, varying the dimensions of the timber beams and their spacing, **Fig. 4-b)**. The spacing (L) between beams varies 16 to 30 cm, the width (B) of the beams varies between 7 cm and 12 cm and can exceptionally reach 24 cm and finally, the beam height (H) varies from 15 cm to 26 cm.

Fig. 4

Timber floors

a) Timber floor view




b) Timber floor detail

## Strengthening technique

The rehabilitation works plan to this complex consider the rehabilitation and strengthening of several timber floors because they do not have the necessary load carrying capacity, but also because regarding the overall building stability they do not brace correctly the structure against possible horizontal movements of the facade, (Branco, 2006). The strengthening work consists in pouring a new concrete slab under the existing timber beams. In this operation, all the connected slab have 8 cm thickness.

In order to realize this work, we must consider 6 steps. The initial state of the timber pavement is illustrated in Fig. 5 and represented by the existing timber beams and a lath and plaster layer.

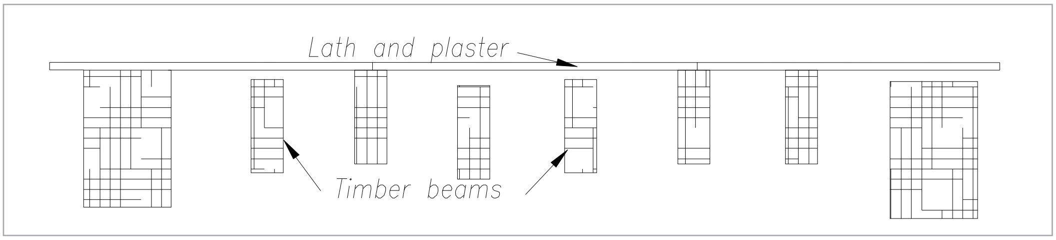



Fig. 5

Initial state

In the first step, the existing lath and plaster layer elements are eliminated, a shoring tower tour is necessary. This shoring tower has beams and a lost formwork, Fig. 6.

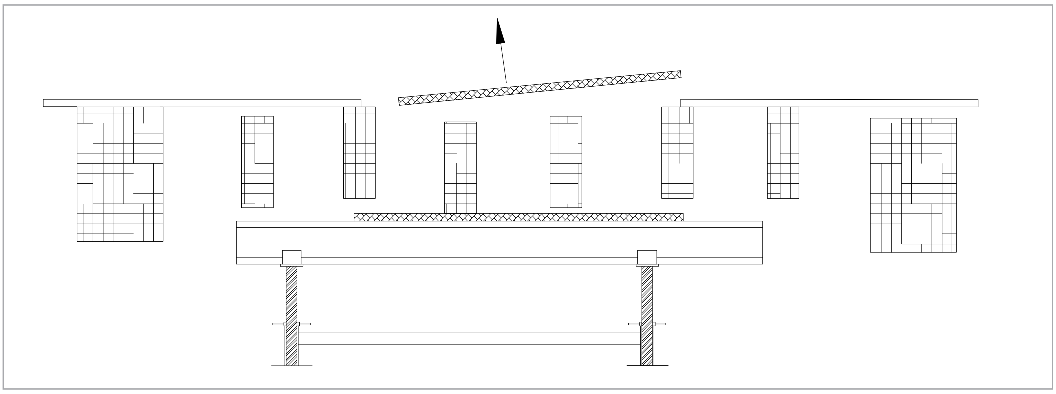


Fig. 6

Existing timber pavement elimination

In the second step, timber boards are put laterally on the timber beams which will be connected to the future concrete slab and cushioning timber elements are put on the timber beams which will be not connected, as illustrated in Fig. 7.

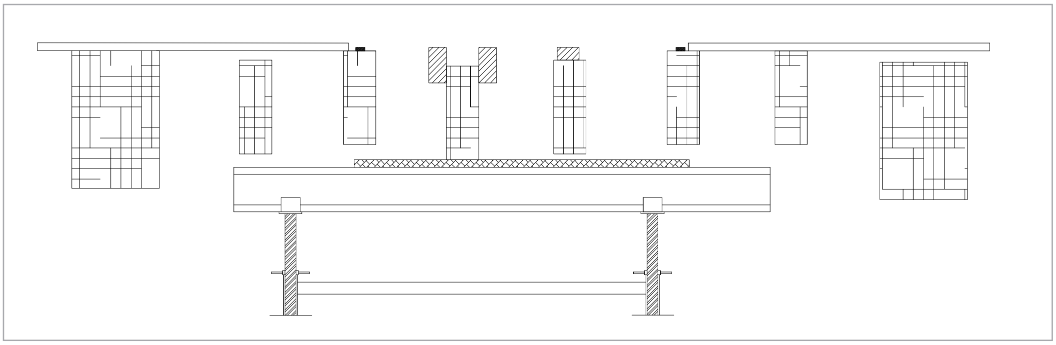


Fig. 7

Timber boards

In the third step, a lost formwork is put under the timber boards and on the cushioning timber elements to pour the concrete slab. Finally, the shoring tower is moved to another area and the previous operations are repeated, Fig. 8.

In the fourth step, connectors are put in place, their spacing and number are obtained after calculations, Fig. 9.

In the fifth step, the reinforcement corresponding to the concrete slab is put in place, Fig. 10. Each time the shoring tower is not used it must be validated by the design office.

Fig. 8

Lost formwork

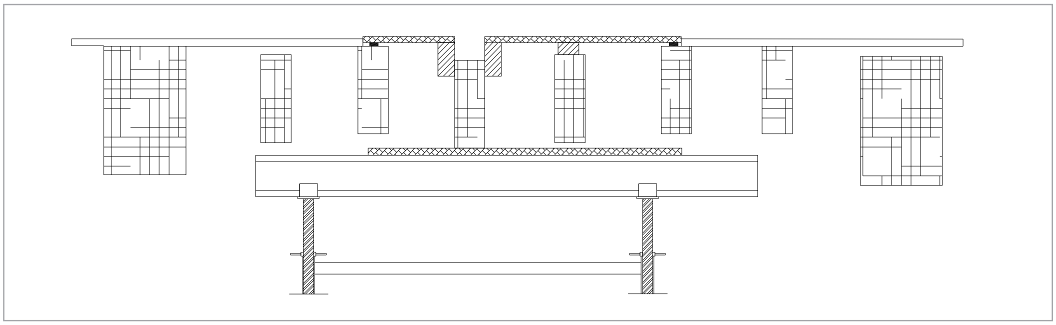


Fig. 9

Connectors

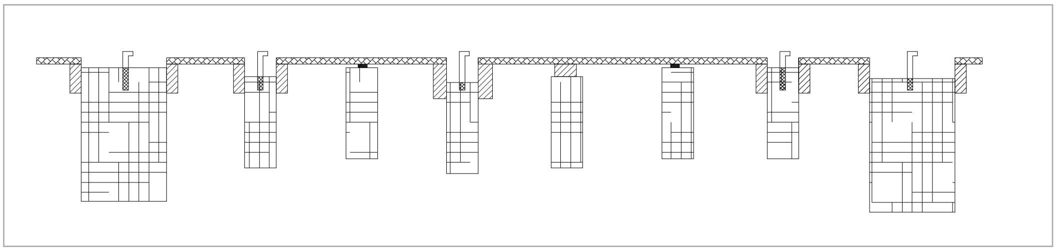
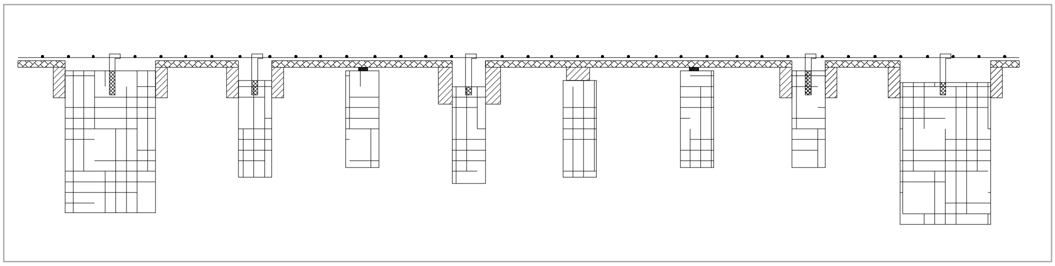


Fig. 10

Reinforcement introdution



Finally in the sixth step, after putting in place the shoring tower under the beams, following the studies performed by the design office, the slab is poured with a concrete pump, Fig. 11.

Fig. 11

Concrete slab connected

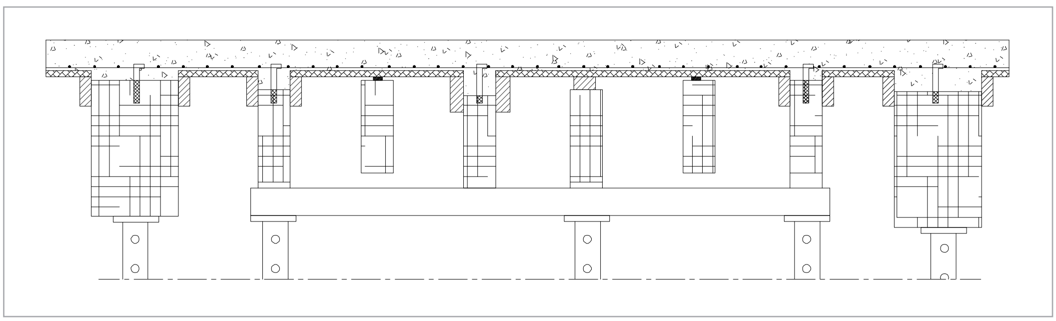


Fig. 11. clearly shows that this technique allowed to maintain an important quantity of existing materials and therefore it can be classified as a sustainable strengthening technique. This will not have been the case if instead a complete 20-25 cm thickness traditional concrete slab should have been poured.

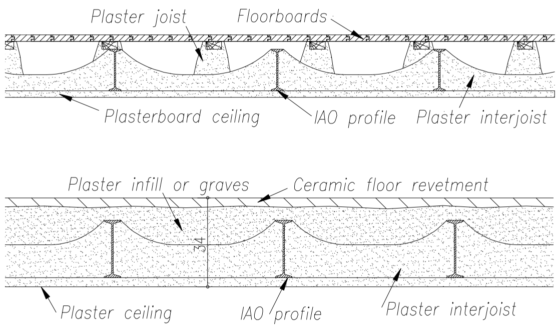
### The metallic floors

Some floors are made of metallic beams, in fact, starting on the 3rd floor of Madeleine building, the floors are realized with metal beams constituted of IAO cross-sections, Fig.12 a). Between those beams, plaster interjoist elements are set, Fig. 12-b). The investigation on metallic IAO profiles indicated high deflections and plaster cover deterioration. Furthermore, the design calculations indicate also that those floors do not have the necessary resistance to withstand the new loads rising from the new regulations (EN 1991-1-1, 2002) and due to the new service conditions, corresponding to a hotel.

Investigation on the metallic IAO profiles allowed to identify three types of metallic floors, depending one the IAO dimensions, the results are indicated in Table 1 and relative to Madeleine building.

The flanges width of the IAO profiles is equal to 6 cm, the height to 16 cm and the spacing between beams varies from 58 to 63 cm. Beyond that, tensile tests ordered to Veritas office and realized in IAO cross-section beams indicated a yield strength varying from 258 MPa and 283 MPa, and a Young modulus varying from 179 to 187 GPa. These results indicate that the metallic profiles still present good mechanical characteristics, in fact, the actual minimum tensile yield strength for metallic profiles is 360 MPa and the Young modulus is 200 GPa, (EN 1993-1-1, 2005). The protection given by the existing plaster infill around the metallic profiles certainly justifies those values (Cardoso et al., 2016).

a ) Metallic floor




b) Metallic floor detail

Fig. 12

Metallic IAO floors

Table 1

IAO cross-section dimensions

| | | Cross-section dimensions (cm) | | |
|---|---|---|---|---|
| Floor | Designation | Flanges width | Height | Spacing |
| 4th | D1 | 6 | 16 | 63 |
| 5th | D2 | 6 | 16 | 60 |
| | D3 | 6 | 16 | 58 |

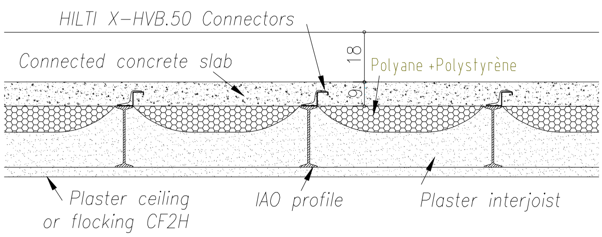



Fig. 13

Connected concrete slab

## Strengthening techniques

The strengthening technique for the existing metallic floors consists in maintaining the IAO profiles and creating a new concrete slab. Three solutions can be considered, in the first a concrete slab is connected to the metallic IAO profiles, the existing plaster interjoist is kept in place, Fig. 13 illustrates this solution. The thickness of the connected concrete slab can vary between 8 and 12 cm.

The second solution, consider the elimination of the plaster interjoist, only the metallic IAO profiles

Fig. 14
Full concrete slab

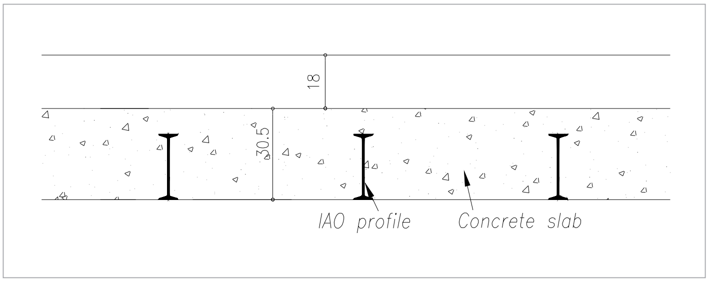
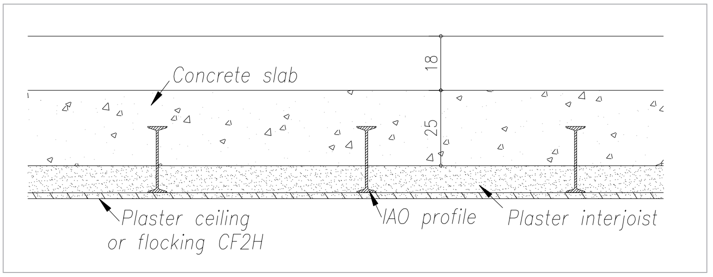



Fig. 15
Concrete slab



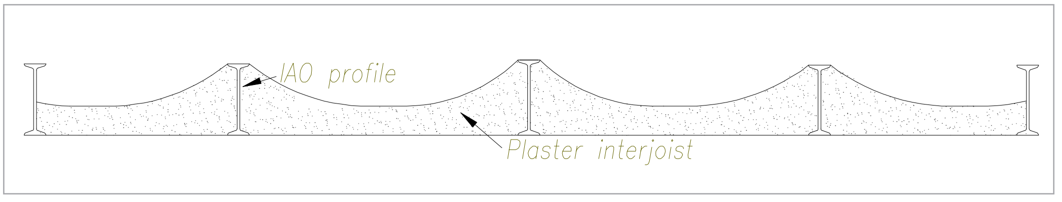

are maintained in place. A traditional reinforced concrete slab is put in place. In this solution, the resistance of the floor is the sum of a concrete slab plus the resistance obtained from the IAO profiles, **Fig.14**.

Finally, a third solution, intermediate between the first and the second solution can be considered. The plaster interjoist is partially eliminated and a concrete slab is poured. In terms of resistance, we can also consider that the resistance of this floor is given by the sum of the IAO resistance and the reinforced concrete slab, **Fig. 15**.

In the followings, we introduce the several steps regarding the strengthening of a metallic floor with a connected concrete slab, corresponding to the first solution, **Fig.13**.

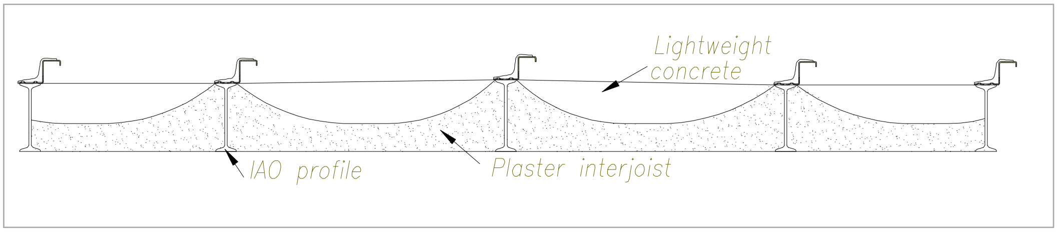
In the first step, the metallic floor is cleaned and only the IAO profiles and the plaster interjoist are maintained, this corresponds to the initial state, **Fig. 16**.

Fig. 16
Initial state



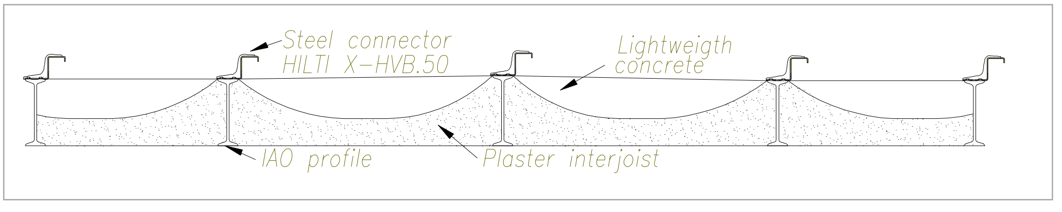

Secondly, a lightweight concrete is added in the volume between the interjoist and the top of the IAO profile, **Fig. 17**.

Fig. 17
Lightweight concrete




Thirdly, Hilti X-HVB steel connectors are put in the top of the IAO profiles, the spacing and number of connectors being calculated by the design office, **Fig. 18**.

Fig. 18
Steel connectors



Fourthly, since the IAO profiles do not have necessarily the same height, polystyrene boards are put in place in order to create a perfectly horizontal surface, Fig. 19.

Fifthly, the slab reinforcement is added, Fig. 20.

Finally, the concrete slab is poured, Fig. 21.

It should be noted that the connectors used are 50 mm, 80 mm, 125 mm or 140 mm height, depending on the IAO profiles height.

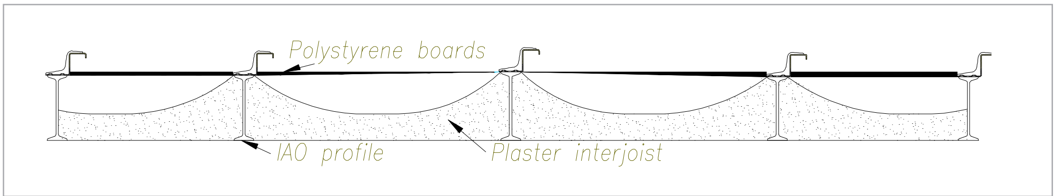



Fig. 19

Polystyrene boards

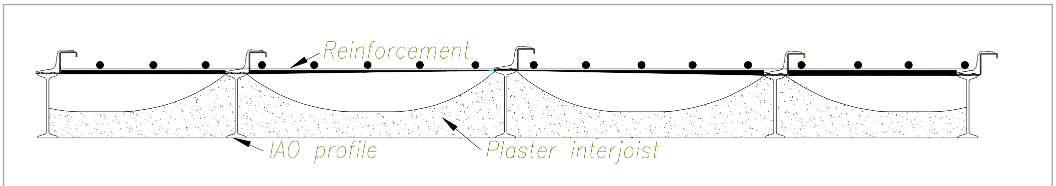



Fig. 20

Slab reinforcement

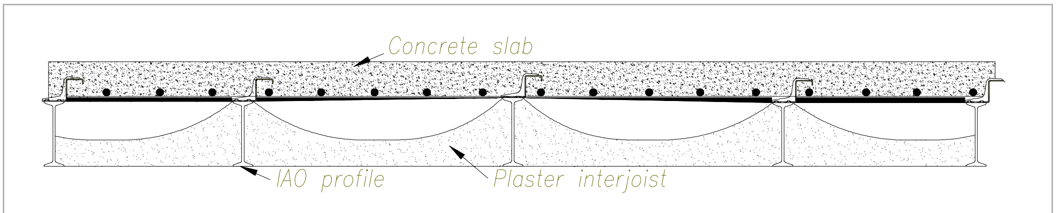



Fig. 21

Concrete slab

## Conclusions

The planning and design of strengthening techniques play a very important role in the global sustainable development. The demand for strengthening has increased in the last years as renewals and refurbishment of old buildings have gained popularity, mainly in the European oldest cities. This type of work requires skilled labor, not only constructors but also in the planning stage, since there is not a universal solution applicable to all cases.

The rehabilitation and strengthening work realized in the floors intended among others to eliminate their pathologies and increase their resistance and stiffness. The strengthening technique described for the floors is essentially based on pouring a concrete slab connected to the timber beams or to the IAO profiles. This strengthening technique retains a great amount of the original structure and minimizes the intervention and the introduction of new elements which lead to a cost-effective solution. It can be cataloged as a sustainable strengthening technique, ensuring at the same time to fulfill the actual requirements in terms of structural integrity, fire safety, thermal and soundproof insulation.

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