Flat Roofs Characterization in Barcelona's Historic Center

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Abstract. Historic centers usually have a dense urban fabric and little availability of open public space. After the covid19 pandemic, this lack has become even more apparent. In this context, the communal flat roofs of the buildings can represent an important potential to improve the quality of life in dense historical centers. Specifically, in the case of Barcelona, the project in which this research is framed studies how to use them as space of care, meeting, and rest specially addressed to the increasingly aging population. Prior to any action of rehabilitation or modification of existing roofs, their characterization is necessary.

This paper presents an in-depth constructive description of the existing roofs in the historic center of Barcelona, never been done before. The different periods of construction show different solutions present that are described in this analysis, detailing the materials originally used and quantifying the main properties of the typologies that influence their behavior. These solutions are georeferenced and quantified in the historic center as a whole. The main interventions usually carried out are also described and geo-referenced. Finally, guidelines and aspects to consider for its rehabilitation for future use are provided, also quantifying the available potential of community roof surfaces that could assume new uses as communal space for citizens.

Keywords: building rehabilitation · historic centers · built heritage · Built stock assessment

1 Introduction

The Ciutat Vella district is the oldest of the 10 that make up the city of Barcelona. Its delimitation corresponds to the old walled city, for this reason, its main characteristic is a dense and ancient urban fabric that is currently in a remarkable state of degradation together with a socio-demographic context marked by residential vulnerability [1, 2]. Faced with this state of affairs, the community flat roofs can become a space of opportunity to improve the quality of life of the residents of this historic neighbourhood [3]. These roofs can offer a meeting space that favours collective and cultural activities among neighbours and reinforces the feeling of belonging to the neighbourhood and the community, in order to strengthen and protect the intangible heritage of the neighbourhood [4].

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For this reason, the present research has focused on the flat roofs of Ciutat Vella, taking into account their potential as meeting and rest spaces for the population of this historic centre [5]. The aim of the study was the constructive typification, characterisation and evaluation of all the flat roofs in the district belonging to residential buildings.

This analysis has allowed the unification of the available information by combining bibliographic sources and on-site visits together with the geographic information system (GIS). As a result of this conjunction, a qualitative mapping has been obtained based on different vectors of the entire Ciutat Vella district. At the same time, the cross-referenced data has allowed the creation of a geo-referenced constructive characterisation of the different historical periods based on their materiality, construction techniques and performance, as well as the main interventions carried out on the roof.

Finally, the physical characterisation has made it possible to draw up an overall assessment of the district and to establish some general considerations for possible intervention.

2 Objectives

The objectives of the research are as follows:

- Constructively characterise the existing flat roofs in the historic centre of Barcelona, differentiating them by period of construction, characterising the materials and construction solutions used and quantifying the main properties that influence their behaviour.
- Locate and identify these solutions on the map of the historic centre of Barcelona.
- Describe the most recurrent repair interventions already carried out.
- Establish guidelines for their rehabilitation and potential use.

3 Methodology

The research consisted of the following methodological phases:

1) The first phase of the analysis aims to provide a description and classification of flat roofs in the Ciutat Vella district according to their construction characteristics. In order to do this, reference studies have been analysed [6–9]. This bibliographical review has allowed us to establish a chronological evolution of the different construction systems used for the configuration of flat roofs in Ciutat Vella and their different combinations. In turn, the bibliographical study has made it possible to establish three-time frames determined by the change in the main material used in the load-bearing structure of the roofs.
2) Next, the second phase of the study corresponds to in situ recognition of the roofs. In order to define the analysis sample, 15 case studies were selected, located within strategic areas for improvement in each of the neighbourhoods that make up the Ciutat Vella district (Raval, Gótico, Barceloneta, Sant Pere and Santa Caterina) (Fig. 1.).

The roof inspection procedure was based on observation and data collection systematised in a technical inspection document. This document recorded the dimensions of the roof, pitch, the location of the vertical communication core, the installations, the

general state of conservation, the relationship with the adjoining buildings and a recompilation of the different repairs or interventions carried out on the roof. The process of recognition and characterisation in situ of each roof was completed with the preparation of the corresponding planimetry, in plan, elevation, section and axonometry, with the aim of obtaining the greatest possible graphic compilation to enable the correct recognition of the shortcomings and potential of each community. In addition to these general inspection visits, surveys were carried out inside some of the roofs to verify the physical characterisation elaborated from the bibliography. For the study of the most frequent interventions carried out on roofs, previous studies on this subject have been analysed in a complementary manner [10–12].

3) The third methodological phase is the mapping of the cadastral database, using the geographic information system (GIS). It should be noted that for this analysis only the smallholding used for housing have been taken into account, according to the data in the cadastral database, as this is the main object of study of the research. The purpose of this graphic representation is to unify the available data, as well as to provide an overall picture of the current situation of roofs in Ciutat Vella. The following parameters have been taken into account in order to create this comprehensive view of the district: construction time frame based on the previous bibliographical study, surface areas of the dwellings and interventions carried out.

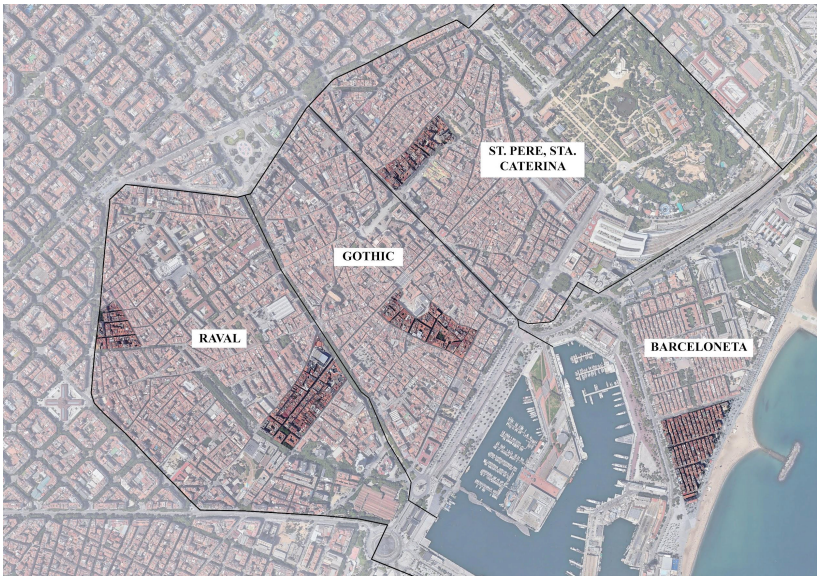

Fig. 1. Strategic areas for improvement

4 Results

4.1 Constructive Characterisation

The construction solutions of the existing flat roofs in Ciutat Vella (Fig. 2) observed are Table 1:

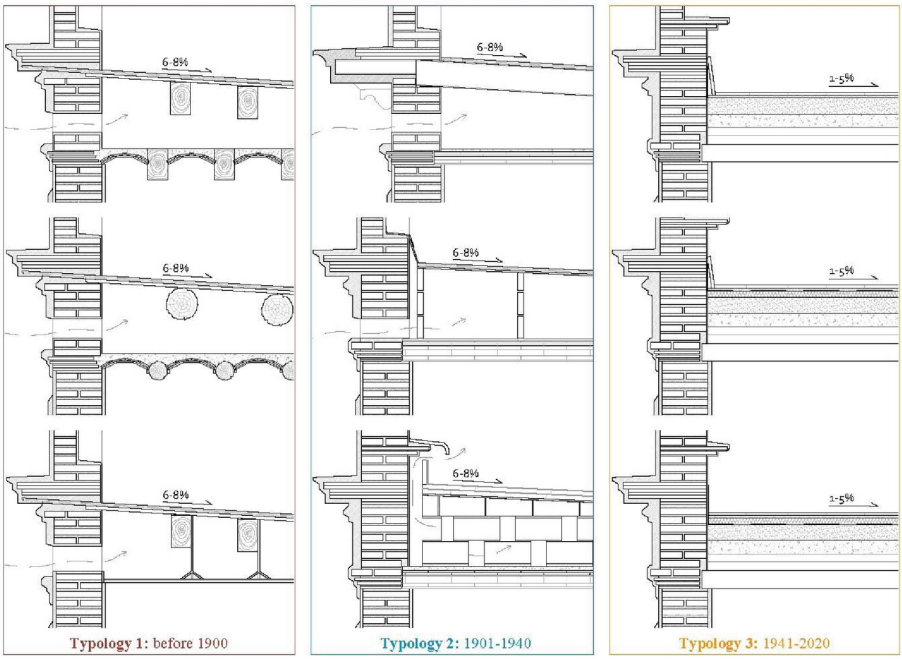

Fig. 2. Summary table of the constructive solutions analyzed by time periods.

Once the results obtained from the constructive characterisation of the different time periods have been presented, Fig. 4 shows the cross-referencing of these data with the Geographic Information System, and this combination generates a global mapping of the district based on its constructive solutions. After the quantitative analysis of these data, it can be concluded that the most abundant typology is the one prior to 1900 with a total of 3257 flat roofs (Fig. 4.).

After determining the main construction characteristics, the plot parameters that can influence the potential use of the roof have been analysed. Table 2 specifies these parameters and their average values within the study areas of each neighbourhood. Based on the data obtained, it can be determined that accessible flat roofs have an average surface area of around 160 m^2. This figure shows the potential of these roofs to accommodate different types of uses in this dense urban context.

Fig. 3. Interior of the air chamber of one of the decks visited. Source: own elaboration.

Table 1. Constructive characterization by typologies

Main features	Typologies		
	1	2	3
Period	before 1900	1901–1940	1941 - today
Structure	Solid wood beams	metallic beams	reinforced concrete
Slope	6–8%	6–8%	1–5%
Construction system for the formation of slopes	Wooden beam structure on top of the last slab	Interior ceramic ventilated partitions (Fig. 3)	Slope-forming light concrete
Waterproofing	Slopes and ventilated chamber	Slopes, ventilated chamber and ceramic flashings	Bituminous film
Ventilation	Through façade	Through façade or roof	Does not ventilate
Weight (Kg/m^2) [13]	266	264,8	200
Thermal transmittance (W/m^2K)	4–4,8	4–5,61	1,92–0,56

4.2 State of Conservation and Most Frequent Interventions

The current state of the roofs selected as case studies was then analysed (Fig. 5), identifying the present damage, the interventions carried out and the geometric characteristics that influence their functionality.

Table 2. Parameters of dimension and occupation by neighborhoods of the plots with access to the roof. Source: own elaboration based on cadastral data.

	Neighbourhoods				
Parameters (average values)	Sant pere and Santa Caterina	Barceloneta	Gothic	Raval northwest	Raval southeast
Facade width (m)	13.69	11.29	13.73	12.76	9.73
Depth of the roof (m)	17.24	8.33	17.51	15.42	18
Roof surface (m^2)	200.51	87.46	213.60	162.21	155.39
Communal roof surface (m^2)	108.97	50.34	116.61	109.17	90.70
% Smallholding occupation	76.63	91.45	82.65	76.22	61.70

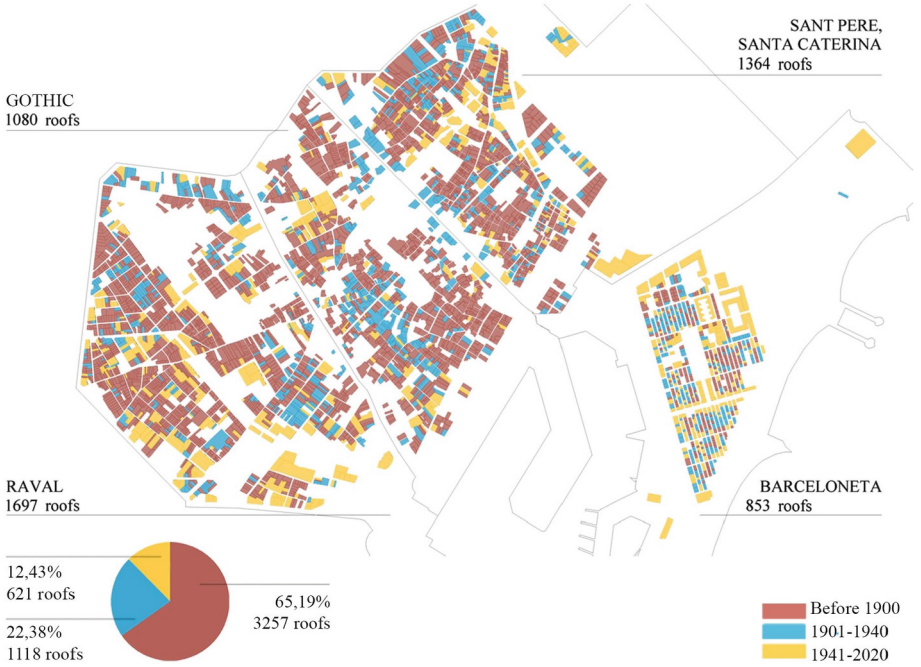

Fig. 4. Classification of roofs in residential buildings by time periods. Source: own elaboration based on cadastral data.

The main problem detected in the roofs was the waterproofing. This can cause mould problems due to water stagnation (1, Fig. 6). In the same figure, number 2 shows the

presence of lichen on the parapets; in most cases, this damage has been solved with a new stucco coating and the installation of a ceramic coping with a ceramic double drip edge (2, Fig. 7) [12]. Another of the main water-related shortcomings is the presence of humidity in the dwellings in contact with the roof and in the stairwells at the height of the roof slab (5 of Fig. 6). In order to repair them, the main techniques used have been the placement of waterproof sheets on the original paving (3 and 6 of Fig. 7), the use of waterproof paints as can be seen in number 5 of the same figure [10, 11] and the placement of ceramic perimeter flashings in those roofs that lacked them (8 of Fig. 7) [12]. This same strategy has been used for specific interventions to seal cracks or repair damage in existing drains (1 and 7 of Fig. 6).

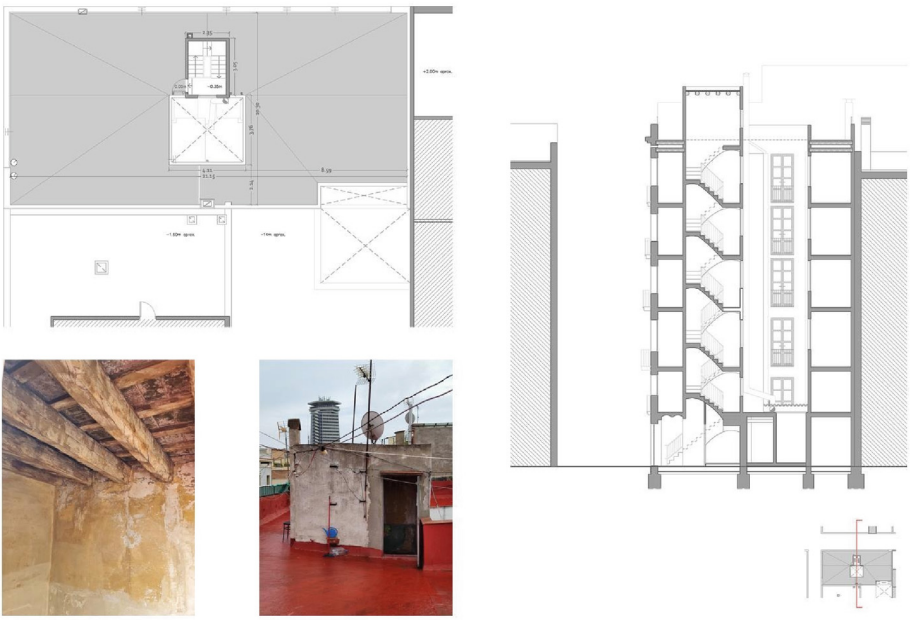

Fig. 5. Example of one of the surveys carried out

As regards the improvement of comfort conditions, one of the most recurrent interventions is the replacement of the stairwell roof with a skylight or the repair of existing skylights (4 Fig. 7), in order to achieve better natural lighting and ventilation in these small spaces [10]. In terms of improving thermal conditions, one of the most commonly used strategies has been the incorporation of thermal insulation under the air chamber and a waterproof sheet over the original ceramic finish covered by new "rasilla" (thin ceramic brick) finish [11]. Finally, in terms of total roof replacements, studies [10, 11] illustrate that the most commonly used strategies in this respect are the total replacement of the roof with a new conventional or inverted roof.

In essence, the roofs analysed mainly show damage due to lack of regular maintenance. Due to the economic conditions of the residents' associations, repairs are only carried out when the damages are visible and not as a preventive measure. Also due to

this economic conditioning factor, repairs are often carried out only partially, so that the appearance of the same damage in new areas can be recurrent. Lastly, with regard to the materiality of the repairs, it is common, as we have seen, to use waterproof paints on the existing pavement. Nevertheless, this type of material lasts between 5 and 8 years in Mediterranean climates, compared with 46–54 years for ceramic finishes [14], so that, despite being a global and economical intervention, this type of solution reduces the durability of the performance of these roofs to a large extent.

After this in situ analysis of the roofs, it was possible to determine, from the point of view of their functionality, that none of the roofs studied achieves the minimum height required for the parapets and protective railings. Furthermore, none of them has access to the roof via the lift, despite the fact that some of them have been intervened with the incorporation of a lift through the stairwell. Despite these limitations, the general condition of the roofs is good, with access through the common stairwell and no problems due to leaks thanks to total or partial interventions. As for their use, most of them are not used by the neighbours and their main function is to house the building's installations.

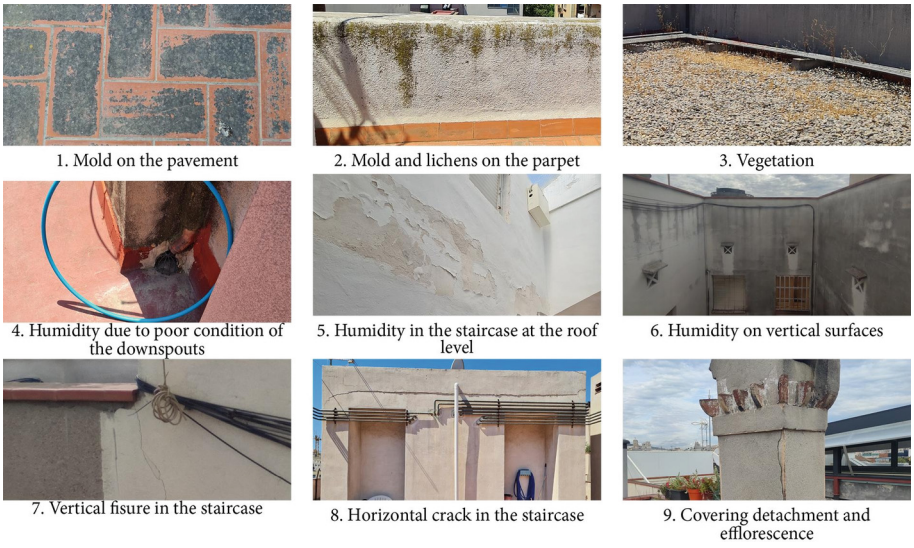

Fig. 6. Most frequent damages

Fig. 7. More frequent interventions

5 Conclusions and Recommendations

This research has characterised for the first time the most common construction solutions that are not exclusive to the Ciutat Vella neighbourhood.

The most frequent construction solutions in the neighbourhood are:

1. Solutions prior to 1900: Roof slabs that form slopes of between 6 and 8% that are superimposed on the last slab, forming a ventilated chamber with an opening to the façade. The load-bearing structure of the buildings from this period is made of solid wooden beams, initially with rough-hewn logs and later with squared wooden beams.
2. Solutions built between 1900 and 1940: In these floors, the wooden beams are replaced by metal profiles with slopes of between 6 and 8%, and they are also characterised by the incorporation of the brickwork for the formation of slopes in place of the double slab.
3. Solutions after 1940: this last period is characterised by the change to a reinforced concrete structure that eliminated the brickwork and the ventilated chamber, making it necessary to introduce the definitive introduction of waterproof sheets derived from petroleum and the incorporation of a 4 cm layer of thermal insulation.

These solutions share a number of common damages, especially in the parts exposed to the elements that have been observed: dampness, mould, lichen and cracks. None of these pathologies is particularly serious or prevents their use, so they are often not repaired or are repaired late, aggravating some of the consequences.

The most common repairs observed have been aimed at: 1) improving safety in the use of the roof by increasing the height of the parapets and adding ceramic copings for their use; 2) improving accessibility with the installation of lifts in stairwells; and 3) improving healthiness with the repair of water damage, especially those causing damage to interior spaces.

This article considers that these spaces have great potential for use, especially in dense urban centres where there is a lack of outdoor space and narrow streets make it difficult to let in sun and air properly. As demonstrated, no major interventions are needed for their immediate everyday use. Interventions needed to increase their potential for use include:

- To improve safety in the use of the space, it is recommended to check the height of the parapets.
- In order to improve accessibility, it is recommended to renovate the exit from the stairwell and to use the areas with the most horizontal planes on the roof. It is also recommended to consider interventions to place a lift in the stairwell where there is the possibility of direct access to the roof.
- To improve healthiness, it is recommended to control areas of humidity and water accumulation in order to avoid possible future pathologies.
- For the improvement of the performance of the roof, this research concludes with the following recommendations:
- In order to improve energy efficiency, it is recommended to implement improvements in the installation of thermal insulation.
- In order to improve the healthiness of interior spaces, it is recommended that damp patches be regularly removed and that air chambers be properly ventilated, if necessary.
- In order to improve its use and maintenance, it is recommended to opt for roof repair solutions with a top layer of "rasilla" (thin ceramic brick), without increasing the weight on the existing structure. And finally, establish guidelines for the correct use, operation and maintenance by the community.

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