Deterioration of residential buildings in the *Ensanche* of Bilbao

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Abstract

Our study focuses on the decay of residential buildings located in the *Ensanche* of Bilbao (Spain). The staggered expansion of this residential area allowed the implementation of innovative building techniques prevailing at each stage. Therefore, it preserves the construction improvements developed within the first decades of the 20th century: the transition from the timber framework with load bearing walls to reinforced concrete structures. The analysis of the evolution of each dwelling, from its original construction up to its current conservation condition, will lead to the identification of the factors involved in the decay of these buildings.
Keywords: decay, damage, residential buildings, Ensanche, Bilbao, timber framework, reinforced concrete.

1 Introduction

Ensanche means widening in Spanish, and it is used to define the urban planning scheme developed in Spanish cities during late decades of 19th century. The original urban planning project for the *Ensanche* of Bilbao was approved in 1876 and it was completed in the late 1970s. It is made up of about 1200 buildings, of which nearly 1055 have residential use. It is worthy of remark that 174 buildings which were built before 1900 are still standing.

Throughout years, all sorts of repairs have been carried out in almost every residential building of the *Ensanche* in order to improve their performance and to achieve the new standards of comfort that society demands. However, the fixings and restorations implemented can end up being harmful, accelerating and increasing the deterioration of the whole building.

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2 19th century urban planning: the *Ensanche*

The growth of the population, as a result of Industrial Revolution, led to overcrowded Spanish cities, causing substantial hygienic and housing problems. The need to transform the limits of old cities became essential.

The development of new urban areas began in 1860 with the *ensanche* projects of Barcelona, by Ildefonso Cerdá, and Madrid, by Carlos Maria de Castro. Both schemes were largely influenced by the transformation carried out by Haussmann in Paris in 1852 [1].

The *ensanche* projects were placed beyond traditional city boundary, in open fields outside old city walls. These urban arrangements were grid based plans, generally formed on principles established by Cerdá [2]. A balance between open spaces and residential blocks is the essence of this type of urban scheme. The height of the buildings is determined by the width of the street nearby, and a network of sanitary and storm drains is also a key factor of the design.

2.1 The Ensanche of Bilbao

The town of Bilbao was founded on a significant site where the river Nervión develops into an estuary. This fact was decisive for its medieval urban progress as well as for its modern development during late 19th century. In 1300, Bilbao was granted the status of city and took also the control of the maritime traffic going through its estuary. A wide range of goods were shipped from these docks, developing a significant trading centre in the area.

The City of Bilbao was confined to a very small municipality and by 1821, the housing problem affecting the city was unsustainable. Queen Isabel II granted permission to Bilbao to increase its municipal district by annexing to the nearby parishes in 1861.

Amado de Lázaro, civil engineer, was asked to draft within the new limits an urban extension plan in 1862. The influence of Cerda's *ensanche* project was clear – reflected not only in the orientation and size given to the blocks, but also in the chamfered corners and widths of streets – in his design [1]. The City Council considered it inappropriate and it was rejected, leaving the urban expansion of Bilbao outstanding.

Political instability slowed down the urban increase puzzle until 1870 when new boundaries of Bilbao were marked out. The council ordered a new *ensanche* project to Alzola, Hoffmeyer and Achucarro, two engineers and an architect, linked with local authorities.

The *ensanche* projects of Barcelona and Madrid were the references employed by the designer to arrange the new proposal [3]. Their scheme was organized around a central elliptical plaza (Plaza Moyua) and a main street (Gran Vía) which divided the new urban area in two.

The project obtained building consent in 1876 but its development became tough. It was an uncertain period in which, besides the slow expansion, the high prices of the plots attracted the bourgeoisie to settle within the *Ensanche*. Thus,

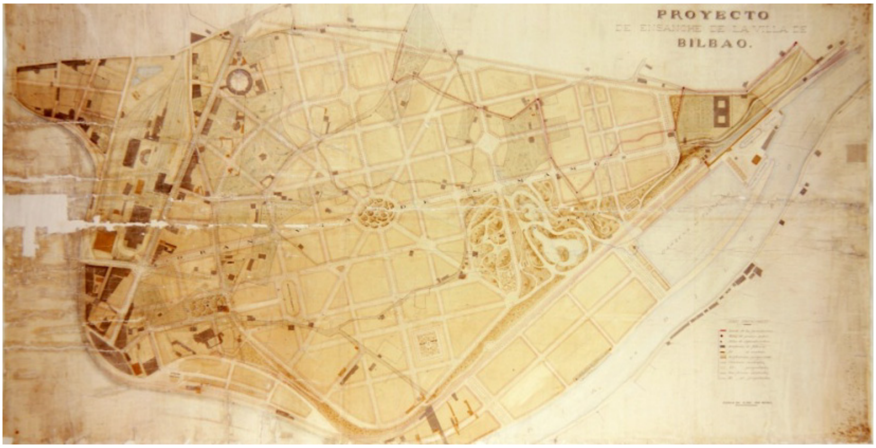

Figure 1: The original Ensanche project designed by Alzola, Hoffmeyer and Achucarro in 1876.

the undeveloped plan made the housing needs worse, generating the spread of disordered suburban areas in the near parishes.

The *Ensanche* of Alzola, Hoffmeyer and Achucarro designed in 1876 is considered the most distinguished area of Bilbao. After this, there were extension projects for the original *ensanche* but none of them showed clearly the characteristics of 19th century urban planning.

3 Original construction systems at the *Ensanche*

The completion of the *Ensanche* took nearly 80 years. Since the area was developed in phases, the new building procedures predominant at each phase were employed to erect buildings within it.

However, the *ensanche* entails a specific building and construction form. The building located between dividing walls and rising around a courtyard is the representative layout of this urban scheme. Regarding the construction itself, two main building techniques are found in the *Ensanche* of Bilbao: on the one hand, buildings with bearing stone walls and internal timber frame, and on the other hand, buildings with a reinforced concrete structure. Main properties of each are described in this section.

3.1 Architectural features and details of timber frameworks

Being a combined system is the special feature of 19th century building technique: part of the main structure is composed of perimeter load-bearing walls in masonry or ashlar stonework, while the internal structure is made of timber which rest on the walls enclosing the building.

As mentioned before, the width of streets established the height of buildings [4]. Ground floor (GF), 3 or 4 similar upper floors (UF) and a non-habitable attic floor under the roof (AF) is the original profile of the buildings built under the ordinances of 1885 and 1904. Formerly the buildings had a dual use: commercial activities and workshops were located on the ground floor, and the rest of the building was for residential use only.

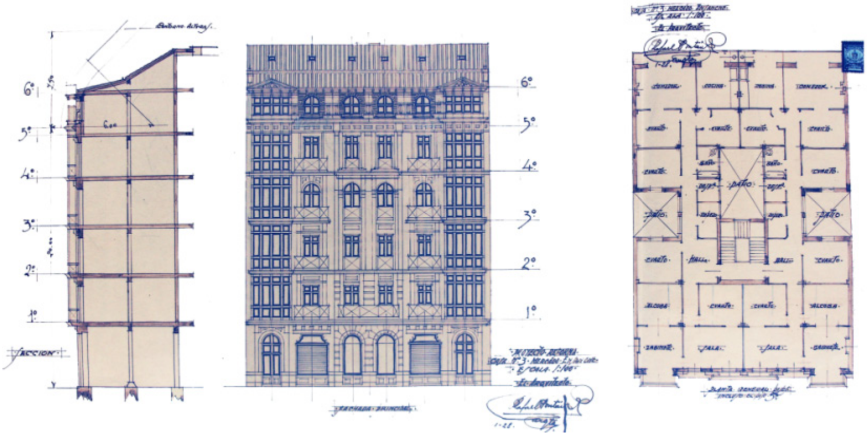

Figure 2: Original plans of a residential building with timber framework (1891).

Since the solid stratus in which foundations rest is relatively close to the surface in this area, there was no need to dig very deep, for this reason few buildings of this time have a basement. Two types of foundations were employed: perimeter bearing walls made of stone and box shape stone foundations for internal posts.

Regarding the floor plan proportions, overall the E*nsanche* is not organized with a standard unit. The technology and building materials employed, as well as hygienic and ventilation requirements set these dimensions. The central characteristic courtyard of the block disappeared occasionally, however each residential building has at least one indoor patio.

The internal structure is built of timber. The timber framework is composed of posts connected with beams which bridge about 4 or 5 m long span. Oak was the timber predominantly used in timber-framed constructions, for its strength and resistance. Iron, stone or fabric posts and metal joist decks with hollow modular ceramic brick floor system were employed on basement and ground floor structures, to prevent the spread of fire [4].

The floor is composed of joists covered with wooden boards or floor tiles. The lower part of the beams and joist were not left exposed, they were plastered: short strips of wood were fixed underneath to provide a base for the plaster.

The main façade is made of ashlar stonework. The rear façade has minor relevance, usually built in limestone with plaster application and painted afterwards. Both façades have openings at each floor and main façades apertures can have balconies or bow windows. The structure of the roof is built with rafters, purlins, wooden panels and tiles. Two pitches roof with 30-40º of tilt is the characteristic roof design.

Floors and roof frames were both figured to support a load – its own load and the overload – of no more than 3 kN/m^2. Overall, these structures were erected with traditional standards in which the size of the elements and their stability were the main factors. The properties related to resistance were irrelevant which resulted in non-optimized structures: timber framework is dimensioned tight in relation with the load it has to support, while the perimeter wall frame is usually oversized.

3.2 Architectural features and details of reinforced concrete structures

Reinforced concrete was introduced in Spain as a new building material by the end of 19th century under French influence. Patents coming from Europe spread its use for structural purposes. Truly important and relevant were the Monier, Hennebique and Blanc systems developed in France and Germany, just like the Spanish systems called Ribera and Zafra [5].

La Ceres flour factory, built from 1899 to 1900, was the first public *building* made with reinforced concrete in Bilbao – it is still standing and reconverted to apartments. It was built under the instructions of Hennebique patent [6]. Different patents were used to build residential buildings at the *Ensanche* during early years of 20th century.

By 1920s the use of reinforced concrete patents began to decrease since new theories based on scientific basis began to arise. Reinforced concrete would be employed under mathematical methods rather than invented procedures. Thus, patents had a short life time of around 20 years. However, there was no reinforced concrete code created in Spain until 1939, and the first specific standard regulating this building material was published in 1973.

With the introduction of reinforced concrete the limitations associated with timber vanished to some extent, although many technical aspects of the new material were still unknown. The sizes related to timber elements changed, introducing a wide range of dimensions. Building materials changed, also the building profiles and volumes, hence it is hard to define the dimensions and building arrangements for this period.

Reinforced concrete structures of the *Ensanche* are composed by pillars, beams and slabs. A wide range of foundations types can be found: spread footing, continuous spread footing, piles, etc.

Depending on the width of the streets in which the building is placed the height changes. The typical profile for reinforced concrete structures is 1 or 2 basements, ground floor, 5 or 6 upper floors and 1 or 2 attic floors set back from building principal alignment – statements related with height changed over time.

Façades do not perform a structural function in this system. Façades are made with one leaf of brickwork, occasionally with two leaves with a cavity in between. Materials for thermal insulation are not employed until late seventies when the worldwide oil crisis of 1973 brought changes in energy saving aspects. Stone cladding often covers the ground floor façade, while the rest of the floors have a face brick or grouting finished. Openings are bigger than in timber frame buildings due to the non-structural character of the façade, and balconies as well as bow windows are employed.

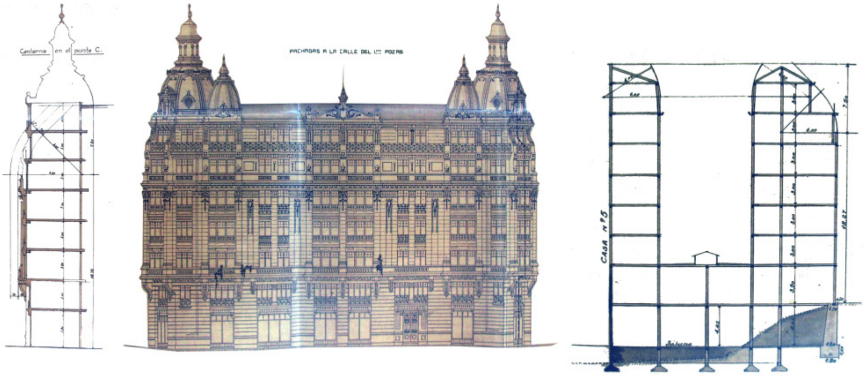

Figure 3: Original plans of a residential building with reinforced concrete structure (1920),

A two pitches roof is less common in this type of structures. Buildings with attics have flat floor using bitumen materials with waterproof properties.

Structural resistance in reinforced concrete made under patents instructions was of about 15 N/mm^2, while concrete employed in the buildings erected during the fifties present a resistance of 8,5 N/mm^2 [7]. It is worth pointing out that Spanish current code defines a resistance of 25 N/mm^2 for structural concrete.

4 Prevailing alterations on residential buildings

Almost all residential buildings forming the *Ensanche* have been refurbished and it is highly possible that some of these interventions have caused specific damage on them. Predominant alterations found in residential buildings are enumerated in this chapter.

4.1 Alterations in buildings with timber framework

Adding new floors: until 1906 most of the buildings conserved the original profile (GF+4UF+AF or GF+5UF+AF). Later on, changes occurred in aspects related with local building ordinances and the original profile began to transform. Many buildings have had their height increase in one or even two floors.

Modern materials: the incorporation of modern materials (steel, concrete, plastics, etc.) in timber frameworks causes a lack of continuity. Modern and traditional materials perform in opposite ways when under factors like sun, moisture, etc.

Lift installation: many were the buildings that had a lift installed inside the gap of the staircase in the early decades of 20th century. It was usual to attach the structure and machinery of this element to the main timber frame of the building. This mechanism generates a dead load growth and a dynamic load on the structure.

Internal loads growth: around 1940, businesses equipped with archives, bookcases and other type of heavy office furniture were accommodated within residential buildings of the *Ensanche*, increasing substantially the load over structure.
Floor improvements: the transformation of wooden floors inside dwelling has been irregular and varied. Different procedures have been implemented such as taking out the wooden boards and laying down some cement to put in place ceramic or stone floor tiles. Frequently, a layer of reinforced concrete has been employed to mend the deformations of timber frame. All of them increase the dead load.
New internal arrangements: partition walls in timber structure have often a structural function. Although these walls are not designed to support loads, due to the deformation suffered by the structural elements, some become part of the structure.
New comfort levels: when these buildings were built, there was neither a heating system nor a washing machine, even less a dishwasher. The stone façades had good performance under original thermal conditions, but the incorporation of modern building services and electrical appliances has changed the internal environment, making it damper.

4.2 Alterations in buildings with reinforced concrete structures

Adding new floors: these sorts of enlargements are less common in this type of building, although some have increased their height by one or two floors which produces a load rise over the main structure.
Modern materials: modern material and high-tech systems employed in construction can be incompatible with the material existing in the building. During the last decades, the energy saving aspects has brought not only integral façades transformation but also improvements of window frames, generating highly hermetic buildings.
Lift installation: apart from installing new lifts, old lifts are replaced. Some replacements involve changes in the original structure. In addition, the vibrations of the new mechanism generate a dynamic load over the concrete structure.
Internal load growth: the implementation of private business in the lower floors of the residential building causes load growth and the structure can be affected.
New internal arrangements: due to changes in the building uses, many dwellings have had their internal layout rearranged. The modifications of structural elements like pillar or beams directly affect the performance. However, partition walls do not perform a structural function in reinforced concrete structures.
New comfort levels: as mentioned before, changes occurred in the electrical appliances and heating systems have altered internal thermal conditions of residential units, making it damper. The brick façades do not perform well under these circumstances and condensation problems arise.

5 Principal damage on residential buildings

Each building technique has its own deterioration not only because of the characteristics of the building material employed but also for the technical relationship introduced between them. All materials have also a particular deterioration depending on their location and its building function.

5.1 Damage in buildings with timber framework

Foundations

As mentioned before some buildings were built without a basement which means the dampness of the land remains relatively close to timber frame. The dampness below ground level cause efflorescence on stone foundations and erodes them. Although ground floor posts were made of iron, the termites existing in the damp earth reach the timber frame and attack it, damaging the whole structure.

The vibrations caused by construction works in the area and also basement diggings affect timber frames, producing cracks. Excavations can leave buildings nearby without a base and cause differential settlement, provoking damage such as cracks, splits between façades and partition walls, etc.

Adding floors to buildings increases dead load to the structure and also to the foundations. Hence, if the maximum load that the ground can support is exceeded, settlements happen, causing aforementioned damage.

Besides, many floor enlargements were built some meters set back from the general building line without considering the layout of the structure underneath. The stress grows on the joists causing disorders such as large deformations of the horizontal structural elements, joist breaking and cracks.

Internal structure

The dampness produced by the filtrations and condensations set on the façades moves into internal timber elements. These pieces, often covered up by decorative materials, cannot breathe and become rotten. Xylophages' insects attack rotten structural elements and damage timber framework, causing strength loss.

As mentioned before, many apartments have been transformed into offices and a wide range of internal refurbishments works have been made. Occasionally posts have been removed or located in other places which involve changes in the performance of the original structure. In addition, as mentioned before, partition walls even if they are not structural elements, due to deformations affecting the main structure, floors often rest on them. Therefore, changing the original layout of partition walls leaves floor above without support, creating important deformations and cracks.

Lifts attached to timber frames cause deformations worthy of consideration. Besides, the dynamic loads generated by vibrations are cyclic loads that generate fatigue on timber elements, reducing its strength little by little.

Façades

Pollution originates colour variation on ashlar stonework, but more critical is the decay that dampness causes. One of the properties of ashlar stone is its low cohesion which makes it is sensitive to water.

Filtrations and condensations are the prevailing problems on façades. Due to its porosity, ashlar stone absorbs rain water easily and the filtrations through it cause efflorescence, erosion and microorganisms.

Condensation is by far the most common cause of dampness in buildings, but it appears to be a significant problem in modernized building since advanced home electric appliances cause a great quantity of water vapour. When moisture-laden air comes into contact with a cold surface, water begins to drop out of the air, and is seen as condensation on surfaces. Stone façades lack thermal insulation and have a big temperature jump between faces – especially in winter in which differences of 20ºC can happen. The façade cannot perform well under this thermal condition, so condensation appears on cold walls, windows, and floors. Mould is the first result of condensation.

Rear façades are normally covered with lime or cement mortars which are afterwards painted. Depending on the dimensions of the courtyard, the air circulation can be limited. Under these circumstances, dampness appears and affects the paint and the mortar layer, detaching them. Pieces begin to fall down and vegetal organisms also occur.

Roofs

The movement of ceramic and slate tiles in a two pitches roof is very common. It weakens the waterproof quality of the roof and water get through timber frame. The structural elements become rotten and consequently, structural strength is affected. Fungus, xylophages' insects and mould appear as well.

Occasionally water is accumulated in cornices and gutters, causing moss and lichen. Also, these places are attractive to pigeon and their droppings deteriorate ashlar stone gravely.

Building services

Many services are built within the walls, making it difficult to make a proper maintenance of these elements. *Water supply* and sanitary i*nstallations cause more problems since the pipes get break and blockage.*

Figure 4: Some of the damage found in buildings with timber framework.

5.2 Damage in buildings with reinforced concrete structures

Foundations

Increasing dead loads affect the main structure and the foundations. As mentioned, if the maximum load that the ground can support is overtaken, settlements can be produced, causing cracks, splits between façades and partition walls.

Internal structure

Basements, built without waterproof protection or with ineffective drainage system, have important damp problems. Dampness causes concrete deterioration and consequently oxidation occurs in steel bars. When steel bars get rusty, their volume increases originating tensions within the concrete. Weak concretes cannot stand the tensions and break into pieces, leaving internal surfaces exposed.

The patents of the early decades of 20th century employed very poor concrete (15 N/mm^2) to make structures. External elements (cornices, windows slabs, etc.) made of this type of concrete under atmosphere's humidity and pollution, get deeply carbonated. Thus, within the carbonated concrete, the steel bars lose their passive film and they get corroded, losing their strength and generating tension inside concrete elements.

During the fifties and sixties many concrete mixtures were made with sand from seaside. This variety of sand has high levels of sodium chloride. The combination of sodium chloride with dampness inside reinforced concrete elements causes corrosion on steel bars, damaging the reinforcement. Besides, during these decades, the reinforcement was composed by smooth steel bars – nowadays they are corrugated to improve the adhesion with concrete – therefore, the union between concrete and bars is not complete, which causes cracks in areas supporting tensile stress.

Façades

Filtrations and condensations cause dampness within the layers forming the façades. Because of this dampness the face cladding becomes detached, making filtration and condensation problem worse and increasing the presence of microorganism.

External thermal conditions also provoke expansion and contraction movements on material composing the envelope of the building. Detachment of cladding occurs and occasionally pieces fall down to the street.

Roofs

The lack of maintenance makes asphalt membrane deteriorate and thus, rain water comes through it to the interior of the building. Water trace generates dampness, which often reaches the structural elements. Elements affected have their mechanical properties damaged. The faulty execution of the joint between the façades and roof causes disturbances on both units.

Building services

Building services are getting more and more efficient and optimized, but the building itself still remains the same. A large percentage of the construction materials forming a building continue to be original, developed under the technology of that time. The improvements that modern building services achieve are often incompatible with the properties of buildings and their performance.

Figure 5: Some of the damage found in buildings with reinforced concrete.

6 Conclusion

Residential buildings have many deterioration types. Some of the damage is closely related to the alterations that involve changes in performance of the building. Within this context building elements suffer two types of decay. On the one hand, there is a natural decay which is hold to the evolution of each material in which the properties can be affected and deteriorated. On the other hand, there is the deterioration caused by the alterations and modifications carried out on different parts of the building

Thus, there is a cause effect relationship between interventions developed in buildings and the damage their present. Often, the construction properties and technical aspects of residential buildings are ignored when works are undertaken. As described, building performance is affected usually by repairs made individually at each residential unit. People in general ignore the performance of buildings, just like the measures and solutions that they can adopt to improve them. The consequence of these procedures causes, in some way, the acceleration of the deterioration and serious structural problems in buildings. Therefore, refurbishments and conservation works have ended up by altering the original construction system affecting its nature and performance.

In summary, decay, alterations and enlargements executed in residential buildings determine their endurance. Besides, the individual evolution of each building forming the *Ensanche* also affects the integrity of the whole urban expansion.

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References

[1] Martín, R., *El Efecto Cerdá: Ensanches Mayores y Menores, Polytechnic University* of Catalonia: Barcelona, pp. 07-105, 2011

[2] Development Ministry of Spain, *Cerdá y su influjo en los ensanches de poblaciones*, Development Ministry of Spain: Madrid, pp. 05-09, 2004

[3] Alzola y Minondo, P., *Memoria del Proyecto de Ensanche de Bilbao 1876*, Colegio Oficial de Aparejadores y Arquitectos Técnicos de Vizcaya: Bilbao, pp. 15-25, 1988

[4] Bilbao City Council, *Proyecto de Ordenanzas de Construcción Vigente en el Casco Viejo y Ensanche de la Villa de Bilbao*, María Echevarría: Bilbao, pp. 03-21, 1885

[5] Sagarna, M., *PhD Thesis: Estudio de la Evolución de la Arquitectura de Guipúzcoa Ligada al Desarrollo del Hormigón Armado*, University of the Basque Country UPV/EHU: Donostia, pp. 109-118, 2009

[6] Rosell, J., *La Fábrica Ceres de Bilbao: los orígenes del hormigón armado y su introducción en Bizkaia*, Colegio Oficial de Aparejadores y Arquitectos de Vizcaya: Bilbao, pp. 127-130, 1988

[7] TECNALIA Corporación Tecnológica, *Informe 007262-IN-CT-11/0*, TECNALIA Unit of Construction, Decay and Refurbishment: Zamudio, 2007

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