



Review

Analysis of Renovation Works in Cappuccinelli Social Housing District in Trapani

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Abstract: The refurbishment of public residential districts represents a current and complex problem. The Cappuccinelli Social Housing (SH) district in Trapani, designed in the late 1950s by Michele Valori and built during the 1960s, is emblematic of the architectural quality and technological innovation of the time it was designed, but at the same time represents the physical and social decay that occurred just after its construction. The neighborhood was examined through a combination of inspections and documentary research. The inspections were conducted for the entire district in order to identify the recurrent external degradation of building components and the related causes, both physical and anthropogenic. This paper investigates the physical–mechanical degradation and problems connected to previous renovation work in this district. Furthermore, technological design solutions are discussed for deep renovation and energy efficiency improvement of one of the terraced buildings of the Cappuccinelli SH district.



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1. Introduction

The importance of deep renovation to existing building stock, recently stressed by the European Commission [1], is well-established in Italian regulations and strategies on buildings and their performances [2].

Public housing districts are relevant in this context, as demonstrated by several researchers investigating their renovations in European countries [3]. Several efforts were dedicated to joining architectural retrofit aspects with energy-saving requirements. In [4], the energy renovation of a city district in a particularly challenging historical city center is presented. The authors carried out an energy assessment of different interventions applied to the SH district in Venice. The introduction of vegetation for climate mitigation in urban contexts and for the energy improvement of individual buildings is widely studied. In [5], the benefits arising from the application of nature-based solutions in urban districts are examined. A set of simulations showed an improvement in the overall comfort conditions of inhabitants in terms of “urban heat island” reduction and living wellness. In [6], the author argues that additions on the façade have considerable advantages for the recovery and improvement of the energy performance of buildings, and proposes this solution be applied to public housing buildings, in accordance with Gaspari J. in [7,8]. Interventions on the building envelope allow for not only improvements in the energy performance of buildings, but also improvements to their appearance and architectural quality, giving new life to public housing. BIM is a new method used to optimize the planning, construction, and management of building artifacts using the software. Through the use of BIM software (Last Planner, Plan Radar, Vienna, Austria), it is also possible to validate the economic benefits of the recovery of public housing. In this study [9], 4D BIM technology was applied

to a case study in Northern Ireland to validate the effectiveness of the software in cases of social housing retrofit, a condition not particularly studied by the scientific community. The authors argue that their model could be expanded to all UK buildings. The authors of this article [10] analyzed Portuguese residential construction in order to demonstrate that the recovery of existing buildings, using a minimum economic investment and ensuring energy improvements, is essential for a sustainable economy. Roof renovation is the most cost-effective measure for improving heating and cooling thermal performance. A study conducted by researchers at the University of Seville [11] in Spain demonstrates how the application of a ventilated roof in a Mediterranean climate allows for a 65% reduction in cooling requirements without a consequent heating penalty.

Social Housing districts are a significant portion of the existing building stock and are frequently based on architectural solutions which are worth being preserved although not optimum for achieving the current technical requirements set for existing buildings. Furthermore, these districts are often affected by large amounts of physical degradation due to lack of maintenance and social marginalization. Finally, they often host vulnerable inhabitants, who should be the primary beneficiaries of public strategies for building renovation. In this regard, solutions aiming at improving both the buildings' energy efficiency and urban environmental quality are considerably effective and also provide relevant social outcomes [12].

The present paper focuses on the public housing district called "Cappuccinelli" in the Sicilian town of Trapani. Cappuccinelli is strategic in the sustainable development of Trapani since it is situated both along the waterfront and on one of the main roads of the town. At the same time, this area is vulnerable to hydrological risks since it is located on a swamp that was reclaimed at the end of the 1930s.

The district is the result of an interesting architectural project [13]. However, it also suffers from relevant physical decay (evident in the number of unauthorized additions and the lack of regular maintenance), which has fostered significant social problems. Because of these weaknesses, for a long time, the municipality ignored the potential of Cappuccinelli for its inhabitants and the town as a whole. Recently, thanks to an announcement issued as part of the National Innovation Program for the Quality of Living [14], the municipality has included the district among the sites selected for regenerating the urban, building, and socio-economic heritage of Trapani in order to improve social cohesion and guarantee the quality of life of citizens with a sustainable perspective.

This paper investigates Cappuccinelli as a reference case to develop planning and design procedures for the refurbishment of Italian public housing districts. In this sense, the circumstance that around 62% of dwellings in Cappuccinelli are owned by private parties—generally, the inhabitants themselves—and not by a public body is relevant given that this is a frequent barrier to urban-scale improvement strategies and renovations of Italian social housing districts.

2. Methodology

The research method adopted by the authors started with the analysis of Cappuccinelli Social Housing district through a detailed examination of a combination of documentary research, onsite inspections, and monitoring activities related to the thermal transmissions of external walls as discussed in previous work [15].

Documentary research was carried out at the archive of the public body "IACP Trapani", which is responsible for public dwellings in the Cappuccinelli district [13]. Two main objects were explored. First, project development was detailed from the awarded architectural concept to the construction of the district, which was characterized by several changes to the original design [13]. Secondly, technical documents of the renovation works carried out by IACP were examined and categorized according to the building and period of execution.

General onsite inspections were conducted for the entire district in order to individuate recurring outdoor degradations of the building components and their related causes, both physical and anthropogenic.

The alterations, classified according to the technical standard UNI 11182:2006 [16,17], were documented by means of photographs and geometric surveys. As far as the anthropogenic degradations are concerned, the types and locations of inappropriate external and structural changes, façade changes in façades (especially for openings), and unauthorized additions were reported systematically. Information collected about damages and alterations in the different blocks was related to the positions of the blocks in the district (especially for their exposure to wind and sea salt aerosol) and the rates of private and public owners per building.

As described in the following section, the study was widened to two blocks, where a detailed analysis of external degradation of the building envelope was carried out. For this purpose, a photogrammetric survey was carried out.

The additional data achieved through the focus on two blocks were used to define an order of priority for urgent renovation works [18] and discuss the technical proposals appropriate to match the deep renovation of the Cappuccinelli district with its architectural features.

3. Data Presentation Analysis and Discussion of Findings

3.1. Cappuccinelli Social Housing District

The “Cappuccinelli” district (Figure 1) was built as part of the national plan of social housing called “INA-Casa”, which was implemented by Italian Law 43/1949. Architect Michele Valori and his group designed the district for a design contest in 1956.

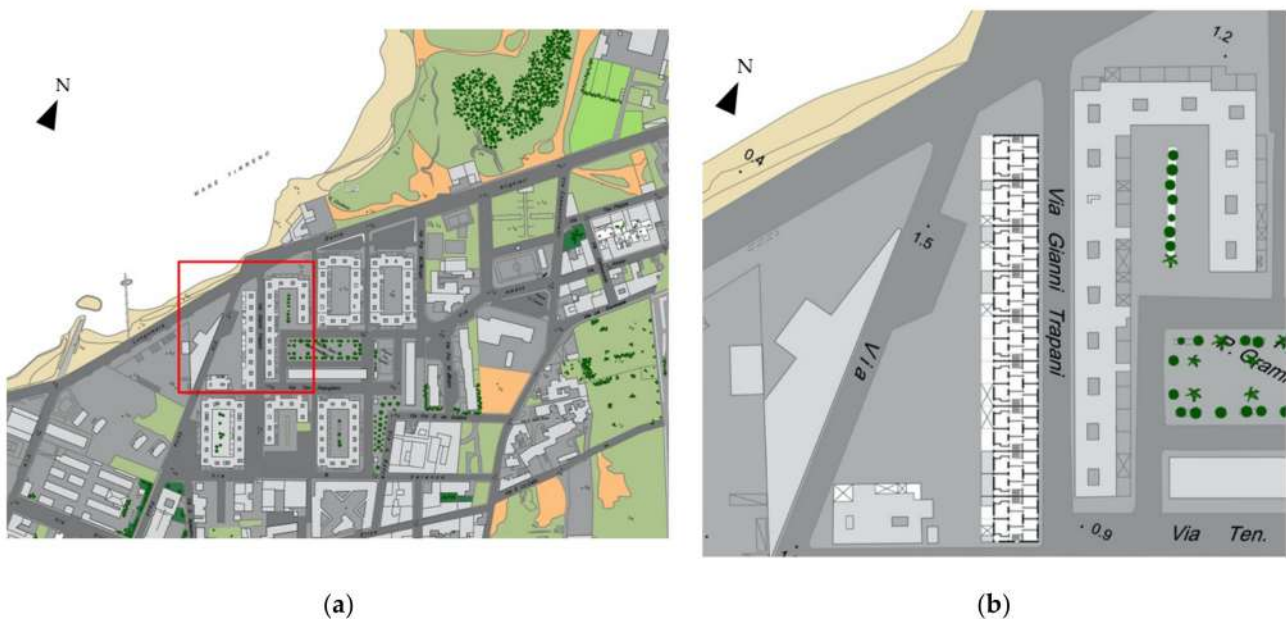


Figure 1. Plan of the Cappuccinelli District (a) and ground floor plan of the terraced block named “L” (b). Source: Rossella Corrao.

A large square is surrounded by two-storey blocks, each including large inner courtyards, and a multi-storey building. The idea, on which the project by Valori is based, creates a strict relation between private and public spaces that are linked by buildings, predominantly terraced houses with different typologies of apartments.

The “courtyard blocks” consist of duplex apartments with four to five rooms. These dwellings are organized in pairs and each one has a small courtyard that is accessible from a portico. This private courtyard is separated from the large common courtyard of the block, which is accessible from a secondary access point at the back of the apartment. The ground

floor of each pair of apartments corresponds to a square. One side of this square is 12.60 m long and corresponds to the module that the district is based on. In the original project, the inner courtyard of each block was dedicated to extensive vegetation with private gardens, equipped areas, and a limited number of tall trees.

The phenomena of social decay impacted Cappuccinelli from the beginning. Many houses were illegally occupied even during the construction work, thus impeding the completion of the district according to the original project plan. Furthermore, unauthorized additions have proliferated: The small courtyards of paired duplexes were frequently closed and many private gardens in the large courtyard were changed to indoor spaces (Figure 2).



Figure 2. Unauthorized additions in the Cappuccinelli district: private gardens occupied by new rooms (a) and other chaotic modifications (b) in the terraced block named “L”.

Physical and mechanical decay join the anthropogenic alterations of the courtyard blocks. Indeed, the buildings have a reinforced concrete-framed structure with infill walls comprising two layers of calcarenite blocks with an air cavity. Close to the sea and exposed to strong mistral winds, the structures suffer severe degradation from metal corrosion that has been accelerated by defective rainwater disposal from roofs. This implies extensive damage to the plasters and localized losses of the outer layer of the infill walls.

The analysis of the district has focused on the two blocks named “E” and “L” (Figure 3). Both have the same modular units as the courtyard blocks, namely a pair of duplex dwellings, but block “E” has an open courtyard while block “L” is a linear block of terrace houses.

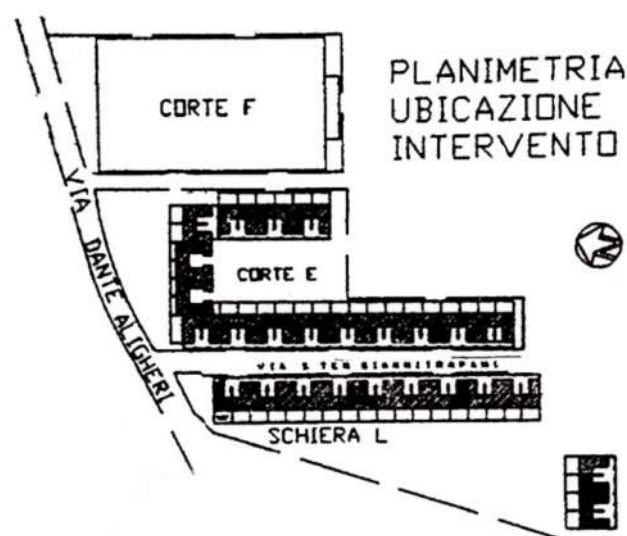


Figure 3. Historical site plan of “E” and “L” blocks. Source: Archive IACP Trapani.

3.2. Deep Renovation Works

In the examined blocks “E” and “L”, renovation works have been carried out frequently in the last three decades, as reported in the archival documents [19]. The realized works include the demolition and reconstruction of the roofs, the restoration of reinforced-concrete structural elements, and the removal and replacement of plasters. Table 1 summarizes the works carried out from 1992 to 2005 in the two analyzed blocks.

Table 1. Renovation works carried out in blocks “E” and “L” of the Cappuccinelli district in the period from 1992–2005. Data source: Archive IACP Trapani.

Year	Block	Number of Dwellings	Renovation Works
1992	E	30	Structural refurbishment. Demolition and reconstruction of some floors. Replacement of plaster, downspouts, roof waterproofing, and toilets.
	L	22	
2000	L	1	Refurbishment of pillars and edge beams. Demolition and reconstruction of some floors. Replacement of external doors and windows. Roof waterproofing. Replacement of external infill walls on the first floor by using lightweight concrete blocks.
2001	E	3	Partial replacement of first-floor infill wall with 12 cm-thick perforated bricks. Refurbishment of pillars and edge beams. Construction of new roof slabs. Roof waterproofing. Replacement of external plasters on the ground floor. Decommissioning of products containing asbestos. Replacement of house water and electrical systems.
	L	1	
2003	E, L	3	Refurbishment of reinforced-concrete pillars and beams, and floors. Demolition and reconstruction of roof slabs with precast elements in brick concrete, 20 cm thick (16 + 4). Partial replacement of infill walls with precast concrete blocks subject to water repellent treatment. Dismantling of water tanks placed on the roof. Refurbishment of water and electrical systems in a dwelling.
2005	E, L	24	Refurbishment of reinforced-concrete structural elements. Demolition and reconstruction of roof slabs. Removal of water tanks from the roof. Replacement of severely oxidized external iron with windows consisting of PVC frames and double glazing. Replacement of external plaster and indoor wall finish. Technical improvement of electrical systems.

The design documents of these renovation works show that no particular attention was paid to the construction and aesthetic details of the original project by Valori. Furthermore, the technical solutions used in the first renovations were replicated without update or revision in the following years, for about one decade, despite the innovative materials and techniques introduced in the building market. Starting in 2001, IACP decided to enlarge the openings on the first floor of the main façades with porticos. This decision aimed to satisfy the necessities of inhabitants, namely increasing the natural lighting and ventilation of the indoor spaces. The architectural impact on the original project, namely the alteration of the geometric composition of the façades, was relevant but neglected, showing that the architectural quality of the project by Valori was not fully recognized.

3.3. Recurring Degradations in Cappuccinelli Buildings

Although several works have been updated over time, the current state of the buildings in Cappuccinelli is generally characterized by advanced decay. Many houses are even precarious, as shown by the recent collapse of a portion of the cornice in the portico of block “E”.

Appropriate renovation works must be based on a more in-depth analysis of the causes of decay, which can be referred to as a list of recurring phenomena. An analysis of recurring degradations and their related causes was carried out according to what was suggested in [18]. Actually, Nowogońska B. and Mielczarek M. have determined a method for quantification of the cause–effect combinations of deterioration in order to define an order of priority for urgent renovation works and in this sense, the authors have quantified the decay of different Cappuccinelli building elements, focusing on building “L”. This is the only block where an original dwelling designed by Valori still exists. The block is also very close to the sea and its façades are particularly exposed to the winds, as compared to the other buildings in the district. Furthermore, renovation works carried out in block “L” are largely documented in the IACP archive. Tables 2 and 3 describe the types of degradation observed in block “L” according to the technical standard UNI 11182:2006 [16,17,20].

Table 2. Degradations observed in the building elements of “L” block.







Degradations Typologies	Description	Cause	Photographic Reproduction	Affected Building Element
Staining	Localized chromatic alteration on the surface	Oxidation of metal elements		Façade
Plaster Exfoliation	Degradation that manifests itself with detachment, often followed by falling, of one or more subparallel surface layers (sheets)	Movement of water within the substrate; action of microorganisms		Ceiling
Plaster Bursting	Local loss of the plaster surface from internal pressure, usually in the form of an irregularly sided crater	Differential dilatations between support and finishing materials		Façade
Plaster Disintegration	Decohesion characterized by detachment of aggregates under minimal mechanical stress	Infiltration of water; reaction between building materials and atmosphere		Façade
Plaster Erosion	Loss of the original surface, which leads to discontinuity of the plaster	Mechanical erosion from driving rain; capillary rise; erosion by abrasion of the cortical layers caused by the wind		Façade
Plaster missing layer	Solution of continuity between surface layers of the material, both between them and with respect to the substrate: generally, a prelude to the fall of the layers themselves	Consistent presence of saline formations; efflorescence; continuity solutions resulting from the presence of cracks and structural lesions; errors in installation and use of unsuitable sands/mortars		Façade

Table 2. Cont.












Degradations Typologies	Description	Cause	Photographic Reproduction	Affected Building Element
Masonry Disintegration	Decohesion characterized by detachment of granules or crystals under minimal mechanical stress	Infiltration of water, capillary rise; reaction between building materials and atmosphere		Façade
Masonry Erosion	Removal of material from the surface due to different processes: erosion by abrasion (mechanical causes), erosion by wear (anthropogenic causes)	Mechanical erosion from driving rain; erosion by abrasion of the cortical layers caused by the wind		Façade
Hole	Fall and loss of portions of masonry	Localized leaks from waste disposal and/or water conveyance systems; consistent presence of saline formations; continuity solutions resulting from the presence of cracks and/or structural lesions; installation errors and the use of unsuitable sands/mortars		Façade
Crack	Individual fissure, clearly visible to the naked eye, resulting from separation of one part from another	Disruption of the supporting masonry system; physical-mechanical incompatibility between substrate and finish; differential dilatations between support and finishing materials		Façade
Efflorescence	Formation of substances, generally whitish in color and crystalline, powdery, or filamentous, on the surface of the plaster	Capillary rising damp; condensation; localized system losses; runoff of rainwater; presence of sulphates; wind action that accelerates the surface evaporation of water		Façade
Flaking	Degradation that manifests itself in the total or partial detachment of parts (flakes), often corresponding to the continuity solutions of the original material	Exposure to atmospheric agents; presence of humidity in the masonry (crystallization of soluble salts)		Façade

Table 3. Degradations of the reinforced concrete elements in the North-East elevation of “L” block.

Degradation Typologies	Description	Cause	Photographic Reproduction	Affected Structural Element
Outcropping armor	Reduced concrete cover, non-existent or expelled due to degradation in progress	Insufficient concrete cover and incorrect positioning of the spacers for the reinforcement		Beams, pillars, floor joists
Corroded armor	Formation of hydrated iron oxide (rust) on the surface of the reinforcement which causes the reduction of the resistant section	Infiltration of rainwater; incorrect design in construction details; use of marine sands		Beams, pillars, floor joists
Lowering of pH	Cancellation of the basic properties of concrete ($\text{pH} \simeq 13$)	Presence of humidity and carbon dioxide; insufficient concrete cover; absence of protective coating of the concrete; porosity and permeability		
Structural subsidence	Changing the geometry of the element	Increase of the acting loads; repeated stress from loading and unloading cycles; absence of the transversal elements of distribution in the floor		Floor joists
Detachment of concrete cover	Separation of the surface concrete layer of the reinforcements it covers	Incorrect positioning of the spacers for the reinforcement		Beams
Crack	Long and deep cracks in the continuity of the concrete	Increase of the acting loads; previous interventions carried out incorrectly; inadequate structural dimensioning		Pillars
Rust spots	Reddish spots on the external surface of the concrete corresponding to corroded reinforcements	Interventions previously performed incorrectly		Façade
Breakage of steel	Total loss of traction resistance, fracture of the entire section of iron	Increase of the acting loads; repeated mechanical stresses; inadequate structural sizing; erroneous evaluation of overloads		Floor joists

A public body (IACP) currently owns seven of the 18 dwellings in block “L” (Figure 4). The only apartment not altered from the project by Valori is owned by a private party and suffers from more severe degradation than the other apartments in the building. Both the geometric and material features of this dwelling have been analyzed.

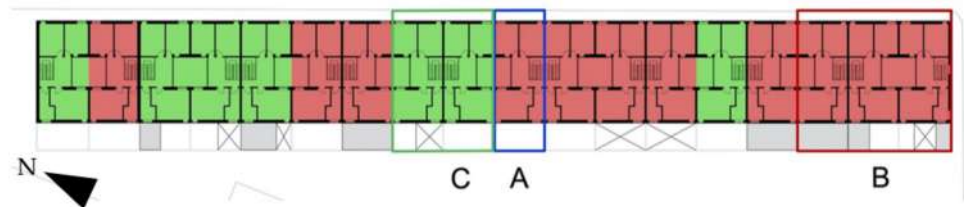


Figure 4. Ground floor of “L” block. Dwellings still owned by IACP are shown in green and private dwellings are shown in red. The blue rectangle identifies the apartment where the project by Valori has not been altered. Source: Archive IACP Trapani.

Figure 5a represents portion A (Figure 4) of the original plan (the project by Valori) and the southwest elevation of the “L” block and identifies its degradations: plaster exfoliation, plaster erosion, lack of plaster portions, masonry disintegration, masonry erosion, and lack of masonry blocks. In Figure 5b, the extent of each degradation phenomenon is estimated as a percentage of the analyzed surface. Plaster erosion is prevalent (31.9%), while other degradations range from 0.6 to 5.6%.

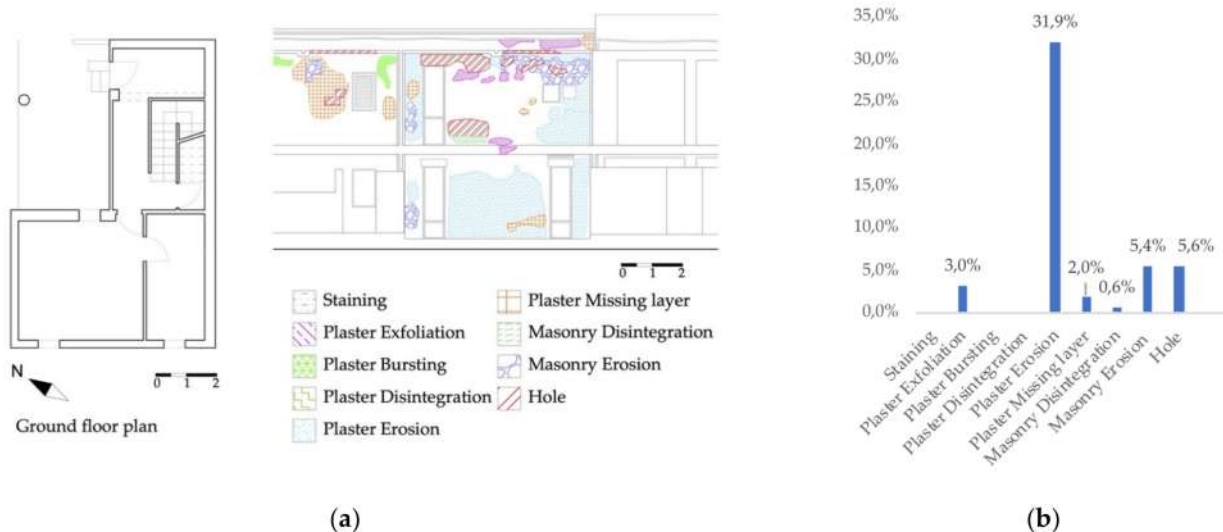


Figure 5. Ground floor plan from Valori project and representation of external visible damages on the façade (a), their extent estimated as a percentage of the analyzed façade surface (b) in the portion A (Figure 4) of the SW elevation of the “L” block. Authors: Erica La Placa, Calogero Vinci.

By extending this analysis to the entire “L” block (Figure 6a), erosion is confirmed as the most frequent degradation (4.5%) in all dwellings whose ownership passed from the public subject (IACP) to the private (original renters) (Figure 6b).

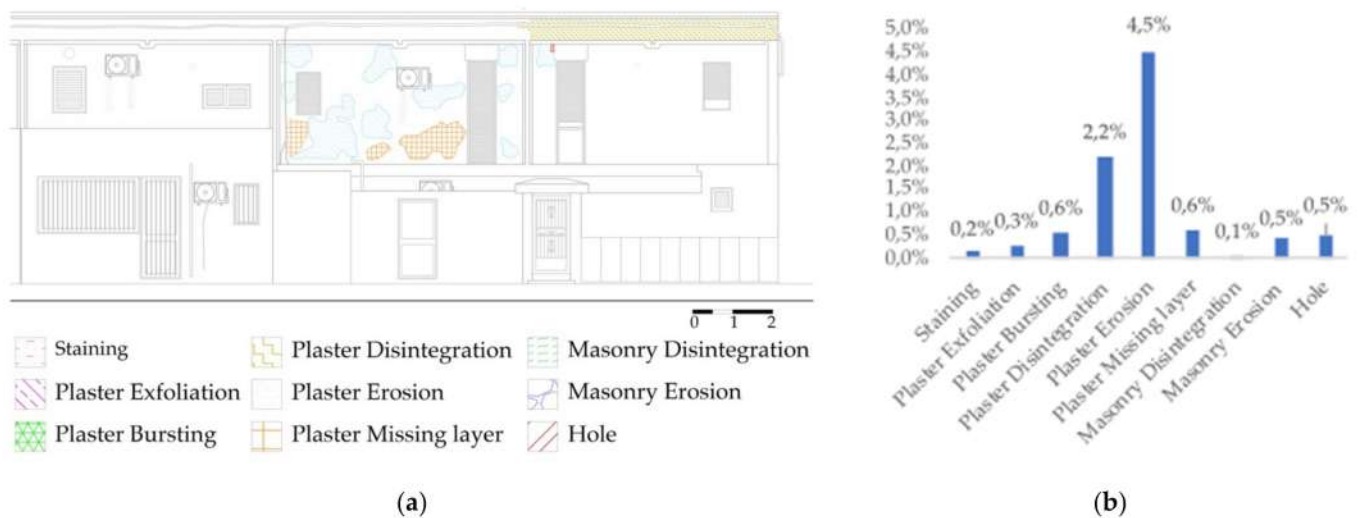


Figure 6. (a) Degradations of the portion B of the S-W elevation of “L” block in private dwellings. (b) Estimation of degradations as percentage of the analyzed surface. Authors: Erica La Placa, Calogero Vinci.

If the part still owned by IACP is considered (Figure 7a), the most recurrent deterioration is the lack of plaster portions (1.1%) (Figure 7b). More generally, the most frequent degradations on the façades of “L” block involve plasters. Indeed, the materials used for this functional layer were not suitable to calcarenite. Being very porous, this stone easily absorbs marine moisture and its content of salts, accelerating the mechanisms of the observed degradations.

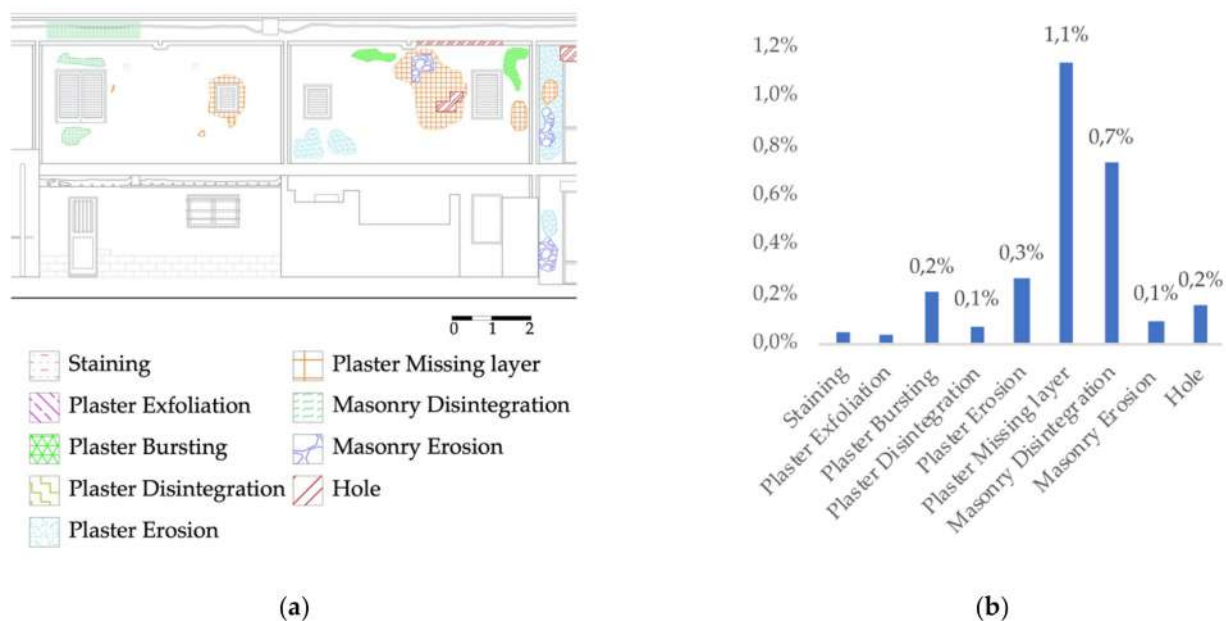


Figure 7. (a) Degradations of the portion C in the SW elevation of “L” block in dwellings still owned by IACP. (b) Estimation of degradations as a percentage of the analyzed surface. Authors: Erica La Placa, Calogero Vinci.

The degradations observed in block “L” are recurrent in Cappuccinelli and the information collected through this focus has been used to identify appropriate technological upgrades that could be implemented in large parts of the district both by private and public owners.

4. Suggestions for Appropriate Deep Renovation

Buildings in the Cappuccinelli district, being close to the sea (about 150 m) and exposed to strong mistral winds, should be equipped with protection systems for reinforced concrete structures in order to significantly reduce the risk of corrosion of the steel reinforcements. However, repairs by the IACP modified the original shape of these building components. As a relevant example, the original shape of the pillars in the porticos (Figure 8a)—a significant architectural detail in the project by Valori—was heavily modified in the renovation works, but their alteration did not make them more effective (Figure 8b).



Figure 8. (a) Original shape of pillars designed by Valori. (b) Consolidation of pillars in the portico of court “B”, executed in 2012. Author: Rossella Corrao.

The design of structural strengthening and rehabilitation works, aimed at overcoming the detected causes of damage (presence of rainwater and sea salts; lack of adequate protection for the reinforcement bars; inadequate structural dimensioning) and complying with current requirements for structural safety, also must consider the architectural concept on which the buildings are based. In this sense, archive research on project development and renovation works carried out in Cappuccinelli were essential to complement the in-situ inspection of the buildings in order to identify the original solutions worth being preserved and the inappropriate repairs.

The use of ventilated façades with plaster finishing and/or innovative living walls, discussed in previous works [9,10], can be considered effective solutions for the protection of the façades from the action of atmospheric agents that are particularly aggressive in the environmental context of Cappuccinelli. Their effectiveness has been examined both from environmental and energy points of view.

Ventilated façades prevent atmospheric agents (rain, wind) from damaging the structure, guaranteeing additional protection for the building and limiting metal corrosion, which widely affects the structures of buildings in the district.

Furthermore, if the ventilated façade is realized with plaster finishing (Figure 9), heat flow can be reduced up to about 70% due to the effects of the ventilation [21]. Compared to modular panels, an outer layer made of plaster minimizes the visual impact of the renovation and preserves the urban and architectural features of the buildings. Reduction in surface temperature, a decrease in solar radiation in summer, and the consequent improvement of indoor comfort (mitigation of overheating) are some of the benefits achieved through living walls (Figure 10), which contribute also to noise insulation and air purification. From this point of view, it is worth remarking that the extensive use of vegetation already characterized the original project by Valori, namely by private gardens and trees located in the main inner courtyards. The introduction of vegetation in order to improve energy performance (Figure 11) has been extensively discussed in previous works [15].

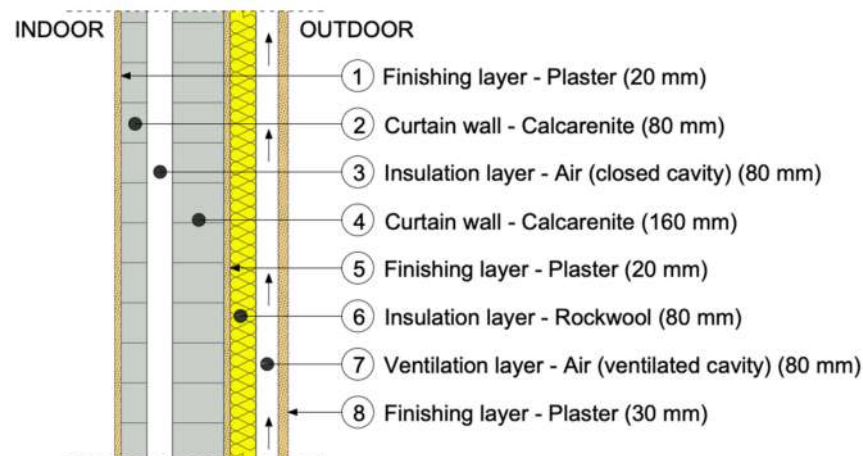


Figure 9. Ventiladed façade with plaster finishing layer. Authors: Rossella Corrao, Erica La Placa.

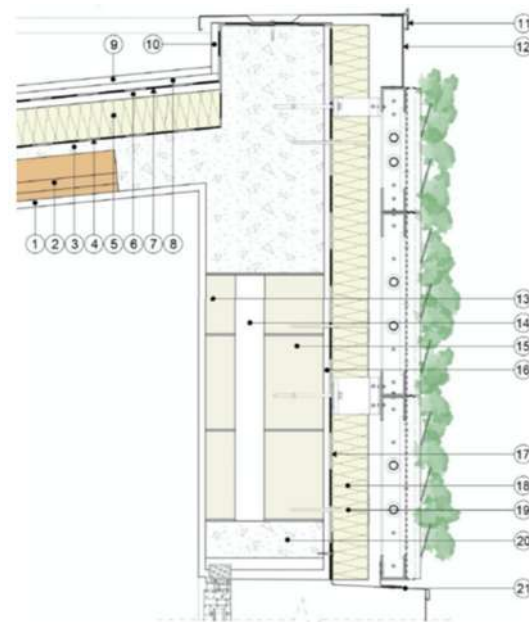


Figure 10. Detail of the living wall system tested to improve energy efficiency of the building envelope of the Cappuccinelli buildings. Authors: Mattia Bruno, Gaetano Di Fede, Giordana Motta. (1) Finishing layer: internal plaster, th. 2 cm; (2) Support element: brick block, h 12 cm; (3) Load distribution layer: concrete, 3 cm thick; (4) Vapor barrier layer: synthetic screen, th. 4 mm; (5) Thermal insulation layer: rigid rock wool panel, th. 10 cm; (6) Stiffening layer: concrete, sp. 3 cm; (7) Water tightness layer: double layer bituminous sheath, th. 4 mm; (8) Connection layer: cement mortar, sp. 2 cm; (9) Finishing layer: brick tiles, th. 2 cm; (10) Protection and finishing element: marble slab, th. 2 cm; (11) Water sealing element: shaped aluminum sheet, th. 2 mm; (12) Stiffening and support element: aluminum profile sp. 2 mm; (13) Resistant layer: block of calcarenite, sp. 8 cm; (14) Insulating layer: closed cavity, 8 cm; (15) Resistant layer: block of calcarenite, sp. 16 cm; (16) External finishing layer: plaster, th. 2 cm; (17) Vapor barrier layer: synthetic screen th. 2 mm; (18) Thermal insulation layer: rock wool panel sp. 10 cm; (19) Fastening element: nail with washer; (20) Load-bearing element: architrave in reinforced concrete, h 15 cm; (21) Water sealing element: shaped aluminum sheet, th. 12/10.

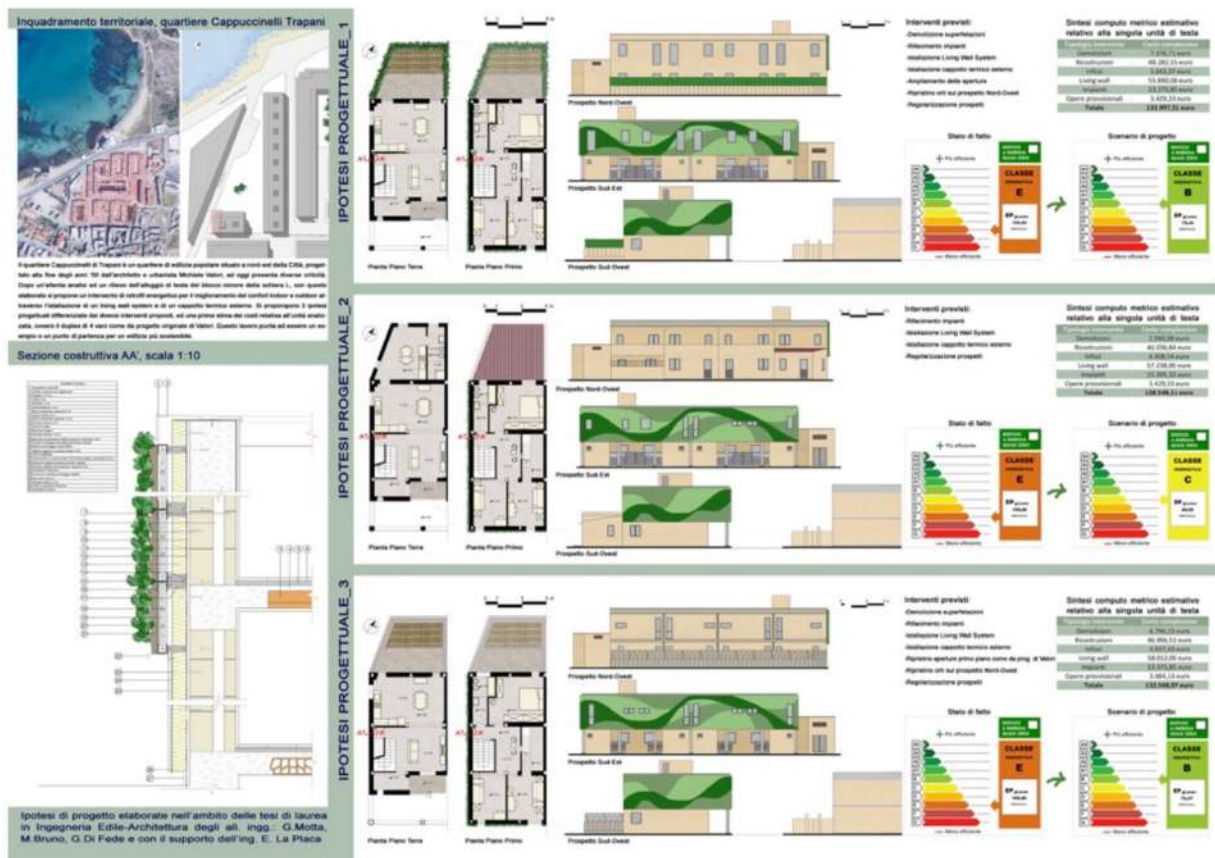


Figure 11. Summary table of the living wall installation on the façades of block “L”. Authors: Mattia Bruno, Gaetano Di Fede, Giordana Motta.

5. Conclusions

The planning and design of effective building renovations should be addressed through a detailed examination of the physical-mechanical degradations and their causes, together with an analysis of technical and architectural features of buildings. This approach is necessary in the maintenance or refurbishment of social housing districts as well. This stock is often based on interesting architectural and technical solutions that are rarely recognized or frequently altered by both inhabitants and responsible public authorities.

In the Cappuccinelli Social Housing district, inadequate renovation works have merged with a lack of maintenance, social difficulties, and hydrologic vulnerability. On the other side, the architectural quality of the original project and the strategic urban location of this district could be a sensible basis to improve its environmental and social contexts.

The relevance of damages has been inspected also in relation to the ratio between public and private ownership in each block. The main difficulty in standardizing the recovery interventions is linked to the high percentage of apartments sold; in fact, 62% of the apartments are privately owned, while 32% are owned by the IACP. In order to solve this problem, the public body should propose design solutions that are suitable for the energy and architectural improvement of the buildings in close synergy with private individuals in order to uniformly redevelop the entire Cappuccinelli district.

In this study, the physical degradations and anthropogenic alterations of the buildings have been inspected and detailed for two blocks of the district. In addition, the relevance of the damage has been inspected in relation to the ratio between public and private ownership in each block.

The results suggest the relevance of systematic detection and mapping of degradations and alterations in the entire district. Indeed, this information is mainly based on visual, external observation and is able to overcome the difficulties of fragmented ownership.

On the one side, it would be useful to estimate the current structural and energy performances of a dwelling in the district, showing the most critical upgrade measures to implement and highlighting a priority order for urgent renovations. On the other side, by showing recurrent building deficiencies, the systematic analysis and categorization of damages support the identification of effective and replicable solutions to renovate the district buildings and to improve the quality of the urban space.

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