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CONSTRUCTION AND BUILDING PERFORMANCE

BUILDING AND DESIGN TECHNOLOGIES

A MODERN "MACHINE FOR LIVING". THE VILLA GIRASOLE IN MARCELLISE IN ITALY

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Abstract

In the twentieth century, Italian architects experimented with the use of new European construction vanguards: concrete and steel materials for building frames, new cladding systems, and many other technologies for structures and envelopes. However, while other countries have imposed heavy economic sanctions on Italy, the Italian Government adopted an economic protection protocol to improve protectionist policies of self-production. This situation has led to the optimization of national resources and the creation of experimental models of architecture, often beyond the "limits of physics". Villa Girasole in Marcellise (Verona, Italy) by Angelo Invernizzi is a current example of this innovation process, which has enhanced knowledge about construction techniques, domotics, and building energy systems. Villa Girasole has been described as a masterpiece of Italian Rationalism and Futurism architecture. In fact, the building can turn on itself with a revolving and circular rails system (as aeronautical engineering systems). With this movement, the building can follow the daily and seasonal orientation of the sun, improving the building's energy performance. Moreover, the building adopted a futuristic cladding system (Alumàn), many insulating Italian materials (Eraclit), and important building systems like concrete framework (with Vierendeel beams) and steel frames. The construction and typological analysis of this masterpiece represent a necessary condition to improve the knowledge of the contemporary design process. In fact, from the heritage experience, the architects can design new building systems that follow the requirements of environmental sustainability and energy saving, with domotics systems and new building materials.

Keywords

Built heritage, Construction and technology, Futurism Movement, New materials, Angelo Invernizzi.

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1. INTRODUCTION

In the twentieth century, Italian architecture was characterized by the research of new forms and types. The Congrès Internationaux d'Architecture Moderne (CIAM), in 1928 organized by the architects of the Modern Movement, promoted "an evocative landscape, a sincere homage to the triumph of industrialization, to the technical and social phenomena of the nineteenth century, which then expanded into aviation and use of electricity" [1]. In Italy, the Futurist Movement will define the transition to the new language of the "civilization of machines", an aesthetic and anti-cultural expression of classicism style in favor of the "machine for living" new form ("La maison est una machine à habiter" [2]), and of the "rational dwelling" [3]. The concept of "architectural dynamism" was born in architecture, representing the "vision of mechanical splendor" [4] found in the works of the famous futurist architect, Antonio Sant'Elia. He imagines the "Città Nuova" as an

> immense tumultuous construction site, agile, mobile, dynamic in all its parts, and the futurist house similar to a gigantic machine. The stairs, like solitary worms, must not hide the elevators, but the stairs, becoming useless, must be eliminated, and the elevators, along the façades, must climb like iron and glass snakes. The house of concrete, glass, iron, without painting and sculpture, rich only in the congenital beauty due to its lines and reliefs, extraordinarily ugly in its mechanical simplicity, high and wide as much as necessary, and not as prescribed by the municipal law, it must rise on the edge of a tumultuous abyss: the road, which will be no longer extended like a subway at the gatehouses level, but it will sink into the earth for several floors, accommodating the metropolitan traffic and joined, for the necessary transits, from metal walkways and very fast-moving belt [5].

The dynamic vision of Sant'Elia finds little concreteness in the construction concept and the executive feasibility.

Some architects such as Marinetti, Carrà, Severini, Balla, and Russoli were entrusted with "the duty of leading the post-war generation towards the final realization of nationalism and the triumph of the fascist state" [4]. The cultural and architectural renewal promoted by the Regime became an opportunity to create a new Italian architectural style; in fact, it was realized different important buildings, such as Palazzo delle Poste in Ostia, the Thermal Power Plant of the Santa Maria Novella station in Firenze, and the Water Tower of the Termini station in Roma (designed by Angiolo Mazzoni).

The extremely dynamic style of Mazzoni's construction represents the first grafts of classical monumentalism, introduced by the nascent architecture of the Regime. Other projects, such as the Helical Skyscraper in New York (1968) by the architect Manfredi Nicoletti, the Savona Palace of Justice (1987) by the architect Leonardo Ricci, the Bridge over the Basento in Potenza (1975) by the engineer Sergio Musmeci, the building in Piazzale Clodio in Roma (1955) by Luigi Pellegrin, and many other examples, constitute just some of the most evocative examples of neo-futurist architecture.

Jean-Louis Cohen defined neo-futurism as "a corollary to technology, being the structures built today products of new materials to create previously impossible forms" [6]. This condition, moving away from postmodernism, pushed a rethinking of the functionality and the ability of architecture to improve performance and living well-being.

2. AIMS OF THE RESEARCH AND METHODS

This study (part of larger research aimed at identifying experimental futurist architectures) systematically analyses one of the most representative buildings of the Futurist movement: Villa Girasole in Marcellise (Verona, Italy), designed by the engineer Angelo Invernizzi in collaboration with the architect Ettore Fagiuoli (1984-1964) and the mechanical engineer Romolo Carapacchi (1900-1974). It was built between 1929 and 1935, and it is considered a masterpiece of Futurist architecture and represents a concrete vision of a "mobile building". This is the only example in Italy of a prototype of a revolving house. Marcello Piacentini defines Villa Girasole as an important reference "on which future researchers will draw on for their knowledge" [7].

Villa Girasole is an important example of a pioneering approach to energy and construction aspects; in fact, it is still considered a manifesto of the way in which an idea could overcome the difficulties and technological limitations to become architecture. This building is a complex of wheels, rails, and gears capable of rotating the entire structure following the movement of the sun.

The idea of rotating buildings constitutes an extreme challenge to the relationship between architecture and construction.

> The component of mobility, the idea of conceiving the house as a moving machine, often recurs in futurist proclamations which affirm the importance of applying serial industrial procedures in architecture, according to

Fig. 1. *Villa Girasole in Marcellise, Verona (Italy). (Image source: Invernizzi A, Fagiuoli E, Villa Girasole in Marcellise. Architettura. Rivista del Sindacato Nazionale Fascista Architetti, S.A. Fratelli Treves Editori, Milano-Roma, 1932, p. 1).*

> the following prerogatives: low production costs, rapidity of construction, possibility to periodically change the house, adaptability in case they are mounted on turntables, safety against earthquakes and cyclones [8].

By nullifying the fixed orientation system, a highly innovative relationship is established in terms of functionality and energy. In 1934 the magazine *Quadrante* published a "revolving house", designed by the engineer Pier Luigi Nervi, with a truncated cone structure in reinforced concrete. Nervi described it as "a notable symptom of the developments in building technology […] that one day it will free our homes from the slavery of immobility" [9] (Fig. 1).

As anticipated by the pioneering figure of Pier Luigi Nervi, the analysis of these constructions represents a valuable field of investigation for the knowledge of the experimental contributions of construction techniques and materials taken to extremes beyond physical limits. The in-depth knowledge and systematization of these futuristic buildings is a helpful tool for designing building systems increasingly suited to the themes of environmental and energy sustainability; it also combines advanced plant and domotics systems capable of "regulating" the energy supply and relative consumption as the environmental conditions. Villa Girasole, in fact, "is also a monument to progress and a symbol of man's ability to control technology for a better habitat" [10], capable of assisting in building the transformations and progress achieved by the sectors of mechanical, electrical, naval, plant and architectural engineering.

3. CASE STUDY: VILLA GIRASOLE, THE REVOLVING HOUSE

The structure of Villa Girasole is realized using reinforced concrete and divided into two parts: the cylindrical support base (with a diameter of 44.50 m surmounted by a large loggia and two rectangular structures) and the platform running around the vertical tower axis (Fig. 2).

For the construction, important excavation works were required on the hill of Marcellise through the construction of tunnels and pit excavations necessary for the preparation of the mechanical components of the building (Fig. 3).

The tower is connected by a central metal rolling system having fifteen wheels rotating on three circular rails. The rolling system supports a mixed structure platform

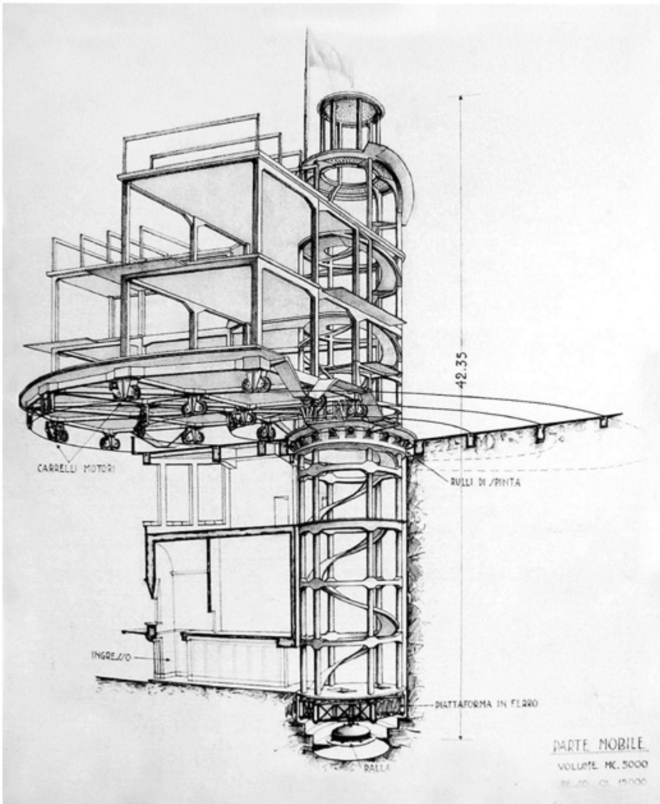

Fig. 2. *Structural scheme of Villa Girasole. (Image source: Piacentini M, Architettura. Rivista del Sindacato Nazionale Fascista Architetti", S.A. Fratelli Treves Editori, Milano-Roma, 1936, p. 4).*

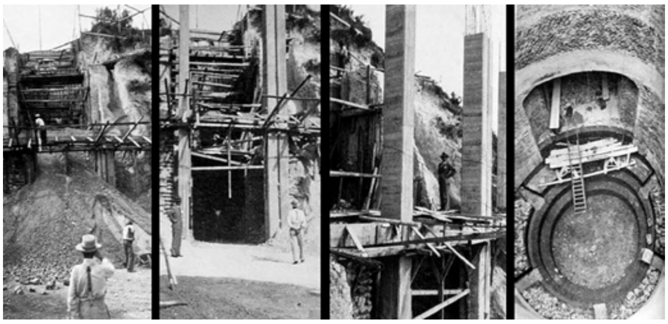

Fig. 3. *Excavation work for the construction of the reinforced concrete structure of Villa Girasole. (Image source: Galfetti A, Frampton K, Farinati V, Villa Girasole. La casa rotante – The revolving house, Mendrisio Academy Press, 2006).*

made of iron and concrete. The extremity of the six reinforced concrete beams has connecting elements called "arms". The elevation structure of the tower was realized with reinforced concrete columns connected to the above-said arms and circular beams. The beams are of the "Vierendeel" typology and are able to withstand the flexural and torsional actions deriving from the building movement (Fig. 4).

Inside the circular tower (42.35 m high and 7.50 m in diameter), there is a helical concrete staircase. The platform (with a weight of 1500 tons) suspended on concentric tracks is moved by motor trolleys with a power of 3 HP (Fig. 5). The time needed to realize a complete revolution is about 9.20 hours with a speed of about 4 mm per second [7].

"The slab that constitutes the base of the rotating structure was constructed from square reinforced concrete blocks of variable thickness, connected by rectangular concrete beams of different shapes, all covered

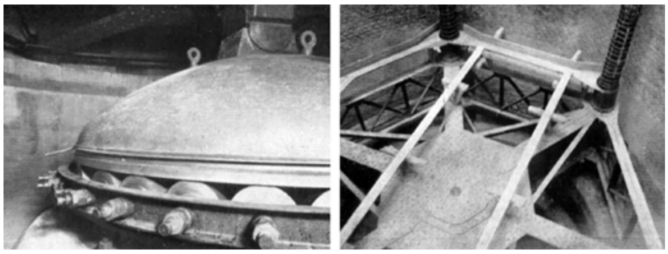

Fig. 4. *The metal bearing and the reinforced concrete beams ("Vierendeel"). (Image source: Piacentini M, 1936, p. 7).*

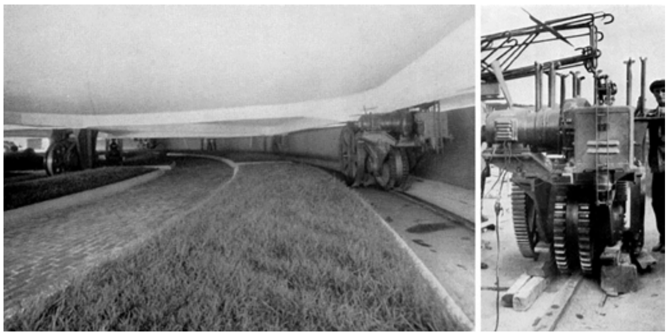

Fig. 5. *The metal bearing and concentric tracks mechanical systems. (Image source: Piacentini M, 1936, pp. 6-8).*

by a concrete screed and Excelsior-type clay floor slab block, designed in Italy during the years of construction of the building" [11] (Fig. 6).

The thrust bearing and the metal platform were made by the "Officine Meccaniche Verrina" in Genova, while the rollers, motor carriages, and rails by "Ansaldo di Sampierdarena" and "Ferrotaie" manufacturing industry. In the calculation of the reinforced concrete structures, also internal actions due to the mechanical elements (such as the rolling systems ones) were taken into account, considering that hinges at the base reduce the internal action transmission associated with movement.

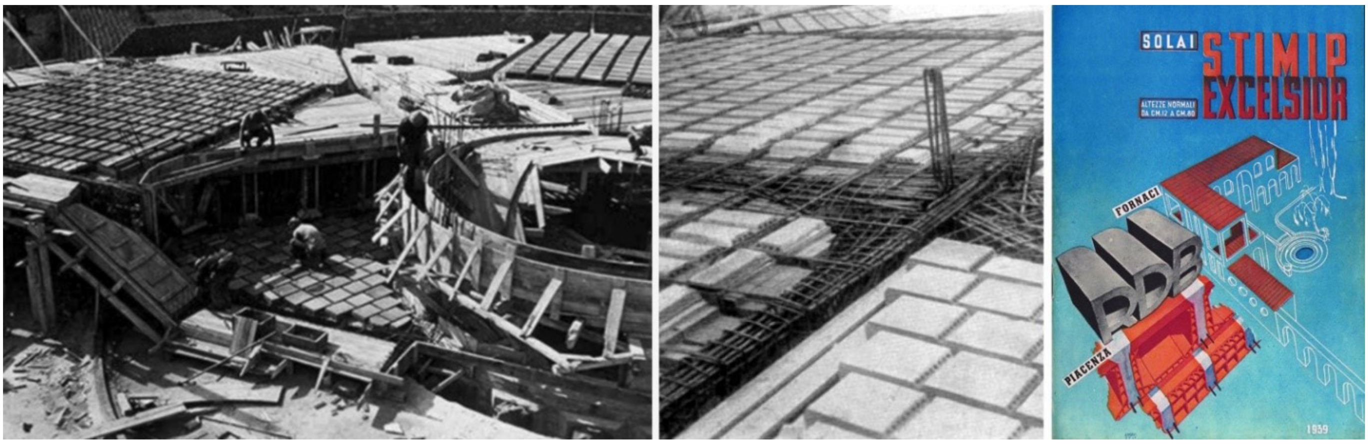

Fig. 6. *Construction of the Excelsior concrete and masonry slab. (Image source: Croft C, Macdonald S, Concrete: Case studies in Conservation Practice, 2019, p. 51 and Piacentini M, 1936, p. 6).*

Furthermore

> the highest quality materials were adopted: concrete with high-strength cement with a safety load of 65 kg/cm2 and homogeneous iron with a safety load of 1200 kg/cm2. The very elastic framework was purposely due to the presence and arrangement of significant quantities of iron and the low height of the beams [7].

The calculation of the structure was performed

> for the most unfavorable conditions, subjecting the construction to strong wind pressure (250 kg/m2 as required by the Italian Regulations for bridges), loading it at the pillars, […] to traction in case of breakage of a carriage and, finally, to a torque which is the frictional moment of the thrust bearing. It is clear that a wall structure on sixteen supports […] would have had to show damage to both the movement and the expansion of the material. This inconvenience was provided by hinging all the pillars from the mobile part to the base, creating expansion joints in the walls [7, 12] (Fig. 7).

Fig. 7. *Reinforced concrete structure of Villa Girasole. (Image source: Galfetti A, Frampton K, Farinati V, 2016).*

The expansion joints are hidden with an 8/10 thick Alumàn sheet metal band, produced by the company "Lavorazioni Leghe Leggere" in Milano, which is specialized in aeronautical, railway, and naval construction and components. The use of this Made in Italy metal alloy provides a distinctive aspect to the Villa, regarding its color, changing with the variation of the sunlight (Fig. 8).

Alumàn is a material composed of aluminum and manganese used for the cladding and roofing systems. The material characteristics are its ability to reflect light and its lightness ("a square meter of 0.7 mm sheet metal weighs 2 kg" [13]). "Taking advantage of its stainless properties, in fact, the Alumàn was used as a cladding system for the Pavilion of the industrial port in Venezia, for an Exhibition in 1932 in Padova, designed by the architect Brenno del Giudice" [14]. The Villa Girasole cladding represents one of the first Italian experiments of "dry envelope" able to anticipate the famous metal constructions of Jean Prouvé (1901-1984) and the Dymax-

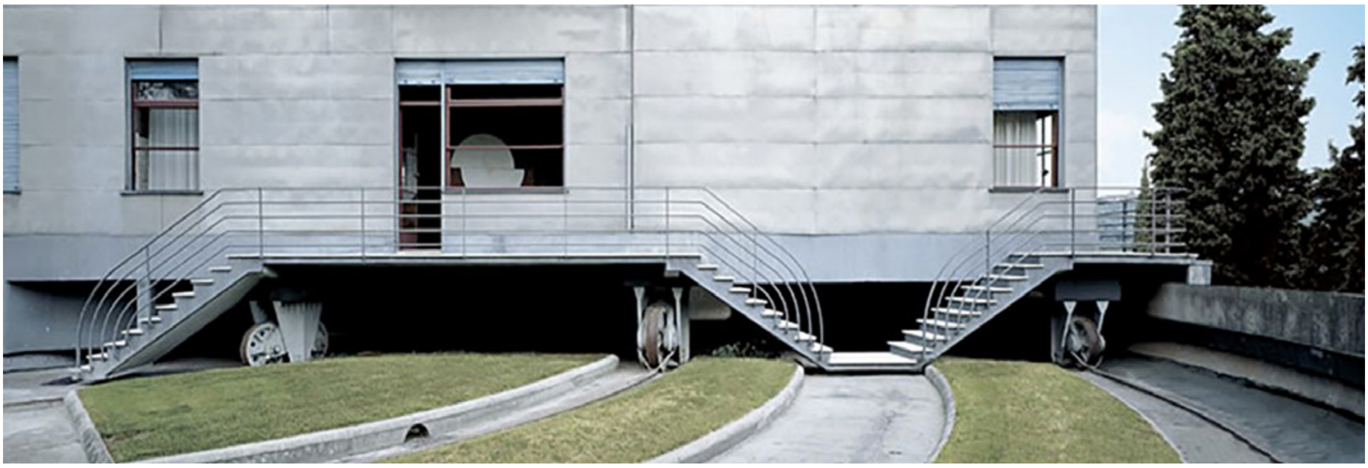

Fig. 8. *Coating of the external surface with Aluman slabs, produced by the company "Lavorazioni Leghe Leggere" (Image source: FAI – Fondo Ambiente Italiano).*

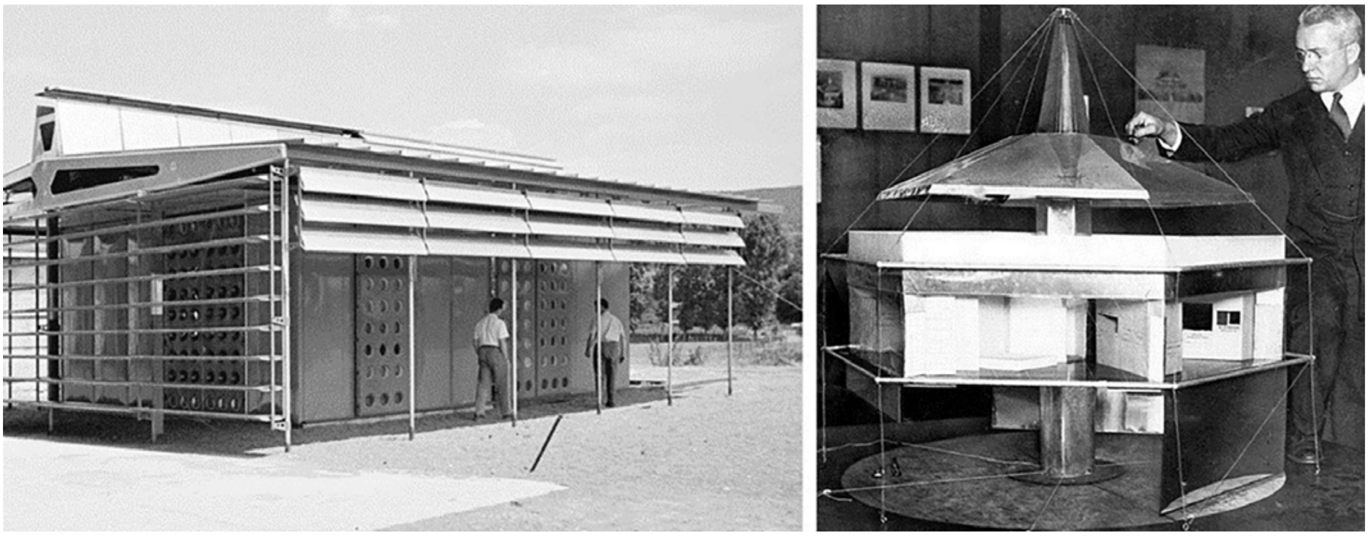

Fig. 9. *Sun-shutter sunshades of the Maison Tropicale (left) and the Dymaxion House (right).*

ion House project by Richard Buckminster Fuller (1895-1983). Even the energy elements (i.e., the "sun-shutter" sunshades of the Maison Tropicale by Jean Prouvé) and the nuclearization of the equipment (used by Fuller in the Dymaxion House) find numerous similarities in the project by Angelo Invernizzi (Fig. 9).

The Villa Girasole also used innovative materials to improve energy performance with thermal and acoustic insulation. The roof is thermally insulated with a layer of bituminous felt from the "Ruberoid" type and by two layers of tarred cardboard joined together by four layers of "Holzcement" bitumen. Walls were built with blocks of "Eraclit", chosen during the design phase for their excellent insulating qualities and extreme lightness to replace the traditional masonry (Fig. 10).

Today Eraclit is still commercialized by the "Società Azioni Eraclit Venier" in Portomarghera (Venezia); "it is mainly based of rot wood fibers (thin and long small shard of wood) compressed and solidified with a special cement mixture" [14]. The name derives from the words "Herakles" ("Hercules") and "lithos" (stone), highlighting the extraordinary technical and performance characteristics of the material, which contribute to characterizing the building envelope and defining a new architectural language of the walls [14].

The tower lantern roof (made using glass blocks) was built using a traditional construction system. The glass bricks of the "Duralux" type (produced by Saint Gobain, Chauny & Cirey) are highly resistant and, at the same time, very light due to the presence of an internal cavity [14].

Another important technological characteristic was an innovative drainage pipes system; in fact, the difficulties of drains and water connections have led to innovative solutions, just tested in the naval sector (the wastewater was canalized in specific watertight tanks collocated under the rolling system). Moreover, the façade has the celestial roller shutters electrically operated by commands placed in the rooms, as well as the presence of a general panel with three commands (forward, backward, stop) capable of moving the entire structure as a primordial example of "automation home" [15].

Fig. 10. *The external wall built in "Eraclit" blocks (Image source: Galfetti A, Frampton K, Farinati V, 2006).*

4. CONCLUSION

The innovation of this architecture is the designer's ability to relate the environment with energy performance and indoor well-being. In fact, Villa Girasole represents one of the first buildings to incorporate not only futuristic covering materials (such as Alumàn) and mechanical systems for movement but also innovative materials hidden in the horizontal and vertical stratigraphies with the aim of improving energy performance and meeting the requirements of thermal and acoustic insulation.

The design process highlights the multiples influences between the engineer's capacity (Invernizzi), the architect's ability (Fagiuoli), and the interior designer (Saccorotti) as well. Villa Girasole represents an important relationship between traditional and modern architecture: the ancient-looking remind of traditional and solid architecture, with columns and masonry; instead, the modern-looking is reminded by structural elements constructed through the reinforced concrete frame, clad in thin metal. At the same time, the rotating portion personifies the aesthetics of a future machine for living.

> Because the top portion of the house is a well-defined object, a clear division is made between the inside world and outside skin. This fold-line between interior and exterior allows the house to be smooth, light and shiny on the outside while remaining domestic, dark, ornamented and typically bourgeois on the inside [16].

Invernizzi's seemingly rational decision to make architecture follow the sun renders Villa Girasole part of a larger history of machines (with the aim to attempt to harness through man-made devices the reproductive, regenerative, and transformative energy of nature) that fascinated and engaged the architects. Even at a weight of 1,500 tons, the mechanics of Villa Girasole is ingeniously designed using just two motors, totaling three horsepower, needed to move the crown at a speed of 4 millimeters a second.

Thus, a complete rotation is possible in nine hours and twenty minutes with the push of a single button. The wheels were designed to facilitate maintenance and are clearly visible in the space between the roof of the garden and the concrete substrate of the building. However, the movement of the vertical shaft began to wear down the building over time. Each turn gives the building an image of a machine, but, at the same time, the wear and tear of the structure increase: in fact, Invernizzi's villa is a time machine about to destroy itself [16, 17].

The analysis of these buildings, sometimes with a utopistic vision, can represent a field of investigation to acknowledge the experimental innovations and the extremization of the construction process beyond the "limits of physics". Therefore, it becomes essential to critically analyze the futurist architectures of the twentieth century, in particular the "prototype" buildings that were the first to incorporate the constructive avant-gardes and the most innovative materials. The in-depth knowledge and systematization of these futuristic buildings is an important instrument to approach today's buildings-systems increasingly suited to environmental and energy sustainability themes, including advanced equipment and home automation capable of regulating the energy contribution and related consumption depending on the environmental conditions.

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