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BUILT FORMS AND UNDERLYING GEOMETRIES IN 20TH-CENTURY ARCHITECTURE: MUURATSALO HOUSE AND LEICESTER ENGINEERING DEPARTMENT BUILDING

Maria Grazia Cianci, Daniele Calisi, Stefano Botta, Sara Colaceci, Sagrario Fernandez Raga, Carlos Rodriguez Fernandez, Michela Schiaroli

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Abstract

By starting from the notions of rhythm, rule, and the analogy between architecture and music, the research focuses on the analysis and the representation of architecture and, in particular, of façades by comparing two case studies: Muuratsalo House by Alvar Aalto (1952-1953) and the Leicester Engineering Department Building by James Stirling and James Gowan (1959-1963). The methodology is based on the comparison among some specific façade categories: texture, basic compositional signs (connection to the ground, windows, connection to the sky), and geometries. The operating methodology follows these phases: i) the analysis of project drawings and photographic documentation; ii) two-dimensional reconstruction in CAD of plans, fronts, and sections; iii) NURBS modeling. By analyzing Muuratsalo House's façades through 2D representations and 3D models, the research highlights the proportional and compositional relationship between walls and openings as a leading principle. The study on the patio's fronts shows how this association gets more complex because the textures, rhythm, and geometry of the materials become the main elements in the compositional grammar of the house. In the case of the Leicester Engineering Department, the model allows the understanding of the general volumetric articulation. The whole configuration is characterized by the juxtaposition of multiple volumes, which impacts the façades, whose openings direct rhythms, textures, and geometries.

Keywords

Texture, Geometry, Leicester, Muuratsalo House, 3D models.

Maria Grazia Cianci*
Dipartimento di Architettura, Università degli Studi Roma Tre, Roma (Italy)

Daniele Calisi
Dipartimento di Architettura, Università degli Studi Roma Tre, Roma (Italy)

Stefano Botta
Dipartimento di Architettura, Università degli Studi Roma Tre, Roma (Italy)

Sara Colaceci
Dipartimento di Architettura, Università degli Studi Roma Tre, Roma (Italy)

Sagrario Fernandez Raga
Departamento Teoría de la Arquitectura y Proyectos Arquitectónicos, ETS Arquitectura, Universidad de Valladolid, Valladolid (Spain)

Carlos Rodriguez Fernandez
Departamento Teoría de la Arquitectura y Proyectos Arquitectónicos, ETS Arquitectura, Universidad de Valladolid, Valladolid (Spain)

Michela Schiaroli
Dipartimento di Architettura, Università degli Studi Roma Tre, Roma (Italy)

** Corresponding author:*
e-mail: mariagrazia.cianci@uniroma3.it

1. INTRODUCTION

From the unhinging of the utopian and rigid visions of modernity, the architectural image of the post-war period acquires a multiple and uncertain fluidity, made of fragments of visual languages that blend into each other, defining "a plastically continuous universe" [1], full of dissonances and alliteration. A new architectural ethics develops, trying to accord with the social dimension, which has become increasingly predominant with the advent of the new millennium.

Though articulated and diversified, façades are built based on elements that find their individuality within more extensive and general categories characterized by similar meanings (such as windows, walls, roofing, etc.). The hypothesis of the existence of archetypical classes in ar-

chitectural composition has often been a subject of investigation over time, starting from the Vitruvian primitive hut, whose main points were subsequently reworked by Semper and Shinkel [2]. Regardless of necessary variations, this research can also be found in traditions far from the Western ones, such as in the Japanese culture, in which every architectural sign, from the roof to the floor, is filled with both spiritual and functional meanings and whose narratives were shared by architects such as Wright and Mies van der Rohe [3]. These primitive elements are comparable to the plurisituational *comunsegni* of a language. A *comunsegno* is a sign that has a shared sense to a given set of interpreters. A plurisituational sign retains its intrinsic meaning regardless of the situation. The signs of a language are connoted by both properties [8].

As it happens in drawing, the very compositional operation of the façade is, therefore, the manifestation of a language: it takes the form of a system of interconnections of signs endowed with a relatively shared and constant meaning, regardless of their specific representation. These signs are related to each other by establishing a rhythm with a rule defining it. Considering architectural orders, they are the best example of rules and rhythm manifesting in architecture. Regarding this, Riccardo Migliari believes the definition of the old academic manuals on the classical order as «tautological and reductive» as «the entirety of ornaments used in architecture and defining decoration as those highlights or polishing used to embellish manufactories». According to him, the best way to define an order is to draw it, but to do so, it is necessary to contextualize what he means by "drawing" of the classical order. The "drawing" of the façade is, therefore, «the representation, in the front view and in the plan, where necessary, of the architecture […] and of its compositional rule», but it is also the interpretation of this rule, i.e., the reading of the dependence of each part on the other and the measurement of the dimensional relationships of the various parts; it also means the draft of a general rule which is not a rule, but rather a weft on which design is based, understood as it has been said [4].

Rhythm and rules are the basis of music; in fact, for centuries, music and architecture have been the subject of fairly in-depth parallelisms by scholars and artists of every field. Primarily, they share the reality of being configurations of elements in more complex systems: on one side, sounds (waves) over time; on the other, masses among space, which produce multiple sensory stimuli and develop functional and semiotic values. Both refer to languages composed of signs suitably juxtaposed according to specific rules and sensitivities, following operations (sometimes conscious, sometimes arbitrary) to carry out work with several communicative values [5]. What the notation of a music sheet gives to the flow of a piece can also be found in the design choices of a façade, where materials, shapes, and lights generate pauses, modify rhythms, and bind spaces. There is also a similar subjection of the two fields to the use of proportions and harmonic progressions, as Boullée argues in contrast to Pérault. However, this tension can be thought or unconscious, which has more marked effects on hearing than sight [6]. «I found one of my writings among some others», said Goethe, «in which I call architecture "petrified music". There is really something about it; the sensation produced by the architecture approaches the effect of music» [7] (Fig. 1).

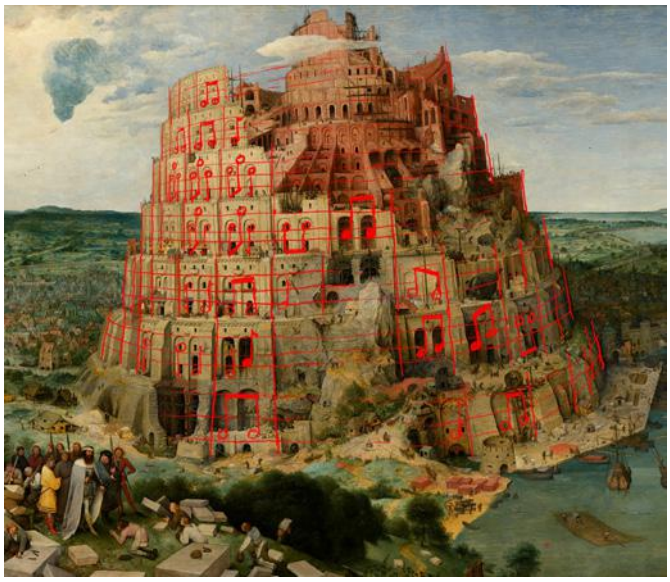


Fig. 1. *Pieter Bruegel,* Babele Tower, *1563. The Babel Tower, as represented by Bruegel in its dizzying masonry rhythms, layered in continuous evolution. Highlighted in red, the spiraling dynamic of the architecture and its fast and varied rhythm recall the characteristics of a melody. Source: Wikimedia Commons; Google Art Project.*

2. METHODS

Starting from the concepts of rhythm and rules and referring to the analogy between music and architecture,

the research tries to conduct a method of analysis and representation of architecture and, in particular, façades through two case studies: Muuratsalo House by Alvar Aalto (1952-1953) and Leicester Engineering Department Building by James Stirling and James Gowan (1959-1963) (Figs. 2 and 3). These architectures were chosen because they differ in typologies and uses, although both exploit materials on the façade to define textures and compositional rhythms.

The Experimental House (1952-1954) was the self-designed atelier and summer home of Elissa and Alvar Aalto. It was inspired by the idea of an ancient Roman atrium. It is located on the rocky summit of the island of Muuratsalo (hence the name of the villa) in the middle of Lake Päijänne. The construction of Muuratsalo was conceived as a synthesis between an architect's private studio and an experimental center, where it is also possible to examine problems that are not yet mature and where the closeness to nature induces reflections on both forms and techniques. The house develops according to the specific needs of the internal spaces and looks for a stronger bond between the living habitat and the natural context outside. It is possible to define the character of the architectural details as typical of the Nordic environment. In its experimental intentions, this building differs from traditional constructions in terms of shape, scale, and type of materials. The elevations towards the enclosed patio have been divided into 50 different areas to experiment with various terracotta and ceramics, modulations, brick sizes, and specific treatments.

In 1957, when University College was granted its Royal Charter and became the University of Leicester, plans for new campus buildings included an engineering building on a site near Victoria Park. The university commissioned the architects James Stirling and James Gowan for the works, and the building was completed in 1963 on the University of Leicester campus in England. Its construction was relegated to a place that was not

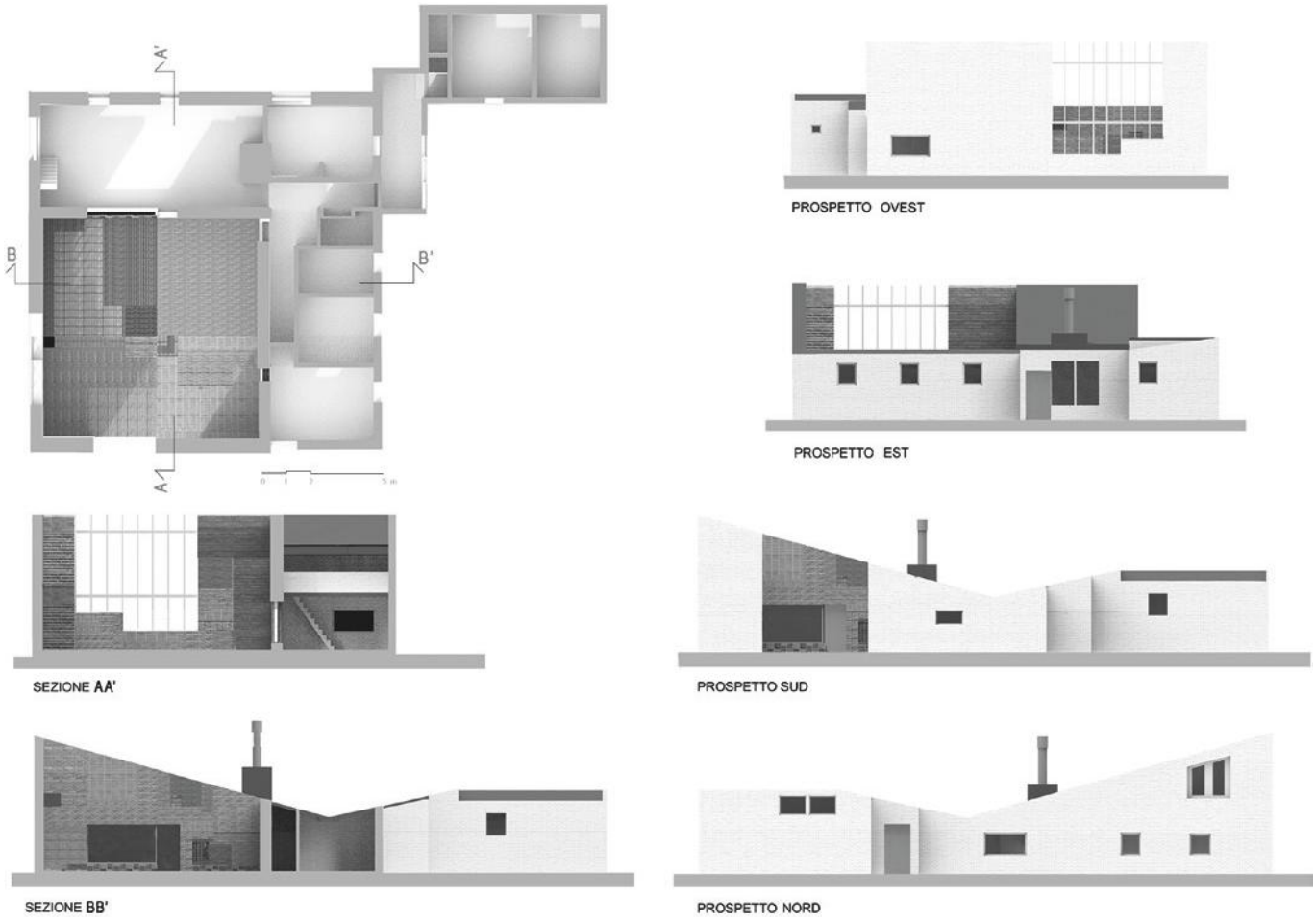


Fig. 2. *Plan, sections, and front views elaborated for Muuratsalo House by Alvar Aalto. Source: images created by the authors.*

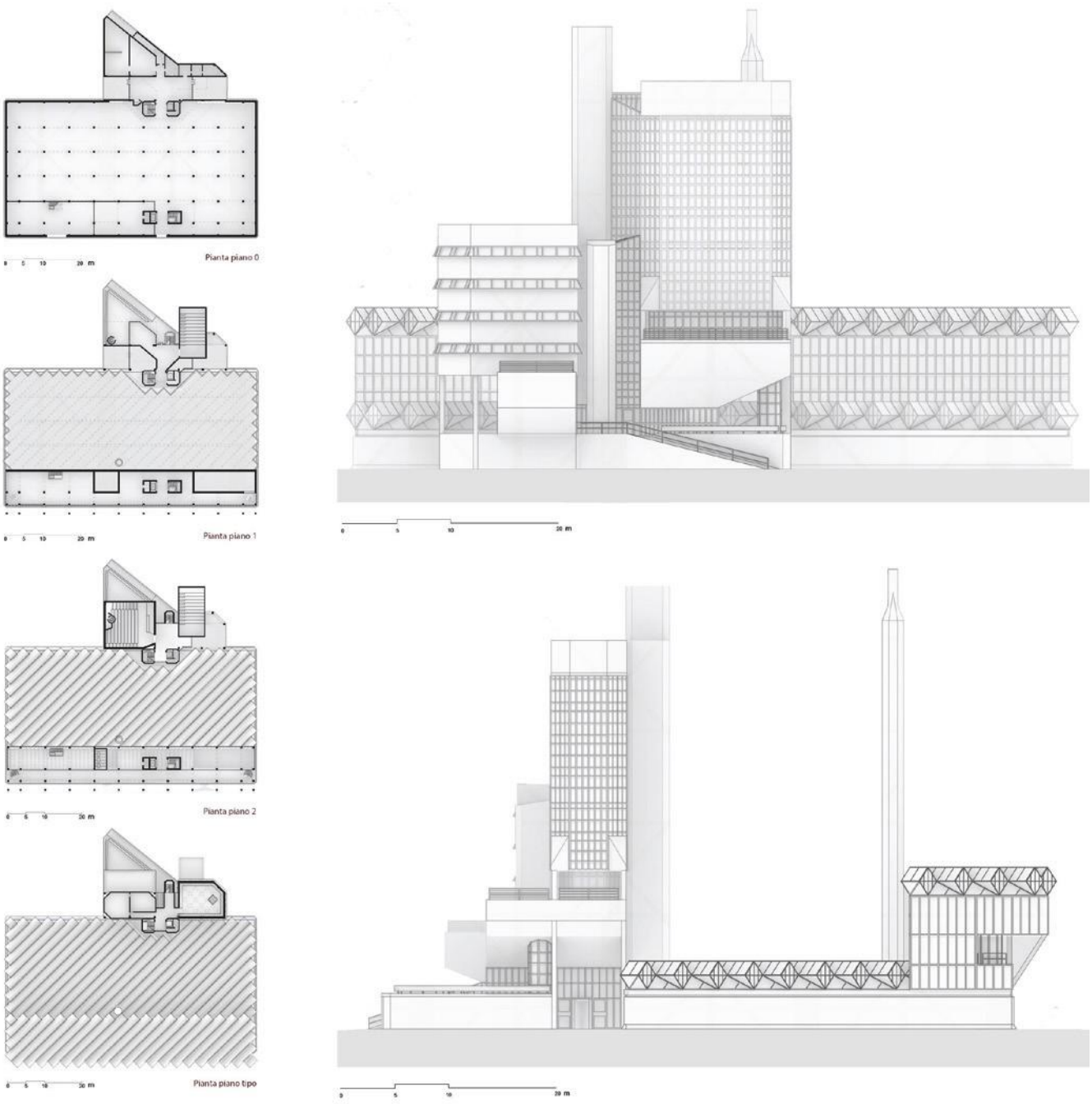


Fig. 3. *Plans and front views of the Leicester Engineering Department Building by Stirling e Gowan. Source: images created by the authors.*

particularly visible, an unwanted corner, and this, rather than an inconvenience, has been a stimulus, a challenge to overcome the characterless buildings of the neighborhood. The engineers wanted a water tank for the plumbing laboratory on the ground floor; therefore, to create the necessary pressure, the tank was placed on top of the tower, which had to be at least thirty meters high.

Two conjoined towers containing laboratories and offices, whose design is inspired by the superstructure of an aircraft carrier, are placed on top of the two cantilevered classrooms. The designed classrooms protrude at right angles, and the tower also hosts laboratories and offices. The ground floor buildings have a distinctive angled roof to allow northern light in – similar to factory roofs – and contain workshops and laboratories. The design of this roof is unique, made of two types of glass: translucent multi-layered glass with an inner layer of fiberglass and aluminum-coated opaque glass. The distinction between the two only becomes visible at night when the building is illuminated. The rippling

"waves" of the two large glazed roofs, angled at 45 degrees to the towers, face north to provide illumination without direct sunlight (which could affect delicate instruments).

Architects James Gowan and James Stirling, plus engineer Frank Newby, created a unique piece of modern architecture designed around the specific needs of the Engineering Department and available campus angle.

The investigation methodology focuses on the comparison of some categories of the façade: texture, geometries, and compositional elements of the façade (connection to the ground, windows, and connection to the sky). The relationship between the two case studies exploits these essential categories of the architectural language to identify how they act specifically on the progression of the façade, using the architectural *comunsegni* as the basis for comparison. In this sense, it is possible to hypothesize interpretations and comparisons between façades with highly different connotations, relating their individual signs to specific shared contents, regardless of their individual manifestation [8]. The metamorphosis of the project lies in the variable character of the basic signs of the architecture, which possess a "range of oscillation" within which to change, even significantly. Therefore, the individual manifestation of the same sign can totally alter the meaning of a façade, add plasticity, impose shadows, accelerate or interrupt its rhythm. Precisely this last concept has always been one of the most frequent properties of the composition. From the colonnade to the curtain wall, the repetition of modules is a process that unifies a system of individuals with a homogeneous meaning. Especially in contemporary languages, the seriality of the elements that mark the tempo of a front is often interposed with individualistic and autonomous signs that vary their course, rebelling against the other components and creating effective compositional contrasts [1]. This is even more significant when the experience of architecture comes into play through the movement around and within it. The dynamics of the space, continuously varying, generate new images conveyed by the accordance of the signs of the building, to the point of making the surfaces almost vibrate through a language of shapes, lights, and materials [1].

The operating methodology follows these phases: i) the analysis of project drawings and photographic documentation; ii) two-dimensional reconstruction in CAD of plans, fronts, and sections; iii) NURBS modeling. To archive an in-depth comparative analysis of the architectural sign and their composition in the geometry façade, the construction of 3D study models is necessary. In some cases, it is not easy to deeply comprehend material variations and intersections among the envelope elements. The modeling of the two works using NURBS surfaces refers to design drawings for the two-dimensional reconstruction phase and information obtained from historical and current photographs, through which it was possible to understand better and replicate patterns and critical points of the projects.

3. TEXTURE

In Muuratsalo House, Alvar Aalto explicitly deviates from linearly following Finnish constructive traditions without losing connection to the genius loci, which characterizes a vast part of its work and which is here manifested at times. The plurality of textures and typologies also envelops horizontal planes, defining a space with multiple rhythms. The continuous variations on the theme create a "paradoxical unfinished microcosm" in symbiosis with the outer nature [9]. The chromatic contrast between the external white-painted masonry shell and the internal red-brick courtyard is evident. The courtyard is partially enclosed by free-walls interrupted by empty spaces to mediate the inside-outside relationship, simultaneously suggesting a sense of archaic and lost, almost as if they were modern ruins [10].

As it is for the bas-relief figurative compositions of the Tabula Iliaca Capitolina, the articulation of the bricks on the walls of the patio of Muuratsalo House by Alvar Aalto seems to have the will of surrounding the visitor with an iconographic narration on masonry, not only as a construction material but also as an element capable of provide unity by its intrinsic properties, and rhythmic subdivision to the multiple opportunities of configuration and proportioning.

The courtyard fronts become a sort of sampler pattern in which ceramic and bricks are combined in different

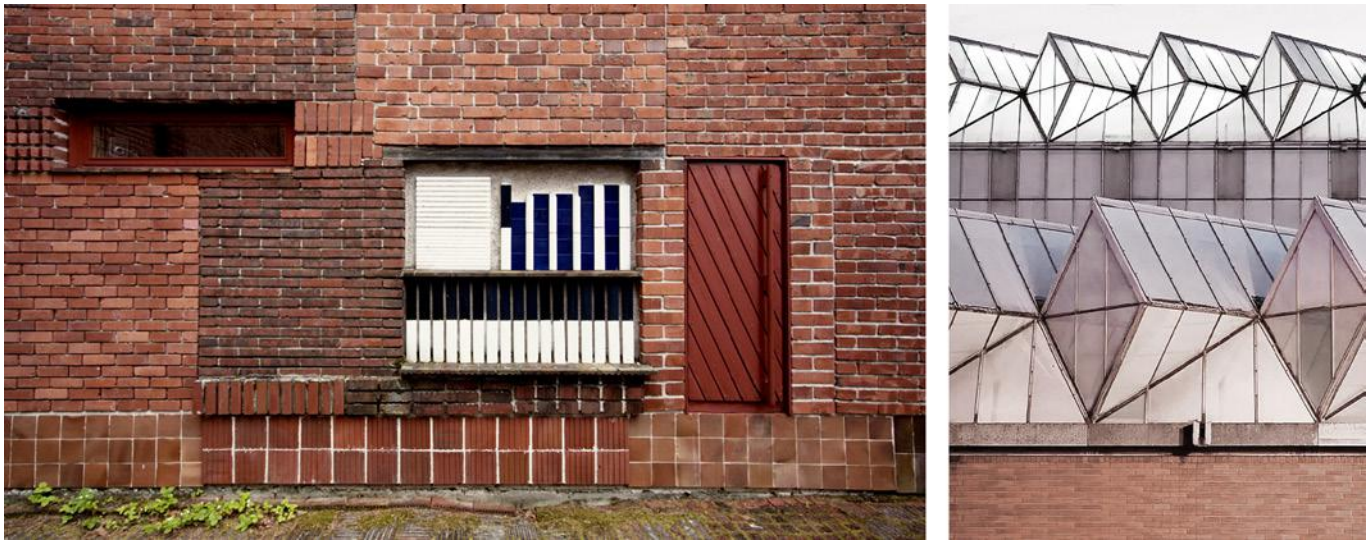


Fig. 4. *Masonry textures in Muuratsalo House, a "sampler" of material and geometry patterns (left). Source: © Hassan Bagheri, http://www.zeroundicipiu.it/2012/04/24/casa-sperimentale-a-muuratsalo; material juxtaposition in the Leicester Engineering Department, where the repeated rhythms of windows and skylights interpose to the linearity of brick walls and concrete (right). Source: [13].*

modules, scales, and treatments. The fifty textures of the patio were also meant to test each solution's optical effects and durability. In Aalto's architecture, there is often a dematerialization of the space, breaking the rigid protocol between inside and outside. In the patio of Muuratsalo House, the built environment is fused with the surrounding landscape; inside and outside are merged to allow the architecture to frame the lake Lehtisselkä, reminding of the way the windows of the ruined façades of collapsed buildings frame the sky in Civita di Bagnoreggio [11].

Muuratsalo House is configured as an étude on bricks, a short study composition on masonry texture in which technical variations on the same material are expressed. In this sense, the square courtyard fronts become the scene for a real architectural performance.

On the opposite view, the Leicester Engineering Department Building by James Stirling and James Gowan shows an "insensitivity" to context, which can often be found in the works of these two architects, manifested as an expression of autonomy from the place, of which the architecture aims to be a landmark. To escape the "routine of modernism", Stirling recovers fragments of the modern language, defining a speech of dissonant references, contradictions, and discontinuities that nonetheless find their own compositional meaning.

The "construction machine" is assembled with the most unpredictable architectural quotations, in which materials and shapes juxtapose but never totally merge. Exposed masonry, broad glass surfaces, concrete, and steel alternate in continuous variations to create different rhythms to the complex volumetric layout, generated to respond to the multiple uses hosted by the building in a specific way. The lack of a predominant front comes from the importance that Stirling gives to the internal organization, which peremptorily directs the external appearance based on its necessities and from which the dissonant and fragmentary narration of the façade derives [9].

The macroscopic contrast between flat red-brick surfaces and wide glass and metal ones is evident in the Leicester Engineering Department. Here, the pattern is based less on the material heterogeneity and more on the juxtaposition between masonry and glass, opaque and transparent materials, red and grey, and blue.

Ultimately, the work of Stirling and Gowan embodies a suite for brick, concrete, glass, and steel, in which the passages, harmonized by the language, follow each other in the form of function-volumes with distinct rhythms (Fig. 4).

4. GEOMETRIES

The compositional grammar of Muuratsalo House appears relatively simple in plan and fronts, as it is for the volumetric layout. Rectangular rooms are arranged in

succession, one after another, around a central square (the patio), which is the pivot of the composition.

The façades looking East and West are made of rectangular planes whose articulation is determined just by the variation of the orientation of the volumes. On each front, the compositional geometry is given by the juxtaposition of rectangular openings and continuous walls. Sometimes, windows can assume the primary role in the composition, as they do for the west front. On the East façade, however, the window is a minimal square opening whose compositional role is manifested by its repetition on the surface. On the South and North sides, the variation is driven by the sloping roof shape; nonetheless, the basic compositional rule, characterized by the openings being either dominant elements or small holes, remains unchanged.

The articulated geometry of the floor and the façades of the patio, realized by the varied use of masonry, contrasts the simplicity of volumes and planes. In fact, the work on bricks with different dimensions and colors determines a composition of mixed rhythms. On the courtyard façades, the rhythm is directed by four main vertical strips and three horizontal ones, subdivided into additional secondary bands according to the brick change (Fig. 5). Geometry and texture merge to manifest the compositional grammar of the architecture.

As far as the Leicester Engineering Department and Muuratsalo House share a composition based on purely flat surfaces (including the cylinders of the spiral stairs, which, by the way, are obtained by an assembly of flat glazed modules), the overall geometry of the first appears extremely more complex and varied, which can be explained as an interpolation of multifaceted prisms. The articulation of the organisms is characterized by an evolving syncopated rhythm, in which voids spiral among volumes, and towers accent the constant cadence of the sheds. The research on the internal functional necessities is translated in a discordant refrain of overhangs and recesses, jumps, and direction changes.

The masonry walls follow substantially linear and horizontal progressions, configured as flat faces of pure volumes, even in episodes like the conference rooms,

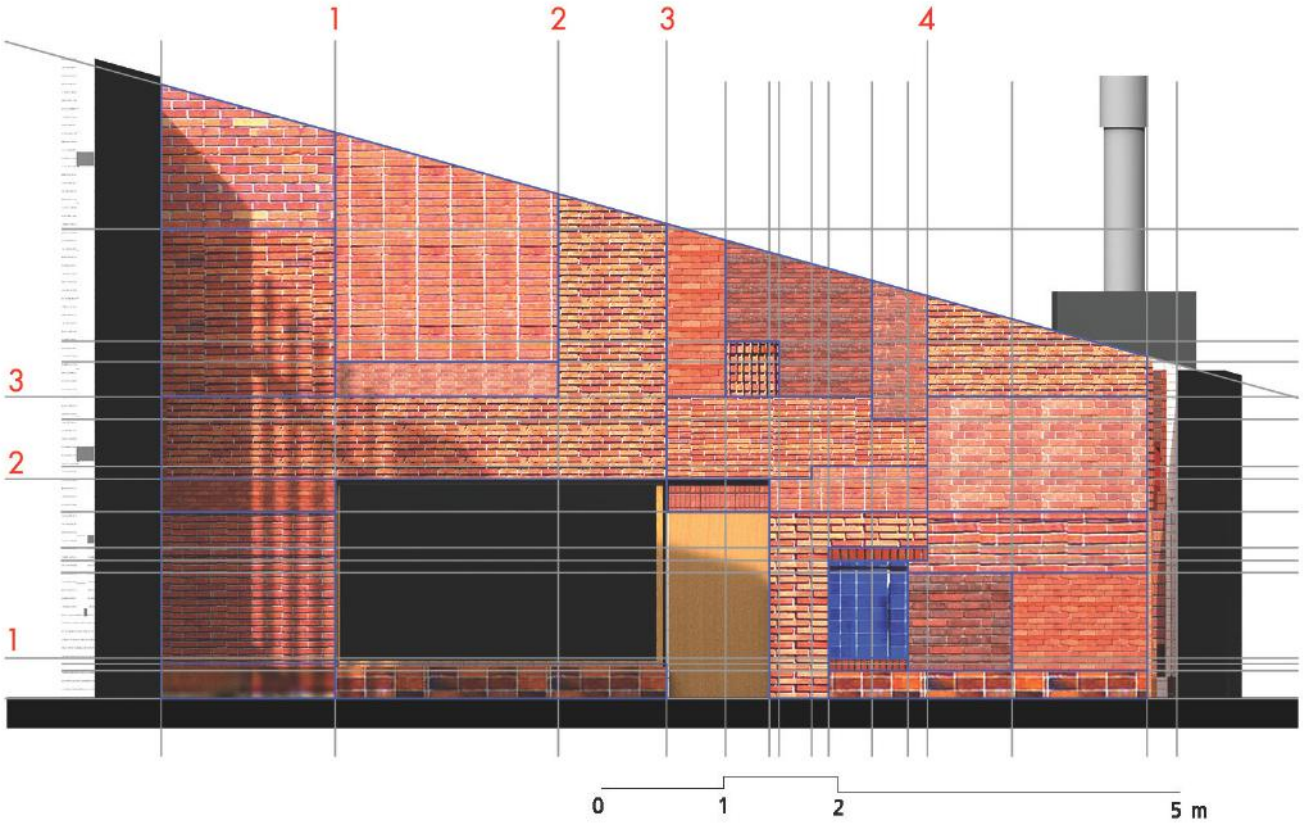


Fig. 5. *Geometric progression scheme on the front of the patio in Muuratsalo House, in which the grid highlights the subdivisions, not only of the openings but mainly of the articulate juxtaposition of different masonry patterns. Source: image created by the authors.*

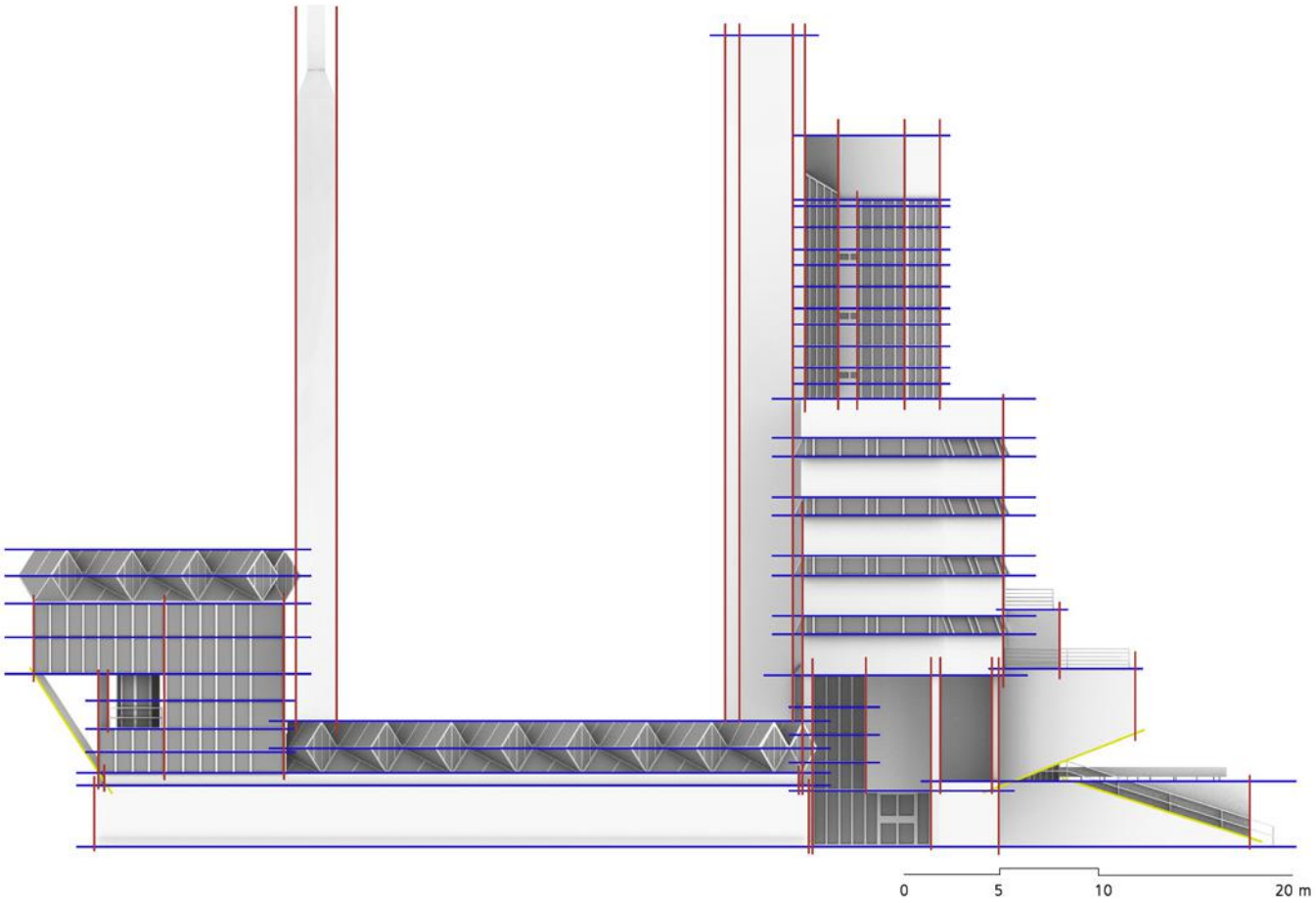
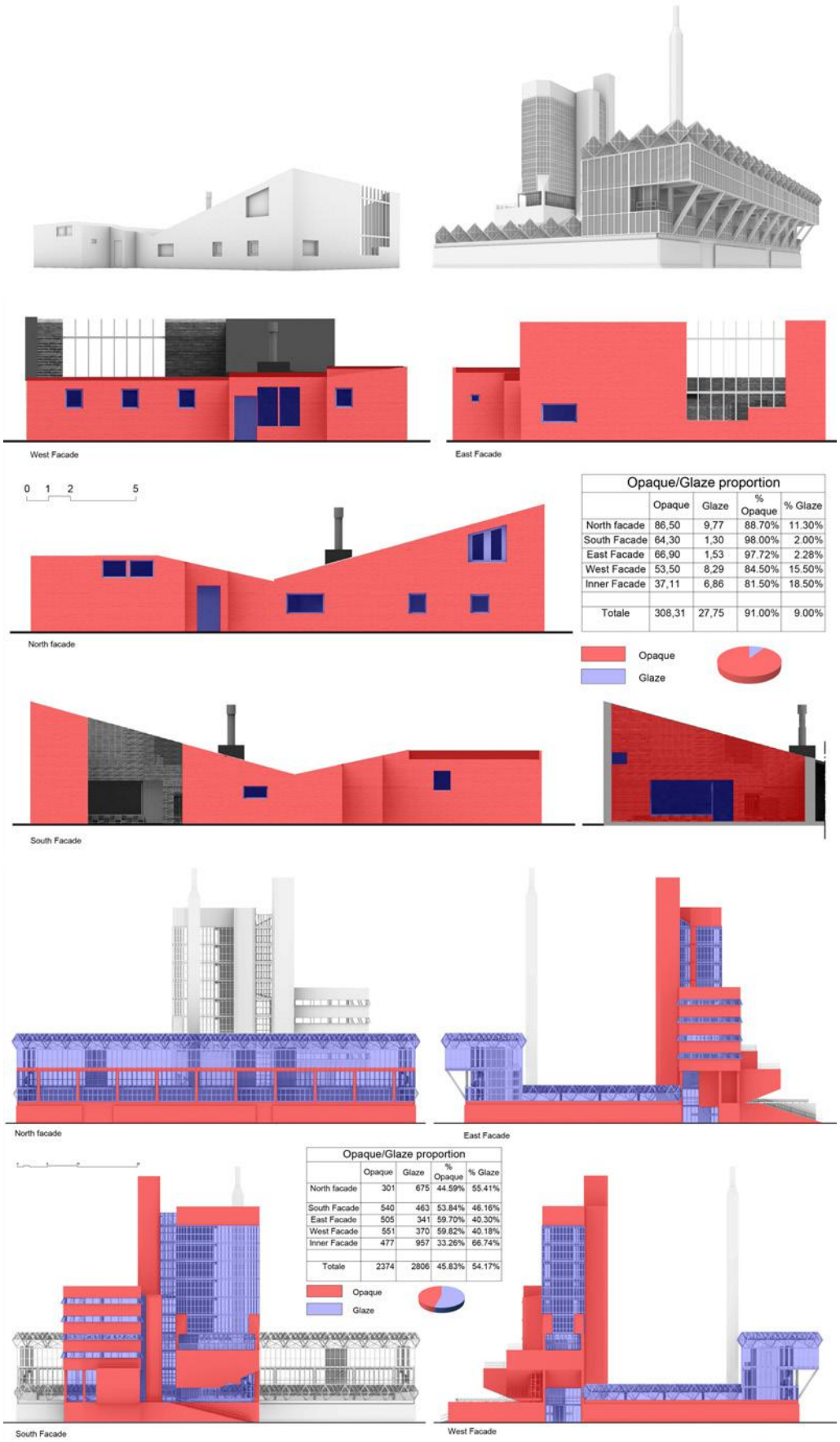


Fig. 6. *Geometric progression scheme on the South-East façade and the roof plan of the Leicester Engineering Department. Observing the main directions of the surfaces, it is evident how the independence of the functional volumes produces continuous fragmentations and gaps in the geometric layout, which is separated into distinct microsystems. By rotating 45 degrees, the glazed sheds break the orthogonality of the building, as it is for the entrance ramp and most of the angles of the other volumes, which are beveled following the same direction. Source: images created by the authors.*

whose *cavee* are represented on the outside with the simple sign of an inclined surface. The window system has the most significant geometric variants, working on alternative compositions with mostly rectangular modules; this dictates a large part of the façades' rhythms and movements. The glazed elements of the office tower are repeated along its vertical with a double tempo, declaring the internal progression of the floors; assuming an oblique direction, they sign top to bottom the volume connecting offices to the stairwell; ultimately, they become "ribbon bow windows" to mark the research tower horizontally. The most iconic element of this architecture by Stirling and Gowan is certainly the shed roof of the laboratory area, whose module, a squared base prism, is repeated at a fast pace over the entire surface, with a plan angulation of 45° in relation to the general direction of the envelope. It creates a strong pattern that overflows from the base and breaks its linearity, creating a complex game of intersections with the glazed block on the back (Fig. 6).

5. COMPOSITIONAL ELEMENTS

In the connection to the ground of Muuratsalo House, Aalto experiments with the "foundationless building", utilizing a floor substructure in the atelier, while choosing a "free-form column structure" for the woodshed, which involves supporting wooden columns on beneficial points of the ground [12]. As for the relationship with the context, while following the natural slope of the land, the white-plastered perimeter walls of the building show a deliberate detachment. Inside the patio, though, the bond with nature and the underlying ground returns, almost as a re-proposition of the idea of the hearth of the Roman rustic villa.



Opaque/Glaze proportion				
	Opaque	Glaze	% Opaque	% Glaze
North facade	86,50	9,77	88.70%	11.30%
South Facade	64,30	1,30	98.00%	2.00%
East Facade	66,90	1,53	97.72%	2.28%
West Facade	53,50	8,29	84.50%	15.50%
Inner Facade	37,11	6,86	81.50%	18.50%
Totale	308,31	27,75	91.00%	9.00%

Opaque/Glaze proportion				
	Opaque	Glaze	% Opaque	% Glaze
North facade	301	675	44.59%	55.41%
South Facade	540	463	53.84%	46.16%
East Facade	505	341	59.70%	40.30%
West Facade	551	370	59.82%	40.18%
Inner Facade	477	957	33.26%	66.74%
Totale	2374	2806	45.83%	54.17%

Fig. 7. *A comparison between the glazed elements of the case studies, from which the will to make a correspondence between external configurations and internal functional needs is observed. In Muuratsalo House (on the left), this is translated into a series of essential signs, while in the Leicester Engineering Department (on the right), the variety is amplified by the multiple meanings of the place. Source: images created by the authors.*

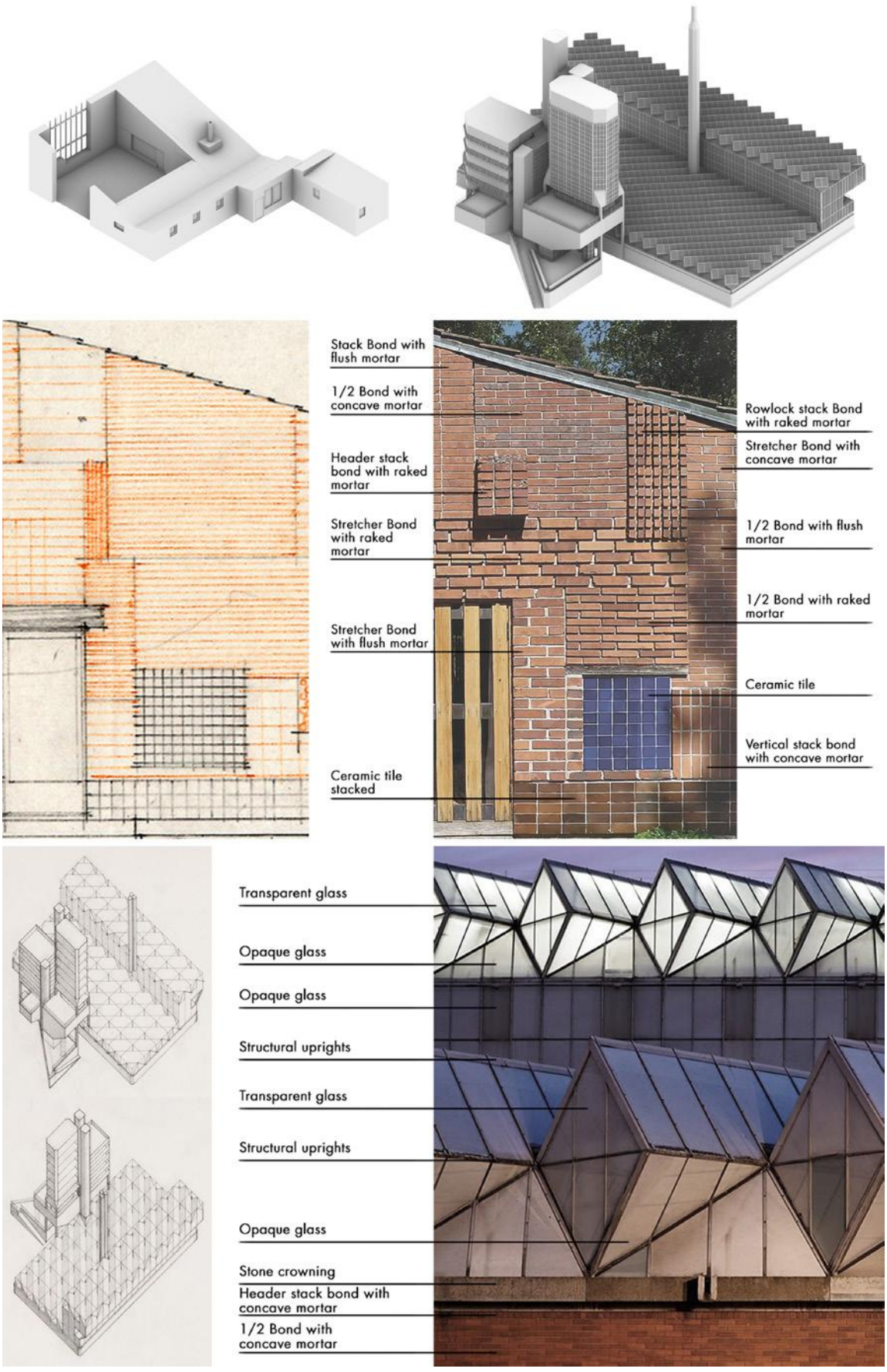


Fig. 8. *Connections to the sky compared through axonometric views of the models (at different scales) drawings and photos, highlighting different rhythms and levels of complexity between the roofs of the two case studies and underlining the difference in material dynamics through the elevation. Source: images created by the authors.*

In the Leicester Engineering Department Building, the connection to the ground assumes the sign of a solid masonry base, continuous and seldom interrupted by openings. Explicitly referencing Wright's Johnson Wax Building, the base defines a horizontal and consistent caesura that serves as an incipit for the game of variations along the elevation.

As for the window element, in Muuratsalo House, the hierarchy among openings is given by the internal distribution. The windows on the private side of the house are small and positioned at the top to avoid prying eyes. A different approach is chosen for the windows of the atelier and the patio; the former was conceived larger to create a visual connection between the internal and external space, and the latter was designed to enjoy the surrounding nature in a reserved/filtered way. The windows placed on the West façade create an almost solemn view of the external landscape, thanks to a texture of vertical elements.

In the Leicester Engineering Department Building, the broad glazed surfaces are countered by the introversion of the walls, generating a multifaceted alternation between the uniform and monotone pauses of the masonry texture and the fast rhythms of the windows, which mark the envelope-like thin ribbons, prisms and big transparent planes (Fig. 7).

The connection to the sky in Muuratsalo House is concise, obtained by alternating solids and voids. The choice of white plaster is perhaps a recall of the color of the stones around the lake Lehtisselkä, willing to create a mediation between built elements and the context, almost becoming a background to enhance the surrounding nature.

In the Leicester Engineering Department, the connection with the sky assumes various configurations according to the diversity of the "functional passages" of the building. The vibrant and repeated movement of the glass and metal prisms counters the assertive closure of the office tower (Fig. 8). The engineering department is also dynamized by another group of signs of different semantics, which cannot be brought into the Muuratsalo House by Aalto: a chimney, concrete pillars and sinuous spiral stairs mounted in glass cylinders identify a set of vertical elements which delineate punctual variations that link surfaces of different nature.

6. RESULTS

The reconstruction methodology chosen for Muuratsalo House and the Leicester Engineering Building, using 2D and 3D models, allowed the critical reading of the compositional language of the two architectures. The research led to different results: i) thinking about the relationship between architecture and representation; ii) using 2D and 3D models to analyze existing architectures.

Drawing is also a critical tool for analyzing, reading, and understanding architecture; therefore, it is necessary to investigate the generative process of shapes through representation. The study of project drawings, the redrawing in CAD, and the 3D modeling are phases connected to each other to lead to a critical reading of architecture.

By operating with aggregations and disaggregation, 3D models continuously force us to consider the relationship among components in spatial, geometrical, compositional, volumetric, dimensional, and hierarchic terms [14].

Analyzing Muurtsalo House through 2D and 3D representation makes it possible to understand how its façades are mainly based on the compositional and proportional relationship between walls and openings. The analysis of the patio's fronts underlines how this association develops a greater complexity because the textures, rhythm, and geometry of the construction material become the main signs of the compositional grammar. Therefore, in this case, the material (bricks) and the assembly techniques generate texture and geometry.

Regarding the Leicester Engineering Department Building, the model initially allowed the understanding of the general volumetric articulation because a complex formal variety characterizes the building. Subsequently, the 2D representation of the fronts and the 3D model were used to understand the relationship among the components of the façades. The whole configuration is characterized by the juxtaposition of multiple volumes, which impacts the façades, whose openings direct rhythms, textures, and geometries (Figs. 9 and 10). In this case, instead, the relationship between glazed components and continuous walls determines changes in textures and geometry.

Fig. 9. *Render of Muuratsalo House. Source: image created by the authors.*

Fig. 10. *3D model of the Leicester Engineering Department Building. Source: image created by the authors.*

7. CONCLUSIONS

Architects have designed their works strictly following geometric modularity ratios and proportional rules for centuries, but during the XX century, those intentions were subjected to a radical transformation. Representation forms have always held, and still hold nowadays, a central role in all the reading processes of the existent reality. In particular, the use of current digital tools fits into the analysis process but also into the creation of configurations, especially regarding complex architectures.

The analysis of architectures through 3D models leads to a continuous confrontation with the geometrical space to understand the volumetric articulation and establish spatial relationships among the parts. It also forces the deconstruction, decoding, and classification by typology of the components, which are the generating operations of a shape. At the same time, the development of the model forces us to think about the ordering structure.

Through the virtual construction of solids and surfaces and their juxtapositions, the model helps to retrace an architecture's morphogenesis process, revealing the architect's design intentions.

The interpretative analysis includes various aspects of the architecture (functions, dimensions, composition, hierarchy). In this scenario, reading two specific elements of the composition, such as geometry and texture, is also included. The work on the two presented case studies expresses an analysis method that includes, on one side, the composition and geometric decoding and, on the other, the communication of the architecture through 2D and 3D representations capable of conveying formal characteristics. In this process, from the study of project drawings to the modeling, the worth is not only in the graphic result but mainly in the methodological process of reading performed through different forms of representation.

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