"Structures of light". Structural morphologies as devices for capturing light

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ABSTRACT

The present paper would look at the principles of architectural composition as analytical distinction of parts, the idea of the structural fragment, the use of open forms and serial repetition, featured in modern and contemporary architecture. Given the possibilities of reinforced concrete structures, light penetrates into the building through the structural frame and shapes the negative-space of the load-bearing form (pattern of light).

Moreover, the gap between enclosure and roofing system, the breaks in the walls, the disconnection at the angles in a masonry structure, become a powerful sources of light. The tectonic node shifts from being the robust part of the structure to a hiatus of light.

Goals, criteria and methods of analysis of the case studies:

In these monumental building, light is the former designing tool. By analyzing the most important historical architectures, the process of spatial design would show the importance of structural form in architecture and it could be used for contemporary approach. The structure bears the loads and creates "machines for capturing the light" at once.

Partialized designs have been drawn and re-created with 3d printing technology. An exemplar list of the case studies is the following:

- Matching separate structures: Hurva Synagogue L. I. Kahn, Casa della scherma by L. Moretti, Nelson-Atkins Museum by S. Holl.
- Gaps between structural series: Kimbell Museum by L. I. Kahn, Padiglione Italia competition entry by F. Venezia, Museum of Architecture in Lisbon by Aires Mateus.
- Tectonic hiatus: Hepworth gallery by D. Chipperfield, Palazzo dell'acqua e della luce by Albini and Gardella.

Keywords: *Spatial design, structural morphology, conceptual analysis, light, tectonic hiatus.*

INTRODUCTION

Contemporary architecture loosened the link between natural lighting and structural morphology, so that the systems to capture and modulate the light is often a complex technological apparatus, added as an additional prosthesis to the construction. However, several fundamental designs, which we will briefly expound, deal with the issue of "capturing the light" from the conceptual phase of the project, as the substance of architectural form and its spatial features.

The need for the traditional wall construction system of making openings according with the path of structural loads, addressed to a rigid choice of the access points of light. And the

effort to take the strength of materials to the limit, trying to overcome the tectonic constraints and use light as an architectural element that materializes the physical space, required a large building expertise. Modern architecture in reinforced concrete and steel overlooked the importance of the opening, conveying structures whose interior/exterior relationship has no material constraints and dimensional requirements.

The ideas and works of Louis Kahn helped to bring emphasis, at the end of Modernism, on the need of the light modulation to characterize architectural spaces [1]. Functionalist architecture neglected the relationship between light and shadow, aiming at the greatest brightness and openness in a building, by the use of large curtain walls. Some contemporary architects, like Steven Holl, took light as primary theme of research, linking it to the phenomenological dimension of space [2]. Peter Zumthor indirectly takes on the theme of light, through its research over materials and grammars of construction. Spanish and Portuguese architects, such as Alberto Campo Baeza and Aires Mateus, reinterpret the value of light sources through a renewed declination of traditional constructive continuity and massiveness [3].

It is evident that contemporary architecture inherited from modernist experience the principle of analytical composition, based on the distinction and separation of elements, the idea of structural fragment, the use of open and serial shapes that do not need closed or box-like construction systems. Even if architects work on continuous systems, they are inclined to apply analytical principles, separations and disjunctions; considering these gaps as points of tension, rather than factors of disaggregation. The hiatus takes the form of a gap that lets the light enter, reconstituting the unity of the building.

Although light is immaterial, it significantly affects the design of architectural forms. In fact, the systems for capturing the light have direct consequences in the sections of the building, even in lightweight structures. Structural parts of the building and constructive elements achieve the role of illumination devices while blindings and reflective elements belong to structural form rather being additional prosthesis. Thick roofs accommodate “rooms of light”, recalling Baroque vibrant spaces. The Nelson-Atkins Museum expansion by Steven Holl, demonstrates how typology can be developed with the main objective to create a "machine to catch the light." Large emerging volumes mark the presence of an underground museum, five "translucent lenses” illuminate the interior galleries through reflective and diffusing shells, acting as lanterns in the dark.

(A. B. Menghini)

STRUCTURES OF LIGHT

Light and space-structural types, luminous devices and construction elements

The research is based on the teaching experience at Politecnico di Bari, Architecture department, gained throughout workshops of the Master’s Degree atelier [4], dealing with the relationship between structural morphologies and architectural space. Moving from the identification of exemplary (paradigmatic) contemporary architectures, in which the form of the structure, with volumes and voids, defines the formal and spatial structure of the building, we addressed to some archetypal space-structure models (the hall, the structural series, and the aggregation of the rooms). We tried to sort and group the examples in genealogies and space-structure categories, by means of a work of classification, generalizing those compositional topics didactically useful for the final process of synthesis. Then the students realized physical *maquettes* and virtual models, choosing a single material to highlight the essence of architectural form. The exercise understands the didactic value of simplification, which forces to distinguish what is essential from what is not. Each building has been partialized, in order to

synthesize the project and show spatial hierarchies, the relationship with the ground, the way they capture the light.

In discontinuous systems, light can penetrate into the building through the structural frame and shapes a negative form of the skeleton (luminous patterns). In these cases, the load bearing lines alternate solid and void, structure and light. In buildings gathering different structures or a series of them, light penetrates the joint and irradiate inside interstitial spaces (luminous gaps). Tectonic nodes, separation of wall and roof, gap of the walls in the corners, and so on can become a powerful source of light (nodes of light). Diffused light passes through folds and fissures, generated by deformations and distortions (luminous disconnections). Lightened area appears, in all these cases, as a negative of the structure [5].

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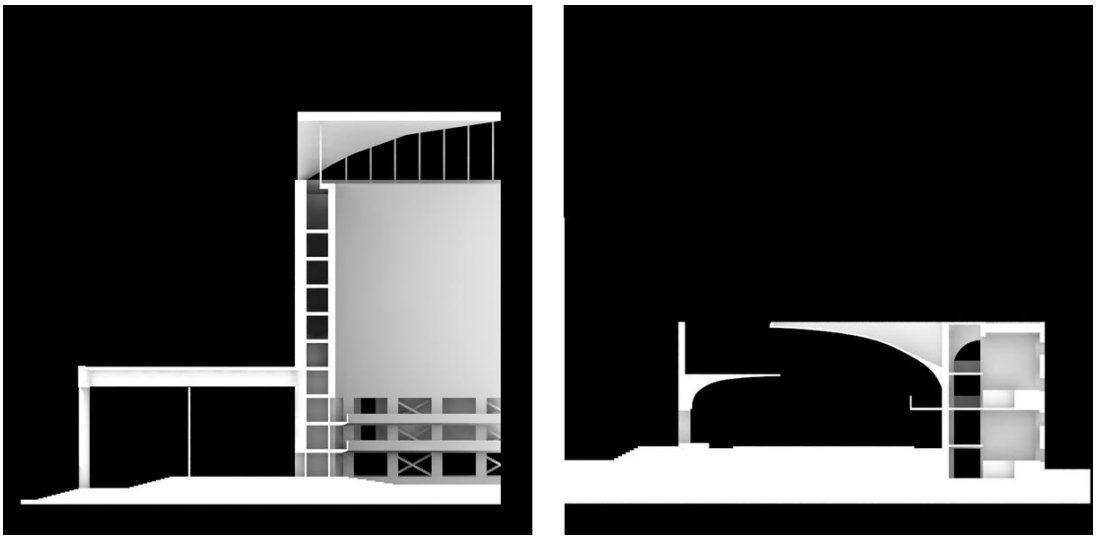

Figure 1 *Palazzo dei Ricevimenti e Congressi* by Adalberto Libera; *Casa della Scherma* by Luigi Moretti

- Luminous enclosure and roofing

Enclosing surface diffuses the light through textures and luminous patterns. The layered pattern in the thick roof of the Nordic Countries pavilion at the Venice Biennale, by Sverre Fehn, represents a significant example of this typology. The same reasoning, developed in three dimensions, acquires the form of portals in the Salvador Allende Museum, by Juan Navarro Baldeweg. Coffered ceiling is a recurring theme in hall-like buildings, declaring the layout of the spans as in the Yale Center for British Art by Kahn, or rather covering large areas with a grid system as in the Caja General in Granada by Alberto Campo Baeza *(Fig 2)* or the I Ching Gallery by Peter Zumthor.

Speaking of wall constructions, repetition of columns allows rhythmical path of light between structural frames. In continuous systems, light invades architecture through gaps defined by resistant geometries (eg the stretches in the walls of the Kolumba Museum by Zumthor and the Stone Museum by Kengo Kuma). In discontinuous systems, light penetrates through the thick series of constructive elements, as in the Topography of Terror Documentation Center three-dimensional cage by Zumthor [6].

Enclosure is developed also as hollow walls, illuminating cavities, enveloping walls, double walls: we have the design, by Francesco Venezia, of the second project for the Neues Museum in Berlin and in his numerous arrangements made within existing spaces. The Kunsthaus Bregenz, a glass box-like building, recalling International Style models, is a sophisticated shell, internally illuminated by a diffused light that penetrates through layered U-shaped floors and spreads softly from the ceilings of the exhibition halls.

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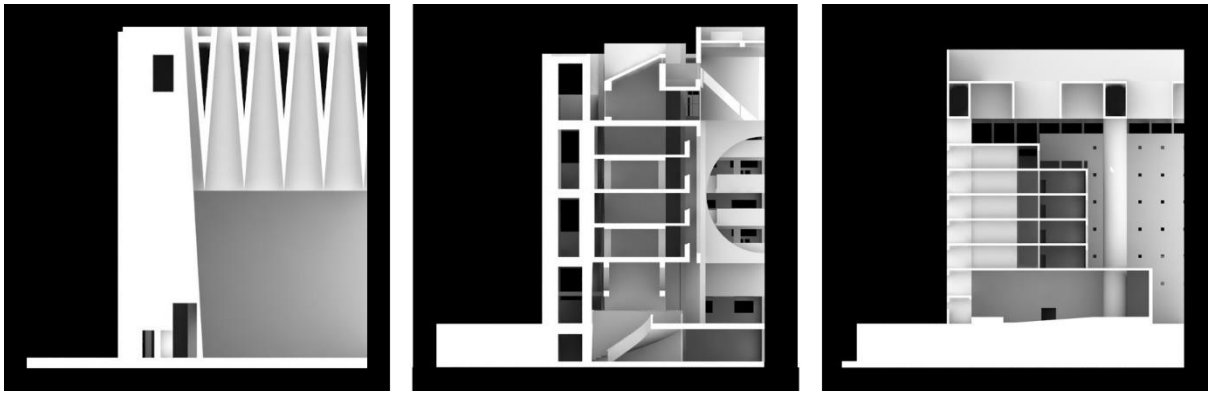

Figure 2 *Herz Jesu Church* by Peter Zumthor; *Exeter Library* by Louis Kahn; *Caja General* in Granada by Alberto Campo Baeza

- Luminous hiatus

Light penetrates through interstices between different structures, marking theirs discontinuities. It can enter between distinctly separate and independent structures, as in the Hurva Synagogue by L. I. Kahn, or in the gap between juxtaposed spans. Wright's "dendriform columns" of Johnson Wax Building are a clear example of how the gap between the spans can become a source of light. The thin light hiatus interposed between "structural plates" in Vals Thermal Baths, by Zumthor, is a more sophisticated variation of this principle. Paradigmatic examples are the light cuts between the two shell-beams that constitute the vaults of the Kimbell Museum, the slot of light between the two cover-shells of the Casa della Scherma by Luigi Moretti *(Fig 1)*, or the light between the two structures in the Italian Pavilion by Francesco Venezia.

Even tectonic nodes, which typically are the strongest points of the structure, can become hiatuses. In the Hepworth Gallery, by David Chipperfield, light passes through disconnections in the angles, contradicting the closure of the rooms. Or even the separation between wall and roof: eg in the Chapel of Ronchamp by Le Corbusier, the Unitarian Church by Kahn, in the Palazzo dell'Acqua e della Luce at E42 by Franco Albini and Ignazio Gardella, or in the Palazzo dei Ricevimenti e Congressi by Adalberto Libera *(Fig 1)*.

(A. B. Menghini)

Case studies: goals, criteria and methods of analysis

This paper analyzes well-known monumental buildings that understand light as a former designing tool, which highlight structural thickness or rather de-materialize the enclosing surface according to designer's vision. For the sake of the analysis, we divided the case studies in three main categories accordingly with a different relationship of the structural form with the light. Namely, how structural morphology influences spatial design.

An exemplar list of the case studies is the following:

- Matching separate structures. The project is composed of different typologies of structures that have been juxtaposed. One can identify every structural element that is formally and statically self-sufficient: *Hurva Synagogue* by L. I. Kahn, *Casa della scherma* by L. Moretti, *Nelson-Atkins Museum* by S. Holl.

- Gaps between structural series. The project gathers a serial repetition of the same structural morphology, which lets the light penetrate by small gaps between them: *Kimbell*

Museum by L.I. Kahn, *Padiglione Italia competition entry* by F. Venezia, *Museum of Architecture* in Lisbon by Aires Mateus Architects.

- Tectonic hiatus. The project expounds its constructive composition, establishing the structure, roof, and envelope as archetypes and dwelling on their connection as paradigm of the composition: *Hepworth gallery* by D. Chipperfield, *Palazzo dell'acqua e della luce* by F. Albini, G. Minoletti, I. Gardella, G. Romano and L. Fontana as sculptor.

The second stage is the recognition of the smaller structural and spatial part of the building that it is sufficient to condense the idea of the whole design. Given the process of inductive reasoning and its implications concerning the part-whole relationship, historical edifices becomes active matter for contemporary design. Partialized designs have been drawn and re-created with 3d printing technology. What follows is a deeper analysis, with text and drawings, of three unbuilt projects, one representing each category. The projects have a very different theoretical background though sharing the same use of light as an architectural element. The structure, being the negative form of the void, curves, bends, twists, flattens to let the light enter and shape the space.

In his 1968-74 *Hurva Synagogue* project *(Fig 3)*, Louis Kahn clearly motivated his analytical composition dwelling on the religious symbolism that the building had to deal with: "I sensed the light of a candle plays an important role in Judaism. The pylons belong to the candle service and have niches facing the chamber. I felt this was an extension of the source of religion as well as an extension of the practice of Judaism" [7]. Being a founding member of the Jerusalem Committee, the American architect seemed to be the best profile to build a new synagogue after Jordanians destroyed the original one in 1948. His formula of a building within a building is clearly expressed, "the bastion-like outer building protects the central space of worship from the heat and sun. The inner building consists of four concrete umbrellas serving as a roof. Between the inner and the outer buildings is an ambulatory which can be also used for additional seating during special ceremonies" [7]. The ritual shapes the in-between spaces and two different structural morphologies: the umbrella, which has a square base and a curved section that reaches the dimension of the ambulatory space, is structurally suspended over the worship space and conveys the idea of a holy threshold since spatial compression introduces the full-height central space. The bastion-like structural morphology, which has a rectangular base and a solid section carved out to provide niches, conceptually belongs to a thick excavated wall. The negative space allows a deep façade and creates an interior in itself, providing intimate space protected from the exterior. Kahn insisted on the idea of architecture as a threshold between what is measurable and what is not, in other words the relationship between silence and light. His design process understands light and structure as a whole, drawing a structure is the same as tracing the way a certain building will treat the light. This character emerges from Kahn's concise words collected by John Lobell, "structure is the giver of light. When I choose one order of structure which calls for column alongside of column, it presents a rhythm of no light, light, no light, light, no light, light. A vault, a dome, is also a choice of a character of light" [8]. When the architect speaks of the plan, the way building stands on the ground and defines what is inside and what is outside, "you can say that it is [the plan] the structure of the spaces in their light" [8]. Kahn invites architects to see beyond the functional character of the structure in order to shape spaces that, retreating from objectivity of the physical sciences, convey a unique human experience.

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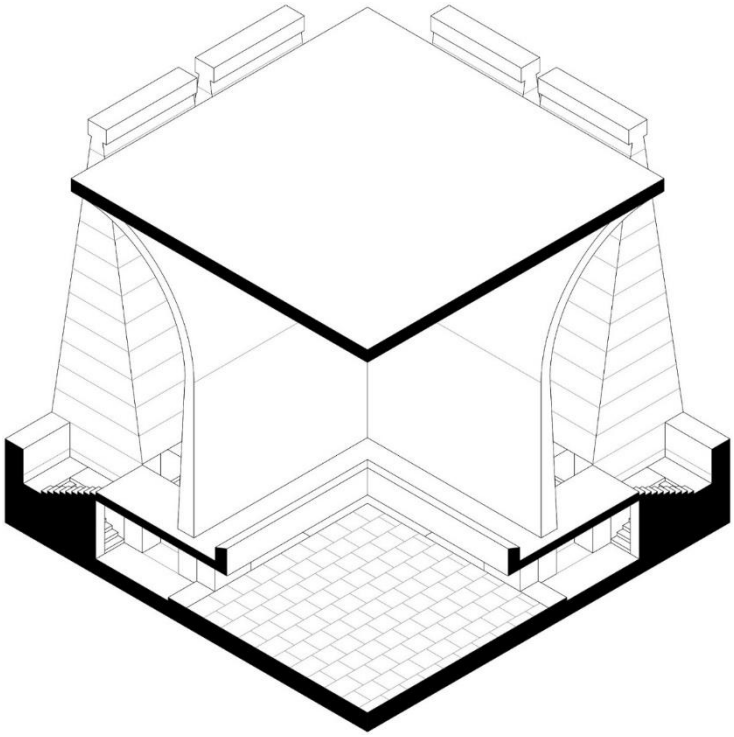

Figure 3 Axonometric view of the *Hurva Synagogue* by Louis Kahn

The 1988 competition for the design of the *Padiglione Italia (Fig 4)* at Venice Biennale (Giardini) was a fundamental step to review the state of the art of Italian academic debate over architecture for exhibitions. Twelve architect were selected to participate and Francesco Cellini, based in Rome, proposed the winning design that was never built. The building to be refurbished was at the center of the Giardini area, facing a large green area on one side, and *Canale di S. Elena* on the other side. Among Gianugo Polesello, Giorgio Grassi, Guido Canella, Gabetti and Isola, Vittorio Gregotti, Adolfo Natalini, Franco Purini, Alessandro Anselmi, was Francesco Venezia that designed an enormous foundation in guise of hypostyle hall, a palafitte that shapes a Baudelairian space hiding the underground exhibition place [9]. Foundations are made visible, as if the operation of subtraction would have revealed piles from the mud and water. We have two types of pillars, each one associated to a precise static role: the larger dimension bears the weight of the roof while the thinner section sustains the series of exhibition galleries. Venezia envisioned a complex section, over the pillars, made up of a structural module repeated accordingly the existent building. Each module had a different length and the form of roof served as device to capture the light. In his famous text *La Torre d'Ombra*, namely The Shadow Tower, Venezia writes that, over the structural relations of the matter, sunlight rules and modifies the way architecture is perceived. While darkness flattens the dialectic of the rhythm, light shows multiple images of the building, that is the time of any architecture, where every ordered element has a double in its shadow. Thus, form mediates instant and duration, ephemeral and permanent [10]. The building seems to float in the air, over the hypostyle hall hidden by the shadow. Light shapes the form of the structure, which is an *ordine gigante* composed of a trilithic system of columns and oversized curved beams conveying the gap that illuminates the space.

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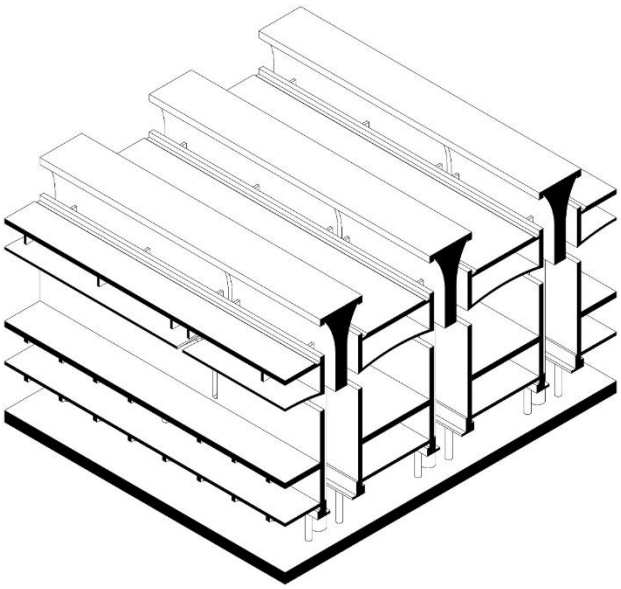

Figure 4 Axonometric view of the *Padiglione Italia* at Venice Biennale by F. Venezia

The *Palazzo dell'acqua e della luce* project *(Fig 5)* is one of the competition entries by Franco Albini, Giulio Minoletti, Ignazio Gardella, Giovanni Romano and Lucio Fontana as sculptor. The competition took place in 1939 and the building was aimed at hosting the Historical Exhibition of the artificial Light. It had to be a monumental fountain, a place for people leisure where light and water are the main elements of the composition. Sixteen teams participated to the competition, including Luigi Nervi, Adalberto Libera, Pietro Bottoni, Giovanni Michelucci, Gio Ponti. Albini's proposal is a white and mute parallelepiped raised off the ground, over a large water basin. A thin wooden structure bears four enclosing vertical surfaces and creates an isotropic tridimensional grid that punctuates the space of the building. Here the interior space is uniform an only virtually divided in geometric volumes; it does not need any horizontal plane since one can see the water plane under his feet. In fact, while most of the entries intended the water expo as a waterfall, the analyzed project used this element as an architectural feature, rendering an even more abstract space, in a condition of suspension, conveying the possibility to illuminate the building from the bottom. The visitor has a predefined path represented by a promenade that takes him from the ground to the top of the building, sneaking through the two stories frame. The project has a coherent tectonic system made of the structure, the enclosing planes, and the walkway, where each architectural element expresses its singularity without merging any other formal field. Light enters space through a tectonic hiatus between the roofing plane and the vertical closure, filtered by the wooden structure. While oblique lightening casts sharp shadows of the wooden frame, the roof denounces its condition of a plane, namely a two dimensional element which leans over the structure. A hiatus occupies the point where roof, façade and structure would join. Lightness and rationality, two most important values in Albini's architecture, find their common ground in an abstract transparency, questioning the weight of the construction in favor of two fluids, the water and the light. Light makes the matter to lose its physical features, weight and volume, and become an "agency" [11].

(G. Resta)

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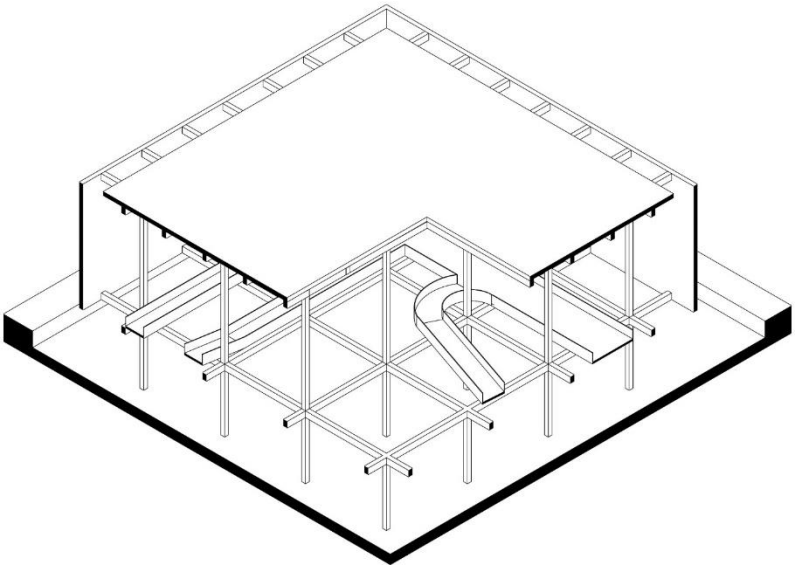

Figure 5 Axonometric view of the *Palazzo dell'acqua e della luce* by F. Albini, G. Minoletti, I. Gardella, G. Romano and L. Fontana

CONCLUSIONS

By analyzing thirty of the most important twentieth century architectures, both realized or not, the process of spatial design would show the importance of structural form in accordance with natural lighting, which we maintain should be included in contemporary approach to architectural design. A renewed link between light and form could be at the beginning of a coherent design where building science and spatial design are no longer two (isolated) field.

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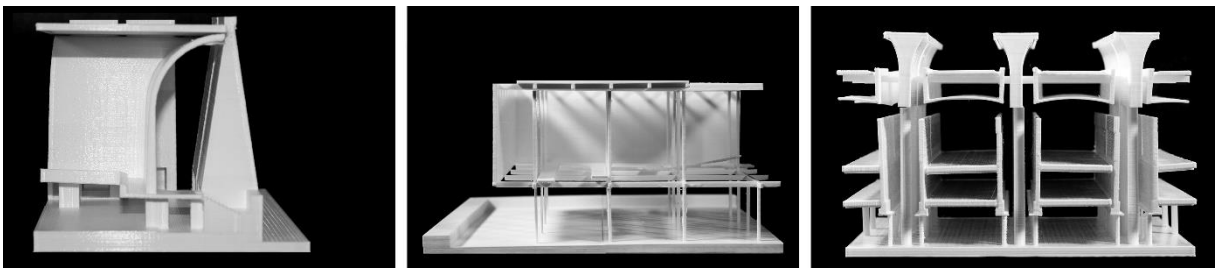

Figure 6 3D printing of the case studies

This would disclose a common ground where quality is the very outcome of the collaborative interaction between architecture and engineering.

(G. Resta)

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