Geometrical Analysis of Vilanova Artigas's Trapezoidal Columns

Wilson Florio, Ana Tagliari

Abstract

Constructive honesty was one of the premises of modern architecture. The best way for architects to make reality perceptible was to leave the structural elements apparent. From 1930 to the 1960s, this discussion took place in Brazil. In this way, one question emerged: What is the symbolism of a structural column in modern architecture? In the present article, we discuss the geometry of columns designed by the architect João Batista Vilanova Artigas (1915-1985) between the '50s and '60s. Vilanova Artigas documented his vision of architecture in his texts, which discuss the relationship between architecture, technique, and construction. We identified concepts that guided his design strategies, particularly how structure shapes architecture. Our research used drawing as a powerful tool to reveal geometrical characteristics in the constructed buildings, as well as to contribute to clarifying these concepts. Based on the original technical drawings, we modeled the structure of selected projects to investigate and reveal the constructive system, paying attention to the geometrical characteristics of the columns. The obtained results allowed us to demonstrate the sculptural character of the Vilanova Artigas columns based on the morphological analysis of the trapezoidal geometries. Furthermore, the research results reveal that Vilanova Artigas designed his architectural projects and structural conception as one thing, in an original and innovative way, harmonizing art and technique.

Keywords: construction process, form-generating, symbolism, reinforced concrete, aesthetic emotion.

Introduction

The column has always been an important element in architecture. Since the Greeks and Romans, the classical orders have played a fundamental role in the construction of the language of a building.
In the modern scenario of the 20th century, Le Corbusier (1887-1965) reinvented the design of the column for the pilotis, devoid of ornaments and with functional protagonism. On the other hand, Frank Lloyd Wright (1867-1959) advocated the structure integrated into the building as a single organism. In Brazil, between the '50s and '60s, Oscar Niemeyer (1907-2012) offered us several creative designs of the modern column, especially in the palaces of the city of Brasília, highlighting the curve and delicacy provided by the strength of reinforced concrete. But the geometry and design of the modern column were explored and enriched by the architect João Batista Vilanova Artigas (1915-1985). This paper presents the results of research that analyzed architectural projects designed by the Brazilian architect Vilanova Artigas. One of the stages of the methodology of this exploratory research was developed in the archives of architectural projects in the Faculdade de Arquitetura e Urbanismo e de Design Universidade de São Paulo (FAUUSSP) library. In these archives, we found important drawings of the projects selected for analysis. In this text, we present the drawings of the architect's projects, which reveal the structural conception. The subject matter is

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previously unpublished material by this important architect of the well-known São Paulo School.
Vilanova Artigas documented in his texts his vision of architecture, which clearly shows his posture as an architect in the relationship between architecture, technique, and construction. In this research, we identified fundamental concepts that guided his design strategies. Experiments with new spatial propositions and technical solutions produced an innovative character, especially in terms of structure as defining architecture, the nationalist spirit, and the valorization of human and collective spaces.
The procedures adopted in this research consisted of a literature review on the subject, a survey of projects and drawings, visits to selected buildings, and analysis of projects through diagrams, drawings, models, and writing texts. The research results reveal that Vilanova Artigas designed his architectural projects and structural conception as one thing, in an original and innovative way, based on his concepts of modern architecture for São Paulo. The architectural project and structural conception together organize the architectural program and contribute to the materialization of modern concepts of its architecture.
The investigation employed theoretical writings, case studies, and graphical analysis to analyze the geometric development of trapezoidal columns in Vilanova Artigas architecture. The main steps were: I) identify the main concepts declared and written by the architect; II) select projects with columns with different geometries; III) 2D redraw and 3D modeling of each column; IV) 3D printing of the modeled columns; V) identify geometrical characteristics; VI) classify types of columns in categories; VII) discuss the results and analyses. The article is organized into four parts: *Introduction*; *Column in modern architecture*; *Research*; *Discussion*.

Column in modern architecture

Physically, a column serves as a point of support and a structural element that ensures the structure minimally impacts the terrain. Structurally, columns are used to transfer the compressive load of a building to its foundations.
Columns are frequently used to support beams on which ceilings rest. But a portico is an assembly where a column is part of a broader structural configuration with beams, trusses, and roof coverings. Therefore, a portico is a structural frame with multiple load-bearing members and a roof, functioning as an integrated system. Historically, ribbed reinforced concrete slabs with trapezoidal beams emerged with Hennebique's patent in 1892. There is no doubt that the structure of Notre-Dame du Raincy, by Auguste Perret, built in 1922, had a significant impact and inaugurated the so-called 'Brutalist architecture' [Collins 2004; Frampton 1996]. The 37 feet tapered columns clearly show the presence of an unfaced concrete support that "imprints half-round and triangular timber fillets from which the column formwork is constructed" [Frampton 1996, pp. 131, 132]. However, it was Le Corbusier, through the concept of *beton brut*, who comprehensively articulated the notion of allowing concrete to reveal its inherent aesthetic by remaining unadorned and untreated.
In modern architecture, Perret made round columns. According to Peter Collins, this shape was preferred because it was most economical, providing constant rigidity from every angle, and because "it was more satisfactory optically as a result of the gradations of shadow and constancy of silhouette" [Collins 2004, pp. 202-203].
As Joseph Rykwert [1996] observed, for ages columns were made of stone as vertical supports. With the advent of reinforced concrete as a malleable material and the ability to calculate the forces within it, architects began the exploration of several different shapes, resulting in the development of columns with a variety of forms, including *V*, *Y*, and *W* shapes, as well as porticos with intriguing angles of inclination, which challenged the canons of architecture in the 20th century.
Modern architects, such as Le Corbusier (1887-1965) and Frank Lloyd Wright (1867-1959), created new ways of conceiving the structure of their buildings, exploring construction techniques in an innovative manner. Le Corbusier advocated for using pilotis as support to elevate buildings above the ground, which are typically organized in a systematic grid, while Wright explored more organic forms that utilize dendriform and trapezoidal columns.
From 1930 to the '60s, modern architecture intensified this discussion in Brazil to promote a national identity. Starting in the '40s, Niemeyer created a set of columns in Brazil that challenged traditional construction techniques, first with the buildings designed for Pampulha in Minas Gerais and later with the architectural ensemble for Ibirapuera Park in São Paulo. Together with Afonso Reidy (1909-1964), they created innovative structures in Rio de Janeiro. As a result of these events, in the '50s, after the great international acclaim of Niemeyer's work, architects like Vilanova Artigas were inspired to create structures

with expressive forms, in search of architecture that had a Brazilian national identity.
In 1956, Henrique E. Mindlin, in his book titled *Modern Architecture in Brazil,* emphasized that the pilotis were "practicable in Brazil because of the climate, the freeing of the ground vindicates all the claims Le Corbusier has made for it and results in a better integration of interior and exterior space" [Mindlin1956, p. 12].
From the increasing appreciation of the architectural expression of structure that occurred after World War II, engineers like Pier Luigi Nervi (1891-1979) began a profound investigation into new ways of conceiving structures for ever larger spans, with columns and porticos left exposed, without cladding or extensive finishes, within what was termed the new Brutalism. As a result, the constructive truth that emerges from the exposed structure serves as a motif for aesthetic expression.
In partnership with engineers knowledgeable about reinforced concrete techniques, architects like Marcel Breuer (1902-1981) explored, especially from the '50s onward, innovative structures. As Robert McCarter aptly defined, "the UNESCO project was a true collaboration for Nervi and Breuer, and Breuer later said that it was Nervi's vision of geometry, his ability to develop an organic system of structure, and his very human genius that made their association meaningful for him" [McCarter 2016, p. 156]. This fruitful partnership also facilitated the development of columns and porticos far beyond what had been achieved up to that point.
As Pier Luigi Nervi rightly wrote, "it would be impossible to create Poetry (Architecture) just as it is to write correct prose (Good Construction) without perfect knowledge of words and the rules of grammar and syntax (Technique)" [Nervi 1963, p. 9]. In this way, art and architecture guided by poetry and technique conducted to honestly reveal the constructive system.
During the 20th century, a growing number of concrete columns and porticos were conceived as sculptural, expressive, and meaningful in their role of suspending buildings off the ground. From the understanding that a beam needs a column, as well as a column needs a beam [Kahn 1969], as Louis Kahn declared in the text *Silence and Light*, in 1969, the columns were lapidated as a diamond.
In fact, as Robert McCarter wrote, "the emergence of visible structure, and its 'sincere expression' in Breuer's work, was paralleled and made possible by his engagement, beginning in the '50s of reinforced cast-in-place structural and finish concrete as his building material of choice. In this way, as Breuer said: 'The structure itself became art'" [McCarter 2016, p. 259]. In the '50s, reinforced concrete was explored in different ways, contributing to achieving a more expressive language.
In his career as an engineer and architect, and after his extensive experience in the design and construction of buildings, Vilanova Artigas declared: "structures have multiplied and differentiated. They enable new volumes, stealing the expressiveness of the old forms. They are the ones that define the building" [Vilanova Artigas 2004, p. 140]. Thus, Vilanova Artigas explored the structure as a fudamental part of his understanding that the poetic construction of space should challenge canons and precepts, providing identity to his architecture.
In Vilanova Artigas's architecture, the creative truth derived from the unveiled structure served as a motif for aesthetic expression itself. As the architect himself correctly stated regarding Perret's phrase: *"l'architecture, c'est l'art de faire chanter le point d'appui"* [Vilanova Artigas 2004, p. 224].
During the '50s, modern architects on different continents explored a lexicon of trapezoidal columns. In Brazil, Niemeyer's *V*, *Y*, and *W* columns in his design for the Lagoa Hospital in Rio de Janeiro in 1951, those designed in Ibirapuera Park for the *Palace of the States*, *Palace of the Nations*, and the *Palace of Agriculture* between 1952 and 1953, and the columns of the *Alvorada Palace* in 1956 are the ones that most inspired Vilanova Artigas in his projects featuring trapezoidal columns. Niemeyer declared that "moving the columns away from the facades" [Niemeyer 1998, p. 27] allowed creating a beautiful effect, and sometimes making a "wall of translucent glass blocks undulates past the circular columns" [Styliane 2008, p. 130]. Furthermore, Vilanova Artigas's work was also influenced by the columns of the Museum of Modern Art in Rio de Janeiro, designed by Afonso Reidy in 1953.
But it is also important to highlight that Vilanova Artigas had visited *Florida Southern College* in 1946-1947, designed by Frank Lloyd Wright between 1938 and 1954, where he could prominently notice the organic, trapezoidal columns of the American architect. The columns of the *Johnson Wax Administration Building* (1936-1939) certainly had a great impact at the time when photos of its construction and the completed work were published.
The trapezoidal columns located inside St. John's Abbey, as well as the tree structures of St. John's University (1953-1968), inspired modern architects.

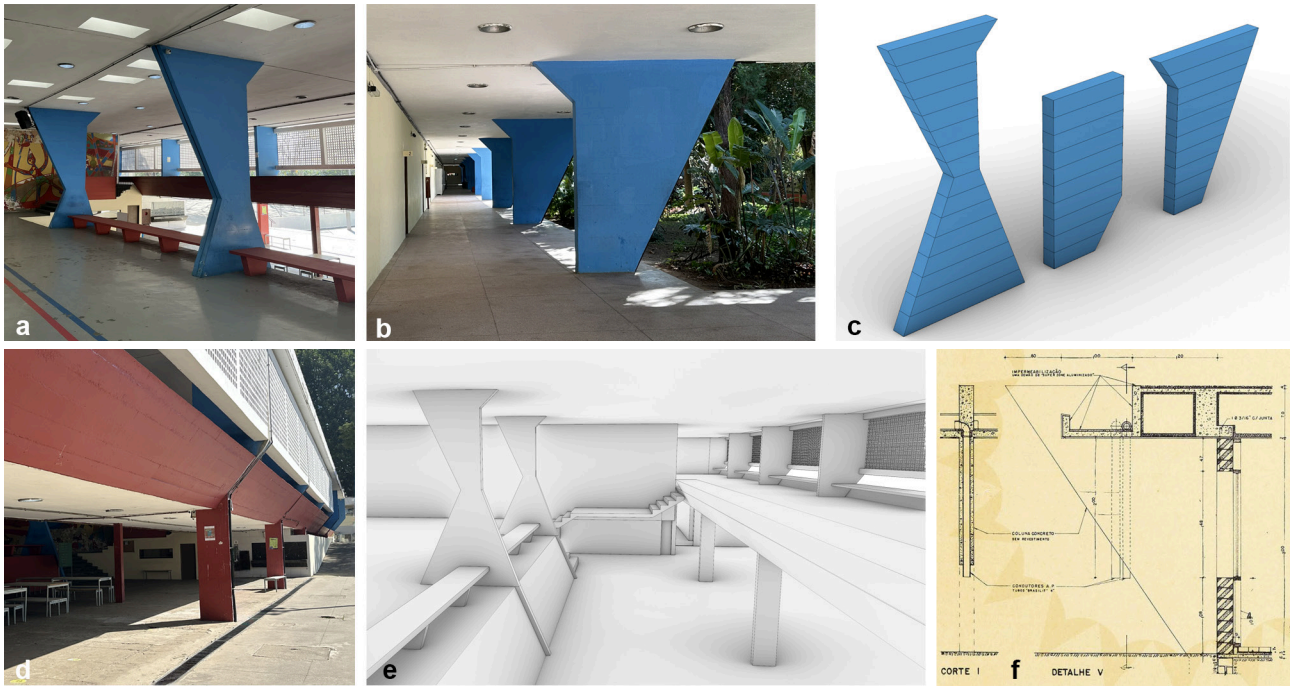

Fig. 1. a., b., d.: Photos of Guarulhos Gymnasium (photos by the authors); c. three types of columns (model by the authors); e. 3D rendering of the interior of the building (elaboration by the authors); f. constructive drawing (surce: Acrópole 1961, no. 274).

In the '50s and '60s, robust columns made new ways to generate space possible. As Louis Kahn well declared, "a column should still be regarded as a great event in the making of a plan" [Kahn 1957, p. 2]. On the other hand, "in architectural literature, columns and capitals are classified as details, but so are *piani nobili*, porches, and pergolas" [Frascati 1984, p. 501], a democratic space.

It is important to note that Vilanova Artigas was probably aware of what was happening in European countries during this period, such as the robust *V* columns of the *Unité d'Habitation of Marseille* by Le Corbusier (1946-1952); the porticos designed by engineer Nervi, particularly for the Pirelli Building in Milan (1955-1956) and the *Palazzetto dello Sport* in Rome (1957); or the columns designed by Marcel Breuer in the UNESCO 4th Building (1955-1958), in collaboration with Nervi. In the context of São Paulo architecture in the mid-20th century, Vilanova Artigas was one of the most important architects, with significant impact and influence on modernist thought in Brazil. Research [Tagliari *et al.* 2017; Lorenzi 2017] has pointed out the gret importance of the *œuvre* of this modern architect, particularly in São Paulo. The significance of his work is not limited only to his architecture but it also encompasses his writings and teachings that have contributed to the formation of São Paulo and Brazilian architecture.

Combining the reading of the texts written by Vilanova Artigas and the analysis of his architecture, it is possible to identify important concepts present both in theoretical discourse and in design practice: I) search for new and varied forms and technical solutions; II) scientific, technical, and artistic experimentation; III) innovative character in the field of technique and science, especially in the exploration of reinforced concrete, with the structure as defining the architecture; IV) nationalist spirit in the creation, development,

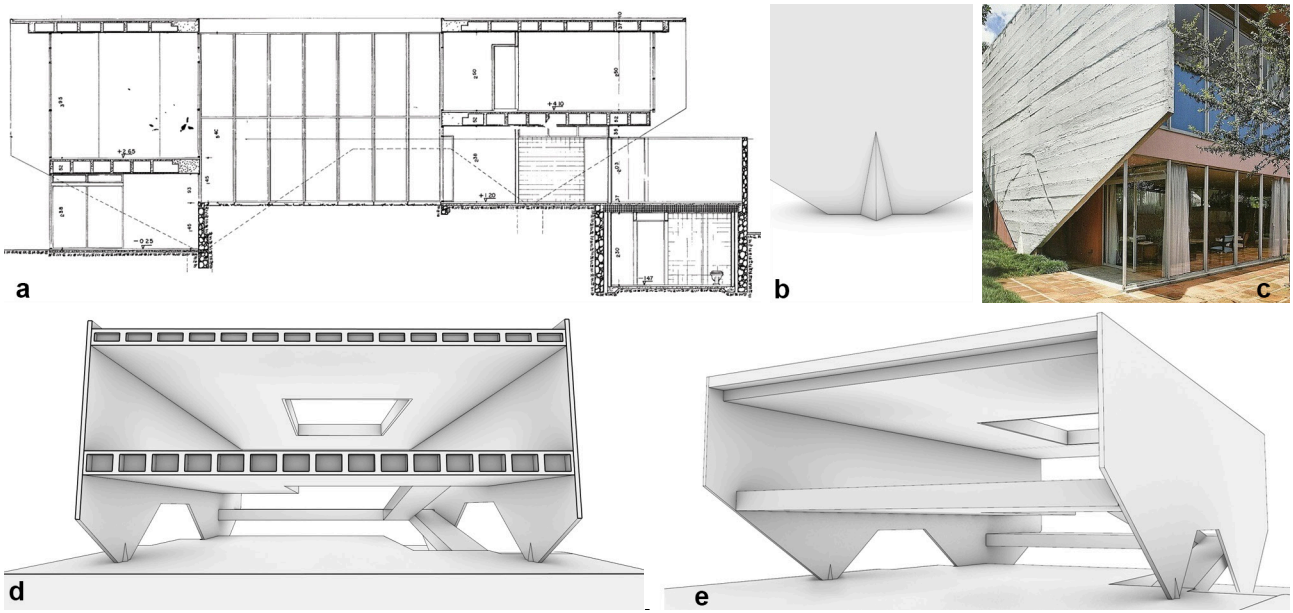

Figure 2. a. Original drawing of vertical section (source: Acervos da FAUUSP); b. detail of the pyramidal support in a portico (elaboration by the authors); c. photo (source: Acervos da FAUUSP); d., e. 3D structural model (elaboration by the autors).

and strengthening of an identity for an authentic São Paulo architecture; V) human environments that promote meetings and interaction or strengthen the collective and social character. As we well note further, for Vilanova Artigas, "in the structures, the findings in the formal Brazilian memory are synthesized today with the ardent desires for cultural independence, the pursuit of harmony and beauty so dear to our people" [Vilanova Artigas 2004, p. 140].

Research

"At first, we made our columns as concrete supports, hidden within walls that seemed load-bearing. Then we freed these columns and showed them as they were. Then we began to deny them in various ways, in countless ways: reducing their number to a minimum, removing them from the vertical, bending their pillar shape, and finally not using them at all" [Vilanova Artigas 2004, p. 136].

In this statement, the different proposals to make the column the very architectural expression of the building are clearly noticeable. Firstly, the columns are concealed inside the walls. Secondly, the construction of pilotis is proposed. The third involves constructing curtain walls, which resemble folds and exert tension on the structure. The fourth comprises lowering the number of columns to just four. In the fifth option, the columns are removed from their vertical position. In the sixth option, the portico's column is tilted. And finally, not using it, like in concrete boxes.
In the *Guarulhos Gymnasium* (1960), there are three types of exposed reinforced concrete columns made up of trapezoids (fig. 1). There are visible marks from the concrete formwork. The blue and red colors highlight the silhouette of the columns. The concrete slabs are exposed, with a finish that does not reveal the construction marks, while all the masonry walls are covered with plaster and paint.
In *Bittencourt II Residence*, Vilanova Artigas took even bolder risks in designing the apparent structure (fig. 2). Inspired

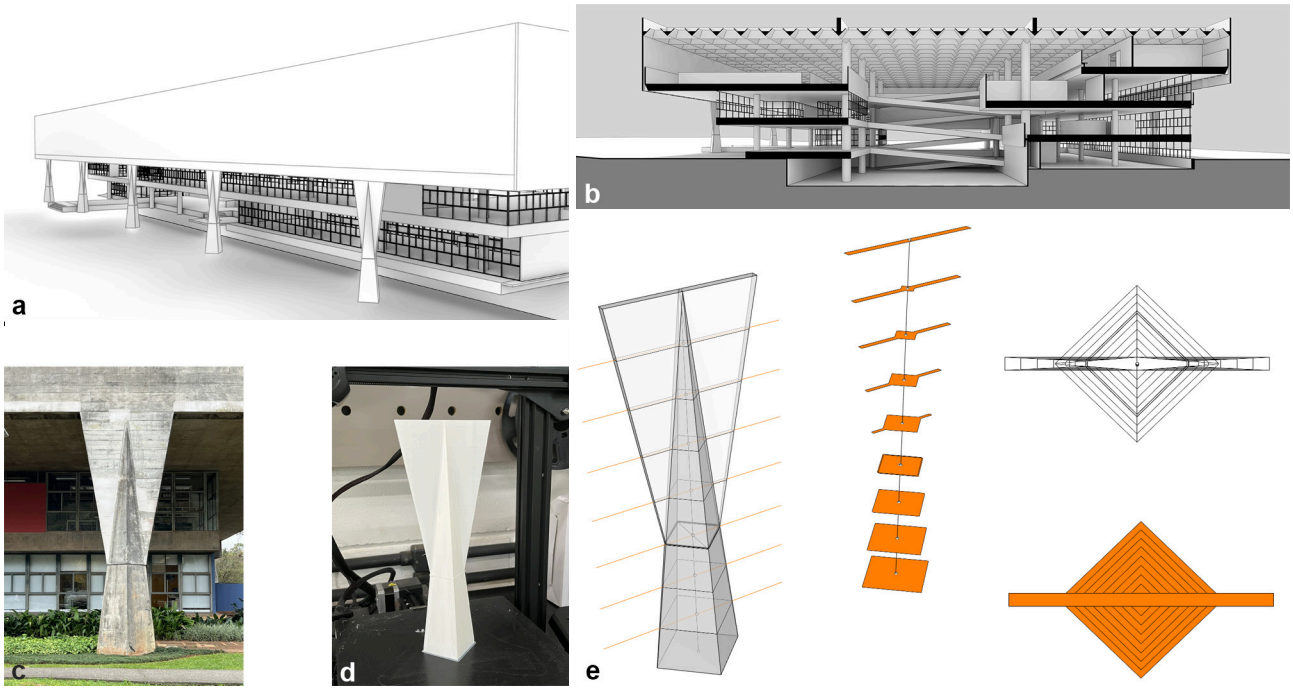

Fig. 3. a. Perspective drawing; b. vertical section; c. photo of the column; d. photo of the physical model; e. column geometry (elaborations and photo by the authors).

also by the boldness of Oscar Niemeyer's structures for the Palaces of Brasília (1956), Vilanova Artigas created porticos and columns that challenged the traditional precepts of the time, as one can note in this declaration: "What fascinates me is creating heavy forms and bringing them close to the ground and, dialectically, negating them. Transform my columns into things that, to the eyes of the demanding engineer, become something to say: This whole thing is going to fall apart!" [Vilanova Artigas 2004, p. 225].
In a challenging way, a small pyramid (20 cm wide by 50 cm high) with a square base intercepts a trapezoidal exposed concrete portico over an extension of 50 cm in width (fig. 2b), concentrating the entire load of the building on just 4 supports (2 on each side of the residence). In the photo of the portico (figure 2c), it is possible to notice the marks of the large concrete formwork boards.
The internal cylindrical columns of the Faculty of Architecture and Urbanism of the University of São Paulo (1962), FAUUSP (fig. 3), sustain the weight of the building's floors, whereas the external trapezoidal columns support the roof with trapezoidal beams. Both are exposed structures that elucidate the construction system.
Figure 3e displays variations in the cross-section along the vertical axis of the outer column. The geometry originates from the intersection of a square-based pyramid with a trapezoidal form. In the photo (fig. 3c), one can notice the marks of concrete formwork.
In this way, the column spacing contributes to establishing the building's length and width, whereas the beam establishes its height [Kahn 1957]. At FAUUSP, the external concrete column and beam efficiently sustain a great roof.
The building for the São Paulo Football Club Locker Rooms (1961) (fig. 4) was designed to have an exposed concrete structure. In figure 4a, the modulation of the concrete formwork boards in the drawing is noticeable, revealing the intentional marks left by the construction. As a part of the

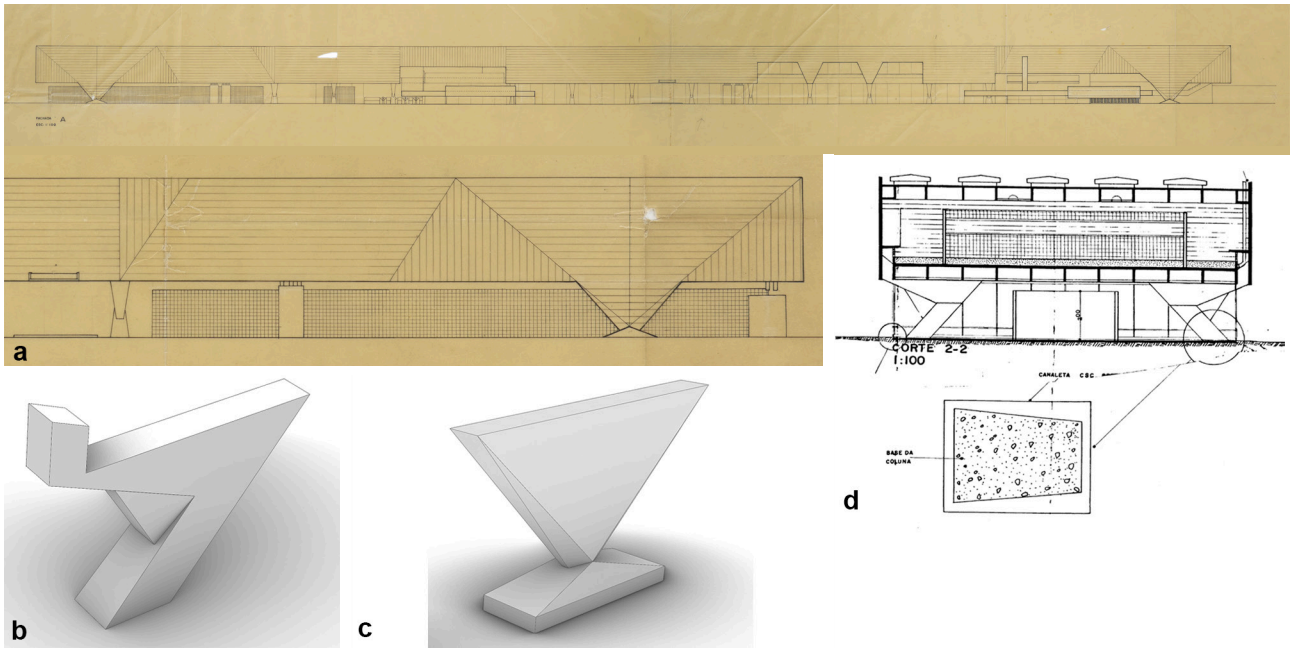

Fig. 4. a. Original drawing of elevation view (source:Arcevos de FAUUSP); b., c.: 3D digital model of columns (elaboration by the authors); d. original vertical section (source: Arcevos de FAUUSP).

portico, the sculptural columns transmit the weight of the building to the ground in such a way as to provide a sense of lightness and suspension. Despite having received a coat of paint, the concrete marks on the columns remain visible. The 'voids' between the triangular and trapezoidal faces in the columns of the sculptural porticos of the Anhembi Tennis Club (ATC, 1963) are a unique feature (fig. 5). The innovation was to create a rainwater collection system from the roof, which would channel the rainwater in a cascading manner from one gargoyle to another until it reached a receiving box in the ground (fig. 5f). This curious invention makes this portico unique, whose sculptural beauty arises from the interplay of light and shadow on its multiple faces. "This is the Anhembi Tennis Club. This portico is what ended up being called 'self-supporting' because it rests on one point, like the FAU column, and has a twenty-meter span to the other side" [Vilanova Artigas 2004, p. 229]. The significant weight of the porticoes at this end enables the tensioning of the slab. Both slabs and beams have a minimal thickness. In the ATC, the exposed concrete was well executed, without marks from the concrete boards, but it revealed its structure in an honest way. Eight trapezoidal columns support the Santa Paula Yacht Club Boat Garage (1961), which measures 15 m in width and 70 m in length, with a cantilevered structure of 10 m (fig. 6). In the elevation view, observers can see the horizontal lines that indicate how the boards of the exposed concrete formwork are arranged. The Santa Paula Yacht Club Boat Garage's technical drawings are impressive due to their meticulous construction and attention to detail.

Discussion

After all, what is the symbolism of a structural column and apparent concrete in architecture? For Vilanova Artigas,

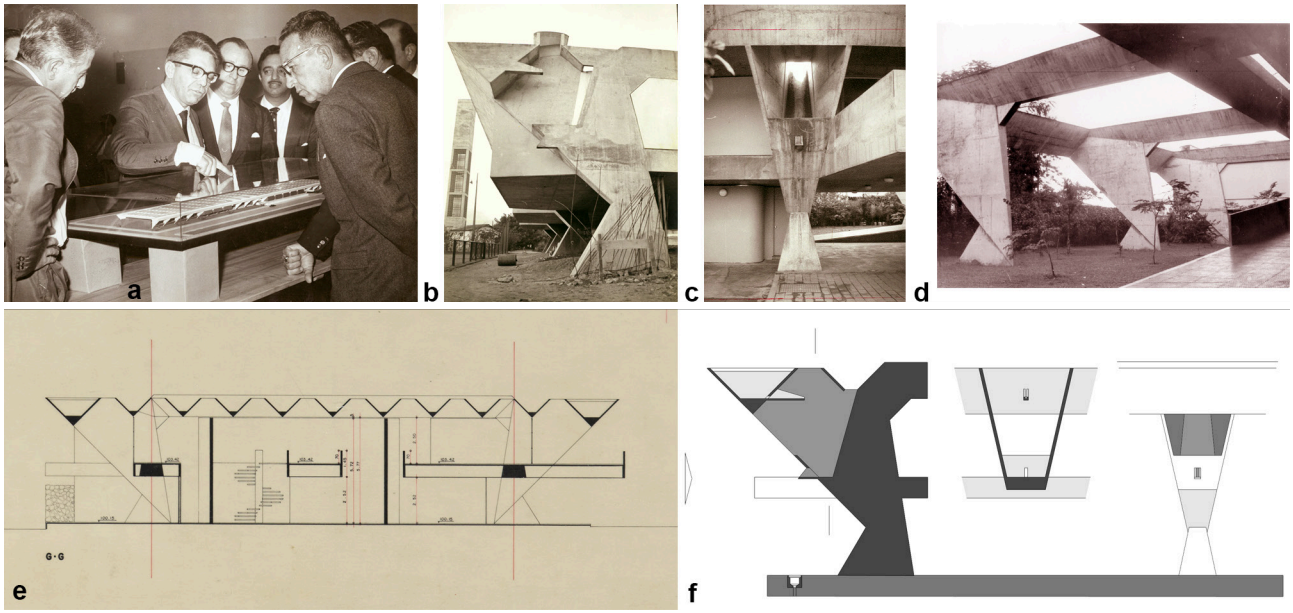

Fig. 5. a. Vilanova Artigas with the physical model (source: Acervos de FAUUSP); b., c., d.: photos of the porticos (source: Acervos de FAUUSP); e. vertical section drawing; f. redrawing of the portico (elaboration by the authors).

leaving the structure exposed meant revealing the truth of the construction, making it more honest, and achieving an immediate understanding of how it is produced. In the words pronounced by Le Corbusier: "and under the pilotis, which reclaim vast and sloping spaces […] these 'pilotis' that I speak of constitute a great achievement of modern techniques" [Le Corbusier 2004, pp. 56-58]. Furthermore, buildings suspended from the ground represented the achievement of technique.

But there is a quote by Kahn that reinforces a very important meaning of the constructive character: "Design habits leading to the concealment of structure have no place in this implied order […]. I believe that in architecture, as in all art, the artist instinctively keeps the marks which reveal how a thing was done" [Kahn 1962, p. 2]. Thus, the marks of the concrete formwork boards left on the exposed concrete surface highlight part of this construction process. Vilanova Artigas documented his vision of architecture in his texts, which clearly reflect his view as an architect regarding the relationship between architecture, technique, and construction.

The solution to technical problems arising from the creation of large spans and sculptural columns symbolized independence. In the words of Vilanova Artigas: "In the structures today are synthesized the findings in the Brazilian formal memory with the ardent desires for cultural independence and the search for harmony and beauty so dear to our people" [Vilanova Artigas 2004, p. 140]. Therefore, the visible structure symbolizes the proud professional and cultural ability to represent Brazilian architecture at that time.

As an engineer and architect, Vilanova Artigas sought to reconcile art and technique, daring in the creation of new ways to conceive and construct buildings. Beyond solving functional problems, aesthetic and psychological aspects were presented. We observe and experience the spatial environment surrounding columns in a building in complementary ways. Firstly, the feeling of lightness and floating in this structural element enables freedom to move. Secondly, the rhythms created by the columns encourage and guide our movement through the space. Thirdly, the scaling and proportion of the areas engender a sense of intimacy as we

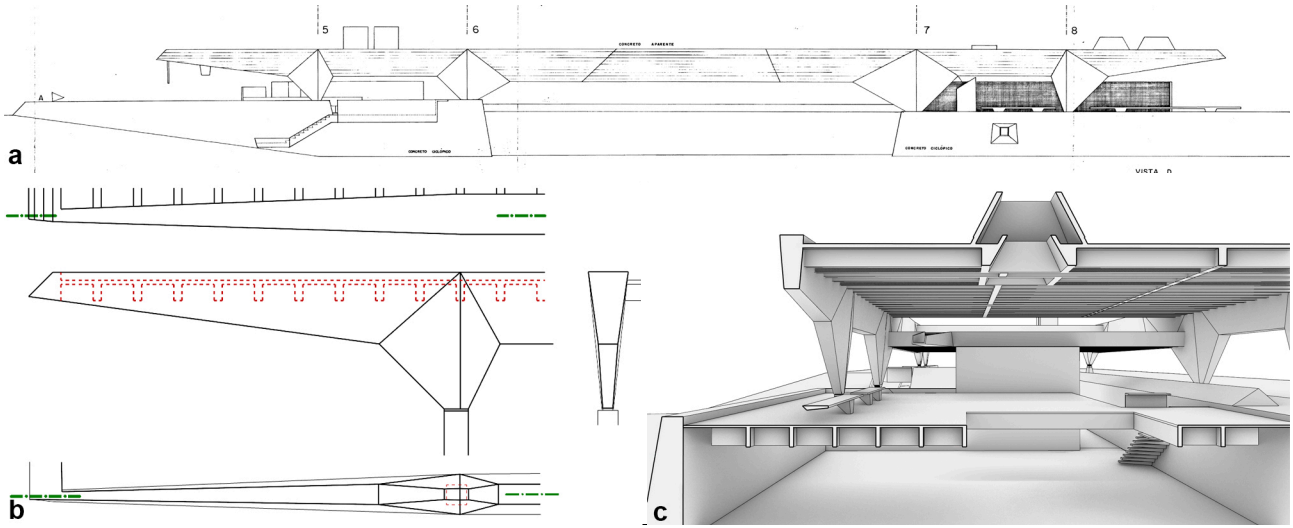

Fig. 6. a. Original drawing of elevation view (Acervos de FAUUSP): b. drawings of the details of the column 1; c. perspective section of 3D model (elaboration by the authors).

traverse them. Fourthly, there exists a juxtaposition between the solidity and robustness of the columns and the expansive space that envelops us. Consequently, the visible structure elucidates the architectural system in a lyrical manner. Vilanova Artigas typically designed structures characterized by a simplicity of forms, featuring monovolumes with a singular prominent roof that contrasts with the sculptural form of the columns. The primary emphasis is on the areas situated beneath the spans and covers. However, the delineated void, characterized by its limits, is equally significant as the functional areas. We considered the most sculptural column for the portico of Anhembi Tennis Club due to its interaction with technical issues, including both structural concerns and rainwater capture, as well as its aesthetic appeal.

In the '50s and '60s of 20th century, the detail in Italy were deeply elaborated by architects "in which the analysis and displays of material, provided by the laws of construction and formation of the architectural object, constituted its principal support" [Gregotti 1983, p. 496]. A similar situation occurred in Brazil with the main architects at the time. In addition to the cylindrical columns particularly designed at the beginning of his career, in the '40s, the columns and porticos created by Vilanova Artigas in the '50s and '60s can be grouped into two major groups: Block 1: a) trapezoidal columns; b) pyramidal columns; c) sculptural columns. Block 2: Porticos: a) trapezoidal with flat slabs; b) sculptural with slabs made of folds. Curvilinear columns, like those at the Jau Bus Station and the Technical School of Santos, are rare in his work.

We can affirm that the morphogenesis of the trapezoidal columns occurred mainly during the '50s and '60s. The projects presented here contain the lexicon of columns and porticos that constitute the foundation of Vilanova Artigas's structural and aesthetic thinking during this period. The plentiful opportunities to design projects related to different themes probably stimulated the architect to create innovative ways to support the buildings with extensive spans.

From columns made of pyramid trunks to sculptural porticos, the architect sought innovative ways to transmit the building's load to the ground, both technically and poetically. As one can see in figure 7, both the columns and the porticos are made up of sections formed by a geometry that varies along the structural piece, that is, the shaft. The shape of the sections varies between rectangular, trapezoidal, octagonal, or multifaceted variations.

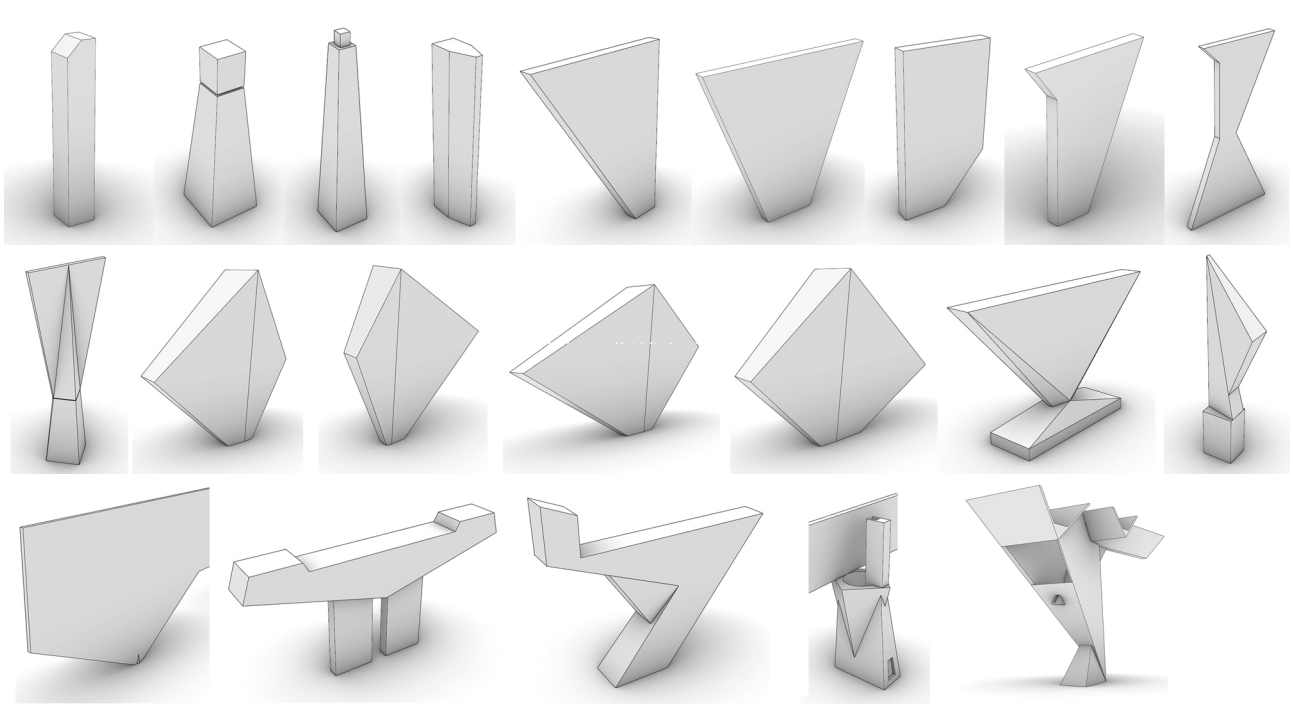

Fig. 7. The morphogenesis of the trapezoidal columns and porticos (elaboration by the authors).

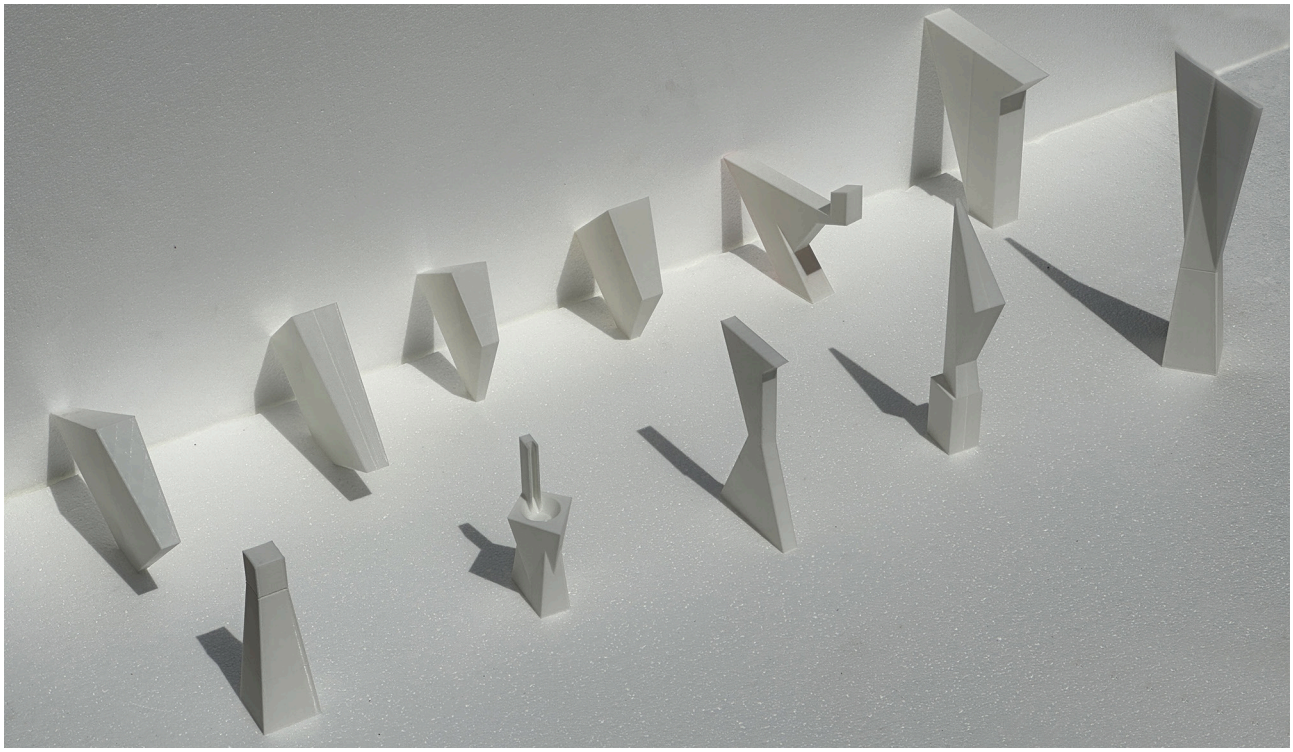

Fig. 8. Photos of the physical models (elaboration by the authors).

We also created three-dimensional physical models (fig. 8) to enhance understanding and offer a concrete experience of the aesthetics of constructive logic. Generally speaking, it can be stated that the external columns are more elaborate than the internal ones in Vilanova Artigas's works. Although both have structural purpose and performance, the sculptural external columns serve to contrast with the austerity of the monolithic volume of his buildings. In fact, the surfaces of the trapezoidal columns are typically smooth; however, the surfaces of the beams and walls of the supporting structures are rough, exhibiting discernible traces from the concrete formwork boards. It can be conclusively affirmed that the tenets of contemporary architecture are evident throughout Vilanova Artigas's oeuvre, especially his quest for the authenticity of construction and the ideal of creating humanized, communal, and democratic places.

Acknowledgments

To the FAUUSP library that kindly made the collection available for consultation. We thank the support of the Plasma Laboratory at State University of Campinas, on behalf of the technician Thiago Henrique Gonzaga.

Authors

Wilson Florio, Department of Fine Arts, State University of Campinas, wflorio@unicamp.br
Ana Tagliari, Department of Architecture and Construction, State University of Campinas, anatagli@unicamp.br

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Sitography

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