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Confrontation between building and ground: notions of force and gravity in the work of João Vilanova Artigas

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ABSTRACT: João Vilanova Artigas (1915-1985) was one of the major thinkers of Brazilian architecture. Engineer and architect, he witnessed the intense industrialization process that took place in the city of São Paulo in the twentieth century. Focused on the rapid changing urban landscape and on the possibilities offered by new construction materials – especially reinforced concrete – his designs were mostly built of large and prismatic roofs supported by strongly oblique and sometimes slender structural elements. Although highly concerned with the physical properties of building materials and with the mechanics of structures, Vilanova Artigas also aimed at addressing the social context in which he lived. He believed that architecture could express the societal dramas of his time – especially the notion of struggle, which he intended to materialize through designs that dialectically opposed the force of gravity, thus revealing a confrontation between building and ground, artifact and nature.

1 INTRODUCTION

All bodies exert gravity. It is the only primal force of nature that technology never managed to nullify, the only one that exerts only attraction, and the only one that remains effective even at infinite distances. The force that attracts an object to the ground is the same that keeps the Earth in orbit around the sun. The reason for this is that although both celestial bodies exert a force of attraction, the sun, by being a body of greater mass, exerts a greater attraction than the gravitational pull of the Earth. The result is a natural balance between both gravitational centers. Similarly, the gravitational force of the Earth is greater than the force of attraction that buildings exert upon it: the body of greater mass attracts the smaller one. It is a law of nature.

João Vilanova Artigas, however, developed an architectural aesthetic that raised questions on the natural flow of gravity. He played with the tacit knowledge that our bodies, as well as other objects such as buildings, are inevitably pulled by the Earth. Through the construction of large and suspended volumes supported by strongly oblique and sometimes slender structural elements, he created new perceptions of gravitation that may contradict the common sense and our bodily experience.

Particularly important for Vilanova Artigas was the design of the encounter between roof and ground. Wisnik (2010:21) remarks that Artigas himself mentioned the importance of leaving a sign of the attitude that always moved him, which was "placing the work in the landscape with some respect for the way it 'sits' on the ground. Balancing, it expresses itself by lightness, the sign of the dialectic between doing something and the difficulty to accomplish it." The lightness that results from this dialectic, however, is not only an act of heroism or an ability to realize something technically challenging. Considering the importance given by Vilanova Artigas to the way the building "sits" on the ground, the transfer of force between building and ground becomes a major issue in his architecture.

2 A TWOFOLD CONCEPTION OF FORCE

2.1 *Action and reaction*

The ground absorbs and reacts to the weight of a building. It is the third law of Newton: action and reaction. If the way a building "sits" on the ground is a key issue for Vilanova Artigas, the design of the ground reaction to the load of a building must also be, by logic, of key importance. In statics, supporting structure and supported elements are always in balance in order to achieve a sum of resulting moments that is equal to zero. Therefore, in rigid bodies, the force that the Earth exerts upon them must be equivalent to the force that they exert upon the Earth.

In order to make the law of action and reaction evident, Vilanova Artigas gradually eliminated the image of a column from his designs – an atittude that led him to a direct connection between roof and foundations. Vilanova Artigas (1999:103-104) explains that "in the beginning we made our columns as a concrete support hidden within walls that appeared to be bearing walls. After that, we freed those columns and showed them as they were. Later, we started to oppose them – in countless and different ways: reducing them to a minimum; bending them to one side; deforming them and, eventually, not using them at all."

Vilanova Artigas designed footings that sprout from the ground in order to meet the roof directly, without the need for columns. Wisnik (2010:21) notes that this attitude is anti-classical and describes Vilanova Artigas's design of the Dressing Rooms of the São Paulo Football Club as "a foundation block that sprouts from the ground to support an enormous concrete beam, with no column to provide the transition. This artistic approach he [Artigas] shared with the master of Taliesin, having a clear anti-classical inspiration. The 'column with no shaft', with the base in contact with the capital, also appears in the Faculty of Architecture and Planning." Therefore, the foundations become the direct support of the roof in his designs.

The same emphasis that Vilanova Artigas placed on the action of the ground in relation to the roof, he also placed on the action roof in relation to the ground. Frampton (2010:4) observes that Vilanova Artigas created "*diaphragmatic roofs* (...) that were sometimes covered and lit from above and at other times open to the air." This is, according to Frampton (2010:6), a new structural type to which he refers as "a folded structure that turns down at its eaves so as to form a continuous concrete apron elevated above grade on reinforced concrete piers." However, in the most significant works of Vilanova Artigas, those folded structures taper down without the need for piers, therefore reducing even more the area of contact between roof and ground.

2.2 *Aware and unaware*

By placing the *diaphragmatic roof* in direct contact with the foundations that spring from the ground, Vilanova Artigas brought to the fore what was previously non-visible. In this case, foundations are raised to a conscious level and play a visually active role in his designs. They react to large and prismatic suspended roofs, and vice-versa. Raising the volume of a building is a realization of the twentieth century. Vogt (2006:152) observes that among pioneers, such as Mies van der Rohe, Walter Gropius, Frank Lloyd Wright and Le Corbusier, the new possibilities of construction "with reinforced concrete enabled them to lift the body of the building from the ground, and to make a previously non-visible surface, its sixth, the bottom, visible." In addition to making it visible, in some of his designs, the sixth side of the building volume, which was previously in direct contact with the ground, Vilanova Artigas also made visible the foundations – an essential part of the building, normally thought of as having a purely technical function. By making the footings sprout from the underground, he raised them to a level of awareness compatible with his aspirations of raising social awareness through design.

Raising the footings to a visible level is but a technical procedure for the construction of bridges, especially the ones built of timber or steel. Nevertheless, in Vilanova Artigas's designs, there is no technical necessity for building foundations that extrapolate the underground level. He actually creates a contradiction by applying an exclusively technical procedure without technical necessity. In his designs, the foundations extrapolate their condition of building elements placed in the underground, and come to the surface – much like a reptile that emerges from the depths of the water to the air, in order to breathe.

The footings sprout from Vilanova Artigas's designs, just as the footings of timber or steel bridges may sprout from the ground or emerge from the water. These essential parts of a build-

ing structure, that normally remain invisible, acquire visibility and become a subject of attention and awareness. Sigmund Freud compared the levels of awareness and unawareness of human mind with the visible and the invisible, that is, what is figuratively above or below the surface of the water. He made, for example, an analogy between the conscious mind and the water of a fountain, which arises that falls back and into the subterranean pool of subconscious. Carl Gustav Jung (1968:18), in its turn, contended that "water is the commonest symbol for the unconscious".

Freud also developed a well-known topographic model of the mind, which he associated with an iceberg that floats with only a small part of it above the surface of the water. But if the footings that sprout from the ground in Vilanova Artigas's designs would be associated with bulks of icebergs, the ground line in his projects may be, by inference, interpreted as a waterline. It is a view that is shared by Vogt (2006:155), who assumes that modernity has produced houses that look like ships that float on the water: "A picture of serene elegance, a colossus in a seemingly effortless balance with the surroundings. (...) The ship glides silently, it swims, it suggests a lightness on the surface of the water, as if it would take off and levitate."

2.3 *Ground and underground*

The tectonics of Vilanova Artigas is based on a the contact between roof and foundations. The encounter of the two is, in many cases, marked by slightly suggested lines of the horizon that set a man-made duality between visible and invisible, up and down, ground and underground. This new horizon in Vilanova Artigas's designs is no longer treated as a natural topography, but rather as a straight and smooth line that can be seen in the Faculty of Architecture and Planning of the University of São Paulo – known as FAU –, the Lanara Laboratories, the Santa Paula Boathouse, and the Guarulhos High School. In the design of the FAU, for example, he builds a line made of a strip in low relief that resembles expansion joints placed in the encounter between the pyramid formed by extension of the footings with the inverted triangle that tapers from the roof down to the ground. Both make up the vertical structural elements of the facade.

By raising the foundations, Vilanova Artigas creates an imaginary ground line above the original ground, and thereby contradicts the common sense that foundations must always be in the underground. In many of Vilanova Artigas's designs, they are visible, yet remain below the imaginary line of the horizon designed by him. Vilanova Artigas thus eliminates from his designs not only the orthodox concept of foundation – which implies a portion of the structure that, in most cases, remains unseen – but also the very idea of underground. In his designs, he apparently makes the entire structure visible in order to make public even parts that normally do not have any aesthetic significance, such as footings. By doing this, Vilanova Artigas turns his architectural design, particularly the structure, into a public asset – an attitude that corresponds to his deep political engagement, and to the social role that he ascribed to architects during virtually his entire career.

Vilanova Artigas *relocates* the natural ground at a lower level in relation to the new line of the horizon created by him, thereby promoting a visual change in the landscape that, to the human eye, significantly changes the relation between building and ground. It is a visual effect that creates a counter-attraction effect in which the gravitational pull of the building becomes more evident. The large volumes of his diaphragmatic roofs become apparently capable of exerting a force of attraction that partially overcomes the gravitational pull of the Earth. Vilanova Artigas's designs thus create a visual effect that alter the direction and intensity of the gravitational force – which naturally points to the Earth (ground) – in the direction of another horizontal plane: the great diaphragmatic and prismatic roof built of reinforced concrete.

2.4 *Vertical and horizontal*

Vilanova Artigas called attention to the transmission of forces between artificial and natural bodies, respectively building and Earth, by enlarging the distance between them in both vertical and horizontal axes. In his designs, large spans, as well as reduced areas of contact between building and ground, are ways of building a gap in the permanent, inextinguishable and – as Vilanova Artigas (1989:72) himself stated – "inexorable" force of gravity. In his designs, the transitions of forces made vertically through hinges – reduced areas of transition of load be-

tween two or more bearing elements or between building and ground – are usually designed in "V" or trapezoidal shapes.

By applying these triangular forms in his structural designs, Vilanova Artigas minimized the point of contact between roof and foundations – which are the primary interface between the volumes of these two building elements. Stresses concentrated in small areas of inverted triangular shapes visually mitigate the gravitational force that flows naturally from the roof to the ground and might make buildings appear lighter. It is a perception related to a common sense apparent in construction techniques such as masonry, which work based on compression forces. Therefore, to the extent that a masonry structure grows in height, its base must become proportionally larger to avoid buckling.

Vilanova Artigas, however, contradicts once again the common sense by distributing vertical loads in the form of inverted pyramids or triangles, that is, through elements with only one vertex in contact with the ground – which makes their areas larger at the top and lower in the base. He thus also contradicts a weight-lightness hierarchy of construction techniques that work based on compression forces – in which thick and heavy elements are located at the bottom, and slender and light ones on top. The reduction of the surface of contact between roof and ground in Vilanova Artigas's designs might cause one to believe that once contact is reduced, loads are also reduced. The opaque box of the FAU – apparently supported by slender pillars – as well as the Santa Paula Boathouse – a viaduct-shaped structure resting upon metal hinges and apparently placed upon stone walls – are just two examples of Vilanova Artigas's designs that visually altered the direction and intensity of the force of attraction between Earth and building.

On the horizontal axis, Vilanova Artigas also increased the area of contact between building and ground through the design of long spans built of reinforced concrete. In other words, by drawing long extensions of construction without vertical supports, he increased longitudinally the distance between roof and ground.

2.5 *Contact and distance*

Vilanova Artigas's designs reduced the surfaces of contact through which loads could be transferred from one structural element to another, and ultimately to the Earth. This attitude, often present in his designs, points to a topic that is historically much debated in science: the concept of force and the mystery about its cause and mode of transmission. For centuries this debate has divided the West into two factions of intellectuals: those who advocated the transmission of forces by contact, and those who believed that they are transmitted by action-at-a-distance. For the layman, however, the answer to the problem may seem clear: the idea of transmission by contact is much more understandable than the transmission by action-at-a-distance. But the fact is that, in both cases, scientists face the same insurmountable obstacles. Jammer (1999:206) explains that "the transmission of motion by impact or contact is as problematic as that by action-at-a-distance."

To human perception, the transmission of force and motion by contact seems to be more plausible than the transmission at a distance simply because, at a macro-cosmic level, one has the impression of touching objects and people. At the atomic level, however, it is known that bodies in apparent contact, in fact, do not touch each other. There is always an empty space between them. Hesse (1961:199) explains that "in the Experimental Researches of 1837 he [Michael Faraday] speaks of induction as an action between 'contiguous particles' and adds a note a year later to explain more carefully what he means by 'contiguous': 'The word contiguous is perhaps not the best that might have been used here and elsewhere; for as particles do not touch each other it is not strictly correct... By contiguous particles I mean those which are next.' So ultimately it seems that even this action is at a distance if regarded on the atomic scale."

Jammer (1999:208) also contends that "logical analysis is powerless and inadequate to explain transfer of motion in either case, whether the force is conceived as an action of contact or as an action at a distance. The two concepts face equal logical and metaphysical difficulties, since both of them are nothing but constructs, descriptive names of perceptible and measurable empirical relations. It is pure prejudice to assume that action at contiguity is more intelligible and more rational than action at a distance. [...] It is only our tactile experience with common objects that leads us to the concept of impenetrability and enables us to formulate the rules and laws of impact, without affording the least information about the real occurrence behind the

phenomenon." The discussion on what causes force and movement is not anymore present among scholars since scientific pragmatism found ways to apply methodologies without the need for interrelating the cause and effect of something named *force*. This pragmatism towards manipulating the effects of different forces, however, does not mean that the idea of cause and effect disappeared from scientific investigation. It simply raised the importance of asking the question "how" instead of "why" a phenomenon occurs.

2.6 *Scientific and unscientific*

Vilanova Artigas's intention to provoke changes of perception related to the gravitational force between buildings and the Earth also raised questions about the notion of cause and effect. By playing with the effects of gravitaty in his designs, he complied with the modern spirit of scientific investigation, which looked for the manipulation of forces, more than for the search of their cause. The relationship between cause and effect, in the case of transfer of force between two or more bodies, loses the logical-scientific sense to acquire an exclusively empirical value. Jammer (1999:208) explains that "it became more and more obvious that the scientific notion of force has little to do with causal explanation, and that, moreover, the connection between 'cause' and 'effect' in science, or antecedent and sequent in the succession of phenomena, is not a matter of logical inquiry, but of experimental experience or observation."

In the absence of a verifiable cause, the very notion of force turns out to be a construct of the mind. Jammer (1999:209) quotes Maupertuis, an eighteenth-century French scientist and philosopher who observed that "we should always remember that the concept of force is but an invention to satisfy our desire for explanation." Deeply linked to mass and motion (F = m.a), the notion of *force* has been always part of a system of beliefs and corresponds to the intellectual and technological status of the period in which it is formulated.

Notions of *force* have already been defined and redefined many times throughout history. It is more similar to a *view of the world*, than to a scientific concept. Jammer (1999:7) explains that "taken originally in analogy to human will power, spiritual influence, or muscular effort, the concept [of force] became projected into inanimate objects as a power to dwelling in physical things. (...) Subsequently classical mechanics redefined the concept of force as the time rate of change of momentum, excluding thereby, at least prima faciae, all animistic vestiges of earlier definitions." From the eighteenth century on, however, the concept of force began to be gradually eliminated from scientific vocabulary in order to become a relational and operational concept without any causal or metaphysical connotation. Jammer (1999:242) observes that, "[...] it became increasingly clear that the concept of force, if divested of all its extra-scientific connotations, reveals itself as an empty scheme, a pure relation."

2.7 *Measurable and immeasurable*

As an architect and engineer who held a degree from a polytechnic school, Vilanova Artigas was familiar with the modern concept of force – which is inseparable from the idea of vector. As a modern engineering science, structural analysis addresses the concept of force in its relational and operational form, representing it with the aid of vectors and force diagrams, i.e., mathematical and geometric constructs. The equivalence of force and vector added to Vilanova Artigas's intellectual background the notion that force is subject to abstraction, quantification, mechanization and to be transformed into a graphical *phenomenon* – which forms the base of the science of statics. Duhem (1991:11) starts telling the history of statics by the development of mechanics made by Aristotle and Archimedes, passing through Leonardo da Vinci, Galileo Galilei and Simon Stevin, among others, until its whole systematization in seventeenth century. Statics, as we know it today, is the result of an intellectual process that culminated with the understanding that the physical world is, in its essence, mathematical and mechanical in its mode of functioning. As translated by Drake (1957:238-9), Galileo contended that the language of the universe is mathematical – the most abstract of all sciences: "Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles and

other geometrical figures, without which it is humanly impossible to understand a single word of it."

Geometry was adopted by the science of statics as a means to represent the physical world through the concept of lines of force, i.e., vectors. Hall et al (1999:3) define force as "that which changes, or tends to change, the velocity of a body. Force is a vector quantity, possessing direction as well as magnitude. A force is not completely defined unless its magnitude, direction and line of action are specified." Vector is therefore a mathematical form used to represent forces acting within a coordinate system of time and space. It is a graphical configuration of the phenomenon of the transmission of forces that occurs within an object that is subject to the laws of static as, for example, a building or a bridge.

However, even if it can be translated graphically in the form of vectors, a force must be necessarily abstracted from a physical *phenomenon* – the later defined by Hoad (1993:349) as the "fact, occurrence" or "that which appears or is seen". What one names *force* has thus never been isolated from its effects in the world of phenomena. The same is true for the concepts of energy, mass or matter. We perceive, identify and manipulate only forms of energy: electric, solar, atomic, never only pure energy. In the same way, we know only the effects of what we refer to as force – such as tension or compression – not its cause.

For methodological purposes however, both concepts of force, either defined as a vector or as a phenomenon, can be treated independently. This is what structural engineering does by understanding the term force only as a support for structural analysis – without taking into account any phenomenological reflection on that term. This discipline only recognizes the quantitative or vectorial dimension of the forces in play in statics. On the other hand, structural design, while also directly connected to quantitative forces, also deals with forces of language and expression related to the generation and the dynamics of form – which are not part of the scientific scope of structural engineering. The difference lies in the fact that language naturally involves expression and, consequently, qualitative aspects that are not subject to mathematical verification. From this viewpoint, structural design, unlike structural engineering, deals with a concept of force that acquires both a measurable and immeasurable sense, which is at the same time quantitative and qualitative – in physical terms as in linguistic and perceptive ones. In addition, the very fact that *design* is a term that etymologically relates to the idea of wish or will, turns structural design into a discipline that shares a concept of force that is located in an intermediate zone between the measurable and the immeasurable.

2.8 *Known and unknown*

Vilanova Artigas used the transition of forces between beam and column in the Greek temple to exemplify the notion of force as something located between the measurable and the immeasurable. Through this example, he indirectly referred to the mystery of the transfer of force in buildings. In his (1989:71) own words: "This expression: 'the points of support must sing' – you know as well as I do that the origin of this quote by Auguste Perret – is an observation by a historian of architecture, of the man who marvels at the Greek column and who knows that at the moment at which it meets the beam it turns into flowers and talks in another language."

The sense behind Vilanova Artigas's idea of "talking in another language" originates in the fact that it is impossible to explain rationally the [up to nowadays mysterious] transfer of force and motion – since it escapes, as previously mentioned, a logic of cause and effect. It is a form of addressing the unknown using a proper linguistic form. By describing as flowers the encounter between column and beam in the Greek temple, Vilanova Artigas constructs a metaphor. The etymology of the word metaphor itself is rooted in the concept of transfer, according to Barnhart (1988:656) "especially the transfer to one word of the sense of another". The flowers of the Greek capital mentioned by Vilanova Artigas are obviously not real flowers. Their image was actually taken from an original and natural context, and placed in an architectural and man-made environment, the temple.

To move an object from one context to another is, according to Da Matta (1983:70), a means for creating symbols: "a skull would be nothing more than a natural remain in a grave, where it belongs ; but it coms to represent a lot in a drawing room or in a kitchen drawer (...). The basis of the symbolization process, then, is the displacement or passage of an object and its aberrant manifestation in a different, unfamiliar domain."

The displacement of an object from its original context to an artificial one creates an interplay between denotative and connotative meanings. The flowers carved in the capital give a particular connotation to the transition of loads between beam and column in the Greek temple. In this case, the displacement of an object fuses and confuses measurable (loads) and immeasurable (language) forces into the single notion of symbol.

2.9 *Objective and subjective*

When measurable and immeasurable notions of force interact in such a way as to be impossible to set a borderline between them, the architect speaks not only another language, but a language that merges objective and subjective meaning. In Vilanova Artigas's designs, technical needs and personal views are merged, among others, through the dramatization of certain aspects of the structure that might lead to an apparent increase of stresses. Ferro (1986:68) explains that Vilanova Artigas used to say, in his lectures, that one "could and should in certain cases exaggerate in some details (...) in order to make the real structure and the actual behavior of [construction] materials even more explicit. It was almost an ethical lie, a didactic lie. But never like the European or Japanese Brutalism, in which the interplay of masses and forms often hide another structure."

Besides being an engineer and architect, Vilanova Artigas was also a professor. He was the founder, among others, of the Faculty of Architecture and Planning of the University of São Paulo – one of the most important in Brazil and South America. Vilanova Artigas worked in a period in which buildings of eclectic inspiration hid or masked load bearing elements behind *stucchi* and stylish facades. As a teacher, he had the opposite attitude by showing the entrails of buildings. More than that, Vilanova Artigas pointed to the mechanics of structures and their relation to the generation of form in his designs – an attitude that was contrary to that of Oscar Niemeyer, to whom structural design also played a significant role. Telles (1996:7) contended that "Niemeyer, unlike Vilanova Artigas, withdraws from the design any structural tension, making the generation of form able to divert, hide and almost nullify the effort necessary to build it". In spite of the essential differences in the design of these two masters of Brazilian architecture, both were pushed forward in their works by a common motif. In an informal conversation with Bruand (1981:302), Vilanova Artigas states: "Niemeyer and I have the same concerns and face the same problems, [but] he [Niemeyer] always endeavours to resolve the contradictions in a harmonious synthesis, whereas I express them openly. In my opinion the adaptation is not the architect's job: existing struggle should not be hidden under an elegant mask – we must not be afraid to reveal it." Whatever contradiction Vilanova Artigas was referring to, he intended to translate it into an antagonism of structural stresses – particularly those involved in the transition of loads between roof and foundations. Vilanova Artigas intended to materialize the "existing struggle" basically through the design of structures – which in his own words (1997:101) were considered the building's "most worthy part".

To contend, however, that structures may express subjective notions such as "struggle" contradicts the very notion of scientific objectivity – at least as defined by the common sense. As a science, mathematics cannot explain architectural language, or vice-versa. Wilber (1996:4) explains that "science *cannot* pronounce on the meaning or purpose of any phenomenon it encounters. That is not its job, that is not what it is engineered to do, and we certainly should not hold that against science [...]. The tragedy is that science moves into scientism by saying: 'Therefore meaning does not exist, since science can't measure it.' There is, however, no scientific proof that scientific proof alone is real. Thus, we needn't prematurely cut ourselves off from such important concerns as 'meaning' simply because a microscope does not detect them."

By inference, Vilanova Artigas's intention to convey the subjective notion of "struggle" essentially through structures built of reinforced concrete, may reach realms of expression that cannot be reached through the application of pure and objective methods of structural engineering. In a documentary recorded by Cabral e Rodrigues (1978), Vilanova Artigas himself stated that he never wanted to "objectify himself as an architect, to the point of being called engineer".

3 CONCLUSIONS

As a primal force that governs structural behavior, the notions of gravity and force became the means for merging mechanical performance as well as aesthetic and social concerns in Vilanova Artigas's designs. Gravitation, which inevitably binds building and ground, turns out to be in the core of his tectonics. This force is conceived by him as twofold which, to a certain extent, blurs the boarders between science and art in his designs. Vilanova Artigas aimed at changing the perceptions of intensity and direction of the force of gravity based on tacit knowledge and on our bodily experience. To achieve his goals, he treated the transmission of loads in an original way, especially when it came to the transfer of forces between building and ground. Some of his exemplary designs feature a direct contact between roof and foundations, mostly dispensing with load bearing walls and column shafts. Technical needs and personal views were therefore fused, among others, through the dramatization of certain aspects of the structure that encouraged him to create unusual relations between architectural form and structural stresses. Vilanova Artigas showed the entrails of his buildings, bringing to light the mechanics as well as the visual dynamics of structures, eventually turning structural design into a public asset.

REFERENCES

Barnhart, Robert K (Editor). *The Barnhart dictionary of etymology*. New York: Wilson, 1988

Bruand, Yves. *Arquitetura moderna no Brasil*. São Paulo: Editora Perspectiva, 1981

Cabral, Fernando Frank; Rodrigues, Eduardo de Jesus. *Vilanova Artigas: espaço e programa para a FAU*. São Paulo: FAU/USP, 1978, DVD

Drake, Stillman. *Discoveries and opinions of Galileo*. New York: Doubleday Anchor Books, 1957

Duhem, Pierre. *The origins of statics: the sources of physical theory*. Dordrecht [etc.]: Kluwer Academic Publishers, 1991

Ferro, Sérgio. *Reflexões sobre o brutalismo caboclo. Entrevista de Sérgio Ferro a Marlene Milan Acayaba*, in Projeto n°86 - Revista Brasileira de Arquitetura e Planejamento, April 1986, pp. 68-70

Frampton, Kenneth. *Vilanova Artigas and the School of São Paulo*. In 2G Revista internacional de arquitectura, n°54, Barcelona: Editorial Gustavo Gili, 2010, pp.4-10

Hall, A.S.; Archer, F.E.; Gilbert, R.I. *Engineering statics*. Sydney: University of South Wales Press, 1999

Hesse, Mary. *Force and fields: the concept of action at a distance in the history of physics*. London [etc]: Thomas Nelson and Sons Ltd, 1961

Hoad, T.F. *The concise Oxford dictionary of English etymology*. Oxford [etc]: Oxford University Press, 1993

Jammer, Max. *Concepts of Force: a study in the foundations of dynamics*. Cambridge: Massachusetts, 1957

Jung, Carl G. *The archetypes and the collective unconscious*. Vol. 9, Part 1. London: Routledge, 1968

Matta, Roberto da. *Carnivals, rogues and heros: an interpretation of the Brazilian dilemma*. Notre Dame, Indiana: University of Notre Dame Press, 1991

Telles, Sophia da Silva. *Oscar Niemeyer: técnica e forma*. In *Revista Óculum n°2*, Campinas: FAU-PUC, 1996, pp.4-7

Vilanova Artigas, João Baptista. *Caminhos da arquitetura*. São Paulo: Cosac & Naify Edições, 1999

Vogt, Adolf Max. *Die Hunde bellen, die Karavane geht weiter*. Zürich: gta, 2006

Wilber, Ken. *Up from eden: a transpersonal view of human evolution*. Wheaton [etc.]: Quest Books, 1996

Wisnik, Guilherme. *Vilanova Artigas and the dialectics of stress*. In 2G - Revista internacional de arquitectura, n°54, Editorial Gustavo Gili, Barcelona, Spain, 2010, pp.11-24