Tectonics & Stereotomy

Regin Schwaen
North Dakota State University, Fargo, North Dakota

ABSTRACT: *In the last decade architectural education has embraced the exploration of tectonics without investigating stereotomy. Educators might have created a semantic pitfall regarding how to define tectonics in architecture. Perhaps tectonics is today perceived to be a technique, but the terminology is architecturally immersed, entangled, and complementary to stereotomy. Tectonics should be taught in relation to stereotomy as they both are fundamental to spatial thinking. Why is tectonics not discussed in relation to stereotomy? Is it because of modernism, factories and production lines, or the path that architects followed during and after the industrial revolution? Is spatial thinking in terms of stereotomy in decline? Has the relation of tectonics and stereotomy, first used by the German architect, art critic, and professor of architecture Gottfried Semper disappeared from architectural teaching, and in such case why has nobody noticed?*
In this paper the author argues that tectonics and stereotomy should be taught in conjunction and that emerging architects should be given the opportunity to elaborate on the differences of the two classifications. Tectonics and stereotomy can be explored building artifacts. The pedagogical question is 'How can tectonics and stereotomy be taught in architectural education' and the outcome is 'A tower made of hundreds of sticks that balance and extrude from a plinth'. The architectural models presented in this paper are the results of a student exercise designed to develop an understanding of the concepts of tectonics and stereotomy in the creation of structures and the intersection of architectural spaces. This paper evaluates the outcome of this challenge given to second year architecture students. They were required to build towers using popsicle sticks, without using glue. The construction of a tower and plinth necessitated the examination of the relationship between tectonics, connections, stereotomy, carving and cavity, to form integral structural architecture.

KEYWORDS: Tectonics, stereotomy, education, architecture, structure.

INTRODUCTION – TOWERS VERSUS BRIDGES

When students in engineering or building and construction are introduced to their first assignment, they are often asked to execute a physical model of a bridge to span between two concrete blocks or similar support. This kind of assignment is often executed with small wooden sticks or similar materials. By placing weights on the structure, load is made tangible for the emerging engineer, and it is often done as a competition among students to see which structure is the strongest. It is an assignment done at many schools all over the world in the first years of study. Architects on the other hand, when finding themselves in a structure class, are often not presented hands-on or design-making objectives when investigating structures in the first or second year, although some instructors might ask students to design bridges and test them in a similar fashion as engineers. If this is done via tangible physical means, it gives the emerging architect a tactile and experiential understanding of structures and load, and it provides a great insight into engineering. However, a bridge is not an objective that architects would often design when working in the field, as it is a structural entity with limited architectural spatial range. When teaching an architectural structures seminar, I struggled to find an assignment that would allow the students to explore structure in an architectural sense. I eventually created the popsicle stick tower assignment. I found that it explores both structure and architectural spaces that would not only involve stereotomy and tectonics, but also the transition between the two classifications. This paper describes a challenge given to second year architecture students that require them to build a tower out of popsicle sticks without using glue. This exercise is suitable for emerging architects that desire to explore space, load, and balance, as well as instructors that are interested in the stimulation of a hands-on-assignment providing significant experiences of integrated principles in the field of architecture and structure.

1. WHAT IS TECTONICS? WHAT IS STEREOTOMY? WHY ARE THEY LINKED?

Perhaps the teaching of architecture would have been more diverse today if Gottfried Semper and his writings had been translated from German to English before modernism. Unfortunately, the monumental study *Style in the Technical and Tectonic Arts; or, Practical Aesthetics: A handbook for Technicians, Artists, and Friends of the Arts* was not translated and published in English until 2004. Architects and instructors will enjoy the following statement on the first page of chapter two: *Classification of the Technical Arts.* Here one can find a description of four categories of raw materials. Based on those raw materials, Gottfried Semper defines artistic activities to be explored and studied such as:

> [There] are four main artistic activities… [that] …require greater of lesser effort and technical procedures to make the raw material serve a definite purpose suited to its qualification... [each] ...divided into the following classes: 1) textiles, 2) ceramics, 3) tectonics (carpentry), and 4) stereotomy (masonry etc.) (p. 109).

This was written in 1860, in an utterly transformative industrializing time when Semper extracted *1) textiles, 2) ceramics, 3) tectonics (carpentry), and 4) stereotomy (masonry etc.).* Notice that tectonics is immediately followed by stereotomy in the four classes. My interpretation of this concept is that tectonics and stereotomy are in opposition to each other just like textiles are in opposition to ceramics. To understand the relationship of tectonics and stereotomy one could look at the first two classes: Textiles are made of strings that become surfaces when woven together that then drape or envelope or embrace something. Ceramics is made using clay that by nature is mass that embodies something. Polarization is helpful when thinking about classification: Textiles versus ceramics followed by tectonics versus stereotomy. To further elaborate on artistic activities and classification, I recommend looking at physical embedded properties and then align those with a concept. Textiles align with tectonics, or 1) + 3), as they are woven surfaces that in architecture often will be dependent on a structure or substructure. Ceramics align with stereotomy, or 2) + 4), as ceramics is a solid, mass, something that often stand alone, and is an excellent material that can be carved.

In Fallacara and Barberio's *An Unfinished Manifesto for Stereotomy 2.0* (2018), the reader not only finds physical digital installations of research in stereotomy, but also a statement of the origin of stereotomy:

> Since ancient times, men have looked at the sky and wondered about its origin, its ending, and the space–time–dimension… …The term "stereotomy" in architectural literature was used for the first time in 1644, in the Examen des oeuvres de Sr. Desargues by Curabelle. It is useful to note that the term stereotomy appeared here without the support of a specific terminological or a comprehensive graphic description for the first time. It was solely used to refer to the sections of solids, probably deriving from the union of two Greek words: Στερεός, "solid", and Τομή, "cut" (p. 251).

About 200 years later it appears to be the classical scholar Karl Ottfried Müller who first mentioned tectonics (p. 34), followed by tectonics and stereotomy linked/defined as complementary, in 1860 by Gottfried Semper's categorizations: 1) textiles, 2) ceramics, 3) tectonics (carpentry), and 4) stereotomy (masonry etc.) (p. 109).

1.1 Tectonics is not a technique

I wonder if there is a misunderstanding among architects and instructors that is etymological, i.e., — that tectonics is perceived as a technique. Or could it be that Gottfried Semper is not that well known, which is understandable because the translation into English of his most significant book emerged late? In his book Studies in *Tectonic Culture* (1995) Kenneth Frampton writes about the etymology of the class or term tectonic and presents how the word has been used in the past*: …Greek in origin, the term tectonic derives from the word tekton, signifying carpenter or builder…* (p. 3). He continues: ...*The first architectural use of the term in German dates from its appearance in Karl Ottfried Müller's Handbuch der Archäologie der Kunst (Handbook of the Archeology of Art), published in 1830…* (p. 4). Kenneth Frampton briefly mentions Gottfried Semper and his tectonic/stereotomy distinction to set the premise of the book, *Studies in Tectonic* Culture on the concept of tectonics only. He does not discuss stereotomy any further nor the categorizations proposed by Gottfried Semper elsewhere in the book. This limited view may lead the reader to misinterpretations, such as in the chapter *Jørn Utzon: Transcultural Form and the Tectonic Metaphor* (p. 246) where Frampton would have served the reader better by not using the category tectonic; instead, he should have presented an examination of the projects within the category stereotomy. I wonder if there is such a thing as a *tectonic metaphor,* because most of the architectural portfolio by Jørn Utzon can be seen as spatial explorations of form, mass, solids, and light, which are findings executed almost entirely in the stereotomy classification. We can observe from Semper and Utzon that tectonics and stereotomy emerge from embedded properties.

2. HOW CAN TECTONICS AND STEREOTOMY BE TAUGHT IN ARCHITECTURAL EDUCATION?

Tectonics and stereotomy are artistic activities. Both are significant operations in spatial exploration that, fundamentally, and in their nature, point in opposite directions. When architects design, they will either come up with ideas that are based on points, strings, edges, surfaces or similar, then act and execute them by riveting, stitching, gluing, and maybe folding something. These are all tectonic activities. When architects work with stereotomy they will be extracting mass in particular areas. The activity is to remove mass to create void or a progression of void. Stereotomy can efficiently be explored in 3D printing. The use of 3D printing is rarely a tectonic activity, as most 3D printers would apply string material that immediately merges into a single mass or a clump. Recently a 3D printing technology has also become available that prints within a soluble material, creating objects that emerge from within! Surrounding soluble material is removed after the print is complete, and this approach can produce highly complex spatial geometries. When 3D printing, the mass unfolds by leaving voids behind where space is needed for functions or to embrace light and air, thus creating a 3D printed spatial investigation in stereotomy that probably would have excited Gottfried Semper. The CNC router or cutter can also be used in spatial exploration, another interesting technology for explorative activity in stereotomy when modifying solids to form space.

2.1 Exploring relations between tectonics and stereotomy in a popsicle tower assignment

Tectonics and stereotomy can be studied with computer, but the haptic experiences are absent. Touch is eliminated as the hand has been reduced to connecting vector point to vector point. This is a pedagogical problem when educating architects. When teaching architectural structures for the undergraduate architecture students, I created a popsicle tower assignment because the tower is a fundamental typology in the field of architecture. The physical stick becomes a thing to think with as they must be interlinked or attached to something as the tower is constructed, however, each student must not only create the tower itself but must also design a plinth to be able to begin a construction. During the assignment, I observed that most of the students began the tectonic activity of tower construction through simple geometry. Also, most students approached the assignment through the application of tectonic activities for tower construction and would single out stereotomy in the development of the plinth. Some did combine the two classifications, and only a few students produced a tower such that the entire structure could be placed in the stereotomy classification.

2.2 Teaching tectonics and stereotomy using sticks and plinth

If one considers a skyscraper, it is made of curtain walls, columns, folded surfaces, individual elements, and something enclosing a steel frame; this describes tectonics. But a skyscraper cannot be placed entirely in the tectonic classification. It cannot be ignored how a skyscraper is fixed to the ground. First there is excavation. To carve is an act that is executed in the classification of stereotomy. Perhaps it is possible to argue that piles driven into the ground is extending tectonic explorations from various structures above ground, but even if rammed piles or pile-driven-profiles are used as the only means, they are all set within the carving of the ground that has been done before anything could be assembled using piles or sticks. In this light, the education of an architect is twofold: Design an assignment that first embraces stereotomy and then tectonic and explore the transition between both. The construction of the popsicle towers was accomplished by asking students to first design a plinth, in solid wood, that along the edges or in the top part required implementing voids or details that would help the transition from something solid to something made as a structure. Figures 1 and 2 show the transformation between tectonics (top/structure) and stereotomy (base/plinth) as popsicle sticks are *pulled* or *extracted* from the plinth or *embedded* or *inserted* into the mass at the same time. Notice the diversity within each individual plinth as seen in figure 2. Some proposals are mass that has been hollowed out, other proposals have surfaces put together rather quickly, creating a wide range of different outcomes and spatial exploration of each plinth.

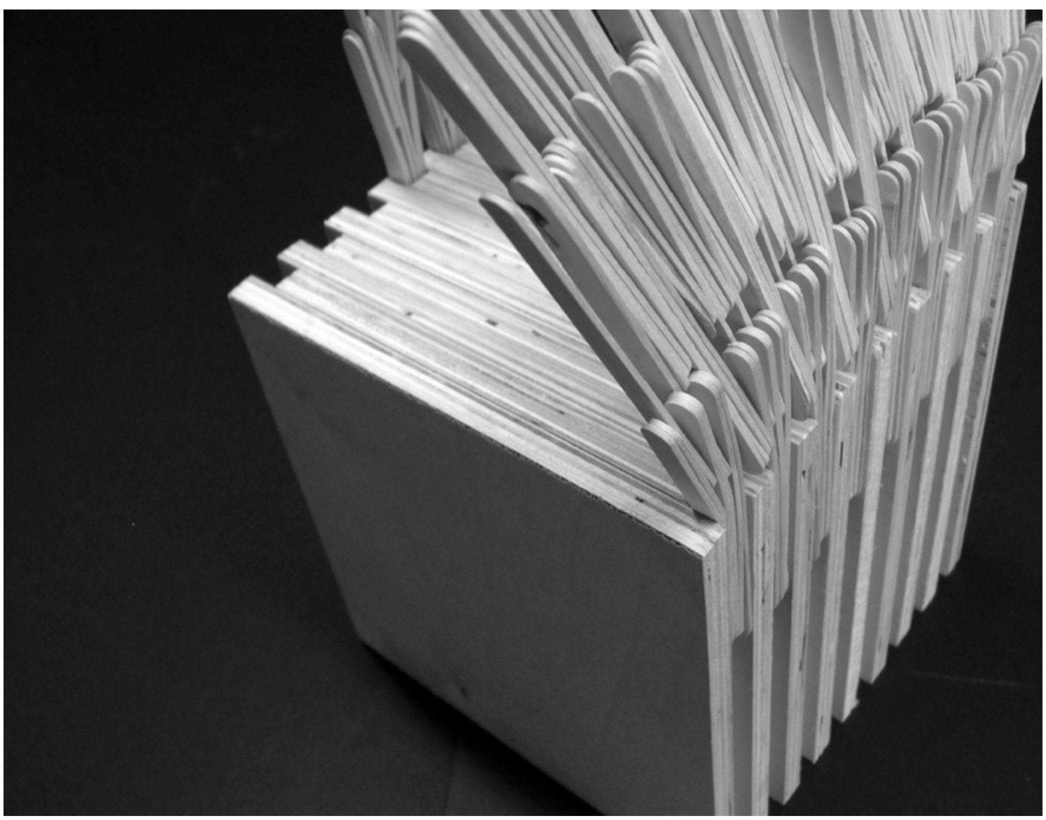

Figure 1 – transition between tectonic (top/structure) and stereotomy (base/plinth)

Figure 2 – various structures executed by different students in an architectural structures class

3. METHOD – OBJECTIVE – OUTCOME

In this exercise the students were required to build a tower rising from a plinth. Conceptually there are five basic requirements for this project: 1) make a plinth using wood or popsicle sticks, 1 x 1 x 1 foot in dimension, that is solid, heavy, and dense, 2) the tower placed on or emerging from the plinth must be a spatial tectonic construct, involving hundreds of connection points using popsicle sticks, 3) develop any method of connecting the sticks, without the use of glue, 4) the tower, including plinth, is to be as tall as the student who is creating the proposal, 5) a photographic record over the course of the construction must be made and the finished tower must be successfully transported to an exhibition area.

Any kind of wood could be used for the plinth, but the tower had to be made of popsicle sticks. The challenge was that none of the popsicle sticks could be glued, but any means of otherwise holding the tower together was permitted, from strings to clips to interlocking systems, or 3D printed connecters of the student's own design. It was important to let the students know that failure, such as a collapsed tower, could be evaluated to be good or even excellent, so recording the efforts while building the tower was as important as the outcome. Photographic evidence of the making of the tower was, therefore, strongly encouraged. Each architecture student had to transport the tower from the architecture school to an exhibition hall, and in doing so the day of stress-testing-while-transporting the physical structures faced a somewhat ultimate test. The restrictions were demanding from a technological aspect, however, when evaluating the design aspects, the outcomes were exceptionally diverse, as seen in figure 3.

Figure 3 – The task was to design and construct a structure made of popsicle sticks that raised from a plinth

3.1 Constraints and possibilities in the teaching of architectural structures

Most of the popsicle structures were static in their design, fixed in space with rigid connections. Some architecture students opted for variable geometry, such as creating a compressed structure for the design proposal, and then simply unfolding the tower on the day the structure had to be transported and presented in the exhibition hall. Figure 4 shows a student who created a balancing act attached to a plinth, and from this position the tower could unfold and be stabilized with static friction within an integrated locking system.

Figure 4 – a tower made of popsicle sticks that was unfolded from the plinth on presentation day

Investigating tectonics is different from stereotomy when making decisions regarding details and connections. To establish a system, a student must select a point in space where elements meet and define a way to connect one popsicle stick to the next and do so efficiently. The students soon found that this act is analogous to weaving, an artistic approach that belongs in the tectonic classification. It was important not to instruct how the students should execute the connection points. Teaching architectural structures should be a place for trial-and-error creativity, letting mistakes happen, and create time and space for students to reflect on those, finding successful ideas by making, thus fostering imagination.

When teaching architectural structure, I was interested in invigorating the environment of the typical lecture hall and creating a formula for learning that would merge the lecture hall and studio environment. I enjoy seeing design proposals and discoveries that students find on their own terms. This hands-on assignment in a structure class would let students work with gravity. By constructing a tower students can *feel* how a structure responds and behaves. The idea was to embrace as many as possible and a range of possibilities, including towers that might be failures. Any intervention of the instructor might limit potential outcomes or path of construction, reducing the number of ideas to which the students are exposed.

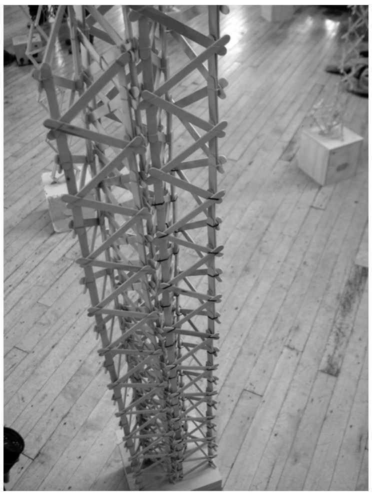

Figure 5 – the triangle is the strongest shape

The approach was to surround the popsicle assignment with lectures and then convert the lecture hall briefly to a studio environment for a display of structures in the making and discussion. Geometry was studied before constructing the popsicle towers. I would ask the students why the triangle is the strongest shape and have them compare triangles and squares using popsicle sticks that were put together not using glue. The students also discussed how it can be that there are not many towers that have a triangle footprint, or, in most cases, no visible triangles in their sections. Students selecting a triangle for their tower design proposal, would create and shape an intriguing spatial and structural exploration, as seen in figure V, but the outcome was sometimes not successful for a few students as seen in figure 6.

In my findings I discovered that tectonics are never flat. Every connection point must be imagined in three dimensions and all students demonstrated to do so in this assignment. Exploring stereotomy was difficult for many students as the plinth often was left as a mass without spatial consideration for a transition or developed implanted anchor point such as carving or similar for the tower.

Figure 6 – a design proposal with no transition between plinth/structure and a somewhat elegant failure in section

CONCLUSION – A SENSE OF GRAVITY

Mathematical principles by Isaac Newton and the theory of general relativity by Albert Einstein brings us an understanding of gravity, matter, and the fabric of spacetime. However, this question is still open in physics:

Where is gravity? Why is matter attracted to other matter? So far, a *gravity-quark* or similar has not been found by scientists. Gravity is not necessarily an equation for architects but is it spatial? In the last decade scientists provided exceptional visual evidence that all material in a galaxy is a balancing act responding to the imploded singularity of a black hole. In *The Eyes of the Skin. Architecture and the Senses* (1996), architect and architectural theoretician Juhani Pallasmaa reflects upon gravity:

> *The sense of gravity is the essence of all architectonic structures and great architecture makes us aware of gravity and earth. Architecture strengthens the experience of the vertical dimension of the world. At the same time as making us aware of the depth of the earth, it makes us dream of levitation and flight.* (p. 57)

From a pedagogical point of view, it is beneficial for students to engage sense of touch, to feel how gravity operates within design solutions, and to get a sense of load in architectural models. Creating a physical hands-on assignment in an architectural structure class that asks students to establish a moment of balance with sticks and connection points will make evident the positive and negative interaction of their strategies with gravity, the primary physical constant affecting all building. Simulated virtual realities are driven by algorithms that first are available at the end of the design process and is not a haptic spatial investigation. This is in stark contrast to immediate learning that students enjoy when creating a physical architectural structure. The popsicle towers instantly respond to gravity while being constructed. Problems emerge during construction, such as an unintended slightly sagging “S-shape” (see figure 7), causing the student to adjust his or her approach, finding a new path, and learning unscripted lessons while going forward.
After teaching the popsicle stick assignment a few times, the benefits became evident. By including theory (tectonics and stereotomy) and studio culture (one or two assignments would interrupt the traditional lecture hall curriculum) to an undergraduate structure class I found students not to be passive listeners but to be engaged with the task at hand. When physically and mentally engaged in hands-on assignments the students were excited to explore concepts such as tectonics and stereotomy while building a tower and a plinth.

Figure 7 – detail of a popsicle structure that would sway and behave differently from the original intention

In my findings students would have no problems exploring geometric principals when thinking and building with sticks and connection points and investigating tectonics. It was the artistic approach in the design of a plinth and being able to engage and study stereotomy that often was challenging. That to carve, to hollow, to extract, to expand, and so on (see figure 8), was often overlooked as most students would define the base as a simple plinth with no transition to the tower. It is perhaps in the nature of human beings that when we first engage in something it is difficult to change. I found that stereotomy was dependent on geometry and tectonics in the upper part of the popsicle tower, and that students used feedback from the construction of the tower when developing the shape of the base. The exploration of the plinth (see figure 1 – first page of this paper) is interesting when a student would develop a transition zone between tower and plinth, but a majority of students would make tectonics primary to stereotomy as seen in most executed proposals. Being the instructor of this assignment, I could not help to think of tectonics and stereotomy to be equal by definition, however, I learned that stereotomy must have additional promotion today. If included in an architectural structure assignment at the same time, tectonics and stereotomy can both be invigorating teaching tools and a fundamental dimension in the exploration of spatial thinking in architecture and architectural structures for emerging architects.

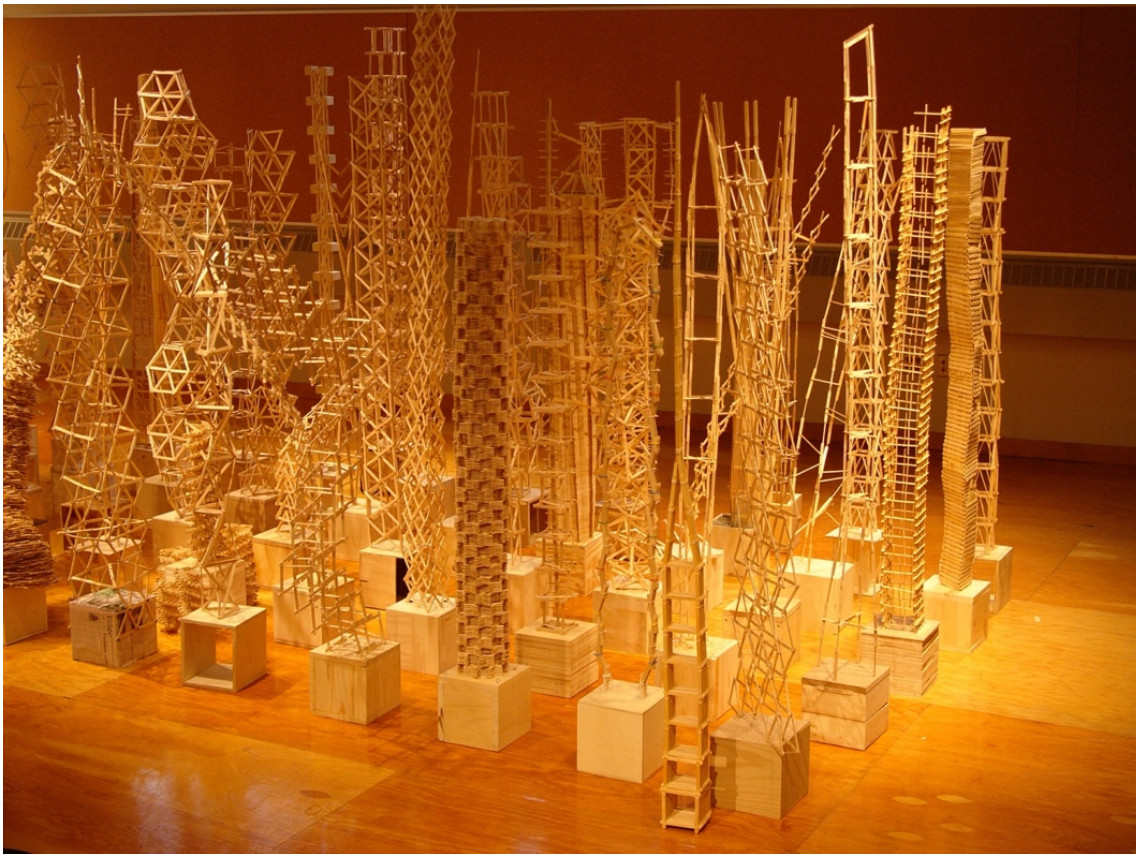

Figure 8 – notice that most plinths are simple cubes with few examples in how to investigate stereotomy

REFERENCES

Baeza, A. C. *From cave to hut: On stereotomics and tectonics in architecture.* Sustancia y Circunstancia. ETSAM 2002-2003. Ed. Mairea. Madrid, 2003 and Pensar con las manos. Ed. Nobuko. Buenos Aires. 2009.

Fallacara, G., & Barberio, M. 2018. *An unfinished manifesto for stereotomy 2.0.* Nexus Network Journal, 20(3), pp. 519-543.

Frampton, K. & Cava, J. 1995. *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture.* MIT Press, pp. 3-4, 246-298.

Müller, K. 1830. *Handbuch der Archäologie der Kunst (Handbook of the Archeology of Art).* Verlag Josef Max, pp. 34-40.

Pallasmaa, J. 1996. *The Eyes of the Skin: Architecture and the Senses*. John Wiley & Sons, p. 57.

Semper, G. 2004. Translated by Harry Francis Mallgrave and Michael Robinson. *Style in the Technical and Tectonic Arts: or, Practical Aesthetics.* Getty Research Institute, p. 109.

CREDITS AND PHOTOS

Andrew Wangler assisted a theory class that I am teaching at North Dakota State University, and I thank him for great conversations regarding tectonics, stereotomy, the heuristic, as well as discussions in advanced emerging printing technologies. I warmly thank Samuel Newman for important editing, feedback, and notes and Pia Sarpaneva for guiding me towards writings by Alberto Campo Baeza. I also thank Paul Gleye for asking me to teach architectural structures from the viewpoint of an architect to undergraduate architecture students thus making this paper possible. All photos are by the author.