TECTONIC AND ATECTONIC EXPRESSIONS OF DIGITAL ARCHITECTURE

التعبير التكتونى واللاتكتونى للعمارة الرقمية

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ABSTRACT

The notion tectonic, from the Greek tekton which signifies builder or carpenter, was used since the 19th century by construction theorists to indicate the relationship between building techniques and design aspects. In contrast, the concept of Atectonic is considered the negation of the authentic tectonic philosophy where main construction technologies and materials have less effect on the observers' understanding of architecture.

In the information age, major shifts took place in the architecture design and construction field. These shifts affected all stages of design and construction process. The use of CAD/CAM technologies resulted in dramatic transformation in both form generation, construction planning, material use and construction techniques. These changes led to a rethinking of tectonic/Atectonic understanding of representational and enological aspects of forms. Many recent research work has focused on discovering and defining a new relationship between the original theory of tectonic/Atectonic and the contemporary digital architecture where concepts like generative forms, design algorithms, material computation may have led to tectonic or Atectonic nature of architecture expression.

In this paper, the terms tectonics and Atectonic will first be defined according to different architectural theories by analyzing work of theorists who founded the original tectonic theory. Then, theses defined terms will be discussed in relation to digital architecture. As the notion "digital architecture" may refer to many aspects of design and construction processes that are affected by the ongoing and swift development of informational and digital technologies, this research is focusing on the morphological expressions of digital architecture. Digital architecture morphology will be examined to terms of tectonic/Atectonic theory on both representational and ontological levels through analyzing selected examples of digital architecture. Through this discussion an evaluation to the nature of digital architecture relationship to tectonic or Atectonic aspects is reached and the new kind of tectonics - digital tectonics expressions is articulated.

KEYWORDS

Tectonic, Atectonic; Digital Architecture; Digital Design; Architecture Morphology. Architecture Expression

الملخص

نشأت النظرية التكتونية فى العمارة فى القرن التاسع عشر والتى تهتم بالعلاقة التكاملية بين النواحى الإنشائية والتعبيرية للعمارة. وفى المقابل نشأ ما يعرف باللا تكتونية حيث تضعف العلاقة بين العناصر الإنشاء والنواحى التعبيرية للعمل المعمارى. وقد صاحب التقدم السريع للتكنولوجيا المعلوماتية والرقمية تغيرات كبيرة وجذرية فى مجال العمارة والإنشاء والذى أدى بالتالى إلى تغيرات فى النظرية التقليدية للتكتونية فى العمارة. وبالتبعية تناولت العديد من الأبحاث تطور النظرية التكتونية واللاتكتونية الذى صاحب انتشار التكنولوجيا الرقمية فى مجالات العمارة المختلفة.

يتناول هذا البحث بالدراسة تطور النظرية التكتونية فى العمارة وكذلك الأبحاث والجهود التنى تناولت العلاقات التكتونية واللاتكتونية. وتحليل نماذج مختارة من العمارة الرقمية وذلك لتعريف ما يسمى بالتكتونية الرقمية.

الكلمات المفتاحية

التكتونية؛ اللاتكتونية؛ العمارة الرقمية؛ التشكيل المعمارى؛التعبير المعماري

1. INTRODUCTION

The alliance between architecture and technology has been a great important aspect of architecture domain. This relationship is what distinguishes architecture from other fields of creative arts, the ability of transforming intangible expressions into physical forms. The human architecture of the Roman, the sacred medieval minsters and the pure abstract forms of the early modernism, manifest the expressional power that a stack of stones and blocks could have. Thus, this interrelationship between expression, technology and architecture has always been a major subject of architecture theory and research. Tectonic theory is one of the important theories that deals with the common space between tech, art and feelings in architecture. It was first introduced by the German archaeologist Karl Bötticher by the end of the 19th century. Followed by efforts of other theorists during the past decade, the tectonic theory had evolved to assimilate the technological metamorphoses during the 20th century. Atectonic is the opposite of tectonic, it's where technological and aesthetic aspects of a building are discrete. By the end of the last decade a new technology has emerged and rapidly developed, digital and communication technology. The enormous amount of exchanged information throughout the world has changed the way of life people already knew, moreover, the emerging digital technology had affected all production and manufacturing fields including architecture. Hence, architecture tectonics should develop new definitions to assimilate the technological changes and its effect on architecture expression.

The aim of this research paper is to investigate the transformation of tectonic theory that resulted from the digital and informational revolution and articulate the effect of this transformation on the expression of architecture. The research starts with a literature review of the past work on tectonic theory.

Then the notion "digital architecture" will be defined by tracking the gradual development of architecture practice under the influence of the digital revolution. Next, the research will discuss what is called "Digital tectonics", a concept that started to emerge in the past 15 years to articulate the relationship between architecture tectonic and digital design media. The research will end with an analytical study of two selected examples to highlight some tectonic/Atectonic expressions of digital architecture.

2. TECTONIC THEORY

The term tectonics is a Greek word means carpenter or builder. Later on, the term tectonics was used to indicate the common space between artistic and technical factors in art and architecture. Tectonics are defined as "the science and art of construction, both in relation to use and artistic design." (Webster's Dictionary) It refers not just to the "activity of making the materially requisite construction that answers certain needs, but rather to the activity that raises this construction to an art form." (Anderson, 1980) This includes the aspects of building techniques, structural elements, and material in addition to aesthetic values. Bötticher, Semper, and others introduced tectonics as a way of connecting the underlying functional aspects of a building to its ornamented, visual facades. (Schwartz C. J., 2017)

The use of this term was first introduced into architecture theory in the middle of the nineteenth century by the German archaeologist Karl Bötticher who defined architectural tectonics as the activity of forming a building. (Scarmack, 2011)

Botticher (1852) addressed the relationship between ontological, the inner structure, and representational, the outer form, nature of architecture by studying Hellenic architecture and the principles with which the Greeks designed their greatest works. He identified two elements of any work of architecture. The first element is Kerneform which indicates the core-form or the underlying ontological truth of the object.

The second element is Kunstform which indicates the outer and ornamental nature of the object. According to Bötticher, Tectonics are the system or concept that ties all the elements of a building together to a whole. (Andersson & Kirkegaard, 2006). The Greek column for example is a simple structural element that transfers loads coming from upper overhead structure to its base which in-turn transfer loads to ground or below structure.

The Greek order of ornamentation reflects the function of the column. The column's head and base, the main points of loads transfer, have the richest elements of the ornamentation which highlights the work below the surface. See Figure 1 and Figure 2.

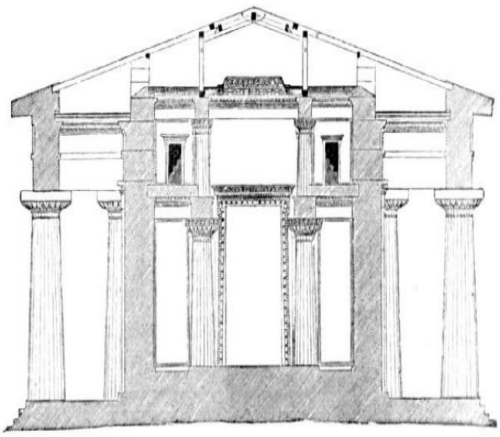


Figure 1 Karl Bötticher's Section o Greek Doric Temple Paestum. (Botticher , 1852)

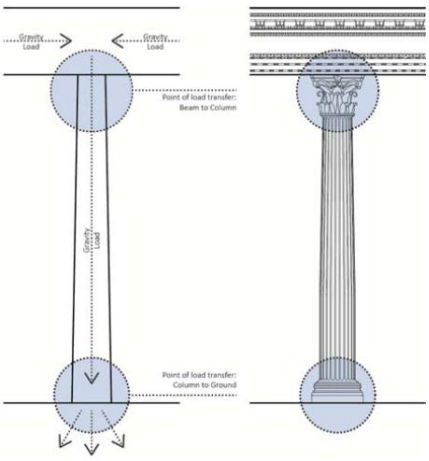


Figure 2 Analysis of a Greek Column (Schwartz C. J., 2017)

While Bötticher was seeking to reveal the underlying forces at work through the ornamentation of the building (Schwartz C. J., 2017), Semper had more interest in the use of material, methods of manufacturing and construction techniques in his definition of tectonics.

The definition of tectonic expanded greatly under Gottfried Semper who is credited by many as the father of tectonics (Scarmack, 2011). According to Semper, "tectonics deal with the product of human artistic skill not with its utilitarian aspect but solely with that part that reveals a conscious attempt by the artisan to express cosmic laws and cosmic order when molding the material." (Herrmann, 1984) In his The Four Elements of Architecture, Semper argued that architecture should be divided into four main elements or parts based upon methods of construction: earthwork (mound), the hearth, framework and roof, and enclosure (light enclosing membrane. Semper also classified the process of building and production into procedures: the tectonics of the frame, in which lightweight, linear components, steel or wood, are assembled to form a spatial field while the Stereotomic of the earthwork, formed by the assembly of repetitious stacking of heavyweight elements or units such as brick or stone. (Scarmack, 2011)

Furthermore, he emphasized the 'joint' as the most fundamental factor of tectonics. (Lim & Liu, 2006). For Semper, and in his opinion, the joint is out of the transitions between building elements that the beauty of architecture emerges. (Andersson & Kirkegaard, 2006). After the work of Botticher and Semper, architecture theorists and researchers continued to develop the theory of tectonics. Sekler (1965) described the relationship between tectonics, structure and construction as "an etymological combination of architecture and technology, originally referring to the craft of the carpenter; expressive forms of prototypes born from technological and constructional necessity; and pure visibility of construction" (Sekler, 1965). He first defined structure as an "essential ordering principles of a work", and construction as a "particular physical appearance of these principles". He then defined tectonics as an ontological/representational relationship which express "qualities that cannot yet be described in terms of construction and structure alone" (Sekler, 1965). About 150 years after its first reveal, architectural theorist Kenneth Frampton brought the ideas of tectonics back into the attention of architectural society and defined tectonics as the poetics of construction. (Frampton, 1995)

In his essay "Towards a Critical Regionalism," Frampton writes: The primary principle of architectural autonomy resides in the tectonic rather than the scenographic: that is to say, this autonomy is embodied in the revealed ligaments of the construction and in the way in which the syntactical form of the structure explicitly resists the action of gravity. (Frampton, 1998). He believes that the tectonic building must demonstrate how gravity is moving through the structure and that we must be able to perceive this reality and be satisfied through our understanding of how the building is stable. (Schwartz C. J., 2017)

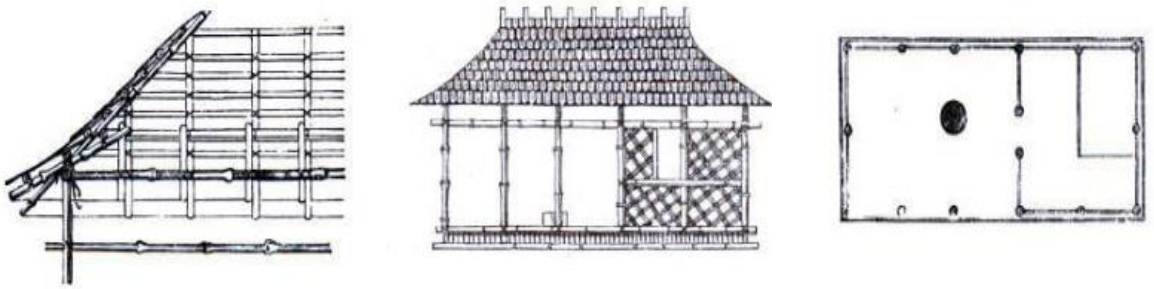


Figure 3 The Caribbean hut from the island of Trinidad represented Semper's four tectonic elements. (Semper, 1989)

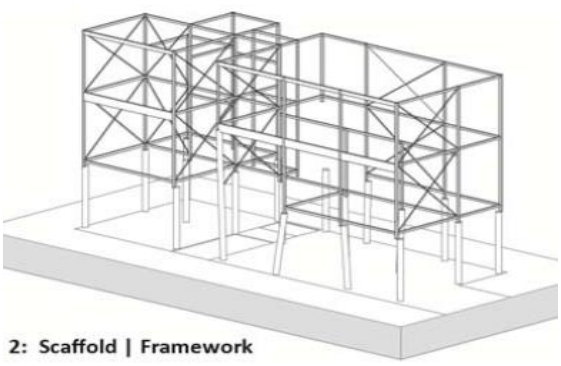
Frampton made, with reference to Semper's distinction between symbolic and technical aspects of building, an interesting distinction between the representational and ontological aspects of tectonic form. He emphasized cultural and contextual nature of tectonics by relating tectonics to its diverse origins in scopes of etymology, topography, metaphor, ethnography, technology and representation as well as ontology. (Frampton, 1995) This division is something in constant need of reformulation in the creation of architectural form, since every building type, technology, topography and temporal circumstances give different cultural situations and conditions (Nilsson, 2007)

Frampton also described two main approaches to the construction of any element in the built environment, tectonic and stereotomic. (Frampton, 1995) Tectonic construction refers to the assembly of elements through joints while stereotomic construction refers to the piling or massing of materials like the stacking of building blocks or the pouring of concrete.

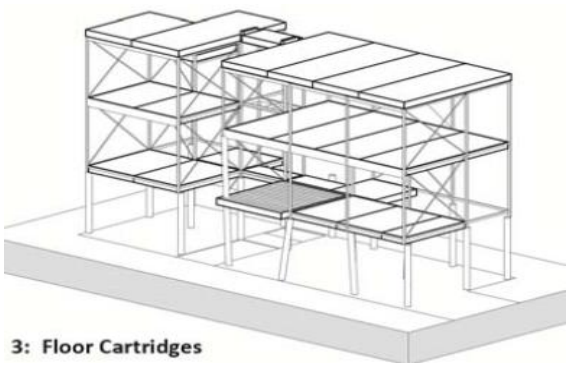
Frampton (1995) highlighted the role of the joint as a main tectonic element. He stated that the 'joint' in a structure is the most essential and smallest elemental unit. The joint is where elements and materials meet, and it is therefore a crucial point in the telling of the logic of a construction. In the joint, the story of materials, overall structure, and laws of nature is embedded, and it thus the most tectonic element of an architectural artefact. (Andersson & Kirkegaard, 2006)

More recent effort have been put to find modern interpretation to the classic theory of tectonics and to relate its concepts to modern models of design/construction practice. In her book "Tectonic Vision in Architecture", Ann Beim defined "tectonic vision" as: "Visionary investigations into new materials, technologies, structures, and practices of construction, as means to construct (new) meaning in architecture." (Beim, 2004) She stated that tectonics today are mostly used to describe aesthetic issues, materiality and the intentions behind constructive solutions, which means interpretations of technology and construction beyond mere instrumental definitions. Building technology and construction practice can become a matter of signification tectonics but only when handled consciously and intentionally. (Beim, 2004). In her paper, (GAO, 2004) summarized five classic factors: detail/joint, material, object, structure, and construction. The factors she drew from the classic theory of tectonics were more common ones, relevant to structural techniques. However, other factors such as perception and topography, relevant to the relationship between architecture and site as well as architecture and culture, are also implied in classic tectonics. (Frampton, 1995).

More recent, Schwartz (2017) outlined a framework for examining the core concepts ingrained in the history and evolution of architectural tectonics. (Schwartz C. J., 2017) The developed framework has educed nine topics, each of which examines a particular characteristic drawn from different lines of historical and contemporary thought of the tectonic theory: Anatomy, Tectonic/Stereotomic, Detail/Intersection, Place, Representation/Ornamentation, Space and Atectonic. (Schwartz C. , 2016) See Figure 4



2: Scaffold | Framework



3: Floor Cartridges

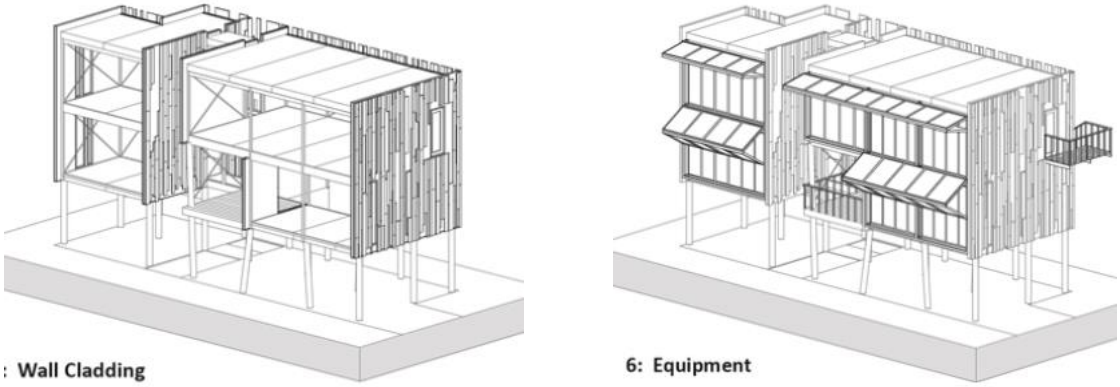


Figure 4 Partial anatomy of Loblolly House by Kieran Timberlake (Schwartz C. J., 2017)

3. ATECTONICS

The Atectonic are the conditions that run contrary to typical tectonic ideas. (Schwartz C. J., 2017) The Atectonic concept was established in the 1960s. Sekler pointed it out when discussing Josef Hoffmann's decorated Stoclet House. (Wei Wu & Chao-Ching , 2014)
Eduard Sekler offers a few ideas of Atectonic expressions in his writings: the construction and structural principles could be out of alignment (i.e. building in one material with the detailing of another), the expression could be vague (i.e. a floating building), the use of exaggerated building elements or manners in which the expressive interaction of load and support in architecture is visually negated or obscured. (Sekler, 1965)
Sekler (1965) distinguished two types of Atectonic. It may result to a building process that is not concerned with building tectonics or to a process that purposely neglects tectonic expression to create specific experience or as a result to certain building conditions: “The tectonic expression may be deliberately unclear, leaving a beholder marveling at vast expanses of matter hovering apparently without effort over a void [or] there may be a tectonic negation created with the aid of Atectonic forms which tend to disturb the viewer”. (Sekler, 1965)
The Atectonic occurs at any point, according to Sekler, in which the expressive interaction of load and support in architecture is visually neglected. (Sekler, 1965)

As an example, Frampton pointed out that in the great iron and glass structure of the 1851 World’s Fair – the Crystal Palace by Joseph Paxton – the cast iron columns were all the same diameter, but carry different loads through unseen variation in the thickness of the column’s wall. (Frampton, 1995) The outer expression of the columns in this project was equal, yet the internal forces at work are not.

The masking or concealing of an architectural element within a building is considered an Atectonic practice. Frampton described this practice In Studies in Tectonic Culture. He posits that architect Adolf Loos “embraced an Atectonic strategy in that his spatially dynamic Raumplan could never be clearly expressed in tectonic terms”. (Frampton, 1995). This design strategy involved the masking of the underlying mechanical construct and, therefore, went against the core ideas of the tectonic.

Another expression of the Atectonic is when materials were not constructed in a logical way following their characteristics, or when they pretended to be another kind of material. Based on Sekler's definition, to show the properties of materials is a very fundamental practical method of tectonic expression. One of the vivid expressions of the nature of material could be considered to be Louis Kahn's well-known 'conversation' with personifying brick.

Kahn 'asked' brick about the form of an opening, and brick 'insisted' on its preference for an arch rather than a concrete lintel. According to Kahn, an arch is the tectonic expression of brick for the top of an opening, as this presents the property of brick. (Wei Wu & Chao-Ching , 2014)

However, the Atectonic expressions, which are composed of tectonic and material selections, are actually a widespread practical method that are used to show the contexts of the projects including cultural and environmental aspects. For example, the use of cladding material that conceals the actual supportive building elements could be used to reach certain thermal insulation or to manifest and to enhance cultural or local characters.

4. DIGITAL ARCHITECTURE: FORM REPRESENTATION/FORM FINDING

Major shifts in the field of design and construction have always took place as a result to paradigm shifts in science and technological fields. The notion “Digital Architecture” relates to the effect of the emergence and the rapid development of digital and communicational technologies that took place by the end of the 20th century. The use of digital design and presentation tools was the first and direct result to the information revolution. (Słyk, 2010) With the invention of Computer Aided Design (CAD) systems, computer has been used to replace the manual tools of the architect, the drawing board, the clay-model, the slide rule etc. in the production of traditional architectural drawings. The dynamic techniques of presentation beside the high quality photorealistic graphics of computer-generated models enhanced architecture presentation and accordingly enhanced the universal perception of work in first stages of design.

The powerful digital modeling tools had another impressive effect on architecture domain, the creation of free forms. The creation of unconventional flowing free forms became possible with advanced modeling programs aid. (GAO, 2004) (Mitchell, 1998)

Moreover, the desire to make buildings look like a rendering, or to produce photo-realistic images and walkthroughs has given way to an opening of the potentials of software to assist the designer with managing complex geometries, parametric organizational diagrams, structural analysis, and integrated building systems. (Vrana & Bell , 2004), However, the advanced digital modeling techniques would not have this dramatic effect on architecture discipline without a parallel movement in the construction and manufacturing field. Without the aid of what is called “File to Factory process” the complex, digitally generated forms couldn’t be transformed into real physical structures. The direct connection between the design model and the manufacturing machines through scripting based on simple rules, enabled a complex building to be an expressively and efficiently engineered product, within a regular budget. (Nilsson, 2007) With the completion of the 20th century Guggenheim Museum, Bilbao, architecture entered a brand new era. The use of computerized techniques opened a new page for free-form architecture; digitally produced architectural form began to appear. (Leach, Turnbull, & C., 2004) (Mitchell, 1998) (GAO, 2004) See Figure 5.

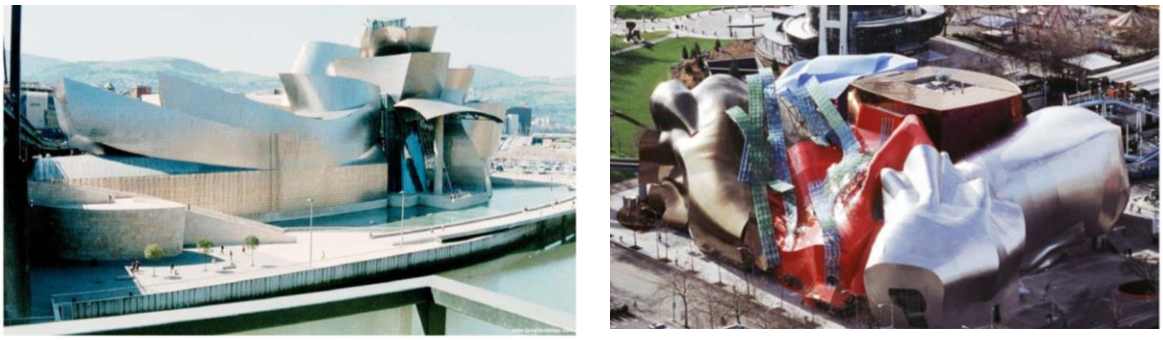


Figure 5 left- Bilbao museum by Frank Gehry – Right- Experience music by Frank Gehry.

Next to the transformation in design presentation and form making tools, the effect of digital information development started to influence the analytical pre-design stage. In the area of technological aspects of a building – such as construction, acoustics, lighting, climate, etc. – the digital tools provide great possibilities for exploration and simulation of future conditions, as well as engineering optimization. With these kinds of possibilities of conducting research before actually building a piece of architecture, the expectations on building design are redefined. The computer in architectural design has shifted from its role as a representational device to that of a tool for simulation and fabrication. Leach (2009) called this transformation a new 'performative turn' in architecture that resulted in the "folding of architecture into the other disciplines that define the building industry". As a result, the demands have been getting higher and there was a new emphasis on building performance, for example in relation to economics, spatiality, culture, ecology, and technology. (Andersson & Kirkegaard, 2006). This emerging demand of highly performing architecture in various and complex conditions paved the way to enhance the role of digital technologies from form making or form presentation to form generation and moreover, form finding. Hereby one of the major advantages of using the computer that was neglected in the first stages of digital architecture, the possibility of generating geometric forms that are not directly controlled by the designer, becomes a major field of research and application in architecture design field.

Oxman (2009) distinguishes the process of form making from form finding processes by articulating how and when contextual conditions, such as structural, topographical, environmental, economical …etc., are affecting formation decision making and accordingly how they influence the design process: "form making is defined as a formal process for the generation of form before or without an analytical process related to the form. In contrast to form-making form-finding is defined as form that emerges under influences of contextual conditions through evolutionary process. (Oxman, 2009).

In a form finding process, instead of modeling an external form, designers articulate an internal generative logic, educed from contextual conditions, which automatically suggests a range of possibilities from which the designer could choose an appropriate formal proposition for further development. (Kolarevic, Digital Morphogenesis, 2003). See Figure 6.

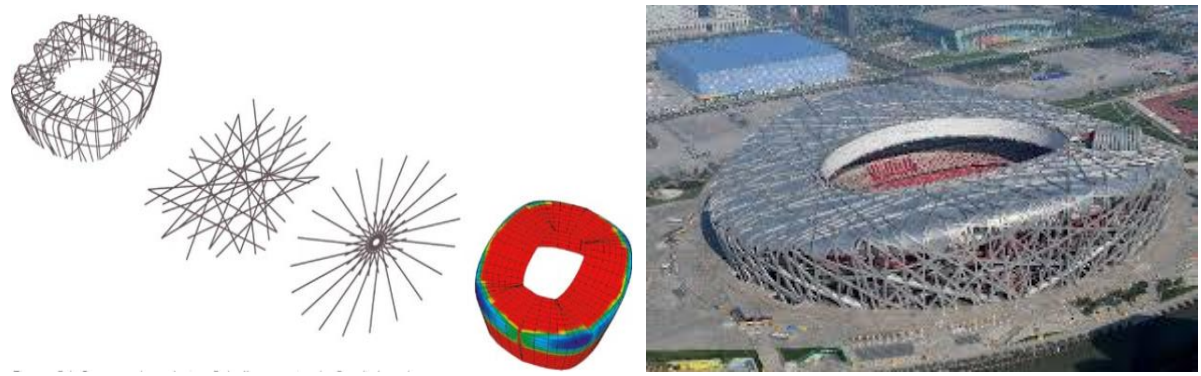


Figure 6 Structural analysis of shell comprised of radial and random patterns. The radial pattern that manages the primary distribution of forces while the random pattern operates as a meshwork that reinforces that whole through redundancy. (Vrana & Bell , 2004)

Therefore, computer in a form finding process is used as a collaborative partner, that gives the architect technical guidelines through the process. (Andersson & Kirkegaard, 2006) The computer generated solutions, called mechanical solutions, are not copied directly from the computer program as an optimal shape or formative solution. Instead, architects in a form finding processes are acting like the controllers of the processes who facilitate the emergence of the bottom-up form-finding processes that will finally contain computational technical aspects as well as the architect's aesthetic considerations. "With this we see a development in the very nature of the architect from the demiurgic 'form-giver' to the architect as the controller of generative processes, where the final appearance is a product not of the architect's imagination alone, but of the generative capacities of computer programs. It is not that the architect here is any less imaginative; rather, the architectural imagination has been displaced into a different arena – into the imaginative use of various processes". (Leach N. , 2009)

Leach (2009) described this logical bottom-up form finding process as "form morphogenesis", a term that is used initially in the realm of biological referring to the logic of form generation and pattern-making in an organism through processes of growth and differentiation. This digital generative processes are opening-up new territories for conceptual, formal and tectonic exploration, articulating an architectural morphology focused on the emergent and adaptive properties of form. (Oxman, 2009). On conceptual level, for example, emerging structural systems are evaluated based on efficiency and are not necessarily dependent on Euclidean geometry.

Parametrically modeled structural systems that achieve increased levels of complexity are not exclusively selected because of form but rather performance. On materialization level, the concentration focuses on using the computer to derive the geometry of the members and joints and how that information can be transferred to templates for digital fabrication. (Vrana & Bell , 2004)

The emphasis shifts from the "making of form" to the "finding of form," which various digitally-based generative techniques seem to bring about intentionally. In the realm of form, the stable is replaced by the variable, singularity by multiplicity. (Kolarevic, 2003). Thus, methodological content resulting from emerging methods and technologies is providing new digital processes and representational potentials that are establishing new tectonics.

5. TECTONICS/ATECTONICS OF DIGITAL ARCHITECTURE

As discussed in previous section, the new possibilities of digital creation of geometric had inspired many architects to build free forms. This stylistic break caused by the emergence of digital tools, has resulted in architecture that seemingly rejects the notion of structural technology, continuity, and morphology. The architects of this movement represented an ideological, conceptual and formal break with the conventional building tradition. (Kolarevic , 2005) Therefore, first generation of digital architecture, where digital technologies were used as form making and representation tools, shows an Atectonic nature. Mitchell (1998) proposed the idea of 'antitectonics' of the digital architecture and related it to the extreme disparities between physical and digital design media: "the fundamental elements and processes of classic digital construction are extremely different and even opposite to classic tectonics. In this new architectural domain, joints just don't matter. Surfaces have not thickness, and they can be fitted together with Mathematical precision. There is no need to accommodate changes of materials. Furthermore, there is no weather to keep out" (Mitchell, 1998)

However, the need for transforming digitally created surfaces and spaces from virtual to physical nature hinders the extreme negligence of tectonics. In Studies in Tectonic Culture, Frampton pinpointed this idea and stated that architecture "was born not from the algorithmic potential of computer programs, but of the tectonic capacities of actual materials." (Frampton, 1995).

The digital representation approach to architecture design combined with the advanced methods of production and solutions that computers provide through CAD/CAM systems have made the construction of the complex free forms possible, but "unfortunately, the elegance and preciseness of the constructions that the techniques enable, are not a part of the building's expression". (Andersson & Kirkegaard, 2006) (Lim & Liu, 2006) The resulted buildings were Atectonic in its nature. The digitally generated forms were a shell-like structure where the complex shapes are just cladding elements underlying the actual building structure.

This is a very Atectonic aspect of the building, as it is not possible to experience the flow of forces through building elements and joints. (Andersson & Kirkegaard, 2006)

It was the emergence of "blobitecture" which caused many architectural critics to speak out against the rapidly growing trends in digital architecture. (Scarmack, 2011) One of the architects that can be placed in the classical appearance orientated digital architecture is Frank Gehry (Leach, Turnbull, & C., 2004). Gehry preferably uses a tactile physical model, instead of a digital manipulation of surfaces on a computer screen. Therefore his use of digital technologies can be seen as a translation of physical models, into digital information that can be used in the final fabrication of the building. (Andersson & Kirkegaard, 2006) (Kolarevic , 2005). See Figure 7

The role of digital technologies, as explained previously, has gradually changed from a form-representation tool to a form generation one. Digital technologies are becoming more involved into the actual formation process, a process that results in coherent structures that are deeply rooted into its context. Thus the deeper meaning of architecture and tectonics is still the same, the truth of the building and its context.

The technical context is however changed because of the new possibilities that lie in the digital tools, and thus the notion of tectonics also has to change. Therefore Bötticher, Semper, Sekler, and Frampton's definitions of tectonic are not sufficient anymore. (Andersson & Kirkegaard, 2006)

Figure 7 Experience Museum under construction – Frank Gehry (Scarmack, 2011)

Accordingly, a new relationship between digital architecture and tectonics has emerged and described as "digital tectonics".

Digital tectonics, as the original tectonics theory by Botticher , Sekler and Frampton, emphasize the interaction between aesthetic and technical aspects in the form finding process. Both the traditional and the digital tectonics are clearly a way of expression the fusion between art and technology the phenomenological and the positivistic. (Andersson & Kirkegaard, 2006)

Beesley & Seebohm (2000) defined digital tectonics as a methodology that combined digital design tools and physical classic tectonics: "digital tectonic is an evolving methodology that integrates use of design software with traditional construction methods .We see digital tectonic design as a systematic use of geometric and spatial ordinances, used in combination with details and components directly related to contemporary construction." (Beesley & Seebohm, 2000)

Another definition of digital tectonics was suggested by Jabi (2004). His definition articulates the coherence of all processes that are done digitally within the creation of a piece of architecture "the poetics of digitally conceived, structurally clarified and directly manufactured architecture" (Jabi, 2004)

In the introduction to their book, titled Digital Tectonics (Leach et al. 2004), the editors defined the term digital tectonics relating to the new collaborative design process and the new role of architects and engineers evolved from the use of digital technologies: "a new paradigm of thinking in architectural culture facilitated by, but not totally dependent on, the technological possibilities afforded by the digital realm." They describe the shift to digital tectonics as a 'structural turn' due to a renewed focus on the structural integrity of buildings and new dialogues and collaborations between architects and engineers. (Leach, Turnbull, & C., 2004)

Relating to Botticher's original definition of tectonics, (Oxman, 2009) highlighted the ontological/representational relationship between digitally generated morphologies on one hand and structure and material on the other hand in defining digital tectonics: "Thus we can say that the digital is completing a transformation of the ontology of structure from a logic of order to dynamic models of material and structure. It is this major conceptual transformation of the relationship of material and structure to space and form that supports digital morphogenesis". (Oxman, 2009)

Lim (2009) and Lim & Liu (2006) tried to set a new theory for digital tectonics that substitute for the classic tectonic thinking and simultaneously can be applied to digital designs that rely heavily on non-classic, digital technology in their design and construction processes. Chor Lim and Yudong Lim identified seven components of classic tectonic thinking: object, material, structure, construction, joint, detail and interaction. (Lim, 2009) The seven components were derived from the previously discussed original theory of tectonics by Bötticher, Semper, Sekler and Frampton and were used to evolve new factors and realizations, which are integrally tied to 'digitally', from the existing tectonic framework. (Lim & Liu, 2006) They later stated that classic tectonic theory could not totally cover digital design and construction with the seven tectonic classic factors and then presented four additional digital factors, motion, information, generation, and fabrication. (Lim, 2009)

6. EXPRESSIONS OF DIGITAL TECTONICS/ATECTONICS

The last section of this research addresses some tectonic/Atectonic expressions of digital architecture. As previously discussed, the process of digital morphogenesis, the fundamental and most recent alteration to conventional design process, has resulted in new dialogue between ontological and representational nature of architecture which is the core of original tectonic theory. However, some recent examples of digitally generated forms have an Atectonic nature according to certain considerations. Both tectonic and Atectonic factors are part of architectural expression which include aspects of every quality of a building that shapes users experience. "The expressive content does not reveal some concealed subject matter to which access must be gained through the form; instead, the building's character comes to expression when it becomes directly perceptible through its architectural gestalt". (Janson, 2014) The last part of this research is a trial to reveal tectonic and Atectonic values behind some emerged digitally generated architecture expressions.
In order to reach the objective, the research focused on a case study of two selected pavilions of the World Expo 2020. Since 1851, World Expos, officially known as International Registered Exhibitions, have been considered a global galleries for innovative and creative solutions in the architectural and construction fields. The selected projects are, totally or partially, digitally generated through a digital form generating processes. Beside, each installation is meant to express one of the Expo sub themes: Mobility, sustainability and opportunity.

6.1 EXPRESSION OF MOBILITY: SOUTH KOREAN PAVILION

> *"The desert sunrises and rays from it are reflected from many dew droplets on a desert flower. The flickers of lights remind me of card stunts of spectators of the soccer stadium, it also takes me to the sing-along rock concert. The cohesive and spontaneous energy of Korean ness is very well expressed in these moments. A vision of a giant stadium-like structure with bright flickering lights comes to my mind."* Architects: Moon Hoon, Mooyuki

The Korean Pavilion is at the mobility district of the Expo. According to the official description of mobility, pavilions of the mobility district highlight the fusion between physical and digital in addition to the enormous amount of exchanged information and ideas that distinguishes modern world: "Experience how the Mobility District creates connections to drive the world forward, breaking down the divide between the physical and digital worlds to build a harmonious, global society where information, ideas and goods are exchanged faster than ever before. (Mobility District, 2021)

The Pavilion is a stadium-like structure which defined by stepped facade covered by three dimensional rotating cubes, making the northern façade a huge screen. See Figure 8. Every spinning cube has one digital face and three analogue color faces in an attempt to bring some freshness to contemporary digital media which the design team claims to become saturated and fatigued. Inside the pavilion is an open space, including a massive event plaza.

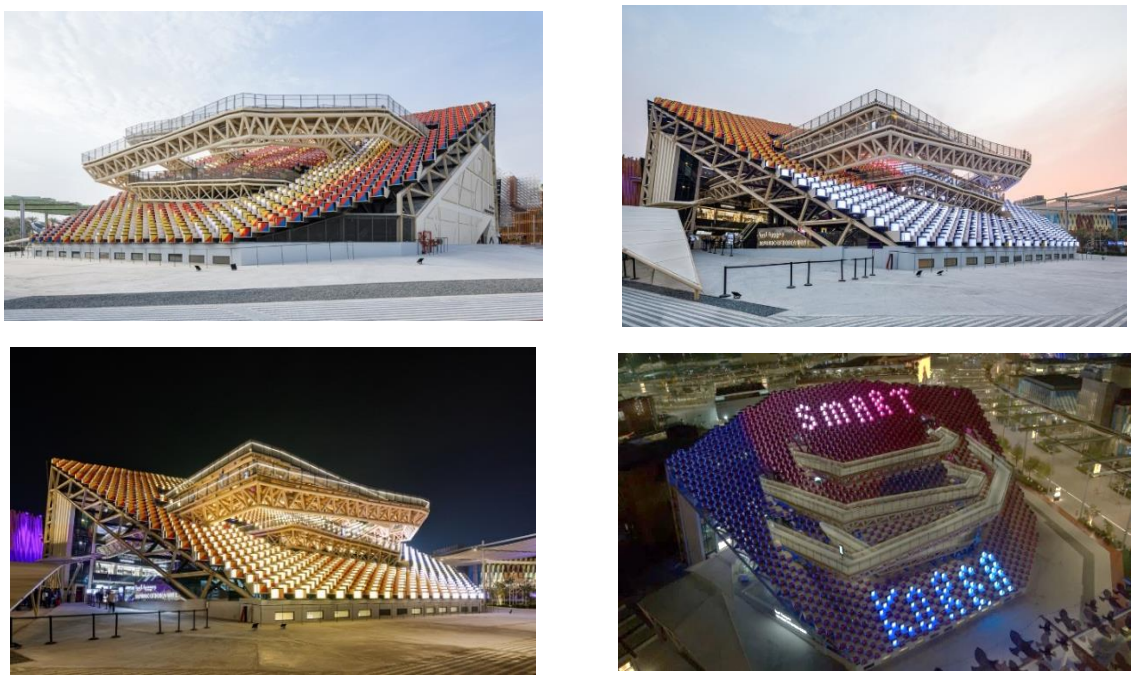


Figure 8 day and night views of the South Korea Spinning Cubes Pavilion at World Expo2020 (Abdel, 2021)

A spiral ramp penetrates the pavilion, allowing visitors to enjoy the exhibition and view the entire Expo. The pavilion digitally generated irregular form expresses mobility and at the same time shows classic tectonic properties. This irregular dynamic structure bring off mobility expression and, at the same time, perform tectonic values of ontological/representational relationship, structural/construction techniques and high-performing material use.

The pyramidal form of the main installation is a result to the special structure and reflects its properties, huge steel trusses that rise from the ground floor to shape the form of the main enclosure. In spite of being partially concealed by the stepped cubical façade, structural members are considered main elements of architectural composition as well. The interiors are in harmony with the exterior spatial experience. The supporting steel trusses shape the main event space and by forming a spiral movement spine, the four spiral ramps, that weave in and out of the building, intertwine and extrude as many viewpoints at differing levels and positions and create a fly-through experience through the entire structure. See Figure 9

A blend of both tectonic and Stereotomic is found in the construction of the pavilion. A tectonic sense is reached by specially treated joining points of the lightweight structural elements where sky light and breath can penetrate into the main activity hall while the Stereotomic sense is reached by the block-like organization of the spinning cubes at the main façade.

The pavilion shows a logical material use that reveals material nature. The lines of forces are articulated by the heaviest material in the architecture composition, the steel trusses, and are directly registered on the outer surface and interior space as well.

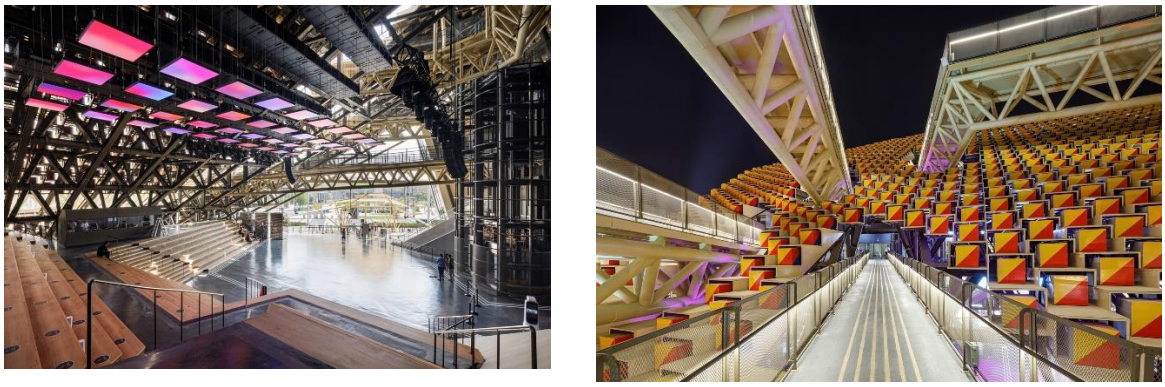


Figure 9 Left- the Madang – Right – Weaving Ramps (Abdel, 2021)

The Korean pavilion reflects traditional Koreans culture and at the same time interact with its context. "I wanted to create a structure that is like a tent in a desert, opened so that the sky can be seen and natural breeze could flow in and out," Moon Hoon from Mooyuki Architects said. (He-rim, 2021)
The tectonic quality of interaction is conveyed in two ways: the reflection of the Korean culture and the interaction with the pavilion context, the Arabian Gulf desert. The idea of the Madang of the traditional Korean house, an open empty space where many activities and events take place, is carried to the Korea pavilion on a large scale, where performances, spontaneous events, and festivals can take place. The large opening at the east is a gesture of blurred boundary where, passer-byes can enjoy the show, even without entering the pavilion. The irregularity of form, open-air seats randomly flocking in the Madang, evoke the expression of mobility in a dynamic interactive way. Like Bedouin summer tents, the southern facade has small apertures where thin rays of sunlight filter through and the breeze blows in.
See Figure 9.
The South Korean pavilion also shows digital tectonic qualities such as motion, information and generation. The pavilion aspires to exhibit the idea of mobility by the use of the array of spinning cubes envelope the facade as an expression of Korean citizens' mobility and their dynamic energy. Stacked and composed, 1597 pieces narrate abstract patterns of motion and words of significant messages (Abdel, 2021). The dynamic façade responds to the change of light around the day and to the information collected from visitors to from an interactive experience to audience.

6.2 EXPRESSION OF INTERCONNECTION: UK PAVILION

The opportunity section encourages the participant countries to promote self-expression and interconnectivity through their installation: "Witness how our lives and actions are interconnected in the Opportunity District. Meet the people worldwide who are transforming dreams and aspirations into the realities of tomorrow, and be empowered to shape the future by unlocking the potential within yourself." (Opportunity District, 2021)

> *"Algorithms are among us, they are an ever-growing part of our culture, their output is based on what they are trained on and who trains them. The pavilion is at once an expression of the ideal of a culturally diverse Britain that I grew up with, tempered with our growing awareness of the part algorithms play in shaping the future of our culture."*- Es Devlin, the architect.

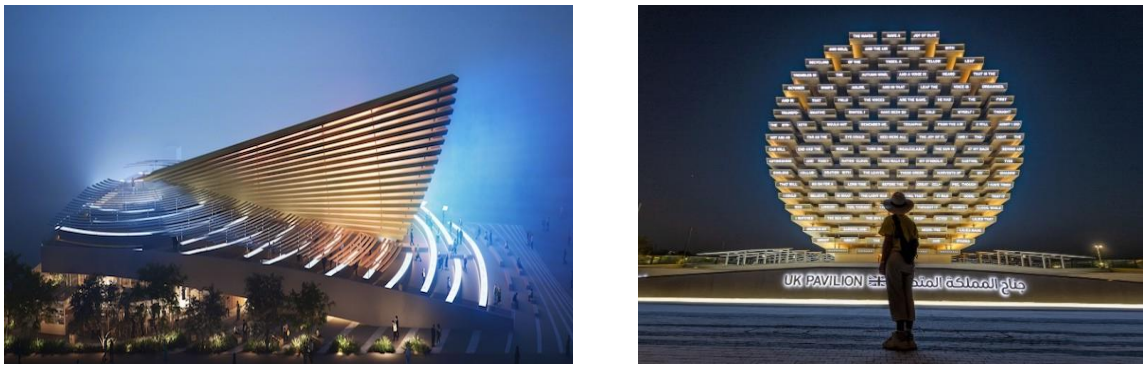


Figure 10 The wooden conical Pavilion of UK at World Expo 2020 (He-rim, 2021)

UK's contribution to Expo 2020 Dubai is a wooden sculptural structure that celebrates cultural diversity and collaboration, highlighting Britain as a meeting place of cultures and ideas. Created by artist and designer Es Devlin, the Poem Pavilion uses advanced machine learning algorithms to transform the input of visitors into collective poems. The latter can be read in illuminating displays on the façade, transforming the pavilion into an exhibit itself. (Cutieru , 2020) At the Poem Pavilion, visitors are invited to donate a word at the "mouthpiece" upon entering the central space, which showcases these contributions in English and Arabic, accompanied by a choral soundscape. An algorithm compiles the donated words into texts, generating a collective poem every minute. The machine learning model was initially trained on internet texts and was adapted to the project through a diverse selection of over five thousand poems carefully curated by a team of poetry curators. The poems recited in English, French, Chinese, and Arabic, the aim is to impart a feeling of unification despite different cultures and lifestyles. The pavilion is consisted of two underground floors topped with a structure which is shaped like a giant conical wooden musical instrument. See Figure 10. Visitors will visit three key areas, entering through an outdoor "Maze of Aspiration" with illuminated displays showing the UK's expertise in artificial intelligence and aerospace, which leads to the spherical Choral Space with its immersive soundscape and chance to contribute a single word to an algorithmic poem displayed for all to see across the Expo.

The final area is the Speech Space, where visitors can see their contribution to the collective message. The superficial centerpiece is a 20m-diameter composition made up of rows of branching slats that extend outwards from one central point to form a circular facade. Cone structure showcases the poetic couplets on a series of LED panels, 742 LED panels, on the front of the façade– a new poem generated every minute by the machine-learning algorithm. The couplets can also be viewed from inside the cone, where they'll be accompanied by an immersive musical soundscape.
Digital tectonics, generation, information, motion and information area initial aspects of the UK pavilion. The algorithmic interactive poems are generated and displayed both internally and externally giving the pavilion its unique character and express interaction with audience. AI technologies that depend on big-data and information generation are the gallery and the exhibits at the same time.

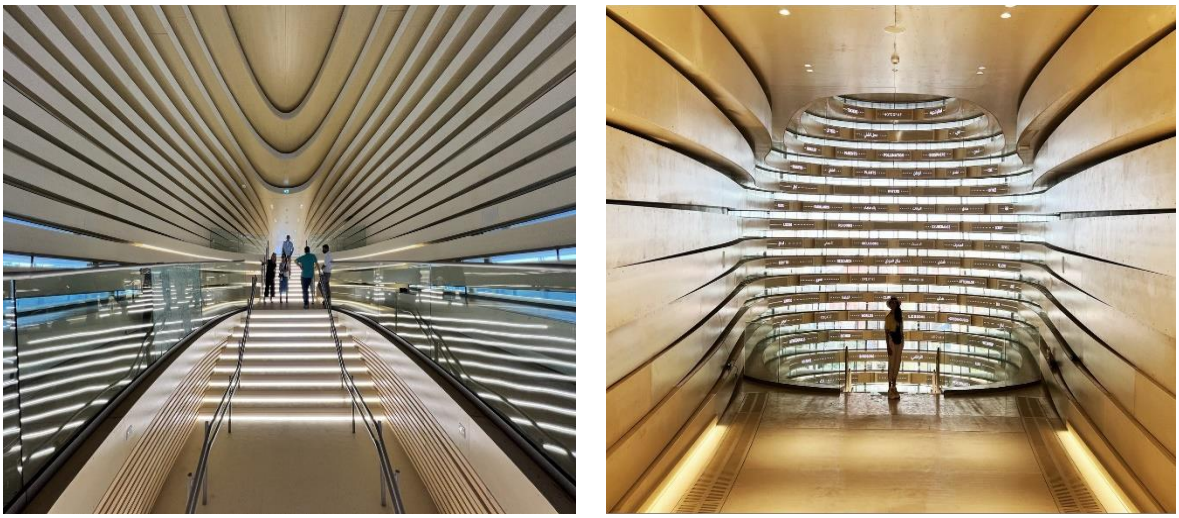


Figure 11 Interior of the wooden conical Pavilion of UK at World Expo 2020 (He-rim, 2021)

The flow of interactive data between the pavilion and its occupants is the main concept that derived the design process. The performative structure is a product of efficient collaboration between a team of architects, designers, engineers, and technical professionals to reach.

The pavilion construction was a mix of tectonic and Stereotomic, the structure is built from cross laminated timber and positioned on a concrete plinth. The structure is made of cross-laminated timber C.L.T. See Figure 12. The pavilion form pushed the boundaries of C.L.T, and timber as a whole by using C.L.T in a non-conventional configuration. Key to C.L.T selection was its strength in two directions; a result of each lamination being at 90 degrees to each other, and its high strength-to-weight ratio. In addition, the use of C.L.T permitted a high degree of flexibility and precision in defining the more free-form internal space by C.N.C machining. This C.L.T special paneling system is a structural system and an enclosure at the same time and creating an inner space, the conical choral space, that reflects the outer structure and reaching a strong ontological/representational relationship.

Figure 12 Installation of wooden structure, UK Pavilion, World Expo 2020

7. DISCUSSION AND CONCLUSION

For the past two centuries, tectonics have been used in architecture theory to refer to the connection between physical and abstract aspects of the art of buildings that resulting in creating special forms with certain architecture expressions. With the emergence of digital technologies, the traditions of architectural logics were challenged by the new potentials of virtual design environment. The possibilities of creating unlimited shapes and forms neglecting the natural laws of forces and materials resulted in rethinking the tectonic theory. Theorists talked about a full replacement of physical architecture with virtual environments where materials are zero thick surfaces and gravity lows are not exiting. These radical ideas were limited to the fact that interaction between construction and material is an important aspect whole comprehension of what it means to construct and build.
This research paper has discussed the terms tectonics, Atectonic and digital tectonics as a possible frame work to describe how technological aspects are affecting the expression of digital architecture.

First, Through the literature study of tectonic theory, it was found that the relationship between tectonics and digital architecture expression can be classified as follows (see Figure 13):

- **Craft-tectonics**: the first definition of tectonics was mainly concerning the art and crafts of building techniques. The aspects of classic tectonic theory were all related to the "craft of building" since all technologies related to architecture at that time were perceptible techniques concerning the interaction between building materials, type of construction and the resulting forms and spaces where representational building characters are reflection to its ontology. That means, the main issue of classic tectonics was the interaction between material and type of construction on one hand, and the communication of the logics of the chosen structure on the other hand.

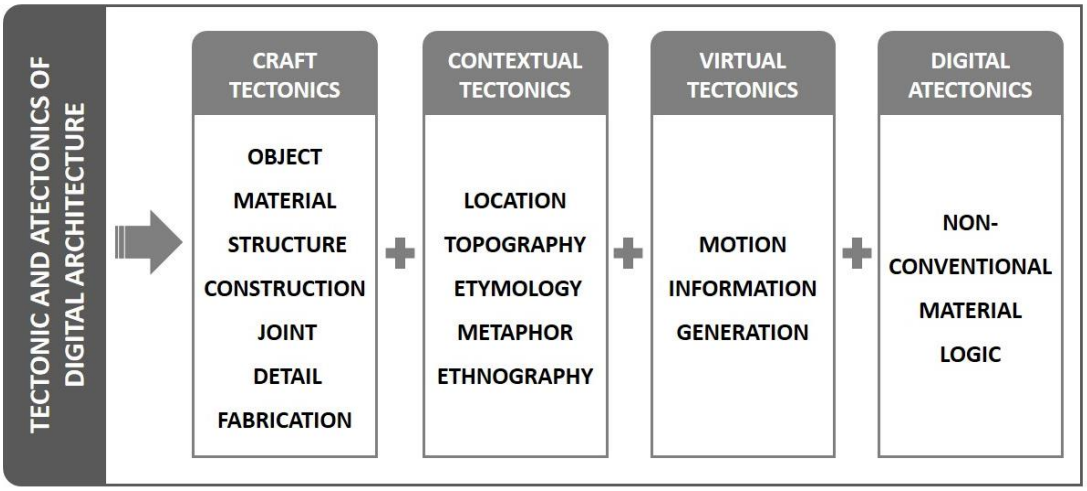


Figure 13 Tectonic and Atectonic of digital architecture (Author)

- **Contextual tectonics**: later theorists, like Kenneth Frampton and others, have expanded the tectonic definition to include contextual factors derived from place, culture and people. They emphasized cultural and contextual nature of tectonics by relating it to its diverse origins in scopes of etymology, topography, metaphor, ethnography, technology and representation as well as ontology.

- **Virtual Tectonics:**
  In fact, it could be said that the major transformation to the tectonic theory that resulting from the digital revolution was considering tectonic processes, not the tectonic logic, reveal the truth of the building and its context. Accordingly, the classic tectonic theory by Bötticher, Semper, Sekler, and Frampton's is not sufficient enough to describe new expressions of digital tectonics. The new digital tectonic framework had included "virtual" technological aspects like motion, information and generation. Although these recent aspects could not be physically handed, it becomes an important technological factors in digital design and built process.

- **Digital Atectonic:**
  According to the literature study, the Atectonic expressions mainly related to the concealment of interaction of load and support in architecture and the use of materials without following the logical way of its characteristics. However, some Atectonic aspects are addressed to express some local and cultural expressions. In another word, Atectonic were found were the construction methods neglect the natural characters of building lows and materials to achieve expressional goals. This original definition of Atectonic was challenged by the emergence of new building techniques and material use that resulted from previously mentioned virtual tectonics. For example, Building materials have obtained new logic of construction to express virtual tectonics like motion and generation. This new logic was a result to the use of digital techniques in the manufacturing process of the material itself.

Finally, from the analytical study of the two examples of digital architecture at the end part of this paper, it was found that computer technology is used to reach certain expressions by the help of virtual tectonics such as information, generation, interaction and advanced fabrication techniques. The boundaries between former definitions of tectonics and Atectonic are blurred, like the use of wooden panels in Uk pavilion, it became possible to compose materials with almost any thinkable properties combined. On the level of ontological/representational nature of the architecture form, this in some ways changes the logics of construction, and therefore also the logics of tectonic structures. The tectonic expressions of digitally generated morphologies are the matter of integrating the traditional terms of craft and contextual tectonics with the emerging and evolving aspects of virtual tectonics where dynamic, interaction, communication, collaboration and performance are the new ways of considering architecture expression.

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