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Digital Tectonic Design as a New Approach to Architectural Design Methodology

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Abstract

Digital tectonics is an evolving methodology that integrates use of design software with traditional construction methods. Computer linked fabrication techniques of many kinds have become an integral part of the design process, while new digital tools are allowing engineers and architects to understand in far more detail the behaviour of load carrying surfaces, and to generate new architectural forms. The digital tectonics design is presented as a fresh approach focused on the role and application of materials and technology in the creation of architecture 21st century. 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. This paper tackles the theoretical and practical aspects of the field. A few examples including: EMP in Seattle (2000), Lord's Cricket Ground in London (1999), Opera House in Guangzhou (2011), Centre Pompidou in Metz (2010) will be presented.

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Keywords: digital technology, digital tectonics, nonlinear shaping envelop, tectonic problems, new challenge;

1. Introduction

Digital Tectonics focuses on the role and application of materials and technology in the creation of contemporary architecture. CAD/CAM technologies create new opportunities by allowing the production and construction of complex forms, which until recently were difficult to design and build using traditional construction technologies. A virtual free surface imposes such technical solutions and materials which question the traditional thinking about a

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building. Computer linked fabrication techniques of many kinds have become an integral part of the design process, while new digital tools allow engineers and architects to understand in whole more detail the behaviour of load carrying surfaces and to generate new architectural forms. In this field, digital tectonics design appears as a new approach to architectural design methodology and application of materials and technology in the creation of contemporary architecture. This approach shows a new way of thinking about the architectural project but at the same time indicates new tasks to resolve.

2. What is a Tectonic in architecture – from Semper to Schumacher

Today, tectonics is becoming a seminal concept in recent discourse in the field of material-based design in digital architecture. It originated from Late Latin tectonicus, from Greek tektonikos "pertaining to building," from tekton (genitive tektonos) "builder, carpenter, woodworker; master in any art (sculpture, metal-work, writing). The person that went back to this phrase was Gottfried Semper, who rejected the traditional theory held by Vitruvious: utilitas, fermitas, and venustas. Semper distinguished the critical elements of architecture in terms of the tectonic, associated with lightweight, linear components and the stereotomic, as a form of heavy earthwork constructions. He also distinguished two types of tectonics, ontological and representational. The former included a minimum set of designs, shaped to emphasize its features and cultural status. The second involved the presentation of an existing but invisible construction element.

Frampton noted that the Semperian separation of tectonics and stereotonics was wrong because the architecture of the human experience generally takes place between earth and heaven [1]. Buildings become meaningless through the act of building them from scratch, by the reign of the structure, through mutual support, to the rhythm of the revetment and window modulation. Frampton also emphasizes the fact that these physical objects almost defy a sense of time and that duration is a value in architecture. When applying this to the terms of tectonic and stereotomic. Currently, Patrik Schumacher [2], a respected authority, claims that the theory of architectural recognizes the rationality of tectonic articulation as strategy of articulation. It is no self-serving pursuit and must remain subordinated to the concern of facilitating social functions. The agenda of articulation selects the final solution from all technically viable solutions according to the phenomenological and semi-logical requirements. The internal ordering of large spaces might be further facilitated by the lawful differentiation of the structural system: the different (longitudinal versus transversal) directions of the space might be indicated by the direction of the primary beams. The centre of a large space might be indicated by the greatest depth of the beams etc. These features might serve as orienting clues within a large, otherwise visually partitioned space like a large market space. However, if a rich network of different and differently related spaces needs to be articulated, then the enlistment of the (technically relatively homogenous) structure might not be feasible by not being versatile enough. (It might lack the requisite variety). On the other hand, to force the structure into articulatory differences might become too forced and cost-wise prohibitive. In such cases the structure might be covered by a suspended ceiling which should be more pliable (with more points of freedom) and thus better to serve the agenda of articulation. The articulatory integration of the morphological consequences of technical requirements is always the more elegant solution than the attempt to fight and deny them by hiding or obfuscating them. In order for architects to pursue tectonic articulation, they need to guide and orchestrate the engineering investigations and then select the engineering options that suit their primary task most, namely to fulfil the posed social functions via framing communications. The adaptive differentiation of structures as well as the adaptive differentiation of volumes and envelopes according to the building's environmental performance (with respect to its exposure to sun, wind, rain etc.), give many opportunities for differential tectonic articulation. Thus, a lawfully differentiated, built environment would be much more legible and navigable than the modernist, isotropic order of repetition. With the development of sophisticated computational design tools - both within architecture and the engineering disciplines - the scope for nuanced tectonic articulation has much increased.

3. Digital Tectonic, Morphogenesis and Envelops

The last dozen years have brought the first attempts to define digital tectonics from concepts such as a generative form-making system [3] to new way of making and thinking about form and construction [4] where the authors put great emphasis on the relationship between the methods of digital design and fabrication processes. On the other hand,

[5] it appears as an attempt to characterize the digital tectonics as a change in thinking about digital design, which increases the importance of structure and the materials that lead to the synthesis of architecture and structural engineering. Therefore, the digital tectonics becomes the basis for a shift in thinking about architecture and construction process, but also becomes the foundation for morphogenesis. The term morphogenesis today represents a body of key concepts relevant to the theory and methods of digital design [6]. Digital morphogenesis is proposed as an emerging body of methods and techniques related to the morphological formalisms and representational models of digital tectonics. Digital morphogenesis uses models of digital tectonics to control the adaptation process. The design process can be freely evolving, or can be result of calculation or external data. The man chooses the strategy of adaptive system, which can affect and make changes. But still we do not know the maximal potential of this paradigm; perhaps it will exceed the current knowledge about the topology and tectonics, leading to new technologies and theories in digital design [7]. Digital tectonics is therefore not only a system of thinking of the building forms and their construction, but it also becomes a factor of generating these forms.

Digital tectonics may also be described by keywords. The interaction between construction and material is an important aspect of revealing the truth of the nature of loads, forces and material properties – in it lies the whole comprehension of what it means to construct and build. It is therefore suggested that digital tectonics is a combination of interaction between material and construction, clear and logical structure, and performative architecture [8]. In this sense, digital tectonics develops as layers that use digital technology, can be freely modified and interact between them, in this way we get digital envelopes. So far, the perception of the envelope in architecture became final discourse of the structure and decoration. Regardless of whether it was inside or outside, it was always a layer that could be removed to reveal the substrate, which was the true inner surface architecture. The term surface therefore usually meant a layer of some thickness, something that covers or masks. To this day there are metaphors in architecture, such as: clothing, clothes, naked structure, "skin and bones," describing how the building is "dressed" by its surface. For Vitruvius and early modernists, surface was a surface layer or external, foreign to the principal tectonic structures. Leone B. Alberti (1404-1472) argued that architecture is first "naked" structure, which is later "clothed" in the ornament. Physical independence of externals (curtain wall) was an important determinant of modernist architecture and a manifestation of techniques and technologies. In the era of digital tools, there is a growing tendency to treat the outer "skin" of a building as an autonomous - independent from other parts of the building.

4. Constructing curvilinear building „skins”

The explorations of constructability of geometrically complex envelopes in the projects of the digital avant-garde have led to a rethinking of surface tectonics. The building envelope is increasingly being explored for its potential to reunify the skin and the structure, as opposed to the binary logics of the Modernist tectonic thinking. The structure becomes embedded or subsumed into the skin, as in *semi-monocoque* and *monocoque* structures, in which the skin absorbs all or most of the stresses. The principal idea is to conflate the structure and the skin into one element, thus creating self-supporting forms that require no armature [9].

Figure 1. Frank Gehry Associates, Experience Music Project (EMP), Seattle 2000.

An excellent example of monocoque structures is the EMP (1997-2000) in Seattle by F. Gehry Associates. CATIA allowed the project team to translate EMP's three-dimensional shapes into coordinated drawings and geometric data that builders and fabricators could understand. The museum consists of 7 elements that look like irregular undulating blobs (Fig.1). Their structure is composed of cages with curved steel ribs. The steel ribs frame cross-sections, produced by contouring. Each of the undulating structural ribs is unique. The cages were covered from the outside with steel mesh 'canvas' on which the liquid concrete mixture was applied with the shotcrete method [10]. Future Systems also applied this solution for such structures during the implementation of streamlined forms NatWest Media Centre (1999), at Lord's Cricket Ground in London. (Fig.2) Semi-monocoque structure is made of aluminium. It was a waterproof skin, easy in forming, anticorrosive material. Shell formed (according to the geometry of the project) and pre-assembled in one of the British shipyards. The whole element was divided into sections with a span of 26.3 m and transported to the place where they were combined and supported on reinforced concrete pillars, [11].

Figure 2. Future Systems, Lord's Cricket Ground, London, 1999.

There are a few production strategies used for two-dimensional fabrication. They often include contouring, triangulation (or polygonal tessellation), use of ruled, developable surfaces, and unfolding. They all involve the extraction of two-dimensional, planar components from geometrically complex surfaces or solids comprising the building's form. The challenge in the two-dimensional interpretation is to choose an appropriate geometric approximation that will preserve the essential qualities of the initial 3D form. Which of the production strategies is used, depends on what is being defined tectonically: structure, envelope, a combination of the two, etc. [9].

Figure 3. Zaha Hadid Architects, Opera House, Guangzhou, 2011.

An example of a building where you can perfectly see the realization of assumptions of digital tectonics is the Opera House in Gaungzhou designed by Zaha Hadid. The request of designers to accurately reproduce this unique form helped to develop a completely new type of steel structural system composed of a decomposable mesh facets on the plane. These facets combine edges and vertices, not maintaining a uniform, smoothly curved surface provided in the project, which would correspond to the conceptual assumptions. The designers then have to solve the problem of insulation system, on which a top layer of granite slabs was laid, and find a way to introduce glazing of the curvilinear shape. To achieve these goals, they designed much denser steel mesh, which is imposed from the top, on the facets of construction. The purpose of this grid was also levelling, as if smoothing of edges and vertices of covering construction facets (Fig.3). Structural "skin" of buildings in Guangzhou is an excellent example showing difficulties in implementation of digital tectonics. It also indicates the need for new materials that will be able to maintain the continuity of "skin" and eliminate additional support system. Architects waiting for new materials that are lightweight and easy to form, are forced to search for a new relationship between the "old" materials, techniques and new geometry [12]. A great illustration of the use of well-known materials for the curvilinear geometry is Centre Pompidou in Metz

(Fig. 4). The building features a hexagonal doubly curved roof constructed using a three-way timber system. It's completely computerised designing process and complex computations, prove that the well-known technology of the Glued Laminated Timber, carefully controlled construction and expert knowledge of appropriate timber jointing techniques - the bolt and multiple screws, can be fully upgraded into the digital age, [13].

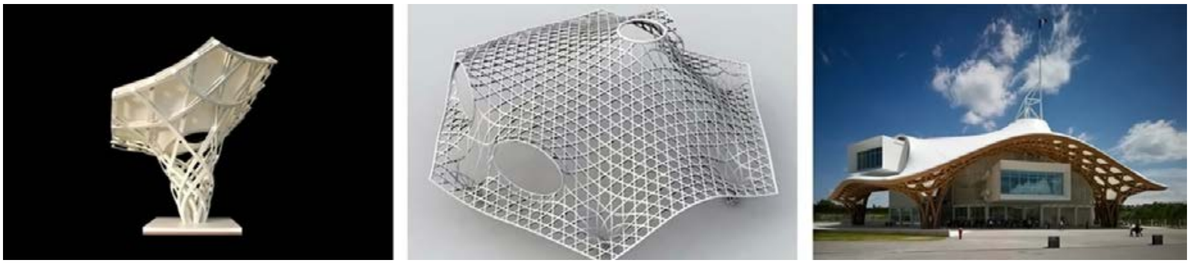

Figure 4. Shigeru Bam, Centre Pompidou-Metz, Metz, 2010.

5. Discussion

The concept of tectonics has a long history in architecture. The idea of the tectonics is one of the decisive moments in the development towards modern architecture. The discussion on the ornamentation and the nature of classical orders later gave rise to a fundamental break from tradition. Today, structural principles are explored and the differences between structural wire frame and enclosing surfaces – between the tectonic and the stereotomic – are starting to dissolve or put into new relations. However, the new possibilities and consequences of digital technology need to be articulated, analysed and presented to architects, structural engineers and the extensive building industry.

6. Conclusion

Digital Tectonics outlines an emerging paradigm in architectural design a renewed interest in structure and a growing synergy between architects and engineers. The last few years were a time of a great development of digital tools for creating curvilinear forms with simultaneously developing the theory and methodology of the design of these shapes. These new architectures emerging from new kinds of industrial production and design tools require new thinking and conceptions of architecture both from the perspective of the designer and the person experiencing the built environment. Growing out of the analogue digital tectonics becomes the primary factor in modern thinking, designing and constructing buildings. One can only expect its impact to bring new materials, technologies and design tools, and even more interesting buildings.

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