NEW TECTONICS: New Factors in Digital Spaces

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Abstract. The issue of tectonics began to be discussed in the architectural field in the nineteenth century. Recently, it has become a new issue again as the new digital space and new form appear as a result of the impact by the computer-aid design process. The objective of this research is to explore the preliminary framework of new tectonics in the digital space by analyzing the design cases. We aim to analyze and conclude the digital and non-digital factors in the new tectonics. Subsequently, this research concludes seven non-digital factors: joint, detail, material, object, structure, construction, interaction; and four new digital factors: motion, information, generation and fabrication.

1. Introduction

The term "tectonic" derives from the Greek term *tekton*, signifying carpenter or builder. This meaning evolved from something specific and physical, such as carpentry to refer to the artistry, method, materials, and even the concept of art, and become an aspect of poetry. In the nineteenth century, the German theorist Botticher first elaborated the concept of tectonics in the architectural domain. He distinguished between the nucleus (Kernform) and decorative cladding (Kunst-form) of the building form, and further this cladding had to be able to reveal the inner essence of the tectonic nucleus. He also proposed the idea of part and whole. The famous German architectural theorist Semper privileges the joint as the primordial tectonics factors as the fundamental nexus around which a building comes into being. Additionally, he divided the built form into two material procedures: tectonics of the frame and stereotomics of compressive mass (Semper, 1951).

Some researchers continued discussing these theories in the twentieth century: Sekler (1957) used some examples to distinguish between structures, construction and tectonics. Gregotti emphasized the essence of detail while Frascari revealed that the tectonic detail is thus the site of innovation and invention (Gregotti, 1983; Frascari, 1984). In addition to the static factor—joint—Frampton proposed that the Coroporeal Metaphor and Topography are also significant tectonics factors. He defines tectonics as "Poetics of construction". The French architect Cache considers that Semper's theory is the condition produced in a new building offered in new industrial development at that time, however, the digital era offers new production possibilities and new condition too. Scientific and technological development creates an opportunity to use diversified materials and to operate different manufacture processes. Information also acts as material (Cache, 2002).

2. Problem and Objective

To consider the value and meaning of tectonics in the digital design process, Gao (2004) analyzed many current digital design cases, attempting to explore the phenomenon of new tectonics. She concluded with five key traditional factors of tectonics from the research among tectonics-related literature found: detail/joint, material, object, structure, and construction. However, we can discover from Gao's study that the factors she drew from traditional theory of tectonics were general ones; which is relevant to the structural technique while, in fact, factors such as perception and topography (Frampton, 1995), which are not relevant to technique, but to the relationship between architecture and site environment, and between architecture and human being, are also implied in the traditional tectonics. In particular, topography is also an essential and influential factor to the construction of the architecture. Therefore, the objective purpose of this study is to proceed from Gao's study, aim to re-integrate the traditional tectonics factors and investigate new tectonics factors derived from the digital architectural design in this digital era. In so doing this paper attempts to integrate the preliminary framework of the new tectonics and investigate the digital & non-digital factors contained within.

3. Methodology and Steps

Case study is being operated according to the following steps:

Step 1

Based on the study of Gao (2004), this research re-inspects and re-identifies traditional tectonic factors from overall literature in order to derive appropriate traditional tectonics factors and define them.

After the discussion of the traditional tectonics factors, three free-form design cases selected from The Far Eastern International Digital Design Award (Feidad) from 2000 to 2002 were analyzed. Designers of the selected works are new generation designers from different countries. The traditional tectonics factors were re-examined in these cases to discern the digital tectonics factors. The cases are as below:

CASE [1]-- Design Merit Award / 2000 (OCEANnorth / Norway + U.S.A)
Ambient Amplifiers-The Logics of Uncertainty
CASE [2]-- Outstanding Award / 2001 (dECOi Architects / French + U.K)
Aegis Hypo-Surface(c) Patent pending
CASE [3]-- Outstanding Award / 2002 (Achim Menges / U.K)
Post agriculture

Step 2

Due to the digital characteristic in the digital design process, some new digital tectonic factors derive from the digital design cases in Step 1.These new digital tectonic factors are being discussed and defined.

After analyzing and defining the new digital tectonic factors, three FEIDAD cases were analyzed by these digital tectonic factors.

4. Analysis

4.1. TRADITIONAL TECTONIC FACTORS

4.1.1. Discussion of seven traditional tectonic factors

This research induces seven important traditional tectonic factors from the literature review. The analysis and the definitions of the seven traditional factors are as below:

1. Joint

As noted previously, Semper (1951) defined the joint as the most basic tectonics factor while the building formed; Frascari (1984) addressed that the joint is the generator of construction; and Frampton (1995) also defined the joint as the smallest unit element of the building. So this research regards the joint as the first tectonic factor. It is defined as the most essential and the smallest unit of the building construction. Its functions as the linkage in different hierarchy between the components in the whole building such as materials, structures, and objects.

2. Detail

Gregotti (1983) defined the detail as the description of the material which can demonstrate the characteristic of the material to make the design more clear. In addition, detail is the principle of the structure. Frascari (1984) defined the detail as the “tell-the-tale Detail”, because each detail tells us the story of the building’s making, placing and dimensioning. Therefore, this research regards the detail as the second tectonic factor and defines it as the way of composition in making, placing and dimensioning the building construction and the method to narrate different characteristics of material.

3. Material

In the study of tectonics, Semper (1951) defined the different methods of assembly in the compositions between different materials: Tectonics of the frame (the wood and steel), stereotomics of the earthwork (the stone, soil, concrete). Cache (2002) redefined the material. He considered that we can use various new materials and production processes in the digital era; taking into consideration that information is also a kind of material. So material is regarded as the third tectonic factor. It is defined as the element which can represent the appearing of the building. The application of material and its method of assembly express the intention of the architectural design, such as using the concrete to represent the heavy volume and using the glass to display slim and gracefully.

4. Object

Boetticher (1843) defined the tectonic as a system that combined a lot of parts. He takes temple of Greece as an example, emphasizes that a lot of parts is combined into a system of a whole. So according to this concept, this research redefines the parts as the object of the building, for instance column, beam, wall, roof, floor, door, window, etc. These objects have certain building meaning and function attribute. This research regards object as the fourth tectonic factor.

5. Structure

Sekler (1957) distinguishes the relationship among structure, construction and the tectonic. In his definition, “construction” carries a connotation of something put together consciously while “structure” refers to an ordered arrangement of constituent parts in a much wider sense. Moreover, he pointed out that “tectonic” is the expression of a relation of form to force which is relevant to “structure” and “construction”. “Structure” and “construction’ are always conducted by the engineer while “tectonic” is controlled by the architect. From Sekler’s definition, we observe that structure is the important factor which can influence tectonics, so structure is regarded as the fifth tectonic factor, and defines it as the component which is enable to display the mechanics principle and the transmission of strength, such as the bearing structure of the different materials. It can be a unit, a concept or a kind of process.

6. Construction

From the preceding definition of the fifth tectonic factor, we can learn that construction is also an important tectonic factor. Sekler (1957) defined construction as the method of realizing the structural concept, and the process of placing the components of the building correspondingly. So this research regards construction as the sixth tectonic factor, its definition is the whole assembly process and the composition framework of the different tectonic factors mentioned above.

7. Interaction

Frampton (1995) emphasized the “Poetics of Construction” while discussing tectonic. He stressed the important role of Topography and Perception (Corpereal Metaphor) in the building construction. The concept of Topography emphasizes the relation between the building and site; while Corpereal Metaphor is the relationship between human sense and the space. Hence we combine these two concepts as the seventh tectonic factor, and call it interaction. The definition of interaction is the relationship between building and the site and the interaction between people and space.

4.1.2. Three FEIDAD cases analyzed by seven traditional tectonic factors

The three FEIDAD digital design cases are as below:

CASE [1]-- Ambient Amplifiers—The Logics of Uncertainty: The designer team of this project is OCEAN north from the UK and the US. The key architects are Birger Sevaldson and Phu Duong. The intention of this design is to investigate the use of computer technology as engine for mediation of processes where form and program reconfigure and redefine each other in a mutual timebased process.

CASE [2]-- Aegis Hypo-Surface(c) (patent pending) was designed by a team called dECOi Architects, comprising architects from France and the UK. This design presents a dynamic, wall-like art decoration, which can react to the actions and sounds of their surrounding.

CASE [3]-- Post Agriculture, designed by a British architect Achim Menges. Its main theme is to reflect, in the spatial presentation of the architectural form, the special conditions captured in the construction site.

The design characteristics are investigated as follows with respect to traditional tectonic factors such as joint, detail, material, object, structure, construction, and interaction.

1. Joint

CASE [1]-- In the design process of this project, the characteristic of the joint is vague. The development of surface is derived from the study of the influence, produced by conceptual environmental factors of the construction site. It appears that the layers in the space are lightly superimposed, instead of being jointed together, as seen in Figure 1(a).

CASE [2]-- The unit element of this dynamic wall surface is an 8.0 m x 8.0 m modular metal piece. The central joint-point links to a computer-controlled activation system, allowing the metal piece to adjust and turn to the desired direction, as depicted in Figure 1(b).

CASE [3]-- The development of the entire structure is founded on a prototype consisting of multiple self-supporting air chambers. This prototype of an airbag pattern became the smallest unit element in the overall design. Meanwhile, all airbags are linked together by joints, forming a giant structural shape, which can be seen in Figure 1(c).

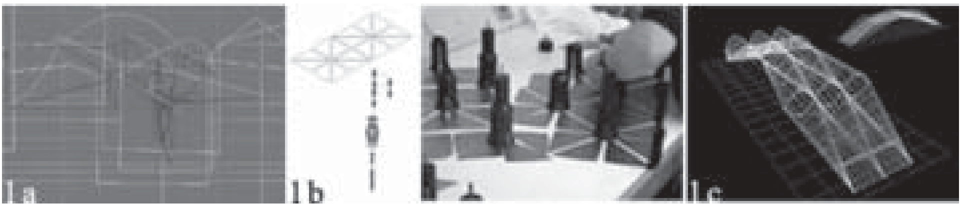

Figure 1.

2. Details

CASE [1]-- Nil.

CASE [2]-- The complete wall is comprised of activators that are put together in a matrix-like arrangement. Each activator is linked to a computer in order to receive and transmit signals. Its unit device consists of a modular piece measuring 8.0 m x 8.0 m. Having thousands of activators, the structure presents itself as a screen with a 3-D effect, evident in Figure 2(a) and (b).

CASE [3]-- As shown in Figure 2(c), the changes of the state of the airbag's surface under a sequence of parameters are indicated in a series of studies using physical models. The structuring and surface form of the airbag unit can be presented in various states through the changes of parameters (such as orientation, deployment and density) and the applications of various strengths, depths and internal pressures at the joints of the structure.

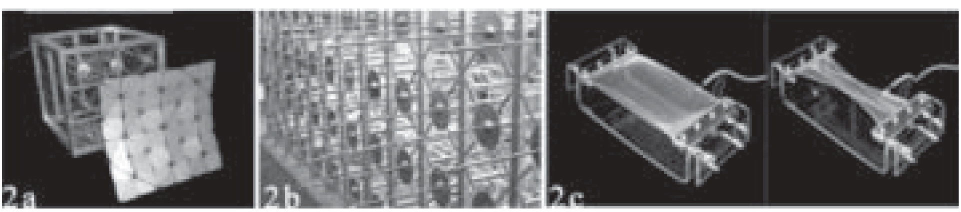

Figure 2.

3. Material

CASE [1]-- In the perspective view, one discovers that the designer presented the characteristics of some materials, whereby a whole piece of glossy and glistening glass was highlighted, as seen in Figure 3(a).

CASE [2]-- This work is actually a big mechanical device piece. The major and substantial materials used are some machine equipment and metal pieces that enable the device's surface to have a dynamic effect. Because this design project is a device that provides visual presentation, the overall presentation of the materials is manifested in the use of light in conjunction with the metal pieces that have reflectivity, as seen in Figure 3(b).

CASE [3]-- In a study that simulated the variation of the airbag, the feature of the membrane material was investigated. As shown in Figure 3(c), the variation of the airbag membrane's state under various conditions became the topic of the material study. In addition to the study of the surface of the airbag membrane, quite a few applications of metallic truss were also observed in the perspective images of the design. The processing of digital images was performed in an attempt to communicate a more real presentation of the feel and look of the material.

Figure 3.

4. Object

CASE [1]-- In Figure 4(a), the basic and generally-understood architectural elements such as column, wall, beam, slab, door, window, et al cannot be identified in the entire architecture. Instead, they are replaced by the spaces defined and enclosed by the surfaces. Every surface generated by the environmental factors in this project could be considered the most basic element consisting of an integral space pattern.

CASE [2]-- Figure 4(b) shows the unit objects of the basic device that has an interactive surface. Each metal piece in the object is linked to a computer-controlled adjustment device. The entire metal device rumbles when in operation and presents a different picture, colour and dynamic effect—as a response to the signals received from their surrounding.

CASE [3]-- Each airbag unit becomes the most basic design prototype. From Figure 4(c) we can observe that the original object developed from the iteration process for the digital and physical objects. The development of the airbag prototype object became the key to the construction of the overall design form.

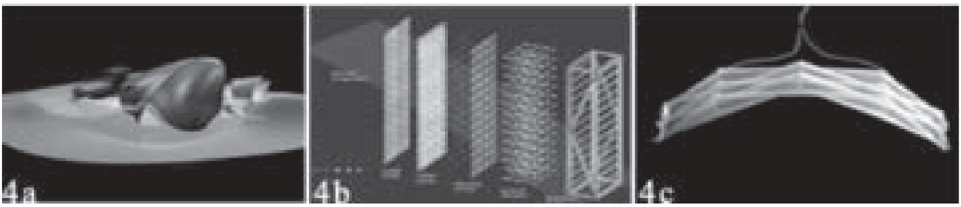

Figure 4.

5. Structure

CASE [1]-- In Figure 5(a), the designer employed a giant spatial truss within a spatial structure to link every activity taking place in the given space. With spatial structures for various activities brought together, the pedestrian who advances in the spatial truss can witness various activities interwoven together. For the structure as a whole, the designer still places emphasis on the relationship among the levels of the architecture.

CASE [2]-- In the concept of the structure the entire structure presents itself as a wave form as seen in mathematical models. Figure 5(b) shows the state presented as a result of the surface structure's geometric motion and pattern. Through the interaction of signals and forms, this kind of structuring method reflects how likely it is to directly transform the pattern to a substantial structure.

CASE [3]-- The design emphasizes an organized model that was generated from the behaviour of a structure at a deeper level, pointing to a dynamic relationship coming from the interaction between the specific external conditions and the internal structural system. From Figure 5(c) and (5d), it is made clear that the entire structure was established on the structure system's functions, at different levels. This enables the structural pattern of the giant system to change under different environmental conditions.

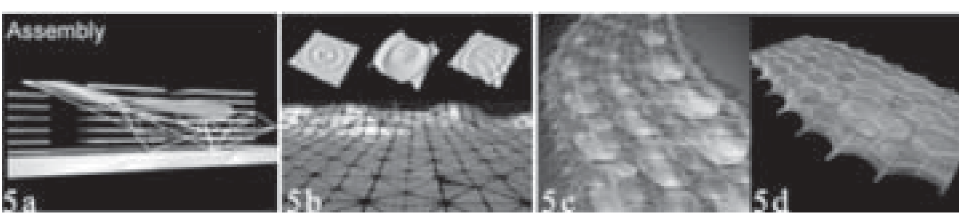

Figure 5.

6. Construction

CASE [1]-- Figure 6(a) shows the contour of the entire design form that was generated after the performing of structural analysis for the extended structure. There is no way for us to identify the kind of structure available in the real world, which could make this form possible. Because of this uncertainty, this structure presents itself as a highly virtual structure. In the digital world, any structural design pattern is possible.

CASE [2]-- This project presents a reaction-sensitive digital device using a mechanical construction, combining an electronic sensor system, a computing system and a program algorithm, and finally linking the whole to a physical mechanical construction as shown in Figure 6(b). The mechanical device continually receives signals from its surrounding during operation. The computer-controlled activator controls the rise and fall of the surface and hence the geometry, giving the rigid machine a sense of beauty in its motion.

CASE [3]-- One can construct a highly changeable space for the airbag's structure from the result of geometric procedures and the application of pre-stressing force on the membrane. Figure 6(c) shows a sketch for the cross-section of the decomposed construction, bringing out the correlation among structure's various levels and the connection of the airbag surface.

Figure 6

7. Interaction

CASE [1]-- The initial form was laid upon the texture of the construction site. The architectural form is closely linked to the ambient environment. The relationship between the construction site and the form can be observed in Figure 7(a), showing a gradually rising "island" from the earth's surface, which evolves from the context of the existent construction site.

CASE [2]-- Interactivity is most emphasized in this project. Through dialogue with the environment, a surface pattern can automatically present the state of the surface that best fits its environment. Figure 7(b) shows the continual images produced in correspondence to the rhythm, sound, and action coming from a musical performance. The wall and the performer jointly form an integral part of the whole stage, instead of merely serving as a background to the stage.

CASE [3]-- The designer utilizes the sophisticated computerized perspective view to present the variation with the state of the environment. The design finally presents a spatial form with a big stretch, which could offer a place, able to provide agreeable light and temperature according to different spatial panning costumed for different activity as seen in Figure 7(c).

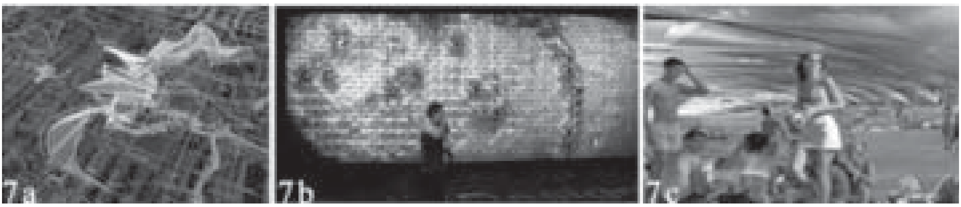

Figure 7.

4.2. DIGITAL TECTONIC FACTORS

4.2.1. Discussion of four new digital tectonic factors

Various and diversified digital media are utilized to aid the design process in the present digital design cases. The characteristics of digital environment such as dynamic manipulating process, immateriality, zero gravity state and multi-dimension, etc; and digital technologies such as 3D modelling software, generative system, algorithms, and CAD/CAM fabrication, are gradually changinge the design method and construction process of the architectural design. Therefore, we found that the seven traditional tectonic factors are no longer sufficient to analyse some characteristics in the digital design cases. Some digital characteristics and phenomena are found in the analysis in Step 1, and these are concluded as follows:

1. Motion

From the analysis in Step 1, we found that these cases use the dynamic process to deduce the design concept, such as utilizing the animation and the morphing operation in form making or form finding process. So we regard motion as the first digital tectonic factor. It is defined as the dynamic operation process in the manipulation of design concept or form finding.

2. Information

There is a characteristic of immateriality in the digital environment. The digital design cases derive the concept of material by merging the information into the building form and function as the new material. Information becomes a new kind of building's surface material. It derives the concept of the traditional factor—material. Hence, we regard the information as the second digital factor. The main definition is the application of dynamic information in the skin or surface of the building as the new appearance material.

3. Generation

Computer techniques such as generative system and algorithm are used to assist the form finding process in the digital design cases. The designers input the parametric and operate the generative system and computer algorithm mainly to generate various design forms automatically and they merely determine or choose the form which they like. Therefore this research regards the generation as the third digital factor. It is defined as the automatically form generation process or concept generation process by the aid of the computer generative system.

4. Fabrication

We found that a new design process emerged before the construction stage in the analyzed design cases. Designers utilize the CAD/CAM fabrication technology such as RP, CNC, and 3D scanner to explore the new method of assemble. It concludes the process of produce, fabricate, testing and assembly the design components. The fabrication process is important to produce and assemble the complicated structure of the free-form architecture. So fabrication is regarded as the fourth digital factor. It is defined as the process of fabricating the design components and the method of construction by the aid of CAD/CAM fabrication.

4.2.2. Three FEIDAD cases analyzed by four new digital tectonic factors

The tectonics of the digital design process is investigated in the following paragraphs with respect to motion, information, generation, and fabrication.

1. Motion

CASE [1]-- As shown in Figure 8(a), the generation of the form of the "Island" was completed in the following process: After performing a series of dynamic deformations, the designer determined the skeleton frame, which was used as the major framework of the surface for the design of the form of the "Island" in the next step.

CASE [2]-- This design concept is to build a wall that can interact with the environment and a surface pattern that can respond to the motions and sounds of the environment by producing different kinds of motion on its surface. The variation of the surface was at first simulated by a computer. From the digital image of the mathematic wave fluctuation, the possible variations of the surface's pattern were then investigated in order to simulate the relationship that reflected a series of variations of a waveform of the surface. Figure 8(b) is a diagram that shows the variations of a waveform and the concept of the activator's operation behind the scene.

CASE [3]-- From the land's density distribution analysis diagram as shown in Figure 8(c), the environment's dynamic density variation and the distributed area are described. With dynamic and digital graphic analysis presented, the variation of values of the regional and national agriculture produce and population is clearly shown, allowing the designer to make obvious the concept to be presented. The dynamic parametric data diagram shows the environmentally-deducted structure, which looks like a generated and changed state.

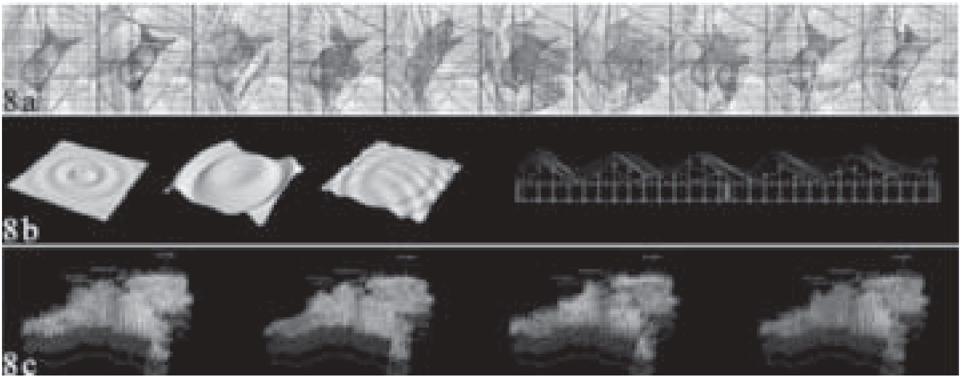

Figure 8.

2. Information

CASE [1]-- In Figure 9(a), the view of a street is a merge of the image and the design space, employing the arrangement of both the back and front spaces and the transparent pasted images of various depths. As shown in Figure 9(b), the presentation of the image is emphasized with images and diagrams interwoven to each other. The material's property is replaced by the information image in order to make up for the lack of the feel and look of the material.

CASE [2]-- The actual feel and look of the material is not emphasized in this design project while the communication of the information carried on by the signals generated by the electronic system replaces the presentation of the material. These signals are converted to the force that drives the activator and enables it to work. The signals sent out from each set of objects must be transformed into different systems. Moreover, the entire work was put mostly under the digital control of a computer, which can be seen in Figure 9(c). The presentation of the physical material is replaced by the digitally-controlled signals.

CASE [3]-- Nil.

Figure 9.

3. Generation

CASE [1]-- In the street scaffold of this project, the modelling of the design form was investigated using particle animation with the possible activity modes in the environment and the arena relationship of the space as variable parameters. In the space's sequential key-frame shown in Figure 10(a) the designer expressed the state between the peripheral service route of the service and a hard pavement system. And finally, from these images, the relationship between the design form and the spatial organization for street scaffold was hence obtained and then converted to the pattern of a framework that might be developed in the structure as seen in Figure 10(b).

CASE [2]-- As seen in Figure 10(c), the computer simulated the wave variations of these surface patterns, which were determined based upon the signals received from the environment. These waveform transformations were converted to data in a matrix that can be controlled and operated by a computer, enabling the computer to recognize the change of pattern that was to be delivered when a different input signal was received as depicted in Figure 10(d). Afterwards, these digital data correlated with the physical mechanical device, which required a combination and an adjustment of many technologies to realize, in the real world, the pattern variation shown in the digital environment as seen in Figure 10(e). The final presentation of the pattern variation was generated by the continual input of different information from environment.

CASE [3]-- The initial 2-D dynamic illustration of the density analysis was converted to a quantified analysis diagram of tendency variation, which is affected by various condition factors. From Figure 10(f) and 10(g), one can see the changes of various environmental factors and an induced organic mode for a relationship among effects. The final airbag form was gradually generated during analysis. At the same time the dynamic environmental factors also became the deformation parameters, which controlled the design form's structure.

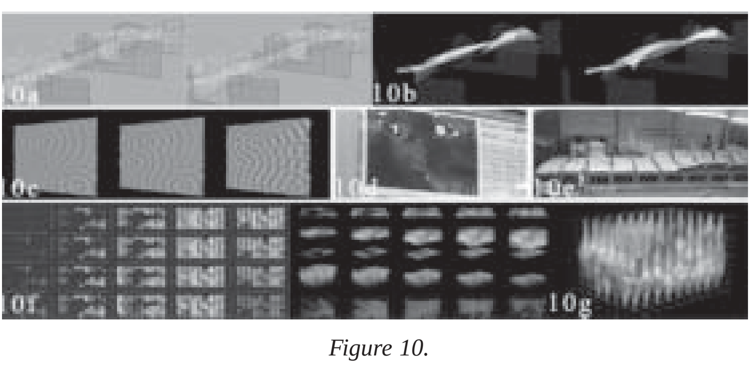

Figure 10.

4. Fabrication

CASE [1]-- In order to explore the possible structures for the design form, CAD/CAM technology was employed during the design process to fabricate precise models. Figure 11(a) shows the physical models done by a Rapid Prototyping machine using the data output from the computer models. The models present the relationship of structures at various levels. This enables the designer to easily grasp the spatial organization of the design form and overall construction, as well as analyze its rationality.

CASE [2]-- Six design prototypes, from small to large, were made in this design project. Each object was fabricated separately and then assembled with others. Each was also tested and its design, modified during the fabrication process. From Figure 11(b) to 11(e), we can see clearly the process of the design and the fabrication of the device, from the smallest object, which failed to show flexibility in the dynamic test. After repeated tests, assemblies, and incorporating modifications to the hardware object and software program, the designer was able to develop a large piece of a wall-like device, which could freely present a surface that produces the natural wave-like form. As for this digitally-controlled device, all objects must be assembled and integrated together under strict conditions. There are on-going tests and modifications in this kind of fabrication process.

CASE [3]-- As shown in Figure 11(f), the object that made up the design form and construction form was investigated and designed, mainly used as the components that could be constructed lastly. The design of the airbag, the test of the special object and the design of fabrication method all play essential role in the design process. Cutting in from the angle of tectonics, both, how the structure's construction was completely put under a framework and built, were investigated as depicted in Figure 11(g).

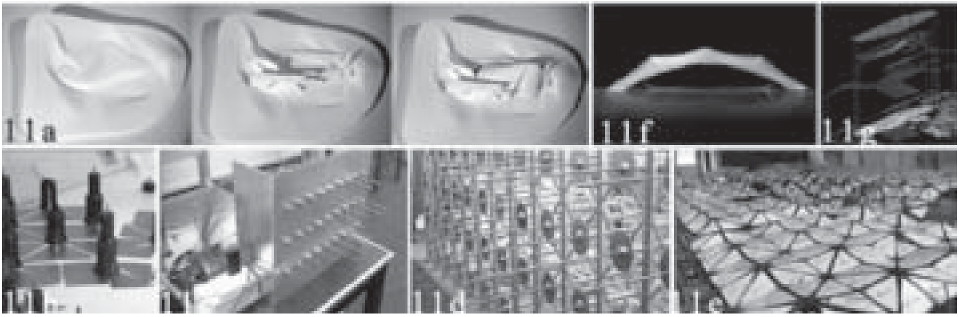

Figure 11.

6. Conclusion

This study re-identifies the traditional tectonic factors from the literature and finally seven tectonic factors were summarized: joint, detail, material, object, structure, construction and interaction. Furthermore, while analyzing the digital design cases, four new digital tectonics factors were found alongside the seven traditional tectonics factors. These digital tectonics factors are motion, information, generation and fabrication. Because the digital media becomes involved in the design process, discussion of the architecture tectonics is likely to change and extend a new tectonics of digital spaces.
The limitation of this research is the case studies are all digital design works of the designer at present new generation, the famous and experienced architect's works should be analyzed and discussed further, to find out the universal phenomenon of new tectonics. It will be the next step of this research. Moreover, the authors hope to continue studying this new tectonics with the relation between creativity in the future.

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