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Digital-Green Architecture Is a Novel Approach to Design that Combines Digital Technologies with Sustainable Ideas

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Abstract - *The trend of digital freeform and the awareness of environmental issues have propelled architecture to a higher level by comprehensively merging new technologies and green concepts. These findings imply that a new framework for comprehending the design process that combines digital technology and the sustainable idea is required. The debate is whether the overall interactions between digital technology and sustainability thinking, as well as the holistic integration of new design methods, should take precedence over micro concerns. This might bring the design process up from a fragmented level to one that is more all-encompassing and universal.*

Key Words: Digital-Green, design process, digital technology, sustainable concept.

1. INTRODUCTION

Utilizing computer numerical control (CNC), rapid prototyping (RP), and digital CAD/CAM technology as new design mediums, researchers such as Frank Gehry, Mark Burry, Larry Sass, Branko Kolarevic, et al. realized the increasing demands for new digital design process. Given the advanced technological capabilities of computation, calculation, and simulation, modern architecture should place greater emphasis on implementing concepts such as habitability, self-sufficiency, and more, rather than just focusing on aesthetic and practical features. As a result, the conventional design process which consists of the schematic design, construction stages, detail design, and design development evolved in tandem with the new structure of the digital design process. The digital design process makes extensive use of the four new steps of computational concept design, analysis, production, and assembly technique . The concept of "green" has expanded beyond a simple focus on being more autonomous, self-sufficient, and able to generate renewable energy on its own. Technology breakthroughs have upped the bar and made building something impossible achievable, which has given the field extraordinary knowledge and potential. Digital technologies must advance together with the traditional sustainable design process, which entails site planning and research, building form, envelope development, finishing, and technical support . The concept of sustainability has changed over the last few decades to incorporate digital technology and self-sufficient green thinking. The digital era has brought about a significant change in design, but new technologies have also had an impact on research and the way architects approach sustainability. An ecological building is "a kind of living organism" that responds to its surroundings, according to Yeang (1999), who defined them in the 1990s. Some of the pioneers of digital sustainability, like Norman Foster with the Reichstag Dome, etc., understood the need of sustainability. Additionally, Kolarevic (2004) proposed that understanding sustainability and using curvilinear shapes are equally crucial strategies. The Carbon Tower by Peter Testa and Ove Arup was cited as an illustration of digital technology that saves energy. Through technology transfer from textiles to the highly-compressed carbon fiber reinforcement of the exterior helix, architects were able to show the elimination of vertical columns between stories. With recyclable and naturally finished stainless steel, Steven Holl's (2005) Silver Water Drop demonstrated his ability to combine landscape and architecture while preserving the digital freeform, echoing Yeang's (1999) concept of bringing a building and its surroundings into conversation. Additionally, David Fisher's design of the rotating skyscraper included prefabricated floor components and a wind-turbine-powered self-powered system. The architecture improved the use of technology and green design, and it thoroughly expresses the idea of digital mobility in a building. For architectural applications, digital technologies like laser cutting, CNC (Computer Numerical Control) technology, and 3D computer modeling offer affordable manufacturing processes. These innovative techniques enable the pre-assembly of building elements, minimizing waste and lowering construction expenses. In addition, owing to technological improvements, scientists and architects may test novel materials throughout the design phase to determine if they better satisfy sustainable standards. These results suggest that in this new era of digital and green design, we need a new framework to understand how digital technology and sustainable principles are combined.

2. PROBLEM AND METHODOLOGY

In the past 10 years, new CAD/CAM technology has enabled architects to create structures using integrated methodologies. The foundation of the digital era is the new analytical software with sophisticated computing, calculating, and simulation capabilities. A few of them were also observing the steady rise in sustainability and sufficiency. It's time to investigate if the combination of emerging technology and the green idea might completely reshape digital architecture. People are now increasingly conscious of environmental concerns and the need for new design principles that take energy and digital savings into account. These patterns force scholars to confront the novel obstacles surrounding the way in which digital architecture will address the problem of sustainable innovation. A significant amount of contemporary digital sustainable architecture is still perceived as being limited to a technical green concept, despite the fact that green concepts are increasingly being integrated into the design process of digital architecture. This includes the process and interaction between digital technology and the sustainable concept, rather than being restricted to being a building's machinery add-on or a hybrid combination of new technologies to sustain the building or the adoption of another technique to design projects. Some of the creative digital free-forms that are connected with these technologies seem to be the direct solutions and novel ways to digital sustainable design. The primary goal of this study is to ascertain if digital freeform, when combined with emerging technology and ecological requirements, can support the New Digital-Green design process's sustainable requirements. By using case studies, the three steps to approach this research are: (1) to conduct a wide investigation of case studies to make a comprehensive evaluation of the new factors for the analysis of new design process; (2) to understand the logics and characteristics of a new digital-green design factor; (3) to analyze the basic design process in terms of from general, sustainable, digital and the preliminarily digital-sustainable architecture to obtain a new model of Digital-Green design process.

3. EXAMINATION OF CASES

The rationale behind selecting these 10 examples is to clarify the subsequent ideas. Initially, projects are chosen from different nations using an unbiased viewpoint. The places are spread throughout Asia, the Middle East, America, and Europe. Second, the buildings incorporate several architectural sizes, including that of a vast public stadium and a private dwelling. Last but not least, the selected architects are adept at experimenting with creating digital architecture that incorporates sustainability concerns. The goal of the 10 instances is to investigate different aspects of the architectures through an analysis of the design processes that include digital manipulation and sustainable design thinking. The link between digital technology and sustainable qualities, as well as the logic of design processes, are illustrated with larger applications through the 10 projects.

4. FACTORS FOR ANALYSIS DESIGN PROCESS

The case study suggests that the digital or sustainable architecture's initial framework might not be enough for the demands of the digital-green design process. Applying fresh elements is required to generalize the new design process and include digital technologies and sustainable concepts. The five basic factors detail/joint, material, object, structure, and construction were grouped throughout the creation of the original design process [22–29]. Seven elements were developed when the five traditional factors were reexamined: the joint, detail, substance, object, structure, construction, and interaction [30]. The classic aspects were reinterpreted with the backdrop of digital thought. Five digital factors concept, manipulation, construction, shape, and space were suggested through the digital design process using innovative assembly techniques [29]. Furthermore, the use of computers and CAD/CAM technology in the design process changed the expression of digital architecture into the combination of digital and sustainable operation. This was made possible by advancements in technology and the growth of green thinking. Once both sets of fundamental components are understood, comparisons are made to determine how similar those factors are, which helps to construct a new design process skeleton. The research would only focus on the most important aspects related to structure, building form (envelope), electrical power, technological principles, environment (water, waste, energy, noise), location (microclimate, green space), and materials while taking into account the functioning of sustainable components. This examination, however, focuses on the new design process that combines digital technology with sustainable idea rather than the pure sustainable mechanical issue. The new design process approach differs from the original expression of digital architectural manipulation by combining green thinking with the digital design manipulation methodology. Consequently, building (structure), materials, object, interaction, and form are the new five Digital-green criteria that are suggested in this research [22–31].

5. EVOLUTION OF DESIGN PROCESS

5.1 Design processes

The new design process approach combines green thinking with the digital design manipulation technique, setting it apart from the original manifestation of digital architectural manipulation. Thus, the new five Digital-green criteria proposed in this research are building (structure), materials, object, interaction, and form.

Case #	Project Name	Architect(s)	Location	Year
1	Phare Tower	Morphosis	Paris	2012
2	The Dynamic Tower	David Fisher	Moscow	2010
3	Bird's Nest	Herzog & de Meuron	Beijing	2008
4	Zaragoza Bridge Pavilion	Zaha Hadid	Spain	2008
5	Silver Drop	Steven Holl	Connecticut	2007
6	BMW WELT Munich	COOP Himmelb(L)au	Germany	2007
7	Carbon Tower	Peter Testa and Ove Arup	Dubai	2005
8	Yokohama Port Terminal	Foreign Office Architects	Japan	2002
9	Swiss Re Headquarters	Foster and Partners	London	1999
10	Reichstag Dome	Foster and Partners	Berlin	1999

Fig -1: Index of ten case studies.

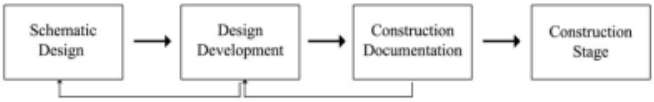

Fig -2: General design process.

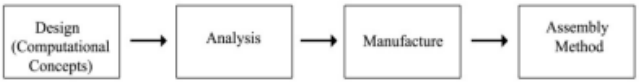

Fig -3: Digital design process [6].

The discipline of digital architecture differs from conventional architecture in its design process due to many modifications. It is also essential to investigate the design process using sustainable methods, as Figure 3 illustrates. Figure 3 is almost exactly like earlier instances of digital or traditional architecture. The design process of combining digital technology and green aspects is started based on the analysis of the prior design processes and proportionate knowledge of the case-study components. The characteristics of computational design media and digital graphics (topological surface, isomorphic field, etc.) enable architects to freely alter the form and create a more functional skin/envelope, maximizing the potential of a dynamic digital design process. Consequently, new opportunities are presented by the developing processes of conceptual design, computational concept, and envelope analysis. Figure 4 illustrates the surprising new shapes and sustainable influence in the new Digital-Green design process. It is believed that this new design method will assist designers in integrating sustainable and digital elements into fashion design throughout the design thinking and design process.

Fig -4: The sustainable design process [34].

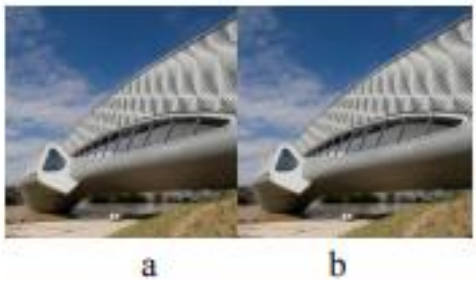

Fig -5: Case 4 (a) and Case 9 (b). Photo credit: Case 4 (a): Luke Hayes; Case 9 (b): Adrian Welch.

Fig -6: Case 4. Photo credit: Zaha Hadid Office.

5.2 Discussion of ten cases

5.2.1 Form

The shape may be dynamic and functionally sound at the same time, thanks to technology and the advancement of green thinking. The growth of the freeform in Cases 1 and 4 was dictated by the need to react to the sun's path in order to reduce glare and heat gain. The south façade's curved double skin and the north façade's flat, clear-glazed exterior demonstrate the building's intentions to reduce heat gain and maximize internal delighting. Flow up the structure to improve ventilation.

5.2.2 Material

Designers might control various types of materials to obtain the dynamic shape one wants to approach while also having sustainable value for the environment by employing computer technology and simulation. Case 4 illustrates the idea of covering the building's exterior with brand-new, eco-friendly glass fiber concrete triangle panels. Case 5 shows how a digital freeform structure made of stainless steel might also be environmentally friendly by reducing heat absorption as the steel becomes naturally polished and recyclable. glass fiber concrete to cover the building's exterior. Case 5 shows how a digital freeform structure made of stainless steel might

also be environmentally friendly by reducing heat absorption as the steel becomes naturally polished and recyclable.

5.2.3 Object

The definitions of fundamental architectural features, such as roof, façade, column, or window, might become ambiguous due to their complete purposes and duties, given the concern for both digital and green design. In Case 3, for example, the structure combined the walls, roof, and stairs into a single, harmonious system. With its load-bearing grid-like layout, the structure acted as both the façade and the structure. The rainwater collecting system's eco-friendly attributes highlight the roof's two purposes in Case 3. In Case 6, the original architectural elements are replaced with new forms and multiple functions to encourage the continuity of natural ventilation throughout the entire building. The façade and the Double Cone column structure merge together with the roof with the solar modules integrated on the surface.

5.2.4 Construction

The aim of computer technology and the needs of sustainable concern offer a completely new way to explore different possibilities in the areas of construction. This feature is particularly evident in Case 2 when the whole skyscraper is to be built entirely from prefabricated parts that are made digitally for fast construction and energy saving. In Case 6, the project uses rectangular pipes to support the glass panes directly instead of traditional round pipes, which certainly reduces steel consumption in construction.

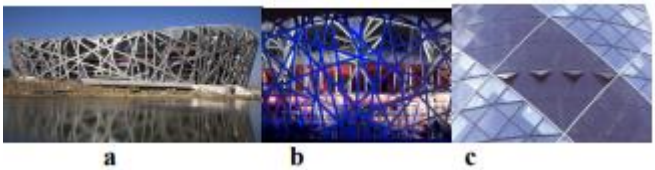

Fig -5: Case 3 (a) (b) and Case 9 (c). Photo credit: Case 3 (a) (b): Ben McMillan; Case 9 (c): Luke Hayes.

5.2.5 Interaction

The project in Case 1 attempts to produce a close interaction between the environmental context and green space with the crown of wind turbines on the roof garden to grow the building's own ecosystem. One example is the shark scales envelope of Case 4, with its shingle's different ways of generation allowing for leading natural light and visual contact with the river, which demonstrate its relationship to the surrounding environment visually and sustainably. In Case 5, with the merging of high technology with green thinking, the ozonation bubbling system and green roof system on the rooftop brings natural light to the interior building and also corresponds to the surrounding site. From Case 8, one can observe how architecture and green space interact with each other. This linear structure, which connects the site to the rooftop green space, the city to the sea, and the interior and exterior, expresses itself as an extension of the urban site by placing the building's green roof into a continuous relationship with the surrounding public park and waterfront. Hence, the interaction between this arrangement, green space and people, emphasizes how digital architecture produces more than just a fluid shape, but also interacts with the surroundings with environmental purpose.

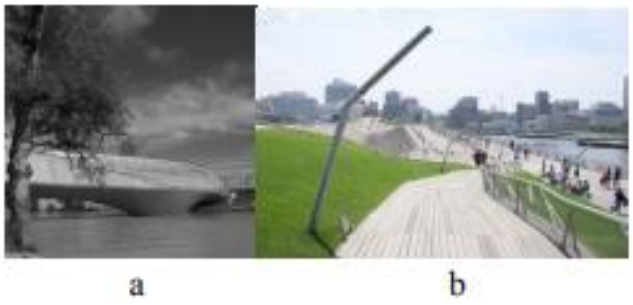

Fig -6: Case 4 (a) and Case 8 (b). Photo credit: Case 4 (a): Zaha Hadid Office; Case 8 (b): Mami Sayo.

6. CONCLUSIONS

In the digital-green era, our research has highlighted the necessity of a deeper degree of interaction between the sustainable idea and the digital design process. Disconnected concerns are the focus of modern digital sustainable architecture. The digital-green trend in architectural design has not only been superseded by design advancements, but the process of completely integrating digital technology with sustainable aspects has also evolved. Using this knowledge, a novel design approach that combines sustainability and digital technology through the use of fresh variables is used in the research. Approach might potentially lead to the development of a conceptual model or computer-generated prototype. Models or simulations to assess the potential of the new factors and the new design method prior to further investigation. We will get a deeper comprehension of the connections between the new green movement and the CAD/CAM technologies-based digital-green architecture in upcoming digital-green projects thanks to this procedure. Examining the novel design process that this study suggests might point future research in the direction of investigating other design mediums or alterations to correlate with digital and sustainable applications. Through a newly integrated understanding of modern technology and sustainable design thinking, the outcome may impact the creation of future work and bring about some degree of change.

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