Structure as a Support for Sustainability

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***Abstract*—"The sustainable design will reach its full potential by studying structure at a deeper level." Although structure is essential for realizing any architectural design; however, it is not highlighted as an important principle in the six fundamental principles of sustainability. Most of the design researchers are looking for designs and materials that are less harmful to the environment. This paper surveys design for sustainability and eco-design strategies and, the use of codes that affected the design process in architecture by focusing on the structure system as the main issue, analyzing the adaptation of three parametric structures to accommodate climate condition, by studying structure control framework from the sustainability point of view. The structures control sun rays, wind power, material and rainwater. So finally, structures achieved the meaning of the environmental control that supports sustainability through a suggested framework will guide architects and designers to get a new way of understanding the structure system and its importance for sustainable design.**

***Index Terms*—Structure sustainability, eco-design, green building, parametric design, algorithmic design, generative design.**

I. Introduction

The structure is the most powerful element in influencing the architectural form so that if it is not considered from the beginning, all other determinants of the building may be deformed or modified.

Architects are obliged to change the forms if the structure system changes and that is why there is an intimate connection between form and structure.

Efficient structural frameworks and recyclable materials became a new challenge for achieving sustainable basic objectives.

Sustainability depends on design being moderate, buildable, durable, replicable, safe, and resilient. (Fig. 1)

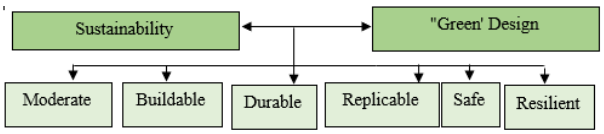

Fig. 1. Sustainable main factors.

II. Eco-Design in Architecture

A. Definition

Eco Design is an approach to design products taking into consideration the environmental impact of the product during its entire life cycle. In an existence cycle appraisal, the life cycle of a product is typically divided into acquirement, assembling, use, and transfer.

Eco-design is a developing obligation and understanding of our ecological impression on the planet. [1]

B. Eco-Design Strategies

Eco-design supports systems that will increase environmental studies in both social and ecological. The hidden reason is to copy biophysical and biological procedures perceiving interdependencies, and in this manner, enhance the ecological sustainability of items and services. [2]

III. Structure and Energy

A. Sustainable Approach

The heading is decreasing energy consumption and polluting emissions; however, the issue appears to be more confusing: how is it conceivable to profoundly reorder the whole plan procedure from a sustainable methodology?

B. Energy Saving

Most trials concentrated on sustainability consider ideas of performance and proficiency. A decent procedure augments the outcome and minimizes consumption.

Energy saving is mainly about the greatest output with the least input.

One of the basics of the energy savings is to change the current energy, For instance:

Passive design strategies such as using the pass of airflows to keep up the perfect temperature states instead of consuming energy in cooling and mechanical ventilation.

The ability to produce energy using renewable sources like sun or wind, rather than using non-renewable carbon-based resources. [3]

IV. Cell Pattern the Base of Nature Structure

Cell shape is the base for each creature. When we control the cell, we might control all the structure to follow the cell character.

Fig. 2. Snow crystal cell shape.

Manuscript received October 14, 2020; revised January 8, 2021.

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DOI: 10.7763/IJET.2021.V13.1187

The voronoi diagram is the nearest form of the cell. it may be seen in numerous forms in nature like snow crystals (Fig. 2) and skin cell shape (Fig. 3).

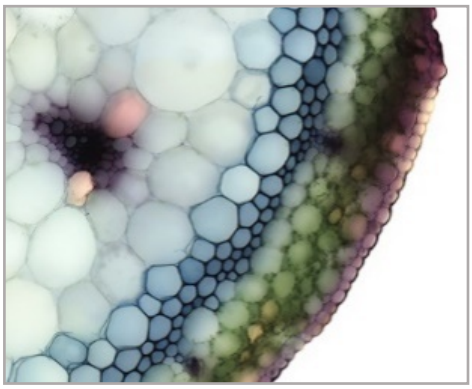


Fig. 3. Skin cell shape.

V. Examples of Structure as a Support for Sustainability

A. Structure 1: Eco-Sustainable Housing–Parametric Design, Residential Competition, Architect: Federico Rossi, Year: 2007

1) Structure explanation

This project located in Oman in the development of new housing typology. The structure is a collection of independent variables with a system of relationships. (Fig. 4)

The structure consists of inhabitable units these units adapt with environmental variables to accomplish the new performative design. (Fig. 5) [4]

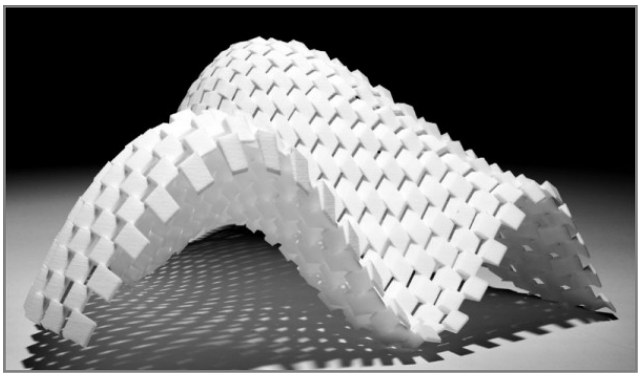


Fig. 4. Eco sustainable structure.

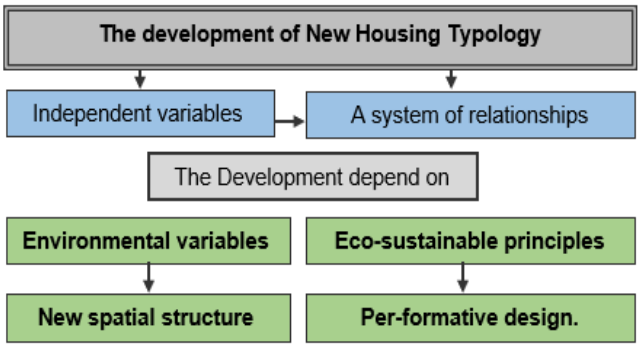


Fig. 5. Eco sustainable analysis, by author.

2) Structure control framework

A parametric model created by using the unit of the structure in a diamond structure inside two strips. A responsive unit established by the control of the thickness, length, and width of the surface. The wall of the structure enlarges the thickness in high temperatures and distorts the diamond structure as indicated by internal pressure and wind speed. (Fig. 6) [5]

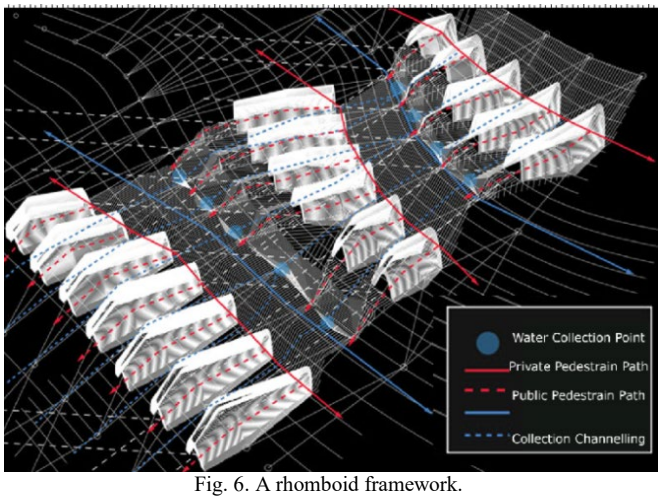


Fig. 6. A rhomboid framework.

In (Fig. 7) the diagram analyses the relation between the parametric model and the different variables controlled in the structure.

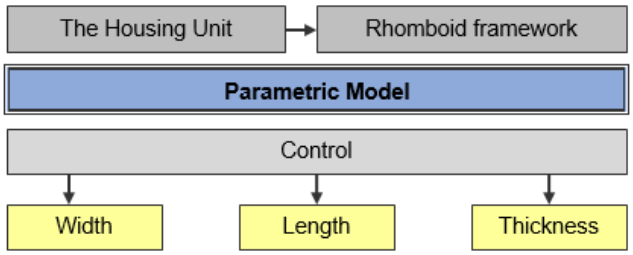


Fig. 7. Analysis diagrams for structure control variables, by author.

3) Solar radiation control

Improving the light conditions and making distinctive small-scale climate areas inside the unit clarified with the uses of local materials and straightforward assembling methods.

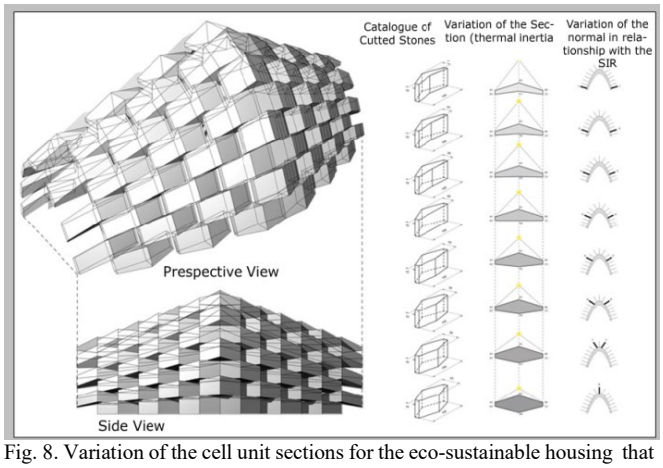


Fig. 8. Variation of the cell unit sections for the eco-sustainable housing that depend on the sun light angle.

The size of the structure unit changes to react with the solar radiation along the complex surface of the structure. (Fig. 8-Fig. 9) [5]

In (Fig. 10) the examination of one unit of the structure that enhances light conditions.

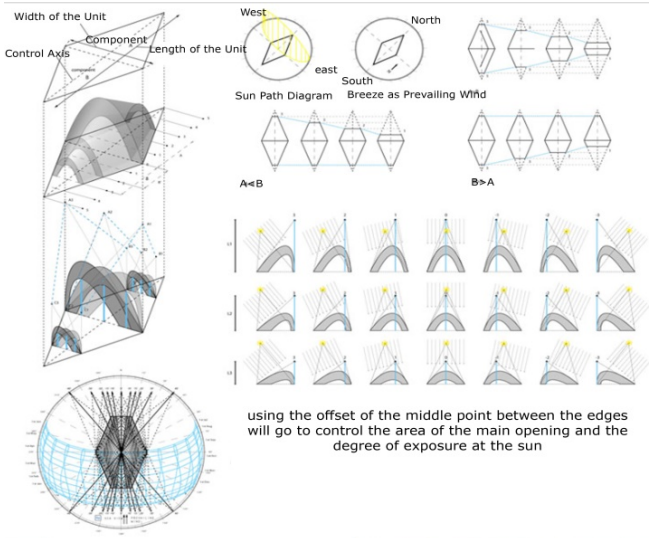


Fig. 9. Sun path Diagram and change of structural unit with different sun angles.

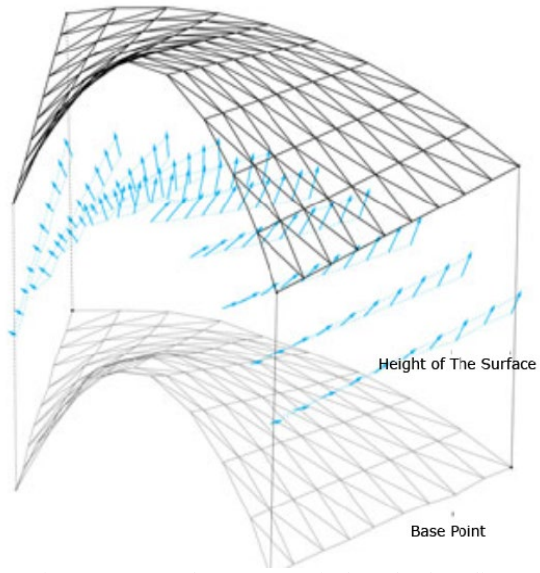


Fig. 10. Arranges the structure unit along the shape line.

4) Material control

In (Fig. 11-Fig. 12) the designer arranges the elements along the shape line to control the quality of different materials.

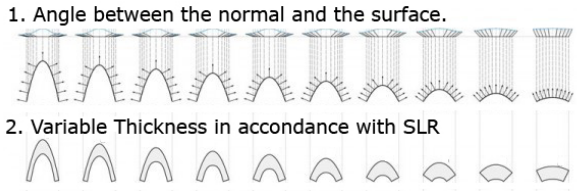


Fig. 11. Variable thickness of the structure unit.

5) Rainwater control

In (Fig. 6) Collecting rainwater through the space between the units used. [5]

B. Structure 2: Qatar Integrated Railway Project, Location: Doha, Architect: UN Design, Year:2012-2019

1) Structure explanation

The structure of the railway station finished by UN Studio, the project includes around thirty-five stations in phase one and around sixty stations in phase two for the new Doha railway Network.

Fig. 12. Vaults rail stations.

The traditional ornamentation and material palette used as a part of the inside spaces mirrors the local culture. These components are complemented by unpretentious lighting and large windows that fill the insides with sunshine. The project mirrors Qatar's rail image by presenting vaults that copy the migrant tents generally found in the locale.

2) Structure control framework

In (Fig. 13) the general arrangement of the project depends on triangular base structures. Differing scales of character (system identity, line identity, and station identity) were created through an arrangement of configuration rules, engineering subtle elements and material layouts. [6]

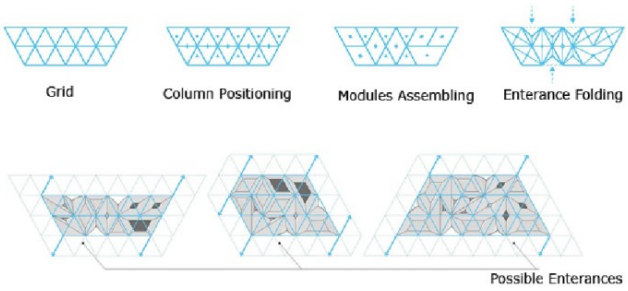
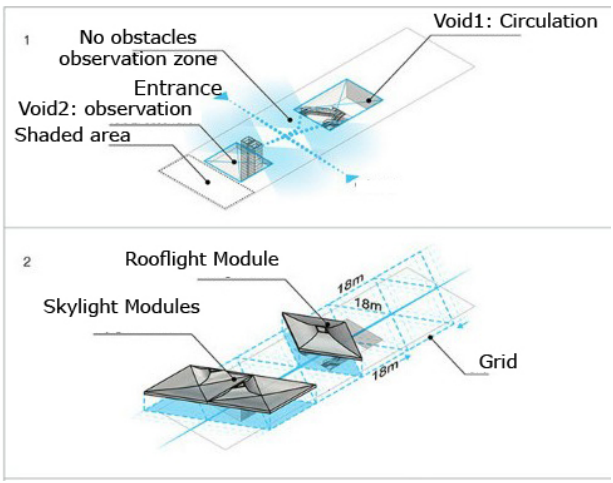


Fig. 13. Triangular grid, column position, modules assembled and entrance folding.

With the use of controlled parametric design, the design can combine contextual variations and parametrically adapt physical factors like wayfinding, daylight penetration, traveler flows, constructive components etc. (Fig. 14) [6]



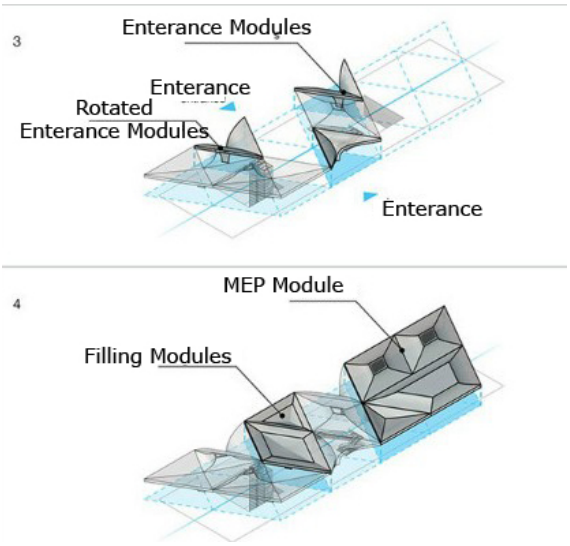


Fig. 14. 3D Explanation for the Entrance folding modules.

3) Solar radiation control

The system captures the daylight of the sun and directs this light into the interiors. [7]

4) Martial control

The project uses a unique material palette. The materialization principles are experienced through a duality of a pure, modest exterior versus a rich, illuminated interior. (Fig. 15) [8]

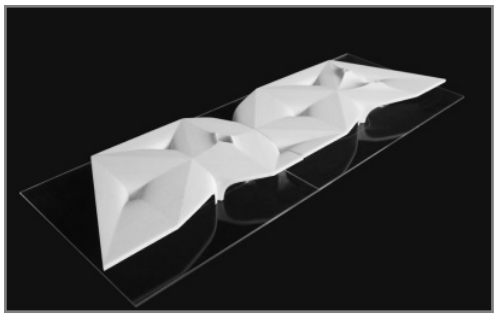


Fig. 15. Unique material in the project.

5) Rainwater control

The design act for an adaptable new architectural system which can change itself to the scalar fronts set within the Metro railway and collect the rainwater through the spaces between the units. (Fig. 16) [8]

Fig. 16. Flexible new structure system collect rainwater through the spaces between unites.

6) Wind control

The structure controls wind power through the Central Control Room which is mobilized by the influence of wind.

C. Structure 3 : Masseria Ospitale Restaurant , Grid shell's Parametrically-Designed Canopy Shade , Location: Lecce, Italy, Architect: CMMKM Architettura e Design, Year: 2010-2011

1) Structure explanation

Matrix shell is a dynamic open-air space uses parametric design.

The structure is made from lightweight wood. The new structure shows ecological creative technique. (Fig. 17)

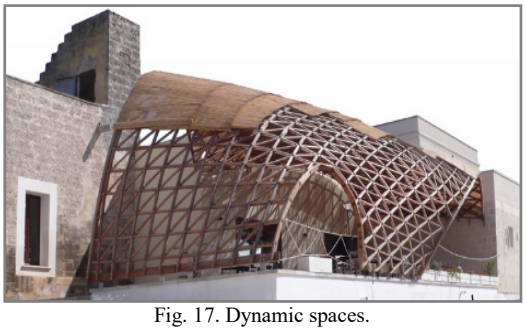


Fig. 17. Dynamic spaces.

2) Structure control framework

The design began with a structure of squares that were forced into twisting through changeable heights and torsion that bend the rods of the network into a cross-section of diamonds. [9]

This unique structure makes an exceptionally complex, however, successful shade structure that revives the restaurant yard.

3) Solar radiation control

The parametrically designed patio cover is an environmental solution that can use renewable resources. (Fig. 18)

Fig. 18. Fabric shade system.

4) Martial control

The relationship between computerized design tools and the fabricated environment, the material used is wood to make connecting with freeform structures (Fig. 19). [10]

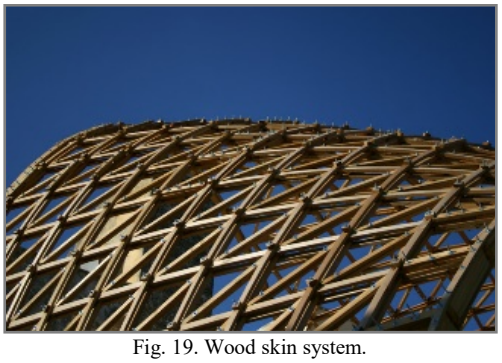


Fig. 19. Wood skin system.

5) Rainwater control

The site is covered with an existing canopy that stops rain water.

6) Wind control

The structure is controlled through an algorithm that alters its density and attraction. The Flexible shape of the grid structure react with the wind. [10]

VI. Conclusion

From the previous review, a group of major points could be realized in the following context:

- Implantation of sustainable concepts gives the same result as reducing consumption.
- Applying green designs often mean survive sustainably.
- The main purpose of eco-design is the elimination of environmental impacts from architectural design.
- Improving Green awareness about ecological footprint on the planet.
- Passive Systems in architecture and its relation to structure form.

The paper suggested a framework for Eco-Sustainable Structure. Its main goal is developing the design process by presenting a new way of understanding the structure system and its importance for sustainable design. (Fig. 20)

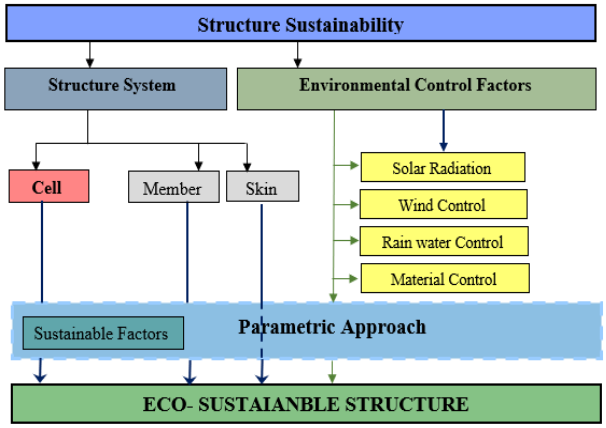


Fig. 20. Eco-sustainable structure framework.

Conflict of Interest

The author declares no conflict of interest in the submitted work.

Acknowledgment

First and foremost, many thanks for GOD "Allah"

I would like to thank my supervisors who stood beside me and supported me and I would like to thank my Dad and my husband for their continuous encouragement for me.

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El-Gendy-Marwa born in 26 March 1983, Cairo, Egypt. Dr. EL-Gendy received her Masters and Ph.D. in Architecture from Ain Shams University – Cairo-Egypt in 2010 and 2017 respectively. Dr. El-Gendy's Ph.D. thesis entitled "Structure as a Form Generator for Sustainable Design". It focuses on the role of structure within architectural form generation, its importance, how architects use computer programming to produce mathematical models to control light in their buildings during studying the parametric "Cell" structure. Dr. El-Gendy attended ATI course in 2018 "Architecture: Performative Design for digital manufacturing" in University of East London. The School of Architecture, Computing & Engineering Docklands Campus London- UK.

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