# Robust Design in Metal Facades Design from Environmental Graphic Perspective

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***Abstract*— This research aims to provide the building with suitable indoor climatic comfort in the most economical manner through its facades. So, it focuses on the effect of architectural robust design as an effective design tool inefficiently of buildings energy-saving putting into account the economic and environmental effects from environmental graphic perspective. The research concluded that it is effective to use "robust design as a design tool" during the stages of the design process as one of the most important inputs, taking into account how does the external and internal noise affects the building metal facade's performance at any conditions. From the environmental graphic perspective, the robust design aims to achieve economic and environmental considerations in the process of metal facades design, through the analysis of the energy and the exploitation of environmental characteristics of the site and access to achieve a comfortable indoor climate and energy-saving.**

***Keywords*— *Robust Design; Metal Facades; Environmental Graphic.***

## I. INTRODUCTION

Architecture is a science that is a mixture of exact science and art. The combination of these two important items makes architecture a difficult but challenging task. A designer has to combine these primary elements in the design and at the same time while expressing the feeling of art, must take very good care of many other factors which play an important role in the building and design environment.

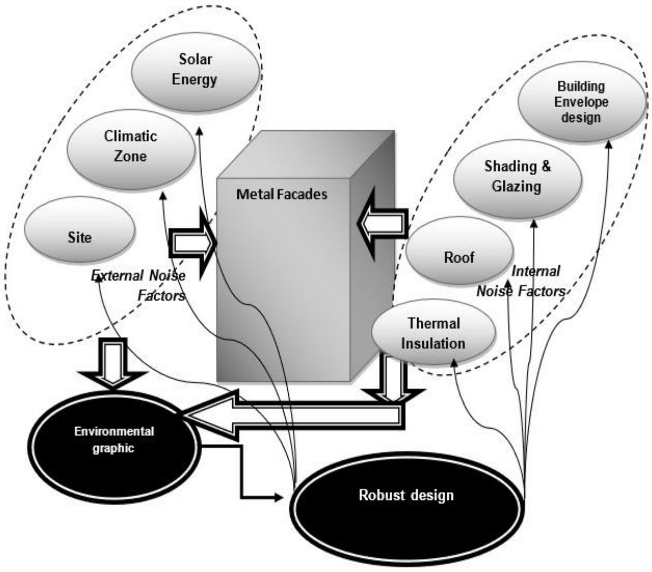
The designer has to evaluate his design and communicate with the others concerning the design, and therefore he has to make variants from which to choose the best. The best way of evaluating the quality of a design and communicating with others is to use the architectural design tools in their optimal way.

In recent years, the topic of the concept of robust architectural design, which is defined as an alternative structure of the architectural system to minimize the deviation between the stakeholder's desired system and the system developed with insensitivity to noise such as risk and uncertainty.

The robust architectural design explores the importance of the level of the indoor environmental quality in buildings, due to its direct correlation with operating energy consumptions in buildings.

Robust architectural design from the sustainable development perspective is a significant issue for future human society, in which energy consumption of buildings occupies a great proportion. To save energy consumed by the building, we have to evaluate and optimize building energy consumption. To achieve comprehensive evaluation and optimization of building energy consumption, more and more attention is drawn to the evaluation and optimization of the whole life cycle of building energy consumption. ( Yan Yuan et al.,2010) Buildings, energy, and the environment are key issues that the Robust architectural design address, especially in the area of sustainable development.

This paper deals with robust design noise factors in the design of metal facades from an environmental graphic perspective, these factors are divided into (External Noise Factor) and (internal Noise Factor), the following diagram showing this factor:




## II. EXTERNAL NOISE FACTORS

With the increasing destruction of our natural environment, and with the realization that we ultimately depend upon this environment, we can explore the role of robust design in designing the built environment to be harmonious with the natural one. How can designers use the external natural and built environments? Through the robust design of buildings energy saving studies involving the integration of a building's site, photovoltaic technology, daylighting, and natural ventilation, how can a building facade respond to its occupants, and sun, wind, daylight, and temperature? How can the designer encourage the occupants to interact with the building facades, learn about them, respond to them, and consequently increase their awareness of it?

Reducing energy use lowers the emissions and pollutants that contribute to environmental degeneration and the related health effects. Appropriate wrapping of buildings, esp. with environmentally preferable building products, reduce the impact of development and building use on nature. Through

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

intelligent or high-performance buildings, designers could solve some problems within the built environment in a more cost-effective and well-reasoned approach than paying for remediation efforts later on. The integrated approach to whole-building design reduces pollution, preserves natural resources, and slows the depletion of reserves exploited by development.

Designer attempts to have an understanding of the external noise factors of robust design impact of the design by evaluating the site, classify climatic types or zones, and the energy efficiency of design" we focus on solar energy" as follow:

*A. Site*

The designer always has the option of designing in a way that does or does not take advantage of a site. When building metal facades and their sites are designed in a way that they take full advantage of the natural site, then they stand the greatest chance of longevity, and of nourishing and sustaining us physically, spiritually, emotionally, and mentally. We can make the connection between the facade and its site. The building metal facade is not a stranger to the land, and in being so, permits us to be intimate with the land.

The climate will determine the basic characteristics of the site to be considered, such as heating and cooling degree days; solar orientation (passive heating / passive cooling), and OS (passive mode; mixed-mode; full mode; production mode and complex mode). (Francisco J. Farias Stipo,2015)

From an environmental graphic perspective taking the site properties in choosing the design form and materials leads to make strong functional and appearing relations among building metal facades and site, the site controls how the facades deal with external changes in optimal response.

*B. Climatic Zone*

The climatic zone largely dominates the shape of the building’s metal facade and the nature of the materials used in it because protecting the human from climatic conditions is a basic requirement for the human and the metal building in general, interaction with climatic conditions provides many design alternatives of the building facade.

To reach optimal solutions, it is necessary to study the climatic elements that interact with humans and interacts with the building's metal envelope and affects its thermal performance, which provides climatic comfort within the building. The energy design of the building envelope provides the optimal design strategies for the building's metal envelope. (Fabrizio Ascione et al.:2019)

From the environmental graphic perspective, the most important biological requirement of the human being is climatic comfort, and therefore, climatic comfort conditions should always be provided in a building (through color, shapes, and material texture) to ensure the continuity in users’ health and productivity. Climatic comfort conditions are defined as the conditions in which more than 80% of users are satisfied.

*C. Solar Energy*

Obtaining accurate data on the intensity of solar energy at a building site is essential for the development of solar energy design aspects. This data is utilized in the building metal facades design, construction cost analysis, and calculation of the efficiency of a project.

Solar energy has many characteristics that make it a very attractive primary energy source. It is supplied through a continuously renewable source, the sun. It has minimal impact on the environment. Finally, present technology makes it possible to collect, convert, and store solar energy efficiently. Despite its advantages, solar energy does possess some disadvantages: it can be collected only during daylight and the quantity of its collection is affected by climatic changes (daily cycle) and varies throughout the year (yearly cycle). These factors lead to an inconsistent supply of energy. To overcome such disadvantages, excess solar energy should be collected and stored. There is also the potential to store energy both for cooling and heating to mitigate the yearly cycle. (Maria Wall et al,2012)

Solar energy entering a building through opaque metal facades is quantitatively analyzed by excluding the influence of outdoor air temperature on the building's net heat gain. The solar energy entering a building through an opaque metal facade is of the same importance as the solar energy entering the building through a window to reduce building heating energy consumption. So, the full use of solar energy to make users are satisfied from an environmental and economical view can be achieved by a significant reduction in building heating energy consumption that can be achieved by appropriate building metal facades design.

From an environmental graphic perspective making full use of solar energy in environmental graphic design items (external envelope, windows, and shading areas) is a feasible way to reduce building.

Fig. 1. integrates solar cell in façade design through environmental graphic aspects

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

*D. zero energy buildings*

Theoni Karlessi et al. (2017) was described the feasibility of the zero-energy building's implementation in the following terms.

- Compliance with existing energy standards and regulations.
- To adapt to the local climate and specific character (a site of archaeological or traditional importance)
- Define project goals clearly and follow the principles of sustainability for successful implementation.
- Taking into account all modern and innovative technologies and ensuring technical and financial feasibility.
- It is tailored according to the decisions and approval of the multidisciplinary team of specialists. (Theoni Karlessi et al. ,2017)

For example, the Green Pixel – zero-energy wall, in which the photovoltaic system was combined with the LED pixels so that these cells collect energy during the day and use them at night to run the interactive media interface with the lowest percentage of energy used at all.

Fig. 2. zero-energy façade design through environmental graphic aspects

## III. INTERNAL NOISE FACTORS

*A. Building Envelope*

A building envelope is one of the most effective elements of the environmental graphic. From an environmental graphic perspective, an envelope is designed to consider various determinants such as environmental, technological, socio-cultural, functional, or aesthetic factors.

A building envelope is what separates the indoor and outdoor environments of a building. It is the key factor that determines the quality and controls the indoor conditions irrespective of transient outdoor conditions. Various components such as walls, fenestration, roof, foundation, thermal insulation, thermal mass, external shading devices, etc. make up this important part of any building. (Suresh B. Sadineni et al.,2011)

Heat loss and gain through glazed areas in the building envelope are critical factors that should be considered when planning a building. To minimize energy loss, envelopes may be tightly sealed with glazing material that has lower heat transfer coefficients. However, buildings with curtain wall structures require increased energy loads, since the glazing itself is not sufficient to mitigate the influence of heat transfer between indoor and outdoor environments. (Yu-Min Kim et al.,2011)

To achieve this, the designer relied on the idea of a virtual representation of the design, which was implemented by combining the rules of perspective, optical illusion, and three-dimensional digital design to implement dynamic and interactive designs that inspire realism to make the flat building facade a multi-dimensional display screen.

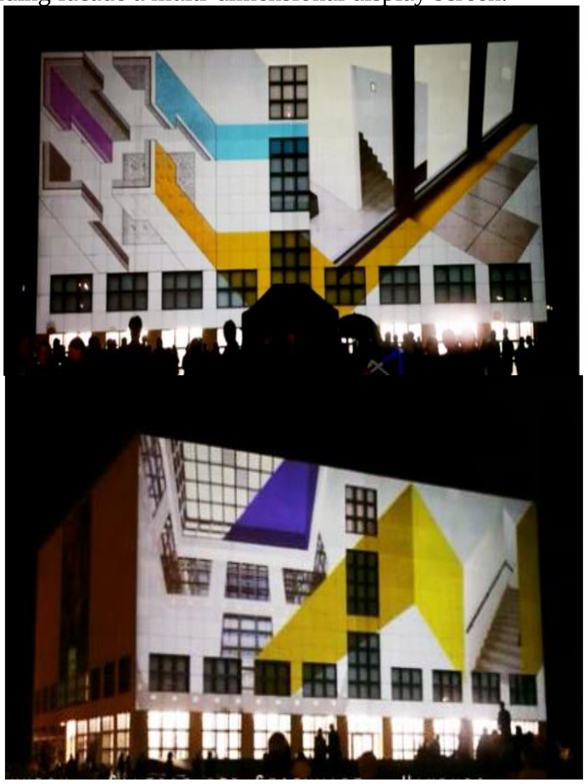


Fig. 3. environmental graphic achieves socio-cultural, functional, or aesthetic factors in envelope design

*B. Eco-roofs (Green Roofs)*

Green roofs (or eco-roofs) are one of the most effective elements of the environmental graphic. From an environmental graphic perspective, it's a sustainable technology used in buildings to convert them to green buildings, which are considered special roofing systems that include layers of vegetation and growing media. From bottom to top, a typical green roof consists of several layers: a regular roof resistance layer, drainage layer, soil layer (substrate with growing medium), and a vegetation layer. Green roofs are becoming popular in sustainable building design due to potential energy savings, environmental benefits, and building code requirements (Elborombaly, D.H., & Molina-Prieto, D.L,2015). Green roofs can offer thermal protection, which may reduce the thermal load and energy demand applied to buildings. Green roofs also contribute to reduce stormwater runoff, expand the lifetime of roofing membranes, add aesthetic appeal, improve microclimate, reduce greenhouse gas emissions, and a reduction of the urban heat island effect in cities.

Mingjie Zhao and J. Srebric (2012) Conclude that the green roof buildings save as much as 22.9% of the heating energy as compared with the energy used by the reference roof buildings when there is no snow on the roofs. Despite this result, energy savings decrease to 5.2% when the snow layer is present. This may be since the existence of the snow layer assimilates the surface differences between the green roofs and reference roofs. The snow layer affects the R-value of the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

whole roof system and the heat transfer process through the roofs, thereby reducing the thermal performance of the green roof. However, in principle, the green roof buildings still have a different energy performance pattern as compared to the reference roof buildings. ( Mingjie Zhao and J. Srebric, 2012)

There are two types of green roofs: intensive and extensive, the former has a deeper substrate layer and allows to cultivate deep rooting plants such as shrubs and trees; while the latter with a thinner substrate layer allows growing low-level plantings such as lawn or sedum. Extensive type is more commonly used as it can be retrofitted easily on existing roofs without modifications to the roof structure and also requires minimum maintenance. They have been proven to be fairly successful in cold climates but need more research on substrate material in hot and dry climates. The green roofs not only reflect the solar radiation but also act as an extra thermal insulation layer. (Suresh B. Sadineni et al.,2011)

Fig. 4. Green-roof Holocaust Museum -Los Angeles

## C. Shading Devices and Glazing Types

The shading device is also one of the most effective elements of the environmental graphic. From an environmental graphic perspective, the performance of shading devices installed on facades at various orientations has been carried out in several fields. One considered the impact of shading design and control on building cooling and lighting demand with various configurations of shading devices fitted for the overheated period under consideration. Another detailing energy simulation performed during the early building envelope design stage made appropriate recommendations on the facade, glazing, shading devices, lighting control options, and natural ventilation to be employed to realize energy-efficient buildings.

Besides the design of the external shading devices installed, the type of glazing used impacts the cooling load of an air-conditioned building. Different glazing will have different properties that determine the amount of solar radiation emitted into internal space as well as the amount of heat being conducted away. ( Kian Jon Chua and Siaw Kiang Chou,2010)

Fig. 5. sun shading facade design through environmental graphic aspects

## D. Thermal Insulation and Energy Efficient

The thermal insulation solutions present nowadays one of the key factors for the assessment of the material composition of building envelopes. One of the main design objectives is thus to reach thermal insulation properties as well as possible. This can easily be accomplished using a thermal insulation layer whereas the most important decision is to choose a proper insulation material. The thickness of the thermal insulation layer is then calculated according to appropriate standards. ( Vaclav Koci et al.,2012)

Jvier Sedano et al. (2009) conclude that effective thermal insulation is an essential component of energy-efficient heating systems in buildings. The more effective the insulation in the buildings, the lower the energy losses due to insulation failures. Thus, the possibility of improving the detection of thermal insulation failures represents a fresh challenge for building energy management.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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## CONCLUSION

The benefits from the robust design of buildings' metal facades are economic (saving money), social (reducing fuel poverty); and environmental graphic perspective (employing aesthetic and environmental design elements to energy-saving). Every new development ideally should have a robust design strategy, setting out how these benefits are to be achieved. So efficient robust design use: means of taking advantage of the contextual features of a building location and microclimate to reduce air conditioning and lighting loads, lowering overall energy consumption as external noise factors affects the quality of metal facades performance. On the other hand, control of internal noise factors from the robust design stage will help reduce consumption and will promote the use of passive means of control. Robust design in building metal facades aims to reduce energy consumption and costs and work to achieve an appropriate integration of passive heating, daylighting, and ventilation.

So, the researchers concluded that it is effective to use "robust design as a design tool" during the stages of the design process as one of the most important input, taking into account how does the external and internal environmental graphic elements affects the building facades performance at any conditions. From the environmental graphic perspective, the robust design aims to achieve aesthetic and environmental considerations in the process of facades design, through the analysis of the energy and the exploitation of environmental characteristics of the site and access to achieve a comfortable indoor climate and energy-saving.

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