The Environmental Formation of the Egyptian Office Buildings Envelopes in order to Develop its Architectural Design

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Abstract- The formation of the external envelopes and its impact on energy and environment is one of the most important factors that affect the quality of the work environment in the office buildings. Since, the industrial revolution and the era of high technology, buildings facades have witnessed a significant and noticeable development. The building skins represent the link between the internal environment (internal architectural spaces) and the external ones, and it also has a major role in controlling the internal climate and creating a micro-environment that meets the expectations of the users and their needs, by controlling the internal environment and providing comfort (psychological, acoustical, visual, thermal, ventilation and lighting comfort).

Index Terms- Architectural Formation, Envelopes, Environmental Design, Office Buildings, Egypt

I. INTRODUCTION

In order to learn about the styles and patterns of the office buildings in the local environment, a visit to the smart village and the Fifth Settlement was made, and it was found that most of the buildings were designed separately from their environment, blindly imitated similar to the trendy office buildings around the world as shown in **fig (1).** This resulted in many problems in the internal environment (internal architectural spaces), such as the lack of the comfortable and stimulating environment for employees, low productivity and the symptoms associated with the sick buildings, as well as the impact on the external environment, such as the separation of buildings from their original cultural identity and their society.

Figure 1 The similarity between the envelop of the National Bank (NBK) in the Fifth Settlement and Bank building located in Manhattan, New York, United States (right), The similarity between BLOM Bank Egypt SAE in the Fifth Settlement Bank and Bank building in Minneapolis, USA (left).

I. RESEARCH PROBLEM

The separation of office buildings from their environment and identity, and the problem of the energy economics in Egypt **fig (2)**. Therefore, the main aim of the research is to answer the following question, "Is the environmental formation of the building skins is the target or one of the ways that should be used to develop and improve the architectural design of the office buildings?". With the

energy problem and the high operating costs afflicting Egyptian administrative buildings, it was necessary to study the methods and techniques used to deal with the problem of the operation and maintenance costs by reducing energy consumption in the buildings and adopting effective and negative environmental design strategies in the external envelopes.

Figure 2 An administrative building in the smart village (right), Huawie Building in Smart Village (middle), BLOM Bank Egypt SAE in the Fifth Settlement (left).

II. Buildings Envelopes Adaptability

A. *The Similarities between Nature and Buildings Envelops*

The most important features of the adaptive envelopes are the responsive process (responsiveness) **fig (3)** to all the various internal and external variables in order to reach the best performance of the building and meet the different user's needs.

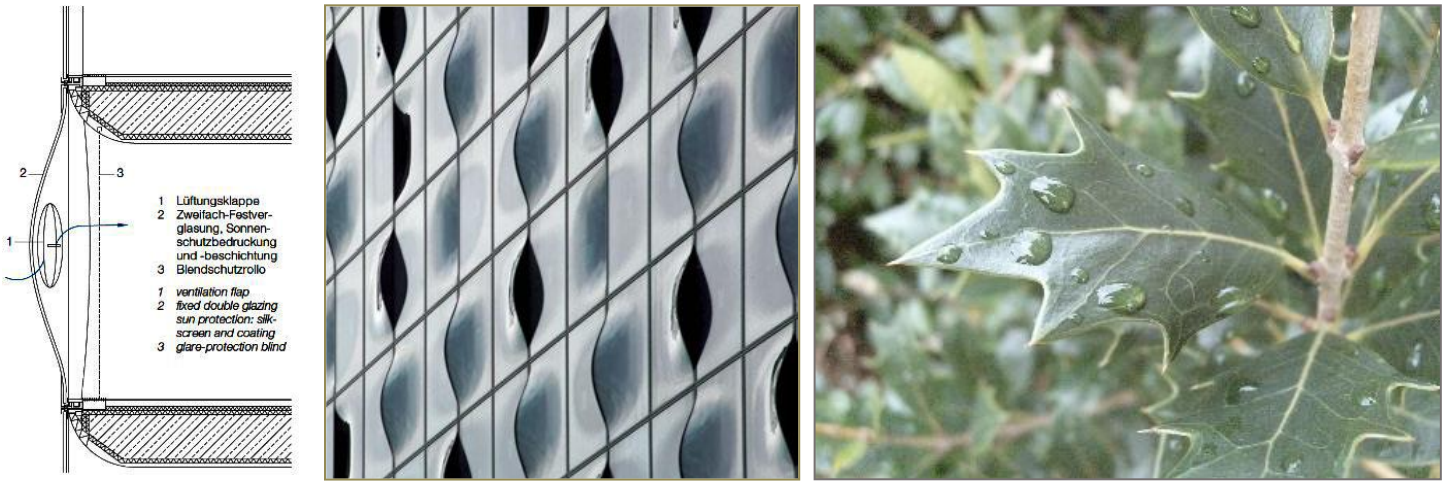

Figure 3 The phenomenon of respiration in plants (right), The breathing buildings envelops, the Hamburg concert hall (middle), Detailed vertical section of the envelope (left). source: (Schittich, 2015).

B. *The Similarities between Human Being and Buildings Envelops*

The vital systems in the human body such as the respiratory system and the breathing process are similar to the ventilation system and the fresh air cycle inside the building **fig (4)**, and the structural system of the building is similar to the structural composition of the human body.

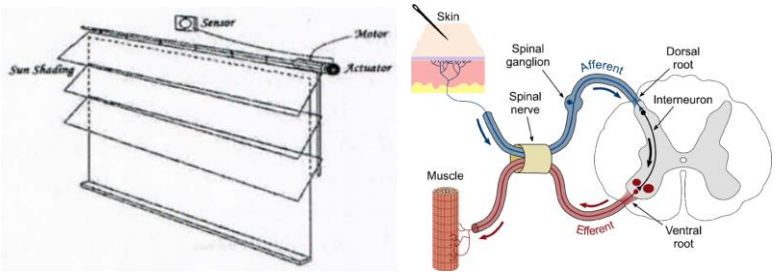

Figure 4 Automatic reaction in the human system (right), Automatic response of sun louvers to sunlight (left). source: (Schittich, 2015).

- *The Similarities between the Adaptation of the Buildings Envelopes and the Human Skin*

The building's envelope resembles the human body and is one of the best biological comparisons for buildings **fig (5)**. The

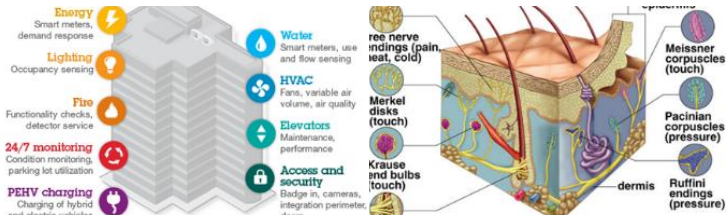

Figure 5 Sensory receptors in human skin (right), Sensory receptors in buildings (left). source: (Gün, 2013).

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envelopes protect the building just as the skin protects the human body, and it covers the building just as the skin covers the human body. The term "Building Skin" was invented because the building's external envelope resembles human skin, which protects the body from cold, heat, and bacterial and chemical threats. The live receptors found in the human skin that respond to stings and pricks, for example, are similar to sensors that detect clouds, rain, theft and fire. These sensors are installed in the building.

III. CASE STUDY: HC SECURITIES & INVESTMENT SAE, EGYPT

A. THE ANALYSIS OF THE BUILDING BEFORE RENOVATION OF THE EXTERNAL ENVELOPES

HC headquarters will be analyzed before renovation of the external envelope (the current situation) **fig (6)** and that analysis in terms of functional ideas (Physical and Non-Physical), Formational, structural and technological ideas, and then clarify how the functions, structures, formation and technology of the building affect its external envelope as follows:

Figure 6 HC Securities & Investment SAE, Egypt

- THE FUNCTIONAL FIELD
  a) Double low-E Glazing

Due to Cairo's climate, which is very hot in summer and moderately cold in winter, low-e glass is very important in summer, as it diffuses heat absorbed from the building, reducing heat transfer through windows. It also reduces heat transfer from the hotter (outer) part of the glass to the cooler (inner) part, thus reducing the amount of heat passing through the window. Low-e glass prevents large amounts of energy from entering the building, thus cooling the inner spaces **fig (8)**.

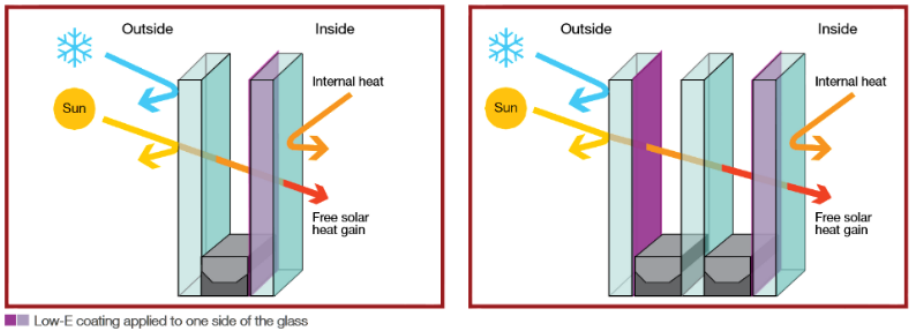


Figure 7 Low-e glass transmits light and blocks infrared radiation (heat).

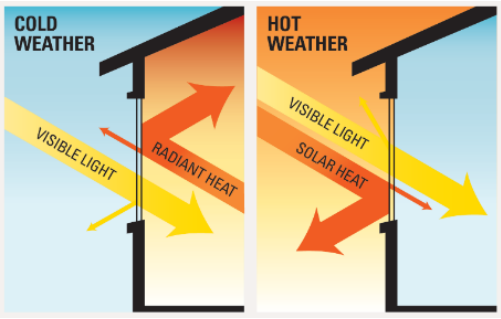


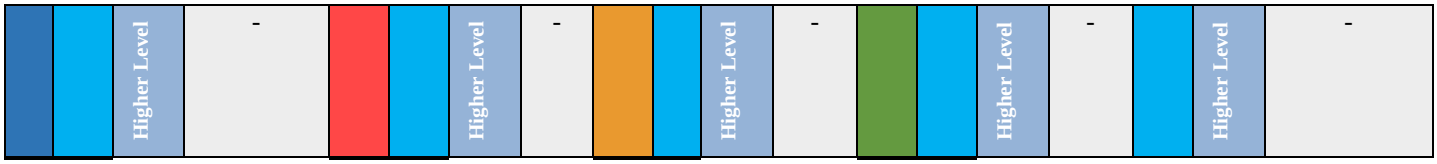
Figure 8 Triple glass with two layers of low-e coating (right), Double glazing with a single layer of low-e coating (left). source: (Rissman et al, 2013)

Figure 9 HC building considered a model for the smart village buildings

Figure 10 HC building Floor Plans before external envelope renovation

An explanation of how to assess the level of impact and development of the building as a whole (before renovation: the current situation)																				
Functional Ideas		The idea's impact level		Formational Ideas		The idea's impact level		Structural Ideas		The idea's impact level		Technological Ideas		The idea's impact level		The idea's impact level		
The Functional Field	Functional Ideas : (Double low-E Glazing)	Lower Level	The idea has achieved many values in one architectural field (function) Thermal Comfort √ Glare Protection √ Heating and Cooling √ Optical Comfort √ Psychological Comfort √	The Formational Field	Formational Ideas	Lower Level	-	The Structural Field	Structural Ideas	Lower Level	-	The Technological Field	Technological Ideas	Lower Level	-	level of influence and development	Lower Level	The building has achieved the lower level of impact in the external envelope
		Acceptable Level	-			Acceptable Level	-			Acceptable Level	-			Acceptable Level	-		Acceptable Level	-
		Intermediate Level	-			Intermediate Level	-			Intermediate Level	-			Intermediate Level	-		Intermediate Level	-

Table 1 External Envelope Ideas Evaluation list of HC headquarters before renovation process, source: the researcher



B. The ANALYSIS OF THE BUILDING AFTER RENOVATION OF THE EXTERNAL ENVELOPES

HC headquarters will be analyzed after renovation of the external envelope (The process of improving and developing the envelope) and that analysis in terms of functional ideas (Physical and Non-Physical), Formational, structural and technological ideas, and then clarify how the functions, structures, formation and technology of the building affect its external envelope as follows:

- THE FUNCTIONAL FIELD
  a) The Idea of ETFE (Nitrogen filled EFTE cushions) in the Northeast facade

The main climate issue is increased solar radiation and building temperature, which requires energy-intensive cooling systems. This system works in a climate where the main problem is solar radiation in the summer and doesn't go through very cold winters like Egypt's. Due to the intensity of the solar radiation and the disturbing daytime glare in the local environment, ETFE pillows were used. It is a system that works best in buildings designed for office or public use **fig (11)**.

ETFE is composed of Teflon, a crystalline polymer (Teflon-based polymer). It is a very light material, with high elasticity and anti-sticking, which prevents it from getting dirty and requires maintenance for cleaning, at the same time it does not lose its properties of elasticity, transparency or strength over time and has no tires, very resistant (1500 kg) and ideal for escaping from fires **fig (12)**.

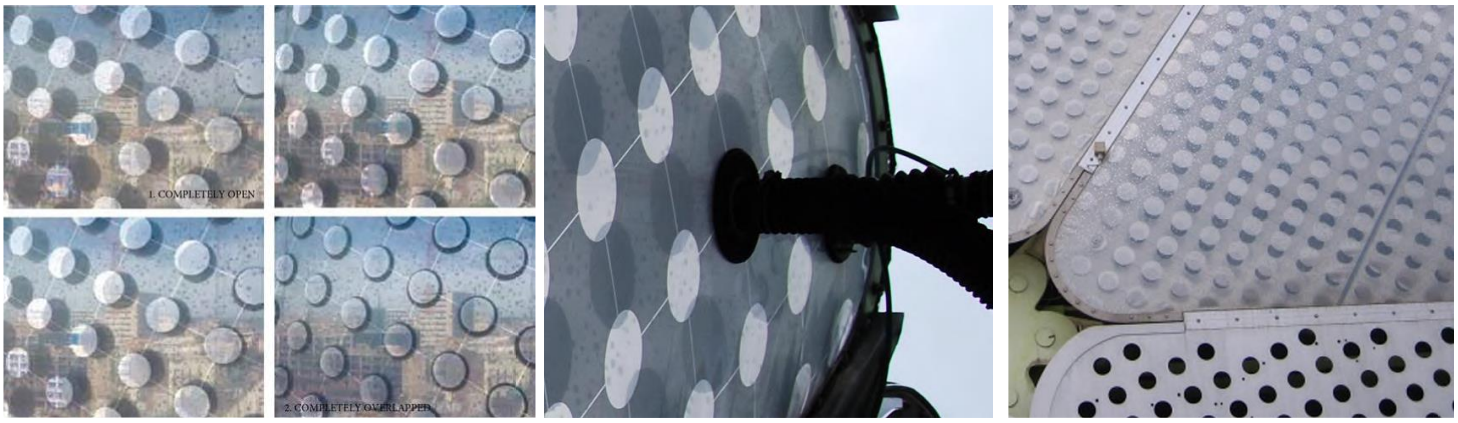


Figure 11 Northeast Facade ETFE Nitrogen Filled Pillows (right), Illustrations of ETFE Pillows on the Northeast Facade (left). source: (Balascakova et al, 2016).

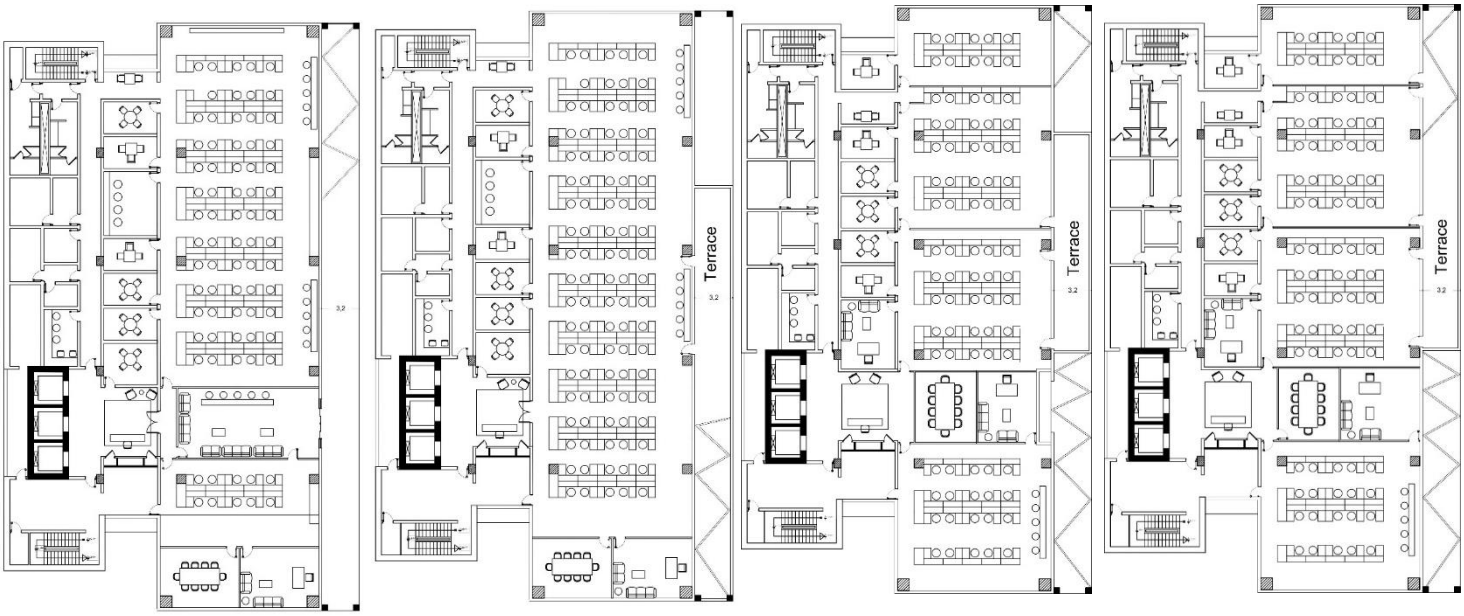


Figure 12 HC Floor Plans after external envelope renovation, ground and first floor plan (right), second and third floor plan (left). source: the researcher

- THE FORMATIONAL FIELD
  b) Forming the Envelope as a Digital Pedrera.

The proposed second envelope to renovate the external facades allowed the building to reveal the performative character of architecture by dealing with the multiple disciplines of art, architecture, advanced technological materials and digital processes. The envelope plays a major role in expressing the personality of the building, in addition to its main function, which is solar shading and thermal insulation. The innovative corrugated configuration of the proposed envelope of the building is similar to that of Casa Milà (la pedrera) **fig (13)**, the envelope provides an element of innovation in color and presents a triangular pattern of whole and empty, concave and convex shapes, resembling molecular structures or reptile skin. The ETFE will be a great mural, depending on the thermal needs of the building. A steel frame was added to install the ETFE cushions as a second external envelope **fig (14)**, simulating the Casa Mila, which provided open spaces and flexibility in the internal divisions by transferring all the loads to the piles; With the aim of absorbing light through squares, courtyards and different facades, a goal that Gaudí was able to achieve by opening great gashes in the facade **fig (15)**. The properties of the material represented a distinctive element that imparts an organic composition to the building, as well as a protective and insulating element for the internal spaces, as it resulted from the desire to give the maximum movement in the external envelope. The irregular mosaic pattern of the concave and convex areas organizes itself behind the protective envelope, absorbing sunlight to save energy, blocking ultraviolet rays (UV light) and self-cleaning of non-stick surfaces. Which adds to the building sustainability and innovative impact at the same time. One of the advantages of the ETFE wall is that it has a balanced and clear performance with clear technical control features. For these reasons and the daring nature of the project, it is reasonable to classify the HC building as a digital pedrera **fig (16)**.

Figure 13 Similarities between HC Building and Casa Mila, source: (Albiñana et al, 2011)

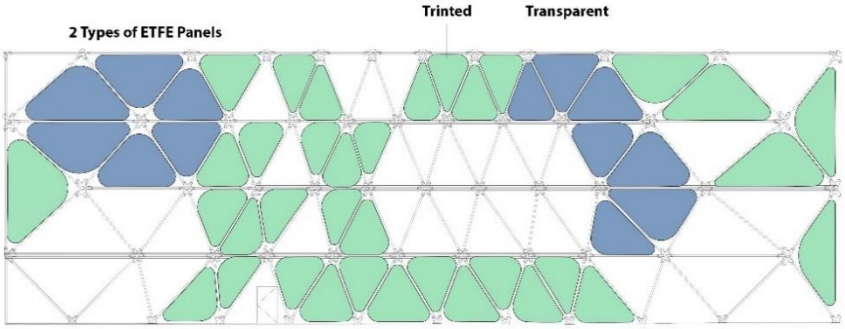


Figure 14 Types of ETFE Pillows in HC Building, source: the researcher

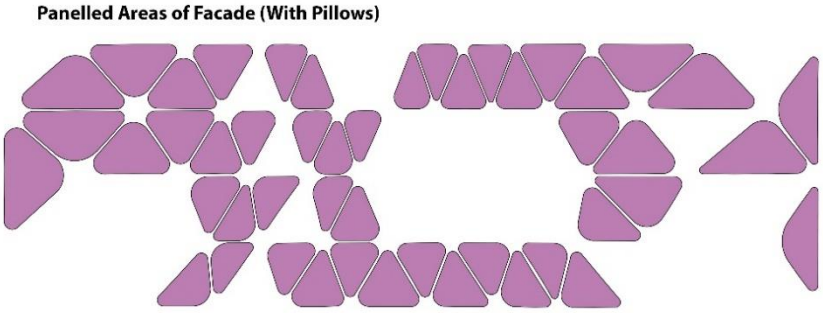


Figure 15 Cushioned areas of the proposed HC building exterior, source: the researcher

- THE STRUCTURAL FIELD
  - c) Steel Truss Frame idea for secondary Envelope support.

The renovation of the building's external envelope has led to the building showing innovation in construction, performance, maintenance and structural system, and in its uniqueness and diversity of its usable spaces, which is in fact a statement of everything the architect-designer wants to express **fig (17)**. A steel frame has been designed and installed on the main facade of the building, so that ETFE cushions are installed on it. These cushions will represent a second facade that protects against direct sunlight and annoying daytime glare and contributes for providing thermal comfort to the interior spaces, as it provides spaces that can be used as terraces or added to the main space and used as a space for administrative offices **fig (18)**. The idea of

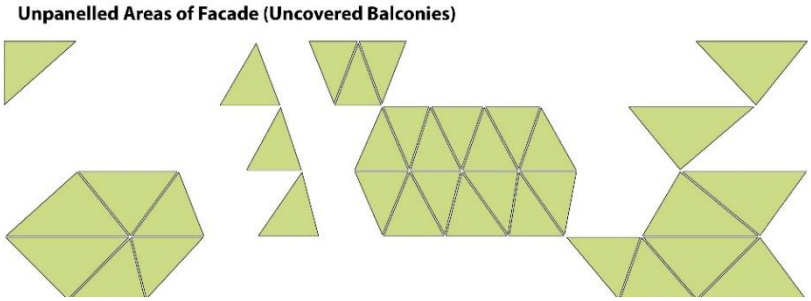


Figure 16 The exposed areas of the proposed envelope for the HC building, source: the researcher

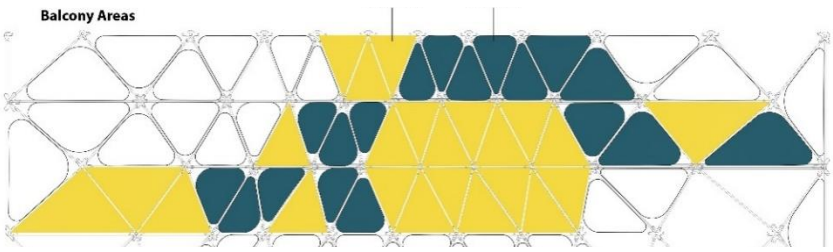


Figure 17 Exposed and covered terraces of the proposed envelope for the HC building, source: the researcher

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digitalization in this building has been defined as the result of working as part of a network, not in a chain or parallel to it, and as a fabric through which it's formed, which in turn reconfigures it through an iterative analysis process until its functions are improved for strength (functionality for strength).

The envelope constructed of a basic steel frame, consisting of a rigid braced frame. The frame type consists of Fink steel beams made of forged-metal girders of seven sections. The frame has a support beam that transfers its load to the rigid support posts. The most effective way to solve the external envelope corrugated design problem is exchanging mass for geometry. In this way, the secondary structure was not resolved by the presence of a dense outer shell that would later become armor; Rather, it was resolved by allowing it to expand into the void.

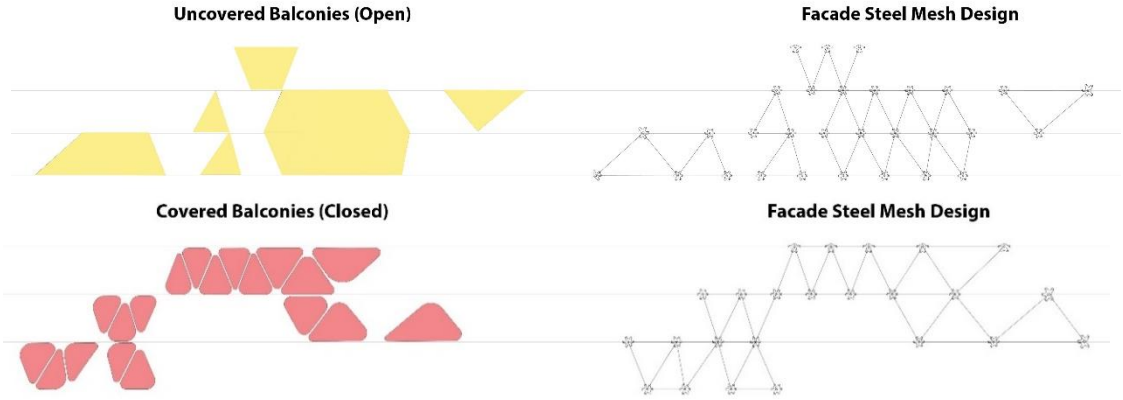

Figure 18 Formative studies for the external envelope of the HC building, source: the researcher

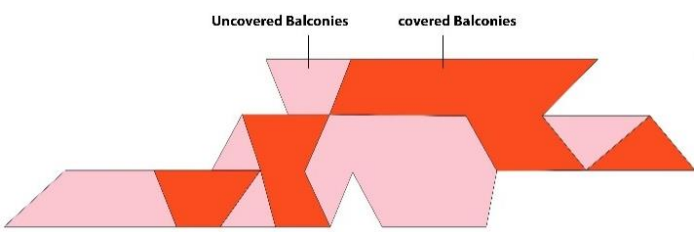

Figure 19 Exposed and covered terraces of the proposed envelope for the HC company building, source: the researcher source: (Albiñana et al, 2011)

- THE TECHNOLOGICAL FIELD
  d) The Idea of using ETFE material to represent the Digitalization in Buildings.

In the age of information, architecture should be a technology platform, where bits, connectivity, new materials and nanotechnology are more important than old materials. We live in a non-physical electronic world, where the design of the network, not its actual size, is what matters **fig (20)**. The HC Building will follow digital architecture. Its facades do not represent industrial construction, instead they develop and represent digital construction, the construction of information **fig (19)**. The main idea (the theme) in improving and developing the HC building is how engineering creates a new balance with the digital use of energy, because we are in the field of innovation and ICT, where energy management is the most important goal. This was done using ETFE material in the design of the building's second envelope **fig (21)**. Or in other words, the building needed a way to realize the idea of digital construction, and it was able to do so by using ETFE. By using ETFE (thylene tetra fluoroethylene) cladding, the building will be able of saving energy. In this case, ETFE provides the advantage of solar filtration. It is also a highly resistant material that is ideal for escaping from fires, and its flexibility can be exploited to create distinctive geometric shapes. Moreover, it is non-stick, which prevents it from getting dirty and requiring maintenance for cleaning. At the same time, it does not lose its properties of elasticity, transparency or strength over time.

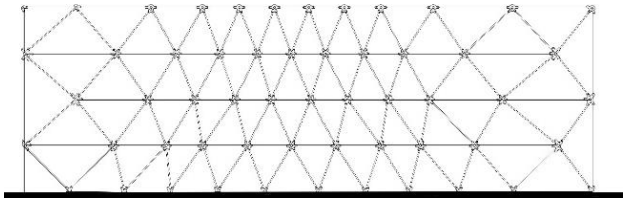

Figure 20 The secondary structural system for the proposed envelope, source: the researcher

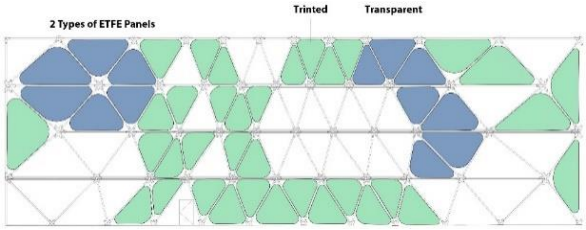

Figure 21 ETFE Cushions Installed On The Secondary Structural System, source: the researcher

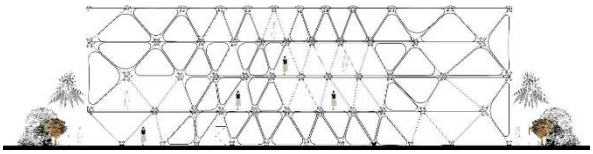

Figure 22 ETFE The northeastern facade after renovation of the external envelope of the HC building, source: the researcher

The use of ETFE material in the building contributed to giving the maximum possible movement in the external envelope through the properties of ETFE. It enabled the designer to form the facade in a distinctive organic form, and for this reason the building was classified as a digital building and a digital pederera. The building's ETFE cladding is inflatable, with up to three air chambers. This not only improves thermal insulation, but also makes it possible to create shadows via the pneumatic system. The first layer is transparent, the second (middle) and

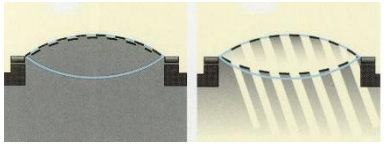

Figure 23 Illustrations of the function of nitrogen-filled ETFE pillows on the northeast facade of a building source: (Balascakova et al, 2016)

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the third are designed to have a reverse pattern design, when the second and third layers are joined together a single opaque layer is formed and thus the shadows are formed, and the inflatable section contains only one air chamber. In this way the entire facade can be managed simply by the movement of the air. This is not done with industrial mechanisms, but with air management, which has very positive and energy-efficient results. The northeastern facade receives high solar radiation and requires an external solar system with double-layer cladding to be regulated, which reduces energy consumption and increases illumination efficiency **fig (23)**. The solution is to use an external film of materials with a solar filter composed of ETFE in the envelope. Three layers of ETFE were used, with constant pressure and variable air circulation between the rooms.

An explanation of how to assess the level of impact and development of the building as a whole (After renovation: The process of improving and developing the envelope)

Functional Ideas		The idea's impact level		Formational Ideas		The idea's impact level		Structural Ideas		The idea's impact level		Technological Ideas		The idea's impact level		The idea's impact level	
The Functional Field	Functional Ideas : (The idea of ETFE (Nitrogen filled EFTE cushions) in the Northeast façade)	Lower Level	-	The Formational Field	Formational Ideas: (Forming the Envelope as a Digital Pedrera)	Lower Level	-	The Structural Field	Structural Ideas: (Steel Truss Frame idea for secondary Envelope support)	Lower Level	-	The Technological Field	Technological Ideas: (The Idea of using ETFE material to represent the Digitalization in Buildings)	Lower Level	-	level of influence and development	Lower Level	-
		Acceptable Level	-			Acceptable Level	-			Acceptable Level	-			Acceptable Level	-		Acceptable Level	-
		Intermediate Level	The idea has achieved many values in three architectural field (function, form and technology) Thermal Comfort √ Glare Protection √ Heating and Cooling √ Optical Comfort √ Psychological Comfort √ Identity √ Diversity and Contrast √ Facility management technology development √ Evolution of computer design √			Intermediate Level	The idea has achieved many values in three architectural field (function, form and technology) Thermal Comfort √ Glare Protection √ Heating and Cooling √ Optical Comfort √ Psychological Comfort √ Identity √ Diversity and Contrast √ changing rhythm √ Evolution of computer design √			Intermediate Level	-			Intermediate Level	The idea has achieved many values in three architectural field (function, form and technology) Thermal Comfort √ Glare Protection √ Heating and Cooling √ Optical Comfort √ Psychological Comfort √ Identity √ Diversity and Contrast √ Facility management technology development √ Evolution of computer design √		Intermediate Level	-
		Higher Level	-			Higher Level	-			Higher Level	The idea has achieved many values in four architectural field (function, form, structure and technology) Identity √ Integration and compatibility of the form with the environment √ Support (stabilization) √			Higher Level	-		Higher Level	The building has achieved the highest level of impact, renovation and development in the external envelope

											Evolution of computer design	√							

An explanation of how to assess the level of impact and development of the building as a whole (After renovation: The process of improving and developing the envelope)																												
The Functional Field	Functional Ideas : (The idea of ETFE (Nitrogen filled EFTE cushions) in the Northeast façade)	Lower Level	Acceptable Level	Intermediate Level	Higher Level	The Formational Field	Formational Ideas: (Forming the Envelope as a Digital Pedrera)	Lower Level	Acceptable Level	Intermediate Level	Higher Level	The Structural Field	Technological Ideas: (The Idea of using ETFE material to represent the Digitalization in Buildings)	Lower Level	Acceptable Level	Intermediate Level	Higher Level	The Technological Field	Technological Ideas: (The Idea of using ETFE material to represent the Digitalization in Buildings)	Lower Level	Acceptable Level	Intermediate Level	Higher Level	level of influence and development	Lower Level	Acceptable Level	Intermediate Level	Higher Level
		-	-	√	-			-	-	√	-			-	-	-	√			-	-	√	-		-	-	-	√

Table 2 External Envelope Ideas Evaluation list of HC Headquarters after renovation process, source: the researcher

IV. CONCLUSION

This study highlights the role of the environmental formation of the external envelope, which contributes in providing several environmental benefits to the internal environment in buildings that lead to reducing the risks of sick buildings syndrome and the health effects associated with it. The outer envelope must be an element for linking and compatibility between the internal environment (interior architectural spaces) and the external environment in order to provide comfortable and healthy environment. far away, without separating the building from the surrounding environment. The various elements of the external envelope (walls, ceilings, floors and environmental installations) must work and perform in a harmonious and balanced way with each other, as they overlap and intertwine in their physical and nonphysical, directly and indirectly. Elements can perform visual, symbolic and practical functions as well. The main financial benefits of achieving this principle are due to the reduced absenteeism rate as a result of providing a comfortable work environment, which results in increased productivity and efficiency. Designing the external envelope using strategies similar to the functions of the human body organs led to the building being a strong-willed system, always striving for balance and integration with all external influences.

1. STANDARDS USED IN EVALUATING BUILDING ENVELOPS

- The envelope must achieve a set of architectural values (functional -formational- structural - technological), and those values must overlap and intertwine in their performance.
- The more the external envelope achieves a number of architectural values, the more successful its envelope formation will be.
- Whenever one of the ideas of the external envelope of a field achieves a number of different architectural values, the idea is characterized by success and effectiveness, and the more it proves the importance of its use in the external envelope (for example, a technological idea has achieved functional, formative, structural and technological values in the envelope).
- The more the external envelope expresses its environment and identity, the more it can be described as the environmentally-formed envelope, so the envelope must express its identity and unique personality with the cultural roots of its environment and surroundings (through the use of environmental materials to highlight the identity during the design of the envelope).
- The building with an environmentally formed envelope must respect its environment, express its original identity, and mimic nature in its functions as much as possible.

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Thanks to my mother who encouraged me and taught me how to work as hard as possible, for which she has all the credit. thanks to my mother Dr/ Hayam Negm who died as a strong warrior, who had a strong will for living until losing her bitter battle against cancer, this is for you mom.

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