INVESTIGATION OF THE ADAPTIVE FACADE CONCEPTS IN TERMS OF SHADING ELEMENTS

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ABSTRACT

Today, due to rapidly depleting energy sources, the importance of energy conservation is emphasized more than ever in the world. There are important duties to building facades in terms of energy conservation and their importance is increasing every day. Façade is a transitional element between interior and exterior environment. It is an important building component in terms of both design context and ability to meet performance needs. As identity cards of buildings, facades tend to draw attention with their designs today. In addition to the different design approaches in architecture, the developments in the facade systems are examined from the perspective of "Adaptive building facades", one of the most remarkable of these, in terms of shading elements. Adaptive facades which has the ability to respond dynamically to environmental conditions are an important breakthrough in shaping the future facades. People want and need to be in structures that are under their control and can adapt to the variability of environmental factors. The traditional static building envelope, under the influence of changing climatic conditions, has become a kinetic element. While the kinetic structure exposed to solar energy responds by moving to changing solar conditions, it is actively engaged in influencing the transition between the inside and the outside. These types of facade systems, due to their ability to adapt to changing conditions, can reduce energy consumption while enhancing indoor comfort. Adaptive facades increase building energy performance significantly in the context of their ability to utilize high thermal performances, natural ventilation and daylight, and optimize solar gains. With the opportunities provided by technological improvements, these systems that adapt according to the position of the sun bring innovative approaches in architecture and the shell transforms a dynamic sculpture with the shape changing form. In the direction of these information, first of all, new concepts in building envelopes are investigated, adaptive facade systems are defined and classified in this study. Secondly, three buildings that make a difference with their facades and their integrated shading systems are examined in detail. In conclusion, it is aimed to create a resource that will help to develop suggestions for design solutions that can be implemented on the facades.

Key words: Building facade, facade systems, adaptive facade

Word Count: 3667 words

1. INTRODUCTION

The building facade system, now appears as a visible reflection of the rapid change and development of technology in buildings. The first impression of the building is given through the building facade. It is the prestige resources for the owners and the users who reflect the superior technology out of this care. Technological progress has reached levels that cannot be ignored in the field of building facade. While aesthetic is certainly an important criterion for building facade, it should be aimed at creating building facades which do not cause any problems during its use and which do not cause any inconvenience.

Building facades were designed with limited material and technology possibilities until the industry revolution. After the industrial revolution, the concept of facade has changed a lot as a result of progress in materials and technology. Along with the oil crisis in the 70s, the importance of facade designs has increased more to reduce fossil-based energy consumption. Building facades that consume less energy, produce less damage to the environment, and even generate energy, appear to be under discussion through different concepts.

With this sensitivity, constantly developing facade concepts have been produced and still continue to work on new ones. Most of them are the facade designs adapt to their surroundings, each with a different feature. From this point of view the purpose of the study is to define adaptive facades and investigate existing examples of adaptive facades with shading elements to gain comprehensive understanding of relatively new facade concept. Desk research and literature review methods are used to put related information together for the conceptual analysis. The conceptual analysis was conducted to gain an overview of the state-of-the-art in the field of adaptive facade concepts and their applications. Adaptive facade concept, shading elements and their contribution to performance requirements and design concept are the subjects that have been reviewed in the study. Lastly, suggestions for future have been developed in the research area.

2. NEW CONCEPTS IN BUILDING ENVELOPES

With the help of technology, it is possible to give various features to the building envelopes. Many concepts such as intelligent, sustainable, energy efficient, kinetic, innovative, high performance, smart, responsive and adaptive are used to describe building envelopes. New concepts are presented and facade alternatives are designed through comprehensive analysis of environmental changes and user needs. However, there are several limitations to be addressed in the use of these new building facade systems, which is often based on the initial investment costs and high maintenance costs of mechanical control systems. The solution of these constraints and the clarity of the system of profit loss balances is an up-to-date issue that needs to be studied. Today, "adaptation" is accepted as an important criteria in the building facade design area and next part of the study clarifies the new adaptive facade concept with different cases.

2.1. Adaptive facades

The concept of “adaptation” in biology (adaptation of living things to changing environmental conditions) is based on the concept of “responding to the external stimulus assessed by detectors by integrated

mechanisms". Adaptive building envelopes, unlike static envelopes, are multi-parameter, high-performance systems that conform to mechanical or chemical routes to meet user needs and comfort conditions (Luible, 2014). Building envelopes, which have the ability to adapt with internal and external changes in climate and user behavior, are creating current trends in architectural research and development activities. These systems have the ability to change functions, features and behavior. Adapting changing conditions is regarded as a critical ability to improve facade performance in uncertain and variable external environments. The basic design goal is to improve energy performance and interior comfort. When the literature review is conducted it is observed that the facades conform to two basic ways;

1) Through intelligent systems (air exchange tracking stations, shading and daylight systems, micro-heating cooling units, etc.)

2) Through intelligent materials (materials with properties such as variability, selective permeability and storage, etc.)

PURPOSE	Thermal comfort Energy conservation Visual comfort Aesthetic considerations
REACTIVE FUNCTION	Accept or reject solar heat gain Accept, reflect or direct visible light
TECHNOLOGY	Shading systems
SCALE	Facade (wall+window)

Table 1. Descriptive parameter sample table for adaptive facade systems

Designed to compensate for heat loss and gain in buildings, shading elements are integrated into the building facade to accommodate changing conditions. Such adaptive facades can be produced in many different ways with the knowledge and creativity of the architect. In addition to improving the physical performance of the building, it is also possible to contribute to the aesthetic characteristics. There are a lot of examples that make different forms of shading. In this study, the following examples of adaptive systems will be examined; the Institut du Monde Arabe in Paris, the Kiefer Technic Showroom in Austria and the Al Bahar Towers in Dubai.

3. EXAMINING THE EXAMPLES OF "ADAPTIVE FACADE CONCEPTS"

The way of designing an adaptive facade is very diverse. What is important is to develop an innovative facade design that can respond dynamically to environmental influences. Developing a design proposal for future building facades by examining adaptable facades is an important research topic. It has been deemed appropriate to conduct this work in order to guide architects and encourage them to design adaptive facades. In this section of the study, the most common type of the adaptive facades with integrated shading elements have been examined through 3 different examples from different regions. The working sample group was chosen from adaptive facade designs that adapt itself to the environment and provide the interior comfort conditions while minimizing energy requirements. As a result of the literature review, the facades have been classified according to their adaptation patterns and the selected buildings have been considered in accordance with the first item of this classification "adaptation through intelligent systems". While choosing these buildings, care has been taken to ensure that they are buildings that shape the future with their eye-catching

designs and shading element use. During the selection process of the facades that we examined their concept, physical properties and performance effects, having more information about the buildings in the literature has been also effective. The selected Institut du Monde Arabe building is very important because it is one of the first examples of the use of dynamic shading elements to design adaptive facades. The Kiefer Technic building with shading elements used on the facade is an important example of the adaptive facades in terms of both with its user control ability and design. Al Bahar Towers won the CTBUH Innovation Award in the 2012 CTBUH Awards program (Council on tall buildings and Urban Habitats, 2013). All three of the buildings use adaptive facades that can either emulate a design strategy or merely performance elements for the building.

3.1. Case 1: Conceptual Analysis of Institut du Monde Arabe

Institut du Monde Arabe was designed by Jean Nouvel and built in Paris between 1981 and 1987. Daylight control is provided by mechanical diaphragm with 30,000 aluminum material controlled by electropneumatic system depending on the light coming on the south facade (Compagno, 1999).

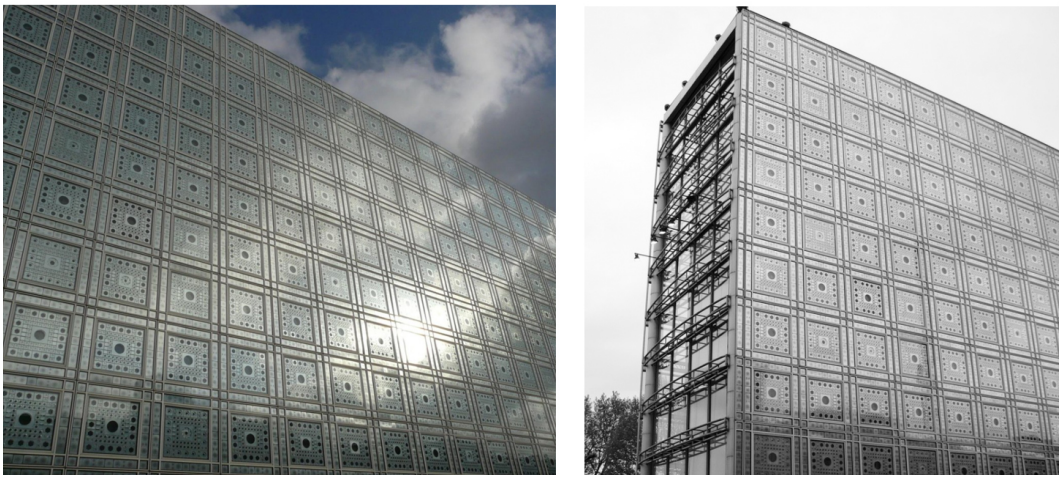


Figure 1. Institut du Monde Arabe (Archdaily, 2011)

The structure also has one of the first "intelligent" building facade to adapt to environmental conditions. The diaphragms, which are located between the double-layered glasses at the southern edge of the structure, are still in operation today. Because this adaptive facade looks south, the building can control the heat effects and interior lighting with same system.

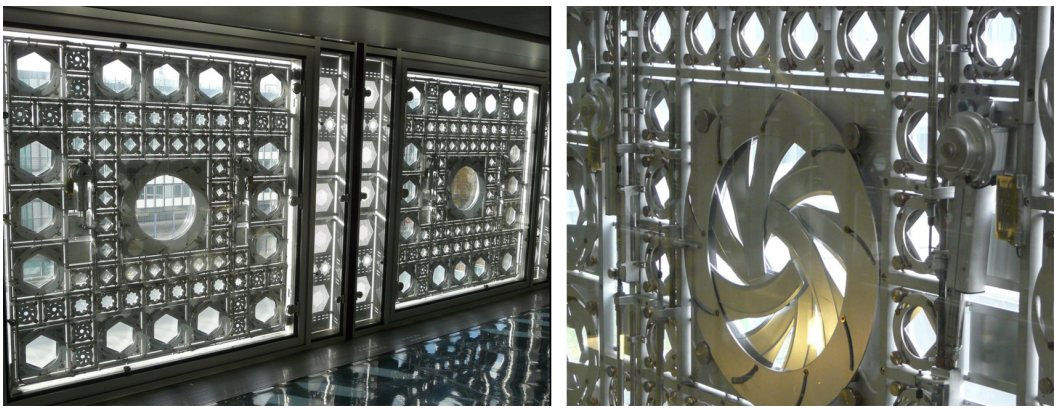


Figure 2. Detail of the shading unit (Archdaily, 2011)

Performance of a solar shading device is related to the geometry transformation of building facade via mechanical systems. The unique windows of the Institute are reminiscent of traditional, complex Arabian textures (Archdaily, 2011). The building facade came out of lots of metal eyes that can expand according to the daylight conditions outside and the interior is exposed to a complex lighting effect that changes with the daylight layers entering the space. Because the amount of light hitting the building and entering the interior is always variable, the movement of the mechanics creates light plays in the interior environment.

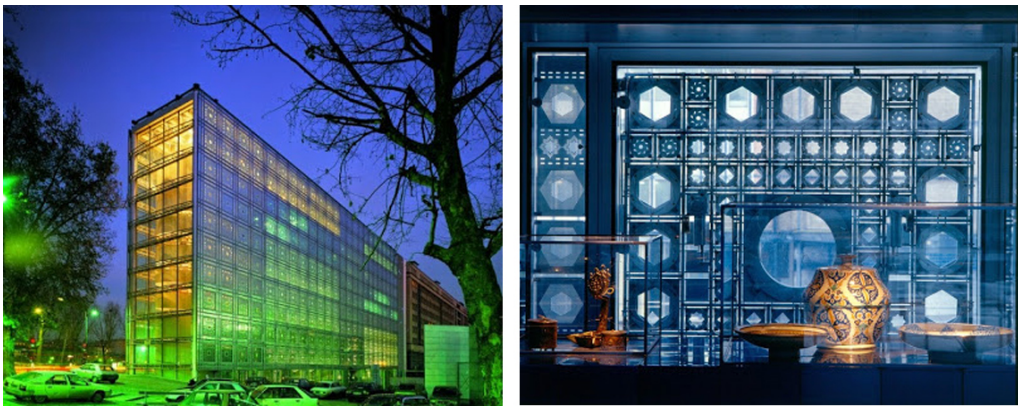


Figure 3. Night view of the building from exterior and interior (Architecturemadefun, 2014)

Differently from the traditional building facades, Arab Institute adopts advanced technology applications and emphasizes the role of innovation and creativity in the design of the facade. The building collects various art from the roots of the Arab and Islamic civilizations. However, the facade design of the building has been an example of guiding innovative concepts by overcoming this emphasis. The unit used on the front of the Institut du Monde building was inspired by a typical Islamic decoration pattern. In this context, the design of the shading element provides the connection to the cultural content of the facade while meeting the performance needs. Considering the technological possibilities of the day it was built, it is quite new to the idea of adding dynamic shading elements to the existing traditional windows, and so it can be seen as early example of the adaptive concept.

3.2. Case 2: Conceptual Analysis of Kiefer Technic Showroom

The facade, which takes adaptation ability from its dynamic behavior, belongs to the Kiefer Technical Exhibition Hall in Bad Gleichenberg, Austria which is used as office building and exhibition area. It is a facade system that allows users to personalize the interior environment with the ability to control outdoor conditions improve indoor comfort (Archdaily, 2010).

Figure 4. Shading system view of the showroom (Archdaily, 2010)

The entire southern facade of the building is covered with white aluminum louver panels, which can be opened and closed with a series of electronically controllable horizontal hinges. At the same time the facade elements can be controlled by optimization programs when no one is in the building (Archdaily, 2010). With 56 different engines used in the facade, light and temperature levels can be set in any room to achieve optimal conditions for different activities (Uys, 2016). The facade responds to both environmental conditions and individual needs. Since this system is located only on the south side, where the sun is most effective, there is not any situation that will cause visual discomfort to the users in the indoor environment. User control is an important feature of the system. System elements can allow the user to customize their own areas with user controls while also acting according to weather conditions to optimize the interior environment.

Figure 5. Different positions of the adaptive shading elements on the facade (Archdaily, 2010)

The facade is the most important part of the building. It is possible to say that architect Ernst Giselbrecht has achieved a modern architectural emphasis that allows the building's outer shell to be taken over entirely. As these facade elements change constantly and show a new "face" every day, every hour. The adaptive facade becomes a dynamic sculpture. It is understood that the facade can be an effective tool not only for performance and design, but also for communication with the environment. Here, through the shading elements, the dimension of communication is added to the performance and design dimensions of the facades.

The architect applied an adaptive facade to control the indoor ventilation and lighting level throughout the entire southern facade of the showroom building, while at the same time presenting various possibilities for users between privacy and transparency. The application of such technology to a building facade and its integration with intelligent features provides a higher level of performance control while reducing environmental impact. Dynamic building envelopes include advanced window technologies that characterize the formation of all new "smart" buildings, innovative frame systems and automatic shading control. Although it is a great idea, the design and implementation of such systems is a very complex task (Sala, 2011). The handling of the building facade was aimed at making a difference through the use of innovative products and a prestigious building design with adaptive and dynamic concept was achieved.

3.3. Case 3: Conceptual Analysis of Al Bahar Towers

The Al Bahar Towers built in Abu Dhabi in 2012, are one of the examples that draw attention with its innovative facade design. The Al Bahar Towers are responding to environmental conditions and works to provide both thermal and visual comfort conditions in the interior by using shading element on the facade.

Figure 6. General view of the towers (Council on tall buildings and Urban Habitats, 2013)

An adaptive outer shell is designed to reduce the negative effect of the sun and is inspired by traditional Arabic architecture in the design of the shading system. Circular towers are covered with airtight glass curtain wall that is made up of panels. Each unit is controlled by a linear module that opens and closes once each day in order to limit the direct solar gain to a maximum of 400 watts per linear metre (Wikiarquitectura). The curtain wall is separated from the kinetic shading system by an infrastructure. The folding system transforms the shading screen into a cage-like mold to provide shade or light from an uninterrupted cover (Attia, 2017).

Figure 7. Shading elements (Council on tall buildings and Urban Habitats, 2013)

The shading components, made of stainless steel, aluminum frames and fiberglass mesh filler, are programmed to open and close according to the movement of the sun. It is estimated that this system will reduce solar gain by 50% which directly reduces the need for air conditioning and results in a reduction of CO2 emissions by 1,750 tons per year (Council on tall buildings and Urban Habitats, 2013).

Figure 8. Detail of the shading system components (Council on tall buildings and Urban Habitats, 2013)

By learning from the problems at the Arab Institute in Paris, all elements and components in shading system have been tested by trying to ensure that they have the same lifetime as the building. The system is also designed with the flexibility to be easily replaced if a part is damaged.

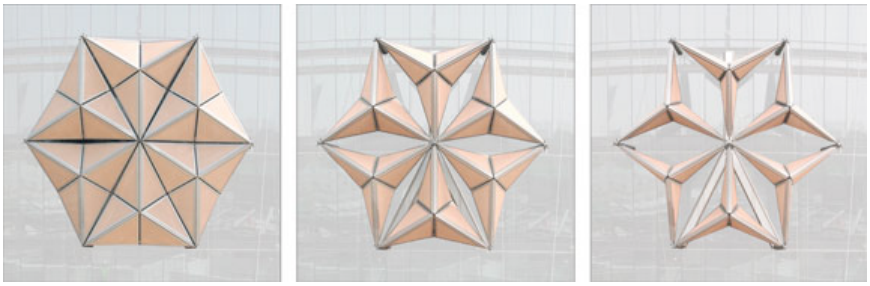


Figure 9. Different movements of the shading system components (Council on tall buildings and Urban Habitats, 2013)

Each tower contains 1049 shading devices. The shading screen is computer controlled to respond to optimum sun conditions and the elements work with a software that controls the opening and closing of the devices according to the sun movement. In cloudy conditions or high winds, a number of sensors integrated into the building envelope send signals to the control unit to unlock all units (Cilento, 2012).

Sun light control is an important feature of the system. As in the case of Institut du Monde Arabe building, on this type of facade, automatic shading and daylight control systems integrate and operate in accordance with all environmental conditions.

In fact, these towers can be seen as a new insight in the design of high-rise buildings in the world where curtain wall facades spread rapidly in very similar features. For regeneration, nature and culture are the most powerful sources of inspiration. The successful integration of the possibilities of technology with the use of design patterns specific to the traditional architecture in the design of the shading element is shaping the facade. The goal is to achieve both a contextually and culturally sensitive design while utilizing modern technology to meet higher efficiency standards. The building offers a modern structure by using advanced technology, while it also carries the characteristics of traditional architecture. The system controls the daylight to reduce demand for

artificial lighting and cooling loads. Decreasing the need for air conditioning directly affects user health and comfort.

4. CONCLUSION

Adaptive facades are shown as a promising solution for the sustainability and aesthetic goals of the 21st century. Today, there are a limited number of reviews that contain information on the operational performance of buildings with adaptive facades. Introducing constructed examples is important for spreading new systems and encouraging innovation. Since each adaptive facade is unique, it is difficult to make comparisons. At the same time, static (such as U-value) are not determinative indicators in dynamic systems.

The adaptive facades of the buildings investigated above have been produced as a result of the integration of numerous innovations from design to application phase. Innovations in computer-aided design technologies, in automation and infrastructure systems, and the advancements of building technology in the construction phase allow for the implementation of an adaptive concept. The necessity of this integration increases the initial investment cost of the system. However, the benefits of these systems throughout their lifetime in terms of energy efficiency and indoor environment ventilation and lighting control are the triggers behind their use.

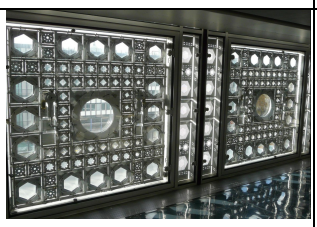
	Location Date	***Shading unit***	***Materials***	***Design***	***Type of control***
Case 1: Institut du Monde Arabe	Paris, 1987		Aluminum diaphragms located between double-layered glasses	Local and cultural design Solar light and daylight control	sun light dynamic control
Case 2: Kiefer Technic Showroom	Bad Gleichenberg, Austria , 2007		white aluminum louver panels	Modern design Solar light and daylight control	user dynamic control
Case 3: Al Bahar Towers	Abu Dhabi, 2012		stainless steel, aluminum frames and fiberglass mesh filler	Local and cultural design Solar light and daylight control	sun light dynamic control

Table 2. Summary of the examined adaptive facade systems

The complicated infrastructure of adaptive systems is one of the difficulties in spreading the system. Changes in up to date requirements, technological improvements and in users, changes in regulations and standards, environmental changes require updating the building facade design.

As a result, building facade systems become multifunctional and adaptive building subsystems, changing the function, feature and behavior to improve the level of whole building performance. These systems are very diverse and the concepts based on the adaptability provided by the shading elements have been examined in this study. With the adaptation provided by the shading elements, heating and cooling energy demands are reduced and solutions to problems affecting comfort conditions such as overheating and glare are sought. While the production of these elements is standard in form and size and is often seen in modular applications, the development of digital technologies has resulted in a variety of design and application. Apart from environmental conditions and performance requirements, it is also seen that one of the biggest factors of preference of this facade system is to design an iconic building and create a sculptural effect. It is important to conduct further research and to produce information as a designer data, in order to be able to identify the advantages and disadvantages of adaptive facade for architects and performance data for engineers.

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CAPTIONS OF VISUAL MATERIALS

Table 1. Descriptive parameter sample table for adaptive facade systems

Figure 1. Institut du Monde Arabe [3]

Figure 2. Detail of the shading unit [3]

Figure 3. Night view of the building from exterior and interior [4]

Figure 4. Shading system view of the showroom [5]

Figure 5. Different positions of the adaptive shading elements on the facade [5]

Figure 6. General view of the towers [6]

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