OVERVIEW OF SUSTAINABLE DESIGN CRITERIA IN HIGH-RISE BUILDING FACADE DESIGN

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ABSTRACT

Buildings are responsible for the high amount of global carbon emissions, structural wastes and energy consumption. The majority of buildings in Turkey are residential buildings and these residential buildings are responsible for the consumption of nearly half of the energy used by buildings as well as high amount of carbon emissions and structural wastes. Building facades are important elements of the buildings for sustainability since they are the elements that provide the distinction between the internal and external environment. It is known that a well-designed sustainable facade can lower the building's negative impacts to environment significantly. Considering the construction of high-rise residential buildings have increased in the last decade in Turkey, the study focuses on sustainable high-rise residential building facade design. The purpose of the study is, systematically evaluating the facades of high-rise residential buildings built in Turkey in the last decade in terms of sustainability criteria and to raise awareness for designers. In order to evaluate in a systematic way, in the first step, high-rise building facade systems were classified and sustainable design criteria for these facades were identified such as; energy saving, providing natural ventilation, efficient use of water, preventing direct or indirect glare, providing alternatives for color, texture and finish details, being lightweight, easy to install, maintain and clean. In the second step, according to the classifications and sustainability criteria determined, 5 high-rise residential building facades built in the last decade in Istanbul, which have the same certificate (Gold) in the LEED assessment system were evaluated. In conclusion, it is considered that a new certification system that examines the building in parts and treats the facade as opaque and transparent surfaces may be useful in sustainable high-rise residential building facade design. In further studies, it is planned to work on a new sustainable building design evaluation system design that might contribute to prevent environmental pollution.

Keywords: Sustainable Design, Building Facade, High-Rise Building.

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1. INTRODUCTION

Approximately 30% of global carbon emissions, 40% of energy consumption and 31% of wastes originate from construction activities (Moussavi, 2017). Dwellings constitute a large part of all buildings. Construction permits in Turkey from 1954 to 2015 show that 85% of the buildings built between those years are residential buildings. In addition, researches show that nearly half of the energy is being consumed by residential buildings (Karahan, 2017).

In addition to consuming energy resources, buildings have many negative environmental impacts such as; water consumption, raw material consumption, waste generation (air, water, and soil pollution), degradation of the ecosystem (decrease of biological diversity), and degradation of human health.

Building facades can significantly affect the performance of the building as they are the elements that distinguish between indoor and outdoor environments (Moussavi, 2017). A building facade can be designed with; the addition of equipment that will allow rainwater to be collected (like rainwater harvesting panels or claddings), the selection of materials that will reduce waste generation (provide reuse or recycle), and design strategies (passive and active design strategies) that will minimize the damage to the ecosystem. In this case, it can be said that the measures to be taken on the building facade design can significantly reduce the negative environmental effects of the buildings.

The building facade can be shaped according to the functions of the building. The facade of an educational structure can be designed to receive a good amount of light to create a good reading-learning space. The facade of a residential building can be designed to; provide light for the kitchen, landscape for the living room, privacy and comfort for the bedroom. In the past, it can be seen that the facades reflect the functions of the buildings. They give more or less insight into the actions that take place inside, and it is possible to easily separate education, health and office buildings from the residences; however, when we look at today's architecture, it is difficult to distinguish visually between an education building, health building, office building or residential building. This may be due to the similarity of these buildings with the introduction of similar facade systems.

It was observed that these similarities increased as the height of the buildings increased. While low-rise houses can be separated from office buildings, similar facade systems are used in order to provide high performance in high-rise buildings. In addition to this problem, considering the surplus of housing production in Turkey, the study has focused on high-rise housing facades. It is aimed at the study to create awareness about sustainable high-rise building facade design strategy practices in Turkey during the last decade. In this way, it is thought that the environmental impacts of the buildings can be reduced by the strategies to be applied in the design of the building facades.

In the study, a literature review was realized and classification related to building facades were made. Sustainable facade design criteria were determined as; energy-saving, provide natural ventilation, efficient use of water, avoid direct or indirect glare and glare, provide alternatives for color, texture and finish details, should be light, should be easy to install, maintain, clean, it should have a visual impact (such as prestige, night view). Then, the facade of 5 high-rise residential buildings constructed in Istanbul in the last decade was examined on the basis of sustainable design criteria.

2. BUILDING FACADE AND SUSTAINABLE DESIGN CRITERIA

The word "facade" has been translated into English from the Latin word "facia" meaning "face" (https://www.merriam-webster.com). Today, the French version of the word "façade" is also being commonly used. Facade, firstly refers to the frontal surface of a building where includes the entrance door then it refers to the other exterior surfaces of the building.

In order to make a systematic examination, the function and elements of the building facade were first determined. Then, sustainable design criteria were determined and high-rise facade systems were classified.

2.1. Functions and Elements of Building Facades

The main functions, of the facade, are carrying the loads, protecting, distributing and finishing (Deniz, 2017).

- The building facade must be able to carry its own load and in some cases the load of the building in addition to its own load.
- The building facade should be able to protect the building against external impacts.
- It should provide indoor comfort for users.
- The building facade must have finishing surfaces that meet the aesthetic functions and provide comfortable and safe surfaces for the users.
- Service systems can be solved inside the building facade.

When the facade is divided into opaque and transparent surfaces; the exterior wall forms an opaque surface, while the exterior doors and windows form transparent surfaces (Figure 1)(Esener, 2018). In some cases, the doors may also be opaque.

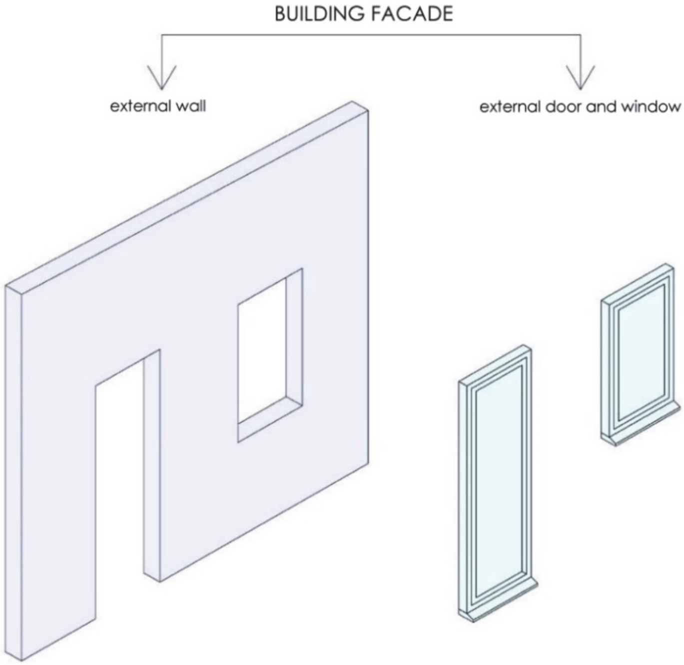

Figure 1 Building facade system (Esener, 2018).

The exterior wall is a planar structural element that divides the external environment and the internal environment in the vertical direction. Its functions are; carrying the loads, separation, isolation and protection. The window and the exterior door are the elements placed in the wall cavities in order to solve the problems of the transition between the indoor and outdoor environment and protection problems together. Their tasks are to provide transition, protection, and isolation.

2.2. High-Rise Building Facades

With the development of technology after the Industrial Revolution, the increasing need for housing in a narrow space has led to the popularization of high-rise buildings. Due to the increasing population and traffic problems and intensive work pace, the need for making good use of the time has led to the combination of multiple functions to produce multifunctional high-rise buildings.

Construction of high-rise buildings in Turkey began in the 1960s. The buildings, which were built until the 2000s, were generally designed for functions such as office buildings and offices. The housing function was then activated. In big cities, high-rise buildings have increased with factors such as; the need for accommodation, landscape and urban transformation needed for the increasing population.

The designers who tried to cope with the construction difficulties faced with the concern of meeting the new needs of the users (prestige, pretension, etc.) started to design structures with different functions with similar visuals. Rooms with different needs (privacy, daylight, ventilation, etc.) have similar facades. This has directly affected the design of residential facades.

High-rise buildings led designers to innovative solutions due to various construction challenges. Wind, rainfall, natural disasters, static problems caused by form are among these difficulties. With the preference of advanced glass, material, service and structure system technologies, visual changes have started in the buildings. The development of elevators, ventilation systems, the use of high-strength materials has allowed the buildings to get taller. With the development of curtain wall systems and the development of glass technologies, the facades began to be designed more freely than the building structure system.

In order to better understand the high-rise facade structure systems, the building facade structure system classification should be made in order to better analyze the samples to be examined. In high-rise buildings, facade systems can be examined in three different ways depending on the relation of the facade with the building system of the building (Figure 2) (Fernandez, 2004).

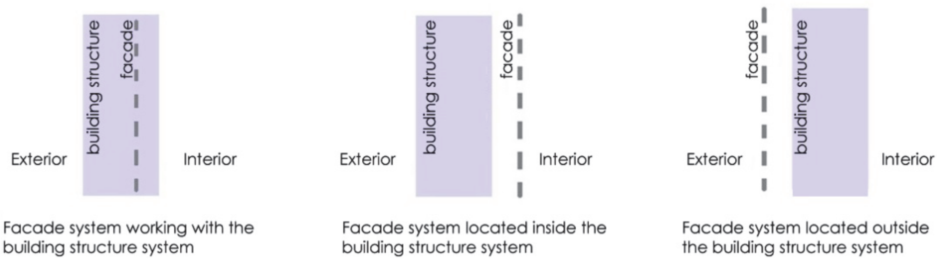

Figure 2 Structural Facade on the left, Exoskeleton in the middle, Skin Facade on the right (Fernandez, 2004).

2.2.1. Facade System Working with the Building Structure System (Structural Facade)

It is formed by filling the gaps between the structural elements. The structure can in some cases be protected against external influences. If it is made of materials like concrete, stone, it is heavier than other systems; pneumatic may be lighter. The movements of the structure may cause deformation on the facade and structural physics problems may arise in the joint details (Fernandez, 2004).

2.2.2. Facade System Located Inside The Building Structure System (Exoskeleton)

It is a facade system located behind the structure. The structural system was removed from the interior. The problem of solving the relationship of service systems with structural elements is eliminated. It is safe in terms of fire. The structure is not protected by the facade against environmental influences. The structure may prevent the facade from receiving daylight (Fernandez, 2004).

2.2.3. Facade System Located Outside The Building Structure System (Skin Facade)

It is a system located outside the structure. It is known as the curtain wall. It protects the structure from external influences and is usually light. Separation from structure provides flexibility in design. It is easy to design roof, facade and structure relations (Fernandez, 2004). Constructing it is easy and is often used in high-rise buildings in Turkey. Therefore, the curtain wall is discussed in more detail in this study.

Curtain wall systems can be designed with one or more layers (double-skin facades, triple skin facades, etc). With spaces between layers, natural ventilation and protection against harmful sun rays can be ensured in high buildings. Multilayer glass coatings filled with argon gas can increase the U-value (Pank et al., 2002). Cladding facades are divided into heavy cladding facades and light cladding facades (Sev, 2009) (Figure 3).

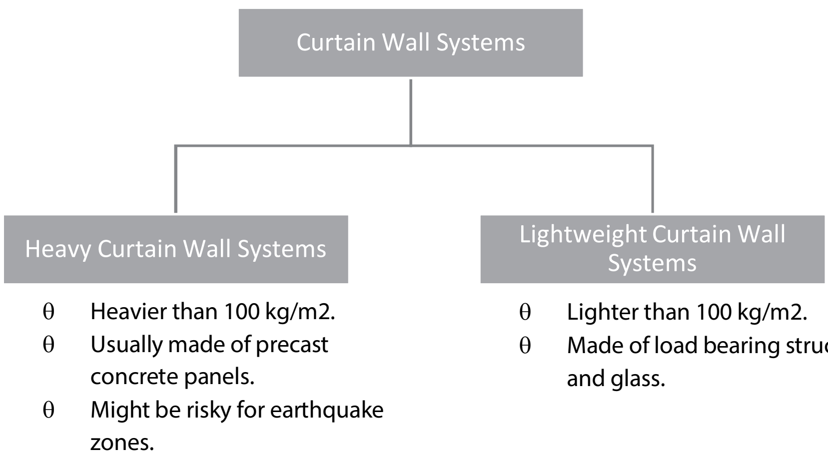

Figure 3 Curtain Wall Systems (Sev, 2009).

Lightweight Curtain Wall Systems: Stick system, half panel system, panel system, structural silicone can be examined under four headings. In the stick system, the vision and parapet units are fixed in separate sections to the frame consisting of continuous vertical and segmented horizontal elements. The vision and parapet units are fixed to the frame consisting of continuous vertical and segmented horizontal elements in one piece (Figure 4).

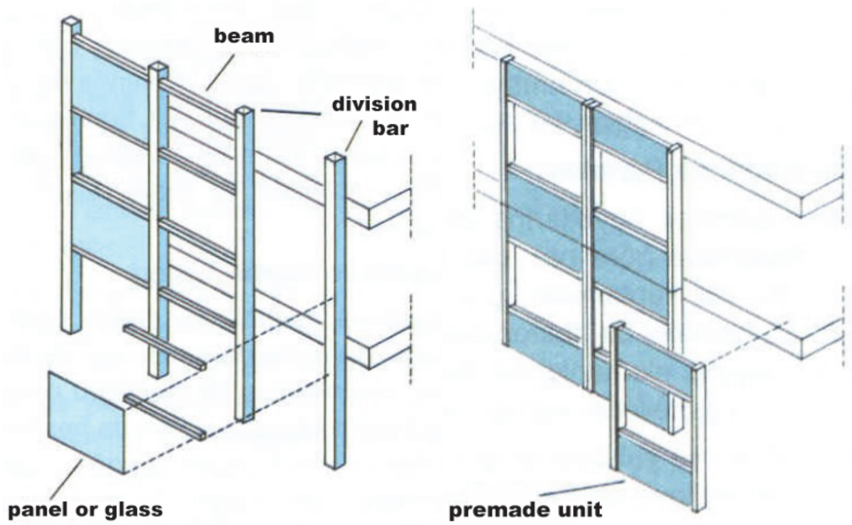

Figure 4 Stick Curtain Wall System on the left, Half Panel System on the right (Candemir, 2002).

Vision and parapet units are prepared in the production center and fixed directly to the structure. The glass panels are fastened directly to the structure of the facade without joinery with high-strength structural silicones (Figure 5).

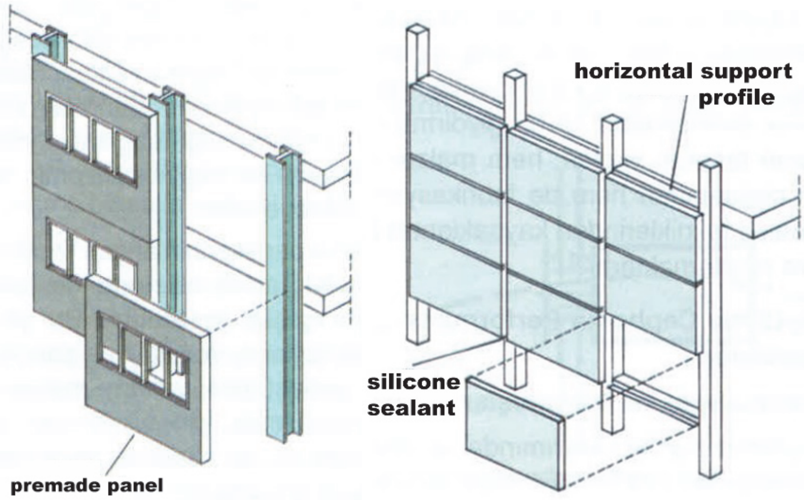

Figure 5 Panel System on the left, Structural Glass System on the right (Candemir, 2002).

2.3. Former Studies about Sustainable Building Facade Design

As mentioned earlier, since the facade is an important element that protects the building from the external effects, it can be very effective in the sustainability of the building. Particularly, if the correct measures are taken, building facades can contribute to energy saving at a good rate. In the literature, various research has been made on the improvements made in building facade systems and their effects on energy efficiency.

In 2018, Hachem-Vermette investigated the effect of photovoltaic panel facades on the thermal performance of the facade in Canada. In Canada, the researcher identified three forms in the study and compared them with the help of a simulation program. As a result of the study, it has been determined that the facade surfaces with sharp edges (protruding) have higher performance than the flat ones. It is stated that this method can also be used in high-rise buildings even if the study is done on small dwellings (Hachem-Vermette, 2018).

In another study, heat insulation and impermeability strategies on walls and roofs in Greece could reduce energy use by 20-40%. In the same study, it was also stated that the roofs and walls covered with blinds and light-colored materials provide approximately 30% benefit in cooling the interior spaces (Balaras, Droutsa, Argiriou, Asimakopoulos, 2000).

In Hong Kong's warm and humid climate, energy savings of 31.4% have been recorded in high-rise residential buildings with the help of passive systems. In residential buildings, measures such as the use of EPS (Expanded Polystyrene) as the thermal insulation material on the exterior wall and the use of reflective coating material have been taken (Cheung, Fuller, Luther, Luther, 2005). In another study, in Hong Kong, DOE-2, an energy simulation program in the field of thermal insulation and heat transfer in facade design, provided an average of 35% of the cooling requirement (Chan, Chow, 1998).

In addition, studies such as comparing thermal imager images of facades made with different materials have been frequently encountered in the literature. In 2017, Alonso, Martin-Consuegra conducted a study in Spain to investigate the effect of facade finishing materials on the building's energy efficiency. Three optical parameters (color, solar reflection, emission) and three production systems (Madrid's traditional production system and 2 different systems proposed to improve thermal performance) were examined. The effect of reflecting surfaces on indoor comfort was found to be higher than the emission. It was concluded that the high reflectivity of the exterior surface of the facade has a significant effect on the indoor thermal performance. It is stated that the use of low emission materials during cold periods is beneficial because it reduces heat loss in the building shell (Alonso, Oteiza, García-Navarro, & Martín-Consuegra, 2016).

In 2015, Ihara, Gustavsen, and Jelle researched the importance of solar reflectivity and the U-values of the opaque and transparent surfaces of the window. In the selection of windows, the importance of window materials and U-values in the energy efficiency of the facade is emphasized (Ihara, Gustavsen, & Jelle, 2015).

In 2017, Djamel and Noureddine's study in Algeria examined the effect of window design on energy efficiency under specific climatic conditions. Different window designs of different sizes were made on Google Sketchup and tested in a simulation program. As a result of the study, it was determined that the excess of the window opening, type of glass (single glass, double glass, etc.) had serious effects on heating and cooling of the building under specific climate conditions (desert climate). Increased transparency leads to more energy consumption. The use of double glazing and three glazing increases energy efficiency. It is thought that it may be useful to use these data on building facades designed in a desert climate (Djamel, Noureddine, 2017).

Building sustainability can be improved by integrating passive and/or active systems into the design. Heating, ventilation, air conditioning (HVAC) systems with artificial measures, electricity and lighting systems, such as active systems can be counted (Sadieni, Madala, Boehm, 2011). Natural measures taken by material selection and design strategies can be defined as passive systems. Many measures to be taken in the facade design can be considered a passive system for the building. For example; measures such as blinds formed on the facade, stratification of the facade for thermal insulation (and the distance of these layers to each other), natural ventilation and lighting with the spaces created, selection of a material that can provide insulation of the facade material, selection of the color of the facade material in the color that absorbs the heat, interior comfort in the building providing facade passive design strategies.

Contemporary facade design is expected to be energy efficient and environmentally friendly (Sadieni, Madala, Boehm, 2011). In order for the design to be successful in this regard, it is necessary for the sustainable design to meet the criteria such as energy efficiency, efficient use of water, sustainable material use, waste management, indoor and outdoor comfort. In 2009, Sev made several classifications in the field of sustainable architectural design. It has determined the criteria that a sustainable building must meet. When these criteria are examined on the basis of the facade, they can be examined as follows (Sev, 2009):

1. Energy-saving.
2. Provide natural ventilation.
3. Efficient use of water.
4. Avoid direct or indirect glare and glare.
5. Provide alternatives for color, texture and finish details.
6. Should be light.
7. Should be easy to install, maintain, clean.

Aesthetic effects such as; night view, facade lighting, the luxurious, prestigious look should be added to these criteria in order to meet today's social needs.

3. METHODOLOGY

3.1. Determination of Sustainable Design Criteria

The sustainable design criteria used in the study were created for the building facade by making use of the former studies found in literature review. It can be examined as follows:

1. Energy-saving: Considering the environmental data; it is possible to orient the building, to provide natural lighting and ventilation by creating occupancy and cavities on the facade, to provide adequate heat insulation, to select the coating materials and colors with respect to the heat, and to support the energy need with the help of active systems that can be integrated into the facade. In addition, careful selection of glass on transparent surfaces can contribute to energy conservation. Many glasses with different heat and light transmittance, UV filter and different colors are being produced today.

2. Provide natural ventilation: The facade must provide natural ventilation for both human health and energy savings. Natural ventilation is provided in high-rise residential buildings with double-skinned cladding facades designed with environmental data in mind.
3. Efficient use of water: In rainy climatic zones, systems that collect rainwater can be designed on the facade. In addition, rainwater collected or treated water can be used in the watering of floor gardens or vertical gardens formed on the facade.
4. Avoid direct or indirect glare and glare: The facade should not cause glare which may adversely affect the living spaces in the environment and users. This may cause heat to rise in the environment and deteriorate comfort conditions.
5. Provide alternatives for color, texture and finish details: One aspect that highly influences the performance of the facade is sealing. In order to achieve this, detailed design has an important place. Careful design of joint details, careful selection of materials and material colors, and if possible a local material selection, can contribute to energy savings.
6. Should be light: The lightweight of the facade system will reduce the load on the structure of the building or on the facade itself. This makes the structure smaller in size. In this way, the amount of material spent is reduced and the fossil fuels to be transported are reduced.
7. Should be easy to install, maintain, clean,
8. It should have a visual impact (such as prestige, night view).

These eight criteria were identified as sustainable design criteria in the study. The facades of the selected structures were evaluated in accordance with the criteria established. During this assessment, the LEED scores and the structural system of the facade related to these criteria were also taken into consideration.

3.2. Case Study

In this study, a total of 5 high-rise residential buildings from the Anatolian and European sides of Istanbul were selected for examination (Figure 6). During the selection process, high-rise residential buildings from different parts of the city, having different facade systems, having the same grade from the same sustainability assessment (LEED Gold Certificate) in the last 10 years were chosen. The facades of the selected structures were evaluated according to the sustainability criteria previously determined with the observation technique and the scores obtained from the certification system.

1-İstanbloom
2-Ağaoğlu Andromeda Gold
3-Varyap Meridian
4-Spine Tower
2-Orya Park

Figure 6 Locations of the case studies.

4. FINDINGS OF THE STUDY

4.1. Istanbloom

Located in Zincirlikuyu District, the building was designed by DB Architecture. The project was completed by Esin Yapı in 2013 and received the Gold (63 points) certificate in the LEED (http://www.usgbc.org/leed/certification#certify) New Building category (Şekil 8) (https://yapidergisi.com/).

Istanbloom's facade design expresses the cultural diversity of Istanbul and the harmony of the buildings of different sizes of the city with masses stacked on top of each other (Figure 7).

- The double skin facade provides 20% energy saving thanks to thermal insulation and heat recovery system.
- Low-e glasses are used on the facade.
- In this structure, which achieved full points in terms of water-saving within the framework of LEED criteria, local plants were preferred in the garden planting and plants consuming less water were used.
- Rainwater collection systems are not designed on the facade.
- With the help of floor gardens, it is aimed to revive the damaged ecosystem on the ground.

- Construction waste management has been established during construction and care has been taken to use recycled materials.
- Solar panels are placed on the roof instead of the facade and these roads provide interior lighting.
- Construction waste management has been established during construction and care has been taken to use recycled materials.

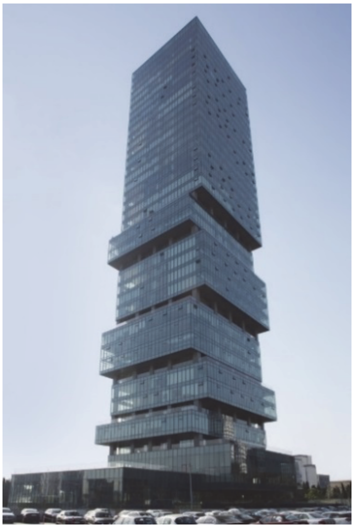

Figure 7 İstanbloom (http://www.yapidergisi.com/).

4.2. Ağaoğlu Andromeda Gold

Located in Ataşehir District, the building was designed by Tuncay Çavdar / Atölye T Mimarlık. The project was completed in 2013 by Ağaoğlu İnşaat and awarded Gold (61 points) in LEED (http://www.usgbc.org/leed/certification#certify) New Building category (http://v3.arkitera.com/).

- The structural silicone facade and the composite sheet coating provide a bright gold color on the facade. It is thought that this situation may adversely affect the visual and thermal comfort of the environment.
- The window areas and heights were kept wide so that the apartments could benefit from daylight as much as possible (Figure 8).
- In order not to endanger the health of the users, products such as paint, flooring, and coating are used which minimize the chemical effect.
- During the construction period, construction wastes were recycled and collected as domestic wastes to minimize environmental damage. At the

same time, various measures have been taken to prevent the spread of construction pollution to the environment, such as washing the wheels of trucks and applying silt curtains.

Figure 8 Ağaoğlu Andromeda Gold (https://tunayapi.com.tr/).

- Rainwater collection systems are not designed on the facade.

4.3. Varyap Meridian

Located in Ataşehir District, the building was designed by Dome Partners. The project was completed by Varyap in 2013 and received Gold certificate in LEED (http://www.usgbc.org/leed/certification#certify) New Building category and 2009 Best High-rise Building "and Best Real Estate Project in 2009, ArkiPARC Real Estate Awards 2013 First Place in Mixed-Use Category 2013 in 2013," Residential in Cityscape Global 2014 " Project Award - Built "(Best Completed Residence Project) (http://v3.arkitera.com/).

- The full areas of the façade, which is manufactured with a panel system, are covered with colored aluminum paneling panels. The facade is produced by breaking into standard modules in certain dimensions (Figure 9)
- In a panel, multiple colors are intertwined, giving the facade a natural look like a vivid texture.

Figure 9 Varyap Meridian Facade Construction (http://gezginharitaci.blogspot.com/2013/04/varyap-meridian.html).

- The effect of efficient shading prevents the heating of the indoor environment by the heated outdoor air.
- Transparent tinted glasses provide a good level of insulation between the indoor air and the outside air with its low heat transmission coefficient. These colorless, eye-free lenses minimize heat losses as well as comfort.
- The buildings are designed not to obstruct each other so that daylight is also introduced and wind corridors are formed.
- Rainwater collection systems are not designed on the facade.

4.4. Spine Tower

Located in Maslak District, the building was designed by Murat Kader. The project was completed by 2014 and the Soma Holding Gold LEED Core & Shell category (66 points) certificate (http://www.usgbc.org/leed/certification#certify) and the 2014 MIPIM Awards, "Turkey's Best Project" award (http://v3.arkitera.com/).

- In order to optimize the energy performance, the design was made by considering the location of the building, prevailing wind, sunlight, heat from the sun, surrounding buildings, trees, land shape.
- Although it is one of the tallest buildings in the city, natural ventilation is provided by opening windows.
- It is produced with a half panel system (Figure 10).
- Recyclable, regional materials are used; however, it can be said that it is a structure that is lacking in terms of the use of low emission materials.

Figure 10 Spine Tower Facade Construction (http://www.saytekno.com/).

- Rainwater collection systems are not designed on the façade.

4.4. Orya Park

Located in Ümraniye District, the building was designed by Kadir Üçvet (https://www.oryapark.com/). The project was completed by Oryataş in 2015 and awarded Gold (66 points) in the LEED Core & Shell category (http://www.usgbc.org/leed/certification#certify).

- When positioning buildings, orientation, natural lighting, and natural ventilation are made to provide maximum benefit.
- By the use of daylight, it is aimed to save energy and costs will be spent on lighting.
- The use of double glazed windows reduces heat losses and noise pollution from outside.
- A filter system is designed for the dirty air from outside and neighbors.
- In paints and coatings, products that could cause harmful gas release was not used.
- Rainwater collection systems are not designed on the facade.
- The panel system is used as a facade structure system (Figure 11).
- Almost all of the materials selected in the project consist of recyclable materials.

Figure 11 Orya Park Facade Construction (http://www.yapifabrikasi.com.tr/).

5. CONCLUSION

Nowadays, environmental pollution problems, the reduction of the emission of toxic gases and energy efficiency have become important due to the depletion of natural resources. It is thought that the sustainable design of building facades, which is one of the important building parts in ensuring the sustainability of the buildings, will be effective in the whole building.

The evaluation of the samples according to the sustainability criteria determined in the study is as in Table 1.

Table 1: Cases: İstanbloom, 2: Ağaoğlu Andromeda Gold, 3: Varyap Meridian, 4: Spine Tower, 5: Orya Park.

Case	Energy Saving	Natural Ventilation	Preventing Glare	Finishing Details	Lightweight	Reusable Materials	Easy to Clean and Maintain	Visual Effect
1	+	+	+		+	+		+
2	+			+	+	+	+	+
3	+	+	+	+	+	+	+	+
4	+	+			+	+	+	+
5	+	+	+	+	+	+	+	+

All investigated high-rise residential buildings:

- Are located in areas that are easily accessible,
- Use double glazing,
- Have a rainwater collection system outside the facade,
- Prefer finishing materials that do not emit toxic gases,
- Provide orientation according to environmental data in design,
- Have a lightweight facade system,
- Preferred recyclable materials.

The high-rise residential buildings built in Turkey (in order to be able to provide high performance) were designed with a facade system that is similar to other buildings with different functions. Meeting the sustainability criteria of the facade system, which covers a large part of the building, will reduce the environmental impact of the construction activities. In this context, the certification systems that evaluate buildings should examine the building in parts instead of examining them in general.

In LEED certification system, which is one of the most popular one in Turkey, it was seen that the building was considered as a whole and the facade was not examined alone. It is known that a well-designed sustainable facade can provide significant energy savings to the structure. Considering that there is a serious need for energy in Turkey, the importance of this evaluation system becomes indisputable.

In order to prevent environmental pollution and leave a livable world for future generations, it is necessary to produce and disseminate an assessment system for national needs on building facades. In further studies, it is planned to work on a new sustainable building design evaluation system design that might contribute to prevent environmental pollution. It is thought that a new certification system that examines the building in parts and treats the facade as opaque and transparent surfaces may be useful in sustainable high-rise residential building design. In addition to this, Turkish government should provide state support and legal arrangements, the chamber of architects should provide more workshops about how to integrate sustainable design elements to a building design and the education system should include classes about sustainability and environmental problems in schools.

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