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INTELLIGENT FACADES AS AN ENERGY-EFFICIENT BUILDING DESIGN APPROACH

ABSTRACT

Need increase for energy-efficient building design because of recent the global environmental problems that started at the begining of twenty-first century have been accelerated building industry and develeped new tools and new technologies. These new tools are enable architects and engineers to develop more reliably solutions that will deliver the desired energy saving performance. Facades provide a key performance contribution to these aggressive goals, if operated as responsive, dynamic elements to control ventilation, daylight, and solar gain. In this context intelligent facades, are very important about energy-efficient building design. The primary objective in designing intelligent facades is to minimize a building's energy expenditure and to generate energy by means of the building facade without compromising user convenience. This study focuses on those parameters and alternatives for intelligent facade design that support the concept of energy-efficient building, and presents practical examples for feasible systems.

Keywords: Intelligent Facades, Architecture, Technology, Energy-Efficient Building Skin, Renewable Energy Sources

ENERJİ ETKİN BİNA TASARIM YAKLAŞIMI OLARAK AKILLI CEPHELER

ÖZET

21 yy.'da ortaya çıkan global çevresel problemler sonucu enerji verimli yapı tasarımı ihtiyacının artması, bina endüstrisini hızlandırmış, yeni teknolojiler ve araçlar geliştirilmeye başlamıştır. Bu yeni araçlar, mimar ve mühendislerin hedeflenen enerji tasarruf performansını gösterebilecek daha güvenilir ve gelişmiş çözümler sunmalarını sağlamaktadır. Cepheler havalandırmayı, aydınlatmayı ve solar kazancı kontrol edebilen duyarlı ve değişken yapı elemanları olarak işletilerek bu etkin performans hedeflerine anahtar bir katkıda bulunmaktadır. Bu bağlamda, akıllı cepheler enerji verimli yapı tasarımı açısından büyük önem taşımaktadır. Akıllı cephe tasarımında temel hedef kullanıcı konforundan ödün vermeden, binanın harcadığı enerjinin yapı kabuğu aracılığıyla en aza indirilmesi ve bina cephesi aracılığıyla enerji üretmektir. Bu çalışmada, enerji etkin yapı kavramını destekleyen akıllı cephe tasarım parametreleri ve çeşitleri üzerinde durulmakta, sistem uygulama örnekleri ile açıklanmaktadır.

Anahtar Kelimeler: Akıllı cepheler, Mimarlık, Teknoloji, Enerji Etkin Yapı Kabuğu, Yenilenebilir Enerji Kaynakları

1. INTRODUCTION (GİRİŞ)

The facades consisting of elements such as the walls, floor, windows, and doors are components that separate the building from the external environment and allow the passage of heat energy. For this reason, some features of the facades, especially the thermal features, significantly affect the energy-efficiency. Energy efficient intelligent façades can regulate light and weather conditions of inside by using thermal protection and solar control measures. For that reason it reduces the primary energy consumption of a building, use of natural, renewable energy sources, such as solar radiation, air flows and creates a comfortable environment for the occupants.

Energy-efficient facade design, which starts with decisions at a building's initial design stage, directly affects a whole array of factors, including the choice of system. This decision (the choice of building system, facade and building material etc.) dirrectly affect energy saving measures. Because with the right decisions, energy consumption and maintenance bills for air conditioning is reduced in the long term. That's why it is very important at design stage, to achieve an effective interaction between the façade, the environment and the building systems. This complexity of design stage can be only successfully by working architects and engineers together for develop optimized solutions that help reduce energy use while providing comfortable and productive environments.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

At the begining of twenty-first century the global environmental problems facing us are dominated by impending risk posed by the greenhouse effect and resulting impact of climate change and also in parallel it reminded us importance of energy saving. In this context, the ecological goal of building design should be to strive for a reduction in total primary energy needs to a minimum and ideally down to zero by using renewable energy sources. By utilizing the building skin itself, artificial lighting, heating, cooling and other energy importing systems can be minimized or avoided altogether. The intelligent facade reduces the primary energy consumption of a building, use of natural, renewable energy sources, such as solar radiation, air flows and creates a comfortable environment for the occupants. For that reason intelligent facade can be defined as changing light and weather conditions using self- regulating thermal protection and solar control measures.

The decision that made at a building's initial design stage is very important for an energy efficient building design. That's why, this paper are investigated intelligent facades to promote the use in building design.

3. THE DESIGNING OF INTELLIGENT FACADES (AKILLI CEPHE TASARIMI)

Facades are crucial to energy consumption and comfort in buildings. Incorporating intelligence in their design is an effective way to achieve low energy buildings. Three strategies are examined: the first is dependence on active systems and element performance, the second implements intelligent passive design strategies only, while the third combines passive design strategies with early integration of active elements. Their impact on energy performance and visual comfort are compared. A design tool that suggests good starting solutions is presented, which takes into account how architects work during conceptual phases [3 and 9].

According to Wıggıngton and Harris the study of examples of building intelligence showed that the façade was performing up to different functions, which influenced the passage of energy from both external environments to the internal environment, and the other way around. The manipulating functions were idenfied as;

- The enhancement of daylight (e.g. light shelves/reflectors)
- The maximization of daylight (e.g. full-height glazing/atria)
- Protection (e.g. louvres/blinds)
- Insulation (e.g. night-time shutters)
- Ventilation (e.g. automatic dampers)
- The collection of heat (e.g. solar collectors)
- The rejection of heat (e.g. overhangs/brise soleil)
- The attenuation of sound (e.g. acoustic dampers)
- The generation of electricity (e.g. photovoltaics)
- The explotation of preassure differentials (e.g. ventilation shimneys) [3 and 15].

The insulation thickness, quality of glazing, the solar screening and the natural ventilation influence the transmission heat losses, surface temperatures on the inside of the facade and the comfort of building;

- **Insulation Thickness:** Transmision heat loss reduces with increasing insulation thickness, with the insulation effect not being directly proportional to the layer thickness. Therefore, in practise, the insulation thickness is determined by the type of construction, the avaliable space, the amount of energy required during manufacture, the building technical services concept, building type and proportion of window area (Table 1) [6].

Table 1. Best practice insulation thicknesses and glazing types for various building types [6,4].
(Tablo 1. Çeşitli yapı tipleri için en uygun yalıtım kalınlıkları ve yalıtımlı cam tipleri)

Building Type	Proportion of Window Area	Glazing Type	Insulation Thizkness (WLG035)
Low-energy housing	<30%	2-pane insulating glazing	15-25 cm
Low-energy housing	>30%	3-pane insulating glazing	15-25 cm
Passive House	<50%	3-pane insulating glazing	25-35 cm
Office building	<50%	2-pane insulating glazing	>15 cm
Office building	>50%	3-pane insulating glazing	>15 cm
Office building, high internal loads	<70%	2-pane insulating glazing	>10 cm
Office building, high internal loads	>70%	3-pane insulating glazing	>10 cm
Office building, thermoactive ceiling	<70%	3-pane insulating glazing	>15 cm

- **Quality of Glazing:** With insulation glazing the designer has a choice of two-pane and three-pane units. For approximately double the insulating effect the latter have 10 to 15% less total solar energy transmittance and 10% lower natural light transmittance (Table 2). In practice the type of glazing is determined by the proportion window area, internal heat loads and heat transfer concept [6].

Table 2. Typical building physical properties of 2 and 3 pane insulation glazing [4 and 6].
(Tablo 2. Tip binalarda 2 ve 3 tabakalı yalıtımlı camların fiziksel özellikleri)

	2- pane glazing units	3-pane glazing units
U_g [W/m^2K]	< 1.1	**< 0.5**
g [-]	0.55-0.65	**0.5**
τ [-]	0.8	**0.7**
R_w [dB]	30-31	**32**

The proportion of window area has a considerable influence on room climate in summer. As is evident below, it is possible to consider large proportions of window area for facades exposed to sunlight. In general terms, large window areas exposed to direct sunlight are only acceptable with exterior solar screening. The south side allows higher transparency than the east or west sides. In relation to the provision of natural light, the arragement of the transparent areas is more crucial than their absolute size, provided that a proportion of window area of 50% is achieved. The height of the top edge of the window plays a role here. With proportion window area greater than 50%, the additional solar gain in winter is scarcely usable (Fig. 1) [6].

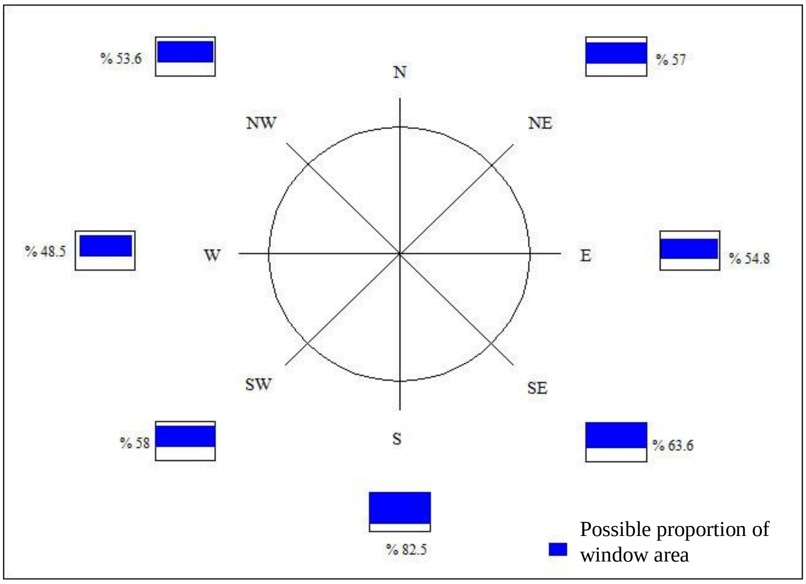


Figure 1. Achievable proportion window area for various orientation [4 and 6]
(Şekil 1. Çeşitli bina yönlenmeleri için uygulanabilir pencere alanı oranları)

- **Solar Screening:** Shading to glazed areas can reduce external sources of heat. In hot climates the building fabric should be prevented from heating up and tranferring heat to the inside, which can be done by using light and reflevtive external finishes and insulating the building fabric [11].

Shading against solar heat gain is the most readily applicable and flexible method of cooling and can be applied in all climate types in which the sun's influence is significant, and to almost all modern buildings irrespective of latitude. The key to good daylighting and thermal performance lies in the design of the building envelope. Shading devices can be an integral part of the envelope, and thus influence thermal and daylighting performance. They may be located at the external or internal face of the facade, or within double- and triple- glazed window or curtain wall systems. In each case solar radiation is prevented, wholly or partly, from entering the building (Fig. 2) [2].

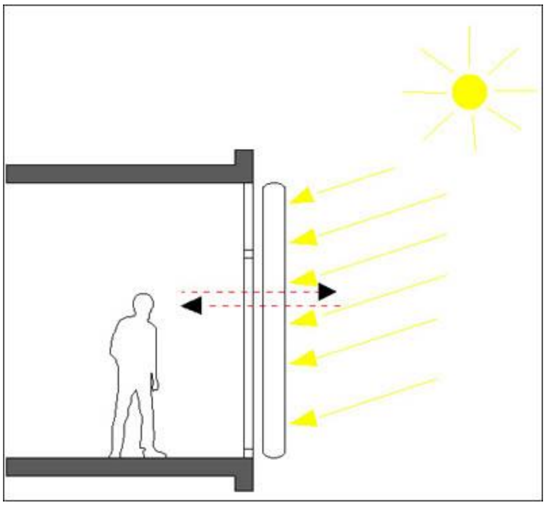


Figure 2. Solar screening in east and west facades [4 and 6].
(Şekil 2. Doğu ve batı cephelerde solar perdeleme)

- **Natural Ventilation:** Another parameter which influences the inside comfort of the building is natural ventilation. Natural ventilation strategy to provide more comfortable indoor environments using less amount of energy has been gaining more applications.

The most common method of natural ventilation is window ventilation whereby different types of hardware and fittings have an impact on the efficiency of the ventilation. Ventilation efficiency is also influenced by the wind pressure exerted on the façade. If ventilation is only provided through one side of the façade, it can be achieved for rooms about 2.5 times deeper than high. Cross ventilation causing "draught" is more efficient, since sufficient ventilation can be achieved for rooms 5 times as deep as they are high. Today, motorised Windows are available that provide automatic ventilation depending on the actual requirement or to facilitate opening windows that are difficult to acces [7].

4. THE CLASSIFICATION OF INTELLIGENT FACADES (AKILLI CEPHELERİN SINIFLANDIRILMASI)

Intelligent façade types are single façade, double facade and combination of these systems (Table 3).

Table 3. The classification of intelligent facades
(Tablo 3. Akıllı cephelerin sınıflandırılması)

1. SINGLE SKIN FACADES	Perforated facades
	Elemental facades
2. DOUBLE SKIN FACADES	Corridor facades
	Building high double skin facades
	Building high controllable double skin facades
	Box windows
3. COMBINED FACADES	Alternating facades
	Baffle Panel Facades

4.1. Single Skin Facades (Tek Kabuk Cepheler)

Single skin facades are generally made up transparent and or opaque areas all in the same plane. The functional elements for ventilation, solar control, energy gain or light redirection are generally arrenged adjacent to one another. Each of these elements can be designed and positioned optimally for its functions independently of the others. The normal rule is that a lower proportion window area has a positive effect on room climate (Fig. 3) [6].

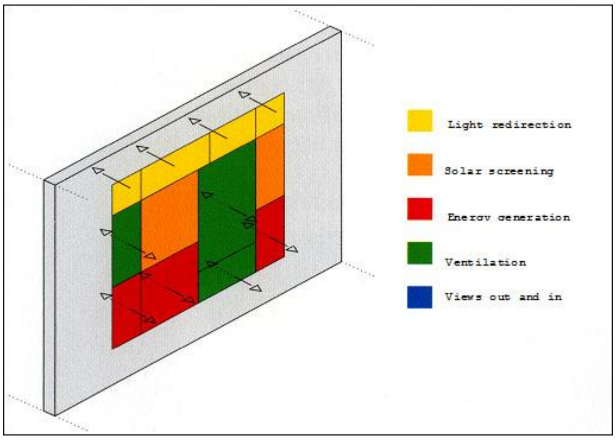


Figure 3. Parallel arrangement of façade elements [4 and 6]
(Şekil 3. Cephe elemanlarının paralel dizilişi)

- **Perforated Facades (Basit Cepheler)**

The perforated facade is the original form of building skin. It consists of a solid load-bearing wall with openings to provide light and ventilation (Fig 4.). There may be additional functional elements which direct light or generate energy, admit fresh air or mechanically ventilate the interior [6].

Perforated walls, panels and screens have been used for centuries as a way to control the level of light entering a building or to offer privacy to the occupants. The functions of perforations have remained largely the same, but the materials and methods of manufacture have altered considerably [3 and 18].

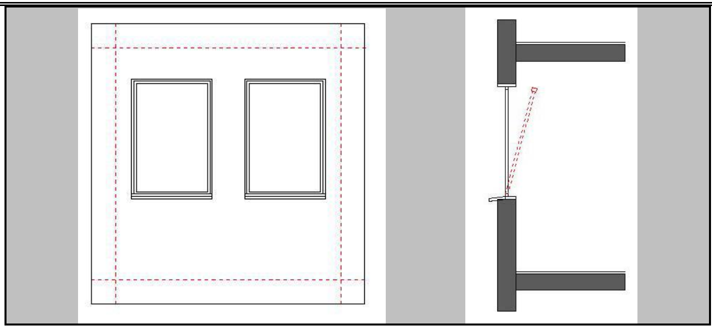


Figure 4. Examples of perforated facades [4 and 6]
(Şekil 4. Basit cephe örnekleri)

Advantages and disadvantages of perforated facades;

ADVANTAGES

- Good sound insulation with closed Windows
- Direct view out
- Low cleaning cost
- Low maintenance cost

DISADVANTAGES

- Natural ventilation may be unconfortable
- External solar screening exposed to wind

- **Elemental Facades (Giydirme Cepheler)**

To achieve a certain level of solar control in a single- skin façade, coatings can be applied to the glass, such as infrared-reflecting coatings and/or coatings to absorb and reflects wawe lenghts in the visible range. As their properties are fixed, they also restrict solar gain in the colder months and reduce dayligting levels [3]. For this reason it is necessary to provide additional adjustable solar control measures in buildings with large surface areas of facade glazing and in buildings where air conditioning requirements are strictly regulated (Fig. 5) [1 and 5].

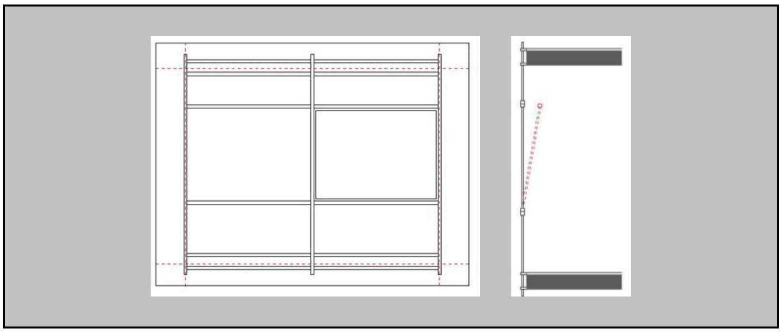


Figure 5. Examples of elemental facades [4 and 6]
(Şekil 5. Giydirme cephe örnekleri)

Advantages and disadvantages of elemental facades;

ADVANTAGES

- Can be prebaricated
- Short construction time
- Little space requirement

DISADVANTAGES

- Poor thermal insulation
- Lower surface temperatures at facade inner side

- No noise reduction for ventilation
- Solar screening difficult to incorporate

An elegant example of the use of this facade type is found in the Hotel Industriel Jean-Baptiste Berlier, a building for small industrial activities and offices in Paris built 1986-90 by the architect Dominique Perrault; the usual monotony associated with an all-glass facade is broken up by discretely placing horrizontal louvres on the inside (Fig. 6) [1].


(a) (b)

Figure 6. a) Hotel Industrıel Jean-Baptiste Berlıer
b) Interior solar shading [1]
(Şekil 6. a) Hotel Industrıel Jean-Baptiste Berlıer
b) Dahili gölgeleme elemanları)

4.2. Double Skin Facades (Çift Kabuk Cepheler)

The term double skin facade refers to an arrangements with a glass in front of the actual building a facade. Solar control devices are placed in the cavity between these two skins, which protects them from the influences of weather and air pollution, a factor of particular importance in high rise buildings or ones situated in the vicinty of busy roads. A further advantage of the double facade is the solar shading it affords in the summer. As reradiation from absorbed solar radiation is emitted into the intermadiate cavity, a natural stack effect result, which causes the air to rise, taking with it addiitonal heat. Computer simuluation and test have shown that natural air circulation can reove up to %25 of the heat resulting from solar radiaition in the cavity.Genarally, given appropriate panes and solar control devices, g-values of proximately 0.10 can be achieved. As the temperature of the air increases a sit rises upwards. It is usual to restict the height of the continous opening to two or three floors. Technical considerations concerned with fire protection and acoustic insulation also play a role. The reduction of wind pressure by the adiditon of the extra pane of glass means that the windows can be opened even in the uppermost floors of a high rise builidngs. Natural ventilation of officies by fresh air is much more acceptable to the builidng’s users an dit has the adiditonal benefits of reducing investments in air handling systems and also reducing Energy consumption. A double skin facade also reduces heat loses because the reduced speed of the iar flow and the increate temperature of the air in te cavity lowers rate of heat transfer on the surface of the glass. This has the effect of maintaining higher surface temparatures on the inside of the glass, which in turn means that the space closet o the window can be bettwe utilised as a result of increate thermal comfort conditions. Energy frm the echaust air stream using a heat exchanger (Fig. 7) [1 and 3].

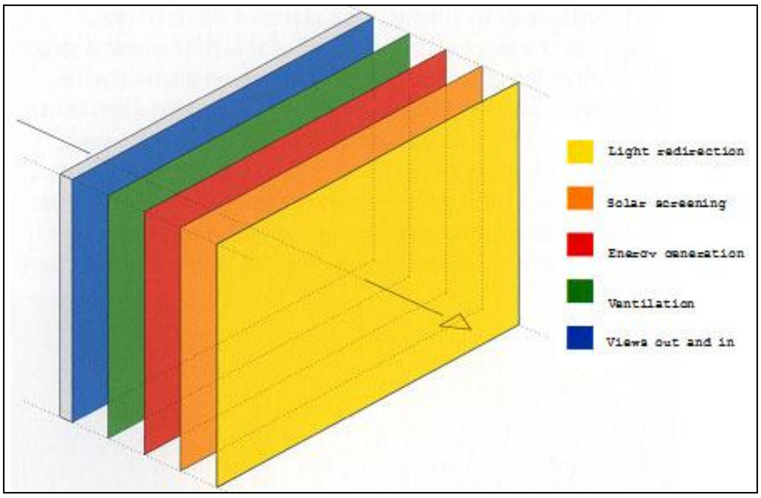


Figure 7. Series arrangement of facade elements [4 and 6]
(Şekil 7. Cephe elemanlarının seri halde dizilişi)

- **Box Windows (Kutu Tipi Çift Kabuk Cepheler)**

The box window is probably the oldest form of a two layered façade. Box windows consist of a frame with inward-opening casements. The single glazed external skins consists openings that allow the ingress of fresh air and the egress of vitiated air, thus serving to ventilate both the intermediate space and the internal rooms. The cavity between the two façade layers is divided horizontally along the constructional axes, or on a room-for-room basis. Vertically the divisions occur either between stories or between individual window elements. Continuous divisions help to avoid the transmission of sounds and smells from bay to bay and from room to room. Box type windows are commonly used in situations where there are high external noise levels and where special requirements are made in respect of the sound insulation between adjoining rooms. This is also the only form of construction provides these functions in facades with conventional rectangular openings (Fig. 8) Each box window element requires its own air intake and extracts openings, which have to be considered when designing the outer façade (Fig. 9) [3 and 10].

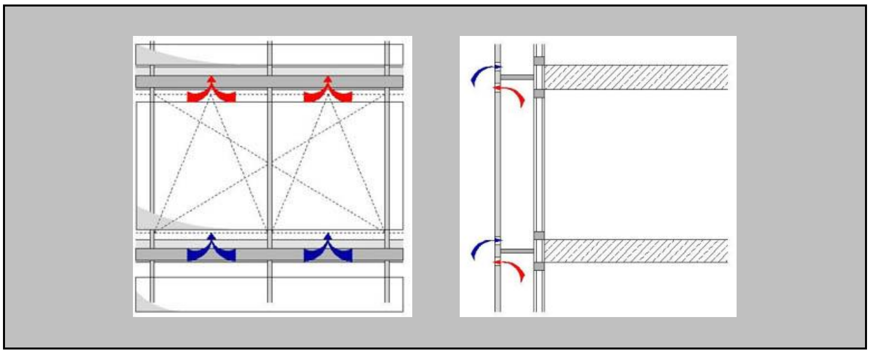


Figure 8. Examples of box Windows [4 and 10]
(Şekil 8. Kutu tipi çift kabuk cephe örnekleri)

Advantages and disadvantages of box windows;

ADVANTAGES

- Comfortable ventilation in winter and in the transition months
- Can be prefabricated

- Suitable for renovation

DISADVANTAGES
- Direct view out limited
- Purge ventilation limited
- Overheating in the facade cavity
- High construction costs

Figure 9. Wiew of a natural vantilated box window [4 and 10].
(Şekil 9. Doğal havalandırmalı kutu tipi çift kabuk cephe görünüşü)

- **Corridor Facades (Koridor Tipi Çift Kabuk Cepheler)**

The corridor facade is a double-skinned facade in which the facade cavity is separated storey by storey with bulkheads (Fig. 10).

Air exchange in the facade cavity is eighter vertically at a floor level, horizontally at the corners of the building, or both vertically and horizontally. If the double skinned facade is ventilated horizontally it is often designed so as to be able to control the pressures in the facade cavity. In this way the facade flaps can be opened or closed depending on the desired pressure conditions (over-or underpressure), wind direction and speed. This allows specific pressure conditions to be set up in the building and the ventilation drive energy demand to be minimised. Facade corridors can transmit unwanted odours and sounds between rooms [3 and 6].

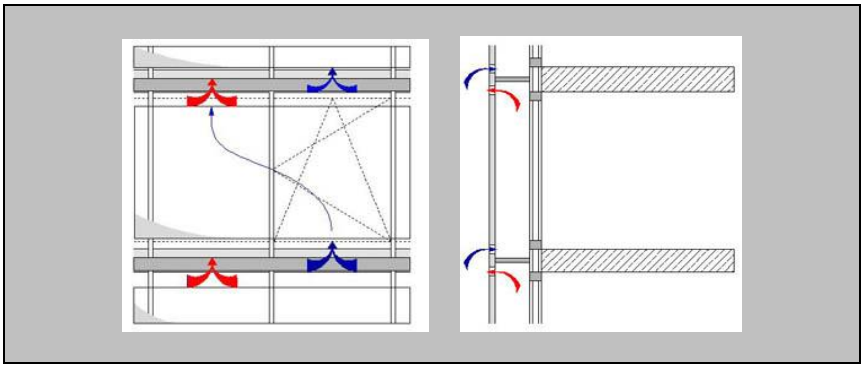


Figure 10. Examples of corridor facades [4 and 10]
(Şekil 10. Koridor tipi çift kabuk cephe örnekleri)

Advantages and disadvantages of corridor facades;

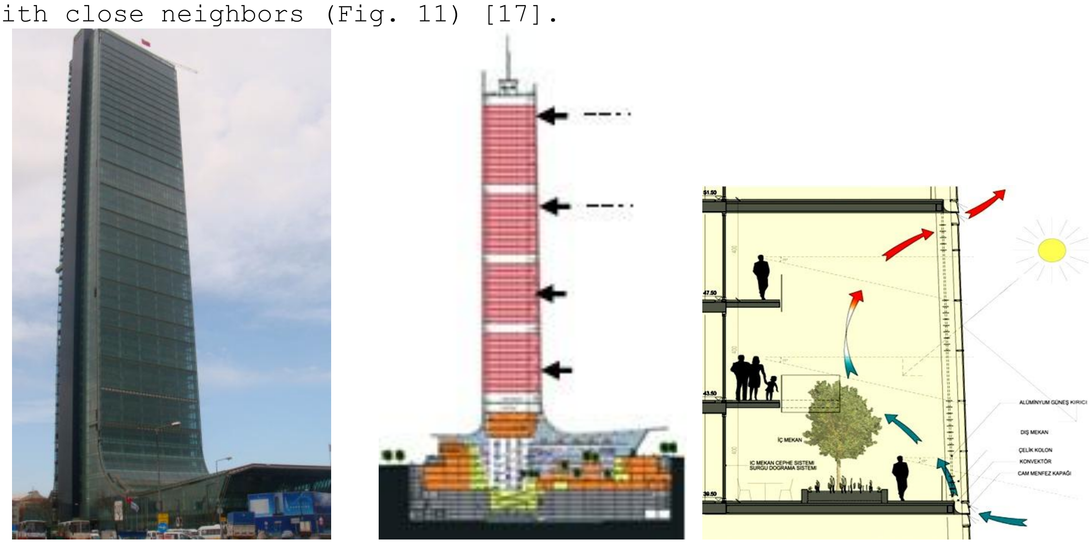
ADVANTAGES
- Pressure conditions can be controlled
- Natural ventilation is possible even under difficult outside conditions
- Homogenous appearance to the facade

DISADVANTAGES

- Overheating in summer
- High construction cost
- Limited view out
- Transmission of sound and odour
- High fire safety requirements

An example of the use of this facade type is İstanbul Sapphire in Istanbul built 2006-2012 by the Tabanlıoğlu Architects.

The building façade consists of two independent shells. The interiors are protected from adverse weather conditions and noise on account of the outer shell. This transparent shell also serves as a buffer zone between the indoor area and the outside, and has a positive effect on structural solutions. The space created between the two shells is used as gardens and terraces of each apartment; every three floors is a component with a garden floor and two floors overlooking the gardens. Around the atrium there are nine or fewer apartments, depending on the size of each unit. Residents are living in a tower, yet have the feeling that they are sharing a 3-floor house with close neighbors (Fig. 11) [17].



(a) (b) (c)

Figure 11. (a) Istanbul Sapphire Building
(b) Facade section [4 and 22] (c) Living zone [4 and 16]
(Şekil 11. (a) İstanbul Sapphire Binası
(b) Cephe kesiti (c) Yaşam alanları)

- **Building High Double Skin Facades**
  (Bina Yüksekliğinde Çift Kabuk Cepheler)

Building high double skin facades the intermediate space between the inner and outer layers is adjoined vertically and horizontally by a number of rooms. In extreme cases, the space may extend around the entre building without and intermediate divisions. The ventilation of the intermediate space occurs via large openings near the ground floor and the roof. During the heating period, the façade space can be closed at the top and bottom to exploit the conservatory effect and optimize solar energy gains. Building high double skin facades are especially suitable where external noise levels are very high, since the type of construction does not necessarily requires openings distributed over its height. As a rule, the rooms behind building high double skin facades have to be mechanically ventilated, and the façade can be used as joint air duct for this purpose. As with corridor facades, attention should be paid to the problem of sound tranmission within the intermediate space (Fig. 12) [3 and 10].

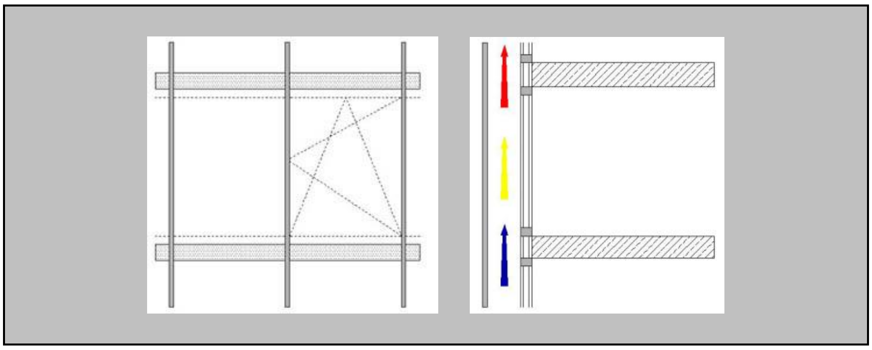


Figure 12. Examples of building high double skin facades [4 and 10]
(Şekil 12. Bina yüksekliğinde çift kabuk cephe örnekleri)

Advantages and disadvantages of buıldıng hıgh double skın facades;

ADVANTAGES

- Very good noise reduction
- Natural ventilation is possible even under difficult outside conditions
- Homogenous appearance to the facade
- Can be simply retrofitted

DISADVANTAGES

- Considerable summer overheating
- High construction cost
- Severely limited view out
- Transmission of sound and odour
- High fire safety requirements

One example of this facade type is the office of Thompson Advertising Agency in Frankfurt am Main, built in 1992-95. The design is based on the “set of shelves” concept devised by the architects Schneider + Schumacher. The individual shelves are the floors and in fornt of them is the full-heigh winter garden like a gaint shop window. The winter garden contains the main vertical communication zones and serves as noise protection against the traffic noise, as wall as acting as a thermal buffer in the colder seasons (Fig. 13) [1].

(a) (b)

Figure 13. a) Thompson Advertising Agency

b) Double skin facade of building [1]
(Şekil 13. a) Thompson Reklamcılık Şirketi b) Binanın çift kabuk cephesi)

Another example of building high double-skin façades is Sanoma House in Helsinki, designed by Arkkitehtitoimisto Jan Söderlund & Co. Oy. Sanoma House Building's east-, south- and west façades are double-skin façades. The facade area is 5000 m2. The facade cavity is closed and can be vented by motor-operated vents at the top and bottom, which are controlled by thermostats (Fig 14).


(a)

(b)

Figure 14. a) Sanoma House [4 and 21]
b)The building's double skin facade [4 and 14]
(Şekil 14. a) Sanoma House b) Binanın çift kabuklu cephesi)

- **Building High Controllable Double Skin Facades (Bina Yüksekliğinde Panjurlu Çift Kabuk Cepheler)**

The building high controllable double skin façade is very similar multi-storey ventilated double façade. Indeed its cavity is not partitioned either horizontally or vertically and therefore forms one large volume. Metal floors are installed at the level of each storey in order to allow access to it, essentially for reason of cleaning and maintenance. The difference between this type of façade and the building high controllable double skin façade lies in the fact that outdoor façade is composed exclusively of pivoting louvers rather than a traditional monolithic façade equipped (or not) with openings. This outside façade is not airtight even when the louvers have all been put in closed position, which justifies its separate classification [8]. Building high controllable double skin facades are divided to horizontally and vertically for ventilating and for cleaning aims (Fig. 15) [3].

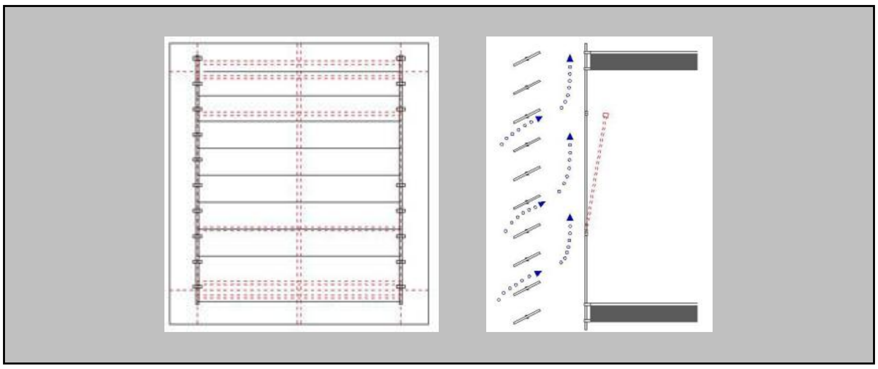


Figure 15. Examples of building high controllable double skin facades [4 and 6]
(Şekil 15. Bina yüksekliğinde çift kabuk cephe örnekleri)

Advantages and disadvantages of buıldıng hıgh controllable double skın facades;

ADVANTAGES

- Variable facade settings
- No overheating in summer
- Improvement of view out possible
- Can be controlled to adjust to outside climate

DISADVANTAGES

- Very high construction costs
- Very high maintenance costs
- High technical costs

4.3. Combined Facades (Kombine Cepheler)

This type of facades, are a combination of single and double skinned facades (Fig. 16).

The principles of both facade types are united in one overall system. The disadvantages of the interaction of the various layers of a multilayered system are avoided by the presence of single-skinned facade elements. On the other hand the system can make use of advantages of the double-skinned facade such as sound insulation and wind protection, sheltered solar screening and comfortable introduction of supply air. In the area of single-skinned facade the low glazing fraction means that solar screening can also be positioned inside the building. The result is a weather-independent overall system [6].

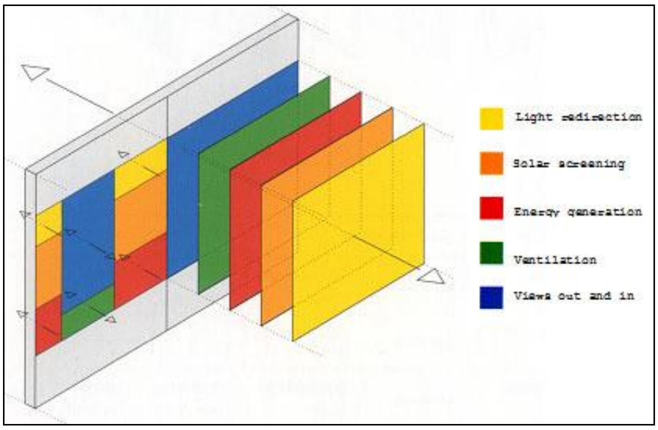


Figure 16. Combined concept [3 and 6]
(Şekil 16. Kombine tasarım)

- **Baffle Panel(Perde panel)**

A baffle panel is an additional panel that is fixed a short distance in front of a window in a perforated or anelemental facade. It is means of minimising the disadvantages of single skinned facades with respect to sound insulation and ventilation. Baffle panels also provide protection to solar screening, allowing it to be operated in almost any wind conditions. They are simple to incorporate and offer reliable protection againsr weather and intruders during night cooling. Baffle panels restrict the user’s view out only to a liited extent. The effective cross-section for ventilation may be considerably reduced if the gap between the baffle panel and the facade is too small (Fig 17) [3 and 6].

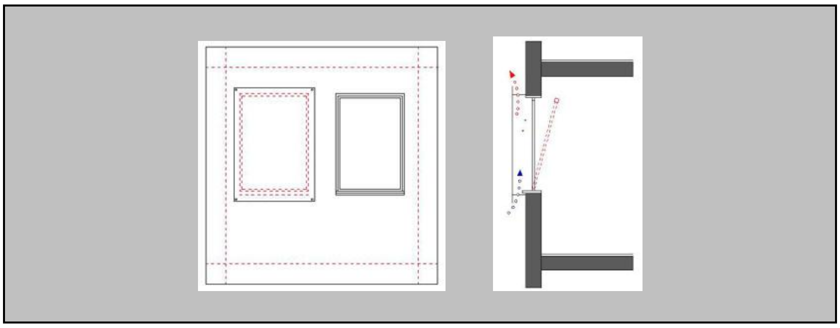


Figure 17. Examples of baffle panels [4 and 6]
(Şekil 17. Perde panel örnekleri)

Advantages and disadvantages of baffle panel;

ADVANTAGES

- Cost-effective way of optimising a facade
- Can be retrofitted
- Simple night cooling
- Little overheating in summer

DISADVANTAGES

- View out restricted
- Purge ventilation limited

- **Alternating Facades (Alternatif Cepheler)**

Alternating facade is a combination of single and doubleskinned facades with the advantages of both. In each room there is at least one element of each type (Fig. 18).

Depending on the outside and inside climate conditions, ventilation can be provided through the single or double skinned facade to ensure confortable conditions in the room almost any time of year. If the surface area of single skinned facade is small it can be also fitted with internal solar screening [3 and 6].

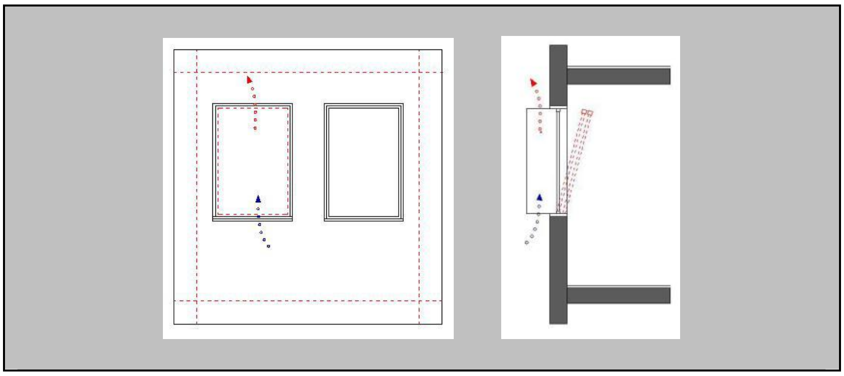


Figure 18. Examples of alternating facades [4 and 6]
(Şekil 18. Alternatif cephe örnekleri)

Advantages and disadvantages of alternatin facades;

ADVANTAGES

- Very high user-acceptance
- Very good level of comfort

- Many ventilation options
- Can be prefabricated

DISADVANTAGES

- High construction costs

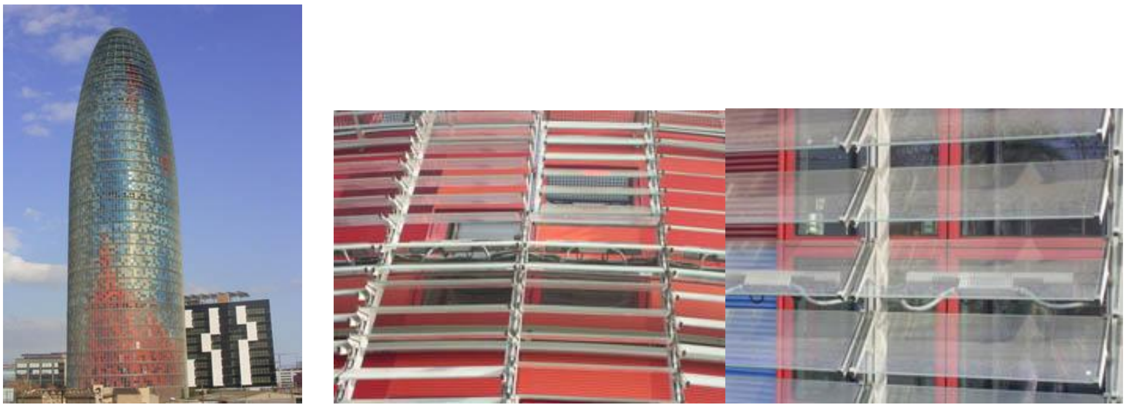
5. APPLICATION SAMPLES OF INTELLIGENT FACADES (AKILLI CEPHE UYGULAMA ÖRNEKLERİ)

5.1. Torre Agbar (Agbar Kulesi)

Locatıon: Barcelona/Spain
Construction Time: 2005
Architecture: Jean Nouvel
Facade Type: Double Skin Facade/Building high controllable double skin façade

Torre Agbar's consists of two non-concentric oval cylinders crowned by a glass and steel dome. The inner cylinder holds the vertical traffic nucleus and the installations. Between this central axis and the exterior there are 31 spacious floors without internal columns. It' s first skin, covering the concantre wall, is a layer of polished aluminium in earthy tones and blues, greens, amd greys, decomposing as they gain in heigh. The second skin is made up of 59,619 sheets of clear and translucent glass [23].

For energy efficiency and sustainability; 4500 windows was designed by Jean Nouvel to achieve natural ventilation and to make the most of sunlight and reduce energy costs. The air flow is regulated by means of the double glazing in the dome, which allows natural ventilation. Reduction in the building's temperature thanks to the chamber of air formed between the two skins, faworing ventilation (Fig. 19) [23].



(a) (b)

Figure 19. a) Agbar Tower b) Agbar Tower's solar screening
(Şekil 19. a) Agbar Kulesi b) Agbar Kulesi güneş kontrol elemanları)

5.2. Instiut Monde Arabe (Arap Dünyası Enstitüsü)

Location: Paris/ France
Construction Time: 1981-1987
Architecture: Jean Nouvel, Pierre Soria and Gilbert Lezenes
Facade Type: Double Skin Facade/Box Facade

Instiut Monde Arabe Building's facade design by Jean Nouvel represents a modern, technological interpretation of a traditional Arab devicei and set sup an aesthetic link with Arab culture.

For the South facade of this cultural institue a special adjustable solar control device was developed, along the lines of the ornate window gratings traditionally found in the Arab world. Build into the 62.4x26 m facade are 27.000 aluminium shutter elements, which open and close by means of an electro-pneumatic mechanism, regulating daylight transmission between 0.10 and 0.30. They are fitted with photo-electric cells and controlled by computer. In order to protect the sensitive mechanisms the 240 square glazed areas, 180x180 m in size, and the 0.40 m wide framing frizes are built up according to the principle of the cavity facade (Fig. 20) [1].

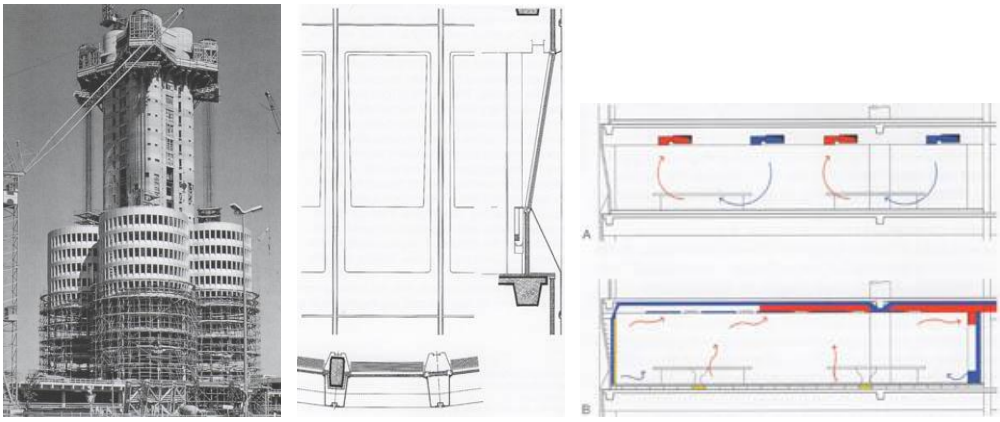
(a) (b)

Figure 20. a) Instiut Monde Arabe Building
b) The adjustable solar control devices
(Şekil 20. a) Arap Dünyası Enstitüsü Binası b)Kontrol edilebilir solar kontrol cihazları)

5.3. BMW Headquarters (BMW Merkez Binası)

Location: Munich/Germany
Construction Time:1968-1972
Architecture: Karl Schwanzer
Facade Type: Single Facade/Perforated Facade

The Viennese architect Karl Schwanzer completed the BMW headquarters building between 1968 and 1972. The BMW high-rise structure was first example in Europe of a facade structure where breast wall, intrados and lintels were composed of a single element. The facade design is particularly noticable. Each element consists of trapezoid, a roughly 2 m2 large pane of antisun glass, which is tilted outward by an angle approximately 9 degree. This ensures that sound is not reflected directly into the room through the facade, but redirected via ceiling. Anothet advantage, albeit not deliberately planned, is the diminished angle of solar incidence. Compared to the real altitude, the sun always seems to be 9 degree higher in the sky. The insolated glass areas and hence the external cooling loads are reduced. This prefabricated facade also called an alcast-facade (alcas=aliminium-cast) (Fig.21) [12].



(a) (b) (c)

Figure 21. a) BMW headquarters
b) Facade section
c) BMW headquarters existing mixed ventilation system and proposed system of air injection of floor level [12,4]
(Şekil 21. a) BMW merkez binası b) Cephe kesiti c) BMW merkez binası karma havalandırma sistemi ve önerilen hava enjeksiyon sistemi)

5.4. Capital Gate Tower (Capital Gate Kulesi)

Location: Abu Dhabi/Birleşik Arap Emirlikleri
Construction Time: 2007-2010
Architecture: RMJM Architecture
Facade Type: Combined Facade/Alternating Facade

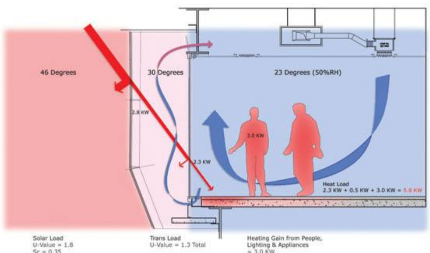
Capital Gate Tower designed by RMJM Architecture and completed between 2007 and 2010 in Abu Dhabi. Tower's cladding consists of two distinct element- a curtain wall cladding system and metal mesh sun shading system. Both were installed by the same manufacturer in order to ensure close coordination between these interlocking systems and the steel diagrid to which they are attached. The curtain wall consists of diamond shaped panels stacked up flor by floor. The curtain wall units are made of two components; steel and glass [13].

The glazing system is made of two silver coatings which are transparent, increasing its light transmission. The curtain wall eliminates glare and keeps the inside of the building cool. Also, the glazing system is highly transparency. The glass used is a highly energy efficient and low-e category glass. This glass has two silver coatings which minimise glare and maximise light transmission. This glass never used before in UAE.

Capital Gate's most visible feature is the "splash," which twists around the building towards the south to shield Capital Gate as much as possible from direct sunlight. The metal mesh eliminates 30% of the sun's heat before it reaches the building, reducing the air conditioning load on the protected floors. It also provides outdoor shade to the main entrance on the ground floor. The upper half of the tower has a double skin facade to reduce the solar heat gain at the hotel levels. This is a modified double façade, which recycles interior air from the guest rooms into the façade cavity. Here it creates an insulating buffer between the hot outside air and the cool inside air. The air is re-used in the room rather than exhausted and replaced with outside air (Fig. 22) [13].

(b)

(c)



(a) (d)

Figure 22. a) Capital Gate Tower [4 and 20] b) Capital Gate's metal mesh [4 and 20] c) Capital Gate Tower's diamond shaped curtain wall[4] d) Double skin facade ventilation system [4 and 13]
(Şekil 22. a)Capital Gate Kulesi b)Metal mesh c)Elmas şekilli giydirme cephe panelleri d)Çift kabuk havalandırma sistemi)

5.5. Reichstag German Parlıament Buıldıng (Reichstag Alman Parlemento Binası)

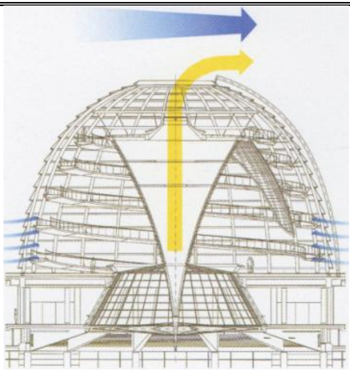
Location: Munich/Germany
Construction Time:1968-1972
Architecture: Karl Schwanzer
Facade Type: Combined Facade/Alternating Facade

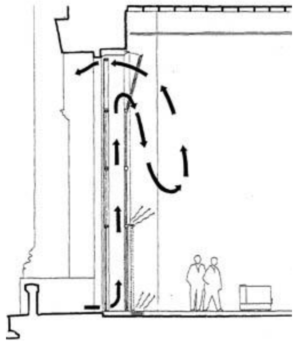
Reichstag German Parliament Building, which was built in 1894, by Karl Schwanzer became a symbol of Germany's commitment to renewable energy in the 21st century. Te building's facades are combination of single and doubleskinned facades.

The impressive iconic dome was designed to allow natural ventilation and daylight into the space. The building has a primary energy use of 57% lower than the requirements for existing buildings and 39% than the requirements for new buildings [19].

As well as the glass dome, another facade element is the moto-operated and/or manually openable windows. The use of windows faciliates the natural ventilation of the internal spaces. The two skins of glazing in elliptical aluminium sections consist of an inner, thermally divided glazing layer, a cavity containing movable sunshading elements, and a fixed outer pane of glass with a periperal ventilation joint. Depending on the external temperature and wind conditions, between half an five times the air volume of the rooms can be changed every hour. Sensors also allow the window to be opened by a central control system. As a result, natural ventilation is possible for a large partof the year. Since the outer skin of glazing protects the inner skin, the latter can be left open as a means of night-time cooling (Fig. 23) [12].

(c)





(d)

Figure 23. a) Reichstag German Parliament Building
b) The iconic domes's section c)Openeable windows
d) Double skin facade section [4 and 12]
(Şekil 23. a) Reichstag Alman Parlamento Binası b) Kubbe kesiti
c) Açılabilir pencereler d) çift kabuk cephe kesiti)

6. CONCLUTION (SONUÇ)

Nowadays there is a growing demand for innovative solutions for enhancement of sustainability in the built environments. According to the professinals of buildings particularly in building envelopes, facades are expected to play a significant role towards the promotion of intelligent building facades in low energy buildings.

For designing intelligent facades local climate conditions, outdoor environment, and indoor spaces with view to parameters such as energy performance, thermal comfort, indoor air quality, visual comfort, etc. parameters should be take account.

Intelligent double facade comprises two parts. Glass surfaces and between these glass there is a ventilated cavity space. This ventilated cavity having a width which can range from 50-1150mm for the widest accessible cavities is located between these two skins. And also there is another double facade type is airtight multiple glazing system. The main differences between these two facades type whether or not integrating a shading device in the cavity seperating the glazings, lies in the controlled ventilated of the cavity. Double facades have many advantage, they can allow lots of light inside when the wheather is dull and overcast. With high visual transmission glazing can usually provide plenty of daylight deep into a builidng, and with this application there is no need for avoiding glare, visual discomfort. Moreover, intellegient facades provide up to approximately 30-35% energy savings compared to convetional facade systems. Finally, it is reduce heating and cooling loads of buildings.

Energy-efficient intelligent building technologies, especially the facade design, play an important role for the proper and sparing use of energy. In line with the latest advances in technology, intelligent buildings compatible with their environment can provide for highly efficient energy use.

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