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## *Multiplication of optical phenomena in double leaf façades*

### *Introduction*

Thermal insulated double glazing is the most common example of use of multi-layered glass structures. The double leaf façade is a further step in the development of this technology. Double façades are used since the early twentieth century, since the development of the modern curtain wall. The first example of the use of this technology in Europe is the building of the Steiff Toy Factory in 1903 [5, p. 595–602] and, in the USA – Hallidie Office Building erected in 1918 for the University of California [6]. Multi-layered façades might be installed in different arrangements: on the entire surface of one wall, or as a glass envelope surrounding the building from all sides. An additional layer of glass in the front of a conventional façade forms a buffer zone, naturally ventilated and lit. This zone might be compared to a *large-scale, flat winter garden or porch with transparent walls* [2, p. 84]. The dynamic development of this technology led to considerable progress in methods of their manufacture and design, but the original concept remained unchanged.

Double façades are frequently researched, published, lectured and spoken about, both in *bona fide* science papers, and popular, advertising brochures. Most authors concentrate on the climatic aspects of this technology. This is caused by a high potential risk of overheating the façade in the summer, resulting from internal and external (sunlight) heat gains and loads. Very few papers research the optical and aesthetic aspects of double leaf façades. One of the most recent ones Thermal simulation of buildings with double-skin façades [9] is not an exception here. One of the models used by authors in thermal simulation of the building is indeed an “optical spectral model”, but the model is used to assess the amount

of solar radiation, which affects the microclimate. Optical visibility issues are not taken into account.

Although the optics of double leaf façades, are still insufficiently recognized, a certain characteristic of multi layered glass structures can be observed and distinguished. This analysis requires a background of issues of light penetration in the quantum scale.

Some individual photons of light penetrate through transparent material, while others are reflected. This phenomenon, observed in the quantum scale (at the scale of single photons of light) causes a reflection of 0÷16% of the photons. The range is due to the multiplication of transparent layers. Materials arranged in layers increase the number of possible reflections of photons: those that pass through the first layer, are reflected by the other, other ricochet (rebound) between. Estimation of the number of photons on both sides of the transparent pane appears to be impossible. Nobel prize winner physicist Richard Feynman describes this theoretical problem with a touch of humour: *Partial reflection from a single surface of glass is a difficult problem, but a partial reflection of two or more surfaces – that's an absolute enigma.* [4, p. 24]. When tests in the quantum scale are made with very weak light sources (capable of emitting single photons), the results from the range of 0÷16% confirm. When it comes to the measuring of the reflection of the whole light flux – the result of 8% is true, which is the average of the previously given range. This behaviour of light particles (photons) is described by Feynman as the “slowing of light”. This phenomenon is frequently observed in architecture.

### *Multiplication of optical phenomena*

Optical phenomena are multiplied in parallel layers of transparent materials. This is due both to their construc-

tion and the predominant point of observation (viewing axis perpendicular to the plane of the façade). Optical phenomena occur on each smooth surface. Modern double façades are composed of at least three panes (one cre-

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ates an external envelope, the other two form an IGU – Insulating Glass Unit). Each pane will both transmit, absorb and reflect light.

### Multiplied reflections

A summary effect will result from the imposition of the multiple light fluxes from both sides of each pane. This multiplication can lead to a total loss of transparency. Double façades *even if clear, produce enough reflection to function as a screen* [11, p. 10]. A clear example of this visual multiplication is an office building at Bockenheimer Landstrasse in Frankfurt. In this case the outer leaf of the double façade is made of single panes of glass that are point mounted by specially shaped brackets. The upper bracket bears the whole weight of the pane, the other two function only as fixing spacers (do not bear vertical loads of the pane). System of glass mounting is made of filigree bars and rods. *Lack of clearly visible structural elements attract the observer's visual attention to the virtual image formed in a façade. Multiplied reflections of surrounding buildings make the load-bearing structure of glass even less visible. This phenomenon intensifies the effect of the façade's "suspension"* [1, p. 38]. Virtual images are formed on every smooth-transparent plane. Superimposing multiplied reflections of tree

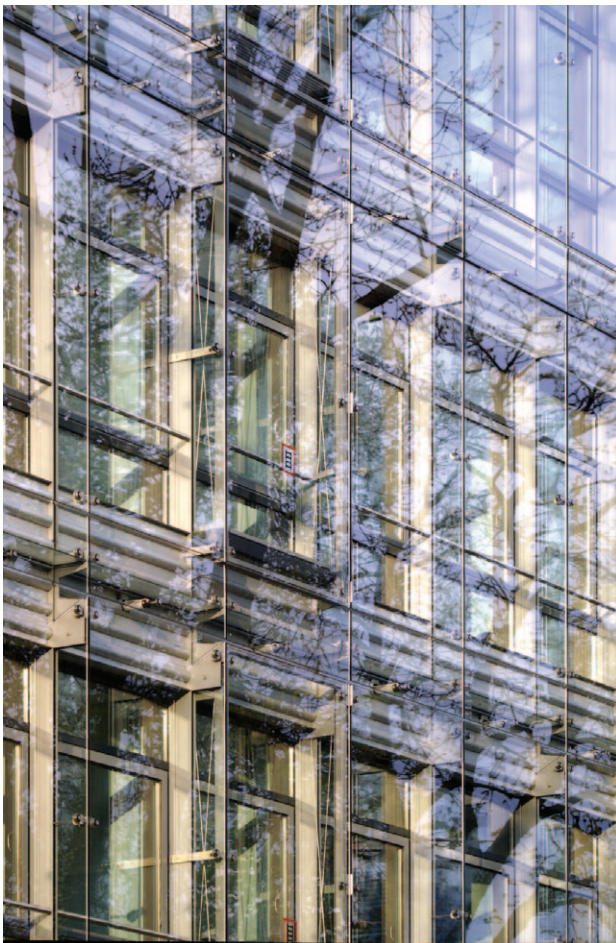


Fig. 1. Office building at Bockenheimer Landstrasse, arch. KSP Architekten, 1998 (photo: M. Brzezicki)

Il. 1. Budynek biurowy przy Bockenheimer Landstrasse, proj. KSP Architekten, 1998 (foto. M. Brzezicki)

branches are particularly confusing for observers (Fig. 1). Despite the use of transparent glazing material, the façade becomes a multi-layered screen reflecting the surrounding world, but not showing the inside of the building [2, p. 92].

Imposing reflections created in double façades lead to the formation of various optical illusions. Under certain lighting conditions, the reflection of the surrounding world can be so intense that the correct perception of double leaf façade can be difficult, or even impossible. A specific optical phenomenon that occurs in this situation is a virtual loss of the image focus – a blurred reflection. When two panes of the façade are located in relatively close proximity, two imposing reflections are not recognized by the human neural mechanism as separate reflections, but as a one that is out of focus. The phenomenon is really unusual. Reflection is blurred, while the rest of the observer's field of view is seen properly – in focus (see Fig. 2). A clear illustration of this phenomenon is the department store of the Galleries Lafayette in Berlin. The double leaf façade of the building is an “optical attraction” [3, p. 98], the effect of image blur occurs due to the relative proximity of layers of glazing – circa 20 cm.

Imposition of virtual images occurs on smooth transparent materials that are arranged in parallel layers. When panes are in close proximity, a slight shift of reflected images causes an impression of an image blur (as it was explained before). When panes are at a larger distance (for example: climatic reasons) other unusual optical phenomena might appear.

Various configurations of transparent panes of glass lead to different formal and architectural appearances. Sometimes the effect of the imposition is almost picturesque, in other cases, even disturbing. Glass panes of the façade are never mounted exactly in one plane, so the reflections in individual sheets of glass are slightly shifted. This fragmentation of virtual image reminds of the cubist style, which is *breaking the continuity of the presentation by the fragmentation of objects and visual integration of image is destroyed* [8]. The designer is unable



Fig. 2. Department store of the Galleries Lafayette in Berlin, arch. Jean Nouvel, 1995 (photo: M. Brzezicki)

Il. 2. Dom handlowy Galeries Lafayette w Berlinie, proj. Jean Nouvel, 1995 (foto. M. Brzezicki)



Fig. 3. Jakob-Kaiser-Haus in Berlin, arch. de Architekten Cie, Pi de Bruijn, 2002 (photo: M. Brzezicki)

Il. 3. Jakob-Kaiser-Haus w Berlinie, proj. de Architekten Cie, Pi de Bruijn, 2002 (foto. M. Brzezicki)

to predict the final effect because it depends on the workmanship and the façade's quality of execution. Judgment and understanding of the fragmented image, depends on the static or dynamic way of perception performed by the observer. Experiments conducted at MIT by P. Sinha, showed that the perception in motion, called *dynamic information processing* [...] leads to visual integration and eventually to recognition [12].

A distinctive example of superimposition of fragmented virtual images is the German parliament office building Jakob-Kaiser Haus. Two segments of the south facing façade of block no. 5 and 6 were designed and constructed as a double layer façade: additional sheet of transparent glazing was placed in the front of standard office building wall with glazed windows. Due to the limited precision of the façade's execution, individual sheets of glass are not exactly in the same plane, so each pane reflects a different section of the building located at the opposite side of the street. Smallest shifts are easy detectible by the observer's eye because the juxtaposed building was equipped with rhythmic and orthogonal decoration. Regularly distributed windows and sun shades are fragmented and moved, almost "trembling". Two layers of glass make the phe-



Fig. 4. CCN Ost Congress Centre, arch. S + P Heinz Seipel Ges. von Architekten mbH, 2006 (photo: M. Brzezicki)

Il. 4. Centrum kongresowe CCN Ost, proj. S + P Heinz Seipel Ges. von Architekten mbH, 2006 (foto. M. Brzezicki)

nomenon even more intense, because two virtual images superimpose [see Fig. 3]. One is formed in the external clear glass envelope, the other in the window's glazing.

Another interesting optical phenomenon resulting from the reflection can be seen in CCN Ost Congress and Exhibition Centre in Nuremberg. The modern Exhibition Centre building, fitted with full-height double leaf façade, was finished in 2005. Under certain lighting conditions, the observer gets the impression that the structural frame elements are doubled (see Fig. 4). The explanation is quite obvious: a virtual image of outer glazing's supporting elements is created on the inner layer of the façade. This misleading phenomenon can be seen only in constructions where the outer envelope of the façade has a distinct supporting frame structure. In accordance with the declarations CCN Ost designers [...] *openness and transparency are prerequisites for meeting place*. [7]. Apparently the double leaf façade was used to emphasize the impression of transparency, but in practice the result is far from the idea. When the blinds are closed in the air-corridor space, the misleading effect of structure multiplication disappears, but the building loses its transparency.

#### Multiplied transmission

Multiplication of optical phenomena occurs not only in the case of reflection or virtual image formation, but also in the case of light transmission. Light flux intensity would be weakened in proportion to the number of penetrated panes. Quantum mechanism of absorption of certain wavelengths of light would influence its colour. If a large number of "clear" filters – panes of glass – are arranged one after another, white daylight penetrating through would significantly change the colour. In architecture this phenomenon is seen mainly during sunny weather, on fully glazed façades of modern office buildings. Before entering the observer's eye, every ray of light passes through several layers of different transparent materials, each time slightly changing colour. This happens six times in façades consist-



Fig. 5. Sony Center,  
arch. Murphy & Jahn Architects,  
2000 (photo: M. Brzezicki)

Il. 5. Sony Center, proj. Murphy  
& Jahn Architects, 2000  
(foto. M. Brzezicki)

ing of three layers of glass (3 times + bounce off inside the room + 3 times), in more complex structures, the phenomenon intensifies. Light changes its colour, due to the type of glass used. In the office building – part of Sony Postdammer Platz complex – observed from the Ben-Gurion-Straße (Berlin-Tiergarten) the glass gets an evident greenish tint [see Fig. 5]. In the “Arkady” Shopping Center in Wrocław the multilayered façade was constructed using brown tinted glass, so the light receives a visible brownish hue.

### Multiplied absorption

Since the turn of the 80-ties and 90-ties in XX century another influential trend could be distinguished is architecture. It began in 1989 from Rem Koolhaas’ es draft design for the famous architectural competition of Très Grande Bibliothèque in Paris. In the proposed building smaller functional elements were contained in one rectangular block made of opaque glass. Different volumes suspended at different levels and different distances from the outside façade only “shone through” the milky glass coat of the building. The building seemed to be covered with a translucent veil, as the Swiss philosopher and doctor Jean Starobinski sees it – a mythical “veil of Poppea”, mistress of the emperor Nero. The idea of a new, so called “opaque transparency”, gained public attention and attracted many artists and architects.

According to Herbert Muschamp: [...] *what links [...] projects, apart from their transparent and translucent skins, is that the building’s skin is used not to reveal but to veil* [10, p. 43]. Glazing no longer performs a classic function of the modernistic curtain wall. New semi-opaque and translucent façades deceive the eye, and produce a magical effect of a curtain. Application of many layers of translucent and semi-opaque materials leads to the formation of zones with different light transmission characteristics. These zones are not “flat”, but gain spatial depth contained between the layers of glass. A unique optical buffer is created, which is analogous to thermal and acoustic ones.



Fig. 6. IKMZ – Technical Library of Cottbus, Brandenburg Technical University, arch. Herzog & de Meuron, 2004 (photo: M. Brzezicki)

Il. 6. IKMZ – Technical Library of Cottbus, Brandenburg Technical University, proj. Herzog & de Meuron, 2004 (foto. M. Brzezicki)

An excellent illustration of this idea is the well known building of IKMZ (Informations-, Kommunikations- und Medienzentrum) – technical library of Cottbus, Brandenburg Technical University (Fig. 6). The multi layer façade of the building was fully enclosed by bent laminated glass, emphasizing the organic clover shape of the building. The panels were covered with

oversized letters in a screen-printed form. The letters are so close to each other that they blend into an ornament so much that individual signs can not be distinguished. The outline of the letters is not clearly defined – visible halftone dots are blended into smooth tones by the human eye. The printed pattern is, however, more visible from the inside than from outside.

### Summary

Optical phenomena developing between the layers of a glass sheets of a double façade can fundamentally change the perception of the building's transparency. Overlapping reflections, multiplying virtual images, misleading optical

illusions and obstacles are difficult to predict. It is therefore essential for practicing designers to be aware of the wide range of possible perceptible obstacles and – depending on the architect's vision – to prevent them or skilfully exploit.

### References

- [1] Brzezicki M., *Analiza teoretyczna elewacji obiektów biurowych z punktu widzenia komfortu mikroklimatycznego miejsca pracy*, Raport serii SPR nr I-1/S-875/09, Politechnika Wroclawska, 2009.
- [2] Brzezicki M., *Zastosowanie zaawansowanych technologii w rozwiązaniach proekologicznych w architekturze*, Rozprawa doktorska Politechnika Wroclawska, Wydział Architektury, Wrocław 2001.
- [3] Campagno A., *Intelligente Glasfassaden: Material, Anwendung, Gestaltung*, Birkhäuser, 2002.
- [4] Feynman R., *QED Dziwna natura światła i materii*, PIW, Warszawa 1992.
- [5] Fissabre A., Niethammer B., *The Invention of Glazed Curtain Wall in 1903 – The Steiff Toy Factory*, "Proceedings of the Third International Congress on Construction History", Cottbus, May 2009,
- [6] *Hallidie Building*. (2010). In Encyclopedia Britannica. Retrieved March 29, 2010, from Encyclopedia Britannica Online: <http://www.britannica.com/EBchecked/topic/252856/Hallidie-Building>
- [7] <http://www.architekten24.de/projekt/ccn-ost/uebersicht/index.html>
- [8] <http://www.picasso.xorg.pl/kubizm.php>
- [9] Manz H., Frank Th. *Thermal simulation of buildings with double-skin façades*, "Energy and Buildings" 2005, Vol. 37, No. 11, p. 1114–1121.
- [10] Muschamp H., *Buildings that hide and reveal*, [in:] J. Kipnis, T. Gannon, *The Light Construction Reader*, Monacelli 2002 p. 28, p. 43.
- [11] Riley T., *Light construction*, The Museum of Modern Art, 1995
- [12] Sinha, P. *How brains learn to see*, *Interactive Transcript* [source:] [http://www.ted.com/talks/pawan\\_sinha\\_on\\_how\\_brains\\_learn\\_to\\_see.html#](http://www.ted.com/talks/pawan_sinha_on_how_brains_learn_to_see.html#)

### Powielenie zjawisk optycznych w podwójnych fasadach

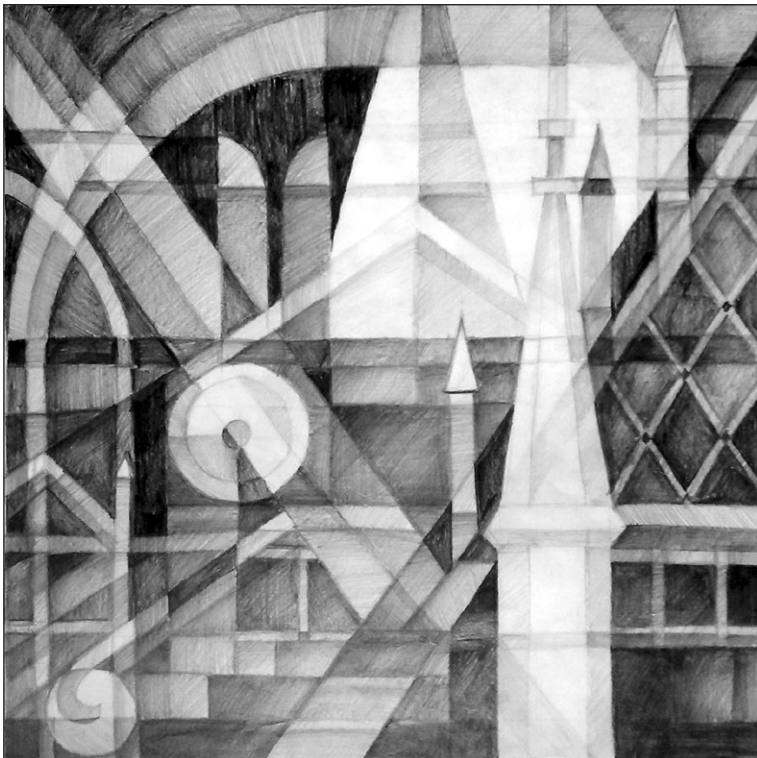
W artykule podwójne fasady są analizowane z punktu widzenia optyki. W wielowarstwowych konstrukcjach szklanych nakładające się odbicia i obrazy pozorne powstają na każdej gładkiej tafli. Ich powielenie może prowadzić do powstania wielu odkształceń obrazu pozornego

oraz mylących złudzeń optycznych, które wpływają na przezroczystość powłoki budynku. Wybrane zjawiska zostały zaprezentowane na przykładzie zrealizowanych budynków w których zachodzą. Przegląd może służyć jako wstępne narzędzie projektowe dla architektów-praktyków.

**Key words:** double leaf façade, optical phenomena, transparency

**Słowa kluczowe:** podwójna fasada (elewacja), złudzenia optyczne, przezroczystość,

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