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THE USE OF GLASS CURTAIN WALLS AS PARTITIONS WITH FIRE RESISTANCE IN RESIDENTIAL BUILDINGS – CASE STUDIES

STOSOWANIE PRZESZKLONYCH ŚCIAN OSŁONOWYCH JAKO PRZEGRÓD O ODPORNOŚCI OGNIOWEJ W BUDOWNICTWIE MIESZKANIOWYM – WYBRANE ASPEKTY

A b s t r a c t

While analysing the available systems of glass curtain walls one can identify potential problems with their use as partitions with fire resistance. In most cases the metal support structure is made of aluminium. Due to its adhesive and separating interlayer made of plastic materials susceptible to the influence of temperature laminated glass, it does not work well in fire prevention. Manufacturers have products with the required parameters to use in fire partitions and qualified in terms of EI. Currently there are post and transom solutions available on the market which possess a certificate to use the whole system in EI60 fire rating. Internal spaces of posts and transoms in metal support structures are equipped with a filling: a reinforcement made of aluminium. Posts, transoms and thermal strips connecting the clamp strip with a support frame and faying surfaces integrating metal structure are subjected to special protection and safeguarding with thermo-expandable material. Additional protection allows for load-bearing parameters of up to one hour on the weakest link in the system. Producers of glass attest their products in classes from E15 to EI 180, so integrity and fire insulation lies within the aluminium support structure in the whole post and transom glass curtain wall system.The analysis of issues related to the use of glass curtain walls in residential buildings will determine the pattern of wall technology selection to the specific fire prevention requirements.

Keywords: fire-rated glass curtain walls, fire protection class of curtain walls, destruction of curtain walls during fire

S t r e s z c z e n i e

Analizując dostępne na rynku systemy szklanych ścian osłonowych, można zidentyfikować potencjalne problemy stosowania ich jako przegród o odporności pożarowej. Metalowa konstrukcja nośna w większości przypadków wykonana jest z aluminium. Szkło klejone ze względu na warstwy klejące i oddzielające wykonane z tworzyw podatnych na wpływ temperatury źle znosi zastosowania z zakresu ppoż. Producenci dysponują produktami posiadającym odpowiednie parametry do zastosowań w przegrodach oddzielenia przeciwpożarowego i kwalifikowane w kategoriach EI. Obecnie na rynku dostępne są rozwiązania słupowo-ryglowe legitymujące się atestem do stosowania całego systemu w parametrach pożarowych EI60. Wewnętrzne przestrzenie słupów i rygli nośnych konstrukcji metalowej wyposażone są we wkładkę – wzmocnienie profilu wykonane z aluminium. Szczególnej ochronie i zabezpieczeniu z materiałem termo-rozszerzalnym poddane są słupy, rygle, listwy termiczne łączące listwę dociskową z profilem nośnym oraz węzły montażowe scalające konstrukcje metalową. Dodatkowa ochrona pozwala na uzyskanie parametrów nośnych rzędu jednej godziny na najsłabszym ogniwie systemu. Producenci szkła atestują swoje produkty w klasach od E15 do EI 180, więc w obrębie całego systemu przeszklonych ścian osłonowych słupowo-ryglowych szczelność i izolacyjność ogniowa leży po stronie aluminiowej konstrukcji nośnej. Analiza problematyki związanej ze stosowaniem przeszklonych ścian osłonowych w budownictwie mieszkaniowym pozwoli określić schemat doboru technologii ściany do konkretnych wymogów pożarowych.

Słowa kluczowe: przeszklone ściany osłonowe do zastosowań pożarowych, klasa odporności pożarowej ścian osłonowych, zniszczenie ściany osłonowej podczas pożaru

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1. Introduction

Architectural and building design is sanctioned by legislation to provide uniform requirements of utility with particular emphasis on the use of the best practices to ensure the safety of people, animals and property. The basic regulation, concerning architectural design issues in Poland is the *Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location (Dz. U. (Journal of Laws) No. 75, item 690 from 2002 and amended)* describing the technical requirements for walls, joints and brittle structures installed at high altitudes. The regulations also apply to the issue of health and safety for users of glass-walled rooms.

The modern nature of the partition and its share in the potential energy gains cause more and more frequent presence of such solutions in residential architecture. A glass curtain wall must comply with the relevant mechanical parameters as well as being a safe element, also in terms of fire protection. It is described in the following paragraphs of *Technical conditions…*:

"§216.1 Depending on the height of the building, residential buildings and collective dwellings, are to be erected in fire resistance classes ranging from [A] to [D]. External walls – excluding structural ones – have to ensure tightness (E) and fire insulation (I) from 30 up to 120 minutes. By definition curtain walls do not serve a structural function – i.e., they do not carry the load of the roof, acting only as a barrier to external atmospheric conditions. Three-storey buildings are exempt from fire rating – including single family, farm and individual recreation buildings (§213.1.a), residential-administrative in forestry holdings (§213.1.b) as well as detached two-storey buildings with a capacity of up to 1500 m^3 intended for the purpose of tourism and leisure (§213.2.a), with a capacity of up to 1000 m^3 with a residential part (§213.2.c)". Due to the level of technological advancement and significant complexity of glass curtain wall systems, obtaining a certificate of fire rating for the entire set requires the use of additional, costly security. In order to reduce production costs and to popularise solutions, the standard catalogue solutions in this area do not possess fire parameters, as in most applications they tend not to be required by law.

2. Technical solutions in glass curtain walls

Due to its adhesive and separating interlayer made of plastic materials susceptible to the influence of temperature, laminated glass does not perform well from the viewpoint of fire prevention. Manufacturers possess products with the required parameters to use in fire partitions and qualified in terms of EI. Fire windows are divided into fire-resistant and fire-retardant categories. Both types of glazing provide protection against heat radiation (defined by "E" parameter of fire rating), while fire-resistant ones serve also as a mechanical barrier to a fire (defined by "EI" parameter of fire rating) [5, 6].

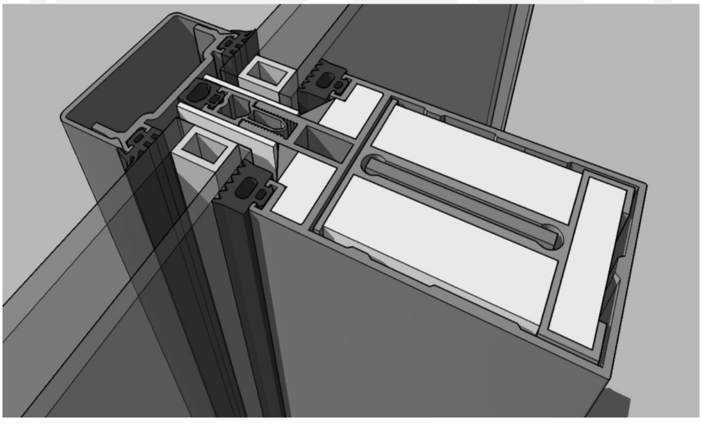
Research on the development of technology of glazing resulted in attempts to fill the interspaces of glazing with a transparent gel-like substance. The gel allows to transfer the heat from the outer to the inner pane of the thermo insulated glazing, thus reducing the temperature and stresses in the glass. Fire-rated glass is about four times more expensive than building glass. Solid laminated glass structures easily exceed 40kg/m^2 weight, which causes that the weight of this type of partitions together with the supporting structure, could reach 100 kg/m^2 –

a threshold defined as a light structure. The use of a special gel-filled fire glazing can increase the weight of the glazing up to more than 100 kg/m^2 (for example, a set of pyro EI120 – 108 kg/m^2). Additionally, the profiles of the metal support structure with a fire-rating significantly increase the weight of the glazed system. They must carry a greater load of windows and swelling masses, which thermally secure the internal structural core used in them.

While analysing the available systems of glass curtain walls, one can identify potential problems with their use as partitions with fire resistance. In most cases the metal support structure is made of aluminium. A few years ago, due to the shortage of raw materials for the production of aluminium, manufacturers were trying to replace it with a much more accessible steel. Technologically, steel as a less malleable material, was less susceptible to profiling treatment (production of highly complex extruded closed profiles), therefore cold-formed profiles were developed: open and welded ones. The structure's weight showed a significant increase in comparison with the structures of welded aluminium and cost calculation allowed for slight savings, but the more important aspect was the raw material availability factor. Natural landform has also proven problematic; extruded aluminium profiles had smooth walls of equal thickness and the edges were rounded to a rounding with a very small circular radius. As a result, the structures of this alloy showed a greater predisposition for their use as final finishing elements. Steel rolling in hot profiling has characteristic surfaces of low smoothness. The edges are rounded with radiuses two or three times greater than for aluminium. The corrosiveness of the material was also considered, again with an indication of a lighter alloy. Using steel it was potentially possible to achieve better fire resistance, thanks to a thicker material; however, due to the problematic treatment, the little "technicality" of aesthetics and the problems of degradation of the material, the solution has not gained popularity.

Currently there are post and transom solutions available on the market which possess a certificate to use the whole system in EI60 fire-rating [7].

They provide tightness and fire insulation for about 60 minutes, but do not provide sufficient mechanical strength; curtain walls must be anchored to the load-bearing elements



Ill. 1. Strengthening the support structure and thermal protection in fire--ranked post and transom systems (yellow color indicates swollen thermal liner, orange and red – proper support layer during fire), own work

of the building and they only provide a filling wall and not possess a structural character. Internal spaces of posts and transoms in metal support structures are equipped with an infill: a reinforcement made of aluminium (Ill. 1). It provides transfer of loads and maintenance of structural rigidity while losing the bearing capacity of an external profile for a certain time. The external profile is in the shape of a box, the inner profile is ribbed and the spaces between them are filled with sealing tapes made of swelling materials. During a direct or indirect fire, a significant increase in the temperature inside the carrier profile, causes swelling of the insulating material to occur. Its task is to protect the internal carrier profile from the increase of temperature outside the carrying capacity of the protected item. An additional security is to fill the joints and larger mounting slots with swelling tapes and the use of steel washers of increased resistance under the bolts. Posts, transoms and thermal strips connecting the clamp strip with the support frame and faying surfaces integrating metal structure are subjected to special protection and safeguarding with thermo-expandable material. Additional protection allows for load-bearing parameters of up to one hour on the weakest link in the system.

An important aspect of the development of a fire near the glass curtain wall is the issue of the spread of hot air inside the structural profiles (Ill. 2, 4). Closed chambers heat up extremely effectively, causing a rapid increase in temperature and air pressure within the posts and transoms of the curtain wall. Spontaneous combustion of materials in the vicinity of the partitions may occur on the upper floors of the building. If curtain walls are one system on the large surface of the facade, then the load-bearing structure is a joint and continuous element at the height of its occurrence. The use of swelling tapes at high temperature, closes and causes "congestion" of spaces inside the metal profile and limits the spread of fire outside the protected area.

The aesthetic criterion for the use of fire protection glazing options is also worth mentioning. Because there is security inside the structure, external dimension, colour and shape does not require any changes. Hence there is the possibility of combining fragments with fire-rating with

Ill. 2. The impact of fire on the curtain wall, visible movement of hot air and gases inside the carrier profiles (source: B. Sędłak, *Fire resistance tests of glass curtain walls*, part 2, in Świat Szkła (The World of Glass) 10/2012)

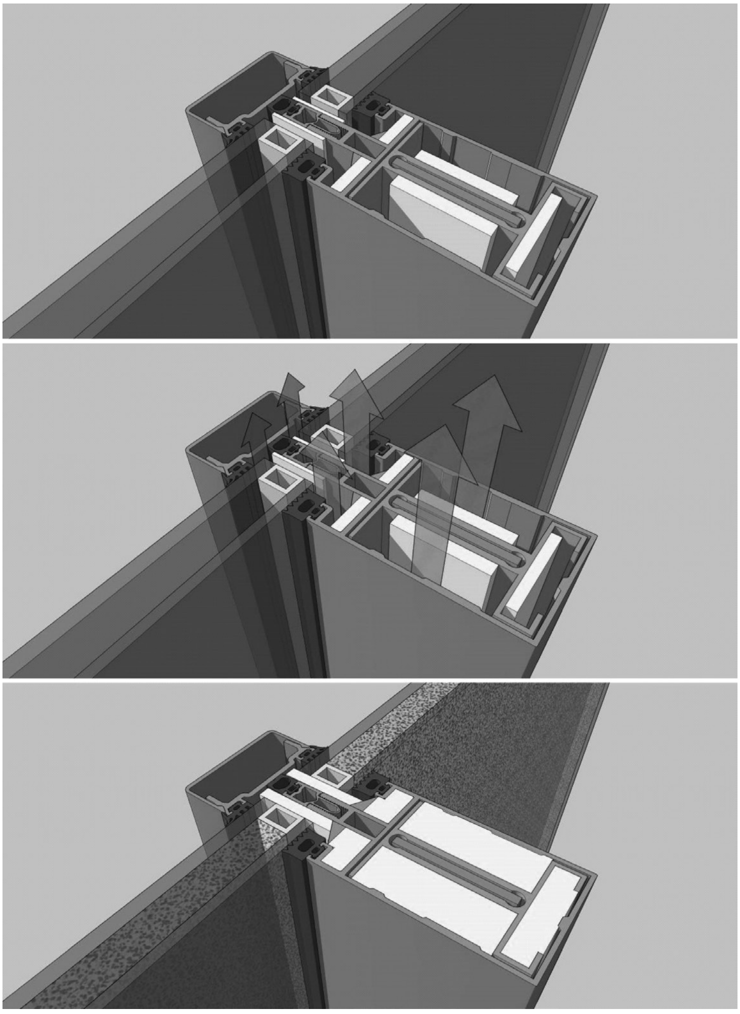
parts of the façade which do not possess it, without any visible external change. Moreover, it is possible to protect the selected nodes or strip of the desired width of the facade.

Double glazing used in fire-rated partitions must come from an assortment providing the appropriate parameters. Producers of glass, attest their products in classes from E15 to EI 180. Fire glazing elements differ from standard solutions in the use of solid transparent substance (gel) between the panes of glass set. The role of the additional security is the absorption and distribution of excess temperature and cooling of the glass surface subject to fire. Reception of temperature enables to preserve the strength of the glass for the required

A)

B)

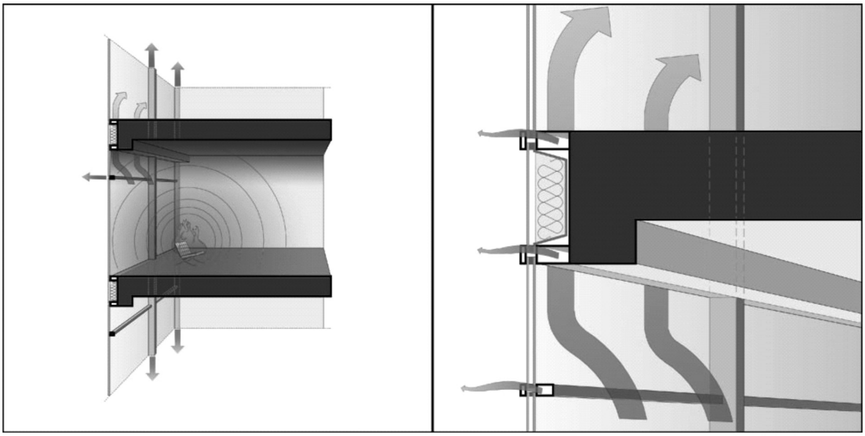
C)



Ill. 3. The impact of fire on the curtain wall components: A) reinforcements and thermal protection seating, B) a hot air flow in the ducts of internal structural posts, C) swelling of thermo-expandable materials and overheat of the gel in IGU, own work

time. Even the gel filling of the inter-chamber also reduces the possibility of the formation of local destructive stresses in the glass, which are the result of point changes in the power balance inside the material. A side effect of overheating the fire glass is a loss of the inter-suspension's clarity. It allows rescue teams to determine whether there is a fire on the other side of the partition and forces investors to exchange the item for a new one, enabling the restoration of protection against fire. Like other known security systems, fire windows are disposable elements.

The whole pole and transom glass curtain wall system integrity and fire insulation depends to a decisive extent on the aluminium support structure elements, sealing the glass seating in the metal structure.



Ill. 4. The problematic node common curtain wall connecting rooms with different ownership structure or in different fire zones – roads conducive to the transmission of fire, own work

In the event of damage or interruption of flexible seals around the perimeter of the glass sets, the transfer of hot gases, smoke and fire to the mounting spaces and the unconstrained heating of the curtain wall structure upwards from the penetration occurs. It is followed by further degradation of the structure of the wall and byo the escape of fire and smoke to the upper rooms (Ill. 4). The air trapped inside the carrier profiles is also heated, pressure increases and the weakening of the structure in parts unsecured against fire occurs. The presence of swelling insulators under the influence of temperature inside the profiles can create a "cork" for the free movement of hot air and reduces the spread of fire and deterioration of the carrying capacity in the whole structure of the curtain wall.

A common aesthetic procedure is used by architects to design large-area glazing over large parts of the facade. In commercial buildings, it is most often the administrative unit in charge of the fire information systems which include smoke, fire and temperature detectors, and integrated evacuation support systems or even fire extinction systems. The ownership structure is not fragmented and the hierarchy of decision-making and management of efficient evacuation is clear and described in detailed procedures. This looks quite differently in residential buildings and especially in collective residential buildings. The ownership structure is very fragmented; individual housing units are adjacent to each other at the interface of the surfaces of walls and ceilings. They often have common, in the physical and static term, outer wall formed as a glass curtain wall. The need to preserve the environmental separation and individual character within the building, causes that the sensors responsible for the early detection of fire are located at some distance from the potential sources of the fire. Also, evacuation procedures are not periodically inspected so that evacuation can be characterized as a set of individual actions, uncoordinated in time, scope and with a strong likelihood of a panic outbreak. The very shape of the facade as a single system is conducive to the spread of fire upon the premises, inside the structural profiles and after the interruption of continuity in glazing gaskets.

It is an extremely important issue; therefore, it is necessary to select available solutions appropriately in order to maintain the basic principles of fire safety. Definitely, the interfaces between ownership structures should be carried out as fire-rated partitions. Such a treatment will reduce the scope and speed of the spread of fire in the vicinity of the curtain wall.

4. Conclusions

Due to their complexity and mounting method, glass curtain walls possess a lot of aesthetic advantages. Unfortunately, they also have drawbacks, such as a low fire resistance. A relatively early stage of development of this type of building skins results in their slow evolution and continuous search for new materials to improve their performance. Currently, in residential single and multi-family buildings of up to three storeys and in buildings with living quarters of capacities specified in §213.2.a and c of *Technical conditions*…, one can apply all kinds of glass curtain walls. In all the remaining residential buildings, exterior curtain walls have to be post and transom systems with a certified fire resistance class. With currently available technologies, fire considerations only allow for the use of post and transom walls in places that require fire classification of partitions. Special variants of curtain walls have appropriate certificates. The aesthetics of the wall is not changed, since the fire protection technology is hidden inside the structural profiles. It is therefore possible to designate the protected areas equipped with the system components, with the appropriate "EI" parameters within a single curtain wall system. This enables the aesthetic integration and cost optimization without the use of fire-ranked elements over the entire surface of the facade. The aesthetic determinant, results in that the advanced systems of glass curtain walls with structural glazing and point mounting as well as the fully glazed ones, do not possess appropriate fire certificates. Glass of possible high fire resistance classes is a construction material and a filler and connectors cooperating in the wall statics are made of metal. A reduction in the size of the rotula prevents the use of internal security and external connector protection technologies would significantly affect the aesthetics of the partition, thus conflicting with the basic premise for the choice of this type of technology: the high aesthetics of the glazing.

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