Vol. 9, No 2/2020, 71-78

DOI: 10.17512/bozpe.2020.2.08

Construction of optimized energy potential
Budownictwo o zoptymalizowanym potencjale energetycznym

ISSN 2299-8535 e-ISSN 2544-963X

Design and assembly errors in the realization of post-and-beam glass facades

Zbigniew Respondek[1] (*orcid id: 0000-0003-0204-5061*)
Kacper Chęciński[1] (*student*)
[1] Czestochowa University of Technology

Abstract: As a result of the dynamic development of technology, glass-aluminum facades are now widely used. Not only representative facades in city centers, but also small buildings, such as commercial and office buildings, are equipped with aesthetic glass facades. To properly fulfill the functions of a curtain wall (thermal protection, water tightness, etc.), glass-aluminum systems must be properly designed and assembled. The aim of the article is to identify the most common errors made when implementing small investments on the basis of information about problems that emerge during assembly, as well as the reasons for complaints filed by investors. The most popular post-and-beam systems on small construction sites were analyzed. The data was obtained from companies operating in the northern part of the Silesian Voivodeship, dealing with the distribution and assembly of these systems. Scoring was made of the negative impact of the identified errors on the structure. It was found that the main problem in this issue is the lack of due diligence during assembly, in particular deviations from catalog recommendations.

Keywords: glass facades, assembly of building elements, quality assessment in construction

Please, quote this article as follows:

Respondek Z., Chęciński K., Design and assembly errors in the realization of post-and-beam glass facades, BoZPE, Vol. 9, No 2/2020, 71-78, DOI: 10.17512/bozpe.2020.2.08

Introduction

Even in the 1990s in Poland, glass facades were characteristic of representative buildings, most often in city centers. Currently, due to the development of building glass technology and glass-aluminum facade systems, the availability of this type of products has increased significantly (Pietrzak, 2014; Pariafsain, 2016). Glass facades are also implemented on small buildings: shops, offices of smaller companies, and even residential buildings. In these small buildings, glass often covers only one front elevation or a significant part of it. Simple systems are installed not only on the facade, but also as internal partitions.

There are many solutions for glass-aluminum systems. Basically all of them deal with an aluminum supporting structure and a filling made of insulating glass units (IGUs). The basic types are: post-and-beam facades, structural and semi-structural facades, point supported facades, unitized facades and the latest ECS facades (Sienkiewicz, 2010; Urbańska-Galewska & Kowalski, 2016; Wang et al., 2019).

In the case of small investments, post-and-beam systems are commonly used, because with a low level of prefabrication they can be implemented by smaller companies. The system consists of a post-and-beam structure, which, depending on the contractor's capabilities, is either assembled on site or partially combined in workshop conditions and transported in larger elements. The filling (IGUs) is mounted on washers using gaskets, clamping strips and masking strips (Fig. 1). Until recently, double-glazed units were used, now, due to the increased requirements for thermal protection, triple-glazed units are recommended.

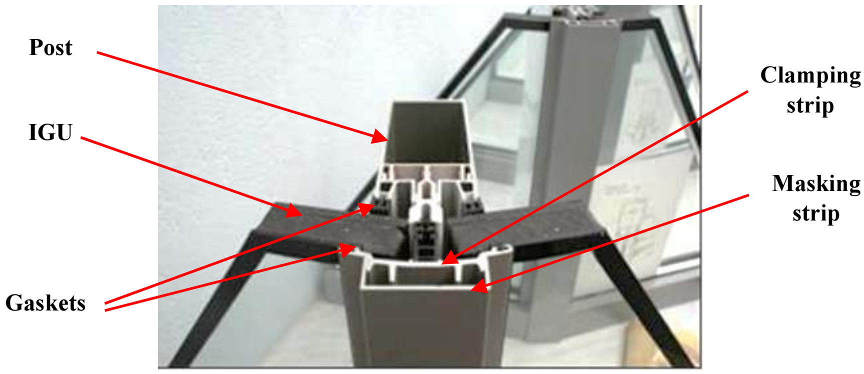

Fig. 1. Model of the post-and-beam facade (Photo: Z. Respondek)

Glass-aluminum systems, due to the large number of structural connections, are sensitive to design and assembly errors. The facade acts as a curtain wall, therefore thermal protection and water tightness are the basic requirements that it should meet. The aesthetics of this structure is also important. The literature describes design and assembly errors of facades and other glass structures. These analyses were based on the visible effects of shortcomings during the operation of these structures (Kosieradzka, 2017; Respondek 2019) or on the failure of entire larger structures (Sentkowski, 2011). Possible failures caused by environmental factors (Mika, 2011; Gierczak, 2013) or loads (Chow et al., 2007; Lu et al., 2018) were also described.

The aim of this article is to identify the most common errors made in the realization of small investments with the use of post-and-beam systems on the basis of information about problems revealed during assembly and the most common reasons for complaints submitted by investors.

1. Methodology of research

As already mentioned, glass facades implemented in post-and-beam systems were analyzed. The data for analysis was obtained by conducting targeted interviews in five companies dealing in the distribution and assembly of such facades, operating in the northern part of the Silesian Voivodeship. The questions concerned practical problems related to the design and construction of facades, shortcomings revealed during internal quality control, and complaints submitted by investors. On this basis, errors made at the design and assembly stage of the facades in question were identified.

The data was not presented in numerical terms, as companies do not wish to publish data on the number of complaints or disclosed errors. As far as possible, these errors are removed on an ongoing basis (although some are revealed after some time) for this reason they are not visible on the structure.

Next, the scoring of the detrimental impact of the identified errors on the structure was made. The partial scores were assigned to six accepted criteria, and then the weighted mean global score was calculated.

2. Results of the research

On the basis of the collected material, it was found that the most common errors related to the implementation of post-and-beam facades can be systematized as follows:

- errors in the assembly of load-bearing structure and gaskets,
- improper selection or installation of glass fillings,
- design errors,
- approval for assembly of glass units with manufacturing defects.

2.1. Errors in the assembly of the load-bearing structure and gaskets

During the interviews, all persons unequivocally stated that the main cause of mistakes is carelessness or the lack of appropriate skills of the assemblers. The most common symptoms of this are, however, improper installation of gaskets, EPDM membranes and the lack of verticality of the posts.

Incorrect assembly of gaskets. A serious mistake is the lack of continuity of the outer seal of the glass wall. The gaskets are delivered in coils or bars, and prior to installation, they must be cut to the appropriate size and their ends glued and stuck to the profile gap. A frequent mistake is a gasket that is too short, which results in discontinuity of the connection. There are also cases when the gasket falls out of the gap or is twisted.

Careless installation of the EPDM membrane. The membrane, commonly known as an EPDM “apron”, is a form of sealing of the curtain wall structure at the connection with concrete and masonry elements. It protects against moisture while allowing it to evaporate from the space between the building structure and the aluminum profile. Incorrect installation is manifested by the apron falling off the profiles or the building structure (usually no glue) or failure to maintain the tightness between the apron strips. Lack of careful installation results in the loss of water tightness of the connection. Sometimes even the thermal insulation of the connection is omitted (Fig. 2a).

a) b)

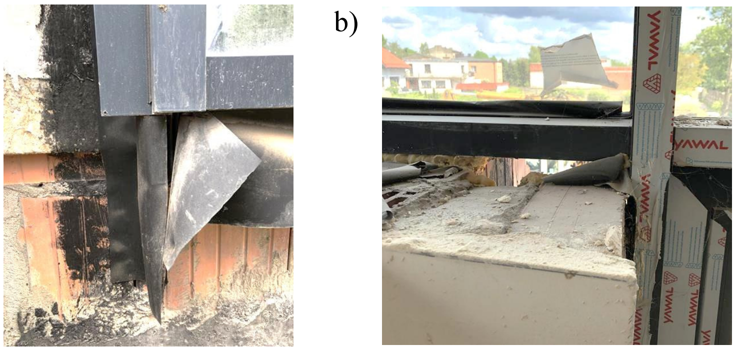

Fig. 2. Errors in the connection of the facade with the masonry elements: a) careless installation of the EPDM membrane, b) insufficient details at the interface with the wall (Photo: K. Chęciński)

No verticality of the posts. It is also a common problem, the whole wall, instead of being one plane, shows many small bends. This is not always clearly visible, but has an impact on the distribution of loads that do not act axially on the other system components. Moreover, the lack of verticality also leads to the loss of dimensional invariance between adjacent posts, which may cause problems with selecting the dimensions of the filling, described in the next section.

Use of inappropriate tools. An example is tightening the anchor bolts of the facade fasteners with the wrong tightening torque. The project provides for bolts, the parameters of which are strictly defined by their manufacturer. The use of too low or too high torque when tightening the screws does not guarantee proper static operation of the connection.

Omission of fragments of system strips. By allowing the product to be used on the market, the manufacturer offers a complete product consisting of many elements described in the catalogs. Omission of system components or the use of substitutes may cause malfunctions. It happens, for example, that in some sections there is no masking or even pressure strip. This is often the result of rushing where temporary assembly strips are removed, the actual strips are "forgotten". This results in water stains on the surface of the glass (permanent stains are formed after a long time), as well as leakage at the edge of the IGU and the possibility of rainwater entering the building.

No spacer on the steel-aluminum connection. This is another example of a system item being omitted. The standard material for the production of elements fixing the poles to the walls is steel. The lack of a spacer on the steel-aluminum interface may cause electrochemical corrosion at this joint.

2.2. Improper selection or installation of glass fillings

Correct mounting of the filling elements affects both the structural properties of the entire system as well as the aesthetic and functional values.

Incorrect support of filling elements. This is a mistake that is often made because of the popular opinion of a minor requirement. In principle, the beams are used to maintain a constant distance between the posts, but their other, equally important function is to transfer the weight of the filling to the posts. Thus, the uneven distribution or lack of the glass washers may result, firstly, in an uneven load on the posts, and, secondly, in a glass breakage caused by large local stresses in the area of the glass-washer interface. It is usually an initially small crack propagating from the edge of the glass pane in a direction close to perpendicular (Fig. 3a).

Wrong dimensions of fillings. Usually the sizes are selected automatically by programs dedicated to a given system, hence the number of errors is limited. Nevertheless, for example, in the case of the need to replace the panes or due to manufacturing errors in the spacing of posts and beams, the dimensions of the fillings may not be properly adapted to the real structure. If the glass is too shallow in the post profile, it may cause leaks. Too deep embedding of the glazing can lead to thermal cracks usually propagating from the side edge of the glass unit (Fig. 3b).

a) b)

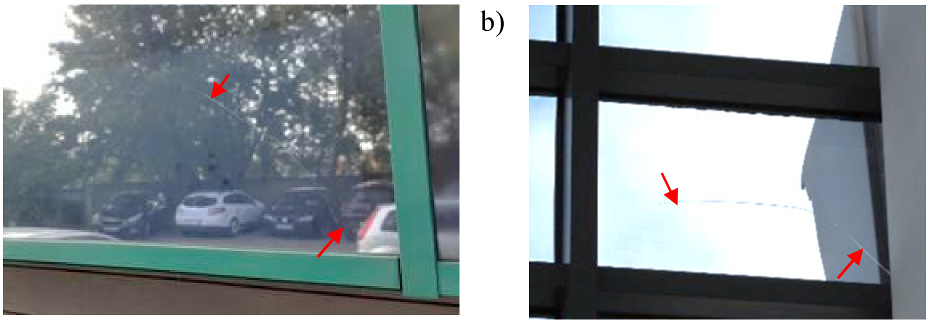

Fig. 3. Cracks in the fillings caused by: a) incorrect support of the glass panes (Photo: Z. Respondek), b) too deep setting of the IGUs (Photo: K. Chęciński)

Reversing the glass plate arrangement. IGU consists of individual panes, which may differ in thickness, type of coating and type of glass. Each unit has an external and internal side specified and marked by the manufacturer. The inversion of the layer system, which happens in the case of inexperienced assemblers, may result in the loss of functionality of the unit in terms of thermal and sun protection parameters, mechanical strength, etc.

2.3. Design errors

The facade design is related to the proper selection of system elements in the context of load conditions and geometric dimensions. On larger investments, the project is carried out by a professional office, on small ones, system elements are selected based on catalog solutions using corporate support software.

Incorrect solutions of details in critical places. The construction of the curtain wall requires special attention to details such as the connection of the curtain wall with the ceilings, and the end of the facade at the bottom and top. Errors in this regard occur frequently and result in deterioration of water tightness and the formation of thermal bridges at the edge (Fig. 2b).

Adoption of an incorrect static scheme. When designing connections of an aluminum structure, one should remember about the high susceptibility of aluminum to thermal movements. There are errors related to excessive stiffening of the structure, leading to excessive stress and deflection of the profiles, which may cause the glass to break. Facades should be designed as "standing" or "hanging". In the first case, the lower ends of the posts have a free support on the building structure, the remaining supports should be movable. In the case of a hanging support, simply support is used on the upper ends of the posts.

2.4. Defects of insulating glass units

IGU are currently manufactured using smart machines (CNC), which guarantees the high quality of this product. However, there are units with defects. Defective IGUs should be eliminated from the delivery. Unfortunately, it happens that they are mounted as fillings. During the interviews, it was admitted that some of the customer complaints related to defective insulating glass units. These defects included, first of all, the lack of proper tightness of the connection of the component panes with the spacer, and secondly, dirt and streaks on the glass surface from the side of the internal gap.

3. Analysis of the results

Based on the collected information, scoring was carried out, showing the adverse impact of the identified design and assembly errors on the structure of post-and-beam facades. Six parameters were selected and assigned partial grades on a scale of 0-5, where "0" means no adverse effect, and "5" – high impact. At the same time, individual parameters were assigned a weight (in parentheses) and a weighted average was calculated. The results of the analysis are presented in Table 1.

On the basis of the presented analysis, it was found that the errors with the greatest negative impact on the structure (global scoring over 3.0) are the incorrect installation of the EPDM membrane, incorrect support of the filling elements and incorrect solutions of details at the connection of the glass-aluminum structure with the masonry or concrete structure. The first two result from assembly errors, the third one results from carelessness or inexperience of the people developing the design.

Table 1. Scoring of the adverse effect of design and assembly errors on the structure of glass mullion-transom facades (*own research*)

Type of error	Frequency of occurrence (0.15)	Effect on structural sta-bility (0.20)	Effect on water tightness (0.20)	Effect on thermal protection (0.20)	Effect on aes-thetics (0.10)	Difficulty in repair (0.15)	Weighted average
Incorrect assembly of the gaskets	4	0	5	3	2	2	2.7
Careless installation of the EPDM membrane	5	0	5	4	0	5	3.3
No verticality of the posts	5	4	0	0	2	5	2.5
Use of inappropriate tools	3	3	0	0	0	2	1.35
Omission of fragments of system strips	2	1	3	1	5	1	1.95
No spacer on the steel-aluminum connection	3	3	0	0	0	5	1.8
Incorrect support of filling elements	4	5	2	3	3	4	3.5
Wrong dimensions of fillings	2	2	2	3	3	2	2.3
Reversing the glass plate arrangement	1	0	0	5	2	2	1.65
Incorrect solutions of details in critical places	4	0	4	4	3	5	3.25
Incorrect static scheme	1	5	0	0	0	4	1.75
IGU drawbacks (leakage)	3	0	0	5	4	2	2.15
IGU drawbacks (dirt)	2	0	0	0	3	2	0.9

Conclusions

Based on the material collected in the study, it can be clearly stated that the main cause of the identified defects are assembly errors. These errors result from careless assembly (gaskets, EPDM membranes, IGUs supports etc.) or omission of system elements. The most common design error is that the details of the connections around the perimeter of the glass facade are not fully developed.

These errors can lead to a partial loss of such properties of the glass curtain wall as: thermal protection of rooms, water tightness and proper structural stability. There are also cases of glass cracks which require replacing, and can be an expensive endeavor, especially at great heights. Eliminating the errors described above will avoid these adverse effects in accordance with the principles of sustainable construction.

The action that should be taken is primarily prevention. Lack of diligence also results from a lack of knowledge and experience. Therefore, employees should be made aware of the consequences of errors made during design and assembly. Assembly procedures must also be enforced by strengthening internal quality control.

Bibliography

Chow, W.K., Hung, W.Y., Gao, Y., Zou, G. & Dong, H. (2007) *Experimental study on smoke movement leading to glass damages in double-skinned façade.* Construction and Building Materials, 21, 556-566.

Gierczak, J. (2013) *Samoistne pękanie elewacji szklanych spowodowane uwolnieniem siarczku niklu.* XXVI Konferencja Naukowo-Techniczna Awarie Budowlane, Szczecin – Międzyzdroje, 20-24 may 2013, 4 p.

Kosieradzka, K., Kozicka, E., Stępniewski, J. & Dmowska, I. (2017) *Fasady metalowo-szklane, Analiza wybranych błędów projektowych i wykonawczych*. Builder, 21, 10, 78-80, (Part 1), 21, 11, 66-69 (Part 2).

Lu, W., Wang, Y., Chen, H., Jiang, L., Duan, Q., Li, M., Wang, Q. & Sun, J. (2018) *Investigation of the thermal response and breakage mechanism of point-supported glass facade under wind load.* Construction and Building Materials, 186, 635-643.

Mika, P. (2011) *Czynniki wpływające na zwiększenie ryzyka wystąpienia naturalnej korozji elementów przeszklonych fasad*. Czasopismo Techniczne. Architektura, 108, 5-A, 129-137.

Pariafsain, F. (2016) *A review of design considerations in glass buildings*. Frontiers of Architectural Research, 5, 171-193.

Pietrzak, A. (2014) *Koncepcja „szklanych domów" w budownictwie energooszczędnym*. Construction of Optimized Energy Potential, 2(14), 60-66.

Respondek, Z. (2019) *Glass building elements – technical aspects of safe usage in the structure*. 7th International Conference System Safety: Human – Technical Facility – Environment, Zakopane, Poland, CzOTO 2019, vol. 1, iss. 1, 291-298.

Sendkowski, J., Tkaczyk, Ł. & Tkaczyk, A. (2011) *Pękanie szklanej fasady kurtyny wodnej*. Świat Szkła, 16, 7/8, 20-25.

Sienkiewicz, R. (2010) *Transparentna architektura – przeszklone fasady aluminiowe.* Świat Szkła, 12(147), 27-30 (Part 1), 1(148)/2011, 16-20 (Part 2).

Urbańska-Galewska, E. & Kowalski, D. (2016) *Układy konstrukcyjne lekkiej obudowy*. Izolacje, 21, 6, 60-68.

Wang, Y., Wang, Z., Xu, K., Shi, Y. & Du, X. (2019) *Experimental and numerical studies on the static and the dynamic behaviors of embedded cable support (ECS) glass facade system*. Engineering Structures, 178, 521-533.