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The influence of the type of frame used in the insulating glass unit on the fire resistance of the glazed partition

Wpływ rodzaju zastosowanej ramki w szybie zespolonej na odporność ogniową przegrody przeszklonej

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Abstract. The aim of the study was to investigate the impact of changing the material from which inter frames of insulating glazed units in fire-resistant partitions are made on the behavior of the entire set in the event of a fire in the light of fire resistance requirements. Two tests on six test specimens filled with insulated glazed units of a similar structure, with the difference being the material of the inter-pane frame and its thickness were carried out. The tests were conducted for frames made of steel, aluminium and plastic. For each material thickness of tested frame was 12 and 18 mm. All of the tested samples maintained their integrity and thermal insulation over the full test distance. The work contains an analysis and comparison of the obtained results. The observations stated that changes in the construction of fire-resistant inter-pane frames of insulated glazed units, if the technical solutions described in the content are used, do not have a significant impact on the test results.

Keywords: fire resistant glazing; glass units; fire resistance; fire insulation; fire integrity; fire safety.

Streszczenie. Celem pracy było zbadanie wpływu zmiany materiału, z jakiego wykonuje się ramki międzyszybowe w przeciwpożarowych szybach zespolonych, na zachowanie całego zestawu w przypadku pożaru w świetle wymagań dotyczących odporności ogniowej. W ramach pracy wykonano 2 badania, w których sprawdzono 6 elementów próbnych wypełnionych szybami zespolonymi o podobnej budowie, różniących się materiałem oraz wymiarami ramki międzyszybowej. Przeprowadzono badanie ramek wykonanych ze stali, aluminium oraz z tworzywa sztucznego. W każdym przypadku sprawdzone zostały ramki o grubości 12 i 18 mm. Wszystkie przebadane próbki zachowały szczelność oraz izolacyjność ogniową w całym cyklu badań. Artykuł zawiera analizę i porównanie uzyskanych wyników. Stwierdzono, że zmiana materiału ramek międzyszybowych w przeciwpożarowych szybach zespolonych nie ma istotnego wpływu na rezultat badań.

Słowa kluczowe: szyby ognioodporne; szyby zespolone; odporność ogniowa; izolacyjność ogniowa; szczelność ogniowa; bezpieczeństwo pożarowe.

In recent years, apart from the somewhat natural progression of the technical solutions used, in response to a significant, progressive increase in requirements for minimum thermal insulation, the segment of insulated fire-resistant glazed units has been changing dynamically. The development needs were increased primarily by rising energy prices and the unstable situation on the raw materials market. Glass manufacturers, forced to look for new solutions, began to implement new ideas and technologies at an accelerated pace.

Modifications in between the panes-space, i. e. the search for the optimal material for making frames used in single- and double-glazed units (and in the future, probably also triple glazed units), became a certain novelty. Testing procedures commonly used in Europe currently only provide minimal assistance to manufacturers in assessing the potential impact of changing the way glass panes are joined on the behavior of elements containing this type of glazing. The lack of clear guidelines makes it necessary to test every possible configuration, significantly increasing the costs incurred by manufacturers to introduce the most popular fire protection products on the market, such as doors, windows or walls, both partitions and facades.

The lack of guidelines regarding the scope of application of test results may be due to the fact that although products of this type have been on the market for some time, knowledge about their behavior in fire conditions is still minimal. The available literature lacks publications directly addressing issues related to the influence of the frame material used in the insulating glass on the behavior of the entire set in which it is mounted. However, there are a number of related publications that contain information on basic knowledge related to fire-resistant glazing. You can find works on research procedures used to determine the fire resistance class of given glazed partitions, their classification and legal regulations related to this type elements, including: [1, 2], as well as publications describing the types of glass used in fire partitions, including:

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[3, 4]. There are also a number of articles [6 – 18] devoted to the behavior of glazing in fire conditions. Most of them focus on external partitions glazing filling. In case of fire, glazing fillings in facades may crack and fall out very easily under due to fire. The inlet of fresh air resulting from the cracking of the glazings and the ejection of flames outside accelerate the development of the fire both inside and outside the building. The thermal behavior of the glazed façade is therefore of great importance for the spread of fire, especially in tall and high-rise buildings. One of the oldest publications emphasizing the great role of glass behavior in fire conditions and its cracking under the influence of temperature was developed in 1986 [5]. In the following years, many different tests were carried out to investigate the mechanism of glass damage as a result of high temperature and the consequences associated with this damage [6 – 18]. For example, in [15] a theoretical critical temperature difference of 80°C was determined. Publication [14] presents test results for float glass and glass reinforced with wire mesh. The authors of publications [12, 13] conducted full-scale experiments in a specially constructed room to investigate the difference in the behavior of a single glazing in the case of different locations of the fire source. As part of the works [10, 11], special software was developed to predict the breakage time of single glass pane in fire conditions. Based on these works, it was determined that exceeding the internal thermal stress caused by the temperature gradient is the main cause of cracks in heated glazing. In publication [8], experimental data were used to verify thermomechanical and heat transfer models made using the ABAQUS software. Two tests were carried out on laminated glazing heated until cracking. In both cases, the source of the fire was a square pool with dimensions of 500 × 500 mm, fueled with N-heptane, with different amounts of this fuel used in the experiments. Heat transfer models developed by computer software were verified based on the recorded temperature on the unexposed glazing surface. In work [6], the behavior of nine different monolithic and laminated glazed units heated by radiation generated by a special heating panel was verified. The publication [18] concerned what happens after the glass breaks and what risk it entails for people evacuating from a given facility and for the rescue teams. Works related to the behavior of glass under fire conditions also include publications [19 – 22], the aim of which was to verify the behavior of glass exposed to both fire and water used to extinguish it, coming from the sprinkler system. As already mentioned, the available literature lacks studies describing the impact of the construction and materials used in insulating glazed units on the fire resistance of the partition. Therefore, as part of this study, 6 test elements were tested with insulating glazed fillings of similar structure with the difference being the material and size of the inter-pane frame, described in detail later in the study.

Materials and methods

As part of the work, fire resistance tests were carried out on 6 test specimens of unopenable windows with 3 different types of frames between fire-resistant glass panes of declared fire resistance class EI 30 and VSG 44.2 laminated glass pane. Steel, aluminum and plastic frames were used. For each case, a configuration with a frame thickness of 12 mm and 18 mm was tested. The glazing was mounted in aluminum profiles, creating partitions with external dimensions of 1,200 x 3,000 mm. All of the test specimens were installed in such a way that the VSG glass was on the heated side.

The view of test specimens before the test is shown in Photo 1.

Photo. 1. Heated surface of the test pieces prior to fire resistance testing: a) double-glazed units with a 12 mm frame; b) double-glazed units with an 18 mm frame

Fot. 1. Nagrzewana powierzchnia elementów próbnych przed badaniem odporności ogniowej: a) szyby zespolone z ramką 12 mm; b) szyby zespolone z ramką 18 mm

The test specimens were heated in a test furnace according to the standard temperature-time curve defined by formula (1), reflecting a fully developed fire inside the building. The heating graph is shown in Fig. 1.

$$T = 345 \log_{10}(8t + 1) + 20 \qquad (1)$$

where:

T – average temperature in the furnace, in Celsius degrees,

t – time in minutes.

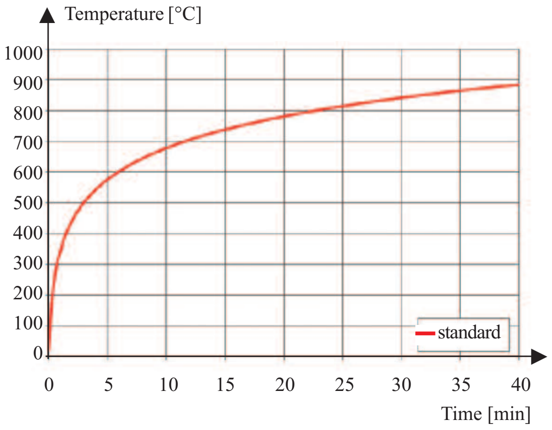
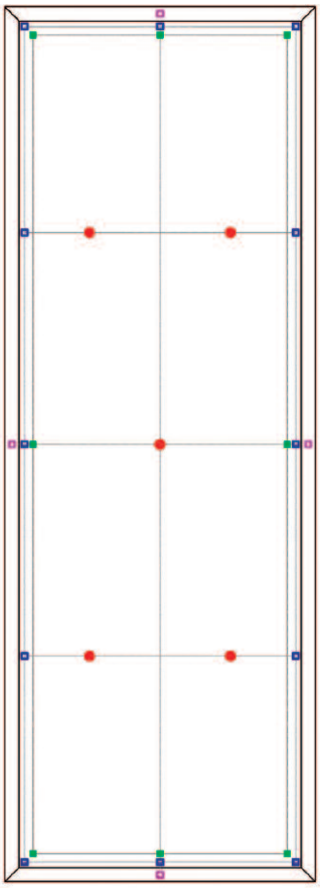


Fig. 1. Diagram of the heating of the test elements

Rys. 1. Wykres nagrzewania elementów próbnych

During the test, the integrity and temperature rise in various places of the unexposed surface and inside the test specimens were verified. Integrity was verified visually and using a cotton pad and gap gauges. Loss of integrity performance criteria occurs when a flame lasting longer than 10 seconds appears on the unheated surface, when a cotton pad placed on the surface of the test element ignites, and when it is possible to penetrate the test element point-wise with a gap gauge diameter of 25 mm or penetrate it over a length of more than 100 mm with a gap gauge diameter of 6 mm. The places of temperature measurement are shown in Fig. 2. Photos 2 and 3 show a view of the unexposed surfaces of the test specimens during the test.



□ termoelementy do pomiaru przyrostu temperatury maksymalnej – 20 mm od krawędzi profilu

■ termoelementy do pomiaru przyrostu temperatury maksymalnej – 50 mm od krawędzi profilu

● termoelementy do pomiaru przyrostu temperatury średniej i maksymalnej – na przeszkleniu

▫ termoelementy do pomiaru przyrostu temperatury maksymalnej w 3 miejscach:
- na profilu 30 mm od krawędzi profilu
- na listwie przyszybowej, prostopadle do przeszklenia
- na ramce szyby zespolonej pomiędzy szybą zespoloną i ogniową

Fig. 2. Arrangement of measurement points according to the length of insulation used
Rys. 2. Rozmieszczenie punktów pomiarowych w zależności od długości zastosowanej izolacji

Photo 2. Double glazing with 12 mm frame
Fot. 2. Szyby zespolone z ramką 12 mm

Photo 3. Double glazing with 18 mm frame
Fot. 3. Szyby zespolone z ramką 18 mm

Research results and their analysis

All test specimens maintained their integrity and inslution throughout the entire 40-minute test. Fig. 3 shows graphs of average temperature rices for each measurement location (glazing surface, 100 mm from the profile edge, 20 mm from the profile edge and frame profiles). Fig. 4 shows the average temperature rices measured inside the test element, on the glazing frame. Table shows the values of the average temperature rices in a given measurement place in the 30th minute of the test (fire resistance time declared for the fire glass). Analyzing the results presented in the previous chapter, it can be noticed that the impact of the used glazing frame in the glazed unit on the integrity and insulation of the partition in which the glazed unit is installed is small for the case of the solutions used in the tests. And most common ones on the market examples were tested. In the case of a 12 mm thick frame and thermocouples placed on the glazing, in the 30th minute of the test the lowest temperatures were recorded on the unexposed surface of the glazed unit with a steel frame, however, for the same frame the highest temperature was achieved on the profile. In the case of an 18 mm thick frame, the temperature on the profile of the partition with the glazed unit with the steel frame was the lowest. The lowest temperature on the glazing surface during the discussed test period was achieved in the case of the aluminum frame, and the highest – in the case of the steel frame. At a distance of 20 mm and 100 mm from the edge of the glazing, the lowest temperature in the case of an 18 mm frame was recorded for the glass unit with a plastic frame, and the highest for the aluminum frame. In the case of both frame thicknesses, the differences between the minimum and maximum temperature values recorded on the unexposed surface of the test elements were small and amounted to a maximum of 13.8 °C for a 12 mm frame and a measurement of 100 mm from the edge of the glazing. It can also be noticed that for each case, increasing the frame thickness increases the temperature on the unexposed surface of the outer frame profiles of the test element. The symmetrical arrangement of the glazed unit in the profile means that increasing the width of the frame increases the area in which the profile is heated after the non – fire rated glazing falls out, which consequently leads to a higher temperature on the unexposed surface of the test elements. In the case of measurement carried out inside, the highest temperature was recorded on the aluminum frame and the lowest on the plastic frame.

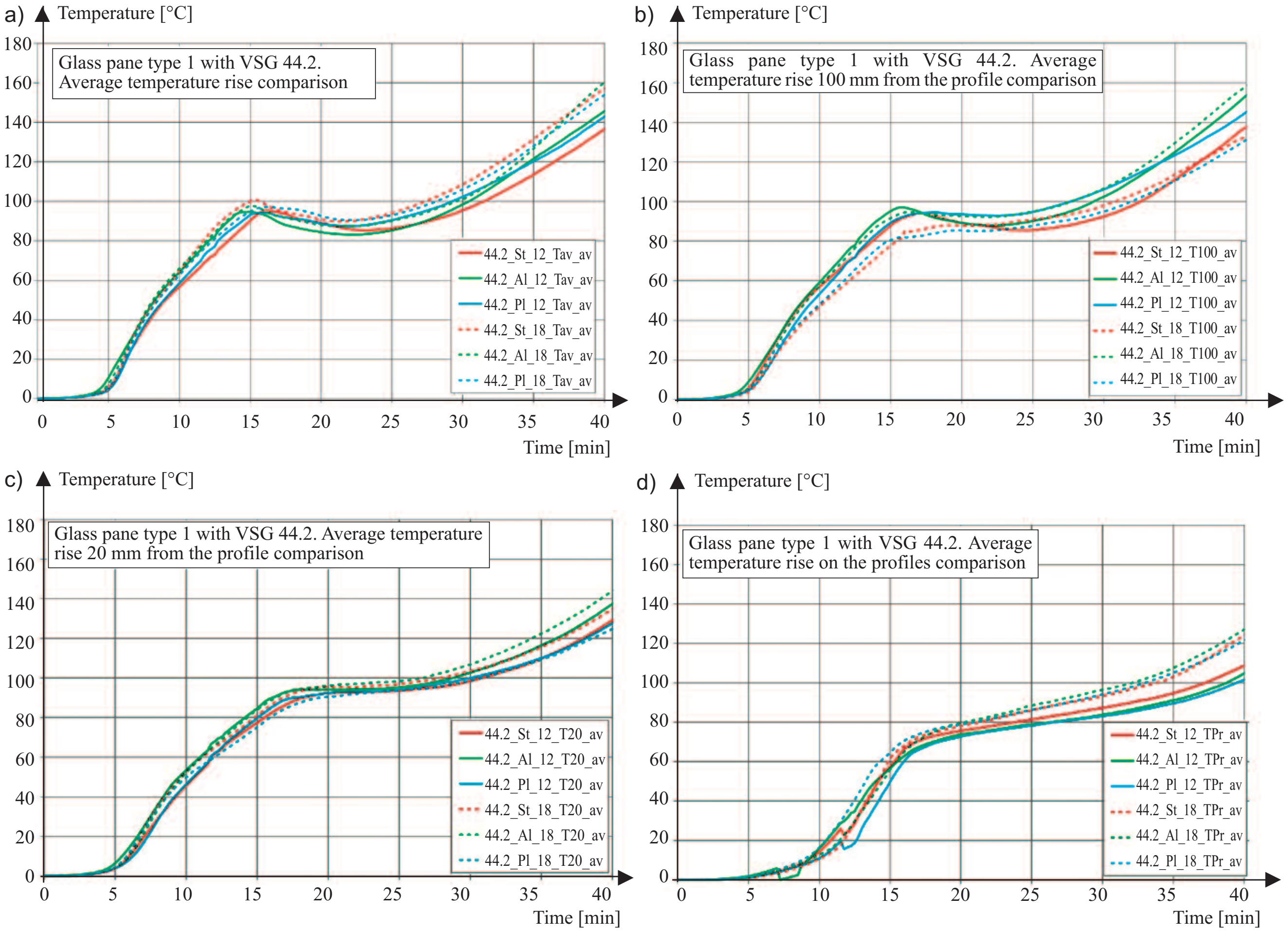


Fig. 3. Average temperature rise on the unheated surface of the test pieces: a) test piece surface; b) 100 mm from profile edge; c) 20 mm from profile edge; d) profiles St – steel frame, Al – aluminum frame, Pl – plastic frame, 12 – 12 mm thick frame, 18 – 18 mm thick frame
Rys. 3. Średni przyrost temperatury na nienagrzewanej powierzchni elementów próbnych: a) powierzchnia elementu próbnego; b) 100 mm od krawędzi profilu; c) 20 mm od krawędzi profilu; d) profile St – ramka stalowa, Al – ramka aluminiowa, Pl – ramka tworzywowa, 12 – ramka o grubości 12 mm, 18 – ramka o grubości 18 mm

Conclusions

Presented in point 3 results indicate that during a 30-minute fire resistance test of partitions with insulated glazed units, the material from which the interpane frame is made is not crucial for the structure performance. Moreover, if we assume that the set of materials selected for comparison is representative of the full range of solutions used on the market, it turns out that the worst case is the aluminum frame – the material with the highest thermal conductivity coefficient among the analyzed solutions. If such a thesis could be confirmed in subsequent studies, it would be a valuable observation in terms of the practical application of the analysis results. However, it should be remembered that the considerations concern only the scope of fire-resistant glass and one type of plastic frame. At this stage, the above reasoning cannot be transferred to the field of insulated glazed units without a specific fire resistance class or to plastic frames made of a material other than the one tested.

In terms of metal frames, based on the results obtained, it can be assumed that obtaining a positive result in testing a structure with insulated glazing with an aluminum frame means that a structure with a similar structure with the only difference being the replacement of the frame material with steel should also maintain the expected fire resitance class in fire test.

The obtained results also indicate a significant influence of the thickness of the frame used on the temperature of the unexposed surface of the frame of the tested elements. Increasing the frame thickness due to the phenomena described in point 4 leads to temperature increases on the profiles, which may have key importance in the case of higher fire resistance classes, where the temperature increase on the profiles is often close to exceed the criteria value.

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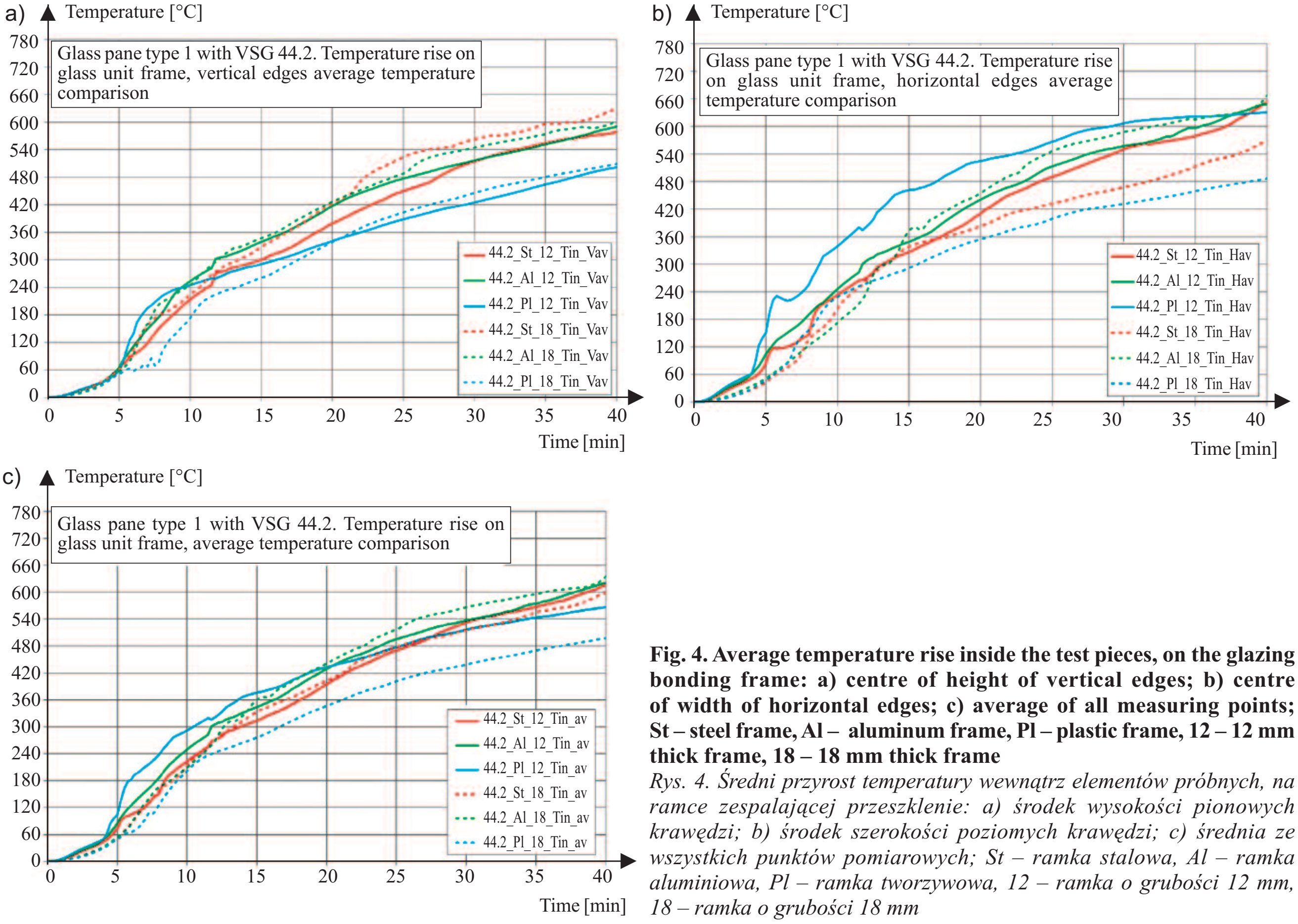

Fig. 4. Average temperature rise inside the test pieces, on the glazing bonding frame: a) centre of height of vertical edges; b) centre of width of horizontal edges; c) average of all measuring points; St – steel frame, Al – aluminum frame, Pl – plastic frame, 12 – 12 mm thick frame, 18 – 18 mm thick frame

Rys. 4. Średni przyrost temperatury wewnątrz elementów próbnych, na ramce zespalającej przeszklenie: a) środek wysokości pionowych krawędzi; b) środek szerokości poziomych krawędzi; c) średnia ze wszystkich punktów pomiarowych; St – ramka stalowa, Al – ramka aluminiowa, Pl – ramka tworzywowa, 12 – ramka o grubości 12 mm, 18 – ramka o grubości 18 mm

The average temperature rise at a given measuring point in the 30th minute of the test

Średni przyrost temperatury w danym miejscu pomiarowym w 30. minucie badania

Measuring place	Average temperature rices in the 30th minute of the test, depending on the frame used [°]					
	steel 12 mm	aluminum 12 mm	plastic 12 mm	steel 18 mm	aluminum 18 mm	plastic 18 mm
Glazing surface	95,6	98,4	102.3	108,6	101,0	106,1
100 mm from the frame profile edge	92,4	102,5	106,2	98,1	106,6	95,0
20 mm from the frame profile edge	98,5	102,7	100,0	103,4	106,8	98,6
Profile	87,2	83,8	83,1	93,3	96,4	94,0
Frame	532,5	536,8	516,2	515,5	566,2	438,7

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