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Research paper

Fire reliability of system aluminum-glass partitions

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Abstract: Aluminum-glass partition systems are used as building facades but also as glazed internal walls designated to form various internal partitions with glass doors. These partitions are designated to create fire compartments as well as separate and soundproof the zones created, without visually limiting the built up area. System fireproof partitions manufactured in fire resistance classes *EI* 30 to *EI* 180 constitute an important product in the offer of domestic and foreign manufacturers in terms of fire safety. The internal and external fireproof partitions are generally designed conformant to deterministic criteria, i.e. the structure of the partition is determined by the formal requirements listed in the legal regulations pertaining to basic requirements which should be satisfied by buildings and their parts. The fireproofing qualities of system aluminum-glass partitions are controlled in laboratories and documented in technical approvals. Partitions designed according to the deterministic criteria may be verified by the fire reliability analysis of the designed structure using the known simple and complex models of the reliability theory. In this paper the reliability formulae for simple and mixed mathematical models of non-renewable objects, which have been applied to model the fire reliability of partitions made by Aluprof, a domestic maker of aluminum-glass systems, under catalog numbers MB-78EI and MB-118EI, have been juxtaposed. The results of calculations allowed for preparing design recommendations, verifying the deterministic criteria for design of fire resistant partitions. In particular the fire reliability analysis prompts for abandoning the design of expensive aluminum-glass partitions made of multi-layered glass having multiple fire resistant layers.

Keywords: glass, aluminum, partitions, reliability, fire, fire resistance

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1. Introduction

Fire retardant properties of building components made of glass and aluminum profiles describe their capability to interrupt the fire spread by containing it within separated compartments. The fire resistance of glass building components is measured according to various criteria, in particular the requirements pertain to: stability R (glass does not break), tightness E, restricting radiation W, and insulation I. The tightness requirement E means, that the partition effectively protects the fire compartment against flame, smoke and hot gases. The insulation requirement I denotes that the average temperature measured on the glass surface of a partition on the protected side does not exceed the prescribed value during nominal duration of fire. The fire resistance of a partition is expressed as the time t measured in minutes, during which the structure of an aluminum-glass partition satisfies one or several of the criteria listed above.

The system fire protection walls are used to create internal or external fire protection partitions conforming to fire resistance class *EI* 30 to *EI* 120.

The sample systems: MB-78EI [2] and MB-118 EI [3] according to the catalogue [1] of the largest domestic maker, cf. Fig. 1, are classified as non-spreading fire. Both systems are based on common components such as layered tempered glass, glazing beads, cooling insets, expanding tapes, gaskets and most of accessories. They differ in the number of glass panes in the glazing package, dimensions of the mounting profiles and thickness of the insulating insets in the profiles.

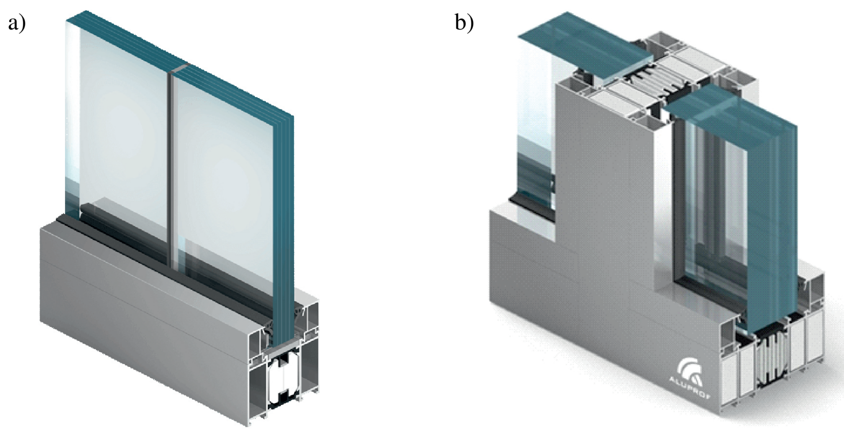

Fig. 1. Structure of the fire barrier: a) system MB-78EI b) system MB-118EI. Source [1]

Fire resistant glass in the system partitions is a multi-layered glass, in which float glass panes are interleaved with intermediate layers, made of gel substrate exhibiting high thermal expansion when affected by high temperature. In the fire development phase, at the temperature of 120°C, these layers expand creating a hard opaque layer constituting temporary protection against fire.

Fire tests of system partitions MB-78EI and MB-118 EI, conducted by Instytut Techniki Budowlanej (Building Research Institute) (ITB) within the framework of documenting the Technical Approval AT-15-6006/2016 [2] and AT-15-9186/2013 [3], covered the partition models with vertical profiles and doors, cf. Fig. 2, as well as a model with free edge, therefore no limit is placed on the maximum length of partitions of this type.

Fig. 2. Aluprof MB-78EI system partition fire resistance laboratory tests

Of three standard curves [11] depicted by continuous lines in Fig. 3, the ISO standard fire curve has been applied during laboratory tests for fire approvals conducted by ITB:

$$\theta_g = 20 + 345 \log_{10}(8t + 1) \tag{1.1}$$

where: θ_g – fire plume temperature in the fire chamber [°C], t – heating time [min].

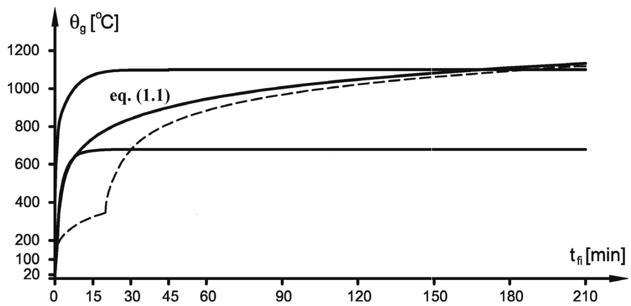

Fig. 3. Standard fire curves (continuous curves) according to PN-EN 1991-1-2 [20]

The fire resistance EI declared by the makers of aluminum-glass partitions (including systems made by Aluprof SA) corresponds to the gas temperature in the test chamber listed in the Table 1.

During standard experimental tests of the models, in early heating phases one may safely touch the glass surface on the protected side, while the internal glass surface may be subjected to the action of flame and gases having temperatures in excess of 1000°C, cf. Table 1. The laboratory tests performed by ITB resulted in experimentally confirmed fire resistance of

Table 1. Gas temperature in the test chamber reached during fire resistance tests of partitions

EI 15	*EI* 30	*EI* 45	*EI* 60	*EI* 90	*EI* 120
gas temperature in the test chamber θ_g [°C]					
739	842	902	945	1006	1049

system partitions, expressed in time t [minutes] warranted by the manufacturer, during which the partitions prevent smoke pollution of protected compartments and propagation of fire.

The requirements pertaining to fire spread prevention and fire resistance mean, that during fire test of the partition under scrutiny the following conditions are satisfied:

– the glazing will not crack under its own weight,
– the partition will remain tight and no gases or fire will penetrate outside,
– the glazing, during the whole test, will effectively cut off the fire, i.e. on the outside of the tested partition the test cotton swab may not ignite nor start to glow,
– the increase of temperature on the unheated side of the glass at the end of fire test may not exceed 140°C, and only locally may reach 180°C.

The simplest, in the structural sense, partitions which may be used to subdivide fire compartments in the public services buildings, are the so called mullion free walls filled with multi-layered fireproof glass according to Fig. 4. System partitions allow for erection of in-

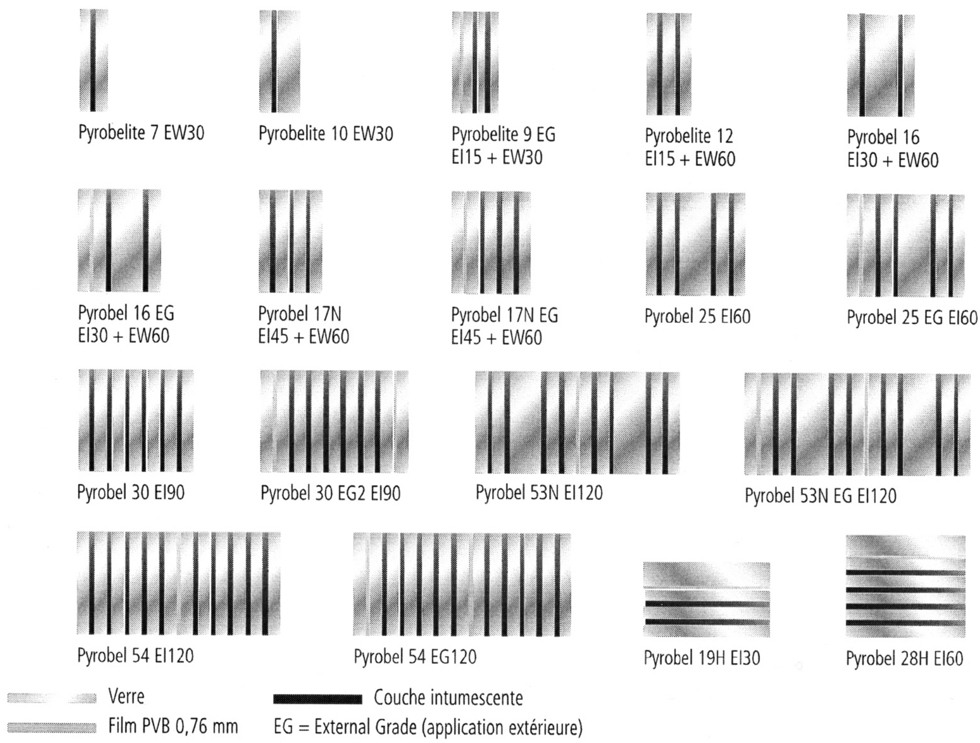

Fig. 4. Multi-layered fire protecting glass panes of the Pyrobel type. Source [5]

ternal partition walls devoid of visible vertical profiles separating individual glazing sections. The distance between panes of layered fireproof glass is only 4 mm thick and is filled with fire protecting expanding material and incombustible silicon. The fire resistant partitions erected this way may exhibit varying fir resistance (cf. Fig. 4), depending on the number of expanding layers in the glazing panel. The dimensions of such partitions may reach 3.6 m in height, without limitations on length and width of repeating modules up to 1.5 m wide.

2. Reliability of aluminium-glass partitions

2.1. Mathematical models of non-renewable objects

The simplest non-renewable object considered in the theory of reliability (cf. papers [4, 6, 10, 18, 22]), for instance fire protecting glass, is characterized by two mutually exclusive random states: state of fitness, when it does satisfy the stated requirements *EI*, and state of unfitness, when it does not satisfy these requirements. Fit is synonymous with in order, while unfit is synonymous with out of order. The time t passing between fire flashover and failure of fire protecting layer in the glass partition is the proper operation time of the analyzed object. The time T is a random variable having the probability distribution depending on insulation properties of the partition, fire intensity and established set of fitness properties E, I, W. When modeling the reliability of an aluminum-glass partition $Q(t)$ one may assume, that at the beginning of fire the object is fit, i.e. $Q(t = 0) = 1$, and service conditions during fire are predetermined, cf. Table 1. The reliability function $Q(t)$ also known as the survival function constitutes the basic characteristic of partition reliability. This function describes the decreasing reliability of the partition (cf. the piecewise linear line in Fig. 5), with passing time of fire exposure, and at the same time depicts the probability of fitness of the non-renewable object, at least until time t, counting from fire flashover.

(2.1) $$Q(t) = P\{T \geq t\} = 1 - P\{T < t\} = 1 - F(t)$$

Function $F(t)$ in the formula (2.1) is a probability distribution function of partition fire resistance, depicted in Fig. 5a with continuous line:

(2.2) $$F(t) = P\{T < t\} = 1 - Q(t)$$

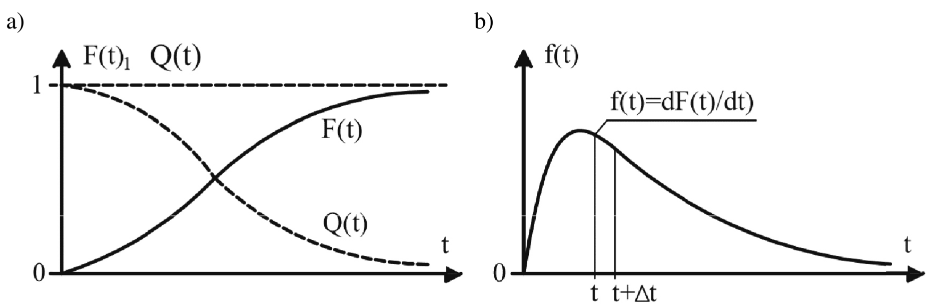

Fig. 5. a) Distribution function $F(t)$ and b) probability density $f(t)$ of random durability

where $q(t)$ denotes object unreliability function. In the theory and engineering practice of reliability, cf. works [17] and [18], it is assumed, that the damage intensity function $h(t)$ characterizes in the best way the changes in reliability of any technical object. The reliability function $Q(t)$, the unreliability function $F(t)$ and the probability density function of durability $f(t)$ may be expressed using this function:

$$Q(t) = \exp\left[-\int_0^t h(x)\,\mathrm{d}x\right] \tag{2.3}$$

$$F(t) = 1 - \exp\left[-\int_0^t h(x)\,\mathrm{d}x\right] \tag{2.4}$$

$$f(t) = \frac{\mathrm{d}F(t)}{\mathrm{d}t} = h(t)\exp\left[-\int_0^t h(x)\,\mathrm{d}x\right] \tag{2.5}$$

Dividing the equation (2.5) by (2.3) one obtains the formula for damage intensity:

$$h(t) = \frac{f(t)}{Q(t)} \tag{2.6}$$

In many technically important cases the experimental sequences of $h(t)$ may be approximated with analytical functions. This allows for direct application of formulae (2.3)÷(2.5) and simplifies the reliability analysis of an object. The statistical analyses of experimental functions $h(t)$ for aluminum-glass partitions are not known, thus theoretical distributions of probability such as exponential, normal or Weibull may be applied to describe the course of this function in the reliability analyses of such partitions. The simplest probabilistic model of the lifetime of a non-renewable object is a random variable T, the damage intensity of which is constant, i.e. does not depend on time: $h(t) = \text{const}$. In such case the formulae (2.3) and (2.4) yield the reliability and unreliability functions as follows:

$$Q(t) = \exp(-ht) \tag{2.7}$$

$$F(t) = 1 - \exp(-ht) \tag{2.8}$$

Formula (2.8) describes the distribution function of the exponential distribution with the following parameters: expected time of fitness $\bar{t} = h^{-1}$ and variance $\mu_t^2 = h^{-2}$. The exponential distribution may be used to calibrate the damage intensity h of a simple fire resistant partition, consisting of a single expanding layer located between two glass panes. Estimating the expected minimum fire resistance time needed to evacuate people at $\bar{t} = 20$ minutes, one obtains $h = 1/20 = 0.05$ [1/min]. The same value of $h = 0.05$ may be assumed for a single fire protecting insert in an aluminum profile according to Fig. 1a.

The Weibull distribution represents a generalization of the exponential distribution, and allows for reliability analyses of systems exhibiting monotonously changing destruction intensity:

$$h(t) = \alpha \cdot \beta \cdot t^{(\alpha-1)} \tag{2.9}$$

where: $\alpha > 0$ – shape parameter of the distribution curve, $\beta > 0$ – scale parameter.

By entering (2.9) into formulae (2.3) and (2.4) one obtains the reliability and unreliability functions for the Weibull distribution as follows:

$$Q(t) = \exp\left(-\beta \cdot t^{\alpha}\right), \qquad t \geq 0 \tag{2.10}$$

$$F(t) = 1 - \exp\left(-\beta \cdot t^{\alpha}\right) \tag{2.11}$$

The destruction intensity function $h(t)$ may be increasing (for $\alpha > 1$), decreasing (for $\alpha < 1$), or constant when $\alpha = 1$ (then $h = \beta$ and equations (2.10) and (2.11) are reduced to the form (2.7) and (2.8)).

2.2. Reliability of simple systems

In the systems reliability theory the objects exhibiting: parallel, serial, serial–parallel and serial parallel reliability structure are called simple. In the fifties of the previous century it has been shown that sufficiently reliable objects may be made of simpler unreliable components. Reliable objects at the assumed level of durability probability are constructed by proper combination of constituting components. This paper presents probabilistic analysis of fire reliability for system glass and aluminum-glass partitions using systems reliability theory solutions limited to reliability of simple objects. While modeling partitions varying in internal structure, to simplify the function notation, a notation system omitting function argument has been applied, i.e. $Q(t) = Q$ and $F(t) = F$.

An object exhibiting serial structure is characterized by block diagram depicted in Fig. 6a. A chain under tension, made of $i = 1, 2, \ldots, n$ links, each of which is fit, i.e. is characterized by the durability T_i or alternatively reliability Q_i, may be considered as an example of such object. The reliability Q_s of an object exhibiting such structure, in the case when the damages of n constituting components are mutually independent, is expressed by the formula:

$$Q_s = Q_1 \cdot Q_2 \cdot \ldots Q_i \cdot \ldots Q_n = \prod_{i=1}^{n} Q_i \tag{2.12}$$

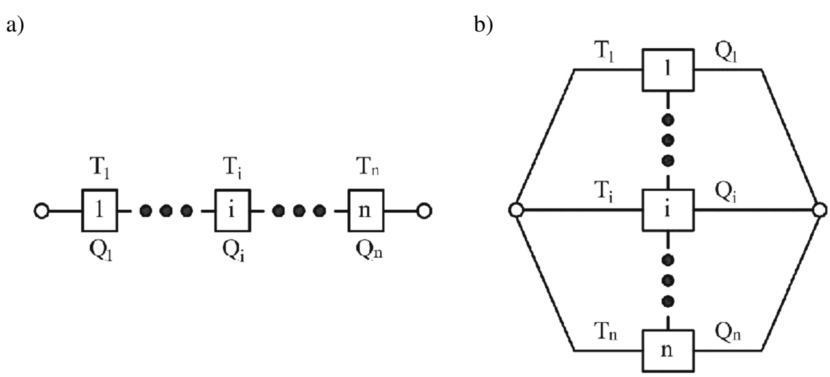

Fig. 6. Block diagrams of simple reliability systems: a) serial, b) parallel

In the special case of an object made of components exhibiting identical reliability, the following holds:

$$Q_1 = Q_2 = \ldots = Q \quad \rightarrow \quad Q_s = Q^n \tag{2.13}$$

An object exhibiting serial structure may be alternatively characterized in terms of durability T_s:

$$T_s = \min\,(T_1, T_2, \ldots T_i, \ldots T_n) = \min\,(T_n) \tag{2.14}$$

or alternatively unreliability F_s

$$F_s = 1 - Q_s = 1 - \prod_{i=1}^{n} Q_i \tag{2.15}$$

A glass-aluminum partition having the structure depicted in Fig. 1b, in the case of glazing with panes with single fireproofing layer (cf. Pyrobelit 7 glass pane in Fig. 4), and single chamber fire insulation in the aluminum profiles (cf. Fig. 1a) may be considered as an example of object exhibiting serial structure. Assuming the reliability level required by the building codes [19, 21], $p_k = 0.95$ for each of $n = 2$ partition components, formula (2.13) yields $Q_s = 0.95^2 = 0.9025 < 0.95$, and thus the partition as whole does not conform to the reliability requirements as stated in the code PN-EN 1990. In order to satisfy those requirements one should increase the reliability of partition components to the level of $p_k = 0.95^{0.5} = 0.975$, which is not rational due to the increase in investment costs. The rational solution lies in the changed partition structure (structure of elements) at unchanged standard requirements pertaining to the insulation reliability of aluminum profiles and glass.

An object exhibiting parallel structure is characterized by block diagram depicted in Fig. 6b. A simple partition made of multi-layered fireproofing glass (cf. Pyrobelit 12, Pyrobel 16, Pyrobel 30 and other glass panes in Fig. 4) may be considered as an example of such object. The reliability Q_r of an object exhibiting parallel structure, in the case when the damages of n constituting components are mutually independent, is expressed by the formula:

$$Q_r = 1 - \prod_{i=1}^{n} (1 - Q_i) \tag{2.16}$$

In the special case of a homogeneous object formula (2.16) yields:

$$Q_r = 1 - (1 - Q)^n \tag{2.17}$$

An object exhibiting parallel structure may be alternatively defined in terms of durability T_r:

$$T_r = \max\,(T_1, T_2, \ldots T_i, \ldots T_n) = \max\,(T_i) \tag{2.18}$$

or alternatively unreliability F_r

$$F_r = \prod_{i=1}^{n} F_i \tag{2.19}$$

Transforming the formula (2.17) one may determine the minimum required reliability Q of homogeneous elements for a given normalized reliability of an object Q_r

$$Q = 1 - \sqrt[n]{(1 - Q_r)} \tag{2.20}$$

Assuming the reliability of a set of n expanding layers in a glazing pane according to Fig. 4, at the level recommended by the code PN-EN 1990, i.e. $Q_r = 0.95$, the required minimum reliability values of each single layer calculated according to formula (2.20) have been listed in the Table 2. The results of calculations confirm the fact well known in the systems reliability theory, that the reliability of a system exhibiting parallel structure increases with increasing number of components. When related to modeling the reliability of glass partitions, the results listed in Table 2 indicate, that in multi-layered structures the reliability requirements towards single layers may be substantially lowered without compromising fire reliability of the whole object, but this is not applied by the glass industry. In particular, with four layers the reliability requirements may be theoretically lowered to median level (durability at the level of probability $p = 0.5$), and with three layers to extreme characteristic value of the distribution (2.10) (durability at the level of probability $p = 1 - e^{-1} = 0.632$).

Table 2. Minimum value of reliability Q in a homogeneous n – element object

n	2	3	4	5	6	8	10
Q	0.776	0.631	0.527	0.451	0.393	0.312	0.259

An object exhibiting serial–parallel structure is characterized by block diagram depicted in Fig. 7a. A system mullion free partition made of n adjacent fireproof glazing panes (Fig. 1a), repeating m times, with aluminum profiles hidden in the floor and ceiling may be considered as an example of such object. The reliability Q_{sr} of an object exhibiting serial–parallel structure and consisting of n sets, each with m components joined in parallel (characterized by reliability Q_{ij} of any i-th element in a j-th set), is expressed by the formula:

$$Q_{sr} = \prod_{j=1}^{n} \left[1 - \prod_{i=1}^{m} \left(1 - Q_{ij} \right) \right] \tag{2.21}$$

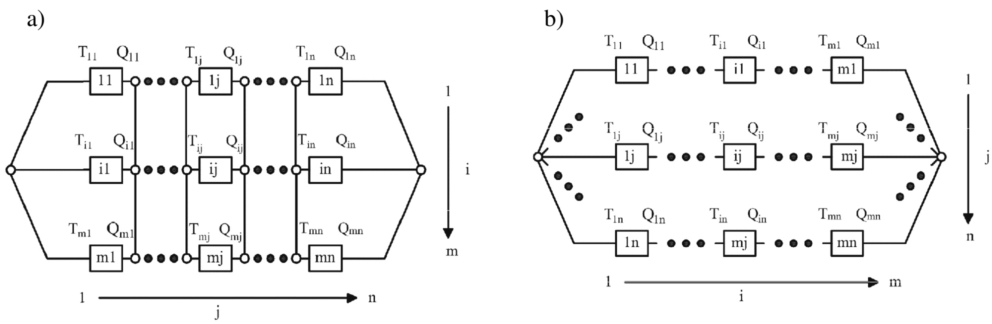

Fig. 7. Block diagrams of mixed reliability systems: a) serial–parallel, b) serial–parallel

In particular case of homogeneous and regular object, formula (2.21) yields:

$$Q_{sr} = [1 - (1 - Q)^m]^n \tag{2.22}$$

Transforming the formula (2.22) one may determine the minimum required reliability Q of homogeneous elements for given normalized reliability of an object Q_{sr}

$$Q = 1 - \sqrt[m]{1 - Q_{sr}^{1/n}} \tag{2.23}$$

The alternative formula for fitness of an object exhibiting serial–parallel structure, expressed in terms of durability is T_{sr} min[max(T_{ij})], where maxima are determined over index i, and minima over index j.

For a system single floor mullion free partition, having the length of $1.5n$ [m] and fireproof glazing panes according to Fig. 4, consisting of m – expanding layers, the minimum reliability requirements for each layer computed according to formula (2.23) at the level recommended by the code PN-EN 1990, i.e. $Q_{sr} = 0.95$ are listed in the Table 3. The obtained results indicate, that the required minimum reliability of a single fireproof layer increases with increasing partition length ($1.5n$ [m]), and at the same time decreases with the number of layers m in the glazing pane. For long partitions $L > 25$ m and low number of the expanding layers, the reliability requirements for single layer may exceed the reliability of the whole system, this means that for large layouts multi-layered glazing panes should be recommended, exhibiting the reliability of a single layer $Q < Q_{sr}$. Multi-layered panes (for $m > 5$), in terms of the results listed in the Table 3 are not a proper solution, as the reliability of the fire proof layers is in general not utilized (the results in bold type).

Table 3. Minimum reliability value Q of fireproof layers in partitions exhibiting serial–parallel structure

n	2	3	4	5	10	20	30	40
m	Q							
2	0.841	0.870	0.887	0.899	0.928	0.949	0.959	0.964
3	0.706	0.743	0.766	0.783	0.827	0.863	0.880	0.891
4	**0.601**	0.639	0.664	0.682	0.733	0.775	0.797	0.811
5	**0.521**	**0.558**	**0.582**	**0.600**	0.652	0.697	0.720	0.736
6	**0.459**	**0.494**	**0.515**	**0.535**	**0.586**	**0.631**	0.655	0.671
8	**0.368**	**0.399**	**0.420**	**0.436**	**0.483**	**0.526**	**0.549**	**0.565**
10	**0.308**	**0.335**	**0.354**	**0.368**	**0.410**	**0.449**	**0.471**	**0.486**

Model of an object exhibiting serial–parallel structure may be applied to evaluate the reliability of system column-beam partitions having the structure depicted in Fig. 1b. One should then apply the formula (2.21), which takes into account different reliability values Q_{ij} of partition components. The links of parallel chain, counting $n = n_1 + n_2$ elements, are made of n_1 single glass plates having repetitive reliability Q_I and n_2 single aluminum profiles having reliability Q_{II}. The reliability of the whole system then equals:

$$Q_{sr} = Q_I^{n_1} \cdot Q_{II}^{n_2} \tag{2.24}$$

where

$$Q_I = 1 - (1 - Q_{11})(1 - Q_{21}) \dots (1 - Q_{m1}) \tag{2.25}$$

$$Q_{II} = 1 - (1 - Q_{12})(1 - Q_{22}) \dots (1 - Q_{m2}) \tag{2.26}$$

In the case of system single floor partition consisting of n_1 glass panes, the number of aluminum profiles equals $n_2 = 3n_1 + 1$. In addition the number of fireproof layers in the glass panes equals: $m - \{2, 3, 4, 5, 6, 8, 10\}$, and the number of insulated chambers in aluminum profiles $m^* - \{1, 3, 5\}$. Assuming for instance: $n_1 = 2$, $m = 3$ and $m^* = 1$, the reliability of fireproofing layers $Q_{11} = Q_{21} = Q_{31} = 0.5Q$, and the reliability of insulation in the profile chamber $Q_{12} = Q$, using formulae (2.25), (2.26) and (2.24) one may determine in a sequence:

$$Q_I = 1 - (1 - 0.5Q)(1 - 0.5Q)(1 - 0.5Q) = 1.5Q - 0.75Q^2 + 0.125Q^3 \tag{2.27}$$

$$Q_{II} = 1 - (1 - Q) = Q \tag{2.28}$$

$$Q_{sr} = Q_I^2 \cdot Q_{II}^7 = \left(1.5Q - 0.75Q^2 + 0.125Q^3\right)^2 Q^7 \tag{2.29}$$

For a sample reliability of a single system element $Q = 0.9$, using formula (2.29) one may determine the reliability of the partition $Q_{sr} = 0,332$, thus the reliability of the whole partition is lower than the reliability of a single system component.

An object exhibiting serial–parallel structure is characterized by block diagram depicted in Fig. 7b, and the reliability Q_{rs} of such object, composed of n serial sets each consisting of m elements connected in series is expressed by the formula:

$$Q_{rs} = 1 - \prod_{j=1}^{n} \left[1 - \prod_{i=1}^{m} \left(1 - Q_{ij}\right)\right] \tag{2.30}$$

When the object is regular and homogeneous, i.e. is made of identical number of elements in each set, then its reliability is simplified to the following:

$$Q_{rs} = 1 - (1 - Q^m)^n \tag{2.31}$$

By transformation of the formula (2.31) one may determine the required minimum reliability Q of homogeneous elements for given normalized reliability of an object Q_{sr}

$$Q = \sqrt[m]{1 - (1 - Q_{rs})^{1/n}} \tag{2.32}$$

The alternative formula for fitness of an object exhibiting serial–parallel structure, expressed in terms of durability is $T_{rs} \max[\min(T_{ij})]$, where maxima are determined over index j, and minima over index i. The calculated minimum values of single element reliability Q, needed to obtain the reliability level of the whole system $Q_{rs} = 0.95$, calculated according to the formula (2.32) for a homogeneous object exhibiting serial–parallel structure have been listed in the Table 4.

Model of an object exhibiting serial–parallel structure may be used to model parallel aluminum-glass partitions, used to separate single aisle fire zones, for instance in communication routes. Number n then denotes the number of single partition components, and the number

Table 4. Minimum reliability value Q of components in an object exhibiting serial–parallel structure

n	2	3	4	5	10	20	30	40
m	Q							
2	0.882	0.794	0.726	0.671	**0.509**	**0.373**	**0.308**	**0.269**
3	0.919	0.858	0.808	0.767	0.638	**0.518**	**0.457**	**0.417**
4	0.939	0.891	0.852	0.819	0.713	**0.611**	**0.555**	**0.518**
5	0.951	0.912	0.880	0.852	0.763	0.674	**0.624**	**0.591**
6	0.959	0.926	0.899	0.875	0.798	0.719	0.675	0.645
8	0.969	0.944	0.923	0.905	0.845	0.781	0.745	0.720
10	0.975	0.955	0.938	0.923	0.873	0.821	0.790	0.769

m – number of constituent partitions in the whole object. In such case the structure of the partition would require the application of the simplest fireproofing solutions, i.e. glass panes with single expanding layer and single insulating chambers in aluminum profiles.

The fire reliability evaluation of serial–parallel partitions made of multi-layered glass panes and multiple chamber profiles would require the application of complex reliability models. Because of relatively abstract character of such building structure, it is not analyzed in this paper.

3. Summary

Internal and external fireproofing partitions are in general designed according to deterministic criteria, cf. sources [7–9, 12], as well as [13–16]. The structure of the partition is affected by formal requirements formulated in legal regulations dealing with fire safety of buildings (cf. laws and other regulations listed in [11], codes, for instance [21] and technical approvals documenting the nominal fire resistance of system aluminum-glass partitions (cf. for instance [2, 3, 5]. The partitions designed this way should be verified by the fire reliability analysis of structures, using simple and mixed reliability models described above in section 2. In particular, the serial model of a partition, in the case when glazing with single fireproofing layer and single chamber fire insulation in aluminum profiles is used, indicates that the partition as a whole satisfies the reliability requirements stated in the code PN-EN 1990 only at very high requirements of fireproofing reliability. Such a solution is not rational, as at relatively high cost of erecting the structure its fire durability is low.

Reliability of most system aluminum-glass partitions made of multi-layered glass may be estimated by application of a serial–parallel model according to Fig. 7a. Numerical analysis conducted for such model of a partition suggests, that due to the scale of such structures, rational application of multi-layered glazing with number of fireproofing layers in glazing pane exceeding four ($m > 4$) is questionable (cf. the values of reliability listed in the Table 3 in bold). Glass panes with high number of fireproofing layers ($m = 6 \div 10$ according to Fig. 4) are expensive and heavy, and in view of results listed in the Table 4, their allowable unreliability is high – which is contrary to the quality requirements of such products. The postulated limiting of the number of fireproofing layers to 3÷4 in the glazing pane, inevitably leads to the lower nominal fire resistance of 45÷60 minutes (cf. Fig. 4, Pyrobel 17N glass, assigned to fire resistance class *EI* 45, and Pyrobel 25 glass of class *EI* 60). Fire is an exceptional occurrence, which will never happen in most of the erected buildings, and thus possible further raising fire safety requirements for partitions above *EI* 60, according to Author's opinion should be ensured by system safeguards, and not by the design and application of fireproofing structures. Electronic fire alarms and transmission of fire alarms are understood here as such system safeguards. Application of fire protection means such as sensors, alarms, smoke vents, automatic sprinkler systems and other assures active fire protection. The basic objective of such protection may be stated as limiting the spreading of fire to allow for speedy evacuation of people and intervention of Fire Brigade. Fire alarm control panels installed in buildings are electronic devices used to confirm a detected signal and trigger a fire alarm. The system sends a fire detection signal through the fire alarm transmission system to the Fire Brigade or automatic fire extinguishing devices and to automatic control of the proper functioning of the fire alarm system. At the end of the system there is an alarm receiving station, located in the fire alarm receiving center.

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Niezawodność pożarowa systemowych przegród aluminiowo-szklanych

Słowa kluczowe: szkło, aluminium, przegrody, niezawodność, pożar, odporność ogniowa

Streszczenie:

Wieloletnie badania naukowe prowadzone w krajach Unii Europejskiej zostały zwieńczone dokumentem technicznym CEN/TC 250 N 1060 [8], zredagowanym w ramach prac Europejskiego Komitetu Normalizacyjnego nad drugą edycją Eurokodów (EC), W edycji tej przewidziano rekomendacje w/z projektowania konstrukcji szklanych, a w szczególności opracowanie odrębnej normy projektowania, zawierającej nowoczesne procedury w zakresie projektowania konstrukcji budowlanych szklanych. Przedstawiony przez autora artykuł stanowi przyczynek do badań w zakresie analizy niezawodności pożarowej przegród o konstrukcji aluminiowo-szklanej. Systemy takich przegród obejmują elewacje budynków, a także przeszklone ścianki działowe, przeznaczone do konstruowania różnego rodzaju przegród wewnętrznych z drzwiami szklanymi. Ich zadaniem jest wydzielenie stref pożarowych oraz oddzielenie i wygłuszenie wydzielonych powierzchni, bez ograniczenia wizualnego zabudowanych pomieszczeń. W ofercie producentów krajowych i zagranicznych ważną pozycję z uwagi na bezpieczeństwo pożarowe stanowią systemowe przegrody ogniochronne, które są wytwarzane w klasach odporności ogniowej od *EI* 30 do *EI* 180. Przegrody ogniochronne wewnętrzne i zewnętrzne są na ogół projektowane wg kryteriów deterministycznych, tzn. o konstrukcji przegrody decydują wymagania formalne sformułowane w przepisach prawnych dotyczących wymagań podstawowych jakie winne spełniać budynki i ich części. Właściwości ogniochronne systemowych przegród aluminiowo-szklanych są badane laboratoryjnie i dokumentowane w aprobatach technicznych. Zaprojektowane przegrody według kryteriów deterministycznych można zweryfikować na drodze analizy niezawodności pożarowej konstrukcji, wykorzystując znane od lat proste i złożone modele teorii niezawodności. W artykule zestawiono formuły niezawodności prostych i mieszanych modeli matematycznych obiektów nieodnawialnych, które wykorzystano do modelowania niezawodności pożarowej przegród krajowego producenta systemów aluminiowo-szklanych Aluprof o symbolach katalogowych MB-78EI oraz MB-118EI. Wyniki obliczeń pozwoliły na sformułowanie zaleceń konstrukcyjnych, weryfikujących deterministyczne kryteria projektowania przegród ogniochronnych. W szczególności analiza niezawodności pożarowej skłania do rezygnacji z projektowania kosztownych przegród aluminiowo-szklanych ze szkła wielowarstwowego o dużej liczebności warstw ogniochronnych. Wysokie, ponad standardowe wymagania niezawodności pożarowej, proponuje się zapewnić na drodze instalowania w budynkach systemów sygnalizacji pożarowej i transmisji alarmów pożarowych.

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