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Structural Mechanics

Fire Risk and Measures for Diminishing the Fire Effect

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Abstract
Taking into account that the logical association between risk on one side and probability – gravity on the other side, we consider that the definitions for fire risk which are not referring to the gravity of their consequences, the single element being the probability, cannot adequately reflect the reality and do not have a practical use. At the same time, by defining the fire as a combustion with non-controlled evolution (according unfortunately to the present trends), excluding any reference to its consequences, we consider that the notion of "fire safely" consistently loses its significance.

KEY WORD: fire security, fire risk, protection measures

1. RELATION SECURITY - RISK

We cannot discuss about the security of people who use an insecure building. The security of users depends mostly on the security of the building they live in. On the other side, we can talk about security only when the risks are maintained between some acceptable limits.

The security of a technical system (as concerns its performance) represents the ability of the considered system of producing no critical or catastrophic events.

A building (as any other technical system) might be associated to a certain security level. This level could be rendered evident by analyzing the security as a function expressed in terms of risk (Fig.1). The higher is the security level ensured by the system, the lower is the level of the associated risk.

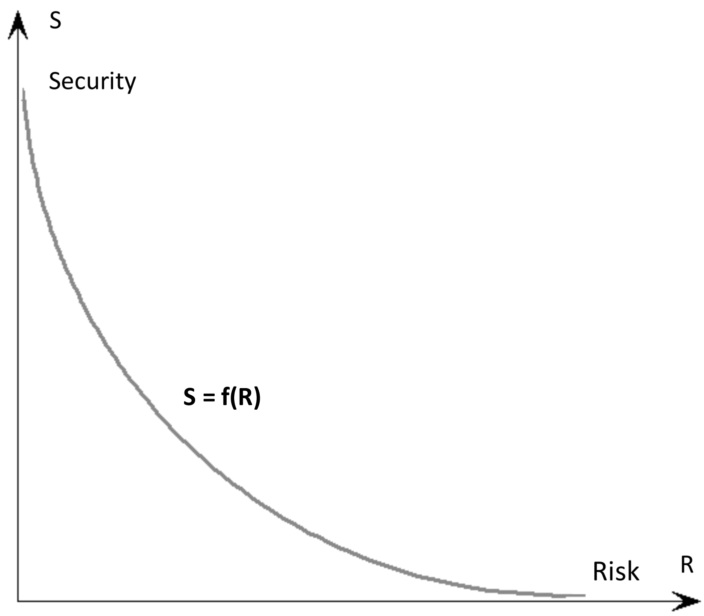

Figure1. Graphical representation of relation security - risk

The risk assessment may be considered as a scientific procedure of answering to the following three questions:

1. What could happen?
2. What would the damage be if it happens?
3. What is the possibility for it to happen?

The risk notion involves the association between two elements:

- the probability of an unfavorable event, P;
- the gravity of its consequences, G.

In other terms, the risk R could be considered as a potential loss, expressed as a product between the probability of the event occurrence and its gravity:

$$R = PxG \tag{1}$$

The materialization of the relation probability – gravity presumes initially the assessment of the criteria for the consequences gravity evaluation. These criteria are assessed based on codes or they are negotiated.

The graph of the relation probability – gravity points out two risk domains: the domain of acceptable risk and the domain of unacceptable risk (Fig.2).

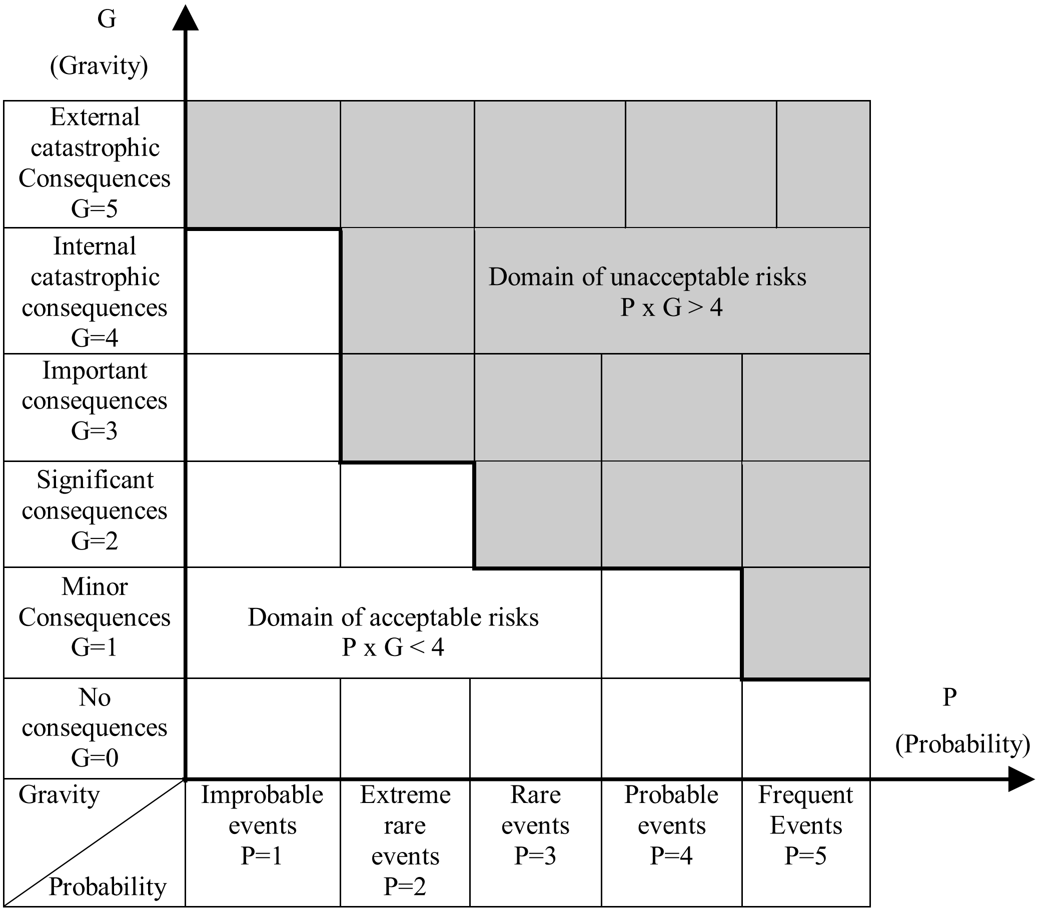

Figure 2. The risk graph in the co-ordinate system probability - gravity

Usually, the profile of risks is concretized by establishing a reference value $(P \times G)_{ref}$ of the product between the value P associated to the probability p of the unfavorable event occurrence (the units of measuring being the number of events in time unit: hour, year) and the level G of its gravity, expressed according to the scale for gravity evaluation.

The assessment of an acceptable risk represents a compromise that is based on the cost of the associated risk, imposed by the necessary security measures. The product (P x G) is considered as acceptable when it is lower, at most equal to the reference value $(P \times G)_{ref}$.

By using the grid probability – gravity and pointing out the zone which separates the two domains (of acceptable and unacceptable risks), three main possibilities of passing from the domain of unacceptable risks in the domain of acceptable risks are rendered evident:

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- diminishing the probability of unfavorable event occurrence by using the *prevention measures*;

- reducing the gravity of its consequences by using *protection measures*;

- transferring the risk (as a matter of fact, its financial consequences) usually towards the insurers. In this case an artificial displacement of the curve between the two risk domains is done.

2. FIRE RISK AND SECURITY

Particularly, when the unfavorable event is a fire, the answers to the first two previously mentioned questions refer to the potential of some possible events to produce damages of a certain gravity (to endanger the considered system). The answer to the third question represents the expression of fire breaking out probability. The relation of fire risk is:

$$R_f = BxA \tag{2}$$

where

R_f is the fire risk;

B is the degree of endangering the considered system;

A is the activating coefficient of the risk factors which takes into account the probability of fire breaking out, too.

Based on the risk expression, given by relation (2), The following definition results: *the fire risk* is the state expressed by the interdependence between the global probability of fire breaking out and the gravity of the event consequences.

3. FIRE RISK AND MEASURES FOR DIMINISHING ITS EFFECTS

It is considered that the fire risk R_f lies in the domain of acceptable risks, when the following relation is satisfied:

$$R_f \leq R_a \tag{3}$$

where R_a is the accepted fire risk for the type of the analyzed system.

In these circumstances, *the building fire safety*, *Sig*, is ensured when one of the following requirements is accomplished.

$$Sig = {}^{R_a}\!/_{R_f} \geq 1 \quad or \quad Sig = {}^{R_{f,ef}}\!/_{R_a} \leq 1 \tag{4}$$

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Starting from the reality that a danger could be diminished by adopting the appropriate measures, the degree of endangering , B, is defined as the ratio between the potential danger, P, and the ensured protection, M, according to a safety scenario:

$$B = P/M \tag{5}$$

The assessment of the risk by considering the applied protection measures represents the so called *effective fire risk*. By introducing rel.(5) in rel.(2), the effective fire risk is obtained:

$$R_{i,ef} = \left(P/M\right) x\ A \tag{6}$$

In order to maintain the fire risk into acceptable limits, two main categories of measures should be adopted:

- *prevention measures*, which reduce the probability of fire breaking out, without modifying the gravity of its consequences;
- *protection measures*, which reduce the risk by diminishing the fire consequences, without reducing the probability of fire breaking out.

The risk transfer towards the insurers does not represent in fact a method of reducing the fire risk because it does not really diminish neither the probability of fire breaking out, nor the gravity of fire consequences.

In the effective fire risk relation, the numerator takes into account not only the risk factors which derive from the substances and fixed and mobile materials, P1, but also the risk factors derived from construction conception, P2. The product of the two categories of factors represents the potential danger, P:

$$P = P_1\ x\ P_2 \tag{7}$$

P_1 is given by relation:

$$P_1 = q\ x\ c\ x\ r\ x\ k\ , \tag{8}$$

where

- q is the density of the thermal load;
- c is the material combustibility;
- r is the danger represented by smoke,
- k is the danger represented by products toxic properties.

P_2 is determined with the expression:

$$P_2 = e\ x\ i\ x\ g \tag{9}$$

where

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- e takes into account the height of the building, fire compartment or room;
- i takes into account the combustibility of the structural elements;
- g takes into account the geometry and the sizes of the fire compartment.

The denominator of relation (6) considers the ensured protection, expressed by factor M. The possible protection measures are:

- *measures of passive protection,* ensured by the structure conception;
- *measures of active protection*, ensured by equipments for fire detection and fight;
- *measures for operative protection,* which imply the organized intervention against the fire with specialized teams and means

The factor of protection measures, M, which takes into account all the protection measures adopted and/or applied for diminishing the potential fire risk has the expression:

$$M = F \ x \ E \ xD \ x \ I \tag{10}$$

Factor F takes into account the passive protection which implies: the degree of fire resistance, the correlation between the building destination and the number of admitted floors, the manner of separating different spaces, the combustibility of finishing materials, the smoke evacuation, and the people evacuation.

Factor E considers the active protection which involves the building equipments for fire signalization and extinction.

Factor D takes into account the operative protection that refers to the intervention at the work place, given by the following relation:

$$D = D_1 \ x \ D_2 \ x \ D_3 \tag{11}$$

where

D_1 quantizes the existence of intervention means;

D_2 quantizes the organization of people intervention in case of fire and its quality;

D_3 quantizes the existence of qualified people who must apply the previous mentioned activity and their qualification level.

Factor I takes into account the operative protection which involves the intervention capacity of the specialized people in fire extinction that is determined with the relation:

$$I = I_1 \ x \ I_2 \ x \ I_3 \tag{12}$$

where

I_1 considers the category of the own civil fire men team (the private urgency service) or of the hired team, according to a convention;

I_2 considers the category of the military fire men team who must enter into action in case of fire;

I_3 considers the time between the fire breaking out and the military or civil fire men intervention

4. CONCLUSIONS

Between these three categories of protection measures, interdependence exists. By an adequate correlation between the passive and active protections we can:

- increase the maximum fire compartment built area (according to code P118-99);
- reduce the limit of fire resistance for some building elements;
- extend the domain in which are admitted the unprotected or partially protected steel structures.

In choosing the protection measures, the economic aspect on long terms should not be ignored.

The adoption of some protection measures referring to building structure (passive protection) could have a high cost, but it will be balanced by lower expenses along the building service period, and vice versa.

Generally, by increasing the weight of operative protection measures compared to the other two types of protection measures leads to a real economic efficiency in case of temporary constructions.

The measures of fire protection should be considered from the design stage, so that an optimum level of fire security to be ensured on long term.

The existing soft for deformability analysis could be easily adapted for heat transfer problems, but also for other problems, as fluid flow or pressure.

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