Ing. Agnesa Iringová

# FIRE SAFETY IN ARCHITECTURAL DESIGN

The aim of the thesis is to point out the main problems connected with architectural design from the view point of fire safety an respecting the state of the structure as well as the European standards.

The thesis is elaborated in a scope needed for the project practise of architects, and my purpose is to use it as the reference book for students at the Faculty of Architecture in the facultative subject of Fire Safety as well as in constructional and disposition .

The thesis is divided into four basic parts:
1) State and EU legislative regulations
2) General requirements and principles of design of fire safety systems
3) Conceptual framework escape routes design buldings
4) Characteristics of building materials from the viewpoint of fire safety, their protection and use

Present legal regulations are defined in the first section. The problems are considered by them in Slovakia. Association of our legislation with European legal regulations is documented in the first part as well.

General principles of fire protection design of buildings in our and foreign practise are introduced in the second part. There is a comparison of the problems with attitude to its design in reconstruction of historical buildings abroad - in USA - as well as in Slovakia.

Basic information is taken from:
- Fire Breaks, *Progressive Architecture*, 1, 1986. (the built object designs in USA)
- my project practise (the object designs in Slovakia)
- Andrew Orton: The Way We Build Out. Form, Scale and Technique. England, 1988. (fire protection design of buildings as well as general principles of characteristics of building materials)
- David Guise: Design and Technology in Architecture, New York 1991. (present legal regulations in USA)
- Interpretative document - EEC Regulation No 89/106 (EU regulations)
- Compendium EEC of model conditions for building regulations - buildings, UNO, New York and Geneva 1996

In a sense of these information it can be said that the principle comprehension of the topic is the same in all countries. The precedence is always to design enough number of safe escape routes and provide fire protection of building constructions.

Built objects are usually divided into some minor fire safety areas which are limited by fire separating structures abroad as well as in Slovakia.

The layout and material design depend extensively on economic situation of investors in individual countries. Countries with highly developed economic system prefer active fire protection of objects sprinkler installation and effective smoke and heat venting installation etc. Fire protection extent obviously follows the requirements of insurance companies which are usually more strict than the state legislative ones.

Passive fire protection is designed in not so highly developped countries, it such as in Slovakia. Active fire protection installations are much more expensive. Means of passive fire protection are for example: the increas of load bearing structural propertis and fire separation constructions, designing of smaller areas of fire compartment, increas of number of escape routes etc.

There are some exceptions as big-area objects with large accumulation of persons for instance supermarkets, exhibition grounds, theatres as well as high-rise bulding s such as hotels, banks etc. where also our legislation requires intensive active fire protection.

The third part of my thesis deals with optimalization design of vertical and horizontal communications which serve to evacuate people. There are also some principles of disposition and construction design of communication centres depending on situation of considered working locations and workrooms, movability and number of evacuated persons.

Current knowledge of mostly used building materials from the viewpoint of fire protection of building is summed up in the fourth part of the thesis. Some requirements for their load capacity, compatibility, heat isolation, radiation and mechanic resistance in fire are defined here as well. The part deals as well with change of physical characteristics at long-lasting heat exposure, with active or passive fire protection and appropriateness of their use for individual workrooms from utility and economic viewpoints. Individual building arrangements and details of wooden and steel constructions are defined.

Possibilities to use computer methods in project design at definition of real fire resistance of typical building elements with respect to ERUCTED 5 STEP 1 (Timber Engineering STEP 1, Centrum Hut The Netherlands 1995) are documented in the thesis too. Design principles are documented on an example of a real building from the anther´s project practice.

Some construction designs of construction elements protection from the another´s design practice, are analysed. Standard designs of fire protection of construction elements tested in test station are elaborated as well. These sources and designs are taken from business documents of home and foreign designers.

Requirements for fire safety of any construction pursue follow the basic aims:

- not to endanger lives of persons in the construction
- to prevent fire development onto surrounding constructions
- to prevent firemen from fire danger.

The requirements are defined in the building code No 237 (07/2000) in Slovakia. EEC Regulation No 89/106 is the basic European legal enactment in building industry. Interpretative document No 2 of the regulation is of decisive importance for fire safety. Regulation

No 288/2000 SB. of the Ministry of the Interior of the Slovak Republic is an application of both documents for fire safety in Slovakia in which basic principles of fire safety are enshrined as far as up building and use of the constructions are concerned.

In accordance with the regulation it is necessary:

1. to divide object into fire compartments
2. to define fire hazard
3. to define requirements for fire separating structures of construction
4. to design optimum way and equipment for evacuation of persons and consider evacuation time
5. to delimit fire risk area around the object
6. to design fire safety equipment in objects for localisation and restriction of fire
7. to design equipment for fire safety intervention in every fire safety project of construction.

An important idea is that fire can be contained by an enclosure in such away that the spread of the fire is prevented. To make this possible the elements of the enclosure must have fire resistance. The fire resistance is applied to elements of construction such as walls, floors and beams. The term "fire resistance" has to be defined more precisely for specific purposes,

such as fire regulations. Normally standard fire tests are used to establish nominal values in hours, for the "fire resistance" of building elements.

The actual required fire resistance of an element, that should behave satisfactorily in fire, will depend on the fire severity. Its most important aspects are the duration of the fire and the maximum temperature reached during the fire.

The total heat released during fire, with a complete burnout results, depends on the amount of fuel present, that is the *fire load.*

In a ventilation controlled fire, the rate of burning can be increased by the increased the ventilation through the openings to the compartment, which, in a building, are almost always window openings. Ordinary glass usually shatters soon after the fire is fully developed, thus enabling the ventilation.

Fire can spread from the room where ignition took place by passing through gaps in the room enclosure. The fire consists of flames, as well as hot glasses which take flame as they oxygen. Fire may also spread from the room where ignition took flake by conduction through the room enclosure.

The flames and hot gases can escape from the room trough windows, doors, suspended ceilings, raised floors and, more insidiously, through service ducts, cable trays or trough the gap around pipes that penetrate the room enclosure. They are then free to spread along corridors, stairways and lift cores, service shafts and cavities.

Compartmentacion is the division of abuilding into compartments which are enclosed by fire-resistant construction.

Another important path for the spread of flames is via windows. Fire may also spread from one building to another, adjacent to it , by flames, flying brands or radiation from the building already on fire. The radiation from the fire varies with distance in the same way as the illumination does from alight source.

### Smoke

The most important threat to the occupants of a building is the smoke produced by fire. Smoke may spread and still be at lethal concentrations in a building even at great distance from fire. Another important hazard of smoke is that it reduces visibility to the extent that it may slow down or even prevent escape from a building.

Smoke consists of the gases relased from the combustible material.

The toxicity of the smoke produced during combustion depends on the type of fuel.

### Fire protection

Aims

Fire protection is necessary when fire prevention, which should have helped to prevent fire from starting, has failed. Fire protection falls into two categories:

- active anti fire measures are concerned with direct intervention in the fire by manually or automatically detected fire, suitably loaded alarms, suppression of the fire, smoke control and any necessary access or communication;
- passive measures are concerned with the layout and construction of the building and access to it. The two paramount aims of passive fire protection are the provision of means of escape, to save life, and the containment of any fire to a compartment where the outbreak started, to limit fire damage and give time for evacuation.
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Every effort should be made to prevent smoke moving from the compartment where the fire started to the other compartments in the building.

### Active fire protection

Active fire protection measures consist principally of detection, alarm, fire suppression, control of smoke and air conditioning systems, use of lifts and evacuation procedures.

Of those installations directly concerned with suppressing or extinguishing afire, as distinct from those helping escape, the most useful is the sprinkler system.

Pre-action sprinklers are the most popular systems in historical buildings because they offer fast reaction to fire as well as protection against water damage of buildings. Precaution systems consist of two connected parts. System valve is activated just after the fire alarm, when originally dry pipes are filled with water and sprinkler hub is opened.

A Pre-action sprinkler can negotiate unheated areas just as dry systems. It can also spray water on fire in the moment when sprinkler hub is open. Pre-action systems however do not carry water in a case of damaged sprinkler hub. Alarm system informs users in a different way.

Flooding systems work similar as sprinklers but they are less suitable for historical buildings because the sprinkler hubs remain open. When the alarm opens the water valve the system floods the building with water.

Halogens systems offer more advantages than sprinkler systems. They use halogen instead of water to stop fire and eliminate problem of damage by water. That is why they are used in locations with electric installation, fine materials or paper. Halogens systems are installed more easily than sprinklers because they use individual gas containers for various rooms in building. The main disadvantages are their high prise and relative efficiency. In a large room or in a room with open door it may happen that gas does not reach the appropriate concentration to die out the fire extinguish.

Alarm systems and control of smoke are necessary in most buildings. These provisions are particularly relevant to high-rise buildings, but also to large area objects.

The newly built complex of market Polls City Centre and entertainment facilities represents a typical home example of active fire protection where it is secured by sprinkler hubs and smoke and heat venting installations. The Historical building of Museum Keys Condon Florence in Washington can serve a foreign model of active fire protection in reconstruction s where all fire separating glass constructions oriented to atrium are protected by water screens from sprinkler installations which provide the fire resistance for hour and a half. All the usable space of the object is protected by a spray system as well. The atrium serves occasionally as assembly hall.

## Passive fire protection

Passive regulations deal with arrangement of fire protection constructions in building.

A typical example of application of passive fire protection is the reconstruction of a historical object of Habánsky doom in Veľké Leve, Slovakia. The object has two level storeys above the ground level , massive masonry external walls. Ceiling constructions and pillars, staircases and carpentry construction are made ofwood. The object was considered as one fire compartment and requirements for fire resistance according to calculations are 45 minutes for loadbearing constructions which secure stabilitỳ of the object and 30 minutes for loadbearing construction of roof and staircases.

The object will serve as a museum of habanian culture and it is important to maintain the loadbearing wooden constructions.

Wooden loadbearing constructions are very massive, with excessive boat learning capacity.

Thus it was possible to consider their load bearing stability as sufficient, evenaufler 30-45 minutes of fire.

It means that they can remain without fire protection. In constructions staircase, pilasters of carpentry constructions etc., where it was proved by calculation that the profile could be reduced from the viewpoint of load bearing capacity wasinportant to use the transparent coat of paint Flamgard.

## Escape routes

Escape from buildings is by designated routes that are protected, as far as possible, against the entry of fire and smoke.

It is convenient to divide up the escape route into four stages: stage one leads from any point in a room to the room exit; stage two leads from the room exit to the exit from the storey level, or to a protected place, usually a protected stairway at that level; stage three leads downwards, or upwards, to the escape level; stage four leads from the protected place to the final exit at the same level, or to another place of safe refuge. The scape routes must always lead to places of safe refuge.

Escape routes are divided into the following types according to a degree of protection for persons on escape:

a) unprotected escape routes
b) partially protected escape routes
c) protected escape routes.

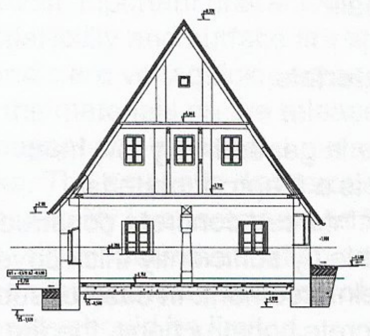
Unprotected escape route is not protected against fire effects. It leads from fire compartment to exit into the free area or partially protected escape route or protected fire escape route.

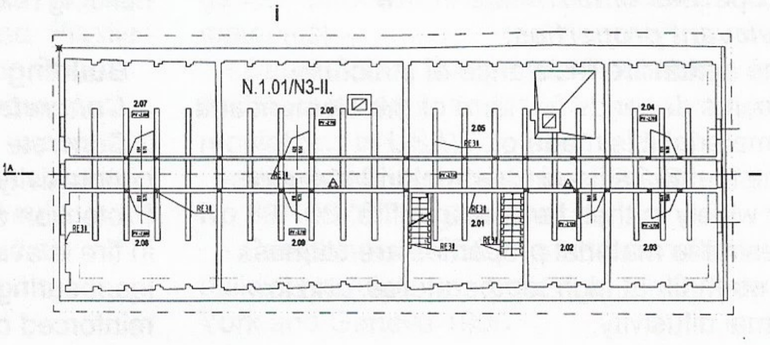
Partially protected escape route is the route which

d) is located in fire compartment without fire hazard or

e) crosses some part of fire compartment without fire hazard or

*Fire Safety – Habansky dvor, Velke Levare*





f) crosses adjacent fire compartment in which there is no production and operation where value of flammable material coefficient is maximum 1.1.

Protected escape route leads to exit into the free area. It is separated from other fire compartments with fire separating structures and fire shutters. Protected escape route is ventilated and enables movement of persons without risk.

Protected escape routs are divided according to time of safe presence of persons into the following types:

a) class A protected escape route, 6 minutes,

b) class B protected escape route, 15 minutes,

d) class C protected escape route, 30 minutes.

Class A protected escape route is protected by natural or forced ventilation.

Class B protected escape route is protected by ventilated fire-fighting lobby, natural ventilation or forced ventilation and emergency light.

Class C protected escape route is that protected route with singly ventilated fire-fighting lobby, pressurised ventilation and emergency light.

Number, length, width and allocation of escape routes are designed, realised and operated in such a way that required time of evacuation of persons is minimal.

Required time of evacuation of persons must not be of higher value than the permitted evacuation time according to the amendment No 6 of regualation No 288.

Permitted time of evacuation is the longest available time of safe evacuation of persons out of the construction or its part.

The width of escape route is expressed by the number of units of escape route.

**Properties of materials in fire**

***Relevant properties:***

The actual fire resistance of structural elements depends on form of the element and on material it is made of.

The materials used for structural elements vary widely in their behaviour infire.

Desirable material properties are stiffness and strength at high temperatures, and low thermal difusivity.

Low coefficient of thermal expansion reduces movement and the potential disintegration of parts of the building infire.

Low thermal difusivity limits the area of an element affected by high temperatures and therefore the loss in strength of the element.

***Fire resistance***

Fire resistance is a specific feature from the view point of building construction. It is expressed in minutes: period of time in which evaluated constructions are able to resist effects of so called normal fire, it means fire continuing under the precisely defined conditions. These parameters are specific for various kinds of building constructions and they differ according to character of load on the concrete construction. That is why there are more standards and testing methods for evaluation of the conditions.

State limits are defined in accordance with aparticular project that means for every construction. The appropriate constructions are chosen according to state limits.

***Flammability of building materials***

Flammability of building materials is their ability to ignite, burn or smoulder. It is caused by the source of ignition.

Flammability of building materials is expressed by flammability class of building materials which is determined by testing.

Building materials are classified in the following classes from the view point of flammability:

a) flammability class A - non flammable building materials

b) flammability class B - uneasy flammable building materials

c) flammability class C1 - hardly flammable building materials

d) flammability class C2 - middle flammable building materials

g) flammability class C3 - easy flammable building materials

**Building materials**

***Concrete***

Concrete has in general very low heat conductivity. It is a fireproof material. Protection of reinforced concrete constructions in fire is available by sufficiently thick cover of loadbearing reinforcement. In case of subtle reinforced concrete constructions, the fire protection is supported with boarding s of fire resistant materials such as boards made from plaster carton F, Ordeal, Promote, Tetris etc.

***Masonry***

Fire resistance of a masonry depends on the form of its cross section .

Classic materials in general - bricks and light concrete - have very good fire resistance depending on thickness of the masonry.

Load bearing wall has load bearing function and it also serves as fire separating construction.

***Steel***

Steel is a non combustible material with high thermal expansion and subsequently very low fire resistance. The loss of consistency of steel changes depend s on its individual type, form, load and heat.

Mezzo and high consistent steel remain firm in temperature to 350oC. In heat exposure above theirs value, there is precipitous loss of consistency and compatibility. That is why it is necessary to protect all steel elements with fire protecting insulation.

Fire protection is available by boarding made from fireproof materials (plaster carton boards, coat paints Pittura, Barrier, Dexamin etc.).

***Wood***

Wood is a combustible material.

Fire resistance of a wooden construction depends on the quality of the wooden section as well as on the ability of wood to carbonise.

Fire exposed wooden travis are subjected to speed of carbonisation approximately 30-50 mm per hour.

Fire resistance of wooden massive as well as stuck load bearing elements can be calculated according to Eructed or defined by test.

Wood can be protected with foaming protective coat paints which slow down the start of carbonisation speed to 30 minutes (Flamgard, transparent Dexamin or fireproof boards Promote, Tetris and plaster carton etc.).

***Plastics***

Most plastic materials are not fire resistant. The most important characteristics of plastics are infallibility and surface fire spread. Plastic materials are very quickly spread the fire.

All the materials on fire release a out of unpleasant and poisonous gasses, vapour and smoke. The smoke is dangerous because it limits visibility in affected areas and subsequently hinders evacuation as well as firemen intervention. The use of plastic materials should be limited.

***Glass***

Glass is used the most often used , it is a non combustible material. Glass in fire cracks and falls out of the frame.

Calcium-silicate glass has mezzo long time of fire resistance - approximately 30 minutes. Boron-silicate glass has a high melting point and retains its compatibility for a longer period of time 30-45 minutes. Stuck glass has fire resistance 60 minutes depending on number of panes of glass. Other method of fire protection of glass represents cooling by water screen from a side of heat exposure.

**Conclusion**

The fire protection is a current and urgent topic. It is pressing not only in newly built strustees but also in reconstructed build designs.

Architects work under strong pressure to design not only economically but to preserve asufficient level of fire security as well.

The aim of my dissertation is to outline the core aspects of fire protection of build inns of all types and make the subject clueless acceptable for students of architecture. It will be strongly suffered by experience of may designing colleagues as wells by my own experience.

The present zu wledge in this topic needs classification and hierarchization.

I hope that it will inspire the students to search for new, innovative and may be even more effective fire safety designs in their architectural designs.

**Literature:**

- Fire Breaks, *Progressive Architecture* 1/1986 (the built object designs in USA) - project practise (the object designs in Slovakia)
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