7. МЕЂУНАРОДНА НАУЧНА КОНФЕРЕНЦИЈА **БЕЗБЕДНОСНИ ИНЖЕЊЕРИНГ**
ПОЖАР, ЖИВОТНА СРЕДИНА, РАДНА ОКОЛИНА, ИНТЕГРИСАНИ РИЗИЦИ И
17. МЕЂУНАРОДНА КОНФЕРЕНЦИЈА **ЗАШТИТА ОДПОЖАРА И ЕКСПЛОЗИЈА**

ZAŠTITA OD POŽARA ZDRAVSTVENIH OBJEKATA

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Rezime: Kritična infrastruktura može biti oštećena, uništena ili poremećena namernim aktimaprirodnih katastrofa, nemarom, teroriznom, nesrećama ili hakovanjem računara, kriminalnim aktivnostima i zlonamernim ponašanjem. Kada se govori o zaštiti kritične infrastrukture, jedna od bitnih grana koje je neophodno zaštiti, jeste i zdravstveni sistem.

U Republici Srbiji ne postoje posebna tehnička pravila koja se bave zaštitom od požara prilikom izgradnje zdravstvenih ustanova. U Pravilniku o zaštiti stambenih, poslovnih i javnih zgrada od požara delimično se spominju i bolničke ustanove. Zbog nedostatka domaćih zakona projektanti se moraju osloniti na inostrane zakone i špropise.

U radu je prikazana aktivna i pasivna zaštita od požara koju je potrebno primeniti prilikom projektovanja zdravstvenih objekata, kao i primeri zakona koji se koriste u drugim zemljama kada je u pitanju zaštita od požara zdravstvenih objekata.

Osim aktivne i pasivne zaštite zgrada zdravstvenih ustanova, potrebno je i redovno vršiti edukaciju osoblja i pacijenata kako bi se sprečili napadi panike i greške koje mogu nastati usled neadekvatnih odgovora na nastanak požara u sklopu objekta.

Ključne reči: kritična infrastruktura, zaštita od požara, objekti zdravstvene zaštite, pasivna zaštita od požara, aktivna zaštita od požara;

FIRE PROTECTION OF HEALTH FACILITIES

Abstract: Critical infrastructure can be demaged, destroyed or disrupted by deliberate acts of natural disasters, negligence, terrorism, sccidents or computer hacking, criminal activity and malicious behaviour. When it comes to the protection of critical infrastructure, one of the most important branches which requires protection is the health system.

In the Republic of Serbia, there are no specific technical rules that deal with the fire protection for construction of health facilities. The Rulebook on the protection of residential, business and public buildings from fire partly mentions hospital facilities. Due to the lack of domestic laes designers must rely on foreign laws and regulations.

The paper presents active and passive fre protection that needs to be implemented when designing health facilities and an example of laws used in ither countries relating to the fire protection of hospitals.

In addition to active and passive protection of medical facilities buildings it is also necessary to continuously educate both staff and patients to prevent panic attacks and mistakes that may occur due to an inadequate response.

Key words: critical infrastructure, fire protection, health facilities, active fire protection, passive fire protection

1. INTRODUCTION

The governing of countries to a large extent depends on the proper functioning of the critical infrastructure systems. The failure of one system can lead to great damage or negative consequences that threaten many other systems of critical infrastructure. Factors that can endanger critical infrastructure are not only terrorist attacks, but also natural disasters or catastrophes caused by technical-technological accidents. In order to avoid unfortunate events, it is necessary to create a good system of prevention, as well as adequate actions to be taken if an accident occurs, It is also important to create a strategy for rapid recovery after an accident that has disrupted critical infrastructure.

Regarding protection of critical infrastructure, one of the important branches necessary to protect is the health system. The paper emphasizes facilities of health care institutions that require a special type of protection, as they are home to people with different clinical pictures, as well as people with reduced mobility. In addition to patients and the staff, hospitals also have much expensive

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equipment that must be protected in the event of a fire. For that reason, special attention should be paid to active and passive fire protection in such sensitive types of buildings.

2. A HISTORY OF THE ORIGIN OF HOSPITAL FIRES

2.1. Fires that have occurred in hospitals around the world

Throughout history, fires that occur in hospitals, have been encountered, and continue to be encountered. In order to better fight such accidents, it is necessary to be well acquainted with all the threats that can endanger their normal functioning and the safe stay of patients. For this reason, it is necessary to first get acquainted with previous cases of fires in hospitals and use these accidents to improve hospitals and prevent the same scenarios. In their paper, Authors *B. Abhishek Shastri, Y. Sivaji Raghav, R. Sahadev, Bikarama Prasad Yadav* [1] presented fire-related accidents that occurred in hospitals around the world and resulted in loss of life of patients and staff.

Table 1 - Fires that have occurred in hospitals around the world [1]

Date	Hospital	City	Number of deaths
18.02.1923.	Manhattan State Hospital	New York	25
1945.	Hartford Hospital	Connecticut	20
1948.	Hartford Hospital	Asheville, North Carolina	9
04.04.1949.	St. Anthony's Hospital	Effingham, Illinois	70
07.01.1950.	Mercy Hospital	Guatemala	41
23.12.1956.	Doctor's Memorial Hospital	Minnesota	8
14.07.1960.	Guatemala Mental Hospital	Guatemala	225
12.02.1968.	Shelton Hospital	Shrewsbury	21
05.07.1972.	Coldharbour Hospital	Sherborne, United Kingdom	30
09.12.2006.	Moscow Hospital	Moscow, Russia	46
26.04.2013.	Moscow Psychiatric Hospital	Moscow, Russia	36
2013.	Psychiatric Hospital in Luka	Novgorod Oblast, Russia	37
2014.	A hospital in Jangseong Country	North Corea	22

2.2. Fires that occurred in hospitals in the Republic of Serbia

Historically, no major catastrophes caused by hospital fires have been recorded in Serbia. But despite that, there were fires, mostly ending in material damage. Table 2 presents cases of fires in hospitals in the last 10 years.

Table 2 - Fires that have occurred in hospitals in Republic of Serbia

Date	Hospital	City	Number of injured
24.10.2009.	DragišaMišović	Belgrade	0
12.3.2012.	Psihijatrijskabolnica	Nis	0

22.11.2020.	Kliničkicentar	Nis	4
14.4.2020.	OpštabolnicaJagodina	Jagodina	0

3. ACTIVE AND PASSIVE FIRE PROTECTION MEASURES

In order to fight fire as efficiently as possible and with as few human and material losses as possible, it is necessary to create such a protection system that aims to suppress fires, as well as to control to prevent uncontrolled spread of fire, which can result in human casualties, as well as enormous material damage. When designing such a complex facility as a hospital, where it is necessary to consider many factors, it is of great importance to take into account the project itself, i.e. the design of the building, as well as the choice of materials that are crucial for protection. This enables additional time needed for safer evacuation of patients and staff, as well as to have as little fire damage to the facility as possible.In order to achieve the described effects, it is necessary to combine active and passive protection measures. Their combination offers, in the first place, a sufficient period of time to evacuate persons who are in the building at the time of the fire, and also the maintaining of a considerably lower temperature of building elements (steel, installation, etc.) on the side unexposed to fire compared to the affected side, butthis also protects expensive equipment. Another advantage is that the fire can be kept within the compartment in which it occurred.

3.1. Passive afire protection measured for buildings

Passive protection measures are measures incorporated during the construction of a building and they, unlike active measures, do not work only during fires. The passive system requires the necessary planning in the design phase of a building, especially for buildings such as hospitals, that accommodate patients with various clinical pictures, as well as those who are not mobile and who cannot be evacuated without someone's help. In addition to the importance of the design of a building, a division into sectors and the organization of premises and of planned exits, the choice of fire-resistant materials and coatings are also important. The most important role of passive measures is to keep the fire only in the compartment where it originated and to slow down its spread, giving people enough time to evacuate safely. For that reason, it is necessary to choose the best possible materials to use during construction, and their behavior during a fire can be tested fortheir the reaction to fire, as well as fire resistance.

3.1.1. Reaction to fire

Reaction to fire implies the behavior of building materials when exposed to high temperatures caused by fire and monitors properties such as: flammability, flame spread rate, heat release rate, appearance of combustible droplets/particles, quantity of smoke, heat output, etc. As the name suggests, these are the parameters of the material that enable the conclusion on how much a material further contributes to the development of fire, therefore these properties are important in the early stages of fire development.

3.1.2. Fire resistance

Fire resistance refers to structural elements that serve to separate individual spaces in the building, and is most important in the phase of a fully developed fire.[2] Fire resistance can be determined in two ways: by calculation or in standard test furnaces. When testing in test furnaces, distinction can be made between: testing of load-bearing structures and testing of non-load-bearing structures.

For load-bearing structures, the test specimen is installed in the test furnace, after which a static load is added to it in order for stresses of the test specimen to appear, which simulates the real situation that occurs on construction sites. The element is then exposed to a simulated fire that occurs in the test furnace and whose temperature over time must behave according to a standard set temperature-time curve.The test lasts as long as all parameters are met, the two most important parameters being insulation and integrity. When testing non-load-bearing structures, there isthedifference that the sample is not exposed to any type of load, while the remainder of the installation and testing procedure is the same as for load-bearing structures.

3.2. Active fire protection measures

Active fire protection measures are measures that require human action or that are performed via automatic systems after a fire breaks out. Their function is most visible during the development phase of a fire, but before it flares up. As the name suggests, active measures are those that require a certain level of human action, and there are manual (control of fire extinguishers) or automatic actions (sprinkler system). Active fire protection measures include: fire detection systems, automatic sprinklers, hydrants and fire extinguishers. After the installation of active systems, it is necessary to adequately educate people regarding the proper handling and functioning of the systems.

4. LEGAL NORMS IN THE REPUBLIC OF SERBIA FOR FIRE PROTECTION OF HOSPITALS

4.1 Laws on fire protection

Serbia has no laws or bylaws related to the design, construction and protection of hospitals from fire, rather the guidelines that designers must follow when building or reconstructing this type of facility are found in several different laws and rulebooks. Due to the lack of laws related to the construction of hospitals, the use of foreign laws and standards is allowed.

4.1.1. Law on fire protection [3]

Article 30 of the Law on Fire Protection[3] states that during the design and construction of a facility built according to the law governing planning and construction, basic requirements of fire protection must be provided so that in case of fire:

- load-bearing capacity of the structure is preserved for a certain period of time;
- spread of fire and smoke inside the building is prevented;
- spread of fire to neighboring facilities is prevent;
- safe and secure evacuation of people, i.e. their rescue is enabled.

If the fulfillment of fire protection requirements cannot be proven in the manner prescribed in paragraph 2 of this Article, the Ministry can accept proof of fulfillment of fire protection requirements according to foreign regulations and standards, as well as according to recognized calculation methods and models if provided by those regulations.

4.1.2. Rulebook on technical norms for fire protection of residential, business and public buildings [4]

Public buildings, which include health care facilities, can be divided into three groups depending on their envisaged height:

- buildings up to 8 meters high (IJ1 and NJ1);
- buildings from 8 meters to 22 meters high (IJ2 and NJ2);
- buildings from 22 meters to 30 meters high (IJ3 and NJ3);

As presented in Table 3, Article 8 of this rulebook contains a classification according to the number of persons who are permitted to be in the fire sector.

Table 3 - Classification according to the number of persons allowed in the fire sector

Number of persons	to 20	21 to 50	51 to 100	101 to 300	301 to 700	701 to 1500	1500 and more
Fire sector	≤ 400	400 to 800	800 to 1200	1200 to	1600 to	2000 to	> 2500

area (m^2)				1600	2000	2500	

Table 4 contains an estimate of the number of persons who can be in the hospital premises according to Article 9.

Table 4 - Number of persons who can be in hospital premises

Purpose of space	Average floor area required for one person expressed as a square meter per person
auxiliary and technical rooms	28
inpatients	22,3
nonstationary patiens	9,3
sleeping rooms	11,1
hall	9,3
garage	18,6
waiting room	1,4
warehouse	46,5

Table 5 contains requirements regarding fire resistance of structural elements depending on the degree of fire resistance of the building according to Article 11 of the Rulebook.

Table 5 - Requirements for fire resistance of structural elements depending on the degree of fire resistance of a building

Construction elements	Position	Fire resistance of construction elements depending on the adopted SOP, expressed in hours				
		I – insignificant	II – small	III – middle	IV – big	V – bigger
Bearing wall	Within the fire sector	1/4	½	1	1,5	2
Pillar		1/4	½	1	1,5	2
Beam		-	¼	1/2	1	1,5
Mezzanine construction		-	¼	1/2	1	1,5
Non-bearing wall		-	¼	1/2	1/2	1
Roof construction	/	-	¼	1/2	1	1
Wall	At the boundaries of fire sectors	1/4	1	1,5	2	2
Mezzanine construction		1/4	½	1	1,5	2
Door surface to 3,6 m^2		1/4	¼	1/2	1	1,5
Door surface of 3,6 m^2		1/4	½	1	1,5	2
Evacuation route construction	/	1/4	½	1/2	1	1,5
Facade wall	External constructions	-	½	1/2	1	1
Roof cover		-	¼	1/2	3/4	1

Regarding the calculation of the required number of evacuation exits and their dimensions, an important factor is the specific thermal power (SPM), which is the number of people who pass through a passage or exit of a certain width in one minute, contained in Article 30. The SPM value for a certain passage width can be adopted as follows:

- for a width of 0.9 meters this is 46 - 62 persons per meter and minute;
- for a width of 1.4 this is 78 - 90 persons per meter and minute;
- for a width of 1.8 meters this is 98 - 108 persons per meter and minute.

Article 31 deals with determining the number of required first exits on the evacuation route, which is done as follows:

- rooms that house 60 persons must have one first exit;
- rooms that house 61 to 500 persons must have at least two first exits;
- rooms that house 501 to 1500 persons must have at least three first exits;
- rooms housing 1501 to 3000 persons must have at least four first exits;
- premises that house more than 3000 persons must have a number of exits in accordance with Paragraph 1, Item 4 of this Article, meaning that for each additional person over 3000 another first exit must be created.

Articles 32 and 33 relate to the length of the evacuation route, which from the starting point to the first exit in rooms that have one first exit cannot be longer than 20 meters. In rooms with more than one exit the length of the evacuation route from the starting point to the first exit may not exceed 45 meters. In above-ground floors the length of the evacuation route from the first exit to the story exit may not exceed 30 meters, while for underground floors it may not exceed 25 meters. For buildings that do not have a story exit, the length of the evacuation route from the first exit to the staircase may have a length of maximum 20 meters.

All evacuation exits must have swivel doors that open in the direction of evacuation. Except story exits, some other structural solution for doors may be allowed, provided that it also ensures safe evacuation of persons, and that:

- doors open automatically by a signal from the fire control central and remain locked in the open position;
- doors have a mechanism to open and remain in a permanently open position when their mains supply is switched off;

near the doors there is a button by whose activation they can be opened and remain in the open position.

5. EUROPEAN NORMS

According to the Rulebook on fire resistance and other requirements that buildings must meet in case of fire, there is a division of buildings and structures into subsets according to the requirements for fire protection, according to which there are six subgroups, with health facilities belonging to group ZPS5. The division was made according to criteria related to the level of the floor for the stay of persons, the surface area of the building, the possibility for evacuation, as well as the availability of openings for evacuation and firefighting.

5.1. Rulebook on fire resistance and other requirements that buidings must meet in case of fire

A good example of a Rulebook on fire protection of buildings has been issued in the Republic of Croatia and refers to products used to construct buildings, with a special section dealing with materials that must be used in the construction of health facilities. The Rulebook on fire resistance and other requirements that buildings must meet in the event of a fire is modeled on the Austrian OIB 2.

Table 6 - Requirements for fire response classes of building elements for ventilated facade elements [2]

Hanging ventilated facade elements	
Classification of the whole system	B-d1
or classification according to individual components	
Outer layer	B-d1
Substructure	
Rod-shaped	C
Dotted	A2
Insulation	A
Thermal facade system	
Classification of the whole system	B-d1
or classification according to individual components	
Surface layer	B-d1
Insulation layer	A2

Table 7 - General requirements for reaction to facade fires [2]

	<6 aboveground floors	>6 aboveground floors
Facade		
Exterior walls	C-d1	C-d1
Facade Assemblies, hanging ventilated and ventilated facades		
Classification of the whole system	B-d1	B-d1
Classification of individual components		
Outer layer	A2-d1	A2-d1
Point substructure	D/A2	C/A2
Insulation layer	B	B[3]
Ventilated facade		
Individual components		
Profile	D	A2
Filled with glass	B-d1	B-d1
Panel Filling	A2-d1	A2-d1
Sealing between profile fillings	E	E
Coating	B	B
Other lining of external walls and non-bearing external external construction parts	B-d1	B-d1
Material for building joints	A2	A2
Fill the balcony fence	A2	A2

Table 8 - Fire reaction classes for construction products used for floor coverings and structures [2]

Floor Coverings On The Evacuation Path

Hallways	$A2_{fl}$
Stairs	$A2_{fl}$
Floor Coverings Built Parts of the Attic	$A2_{fl}$
Substructures	
System classification	D - d0
Classification of individual components	
Substructure	A2
Insulation layer	B-d0 or D-d0
Cladding or suspended ceiling	B-d0 or C-d0
Ceiling lining evacuation route	
Hallways	B-s1,d0
Stairs	A-s1. d0

Table 9 - Fire reaction classes for roofs [2]

Plains	
Top layer at least 5 centimeters thick or equivalent material	
Insulation (waterproofing)	D
Heat isolation	B
For cases when the top layer does not correspond to the previous point	
Insulation	B
Heat isolation	B
Sloping roofs (20º slope ≤ 60º)	
Lining	A2
Roofing foils	E
Roof construction	A2
Heat isolation	A2

6. CONCLUSION

With the development of society and with increasing attention devoted to the protection of critical infrastructures, the systems used to ensure its normal functioning are changing and improving day by day in accordance with the perception of new problems. To make this possible, it is necessary to study in detail all unfortunate events that have happened throughout history and which should serve as an example of what needs special attention regarding weaknesses of health facilities.

In the Republic of Serbia, there are no special laws or bylaws dealing with the construction of health facilities, or their fire protection. Most data on the construction of health facilities comes from the Rulebook on the protection of residential, commercial and public buildings from fire.Due to the lack of domestic laws, when designing such a complex facility, designers must use foreign laws and rulebooks. Therefore, an example is given of how our neighboring country, the Republic of Croatia, has adopted laws and rulebooks for this type of facilities, following the example of Austria.

When comparing the laws and regulations in force in the Republic of Serbia, concerning the construction of health facilities, and the Republic of Croatia, which has harmonized its laws with EU member states, it is concluded that in the Republic of Croatia the construction of this type of facilities is explained in detail, emphasizing limitations regarding the materials used when constructing buildings. But despite great shortcomings, the Republic of Serbia is also following in the footsteps of the European Union in terms of regulating laws, with the good example of our neighboring country, which has harmonized its laws with EU member states.

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