The Differences Between Standards in Fire Protection - the Case of the Object With the Roof in the Form of Hemisphere

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Fire presents a process of uncontrolled burning and can highly endanger human lives and material properties. Because of that, fire protection must be precise and universal. However, it is not the case in real. There are many different standards related to fire protection with similar, but very often with different rules in fire protection related to the same case. So, what to do in such case, when you have different results and solutions for the same case or problem?? One of the very good ways is to simulate potential problem and apply all standards and compare. This paper was written to present the fire spreading in the object with the roof in the form of hemisphere and arrangement of smoke detectors related to German standard VDE 0833-2, simulated in FDS.

Key Words: *fire, protection, standard, hemisphere, simulation*

1. INTRODUCTION

Fire protection presents very important, serious and precise discipline with strict demands, rules, regulates and similar. The main rule in the fire safety is to predict and eliminate the fire at the early stage. There are determined number of standards dealing with fire and fire protection. These standards have strict rules that must be applied. The most famous standards are EN-European norm, BS-British Standard, NFPA 72- National Fire Protection Association, НПБ 88-2001-Нормы пожарной безопасности (ГОСТ 26342-84), German standard VDE and others. It is an interesting thing that noted standards very often have similar but also and very different rules and demands for similar or identical situations. So, there are logic question that should be asked, what to do when for the same object and same case, standards reference different rules? There are some very specific examples where standards have differences: corridor, ventilation, arrangement of fire detectors in special cases etc. Corridor is, of course, maybe the most distinct example because, at the first step, every standard defines corridor on different way while some standards don't define them at all. The similar thing is for arrangement of smoke detectors in ventilation-some standards don't have such definitions and rules at all. Also, for special cases, almost every single standard has its own rules for the same case. There are many of these cases: object with the no standard geometry, objects with double-perforated ceilings, objects with the ceiling in the form of honey comb, objects with the ceiling with beams, object with the different form of the roof etc [1, 3, 4].

Objects with the roof in different forms present

special cases in the sense of the fire detectors arrangement. The roof form can be realised in different ways: with plane roof (the most of cases), with the roof in the form of arch, with the roof in the form of hemisphere etc. So, in those cases, fire detectors arrangement must be different than in normal cases [4].

The roof in the form of hemisphere presents one of very special cases in the fire protection, in the sense of fire detectors arrangement, because of its form [1].

Related to the European standard EN 54-14, in the case with ceilings and roofs with slopes, heat and smoke detectors must be installed as in the next note. The covering radius of fire detector can be increased for 1% for every of 1° of the slopes, up to maximal 25%. It is little different in the case with roof with more slopes, where below the top of every roof one detector

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should be installed, except in the case that the difference between the lowest and the highest point is smaller than 5% related to the height of the top of the roof up to the ground-in that case roof can be treated as plane ceiling [1, 5].

British standard BS 5839-1 almost identically treats this topic as European standard, except in the cases when the difference between the lowest and the highest point is smaller than 150 mm for heat detectors and when the difference between the lowest and the highest point is smaller than 600 mm for smoke detectors, when the roof can be treated as plane ceiling [1, 6].

Russian standard НПБ 88-2001 (GOST) doesn't analyse the installation of point fire detectors below slope roofs and ceilings. In practice, this standard applies the rules from European and British standards related to this topic. Also, there are slight differences between this standard and German standard in the case of more slopes [1, 7].

Related to German standard VDE 0833-2 for installation of fire detectors in special cases when the roof is present in the different forms, two cases must be distinguished, for roof`s slope up to 20 and over 20. The appliance of these rules is presented on table 1.

Table 1. The distance of smoke detectors in different cases of the roof`s form related to German standard (table source: Blagojević, M. Fire protection systems designing)

Room`s height R_H	Slope of the roof α	
	angle α< 20°	angle α> 20°
	D_L	D_L
up to height of 6 m	mostly up to 0.25 m	from 0.2 m to 0.5 m
from height of 6 m to 12 m	mostly up to 0.4 m	from 0.35 m to 1 m
(from height of 12 m to 16 m)-in the dependence of ambient characteristics (the way of smoke spreading and development)	from 0.25 m to 0.6 m	from 0.5 m to 1.2 m

Also, this standard analysis the installation of point smoke and heat detectors for ceiling in the form of hemisphere, as it is presented on figure 1.

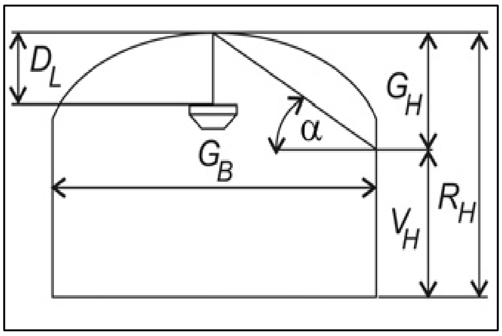


Figure 1 - The installation of smoke detectors in the object with the ceiling in the form of hemisphere (figure source: Fire protection systems designing, Milan Blagojević, 2018).

These objects demand the calculation of angle α marked on figure 1 exactly as it is presented in table 2.

Table 2. Angle α calculation

The relationship between G_H/G_B	angle α
$G_H/G_B \leq 0.2$	$\alpha \leq 20°$
$G_H/G_B > 0.2$	$\alpha \geq 20°$

On figures 1 and in the table 2, G_H presents the height of the circular arch; G_B presents the width of the hemisphere, V_H presents the height of walls or height of the object without ceiling or roof while R_H presents the height of object [1, 8].

Related to American standard NFPA 72, there is a general rule for point detectors that must be installed at list 36 inches (910 mm) from the vertical plane of the top of the roof. There are also more rules in the case of presents of beams below the ceiling [1, 9].

The best rule in fire protection is the prediction. Today, one of the very modern, precise and expedient way for prediction is the use of simulation software and simulation. Simulation software enables precise and safe prediction and have a lot of benefits.

This paper was written to show and present the fire in the special kind of object-object with the roof in the form of hemisphere and arrangement of detectors related to German standard VDE 0832-2, simulated in FDS.

2. SIMULATION SOFTWARE

Simulation software presents very important engineering tool in the solutions of many different problems in many different spheres of science. One of the most famous and used simulation software, related to the fire protection, is FDS with its graphical environment-Pyrosim. Noted simulation software enables huge benefits in smoke and fire spreading in particular object, what is of crucial importance in the sense of fire detectors arrangement. For the purpose of this paper, FDS version 6.8.0 was used, while the version of Pyrosim was 2024.2. It is possible to simulate fire, smoke, extinguish with water or carbon monoxide etc, with numerical and graphical presentation of results.

Huge software possibilities also enable import of complete graphic versions of the objects from some other software specialised for drawing and graphic (in the most cases it is Auto Cad) and different analyses related to fire, smoke, extinguish etc.

Very important note is that Pyrosim and similar simulation software demand strong computer configuration in the sense of hardware. That purports strong processor, lot of RAM memory and strong graphic card. For the purpose of this paper, the laptop HP ZBook Fury G8 was used. This laptop has powerful processor Intel Core i7-11850H, 16 x 2.5 GHz Turbo 16 x 4,8Ghz, 64 GB RAM DDR4 and two graphic cards, Intel UHD and NVIDIA RTX A2000 (6GB VRAM) [10].

An example of simulation software FDS with its graphical environment Pyrosim in the realisation of fire and smoke in the museum is presented on figure 2.

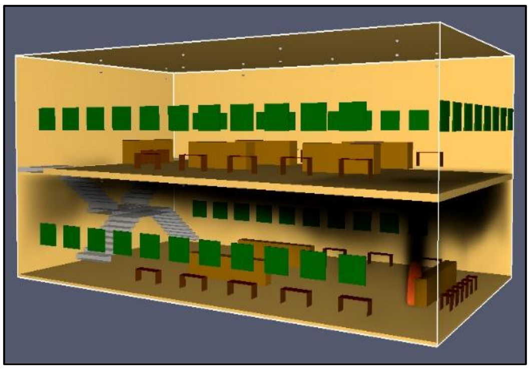


Figure 2 - An example of the fire and smoke spreading in museum

3. METHODOLOGY

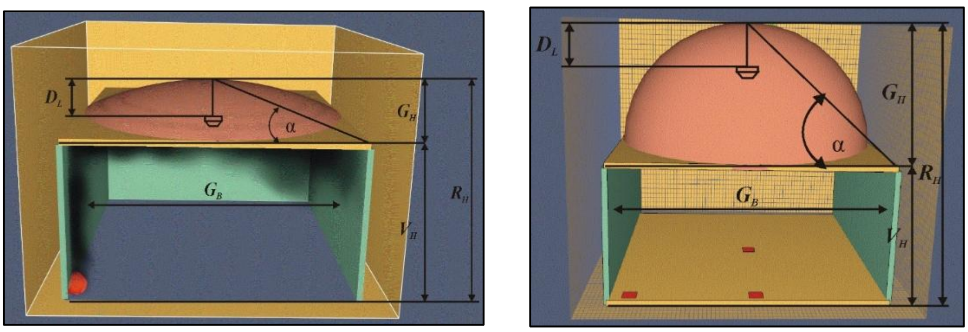
The object simulated in this paper presents the object with the roof in the form of hemisphere. There are many different objects built that have similar roof (mosques, shopping centers, sports halls etc.). The base of the object is square with dimensions 10 m x 10 m. Walls of the object with the ceiling in the form of hemisphere were made from concrete (depth 20 cm). Simulation models-objects were realised with different height of the hemisphere.

There were two different simulation models of the object, related to the height of the hemisphere and angle α. The first simulation model purported an object with $\alpha \leq 20°$ (G_H/G_B=0.1), while the second simulation model purported an object with $\alpha \geq 20°$ (G_H/G_B=0.5). The length of both simulated objects (radius) objects was the same in the horizontal direction (10 m), but in the vertical direction, for the first simulation model, height-radius was 1 m, while for the second simulation model height-radius was 5 m. The heights of the objects were the same for both simulation models (6 m, 10 m and 15 m).

The simulation of fire for both simulation models was realised in the form of burner with dimensions 0.5 m x 0.5 m. The HRRPUA-heat release rate per area of every fire was analysed as slow fire (177 kW/m^2 for 200 seconds), middle fire (744 kW/m^2 for 200 seconds), fast fire (1.876 kW/m^2 for 200 seconds) and ultra-fast fire (quantity of released heat was 7440 kW/m^2 for 200 seconds). Burner's positions for both simulation models were at the corner of the object, at the middle of the side of the object and in the middle of the object. Smoke detectors were located at the same way as it was determined in table 1, related to the height of the object.

No matter for the proper height related to standard, simulation was realised for all three heights (0.25 m, 0.4 m and 0.6 m for the first case and 0.5 m, 1m and 1.2 m for the second case). These heights of the smoke detectors were referenced related to German standard VDE 0833-2. The threshold of the smoke detectors was 3,25 %/m of obscuration. Related to all noted, there were 72 simulations completely for potential every case in this study.

Both realised simulation models with marked dimensions and burner`s positions are presented on figure 3 (a, b).



a) b)

Figure 3 - Simulation models of the object with the roof in the form of hemisphere, with marked dimensions and with smaller angle α and burner at the corner of the object (a) and with bigger angle α and all simulated burner`s positions-at the corner, at the middle of the object and at the middle of the side of the object (b)

4. REALISED SIMULATION RESULTS

All of simulation results, for both simulation cases are presented in tables from 3 to 8. These results purport calculated reaction times of smoke detectors (in seconds) arranged in the object related to German standard VDE 0832-2. Because of the limitations of the paper, only a several figures from different simulation moments are presented on figures 4 and 5 (a, b), for both simulation cases. Green colour in the table marks detector`s height that should be used while red colour in the table marks detector`s heights that shouldn't be used related to German standard VDE 0833-2.

Table 3. Simulation results for objects with arch angle α < 20° and height of the object of 6 m.

Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m
Slow fire	45.9	45.6	45	17	16.8.	16.4	56.5	56.7	65.8
Middle fire	42.6	42.2	40	16.6	16.3	16.1	52	52.3	52.8
Fast fire	36.9	36.5	36	16	15.9	15.3	49	49.2	49.9
Ultra-fast fire	30.3	30.2	30	11.2	11.2	10.6	39	39.3	40.3

Table 4. Simulation results for objects with arch angle α < 20° and height of the object of 10 m.

Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m
Slow fire	52	52	50	35	34.4	33.9	62.9	62.7	62.24
Middle fire	50.3	50	48	22.4	22	20.6	60	59	52.6
Fast fire	42.4	42	40	21.9	21.6	20	50.3	50.1	42.7
Ultra-fast fire	35.3	35	32.4	19.8	19.8	19	39.4	39	37

Table 5. Simulation results for objects with arch angle α < 20° and height of the object of 15 m.

Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m	Height 0.25 m	Height 0.4 m	Height 0.6 m
Slow fire	61	60.2	58.3	52.8	51	50.3	72.4	71.2	69.9
Middle fire	57	53	51.3	39	38	37.5	59	56.3	54.2
Fast fire	50	47.3	45.3	33	34	35	53.7	52.9	51.3
Ultra-fast fire	38	36	35	28.3	27.4	26.3	43.4	42.5	42

Table 6. Simulation results for objects with arch angle α > 20° and height of the object of 6 m.

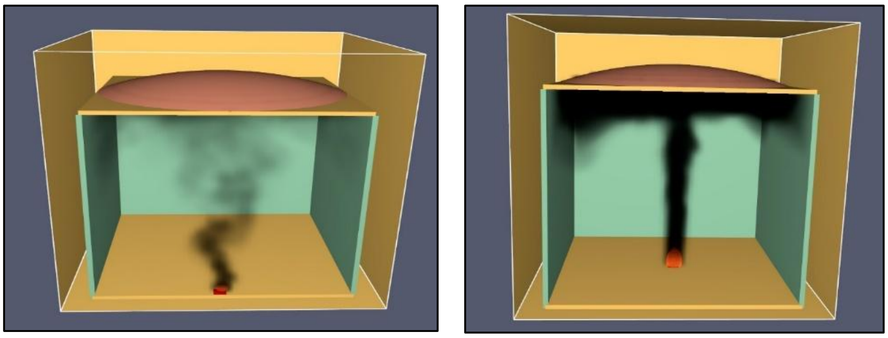
Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m
Slow fire	46	47.4	48.3	23	22	20.7	58.5	59.2	68.5
Middle fire	43.5	43.1	41.9	17.8	15.4	13.3	54	53	56.6
Fast fire	38	38.7	38.9	17	16.7	16	50	51	52.3
Ultra-fast fire	31	32	30.4	13	12.2	11.7	42	43	44

Table 7. Simulation results for objects with arch angle α > 20° and height of the object of 10 m.

Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m
Slow fire	54.6	54.3	51.1	36.2	34.5	32.5	79	79.7	80.4
Middle fire	51	51.5	51.5	23.5	22.2	21.4	65	66.8	67.8
Fast fire	46.4	43.5	44.5	18	17	16	60.2	60.9	62
Ultra-fast fire	36.4	36.1	36.8	19.6	18.9	17.7	50.5	51.8	52.7

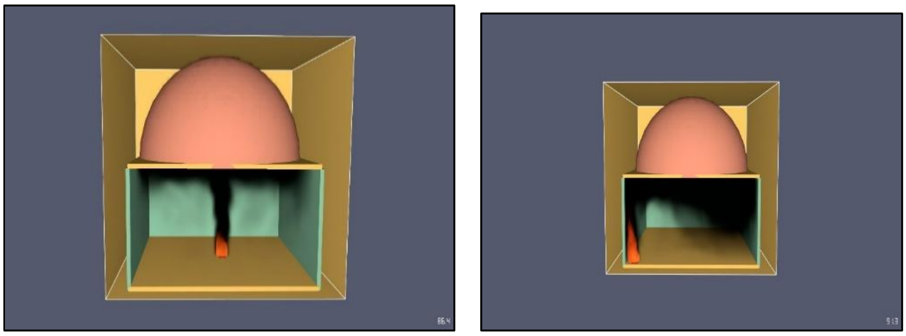
Table 8. Simulation results for objects with arch angle α > 20° and height of the object of 15 m.

Positions of the burner	At the side of the object			In the center of the object			At the corner of the object		
Height of the detector\ fire type D_L	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m	Height 0.25 m	Height 1 m	Height 1.2 m
Slow fire	66.5	67.4	63.3	59.2	59.7	60	81	82.2	83
Middle fire	60	62.7	62.4	41.3	41.8	42.6	70	71.3	72
Fast fire	54	55	55.4	37.3	38.1	38.9	61.4	62.3	63.1
Ultra-fast fire	39	39.5	39.6	30	30.7	31.6	47	48.9	50.3



a) b)

Figure 4 - Simulation moment for the first case and middle fire with burner`s position at the middle of the side of the object (a) and simulation moment for the first case and fast fire with burner`s position in the middle of the object (b)



a) b)

Figure 5 - Simulation moment for the second case and fast fire with burner`s position at the middle of the side of the object (a) and simulation moment for the second case and ultra-fast fire with burner`s position in the middle of the object (b)

5. RESULTS ANALYSES

Simulation results for the first simulation model, where angle α < 20° showed that reaction times for smoke detectors can be pretty different related to the height of the object and related to the burner's position. (tables from 3 to 5). The fastest reaction of smoke detectors was for the case when the height of the object was 6 m and burner was in the middle of the object (10.6 seconds), for ultra-fast fire. The slowest reaction of smoke detectors was for the case when the height of the object was 15 m and burner was at the corner of the object (72.4 seconds), for slow fire. Of course, it was expected because of differences in the object`s height and because smoke spreading was different related to the burner`s position in the middle of the object and in the burner`s position at the corner of the object.

Simulation results for the second simulation model, where angle α > 20° also showed that reaction times for smoke detectors can be pretty different related to the height of the object and related to the burner's position. (tables from 6 to 8). The fastest reaction of smoke detectors was for the case when the height of the object was 6 m and burner was in the middle of the object (11.7 seconds), for ultra-fast fire. The slowest reaction of smoke detectors was for the case when the height of the object was 15 m and burner was at the corner of the object (80.4 seconds), for slow fire.

6. DISCUSSION

What is the most important thing in this study is the fact that standard proper value that must be used, in this case the determined height of hanging of the smoke detector, can be changed with other value that mustn't be used and the results would be almost the same. In every of six tables, from 3 to 8, there are green marked values-values that must be used related to standard and red marked values-values that mustn't be used also related to standard. It is obvious that simulation results showed that differences in reaction times of smoke detectors, between standard proper value of smoke detector`s hanging height are only in few seconds, what is negligible. This results proof that, without mistake, all three values related to standard can be used, no matter on the fire type. Adhering to the standards is mandatory, in legal and technical sense. But this paper shows that in some occasions, other possibilities can be used without mistakes related to safety and reaction speed of alarming. The future investigation will be in the direction to analyses more different standards and to compare realized results. Also, the future investigation will be focused on the fire detectors arrangement in special cases, with the consultation of simulation and artificial intelligence [11-14].

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REZIME

RAZLIKE IZMEĐU STANDARDA U ZAŠTITI OD POŽARA - SLUČAJ OBJEKTA SA KROVOM U OBLIKU HEMISFERE

Vatra predstavlja proces nekontrolisanog sagorevanja i može značajno ugroziti ljudske živote i materijalna dobra. Zbog toga, zaštita od požara mora biti precizna i univerzalna. Međutim, to u stvarnosti nije slučaj. Postoji mnogo različitih standarda koji se odnose na zaštitu od požara sa sličnim, ali vrlo često i različitim pravilima u zaštiti od požara koja se odnose na isti slučaj. Dakle, šta učiniti u takvom slučaju, kada postoje različiti rezultati i rešenja za isti slučaj ili problem? Jedan od veoma dobrih načina je simuliranje potencijalnog problema i primena svih standarda i upoređivanje. Ovaj rad je napisan da bi se predstavilo širenje požara u objektu sa krovom u obliku hemisfere i raspored detektora dima u skladu sa nemačkim standardom VDE 0833-2, simuliran u FDS-u.

Ključne reči: *vatra, zaštita, standard, hemisfera, simulacija*