Simulacija širenja dima u dvostrukim (perforiranim) stropovima

Simulation of smoke spreading in double (perforated) ceilings

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SAŽETAK

Instaliranje detektora za dojavu požara predstavlja veoma odgovoran i važan zadatak u zaštiti određenog objekta od požara. Pravila za postavljanje različitih tipova detektora požara data su odgovarajućim standardima. Ta pravila se ponekad mogu dosta razlikovati od standarda do standarda, iako imaju istu svrhu. To je naročito evidentno za posebne slučajeve postavljanja detektora požara, kao što su stube, hodnici, potkrovlja s preprekama i gredama, kosa potkrovlja, dvostruki stropovi i slično. Velika pomoć za ovakve i slične probleme je upotreba softvera za simulaciju požara. Upotreba softvera za simulaciju požara ima velike benefite u smislu cijene, sigurnosti i zaštite ljudskih života te materijalnih dobara. Ovaj rad je napisan kako bi pokazao simulaciju reakcije javljača dima u dvostrukim (perforiranim) stropovima postavljenim iznad i ispod perforiranog stropa.

Ključne riječi: požar, detektori, perforirani strop, dim, simulacija

Summary

Summary: The installation of fire detectors is a responsible and important task in the fire protection of a structure. The rules for different fire detectors are stipulated in the appropriate standards. Those rules can vary from standard to standard, although their purpose is the same. This is particularly evident for the special positioning of fire detectors, such as in stairwells, hallways, ceilings with obstacles and beams, sloped ceilings, double ceilings and the like. Fire software simulation software has proven to be a valuable tool in resolving such issues. This software has multiple benefits, such as price, safety and protection of human life and property. This paper outlines the results of a simulation of smoke detectors in double (perforated) ceilings, installed above and below the perforated ceiling.

Keywords: fire, detectors, perforated ceilings, smoke, simulation

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UVOD

Introduction

The positioning of fire detectors is very important in fire protection. The primary purpose of detectors is to detect fire and its products at an early stage. They can be classified in several ways, based on different criteria: means of activation, work principle, coverage area, etc. The optimal number of fire detectors, their types and their proper arrangement in a structure has a direct influence on the properly timed reaction of fire detectors. Fire detector arrangement is regulated by official standards, such as BS (British Standard), EN 54 (European norms), NFPA (National Fire Protection Association), НПБ 88-2001 (Нормы пожарной безопасности), VDE 088-2 (Verband der Elektrotechnik; originally the Association of German Electrical Engineers, now the Association for Electrical, Electronic & Information Technologies) and others. Although the purpose of proper fire detector arrangement is to detect fire and its products at an early stage, there are many differences between the standards to address the same issues. These differences are especially evident for special cases of arranging fire detectors, such as in hallways, ceilings with obstacles and beams, sloped ceilings, double ceilings, hallways, rooms with ventilation installations, rooms with electrical and other equipment, etc. Generally, the rules for fire detector arrangement in special cases are modifications of the main rules based on spatial dimensions.

INTERPRETACIJE STANDARDA ZA PERFORIRANE STROPOVE – *Interpretation of standards for perforated ceilings*

Perforated ceilings are one form of ceiling construction. There are two possible ways to install fire detectors in this case: above or below the perforated ceiling. In most cases, the holes in the perforated ceilings are too small, suggesting that there is no ventilation that would spur fire development, and so fire detectors in such cases are positioned below the ceiling (Blagojević, 2015).

According to the EN 54-14 standard (which is the same as British Standard BS 5839-1), detectors can be positioned above perforated ceilings in the following cases:

- more than 40% of the surface of each square meter of ceiling space is perforated,
- every hole in the ceiling is larger than 10 mm x 10 mm, and
- ceiling thickness is not greater than three times the minimum dimension of the holes in the ceiling.

This standard also notes that in some cases, fire detector installation should be considered for spaces that are not limited with ceiling, i.e. without a stratification effect (BS 5839-1, 2002; EN 54, 2015).

The German standard (VDE 0833-2) considers fire detectors installation below the perforated ceiling in the same way as the European standard, with the following adaptation to the first criteria:

- the detector can be found inside the double ceiling (above perforations) in the case when the space of perforated ceiling openness is greater than 75% in relation to the complete area of the ceiling.

If the noted conditions are realized, there is no need for detector installation below the perforated ceiling. Of course, the type of fire, fire load, degree and influence of ventilation on smoke movement through the perforated ceiling also should be considered. This standard additionally considers different structural solutions in the room, such as lowered ceilings sections, platforms, bars and similar. Important factors for an additional number of detectors are the length, width and space of platform. When several platforms are positioned one above the other, a smoke or heat detector should be positioned at the lowest level (DIN VDE 0833-2).

According to the Russian standard (НПБ 88-2001), the installation of fire detectors in double ceilings should be treated in the same manner as installation in narrow areas, such as hallways, with a width less than 3 m and height of 1.7 m. In that case, the maximum distance between detectors can be increased by 1.5 times (HNB 88-2001).

According to the American standard (NFPA 72), areas in double ceilings and between ceiling layers should be considered separately. Furthermore, this standard states that fire detectors in double ceilings must not be used as a replacement for detectors intended to supervise the room (NFPA 72, 1999).

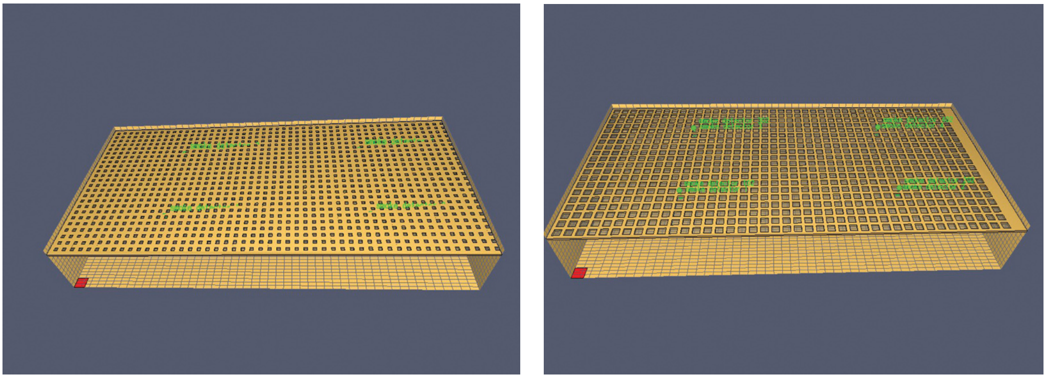
It is important to note that terms for double ceilings vary among standards: EN 54-14 and VDE 0833-2 use the term *false ceiling*, British standard BS 5839-1 uses the term *perforated ceiling,* while NFPA 72 uses the term *suspended ceiling.*

The objective of this paper is show a simulation of smoke detector reactions installed above and below a perforated ceiling, in relation to the degree of ceiling perforation.

SIMULACIJSKI MODEL -*Simulation model*

The simulation model was created in PyroSim software, version 2016. This software is specialized for fire simulation, fire and smoke development, determination of fire detectors reaction times and the like, and it is the graphical user interface for the Fire Dynamics Simulator (FDS).

The simulation model applied here represents a room 25 m x 12 m x 4 m in size, with a double ceiling. The degree of peroration was set at 16%, 43.7% and 80.5%. The fire source was modelled as a burner with dimensions of 0.7 m x 0.7 m with a heat release rate per area (HRR) of 5, 25 and 50 kW/m^2. The burner was positioned were in the corner of the room and in the middle of the room. The distance between the perforated ceiling and top ceiling was 40 cm. The threshold of smoke detectors was 3.25%/m of obscuration. Figure 1 shows the simulation room with perforated ceiling and perforation degree of 16 % (1200 holes with dimensions 0.2 m x 0.2 m) (a), the same room with ceiling with a perforation degree of 43.7% (820 holes with dimensions 0.4 m x 0.4 m) (b), smoke detector arrangement and burner position in the corner of the room (Thunderhead engineering, 2012).

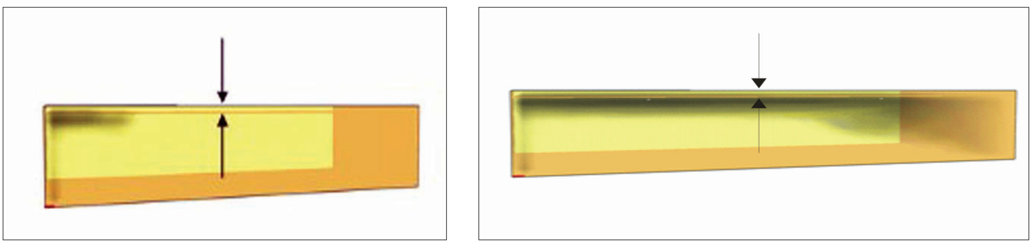


Slika 1. Simulacijski objekt s perforiranim stropom (stupanj perforiranosti od 16 %) (a) i (stupanj perforiranosti od 43,7 %) (b) i rasporedom detektora dima u PyroSim softveru

Figure 1. Simulation structure with perforated ceiling (perforation degree of 16%) (a) and (perforation degree of 43.7%) (b) and smoke detector arrangement in PyroSim software

SIMULACIJA - *Simulation*

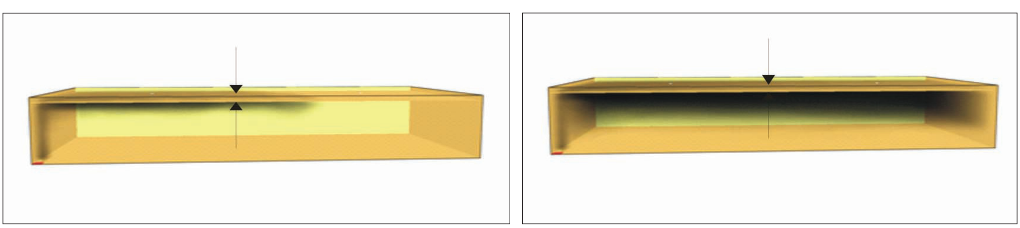
Simulations in this paper were realized on laptop (Lenovo B51-30-80LK00H6YA with Intel Pentium N3700 1.6 GHz (2.4 GHz), four cores, TDP 6W, 4GB of DDR3L memory at 1600MHz). It is recommended that the computer used for simulation should have a strong processor and sufficient RAM memory, as these kinds of simulations use much of the hardware resources. The simulation time was set to 300 seconds for every simulation. According to the determined simulation time, complete numbers of elements in the simulation (walls, burners, detectors, fans and similar) and numerical and graphical characteristics of simulation (e.g. number of particles), the complete time needed for the simulation could take from hours to days. The examples of simulations are presented in Figures 2 to 9, while the complete simulation results are shown in Figures 10 and 11. The arrows in Figures 2 to 9 show the space between the ceiling and perforated ceiling.



a) b)

Slika 2. Simulacijski trenutak poslije 26.7 sekundi (a) i poslije 295.5 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 5 kw/m^2 i stupanj perforiranosti od 16 %

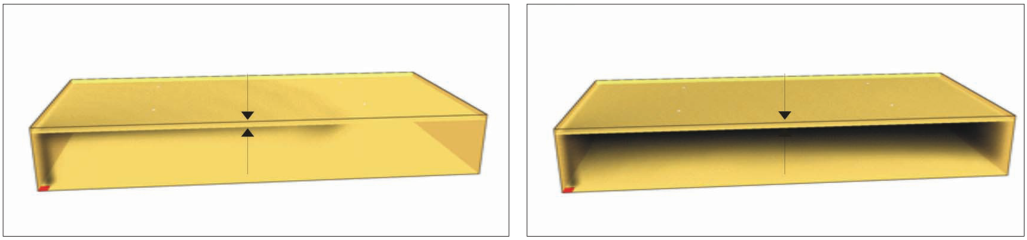
Figure 2. Simulation after 26.7 seconds (a) and after 295.5 seconds from the start of simulation, for the first burner position, burner HRR of 5 kw/m2 and perforation degree of 16%



a) b)

Slika 3. Simulacijski trenutak poslije 56.1 sekundi (a) i posle 297 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 25 kw/m^2 i stupanj perforiranosti od 16 %

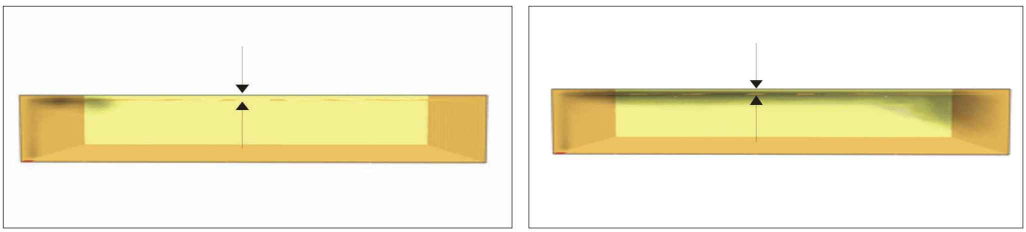
Figure 3. Simulation after 56.1 seconds (a) and after 297 seconds from the start of simulation, for the first burner position, burner HRR of 25 kw/m2 and perforation degree of 16%



a) b)

Slika 4. Simulacijski trenutak poslije 49.2 sekundi (a) i poslije 297.9 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 50 kw/m^2 i stupanj perforiranosti od 16 %

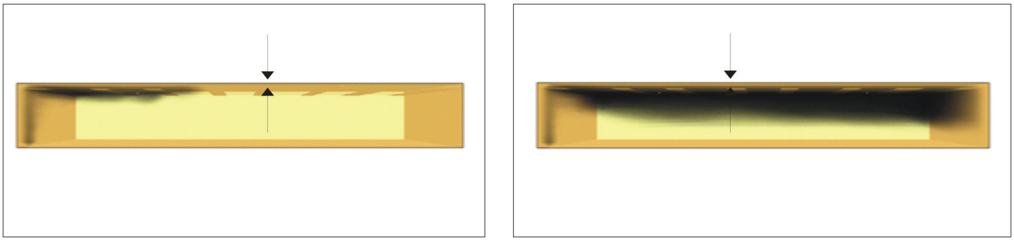
Figure 4. Simulation after 49.2 seconds (a) and after 297.9 seconds from the start of simulation, for the first burner position, burner HRR of 50 kw/m^2 and perforation degree of 16%



a) b)

Slika 5. Simulacijski trenutak posle 33 sekundi (a) i poslije 297 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 5 kw/m^2 i stupanj perforiranosti od 43,7 %

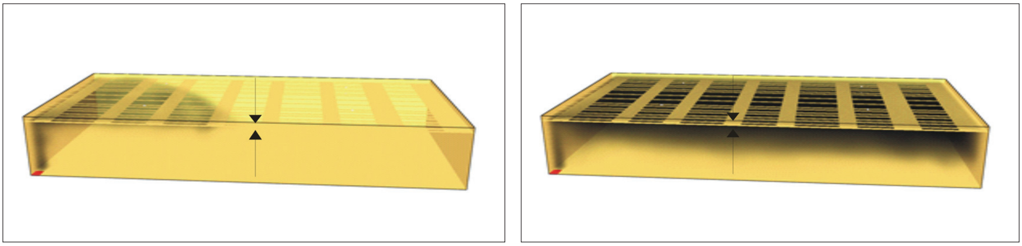
Figure 5. Simulation after 33 seconds (a) and after 297 seconds from the start of simulation, for the first burner position, burner HRR of 5 kw/m^2 and perforation degree of 43.7%



a) b)

Slika 6. Simulacijski trenutak poslije 37.8 sekundi (a) i poslije 294 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 25 kw/m^2 i stupanj perforiranosti od 43,7 %

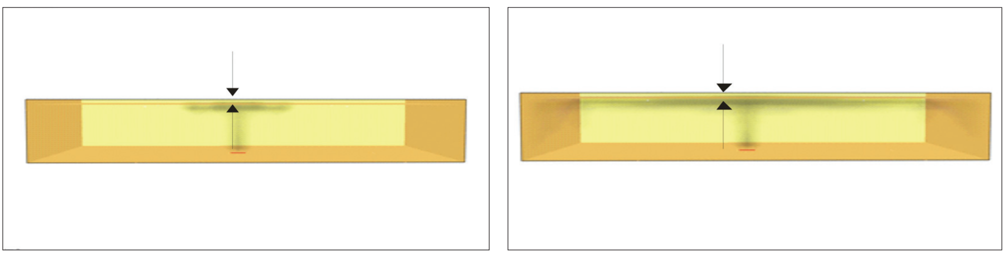
Figure 6. Simulation after 37.8 seconds (a) and after 294 seconds from the start of simulation, for the first burner position, burner HRR of 25 kw/m^2 and perforation degree of 43.7%



a) b)

Slika 7. Simulacijski trenutak poslije 35.7 sekundi (a) i poslije 298.5 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 50 kw/m^2 i stupanj perforiranosti od 43,7 %

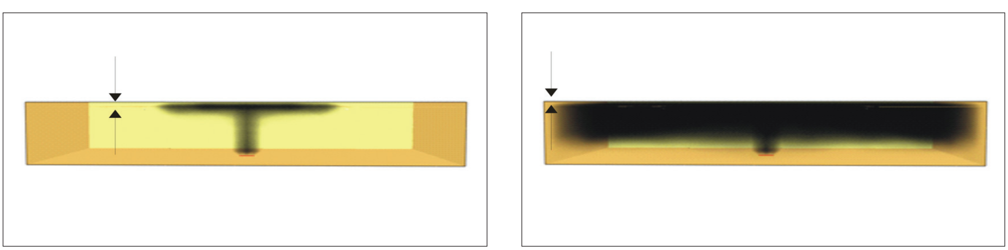
Figure 7. Simulation after 35.7 seconds (a) and after 298.5 seconds from the start of simulation, for the first burner position, burner HRR of 50 kw/m^2 and perforation degree of 43.7%



a) b)

Slika 8. Simulacijski trenutak poslije 29.4 sekundi (a) i poslije 132.9 sekundi od početka simulacije, za prvu poziciju grijača, HRR grijača od 5 kw/m^2 i stupanj perforiranosti od 80,5 %

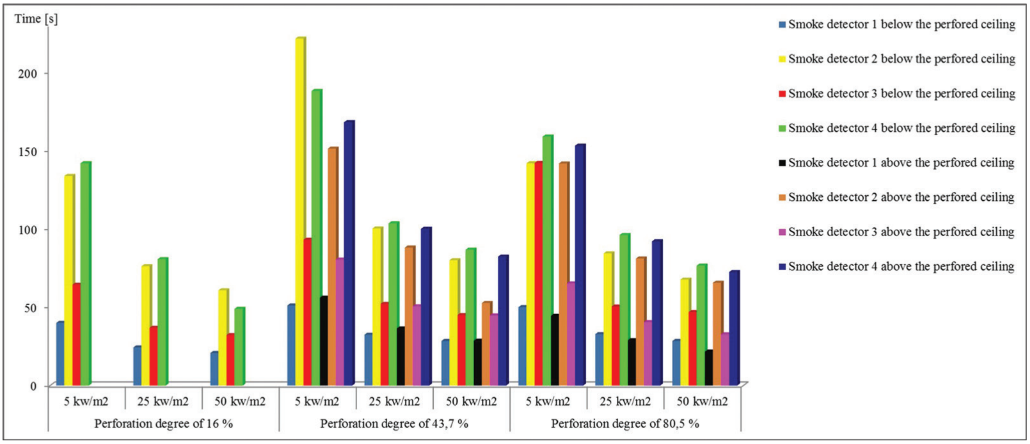
Figure 8. Simulation after 29.4 seconds (a) and after 132.9 seconds from the start of simulation, for the first burner position, burner HRR of 5 kw/m^2 and perforation degree of 80.5%



a) b)

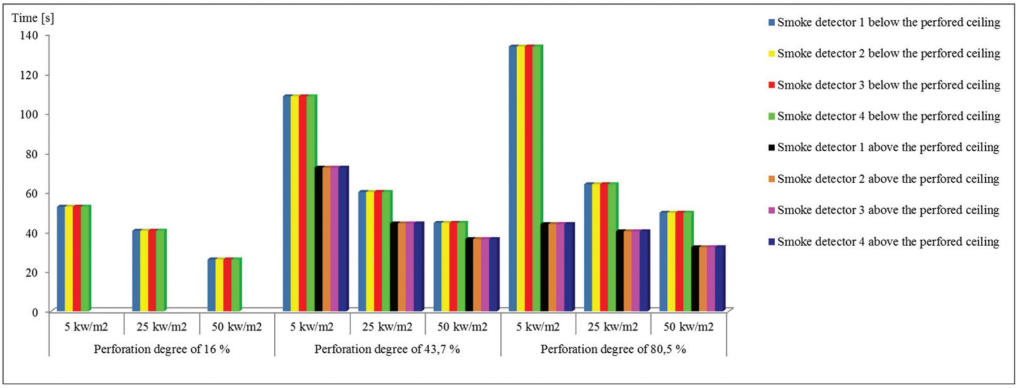
Slika 9. Simulacijski trenutak poslije 22.2 sekundi (a) i poslije 289.8 sekundi od početka simulacije, za drugu poziciju grijača, HRR grijača od 50 kw/m^2 i stupanj perforiranosti od 80,5 %

Figure 9. Simulation after 22.2 seconds (a) and after 289.8 seconds from the start of simulation, for the second burner position, burner HRR of 50 kw/m^2 and perforation degree of 80.5%



Slika 10. Kompletni simulacijski rezultati za sva tri stupnja perforiranosti, sva tri HRR grijača i prvu poziciju grijača

Figure 10. The complete simulation results for all three perforation degrees, all three burner HRRs in the first burner position



Slika 11. Kompletni simulacijski rezultati za sva tri stupnja perforiranosti, sva tri HRR grijača i drugu poziciju grijača

Figure 11. The complete simulation results for all three perforation degrees, all three burner HRRs and the second burner position

ANALIZA REALIZIRANIH REZULTATA – *AAnalysis of results*

An obvious limitation of the paper is the inability to present all the simulation figures. For example, there were two burner positions (in the corner and in the middle of the room), with three burner HRRs of 5, 25 and 50 kw/m2, and three perforation degrees of 16%, 43.7% and 80.5%. Given the presumption that each simulation should be presented with a minimum of 4 figures, this would imply the need for 72 figures for a complete presentation, which is unreasonable for such a paper. Also, it would take 144 diagrams to present the dependence of obscuration [%/m] from time [seconds] for every smoke detector, for both burner position, for all three burner HRRs, and for all three perforation degrees.

Figure 10 shows the results for the first burner position. In the case of a 16% perforation degree, all four smoke detectors above the perforated ceiling did not react for 300 seconds. For the two other perforation degrees, all smoke detectors reacted; four smoke detectors below and four smoke detectors above perforated ceiling. The reaction times for smoke detectors above the perforated ceiling were shorter than for those below the perforated ceiling (for the 43.7% perforation degree), except in the case of smoke detectors marked as 1 and 01 (smoke detectors below the ceiling were marked as 1, 2, 3 and 4 while smoke detectors above ceiling were marked as 01, 02, 03 and 04 as shown in Figures 1a and 1b). The differences in detectors positioned above and below the ceiling were even smaller for the 80.5% perforation degree, also with the exception of smoke detectors 1 and 01.

Figure 11 presents similar results for the second burner position. Here also, all four smoke detectors above the perforated ceiling did not react for 300 seconds with a perforation degree of 16%. For the two other perforation degrees, all smoke detectors reacted; four smoke detectors below and four above the perforated ceiling. The greatest difference between reaction times for smoke detectors above and below the perforated ceiling was for the perforation degree of 80.5% and HRR of 5 kw/m^2. By comparing Figures 10 and 11, it can be seen that the reaction times for all detectors were shorter when the burner was positioned in the middle of the room (second burner position). Also, the reaction times for detectors above or below performed ceiling were almost the same in every simulation case where the burner was positioned in the middle of the room, as all smoke detectors were equally distant from the burner.

ZAKLJUČAK

Conclusion

These results generally confirmed the standard references. It can be seen that a smaller perforation degree (16%) prevents smoke from filling the space above the perforated ceiling fast enough so that the smoke detectors above the perforated ceiling can react. For the other two perforation degrees (43.7% and 80.5%), each smoke detector reacted, both above and below the perforated ceiling. However, predicting the limitations of perforation degree is difficult. This depends on many different factors, such as structure size and shape, its contents, fire type, arrangement of detectors, detectors types, etc. Simulation software is a useful tool to predict such factors in a fast, inexpensive and, most importantly, safe way for life and property. The great benefits of simulation software make this an invaluable and mandatory engineering tool in fire protection. For example, usage of simulation software makes it possible to test the spread of fire and smoke different double ceilings with different perforation degrees, different burner HRRs, different burner positions in the structure, different fire types, different ambient conditions, and different elements that structure consists, and more (Jevtić, 2014; Jevtić, 2015).

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