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SIMULATION OF EVACUATION –THE CASE OF ELECTROTECHNICAL SCHOOL LABORATORY SECTION

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Abstract. *One of the most important tasks in designing fire protection systems is the evacuation. This is especially important for residential objects and other objects with great number of occupants, such as schools, hospitals, etc. This paper presents the simulation results of evacuation in the laboratory section of the Electrotechnical school „Nikola Tesla“ in Niš. The programme used for the simulation of evacuation was Pathfinder.*

Key words: *Evacuation, Fire, Simulation*

1. INTRODUCTION

The term evacuation generally refers to the safest, shortest and fastest way of movement of people, animals and material properties from endangered object or location to the secure place. The causes of evacuation could be different: fire, earthquake, overflow, etc. Depending on to the cause of evacuation, the proper design strategy can be developed. The explorations in the field of evacuation in case of fire started in the late seventies of the 20th century, and they were triggered by several catastrophic fires, where one of the worst was in the workshop in Brussels with 300 people killed. The evacuation involves certain predetermined paths that are the safest and the fastest possibilities to get to a safe area.

Evacuation design involves detailed knowledge about the building and the possibilities for development and propagation in an object. For example, the development of fire is presented in the ISO 834 standard, where the temperature at a specific moment could be read. According to this standard, the temperature after 30 minutes is 822 °C, after 60 minutes the temperature is 925 °C and after 120 minutes the temperature is 1029 °C. The presence of smoke is unavoidable part of fire and according to the object purpose, smoke could be composed of many different components such as carbon dioxide,

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carbon monoxide, methane, sulfur products, etc. It is well known fact that before death, man can spend about five minutes in fire and smoke. These facts are very important in order to incorporate proper materials in buildings, especially at the locations which could be primarily exposed to fire.

A qualitative presentation of fire according to the time of propagation shows that three stages in fire propagation could be distinguished: the fire development stage (development from ignition to the “flashover”), the fully developed fire stage and the calming fire stage. The term “flashover” involves the fire overtaking all combustible materials in an object or a room. All these stages differ for each object and their purposes. According to the above mentioned facts, it can be concluded that fire is a very complex issue and that it is necessary to know the exact nature of fire in order to design the effective, safe and quick evacuation route.

Evacuation routes are designed as primary and secondary. Primary evacuation route is most frequently a route for normal communication inside the building. For example, these routes could be stairs, hallways, corridors and other surfaces used for communication in the building or on a separate floor. Their dimensions differ, depending on the type of the building. These routes are used by fire services in case of fire. The secondary routes depend on the building’s purpose. These routes most frequently involve the evacuation using windows, roofs, etc. Both types of evacuation routes must satisfy certain standards and demands in terms of the number of people, type and purpose of the building, speed of people moving, time necessary for evacuation, etc. [1,2]

This paper has been written to show the possible real situation in the building occupied by a lot of pupils (occupants), randomly located in the laboratory section of the Electrotechnical school ”Nikola Tesla” in Niš.

2. SIMULATION MODEL

One of the best ways to check the accuracy and correctness of the evacuation route project is simulation. Pathfinder is an agent-based egress and human movement simulator. Pathfinder provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis. The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data (e.g. FDS geometry).

Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator, but are represented implicitly because occupants cannot move in places where no navigation mesh has been created. Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow. Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between the stairways and the connecting doors. Occupants are modeled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc).

Pathfinder supports two movement simulation modes. In "Steering" mode, doors do not act to limit the flow of occupants; instead, occupants use the steering system to maintain a reasonable separation distance. In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density. Simulator users can freely switch between the two modes within the Pathfinder user interface and compare answers.

It can be seen that this simulator provides lot of possibilities that can be used. One particularly appropriate is importing files created in 3D CAD, FDS and PyroSim. These files have their own geometry which can be used in Pathfinder and significantly save time needed to complete the evacuation and fire design. The imported geometry is sent as-is to 3D Results, resulting in a clean and fast graphical representation of the data [6].

The first step is to create the proper simulation model. For the purpose of the investigation in this paper, a simulation model created in PyroSim was imported in Pathfinder simulator. This model was created according to its real dimensions and objects inside it. The laboratory section of the Electrotechnical school “Nikola Tesla” occupies three floors and ground surface of about 708,05 m^2(40,46m x 17,5m). On the first floor of the laboratory section, there are several laboratories, staff office, carpenter room, canteen, pupils’ club and a room with refrigeration devices. On the second and the third floor, there are laboratories only. Taking into account that the Electrotechnical school “Nikola Tesla” in Niš is the secondary vocational school with more than 800 pupils and more than 100 employees, the number of persons in laboratory section of the school is always between 40 and 120 per floor. Persons could be positioned strictly in the laboratories (course time), or randomly on the floors (pause time). The simulation was carried out in both cases. The implied speed of persons was 1.2 m/s. The implied behavior of persons was to leave the object through the shortest route to the exit. The laboratory part of the Electrotechnical school “Nikola Tesla” and its simulation model in PyroSim are presented on Figures 1 and 2 [7].

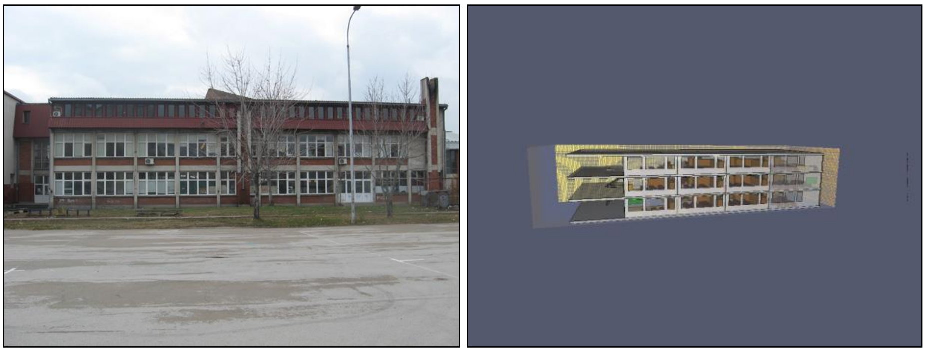

Fig. 1 Laboratory section of the Electrotechnical school “Nikola Tesla” in Niš (left) and its proper simulation model in PyroSim (right)

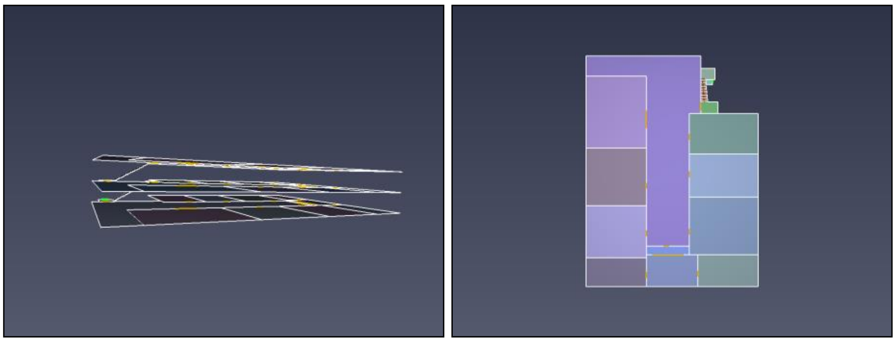

Fig. 2 Simulation model in Pathfinder-side view (left) and above view (right)

In Figure 2, it can be noticed that there are no walls, doors, chairs and desks, only their contours with the aim to make occupants and routes visible. In the same model, different occupants' speed can be analyzed which could have a great influence on overall evacuation time.

3. SIMULATION

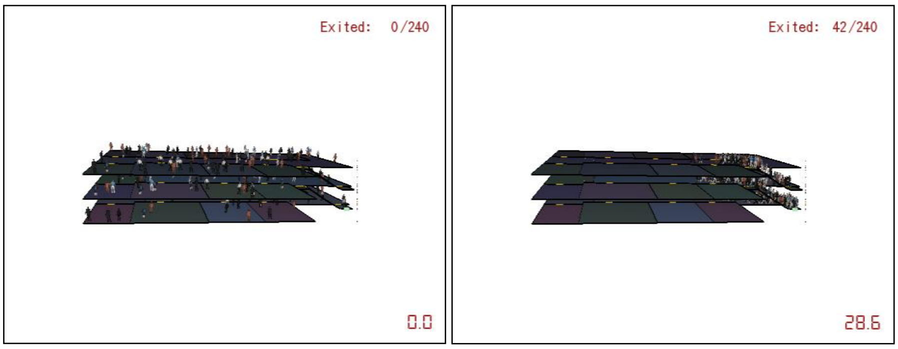

Fig. 3 An example for simulation of 80 randomly placed persons at the start (left) and in 28.6 seconds (right)

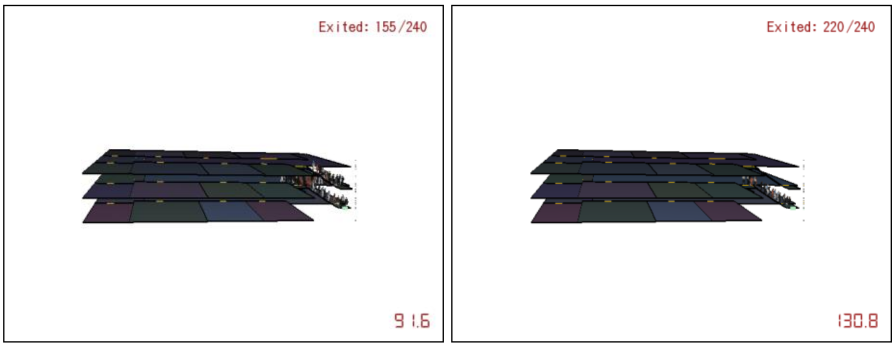

Fig. 4 An example for simulation of 80 randomly placed persons in 91.6 seconds (left) and in 130.8 seconds (right)

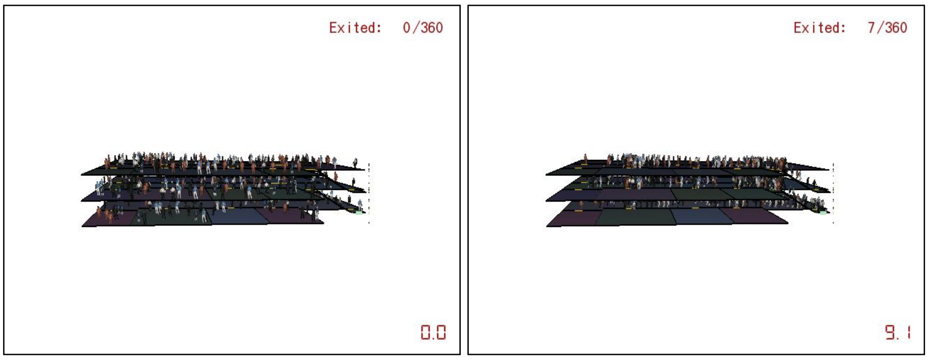

Fig. 5 An example for simulation of 120 randomly placed persons at the start (left) and in 9.1 seconds (right)

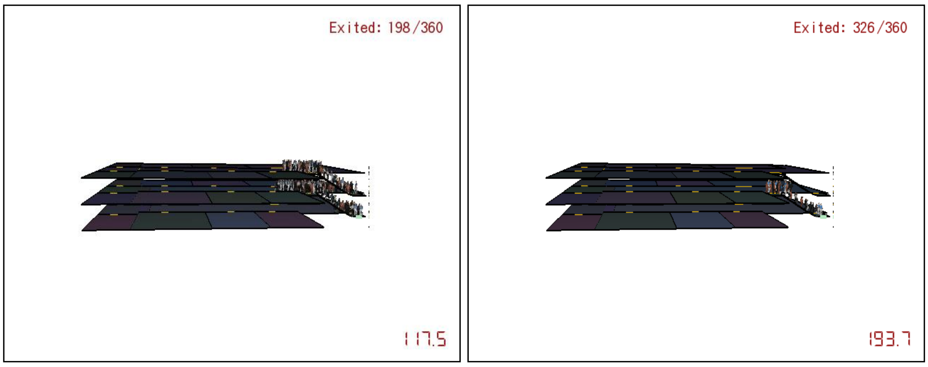

Fig. 6 An example for simulation of 120 randomly placed persons in 117.5 seconds (left) and in 193.7 seconds (right)

Figures from 3 to 6 show determined simulation time moments, in case with 80 occupants per floor (240 occupants total) and in case with 120 occupants per floor (360 occupants total), where the occupants in both cases were randomly positioned. It is important to note that simulation itself does not take much time (every simulation lasted approximately 5-7 minutes), unlike the design of the school laboratory part in PyroSim which is rather time-consuming.

4. The simulation Results

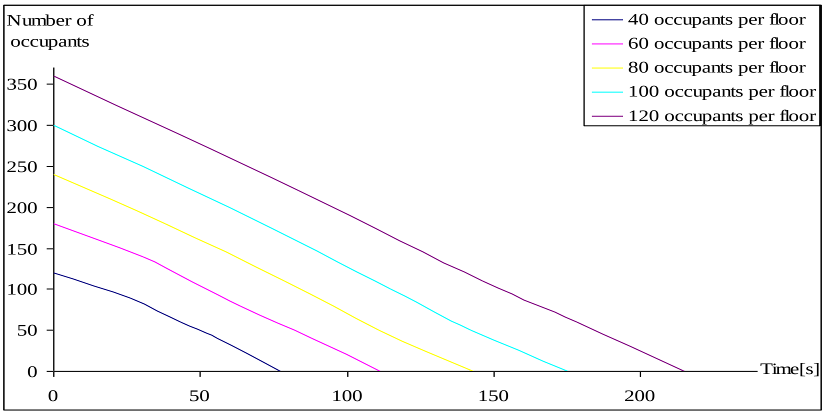

Fig. 7 Number of time-dependent occupants in case of randomly positioned occupants

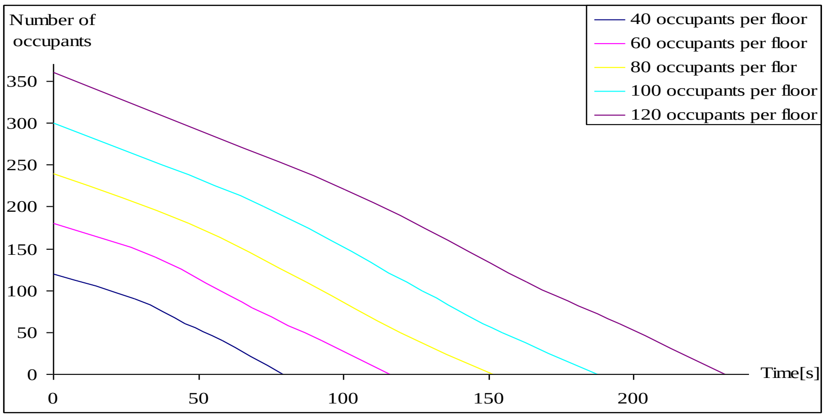

Fig. 8 Number of time-dependent occupants in case of laboratory-positioned occupants

5. Disscussion and Conclusion

Figures 7 and 8 show the number of time-dependent occupants in case when the occupants were randomly positioned and in case where the occupants were positioned in the laboratories. These two cases were appropriate to the real-life situations - the occupants (pupils) were on break and occupants were attending classes. As it was expected, the simulation showed that evacuation times were slightly different; if occupants (pupils) were attending lectures, they would need more time for evacuation (231.7 seconds for 120 occupants-pupils per floor), unlike the occupants (pupils) who were on break (214.8 seconds for 120 occupants-pupils per floor). The shortest simulated time was in case when the occupants (pupils) were randomly positioned (40 occupants-pupils per floor) and it was 77 seconds. According to the speed of the occupants-pupils (1.2 m/s), it can be concluded that calm and cool pupils could exit the building (laboratory section of the school) in a relatively fast and safe manner. The primarily evacuation route (stairs and halls) was strictly determined which is another positive fact in case of eventual evacuation from the building (school laboratories). It is also important to note that the evacuation time and route could be different if a laboratory or other room in school were overtaken by fire, which could be the subject of further research. Also, the same thing could be analyzed for the evacuation time according to the occupants' speed. In order to provide valid data to compare with, the real measurements were carried out in three cases (20 pupils per floor, 40 pupils per floor and 60 pupils per floor randomly positioned). The measured results are presented in Figure 9.

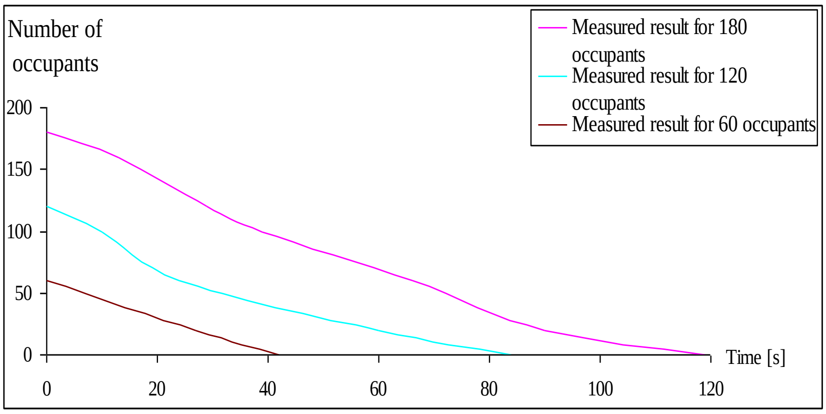

Fig. 9 Number of time-dependent occupants in case of randomly positioned occupants

These results showed slight difference of simulation results, due to many reasons - speed of pupils, their behavior and the like. The results also confirmed that the simulation model and realization of the simulation scenarios were done correctly.

The term evacuation could involve many tasks and potential situations which are not related to fire only. The design of the evacuation routes with complete technical references for fire protection is very complex and hard task. There are a lot of different parameters that should be calculated and estimated in order to ensure safe and fast leaving of the building. The programmes such as Pathfinder are of great help and assistance in solving these problems [3-5].

REFERENCES

1. Blagojević, M., *Alarm systems*, Faculty of occupational safety, Niš, 2011.
2. Bobinec Naprta, D., *Fire and evacuation*, script manual, Zagreb.
3. http://www.aurora-il.org/fireprevention/commercial/evacuationplan.php
4. http://www.firesafe.org.uk/fire-emergency-evacuation-plan-or-fire-procedure/
5. Kmjetin, S., Drpić, M., Milutinović, S., Lukić, R., Kleut, N., *Technical recommendation for fire protection of residential, business and public buildings,* Federal Standardization College, Beogrd, 2002.
6. Thunderhead, Pathfinder Exmple Guide, 2012.
7. Thunderhead, *PyroSim Exmple Guide*, 2012.

SIMULACIJA EVAKUACIJE-SLUČAJ LABORATORIJSKOG DELA ELEKTROTEHNIČKE ŠKOLE

Jedan od najvažnijih zadataka prilikom projektovanja sistema za zaštitu od požara je evakuacija. Ovo je posebno važno za stambene objekte i druge objekte sa velikim brojem ljudi, kao što su škole, bolnice itd. Ovaj rad predstavlja rezultate simulacije evakuacije laboratorijskog dela Elektrotehničke škole „Nikola Tesla" u Nišu. Program koji je korišćen za simulaciju evakuacije je Pathfinder.

Ključne reči: *evakuacija, požar, simulacija*