

SIMULATING BUILDING EVACUATIONS WITH A MODEL

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ABSTRACT

A computer-model is used to simulate the evacuation of the occupants in a building. The aim of the simulations is to establish an equal level of fire safety in accordance of the building regulations. Simulations can also be used to optimise the design of the escape routes (numbers of exits, dimensions of staircases). Most of the simulations are applied with more complex buildings (for instance “High rise buildings” (approximately more than 15 stories), cinema’s, discotheques, shopping centres). Comparing the results from an evacuation-simulation with the results from a smoke model calculation provides an excellent insight to the safety of the designed escaping possibilities.

INTRODUCTION

In the Netherlands the building regulations are prescribed in the “Bouwbesluit” (2003). One of these requirements is the maximum walking distance within a smoke compartment to the nearest exit and the minimum exit-width of this compartment. The intention of this requirement is to prevent people getting injured or even die by staying too long in a room filled with smoke. The maximum allowed walking distance to an exit is based upon the numbers of people in that smoke compartment. Generally this requirement is suitable for the average buildings (such as offices), but in some more specific cases (e.g. theatres, cinema’s and exhibitioncentres) this basic principle isn’t suitable.

If you want to deviate from the given requirement, you have to prove that your solution is having (at least) an equal level of safety.

To demonstrate that the chosen solution complies with the given requirements, we developed a fire safety concept which combines the results of a computer model for evacuations and a dynamic computer model for the calculation for the smoke and heat production in a room.

SITUATION CHURCH

Figure 1 presents the floor plan of a church. The seats are permanently fixed on the floor (pews from oak wood). The maximum walking distance to an exit is approximately 35 m (maximum allowed walking distance according to the Dutch building regulations is 30 m) the fire department also limited the maximum allowed visitors to 700 persons, based upon the total width of all exits of the church (the desired number of visitors is 1.600 persons). Because the monumental character of the church, it isn’t possible to create extra exits or smoke compartments.

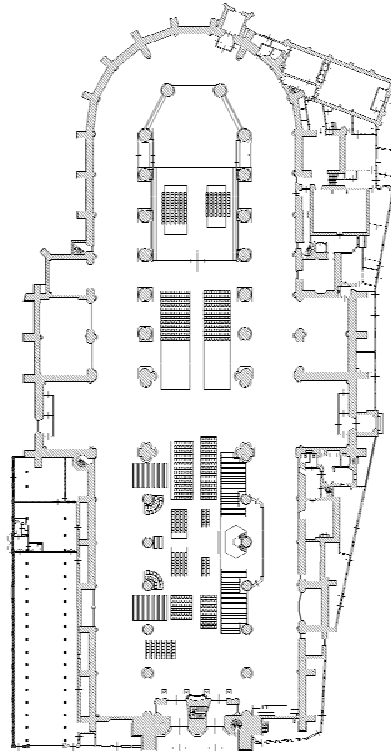


Figure 1: Floor plan of a church.

SIMULATION

Overview

To prove that the church possesses a certain level of fire safety itself, we have chosen to combine the results of an evacuation simulation model and the results of smoke calculations.

The smoke production of a fire in a room can be calculated with a computer model that's developed at our company. The calculation method is based on the Dutch standard NEN 6093 and the TNO-report "richtlijn vultijdenmodel grote brandcompartimenten".

These calculation models calculate the transient conditions that take place during the spread of a fire, these conditions are (see e.g. "achtergronden vultijdenmodel grote brandcompartimenten", 1996, NEN 6093, 1996, "richtlijn vultijdenmodel grote brandcompartimenten", 1996, "rookafvoer uit hoge ruimten; ontwerp / rekenmethoden", 1991)

- The size of the fire;
- The smoke production of the fire (included the mixing of the smoke with "fresh" air);
- The smoke temperature;
- The optical density of the smoke;
- The thickness of the smoke layer.

The data that is needed for the calculations are:

- Dimension of the room ($l*w*h$);
- Openings in the walls and the ceiling;
- The thermal properties of the walls and the roof (because these are cooling down of the smoke layer).

The parameters which are used to calculate the development of the fire are:

- The speed of firespread^{*1};
- The rate of heat release of the fire^{*1}.

^{*1} based on the materials and their behaviour in the church (e.g. oakwood chairs)

After each time interval (mostly 0,1 sec) the energy/mass-balance is solved to determine the final fire and smoke spread in the time.

The results of the calculations are made visible in graphs.

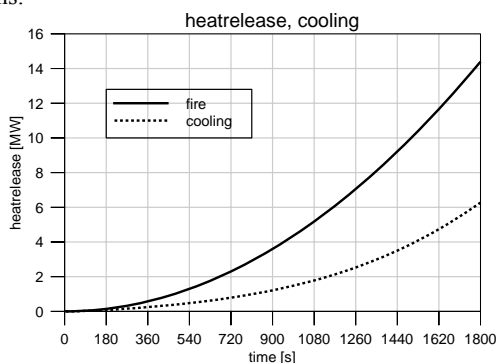


Figure 2: heat release of the fire, cooling down of the smoker layer and eventually the smoke exhaust ventilation

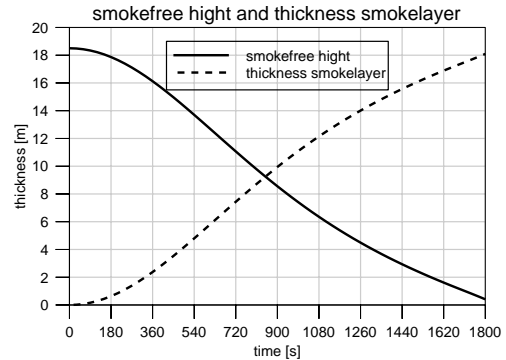


Figure 3: Smoke free height in the room and the thickness of the smoke layer.

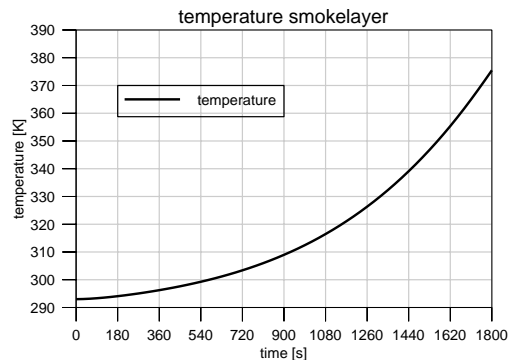


Figure 4: Smoke layer temperature.

Mostly more calculations need to be made for one room. The representative calculation is the calculation that reaches one of the critical criteria at the shortest time.

The criteria for a safe escape are (see e.g. "vluchten bij brand uit grote compartimenten: bepalingsmethode voor veilig vluchten", 1997):

- The smoke free height is less than 2,5 m¹ (above floor level);
- The smoke layer temperature exceeds the temperature of 200°C (473 K) (above 473 K cellular material will reach its flashpoint, which can lead to a flash-over situation);

30 seconds after **one** of the above criteria has been reached, the escape route is blocked by the effects of the fire (based on the assumption that people can walk 30 seconds without breathing).

With the used smoke calculations it's now possible to predict the time that's available for escaping the room in case of a fire.

To assess if the given time by the smoke calculations is enough for the occupants to leave the room (= smoke compartment), we used evacuation simulations to calculate the time that the occupants need to leave the room.

For the evacuation simulations we used Simulex from IES4D from Edinburgh Scotland. This program models the escape movement of each individual occupant through the building. The walking speed is assessed independently for each person. The walking speed depends of the individual "basic" walking speed of this person, and the near surrounding obstacles (i.e. walls) and people near the specific person (see e.g.: Olsson, 1998, Thompson, 1995, Thompson, 1996, Thompson, 1995.)

The floor plans of the church have been used to create the Simulex model. Because the average visitor of the church is mostly an elderly person, the occupants in the model are given the properties of elderly persons.

Figure 5/9 represent the evacuation simulation (time interval 60 seconds). The dots are the occupants in the church

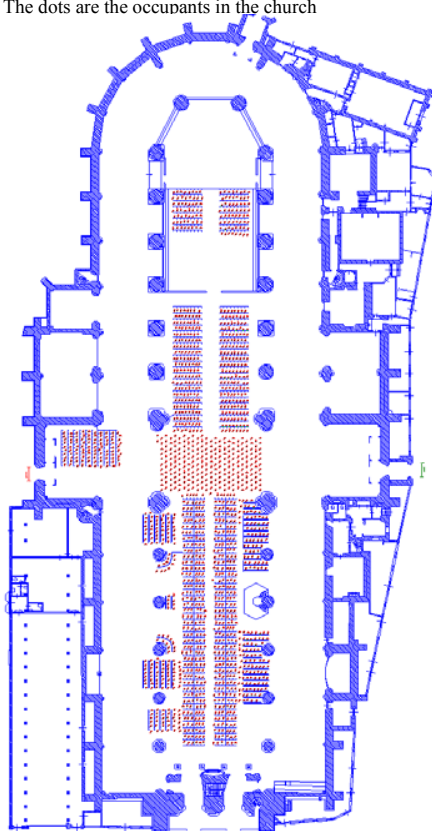


Figure 5: Simulation at start (0:00).



Figure 6: Simulation at 1:00 (60 seconds).

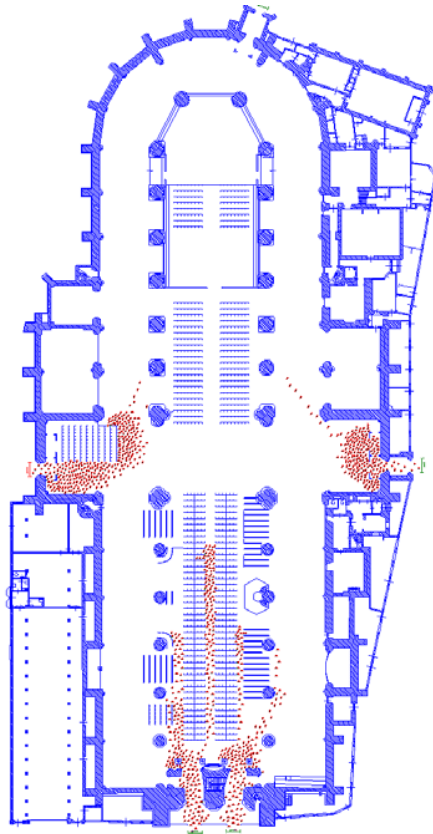


Figure 7: Simulation at 2:00 (120 seconds).

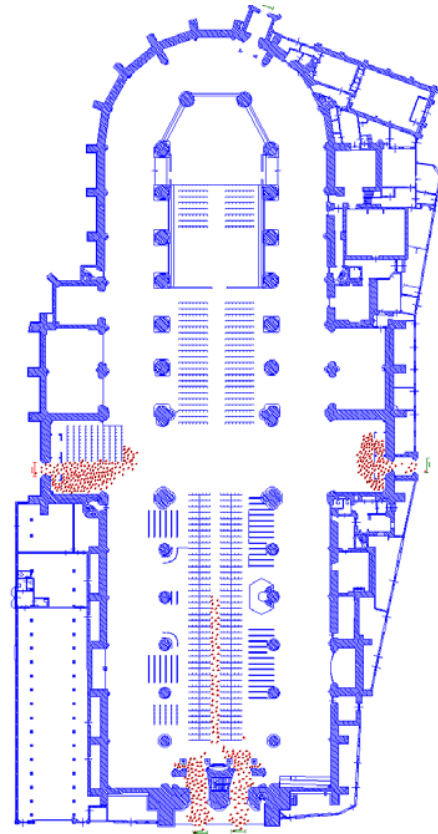


Figure 8: Simulation at 3:00 (180 seconds).

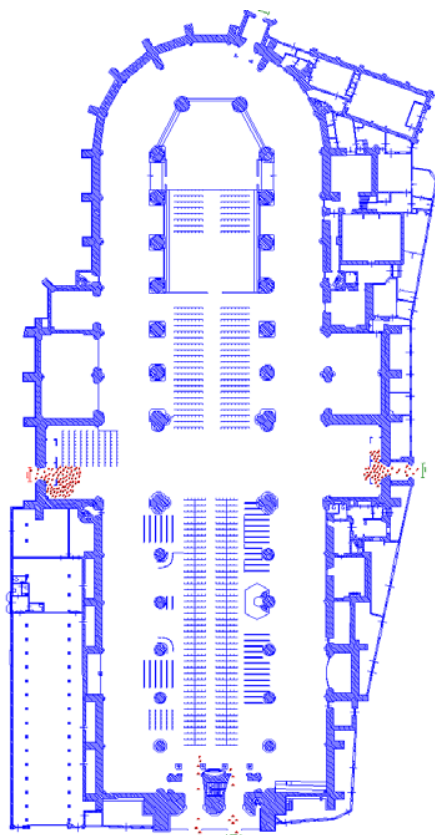


Figure 9: Simulation at 4:00 (240 seconds).

The results of the combination of the smoke calculations and the evacuation simulations are:

“The critical time based on the smoke calculations is ~25 minutes, the church is evacuated at ~ 5 minutes. The height of the church in combination with the used materials in the church will not lead to a fire that threatens the occupants in the church”

The investigation proved that the church is safe enough to accommodate 1.600 people.

CONCLUSIONS

With the use of computer models to calculate the smoke production and the evacuation time of a smoke compartment, it is possible to achieve that you can create larger rooms than the default regulations will allow. The method is more used in theatres, exhibition centers and churches.

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