Fire safety topics for master thesis TU/e

HOT TOPICS –2020

Physiological aspects in personal safety

What is the resistance of building occupants to heat flux, convective heat and toxicity of smoke gases? Is it possible to define the resistance of the human body in a mean value with a standard deviation, for several categories of age and damage levels (1st degree, 2nd degree, lethality)? Not only the human skin, but also the respiration system is relevant in relation to this research question.

Evacuation safety: probabilistic approach of ASET and RSET

Safe evacuation of building occupants is possible when the required safe egress time (RSET) doesn't exceed the available safe egress time (ASET): ASET > RSET. The larger the time gap is between ASET and RSET, the higher the safety level is. This can be expressed in a safety factor: ASET = (safety factor) x RSET. What safety factor is needed for a reliable evacuation risk subsytem? Solving this question is possible in a time dependent approach for personal safety, taking into account:

- The amount of building occupants in time (RSET)
- The heat and radiation dose on building occupants in time (ASET, stratified situation)
- Visibility, heat and toxicity dose on building occupants in time (ASET, mixed situation)

The probabilistic approach means that a sensitivity analysis is needed for all stochastic boundary conditions, related to fuel and fire characteristics and evacuation characteristics of the building occupants.

An overview of international literature and standards regarding the acceptable conditions for building occupants is part of the research.

Evacuation safety: reliability of a stay-in-place concept

In case of fire the personal safety of building occupants is guaranteed by the escape routes. When escape routes are blocked or cannot be used by the building occupants, personal safety has to be guaranteed in a different way. By creating very reliable lines of defense in the building (reliable fire and smoke resistent separation constructions, reliable load bearing structure) a 'stay-in-place' concept might offer a solution.

What is the reliability needed for the above mentioned lines of defense, to realize a stay-in-place concept that provides a safety level comparable to a normal evacuation concept? Is it possible to add redundancy to a stay-in-place concept?

Fire resilience: probabilistic approach of AST and RST

In most building codes personal safety of building occupants is the main objective. Because in most building codes an evacuation concept is applied in case of fire, a burn down scenario is acceptable, as long as there is enough time for building occupants to evacuate the building. Apparently, fire resilience is not one of the fire safety objectives in the building code. The risk subsystems 'fire and smoke resistance of compartmentwalls' and 'fire resistance of load bearing structure' are so called Lines of Defence, they don't have to be extremely reliable.

Both separation constructions and load bearing elements can be assumed to be fire safe, when the required safe time (RST: the thermal load by a natural fire, expressed in minutes Standard Fire Curve) doesn't exceed the available safe time (AST: the fire resistance of the construction in minutes Standard

Fire Curve). In the comparison AST > RST time don't apply to real time, but applies to a thermal energy according tot he standard fire curve. The larger the interval is between AST and RST, the higher the safety level is. This can be expressed in a safety factor: AST = (safety factor) x RST.

The needed safety factor depends on the acceptable failure probability of a separation construction or a load bearing element, taking into account:
- The fire resistance according to the standard fire curve (AST)
- The thermal load, caused by a natural fire, expressed in minutes Standard Fire Curve (RST)

The probabilistic approach means that a sensitivity analysis is needed for all stochastic boundary conditions, related to fuel and fire characteristics and construction characteristics.

Airtight buildings, consequences for fire development and smoke propagation

Part of the energy transition for climatization of buildings is to reduce energy losses through external separation constructions. The consequence is that external separation constructions become more and more thermal well insulated and air tight.

In case of fire airtightness doesn't really influence the fire scenario, but in a developing localized fire scenario, the internal gas pressure increases. Since the internal gas pressure is the main driving force for smoke propagation in a building, the smoke propagation in an airtight building will increase. Airtightness of external separation constructions might lead to smoke propagation in the escape routes of the building.

How hazardous are airtight external separation constructions for escape routes inside a building in case of fire? What possibilities do we have to solve this problem?

Reliability of fire and smoke compartmentation, depending on the safety concept

Fire and smoke compartmentation are 'lines of defence' in a performance based approach of fire safety. Although compartmentation is only a barrier in fire and smoke propagation, not directly related to personal safety (the main objective in fire safety), an extremely reliable barrier means that the consequences of fire and smoke are limited to a specific area or compartment in the building. Outside this area building occupants are safe, there is no need for evacuation. In that case evacuation can be seen as a redundant measure for a 'stay-in-place' concept.

What reliability for fire and smoke compartmentation is needed in case of an evacuation concept in case of fire according to the building code? And what reliability for fire and smoke compartmentation is needed when a stay-in-place concept is applied in case of fire?

Reliability of separation constructions in case of fire can be expressed in fire and smoke resistance. Also adjoining (external) separation constructions, like facades and roofs, connected to the separation construction, must be taken into account, because they are influencing the fire and smoke resistance of the compartment wall.

Pressurized escape routes

Pressurization systems for escape routes need to comply to EN 12101-6. This standard gives the assessment criteria and boundary conditions for pressurized escape routes, related to the objectives of the pressurization system. For the dimensioning of the pressurization system, normal operating conditions are always assumed. What does that mean for the reliability of the system under fire conditions?

Smart spinkler protection

In a normal sprinkler protection the sprinklerheads will be opened when the temperature of the sprinklerhead exceeds the activation temperature. Depending on the RHR-density and the fire development a certain amount of sprinklerheads will be opened. When the fire moves in time, not all sprinklerheads will be effective. Is it possible to have a more effective and reliable sprinkler system with smart sprinkler heads, which are opened and closed at pre-set treshold values?

A new fire curve for residential functions?

Most residential functions contain small rooms. In small rooms the fire load never is uniformly distributed. This means that the so called t-squared curves, used as design curves for natural developing fires don't give a realistic fire development in small rooms. Is it possible to develop a new design fire for residential functions?

Parkings: travelling fire scenario and consequences for load bearing structure

A pre flashover fire is hardly hazardous for separation constructions and load bearing building structure. Only 10% of the heat is released in the pre flashover situation (localized fire), most of the energy is released in the post flashover fire (compartment fire). In large compartments it might be possible for the Fire Service to put out the localized fire. This is a very risk reducing measure, while at the other hand the offensive indoor attack is a riskful attack for the fire service. After flashover, an offensive indoor attack is not possible. A defensive fire attack is more suitable in that situation.

Sometimes the flashover condition won't be reached with a natural fire, due to heat capacity of separation construction and ventilation flowrates. When it is not possible to put out the localized fire, this fire remains localized but starts travelling to other cars. The localized fire becomes a travelling localized fire.

Of course the thermal load of a travelling localized fire is more severe than the thermal load of a localized fire. If this thermal load also exceeds the thermal load of a compartmentfire is not very likely. What is the thermal load of the travelling localized fire on load bearing elements? What are the consequences?

Tunnels: Influence of fire scenario's on the thermal load of concrete tunnels

In concrete tunnels the spalling behaviour of concrete, exposed to a thermal load caused by a fire, is very unpredictable. Especially traditionally reinforced concrete with a density appears to be very sensitive to spalling. Reinforced concrete with fibres might be a solution in this case. The question is: what are acceptable failure probabilities of a tunnel, taking into account personal safety of tunnel users and fire service, societal acceptance, societal costs when the tunnel is not available in the infrastructure, etc. To answer this question, the probability distribution functions of several boundary conditions need to be known. The fire scenario is one of the most difficult stochastic boundary conditions.

Supertall buildings: Probabilistic approach on the fire safety of supertall buildings (200 – 400 meter)

For tall buildings (70 – 200 meter) a SBR-directive has been developed, based on a probabilistic approach, related to the Dutch Building Code. Is this probabilistic approach also applicable for supertall buildings? Several risk subsystems should be taken into account:

- Safety of the building (load bearing structure)
- Safety of compartmentation and subcompartmentation (separation constructions, fire or smoke resistant)
- Safety of building users (evacuation not possible: stay in place concept)
- Safety of the fire service

Technische Universiteit
Eindhoven
University of Technology

More info:
Ruud van Herpen
fellow Fire Safety Engineering TU/e – Nieman Consulting Engineers
Email: R.A.P.v.Herpen@tue.nl