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NFSD

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Edited by Anne Dederichs, RISE Research Institutes of Sweden

Preface

It is our pleasure to hand over to you this book of abstracts for the Nordic Fire & Safety Days 2017 organized by RISE, Research Institutes of Sweden in collaboration with the Technical University of Denmark, Lund University, Norwegian University of Science and Technology, University of Stavanger, Western Norway University of Applied Sciences, Luleå University of Technology and Iceland University as well as VTT Technical Research Centre of Finland Ltd, the Danish Institute of Fire and Security Technology and Aalborg University in Copenhagen.

We are very proud to present the abstracts of 62 Nordic and international contributions in the present book of abstracts. The work demonstrates a significant scientific depth and societal relevance. The conference is a response to the extensive interest in the areas of fire and safety engineering in the Nordic countries in the past decades. As the programme and the abstracts show, the NFSD follow up on challenges with respect to safety dealing with aspects of fire and actions of the rescue service as well as human behavior and risk management. This year there is a special focus on fire safe furniture and the intervention of the rescue service.

Anne Dederichs, RISE Research Institutes of Sweden (conference chair)

Table of Contents

DAY 1

DAY 2

Fire Protection of Extensive Green Roofs

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***Keywords:** Green roof, combustible roof covering, fire spread, roof fire*

Green roof coverings have become more and more common within the construction industry throughout the last decade, and the desire to use these types of roof coverings are increasing. One of the main reasons for this is the increased demands on sustainability awareness which has become a greater trend in almost every sector of the society.

A "green roof", i.e. a roof covered with vegetation, is generally constructed by several different layers with their own unique function and material properties. The market offers a great range of different products but the buildup is typically the same, and as follows (from the structural support and up): On the structural support a water proofing layer is installed, followed by a root protection board, drainage layer, water storage layer, growth medium and lastly the plants.

These types of roof coverings have been developed and widely applied in a relatively fast pace. However, the fire protection community along with the regulation has not kept up with this development. Therefore, there is a need to investigate and assess the fire properties of these kinds of green roofing solutions to make sure that we don't sacrifice safety for the sake of sustainability. Furthermore, there is a need to develop Swedish (or Nordic) guidelines on how to safely construct different types of green roofs in regards to fire safety.

The thesis addresses green roof constructions, more specifically a certain type of extensive green roofs covered with a vegetation consisting of a mixture of grass, succulents and herbs (Swedish translation - örtsedum). This type of roof covering does not comply with the general recommendations given in the Swedish regulation, as it does not pass a BROOF(T2) test.

The aim of the report is thus to evaluate this type of green roofs from a risk perspective. Furthermore, the aim of the report is to identify the risk of substantial fire spread on roofs in Sweden given an increased usage of this type of roof coverings.

Based on the studies of the vegetation's fuel properties along with performed experiments, the properties of this type of green roof vegetation were analyzed. The experiments consisted of two sets of tests, where the first aimed to investigate the temperature profile through the growth medium when a section of roof covering is affected by heat radiation and the second test aimed to investigate the risk of wind-induced fire spread over an extensive green roof. The material used in both these experiment settings were the same and consisted of vegetation (grass, succulents and herbs of approx. 10 cm height) pre-grown on a base of coconut fiber together with growing medium with low organic content. The test specimens were conditioned to three different levels of moisture content before used in the experiments.

The first set of experiments were carried out using a slightly adjusted version of the ISO 5660-1 cone calorimeter test [1]. In this set of tests the irradiance level from the cone was set to 25 kW/m2 for 15 minutes. The thickness of the growing medium and the vegetation's moisture content was then varied between the different tests to determine the time to ignition, heat release rate and the temperature profile vertically through the test specimen was measured.

The second set of experiments somewhat resembles the ENV 1187 test 2 roof-covering test method, with substantial modifications made to suit the aim of the project [2]. Each test was carried out with two test specimens of the dimensions 30x50 cm placed in a test-rig and with a pre-defined safety distance ("fire break") between them (10, 30, 50 cm). The source of ignition used was the same as the standard wood crib used in the ENV 1187 test 2 method and the wind speeds used were 0, 3 and 6 m/s. In these experiments, which lasted for a duration of 15 minutes, the flame spread rate and the production of burning brands were observed.

The results from the tests in the cone calorimeter show that there is a low risk that layers under the growth medium can reach critical temperatures as a result of external heat radiation. This due to the insulating effect of the growth medium, which, in itself is practically noncombustible.

Furthermore, the results from the fire spread tests indicate a low risk for substantial fire spread on extensive green roofs given adequate fire breaks, depending on the level of moisture. In most cases the fire self-extinguished after only a couple of minutes and flame spread across the "fire break" occurred only in 2 out of 36 tests. The sparks and burning brands generated by the fire did not contribute to the fire spread as the energy content in these brands were too low to start new fires ahead of the "fire break".

The main conclusions from this study is that a roof covering, such as the tested, does not contribute to an unacceptable risk of fire spread in urban environments given that adequate fire breaks are installed. However, further investigations need to be done on roof coverings with more developed (e.g. higher and denser) vegetation together with tests in bigger scale, in order to give a more realistic foundation for future guidelines on construction of extensive green roofs in regards to fire safety.

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USCG Fire simulation of water mist suppression using an ignition source

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Keywords: Water mist, Extingusihing, Simulation, CFD, FDS

Prediction of the effect of extinguishing using water mist can be a useful tool and a complement/alternative to full-scale fire test. The present case is simulation of the fire test using different water mist nozzle in a mock-up engine room. The US Navy carried out these tests [1]. Results from simulation of the extinguishment of fire in Engine rooms have been presented earlier at Interflam, [2]. One of the problems with these simulation was the auto ignition temperature could only be set globally, - this meant the fire could reignite at various places in the engine room, even if the room temperature had come down. Since then a new feature has been added to FDS 6.4.0 (5 Apr 2016) and the possibility of an ignition source.

From the release note to FDS 6.4.0:" Add AUTO_IGNITION_TEMPERATURE to INIT namelist. This addresses the problem of spurious re-ignition at OPEN boundaries. You can now set a low AIT near the burner surface to act as an ignition source and set a high AIT elsewhere in the domain to prevent spurious re-ignition. An example may be found in the "UMD_Line_Burner validation series."

One case using a spray fire of 1 MW and two different ventilation conditions were investigated. Firstly, the natural ventilation with the ignition source places close to the release point of heptane. In can be seen in figure 1 that the fire is extinguished, but it reignites a number of times with peak of up to 12 MW (deflagration). In the second simulation for the natural ventilation a box was inserted on top of the ignition source at, which is 10 seconds before the water is turned on. The fire are extinguishes after about 15 seconds and did not reignite within the 300 seconds.

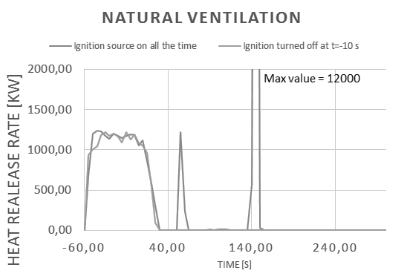
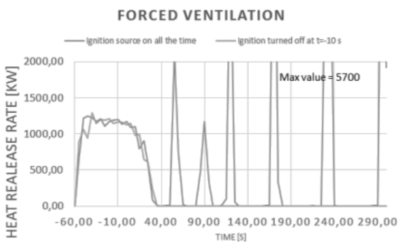


Figure 1: Natural ventilated scenario 1 MW spray fire HRR.



Similar performances are observed for the forced ventilation case, see figure 2. With the ignition source on all the time, - the fire reignites 6 times after it have been extinguished. When the ignition source is turned off 10 seconds before the water mist is turned on, no reigniting happens and the fire extinguish at about 25 seconds after the application of the water started.

The time to extinguishment is defined, as the time where the heat release rate is half of the average heat release rate. In table 1 the extinguishment time from the simulation is compared to the experimental results. It can be seen that this time is slightly longer for the simulation than for the experiments, but still within the same order. Further the simulation show the same trend as the experiment, that the forced ventilation case take longer to extinguish than the natural ventilation case.

Tabel 1, results of simulation, 1 MW spray fire,
Time to extinguishment.

Ventilation	Experiments	Simulation
Natural ventilation	15 s	20 s
Forced ventilation	17 s	25 s

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Development tool for ETICS façade fire testing

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Keywords: fire safety engineering, facades, etics, experimental, modelling

Background

Sustainability and reduction of energy consumption have become increasingly important in recent years. The built environment constitutes a large portion of the total energy consumed and is thus the focus of substantial efforts for improvement. The most common solutions to reduce energy consumption are to increase the thickness of insulation, utilise higher performance insulation, or to add insulation to the exterior of the building. The lattermost of these are known as External Thermal Insulation Composite Systems (ETICS). The two main varieties include either expanded polystyrene (EPS) or mineral wool (MW). Phenolic foam and polyurethane-polyisocyanurate (PUR/PIR) foams are also viable options. A typical section consists of the following: exterior wall; render, adhesive or fixing system; insulation; first layer of render with reinforcement; final render on the external face of façade.

Research significance

There has been an increasing number of fire incidents involving the building façade [1] which has led to the desire for a suitable method to assess their flammability. Existing façade test methods are expensive and time consuming, and deliver little information on how a system performs. This acts as a barrier to small and medium-sized enterprises (SMEs) entering the market as they cannot afford the risk of failing the test. In addition, there is insufficient knowledge delivered from the results to then adequately improve the performance of the system. Therefore, there is clear need for a development tool capable of scoping the performance in a full scale test, and delivering information on how the system performs. This can be achieved through development of a testing methodology built upon performance based principles connected to a model capable of predicting the results.

Flammability

The fire properties of EPS insulation used in ETICS are very poor – the onset of thermal decomposition occurs rapidly, the material is easily capable of sustaining flaming, and experiences melting and dripping, which can further enhance flame spread [2]. Hidalgo et al. [3] found the pyrolysis temperature of EPS to be in the range of 306–390°C, but suggested a critical temperature of 240°C due to the melting behavior. The low thermal inertia of the material results in a rapid temperature rise at the surface and thus melting and pyrolysis occur quickly [4]. Polystyrene-based materials typically achieve E or F in the European classification system, EN 13501-1 [5], which in some instances can limit their usage. Phenolic foam is a thermoset material which chars at higher temperatures (around 425–450°C [3]) and thus has limited flame spread. Mineral wool can generally be regarded as non-combustible for low binder contents, but requires greater thickness to achieve the same thermal performance.

Current work

The existing work involves three projects: the development of a reduced-scale experimental methodology; development of a model to predict material behaviour in full-scale and for real buildings; and two highly instrumented full-scale tests to validate the results of the other two projects. The goal is to provide a development tool to accurately predict the behaviour of ETICS on a large-scale or on a real building based on inexpensive reduced-scale experiments. Minor product variations can be assessed by the model having performed the reduced-scale experiments. The existing work is focused initially on ETICS. However, the intent is to expand the scope to other more complicated façade systems – such as ventilated façades – once the reduced-scale methodology and associated model have been validated and are fully operational.

Acknowledgements

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Modelling approach for the threat quantification of cascading failures

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Keywords: cascading effect, modelling, critical infrastructure, crisis management, threat quantification

In a crisis situation, the tight coupling and complexity of relations between various sectors, infrastructures and services can trigger cascading failures, which could disrupt the critical societal functions and lead to multi-sectoral collapse. Therefore, the management of the threat of cascading effects has been identified as one of the key challenges for public-private partnership.

The European PREDICT project [1] aims at delivering a comprehensive solution for dealing with cascading effects in multi-sectoral crisis situations covering aspects of critical infrastructures (CIs). The PREDICT solution is composed of methodologies, models and software tools, which will increase the awareness and understanding of cascading effects in crisis situations. It will enhance the preparedness for such effects and improve the capability to respond in case of a crisis.

The "Incident Evolution Framework" work package aims at developing a generic methodology for understanding the incident evolution and the response operations that are needed to prevent potential cascading failures. As a part of this work, a modelling approach for threat quantification was generated using the PREDICT case studies as development environment. The threats to the CIs in the case studies, as well as their vulnerabilities and interdependencies, were identified and characterized in order to define the modelling requirements for threat quantification.

A general modelling approach was developed using a flooding scenario in a densely populated area as an example. An accident scenario map, locating the initiating events and CIs, was defined and a hexagonal grid was laid on the map. The relevant CIs for each hex were identified, and their interdependencies and vulnerabilities were defined in the model. A reference point was chosen for each hex. The threat function results on the reference point were then applied to all CIs in the hex. The threat function describing the expected level of water in the different locations of the polder area at a certain time was provided by a separate modelling tool. The initial failure times (i.e. not considering the interdependencies) of the CIs were determined. The final failure times were determined taking into account the interdependencies between the CIs, and the cascading effects were assessed.

The application of the modelling approach to the flooding scenario produced failure time estimates for CIs taking into account their interdependencies. The modelling can reveal the cascading failures in which a CI is lost due to a failure of another CI. The numerical results of the example demonstrated the feasibility of the modelling approach.

The threat quantification modelling approach can be similarly applied to other accident scenarios where the threat starts to spread to the surroundings and cause damage to the CIs. The modelling approach requires that sufficient data on relevant CIs and their locations, interdependencies, vulnerabilities and initial failure times due to threat functions, for example from simulation tools, is available. Depending on the input data available, model parameters can be implemented either as single-value point estimates or as probabilistic distributions.

Threat quantification modelling can be utilized in crisis management in both the preparedness and training phase and the response phase. In the preparedness and training phase, the modelling illustrates the progress, influencing factors and potential cascading effects of accident scenarios. It gives guidance for the planning of emergency response by revealing the CIs that are important to protect in order to mitigate or prevent the escalation of the accident. To support contingency planning, the threat quantification modelling can reveal crucial vulnerabilities and interdependencies which should be eliminated or mitigated to strengthen the resilience of the CIs. In the response phase, scenarios pre-examined in the preparedness phase can be used as references to support decision making. New simulation results on the threatening phenomena can be input to the threat quantification model to correspond the real-life accident, and predefined vulnerabilities and interdependencies can be adjusted by expert judgement using the information obtained from the evolution of the crisis.

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Developing a risk and capability assessments methodology for the Baltic Sea Region

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Keywords: Risk assessmnt, Capability assessment, methodology Baltic Sea Region

This paper reports on work carried out within the EU funded project "Risk Management Capability Based on Gaps Identification in the BSR", where the aim was to build knowledge on disaster risk management capability assessments and the development of a more common understanding of such assessments at national level in the Baltic Sea Region. This was a cooperative project with partners from Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland and Sweden. The project was coordinated by the Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania, starting in January 2015 and ending in December 2016.

The aim of the project was to contribute to the implementation of a macro-regional civil protection strategy and joint macro-regional prevention and preparedness approach towards major hazards and emergencies as set forth under the Policy Area Secure in the 2013 Action Plan. It built on the results of the project EUSBSR 14.3 – European Union Strategy for the Baltic Sea Region Flagship Project 14.3 on Macro regional Risk Scenarios and Gaps Identification – implemented during 2012–2013.

Among other things, the EUSBSR 14.3 project produced six scenarios (Extreme weather/storm, Flooding, Forest fire, Pandemic flu, an Accident at Sea and a Nuclear accident) and corresponding methodology for scenario development as well as assessments of impacts/consequences and likelihood. At the time several participating countries had just initiated or were in the process of finalizing national risk assessments in accordance with the EU Risk Assessment and Mapping Guidelines for Disaster Management (SEC [2010] 1626 final) which meant that the EUSBSR 14.3 project increased awareness on cross-border dimensions of risks. One insight from the EUSBSR 14.3 project as well as from national risk assessments in the region is the need for developing assessments of risk in close connection to assessments of capability.

With a view to the guidelines for assessments of risk management capability in accordance with the EU Decision on a Union Civil Protection Mechanism (1313/2013/EU), the project attempted to survey and collect data on existing ways of assessing capability in the civil protection systems of the region.

Along with relevant aspects of the EUSBSR 14.3 project as well as national risk assessments, these findings served as a basis for developing a methodology for future assessments of capability among the Baltic Sea States with a special focus on cross-border dimensions. This can include events occurring in one Baltic Sea State of direct impact on the territory of another/others, events in border areas, events simultaneously affecting several countries in the region and events in a Baltic Sea State affecting residents of another, temporarily abroad, as well as events occurring in one country that can be dealt with – only or more effectively – with the assistance of other countries.

The aims of the project were met in various different ways. All project partners took part in developing and answering several questionnaires, investigating the status and expectations regarding disaster risk management in the project partner countries.

No single methodology for risk and capability assessments had previously been presented or agreed upon within the Baltic Sea Region. The project group concluded that it would be of great benefit for the Baltic Sea Region countries if a harmonized methodology for risk and capability assessments could be formulated and developed within the region. The methodology would have to be practical and flexible, should be applicable at all levels of government and to all actors in the field and should allow scenario analysis as well as experience from exercises and emergencies to be taken into account.

Through a series of meetings and workshops, a methodology was developed by the project partners and tested on a given scenario (Extreme weather/storm). The project partners all agreed that the methodology developed and tested within the project would serve as a bases for a methodology for the BSR, to be improved upon and further developed within the region.

A simple description of the methodology is given in this paper.

Fire Safety Decision Making Under a Systems-Theoretic Safety Paradigm

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Keywords: (fire safety level, deterioration, decisions)

On July 23, 2015, a fire broke out and left major parts of the 15 000 m2 "BASA-house" in Tønsberg, Norway, in ruins. SP Fire Research carried out a post-fire evaluation in order to identify national learning points. This abstract relates to SP´s evaluation and how their findings may be interpreted in a systems-theoretic fire safety paradigm.

The BASA-house was erected in 1963, with several extensions – the latest in 1985. Originally, SABA, a production facility for diapers and sanitary pads used the building in their operation. SABA closed down their factory in 2002. The building was sold in 2003. In 2015, the building was used as a rent-a-space storage facility, housing some 70 different companies at the time of the fire.

The level of fire safety of the BASA-house should have been high, taking the technical safety systems and the Norwegian regulation into account. The building was fitted with an automatic fire alarm system, an automatic sprinkler system and a set of fire rated walls dividing the building into five fire-compartments. SP´s investigation (Sesseng et al., 2016), however, points to several facts, indicating that the fire safety level was poor. A major issue was the regular shutdowns of the sprinkler system due to leakages and maintenance. The sprinkler system was out of service during the fire. Several unwanted alarms in the past undermined the users´ confidence in the alarm system. The passive fire safety measures, i.e. fire walls and fire doors, also had major weaknesses.

The story of the BASA-fire is about gradual deterioration of the fire safety level. The evaluation points to several instances that potentially could have identified critical safety issues. However, no-one noticed that the level of fire safety had been driven outside the boundaries of good operational practice. Similar deterioration stories exist. Consider the Station Nightclub fire on Rhode Island, U.S., in 2003, where 100 people lost their lives. At some point in time it was decided to fit the walls and ceiling around the stage with plastic foam sound insulation. The plastic foam was ignited by pyrotechnics (Grosshandler et al., 2005). Another example is the Gothenburg discotheque fire in 1998, where 63 people lost their lives. The building´s occupant limit was set at 150 people, while ca. 400 people was present in the building the night of the fire (Mostue, 1999). Poor decisions led to fatal consequences.

Organizations and individuals make decisions continuously that affect the level of fire safety. Unfortunately, poor fire safety decisions may be appropriate business decisions and, most of the time, poor decisions comes without serious consequences, because the latent weaknesses require a critical reflecting safety management system. Institutionalized poor fire safety decisions as a part of daily operations, increase the risk of a disaster to be just around the corner. Fire safety engineering in Norway focus largely on the verification of technical fire safety measures imposed by the technical regulations. The Nordic INSTA-collaboration on development of probabilistic fire safety analyses, seem to have a similar goal (Baker et al., 2016). This is understandable from a project execution perspective. From a fire safety perspective, however, the efforts are less understandable. Current fire safety engineering and its technical rationalism, is over-simplifying fire safety, and practically excludes the important issues of organizational and individual decision making in daily operation. Fire safety is an emergent property of a broad socio-technical system that need to be managed rather than verified. Such a conclusion should lead to major changes in the way fire safety engineers conduct their work and the way Norwegian fire safety regulations are organized. Enabling building owners and managers to successfully accomplish this task should be the major goal of the regulations and fire safety engineering.

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The effect of platform- and tunnel design on the evacuation performance of wheelchair users *– A qualitative study*

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Keywords: Evacuation, impairment, tunnel, train, safety

About 500 000 people in Sweden have a mobility impairment, thereof 80 000 wheelchair users. This part of the population has the same rights with respect to safety, as the rest population in Sweden. In the past years an increasing amount of elevated platforms, platforms located at a level elevated from the rail top surface, have been designed, with the purpose in increasing person safety of the passenger. Limited information exists on the effect of platform design on the evacuation characteristics [1]-[5]. The purpose of the current investigation is to study human behavior when escaping along elevated platform, with respect to wheelchair users. The work contains a qualitative and quantitative analysis of the effect of the width of the elevated walkway, people's ability to pass others who are walking slower and the possibility for people using wheelchairs to evacuate. Data from one large scale experiment, carried out at subway station Skarpnäck, Stockholm in 2016 is analyzed. The experiments involve 111 participants including three wheelchair users aging 64, 48 and 31. The experiment was divided into five runs. In the 1st and 3rd run all the participants walked from one end of the walkway to the other and also in the 5th run, except that wheel chair users did not participate here. The width of the walkway was varied from 1.2 m to 1.05 m and down to 0,9 m. In the 2nd and 4th run the participants were divided into two groups. One group walk, like earlier, from one end of the walkway to the other, and the other group started in the train that was parked next to the walkway and joined the flow on the walkway. The width of the walkway was varied from 1.2 m to 1.05 m. When the test was completed the participants was asked to take part in a survey.

The survey contained questions on the effect of platform height and on the pedestrian movement. Several participants including one wheelchair user report the feeling of discomfort stimulated by the height and width of the platform. The width was of great importance with respect to feeling safe during evacuation. The participant recommended an even larger width than ones used in the current trial. Furthermore, she suggested that a raised strip was mounted at walkway edge, to prevent the wheelchair's wheels roll over the edge.

On the collected video footage can be seen that the wheelchairs generally chose to move along the walkway inside edge (against the wall), regardless of the width of the platform and the person density. The videos show a gap in the flow before and after the wheelchairs. The door large spawning varied depending on how crowded it was on the pavement.

Other participants generally showed concern for wheelchair users by watching out for them and giving way. One of the wheelchair users hesitated as the end of the train was reached exposing the gap downwards top the track area. It was observed the other participants remained positioned behind the wheelchair user, confirming, that she was feeling good and in the run afterwards accompanying her along the sidewalk all the way from the point she hesitated to move along the platform. Altruistic behavior of evacuees has been seen in other studies [3],[5].

Furthermore, participants showing consideration for wheelchair users was in connection with co-flow when participants exiting the train merge with the flow on the platform. The participants who stepped out of the train gave way to the wheelchair user who was on the platform.

One out of three wheelchair users participating in the test experienced discomfort caused by the height and width of the elevated walkway. This resulted in that she only took part in half of the runs.

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Reaction and decision time of evacuees

A study regarding the influence of alcohol on the reaction and decision time

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Keywords: (Evacuation, Reaction and decision time, alcohol)

Night club fires worldwide have demanded many lives [1,2]. People in night clubs are often affected by alcohol or other substances. The knowledge on the effects of alcohol on evacuees is relevant for the fire safety design and for ensuring an acceptable safety level in nightclubs. Literature provides limited information on the effect of alcohol on evacuation [1-5]. Previous studies have shown that the walking speed of alcohol influenced evacuees in groups is slightly increased. Furthermore, it was seen, that the sound level in alcohol affected groups increased and the ability of taking in instructions was negatively affected [2].

The aim of the current study is to investigate how consummation of alcohol impacts the reaction and decision phase of an evacuation. One focus was the determination of the efficiency of the notification methods. The experiment consisted of two reference experiments, where the participants were sober and two similar experiments conducted under the influence of alcohol (0,46 - 1,08 promille). The trials involved two notification methods: verbal warning and tone alarm. During the tone alarm experiment, music was playing in the room. The music was interrupted by the tone alarm. The verbal warning experiment was conducted in a silent room and the participants were subjected to a spoken message. During the experiments the participants were asked to do small assignments and their concentration abilities and their evacuation characteristics when warned in different scenarios were observed. The participants were given partial information prior the experiments. They knew that the effect of alcohol on the evacuation behavior was studied and that they had to carry out small exercises. 28 students with an average age of 22.5 years participated at the experiments conducted at the Technical University of Denmark. All participants carried out both the reference and experiment with alcohol. The experiments were conducted in two rooms. The intake of alcohol was undertaken in the Drinking Rooms. Then the participants changed into the Experimental Room to carry out the exercises and the warning experiment. Reaction and decision time for these experimental conditions was measured, with respect to carrying out the exercises, reacting on the instructions in the Experimental Room and exiting the room.

The study has the following surprising findings: no significant difference was seen in the measured reaction and decision time with respect to reaction to the warning and exiting the room, when the participants were influenced by alcohol. No significant difference was seen in carrying out the exercises. However, a difference was found in the behavior and ability to maintain focus on the assignments, when under the influence of alcohol.

There was a significant difference in the sound level between the experiments done without influence of alcohol and when influenced by alcohol. The sound level was increased (not measured) in the Drinking Rooms. After alcohol intake, the helpers standing in the hallway had to raise their voice significantly to get the attention of the participants, when giving information. However, this behavior was changed again when the participants entered the Exercise Room. The sound level decreased. The participant's ability to react on both the spoken message and the tone alarm and start the evacuation almost instantly after the warning had been initiated.

The alcohol intake affected the evacuation in a different manor, than expected. Apart from a biological effect, a cultural cognitive effect needs to be considered [6].

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Awareness of fire risk reduction among Cyprus International University (CIU) students

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Keywords: (Fire prevention, Fire Adaptation, Fire Readiness, Fire related Knowledge)

Students have to be educated on the dangers of fire, prevention of fire, fighting of fire, adaptation to fire disasters and being ready for fire disasters. Students in CIU campus apartments concentrate on studies and at times neglect their safety. These apartments on campus have no fire detection systems [1] (Fire extinguishers, Fire alarms, sprinklers, etc.) In place in case there is a fire, it will be difficult to apply any safety measures. This study asks the following questions; are students aware of fire disasters, do they have knowledge about fire disasters and readiness behavior towards fire disasters?

There have not been any studies conducted on the risk of fire disasters on CIU campus. But there have been studies conducted in other institution [2] [3] but without real life scenarios inclusion, however, this study is to explore the awareness of students on the following, Fire disaster and its related knowledge, Readiness behavior towards fire disasters, fire outbreak awareness and the use of fire detection systems. Students with an age range of 15-40 from CIU were given questionnaires to know about the extent of their knowledge on fire disasters. Questions were asked under awareness of fire disasters, student's readiness behaviors towards fire disasters and knowledge of fire disasters [4]. Statistical analysis was conducted using reliability test, independent sample t- test to check the relationship between student's opinion and fire disasters. One Way Anova to check the impact of age of the fire disaster variants. Also to check students' knowledge, awareness and readiness, to fire disaster. From the test conducted, the distribution was normalized (Kolmogorov- Smirnov test) with a value of 0.200, with equality of variance (the Levene's test of equality of variance) of 0.969, a reliability test (Cronbach's alpha) of 0.680 which showed the reliability of the test conducted. With the independent t- test and one way Anova used. The study concluded that students have little knowledge relating to fire disasters on CIU campus. However the results are not encouraging so it is necessary for further education of fire disasters and its related knowledge promoted to students, which is very vital to the well-being of students. That is, students still seem confused about the related knowledge about fire disasters, there was a satisfactory result for readiness behavior and fire awareness. A lot of students think that it is important to have knowledge about fire disasters and not the related knowledge. They have no notion as to how to go about to act during fire emergencies, or how to prepare for fire emergencies and after fire emergencies. It was also clear that age of students did not matter when it came to the awareness of fire disasters. This is because all the age groups are aware of fire disasters.

It is recommended that CIU school authorities take the initiative in creating awareness of fire disasters and its related knowledge to students. To make students interested in learning about fire, the staff can have extracurricular activities and fire disaster related education campaigns.

It is also recommended that further studies be conducted with the addition of two more variable that is, fire disaster adaptation and fire disaster risk perception get a broader response and view to be able to make a conclusive decision based on the findings.

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Desensitisation of Optical Flame Detection in Harsh External Environments

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Keywords: Detection, Fire, Safety, Design, Environment

After the Piper Alpha disaster in 1988, the industry was given an abrupt awakening to the potential for disaster offshore. A breakthrough from this event was the increase in awareness of safety. Subsequently, the industry witnessed a great deal of time, money and effort invested in the development of appropriate technologies and safety systems to help mitigate the potential hazards naturally present on site. One of these technologies included optical based flame detection.

This paper aims to analyse the dangers of using an inappropriate technology for the hazards in question, and in particular, failing to take account of environmental factors to ensure a safe and reliable system.

As the process industry moves towards the reduction of the potential for 'fail to danger' in safety related systems (with an increase in the prevalence of IEC 61508 and IEC 61511), it is of great concern that flame detection technologies (whether one feels this can be classed as a Safety Instrumented System [SIS] or not) applied today still provide this potential, and even worse, may never be accounted for in design. In particular, the guidance within 'ISA TR84.00.07 Guidance on the Evaluation of Fire and Gas System Effectiveness' shall be reviewed with respect to flame detection design in the hazardous industries.

The four primary forms of flame detection are analysed. These are Ultraviolet, Infrared, Multi Spectrum Infrared and Visual based detectors. Each detector has its own strengths and limitations and each will be analysed in depth. This allows the designer to select the appropriate technology to the application.

Factors affecting the sensitivity will be reviewed including dirty optics, weather (including rain, mist, lightning etc.), radiation from equipment within the field of view and sunlight. Each of these factors can have a significant impact on all optical based flame detection technologies. Some of these are incorporated into independent certification of detectors (i.e. the FM 3260 test report), however, the impact of many of these factors, and the extent of the impact for each individual site is open to interpretation of the designer. The assumptions which are often made shall be reviewed in the paper.

Examples of some 3D modelling analysis will also be included, reviewing how optical based flame detection is typically modelled within the hazardous industries. This will reflect the significant impact detector selection and desensitisation assumptions can have on the overall coverage within an area, and whether this could be deemed adequate or otherwise.

The main conclusion to be drawn from the paper is that the viewing characteristics provided by the manufacturers of optical flame detectors, represent the characteristics of the flame detector as per ideal test conditions. These conditions are rarely met after application in the field.

Therefore, during any flame detection system review, desensitisation should always be included and will play an important role in minimising the potential for fail to danger of a safety critical event. It is crucial to remember optical detectors located on a plant offshore in the UAE will be affected in an entirely different way to the same detectors installed onshore in Alaska - this must be accounted for in design.

Source material used within this study consists of guidance documents relating to optical flame detection design. Practical, recorded on-site testing of detection technologies exposed to varying environmental conditions is a significant source in this paper and helps in validation of design practices. Author experience in designing flame detection systems for most of the major oil and gas operators, each with vastly different requirements, is also a source which is drawn on for purpose of this study.

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Heat Release Characteristics of Ethanol-Water Mixtures

Intermediate and Full Scale Fire Tests

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Keywords: fire test, ethanol-water mixture, pool fire, mass loss, heat release rate

The Finnish Safety and Chemical Agency (Tukes) has published a guideline concerning the storage of flammable liquids in retail stores [1]. The interpretation of this guideline has raised questions about the fire safety of liquor stores, taking into account especially the storage of alcoholic beverages with an alcohol content of 20 vol% or more. Fire authorities have considered that further clarifications and studies are needed, in order to ensure the fire safety of liquor stores.

Motivated by these concerns, and given that very little information is available in the literature, an experimental study of the fire behaviour of ethanol-water mixtures has been performed. The study included pool fire experiments in the small, intermediate and full scale, and a series of demonstrative fire tests of retail arrays of plastic bottles containing strong (ca. 40 vol%) alcoholic beverages.

The intermediate and full scale fire tests performed are described in this presentation. The small-scale pool fire experiments using the cone calorimeter apparatus have been previously reported [2]. The goal of the small-scale tests was to obtain data on the heat release rate and effective heat of combustion of ethanol-water mixtures for estimating the heat release and fire load which can be caused by alcoholic beverages in liquor stores. Furthermore, small-scale tests were needed since in the tests in the intermediate and full scale, all relevant quantities could not be measured. Thus, the small-scale test results were essential for the interpretation of the larger scale tests.

In the intermediate scale, 19 pool fire tests with different ethanol percentages (20–96.1 vol%) and layer thicknesses (5–25 mm) were performed, using a square pool of 440 × 440 mm2. The pool with the ethanol-water mixture was positioned on a weighing platform under a hood. During the tests, the heat release rate and the mass loss were measured, as well as gas temperatures at five heights above the pool. The purpose of these tests was to study the burning of ethanol-water mixtures as pool fires. The combination of heat release rate and mass loss measurement provided data for interpreting the results of large scale tests where heat release rate could not be measured.

Large scale pool fire tests were performed in open interior space in the large fire test hall of VTT. The tests were made using three square pools of sizes 440 × 440 mm2, 800 × 800 mm2 and 2 × 2 m2. 10 tests were performed with ethanol percentage of 40 or 50 vol% and layer thickness of 10, 50 or 100 mm. During the tests, mass loss and gas temperatures at five heights above the pool were measured. The comparison of the 440 × 440 mm2 pool tests in the large and intermediate scale with similar ethanol percentages and layer thicknesses provided scaling factors between mass loss and heat release rate, making possible to estimate the heat release rates of the large scale tests.

Finally, three demonstration tests were performed for piles of plastic 0.5-litre liquor bottles (39 vol%) in arrays typical for retail stores of liquor. In each test, there were four layers of bottles, each layer with 96 bottles arranged on cardboard frames. The piles were placed on a weighing platform, and gas temperatures above the piles were measured. The purpose of the demonstration tests was to illustrate the ignitability and burning behaviour of liquor bottle piles, and to estimate their heat release rate for risk assessment.

The results of the tests performed can be used in performance-based fire safety design for estimating the burning behaviour of alcoholic beverages and the fire load caused by alcohol. For instance, the estimated heat release of the piles of bottles tested was ca. 1.5 MW at the most, and the growth time constant of the fire was larger than 600 seconds, indicating that the fire grew slowly. On the basis of this study, if a liquor store is a part of a shopping centre or in connection of a large supermarket, no additional performance-based fire safety design is needed for it. The design fires used in the fire safety design of shopping centres are typically much more severe than the fires of alcoholic beverage packages can be according to the tests performed.

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Fire-induced pressures in modern airtight apartment buildings

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Keywords: pressure, energyefficiency, fire risk

The potential risks of fire-induced pressures were recently observed both in practical fire service operations and experimentally [1, 3]. The observations in [1] indicated that the pressure can prevent building occupants from opening the inwards-opening doors, therefore challenging their ability to escape from a burning apartment. The pressure was also found to be sufficiently high to break light-weight structures, indicating a new mechanism of losing the fire compartmentation. Simulation methods for predicting the peak overpressure and smoke transport were then validated [2,3].

The experimental results indicated that the air-tightness of the burning apartment strongly affects the observed peak pressures. Air-tightness of the building envelopes is one of the primary building properties to focus when improving the energy efficiency of new or existing buildings. Therefore, the tightening new energy efficiency requirements may create a new fire safety risk for residential buildings. Quantification of the risk and search for potential pressure management methods are needed.

In this work we used the validated simulation tool (FDS) to investigate the influence of envelope air-tightness and ventilation arrangements on the level and duration of the over pressure in a realistic apartment fire scenario. Additionally, the amount of smoke spreading through the ventilation network to the neighboring apartments was studied. The results indicate that without a specific plan/action for pressure management, the fires in near-Zero level buildings with standard envelope permeability of q50   0.75 m3/m2h, will lead to dangerous pressure levels if the fire growth rate is fast (or ultra-fast). Requirements for the area of additional leakages serving as pressure relief paths were found through iterative simulations. The possibilities for using the ventilation network for the pressure management were also studied by simulating the smoke spreading through the ventilation network. It turned out that the sufficient pressure management could be achieved and smoke spreading prevented if the inlet side of the ventilation network was closed by smoke damper, and the outlet side kept open and exhaust fan operating. The feasibility of such an operational solution naturally requires additional studies in different buildings and conditions.

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Ventilation in tunnels: a numerical comparison between different modelling approaches

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Keywords: ventilation, tunnels, multi-scale modelling, FDS, IDA

With the present work the authors aim to compare different modelling approaches for the design and verification of tunnels' longitudinal ventilation. Tunnels are critical infrastructures due to their vital role in the transport of people and goods, but, a safe design of these structures still present critical aspects. High fire loads, huge length and strong interaction between fire and structure make the design of the ventilation system a challenging task. The tunnel's ventilation should be designed with accurate and reliable numerical models, but in a reasonable amount of time.

Computational fluid dynamics (CFD) is capable to simulate accurately the flow field induced by a fire and by the ventilation system. However the cost of the simulations is still prohibitive for long tunnels since the fire region and the ventilation devices require a refined mesh to provide reliable results [1]. In the engineering practice CFD is not a design tool, but more a verification tool, where it is common to design the tunnel with a one dimensional approach, assuming that the flow field is uniform along the section of the tunnel [2]. This approach allows to simulate long tunnels with a limited computational cost, but it doesn't allow to simulate explicitly three dimensional flows. Near the fire or near the ventilation devices some correlations are used to include the three dimensional effects. Both the above mentioned methods have strengths and weaknesses, these can be overcome with a hybrid approach which takes the best from the two models. Long portions of the tunnel can be simulated with a one dimensional model, but jet fans and fire should be simulated with a three dimensional approach. A Multiscale model for tunnel's ventilation has been already proposed in the literature showing a great potential for engineering problems [3].

A short tunnel has been designed in order to compare the three approaches. The tunnel is 200 m long, 5 m high and 5 m wide. The tunnel is longitudinally ventilated by means of two jet fans located near the inlet portal. A fire source is located in the center of the tunnel, with an increasing HRR.

The one dimensional simulation of the tunnel has been carried out with the software IDA tunnel [4], which allows to simulate the jet fans by considering the momentum exchanged between the high speed jet and the main flow. The fire in the tunnel is simulated as source of mass and heat and adding a local pressure loss. The present model strongly relies on the input parameters which are based on empirical correlations, therefore their applicability can be limited. The three dimensional simulation have been carried out with the CFD code Fire Dynamic Simulator (FDS 6) [5], this allows to simulate the fire and the ventilation devices explicitly, without the need for the designer to set further parameters. Jet fans are modelled as source of mass and momentum and their efficiency is evaluated in the simulation. The fire as well is simulated with better accuracy because the model takes into account the pressure losses induced by the mixing of smoke and fresh air, by the temperature rise and by the higher longitudinal velocity of the smoke. The multiscale model is simulated with the code FDS by resorting to the HVAC routine implemented inside the program [6]. First, only fire region is simulated with the three dimensional model, while the remaining part of the tunnel is simulated with a one dimensional approach.

With the present comparison the authors want to quantify the differences between the models, assuming that FDS is capable to provide reliable results. But also to identify the sources of differences, fire region and jet fans. The goal of the present work is the evaluation of the computational time of the three methods, since this remains the main drawback of three dimensional CFD simulations.

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Fire detection in engine compartments

New test method, certification rules and guidelines for heavy vehicles

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Keywords: Vehicle fires, engine compartment fires, fire detection, SP Method 5320, UN ECE Regulation 107

Statistical data indicate that approximately two thirds of vehicle fires start in engine compartments [1-3]. Furthermore, the number of fires in engine compartments may increase in the future due to higher operational temperatures resulting from stricter regulations on noise and emissions. High temperatures, high airflows, complicated geometries, large amounts of soil, dust, and pollutants, and the wide range of surface temperatures typically occurring during normal operation conditions, complicate operation for all types of fire detectors. A study [4] previously performed by SP shows how the complex geometries and airflow in an engine compartment may affect fire detector performance. CFD-simulations visualised that heat detectors are highly affected by ventilation and location and would be unlikely to detect a fire unless its plume directly impinges on the sensor. This has been confirmed in full scale testing [5, 6].

There are good prospects to extinguish and limit the consequences of vehicle fires if they are detected at an early stage. However, even when fire detection systems are installed, vehicle fires are most often first detected by the driver, by passengers or by people passing by, [7, 8]. Full scale experiments have shown that if a large fire breaks out in the engine compartment of a bus there might be only three minutes available for evacuation [9, 10]. Experiments and fire investigations have also shown that the time available, after the fire is detected by the driver, can be insufficient for evacuation of a complete bus [10, 11].

During the last 10 years SP Fire Research has put significant work into improving fire safety of heavy vehicles, primarily focusing on buses. SP's test method for suppression systems installed in bus engine compartments, SP Method 4912 [12], was launched in 2013 and has gained strong international sympathy [13]. Parts of the method have been implemented in European legislation for buses, through UNECE Regulation 107 [14]. Swedish as well as foreign bus manufacturers have expressed a desire to include a test method for fire detection systems in the standard, as an elaborate standard would create competitive neutrality keeping a high safety level. Given the obvious importance of including fire detection systems, SP initiated a project for this purpose in 2013. The main objective was to develop a test method for evaluating fire detection systems meant for engine compartments of heavy vehicles, including but not limited to buses.

This has resulted in SP Method 5320, which will complement SP Method 4912 to increase fire safety of buses and other heavy vehicles.

The requirements should guarantee that detection systems have an acceptable performance and durability level. The test results should also point out strengths and weaknesses of the systems with respect to different fire scenarios, vehicle types and driving conditions. The possibility to compare different fire detection systems enables the vehicle operator or manufacturer to choose a better system if a higher safety level is desired. This may motivate fire detection system manufacturers to improve both the detectors and their test results.

It is important that the tests not wrongly favour or disqualify a certain detection technology or system configuration. The tests should therefore represent a realistic fire challenge and be conducted in a test setup which is similar to what the system would experience when installed in a heavy vehicle engine compartment. With that in mind, it is also important that the test setup and test procedure is repeatable and reproducible. This will enable a technology-neutral comparison of different fire detection systems to be available for vehicle manufacturers and operators.

In early 2017 SP Certification will publish new certification rules related to the new test method for fire detection systems installed in engine compartments of heavy vehicles. Certification allows the use of SP's quality symbol, the P-mark. Based on the new test method, in 2017 a proposal will be made for implementation of new requirements in UNECE Regulation 107. For buses today, Reg. 107 requires that the driver is provided with an acoustic and a visual signal in case of an excess temperature in the rear engine compartment. There are no existing performance requirements for fire detection systems, but if the suggestion provided by Sweden is implemented there will be in the future.

This paper gives an outline of the new certification rules, test method and corresponding research.

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Verifying fire safety in tall timber buildings

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Keywords: fire safety design, risk analysis, verification, tall buildings, timber

Sweden has limited experience in designing and constructing high-rise buildings. The Swedish building code contains general recommendations on those fire safety features that should be employed when designing building with no more than 16 floors. Buildings taller than that are left with a requirement that the design of the building should be verified against the performance requirements specified in building code and that the fire protection should be evaluated in an overall assessment based on the risk profile of the building. A warning is given to use general recommendations (of lower buildings) as a reference and the engineer is obliged to use analytical design methods to show code compliance as prescriptive design is not an available option. The building code enforces the use of analytical design for buildings with a very high need for protection. Such buildings belong to a specific building class called Br0. The building code gives few details on regarding analytical design but states that special consideration must be given to the following aspects when design fire safety in Br0 buildings:

- if external fire-fighting responses are not possible,
- if internal rescue responses can be complicated,
- if the anticipated consequence is great
- if the evacuation process can be associated with significant difficulties

The lack of detailed recommendations on analytical design of Br0 buildings has motivated the Swedish SFPE chapter to publish a design guide to aid the fire safety design process. The design guide raises several questions related to the aspects needed to be addressed. However, the design guide is based on the current high-rise building tradition. Thus, it focused on the use of traditional construction materials such as concrete and steel.

An ongoing shift towards more sustainable construction materials in the Nordic countries challenges traditional fire safety concepts as well as our design approaches. As engineers, we face to consider new risks and the lack of knowledge and experience of these risk could oppose a potential threat to the fire safety in a sustainable building, e.g. a high-rise made of timber. An ongoing research project "Tall timber buildings – concept studies" has the aim to develop feasible concepts for planning and designing timber buildings higher than 20 floors according to present regulations. Fire safety is an essential part of the project, but as the regulations do not cover fire safety in buildings taller than 16 floors, there is a strong need to develop guidance specific to the use of renewable materials.

SBUF, the construction industry's organization for research and development has financed an initiative to develop the Br0 design guide published by the Swedish SFPE chapter to cover aspects related to the use of renewable materials, e.g. timber. The addition to the design guide will focus on the similarities as well as the differences when comparing traditional and renewable construction materials. Key aspects that need to be address when developing the design guide is fuel load, load-bearing structures, escape, fire service intervention and fire spread. Fire sprinklers are normally a fundamental add on to timber buildings and these systems have excellent lifesaving and property protection records. But, there are fundamental difference in risk when replacing passive fire safety with active measures. Thus, special attention must be given to the differences between active and passive fire safety features and their failure modes. Time to failure is of great interest and there are fundamental differences between e.g. sprinkler water being shut off and insufficient coating of structural members.

The presentation will give an introduction to the design approach of Swedish high-rises and focus on the fire risk related issues that need to be addressed when verifying fire safety in tall buildings made of renewable materials (e.g. wood).

Fire Safety Science Without Borders

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Keywords: (Fire loss, Fire and burn injuries, Garment industries, Childhood burn injuries, Globaliztion)

The fact that the Nordic countries have one of the lowest fire loss rates on the globe is no accident. A century or more of fundamental and applied fire safety science research, its application to regulation of facilities and products and their enforcement at the local level, and the creation of a culture of safety founded on that research has created a fire safety system second to none.

However, on a global scale, the collective burden of fire and burn injuries is still a major problem, causing on average 300 000 yearly fatalities.

This presentation will explore how the fire safety science community might contribute to reducing the fire problem in emerging nations, where a small percentage loss reduction in industrial applications and simple preventive measures in residential settings would have a major impact on safety. It will address a recent case study in the Bangladesh garment industry and also discuss the major problem of childhood burn injuries. A potential roadmap for the research community to contribute to reduction in the global fire problem will be outlined.

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Fire Safety´s Contribution to a Sustainable Society

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Keywords: (Fire safety, Green technologies, Sustainability, , Code requirements, Research agenda, Multidisciplinarity)

For decades, sustainability has been a topic of discussion for innovators and designers looking to conserve resources in the built environment. As green technologies and materials are becoming more affordable and available, the market demand for sustainable infrastructure and alternative energy has increased.

Decades of building experience with traditional building materials have led to well-established building and life safety codes and standards. When new materials and systems are added to the built environment, the solution to the fire safety equation changes. Societal expectations for how our buildings respond to other hazards, including fire, also change with time. New solutions might protect against one risk, but could at the same time be creating new risks of their own. One example is the debate regarding flame retardants. This presentation will outline some of the potential fire hazards associated with sustainable materials and technologies and summarizes some of the mitigation strategies which might include operational criteria, code requirements or both. And how should these new technologies and perspectives affect the fire research agenda? Our proposition is that the fire safety community must broaden its scope and join forces with other disciplines/sectors in order to fulfill a role as a key actor in the formation of a new sustainable society.

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New initiatives for fire safety research and innovation

Berit B. T, Research Council of Norway

The Norwegian Research Council has received a donation from the Gjensidige Foundation that enables a new research initiative on fire safety. The donation is part of a larger gift, 300 MNOK, to the Norwegian society in occasion to the Foundation's 200 anniversary. The gift called "Det store brannløftet" is comprised of different measures that, on short or long term, will make every day safer for Norwegian citizens. A part of this is measures for enhancing competence and knowledge building the Norwegian Research Council has mapped the research area through publication databases, interviews with central research actors, government officials, fire departments, insurance agencies etc. The mapping has made the basis for a new research initiative that we are launching this autumn. The research initiative shall strengthen research through capacity building and international collaboration and build knew knowledge in areas with high risk, such as fire management, coordination and learning, energy-carrier, groups at risk, health risk as well as fire extinguish, detection and prevention of fire. Funding will be available for Norwegian research institutions in collaboration with international research partners, as well as private and public actors.

Smouldering fires in wood pellets: the effect of varying the airflow

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Keywords: smouldering, pellets, forward, reverse, airflow

Introduction: Smouldering is a flameless form of combustion, deriving its heat from heterogeneous reactions occurring on the surface of the fuel when heated in an oxidizer environment. Smouldering is of interest both as a fundamental combustion problem and as a practical fire hazard, for instance in industrial storage units [1]. Many materials can sustain a smouldering reaction, among them wood pellets, which are becoming more widely used as an alternative to oil -fired central heating in residential and industrial buildings. Smouldering fires are difficult to detect, becoming a hazard that must not be underestimated [2].

The influence of varying the airflow, using two different configurations of smouldering combustion was studied: reverse and forward propagation. These are defined according to the direction in which the smouldering reaction front propagates relative to the oxidizer flow. In reverse smouldering, the reaction front propagates in the opposite direction to the oxidizer flow. In forward smouldering the front propagates in the same direction as the oxidizer flow: convective transport is in the direction of the original fuel ahead, preheating it before the smoulder zone is reached [2].

Methods: The test setup consisted of an insulated steel pipe heated to 360 °C from below by a hotplate [3] [4], see Figure 1. Sample temperatures were measured using thermocouples positioned every 2 cm vertically. In the original setup the bottom of the pipe was closed. The air entered and exited at the top of the pipe, while the combustion propagated from bottom up, giving a semi-reverse airflow system. To obtain a forward flow, the pipe was raised 1 mm allowing air to enter from below. The chimney effect arising caused the main airflow direction to coincide with the main propagation direction, giving a forward airflow configuration. A total of eight tests were made, four in each configuration.

Results and conclusions: By changing the airflow from semi-reverse to forward several differences were observed. In forward airflow the samples needed a shorter time (4 hours) of external heating to have an onset of self-sustained smouldering, compared to the 6 hour needed for the semi-reverse airflow. Forward smouldering reached higher maximum temperatures (610-650 °C) than the semi-reverse cases (545-550 °C).

The combustion duration also distinguished the two airflow systems, with average total combustion duration of 55 hours for the semi-reverse airflow and 30 hours for forward. The

total mass consumption was, on the other hand comparable for the two, -92 ± 0.5 %, giving a mass loss rate of 0.3 g/min for semi-reverse vs 0.6 g/min for forward.

The overall combustion behaviour of the two cases was similar, but with a difference in the stagnant temperature period before the maximum temperature, see Figure 1. This period was 3.5 h shorter and had a more stable temperature development in the forward airflow case. The results indicate that forward smoulder propagates faster than reverse, with a more stable and intense combustion as the oxygen supply is moving in the same direction as the smouldering.

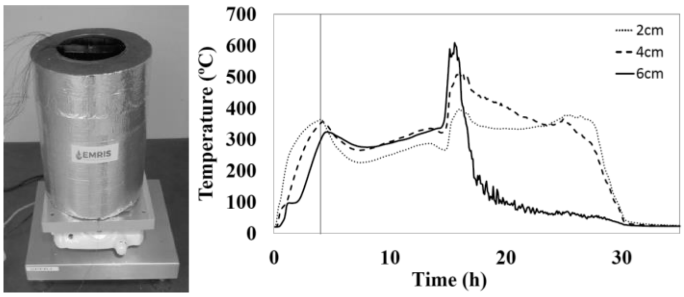

Figure 1. Setup used in the study (left) and temperature development versus time (right), vertical line indicates when the external heating was turned off.

To conclude, the airflow configuration seems to influence smouldering both in terms of maximum temperatures, heating period and combustion behaviour. More tests will be done in the following months, providing data to develop numerical analysis, enabling a better understanding of the fundamentals of smouldering combustion which will be applicable to understand and avoid fires caused by self-heating in large scale storage facilities.

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Modelling and Stochastic Analyses of Travelling Fires

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Keywords: travelling fire, FDS, wood cribs, fire spread

The dynamics of compartment fires has evolved over time along with the construction trends. The magnitude and severity of fire risk has also increased along with the increase in the size of structures [1]. Behavior of fires in large compartments is not understood as well as fires in small compartments and the assumptions of homogeneous heating of structures would fail [2]. The concept of travelling fires was introduced by Stern-Gottfried and Rein [3] to explain the possible behavior of fire in compartment sizes larger than 500 m2 [4]. It was proposed that the fire had a more dynamic nature than the one observed in smaller compartments. The fire was assumed to travel across the floor area consuming the available fuel along with the oxygen and cause a non-linear cyclic thermal loading across the structure. This uncertain nature of such fires requires detailed analysis, and an engineering methodology for addressing fire in large compartments, similar to the design fire curves of the Eurocodes [3], needs to be developed.

Applicability in engineering analyses requires that the method is computationally inexpensive and produces a sufficient resolution of temperature fields. The aim of this work was to develop a reliable and fast modelling procedure for producing a set of stochastic travelling fire temperature curves using the Large Eddy Simulation based CFD code, Fire Dynamics Simulator.

The first step of this process was to validate the ability to model fire spread in wood crib fire load with a simple pyrolysis model such as the ignition temperature [7] model. The model was validated using the SP model scale tunnel fire experiments conducted by Hansen and Ingason [5&6].Initial tests were conducted to determine the appropriate parameters required for the modelling such as the heat release rate per unit area (HRRPUA) and ignition temperature. Next, the SP tunnel fire experiments were simulated to obtain the fire spreading behavior in wood cribs. The fire spread was analyzed under different longitudinal ventilation velocities and with the wood piles placed at varying distances.

When modelling the wood crib experiments, an ignitor model was developed and validated to reproduce the ignition behavior of the experiments. In engineering analyses, the ignition sources are usually too small to be resolved by the computational mesh. . The engineering application needs a generic, faster fire spread model that can build up the initial fire development phase. For this purpose, the radially spreading fire [7] model is used. The fire spread rate required for producing the same heat release rate and ignition of the adjacent wood piles is found out iteratively. The ignition temperature -based pyrolysis model is used to model the spread of fire beyond the initial region. For the stochastic analyses, a model compartment was developed with randomly distributed office fire load. A point of ignition was randomly chosen and curves with different growth rates were applied. The temperature and heat flux fields within the compartment at various points were recorded. These data can then be used to analyze the performance of the structure in a travelling fire scenario.

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Photovoltaic installations on warehouse buildings
– *an experimental study of the propagation of fire*

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Keywords: PV, propagation, full scale, reflection, defelction.

An increased focus on renewable energy, a desire to gain good publicity and especially the possibility of decreasing the energy cost in a world where the demands for energy increase, are important reasons why photovoltaic (PV) panels are becoming more and more popular. For companies with large flat roof constructions on buildings, such a solution can even be cost-beneficial, because it allows for utilization of the otherwise unused roof space. However, the installation of PV arrays also introduces an electrical system powered by an infinite source of energy, the sun - which cannot be switched off if needed. The installation of large electrical systems increases the possibility of electrical malfunctions and thereby the possibility of ignition and propagation of fire underneath the installations [1] [2]. The project focused on the fire dynamics underneath the PV installations, as historical data have shown that fires will occur.

The influence of PV arrays on flat roof constructions in case of fire was studied experimentally with four full scale tests and also in a parametric study. The four full scale experiments were all based on an existing light roof construction made with a self-supporting metal sheeting, 150 mm EPS (expanded polystyrene) and a PVC based roofing membrane. The use of EPS, a highly flammable insulation material, was considered to be a likely worst-case scenario, and to prevent ignition of the EPS, three different mitigation solutions were tested on top of the existing roof constructions. The three mitigation systems consisted of either a layer of 40 mm PIR insulation, 30 mm mineral wool or 30 mm mineral wool combined with a single layer of alufoil, which were all placed on top of the existing roof construction together with a second layer of PVC based roofing membrane. The mitigation layer of PIR insulation was tested twice. An array of PV panels with the dimension of   were placed on top of all the full scale tests and all tests was ignited with a wood crib.

The fire-induced re-radiation underneath a PV panel was examined in the parametric study [3]. The set-up was designed with a centred gas burner, two movable Hukseflux heat flux gauges with a working range around 5 kW/m2, and a PV panel with an adjustable elevation and angle. The heat flux received, as a function of different distances from the gas burner, were examined for different positions of the PV panel and a comparable baseline test without the influence of the PV panel.

The parametric study revealed that the transfer of heat reflected from the point source were largest underneath the most elevated part of the PV panel. Positioning the PV panels in the same height and angle as in the matching mounting system used in the full scale tests, it was concluded that the reflection of heat from the panel increased the received heat flux significantly. Depending on the heat release rate from the point source, the received heat flux underneath the panel increased with 100% – 400% for heat release rates from 4 kW – 8 kW, compared to the received heat flux measured in the same distances without the reflection. The influence of the additional contribution of heat provided by the reflection underneath the panel, and deflection of the flame, towards to subjacent surface of the roof construction was consolidated in the full scale tests.

In all four full scale tests it was seen that when the roofing membrane was ignited, it contained enough energy for the fire to spread outside the domain of the ignition source whereupon it propagated underneath the whole area of the tested PV arrays. When the fire reached the edge of the PV array, and thereby an area without the additional heat contribution defined in the parametric studies, the propagation was sporadic and strongly controlled the deflection of the flames from the main fire underneath the PV array. For all three mitigations solutions, it was observed that parts of the EPS melted due the heat from the fire underneath the PV array. For the two tests with a mitigation layer of PIR insulation, the EPS insulation was ignited after approximately one hour. It is assumed that the ignition occurred due to a heat related degradation of the PIR insulations mechanical stability resulting in a penetration and thereby an ignition of the subjacent insulation. The EPS insulation was not ignited in the tests with mineral wool.

The findings of the study indicate that the propagation of a fire involving PV installations is not only caused by an increased fire load – but to a great extend also due to the changed fire dynamics underneath the PV installation. Based on the thesis it is recommended to evaluate a roof constructions fire related properties with respect to the changed fire dynamics – before installing large commercial PV systems.

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Performance Based Design and Compliance

Societal Expectations and Fire Safety Outcomes

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Keywords: (5 key words)

Fire safety has a long history of regulations as a means for society to prevent disastrous outcomes in the event of fires. Traditionally, fire safety regulations have been the product of reactions to occurred events. As regulations have advanced and performance-based regulatory systems have become more prominent, a shift can be seen from reactionary to precautionary principles. This shift has also an effect on the drivers to regulatory change, see figure 1.

Figure 1 Shapers of regulatory regimes and related outcomes.

This shift will be explored in this presentation with regards to shapers of regulatory regimes and its related outcomes. The focus is in the current paradigm in fire safety regulations in Sweden, i.e. performance-based design, which is also relevant for other countries such as our Nordic neighbors.

Cornerstones in performance-based regulatory systems will be presented based on risk governance research [1] [2]. Challenges relevant for the Swedish implementation of performance-based design will be presented.

The challenge and need of following up compliance of regulations in a performance-based regulatory system will be presented. Methods to follow-up compliance [3] from a national perspective will be discussed and related to how compliance may be improved. Examples of employment of such methods will be presented.

Based on the results implications for performance-based design will be discussed and related to possible ways to improve quality in the current regulatory setting.

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Wildland fires and scarification

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Wildland fires may cause severe economic losses, and in some cases also affect urban areas. Examples of the latter are the fires in Laerdal and Flatanger in Norway 2014. The Swedish Contingency Agency (MSB), in collaboration with Swedish Meteorological and Hydrological Institute (SMHI), has since 1996 employed the Canadian Forest Fire Danger rating system for risk assessments, issued to the local fire rescue services and forestry operators [1]. The general risk level is indicated by the FWI index which integrates various drivers of fire intensity such as fuel moisture and wind. It builds on a set of primary indices, including DMC that relates to the moisture content of the humus layer. [2].

Amongst operators within the forest sector the risk of fire ignition from forestry machinery is well known. Fires are ignited during both harvesting and forwarding but in particular during scarification. Operators frequently need to suppress small fires detected in the tracks behind the machine. However, the extent of this problem is not well known. Since it was established that scarification was the source of ignition for the large fire in Västmanland in Sweden 2014, the need for better risk assessment has become clear [3].

This study summarizes the occurrence of wildland fires caused by forestry machinery, which have led to an incident by the fire rescue service. The data is limited to the years 1998-2015. We have coupled all incidents with the risk indices for the day of ignition, estimated within the nearest 11 x 11 gridpoint.

The data shows that the majority of wildland fires caused by scarification occurred during the early summer months (May-July) [3]. The time for the fire rescue service to reach the fires was on average 34 min. Compared to wildland fires in general, a greater proportion of the reported wildland fires caused by scarification were larger than 0,5 ha. This is likely due to the fact that these fires typically occur on clear-felled areas with very suitable fuels, and possibly also further away from the bases of the rescue services. However, there was no clear correlation between area burnt and response time for the rescue service.

A smaller fraction of the known fires ignited by forestry machinery occurred during days with a very high FWI compared to large forest fires of any cause of ignition. This is likely due to the fact that forest managers avoid operating scarifiers when the fire risk is very high. Still, almost 35 % of the fires leading to a fire rescue service incident were ignited at FWI >21.

There was a distinct correlation between moisture in the humus layer and the fires caused by machinery, since 80 % of the fires occurred when the Duff Moisture Code (DMC) exceeded 30. In fact, the threshold with regard to DMC was higher for these fires than for forest fires of all ignition causes combined. Most wildland fires in general occur during the summer, since people utilize the nature more frequently. But forestry work may occur during the entire year if there is no snow or ground frost. These seasonal trends were evident in the relatively high Drought Code (DC) levels, i.e. the index indicating moisture content in deep organic soil layers.

In conclusion, when assessing the risk for wildland fires caused by forestry operations, the DMC index can act as an important complement to the FWI index.

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A discussion on learning from fire investigations; concepts and methodologies

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Keywords: fire investigation, learning,

Fire investigation is an activity currently related to responsibilities, liability and Police investigation. In this paper, we will focus on the potential learning in the emergency response organizations as well as the civil engineering industry by focusing on investigation of fire incidents in a broader context than in the current practice. This includes exploring the possibilities for employing new methodologies and models for the use in fire investigation. The paper focuses on the potential learning in fire investigation by employing new methods and methodologies. In this way, the project might pave for new insights not only benefitting the public sector, but also in the industry in general.

Fire incidents in Norway over the last years have shown that there are more to be analysed after a fire than the causes of the fire and associated responsibilities. The last 10 years there have been several fires that could provide knowledge beyond determining the initiating event, for example:

- Urtegata 31: Fire in a residential building in Oslo 2008, 6 fatalities.
- Gullskogen: Fire in a residential building in Drammen 2008, 7 fatalities.
- Lærdal, Flatanger og Frøya: 3 large wildland fires early 2014 due to unusual dry winter. No fatalities, but rapid fire spread due to strong wind, which caused severe property damage.
- Oslofjordtunnelen 2011: Fire in a heavy goods vehicle in a subsea tunnel that trapped 9 people in the smoke which had to be rescued by emergency responder.
- BASA fire in Tønsberg 2015: Large fire in a storage/industrial building with severe property damage.

Increased learning from fire incidents have been identified by the Norwegian Directorate for Civil Protection (DSB) as an important part of managing fire risk in the society. Although the importance of learning from incidents are well known, the study of the organisation of the fire brigades in Norway identifies that there is a lack of structure, methodology and competence to obtain this knowledge from real incidents [1]. The above mentioned examples are analysed by use of the Sommer, Njå and Braut's learning model [2].

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Socioeconomic Differences in Residential Fire Mortality in Sweden: a case-control study

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Residential fire is by far the largest category of fatal fires in Sweden, accounting for about three-quarters of all fatalities [1]. This study aimed to investigate socioeconomic differences between residential fire fatalities and a control group in Sweden using the case-control method.

Data on the fatalities were obtained from a compiled database using linked data from the database on fatal fires, the database on forensic examinations, and the Cause of Death Register [1]. Four controls per fire victim were matched on age at death and sex from the Swedish population register. Data on socioeconomic variables were linked to both cases and controls by Statistics Sweden.

The results show clearly that residential fire fatalities to a significantly greater extent were, living alone, having low income, living in rented apartments, and were unemployed compared to the control group.

This is consistent with results from previous studies [2]. Further, we compared different fire clusters/fire scenarios identified in a previous study [3] with regards to socioeconomic characteristics.

The results from this study can be used in guiding and targeting informed fire mortality prevention strategies.

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Fire fatalities in Norway

An analysis of 350 fires from 2005 to 2014

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Keywords: (fire fatalities, fire risk, fire prevention, statistics, investigation)

Individuals that may be categorized in different ways as vulnerable are overrepresented in the fire fatality statistics in Norway and internationally. With this in mind the Norwegian Government appointed a special committee to examine the fire safety of certain risk groups. One of the conclusions of their work, which was presented in an Official Norwegian Report (NOU 2012:4) [1], was that there was a need for improved knowledge about groups at risk. It was suggested to perform research to improve the knowledge about risk connected to critical factors. Targeted measures can then be implemented based on this knowledge. SPFR has recently performed a project with this in mind, commissioned by the Norwegian Ministry of Justice and Public Security and the Directorate for Civil Protection (DSB).

The aim of the study has been to analyze fire statistics and other sources in order to retrieve more details about the victims of fatal fires and to find explanations as to what led to the fatalities. We have attempted to answer the following questions in the study:

1. What are the risk factors associated with the Norwegian fire fatalities?
2. What are the causes of Norwegian fire fatalities?
3. How can fatal fire best be prevented?

In our study we have investigated fatal fires which occurred between 2005 and 2014. Information from the fire statistics database of DSB, police investigation reports, the victims' medical journals and the Norwegian Cause of Death Registry has been gathered. In the time span mentioned, 517 fatal fires occurred, from which we got access to police investigation reports from 350 fires where there were 391 fatalities.

The extent of information from the police investigation reports varies greatly, but they generally include details about the building, room of origin of the fire, type of fire and other circumstances surrounding the fire. They may also contain information about how and by whom the fire was detected. The police investigations reports also allow for a clearer picture of the individual victims of the fire through for example witness interviews and autopsies. By accessing the victims' patient journals we have been able to further explore whether there were any health factors that can be related to increased fire risk, e.g. reduced mobility, cognitive issues, drug or alcohol problems, etc.

The preliminary results are indicating that there is a clear pattern of risk factors associated with fire fatalities. For example, the use of alcohol has been identified as a considerable risk factor in previous studies, e.g. reference [2], and also our study considers whether the victim was influenced by alcohol in connection with the fire. The full results of the study will be published towards summer 2017.

In many cases the risk factors have been known by people in the victim's surroundings (relatives, health personnel, etc.), obviously without them being able to prevent the fire or its consequences. This demonstrates the complexity in implementing fire safety measures in that the preventive work can be performed by different people with different roles with regards to the individual at risk.

Our results will be viewed in conjunction with our previous study on organizational and technical fire prevention [3,4]. By more fully understanding the details in the individual cases through analyses of the underlying causes of the fire fatalities, we hope to be able to recommend ways of successfully prevent fire fatalities.

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Has fire-related mortality in Sweden changed over time?

Adressing the issue of overdispersion in Poisson regression

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Keywords: Fire-related mortality, Poisson regression, Overdispersion, Time covariates, Accident data.

We were asked to model the occurrence of fatal fires in Sweden, to answer the question whether or not the number of fatal fires has changed over time. The task was given by the Swedish Civil Contingency Agency and the Division of Fire Safety Engineering at Lund University as part of their preventive work against fire related deaths.

The Poisson distribution has a long history of usage in modelling accidents and mortalities. The most famous example is given by von Bortkewisch, who used the Poisson distribution to model the number of Prussian soldiers killed by horse kicks.1 Fatal fires can be expected to follow the Poisson distribution for the same reason as fatal horse kicks, since they are independent events that happen with a relatively low probability. One of the key features of the Poisson distribution is that it has one free parameter , which happens to be both the mean and variance of the distribution. Empirically, however, it is often found that count data, which is expected to be Poisson distributed, has a variance larger than the mean, so called overdispersion. When present in Poisson regression, overdispersion will, if not accounted for in the model, lead to incorrect estimations of the coefficient variances. In our study, we addressed the issue of overdispersion in the context of modelling fatal fires. This was done by applying Poisson regression with time covariates on a dataset containing the number of fatal fires in Sweden from 1999 to 2015.

It is generally known that there can be different reasons behind the excess variation of a Poisson regression model. There may be omitted predictors in the model. Overdispersion may also stem from dependence between some of the events in the point process, which violates the assumption of independence of the Poisson distribution. This applies for example in the modelling of the number of fire-related deaths, instead of the number of fatal fires. Overdispersion can also arise when the conditional mean varies between different parts of the data. One can, in that case, interpret the overdispersion as a cause of there being several Poisson distributions in the data.2

The data used in our study came from the database IDA,3 provided by the Swedish Civil Contingency Agency. The database contains, for example, monthly data of fatal fires from 1999 to 2015. The monthly data varies intensely, which makes modelling difficult if the explanatory variables do not vary to the same extent as the response variable. For this reason, we summed the monthly data into quarterly data. The data exhibits overdispersion with mean and variance of 27.5 and 92.9 respectively. Regressing on the quarterly data, we fitted a model containing seasonal components and a linear trend. A binary variable indicating a breakpoint in mid-2012 was also added, to model a graphically observed drop in the number of fatal fires. The regression model we used successfully eliminates the overdispersion in the data, which led to the conclusion that the excess variation is a result of there being several Poisson distributions during the period. The model estimates a higher rate of fatal fires during the winter, and a lower rate during the summer. The linear trend depicts a steady decrease in the amount of fatal fires during the time period, of approximately 0.4 % per quarter. Lastly, the breakpoint in mid-2012 describes an additional decline in the rate of fatal fires by approximately 21.3 %. Caution must, however, be taken when interpreting the breakpoint, as it cannot be seen as proof of a drop in the rate, but only as a measurement of an observed change.

In conclusion, our model shows that the issue of overdispersion in data of fatal fires is, in this example, caused by the presence of several Poisson distributions with different conditional means that appear during the time period.

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Toxic emissions, human absorption pathways, smoke poisoning and long- term health effects due to combustion of plastics in modern buildings

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Keywords: plastic, smoke, toxic compounds, biomarkers, human absorption pathways, smoke poisoning, asphyxiation, carbon monoxide poisoning, chemical injuries after inhalation of toxics and long-term health effects.

Abstract
The use of cellular plastic (foam plastic) in upholstery of furniture and interior insulation in modern buildings has become exceedingly widespread. Presently there is little knowledge available regarding the toxic compounds released from these products during a fire. Of this reason it is crucial to achieve greater insight into the different types of cellular plastics on the market and their potential health effects on humans. Our purpose is to gather sufficient knowledge of the health effects associated with fires in modern buildings so the physiologic effects (symptoms) can be understand and the correct medical treatment administered.

The project provides the physical principles and the chemistry during combustion of different

plastic products. The project will establish a background on this field, and propose acceptance criteria for human exposure of certain toxic fire gases. An introduction given to respiratory physiology where thermal injuries, carbon monoxide poisoning and chemical injuries after inhalation of toxic smoke particles, vapors and gases is discussed. Different human absorption pathways are analyzed, for instance dermal uptake. The results could give valuable information about long-term effects of toxic emissions from fires in plastic-based products.

The method: A survey planned on a cohort, using a group of citizen representing an expected non-exposed group. This group we compare with a group of firefighters with an expected high- exposure frequency of fire emission products. Relevant biomarkers in blood and urine of the two cohort-groups analyzed, in order to reveal the presence of toxic compounds in human body, and uniquely related to an exposure of combustion products of plastic. As part of the project, we will investigate the major human absorption pathways, i.e. from air-to-human. Expected absorption pathways could be inhalation, dermal uptake and intake of soot particles by swallowing of saliva under/after an emergency.

Finally, the project will conclude on the results and propose remedial measures for firefighters,

emergency authorities, consultants and the construction industry.

The project planned to run for 3 years and collaboration partners will be final appointed, but with expected participants from the following: Technical University of Denmark (DTU), Aalborg University (AAU), University of Southern Denmark (SDU) and National Research Centre for the working Environment (NFA).

Learning points from real incidents – learning from what?

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Keywords: Learning, frontline command, action-camera, struck

The increasing implementation and use of action-cameras in real incidents display a willingness amongst the practitioners to examine and explore their practice conducted during real emergencies. Nevertheless our research conducted in Denmark and Norway have shown that the practitioners and learning-teams are being challenged by processing the data-material in a way, which not only confirm what they already know, but provide them with learning-points related to the tactical, technical and managerial aspects of the emer-gency response. Even though research have provided models for learning in emergency response work [1], the core contents of the learning-point remains vague, and the question remains, do we know what we should learn from?

Our research conducted in Denmark and Norway have focused upon the practice conducted by frontline commanders. Frontline command is often presented as a cognitive endeavour, where the individual manager by intuition and experience is able to recognise a pat-tern, which allows the individual to implement a course of action based on extracted cues, recognized plausible goals etc. [2]. Such a notion of frontline command can furthermore be identified in the formal educational programmes regarding incident command [2]. The programme expects that the graduated commander is able to identify, implement and monitor the response activities through 'anomalizing' and 'proactive sense-making' [3]. By conceptualizing the practice of the frontline in such a way, the learning-points related to the practice of the manager tends to focus solely upon the tactical and technical aspects, but learning-points related to the managerial aspects is being relegated to the background.

We acknowledge the individual dimension of frontline command, but reframe incident command as relation-al management and the frontline manager as a sense-facilitator. Such a notion calls for theoretical concepts, which is able to grasp the tentative interruptions in the sensemaking processes. We propose that the concept of being struck [5] allows us to investigate the interwo-ven cognitive, physiology and emotional processes of interruptions during real incidents. The interruptions in the sensemaking-processes were recorded (N = 25 cas-es) by action-cameras mounted to frontline com-manders. The recordings were analysed in a dialogue process together with the commanders, and the inter-ruptions in the sense-making processes were then ana-lysed and mapped into themes.

The empirical findings show that the interruptions in the sensemaking-processes can be condensed to three themes, which display common learning points:

1. Interruptions linked to the socio-cultural as-pects of being an incident commander in the particular context.
2. Interruptions linked to the way language is used to discursively negotiate power and legit-imacy.
3. Interruptions linked to how emotional and physiological aspects affects the sensemaking processes.

The study contribute to our notion of learning-points related to learning from emergencies, and challenge thereby a solely cognitive endeavour of frontline command.

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Integration of fire engineering tools and calculation methodologies *Development of FirePlatform project*

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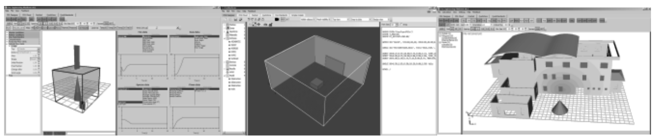
Keywords: Fire engineering methods, numerical calculations, fire modeling, fire scenarios, risk assessment

The availability of fire engineering tools is an important factor shaping the discipline of fire protection engineering. Currently in fire protection engineering a large number of calculation tools is available. It does not mean however that the process of using them is always smooth and comfortable. Some tools are quite old with archaic or impractical user interface, which does not mean that their calculation algorithms are bad, but it makes it harder to use them and they become unpopular while other tools take their place. The multitude of available tools is not a good thing for everyone because it makes the design verification harder for AHJs, which are usually less familiar with the tools than engineers are. The same problem exists in fire science and engineering education. It is not convenient to teach many different tools that are disconnected and the level of integration is very low. The time needed to build a model and see the results should be very fast for the student to understand various interrelations. The selection of the right tool for a job is a separate problem, but in general the variety of ways a problem can be analyzed can be considered as a confusing aspect of fire engineering for many outsiders. In practice most engineers keep many tools for various occasions including self-made spreadsheets. The aggregation of useful tools seems like a reasonable idea and in fact it happened in the past that some good packages were developed. The concept of this paper is to describe the philosophy for a multi-module integrated calculation tool package which is proposed in a form of FEP and the vision for it in the future. The current capabilities and those available soon will be presented. The benefits of the FEP for fire science education and the concept of a smooth fire protection engineer's workflow will be discussed.

What are the important factors for fire engineering tools? Among others: availability, cost, speed of use, user friendliness, learning curve, time to see results, number of potential uses, effectiveness in addressing the main purpose, visual appeal and attractiveness of results, interactivity, integration with other tools, variety of input and output options, scalability, reporting capabilities, varied use of computational resources, multi scenario capabilities, addressing probabilistic aspects, validation and credibility of sub-models, ongoing maintenance, support and continued development, recognition and acceptability in the field. The problem with many existing tools consists in not addressing some of the above important factors. The common inconvenience includes the necessity to use separate tools for calculation and presentation of data which requires various data transfers. The time aspect is one of most critical because calculation tools should support the work of fire protection engineer in a smooth way. Ideally a quick initial analysis should be performed within few minutes or even quicker. Short time of single calculation setup allows engineer to quickly test various design options or scenarios. If a more complex calculation is needed the time to setup the model is as important as the calculation time. Many of the abovementioned needs are addressed in a variety of ways in a new software package – Fire Platform. FirePlatform consists of a number of modules addressing various aspects of a fire protection engineer's workflow. It is being actively developed to include a growing number of features. The current set of modules includes the following modules: FireRad, QuickZone, FDS Designer, FDS Cloud, QuickStandards.

The QuickZone model can be used for many initial assessments for compartment fires, while FireRad is a tool to study external fire spread by radiation. FDS Designer is a tool for building FDS models and the FDS Cloud is a facility to run any number of FDS simulations directly on the cloud resources, making the process very easy to start and monitor. QuickStandards is a tool making calculations based on technical standards very fast and easy. Some other modules are under development and they involve egress and structural response analysis. Snapshots below present some of the discussed modules of the Fire Platform.



Learning fire and rescue work by experience-sharing

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Keywords: learning, knowledge, emergency response, experience-sharing, experience transfer

Learning in emergency response organizations is a widely discussed topic in the study of societal safety. The need to improve experiential learning was one of the conclusions in a report commissioned in 2013 by the Norwegian Directorate for Civil Protection and Emergency Planning (DSB, 2013). DSB is the supervising and administrative authority for the fire and rescue services in Norway.

The master thesis presented in this abstract deals with some of the prerequisites for and challenges with fire and rescue personnel's learning through experience-sharing after emergency responses. Experience-sharing is a comprehensive concept not easily defined. Learning in emergency response organizations is also challenging with regards to how to express and measure learning. Experiences and learning after real incidents were at the core in the thesis work. The purpose was to study the phenomenon as it was considered by fire and rescue workers at different levels in the organizations. The major issue was: How can fire and rescue personnel learn from each other by sharing their experiences?

Through 16 interviews with employees at various levels and document studies, including the organization's intranet and systems for reporting and evaluating emergency responses, the thesis studied transfer of experience in a major fire and rescue organization in Norway. Important theories illuminating the major issue used in the thesis were; learning in emergency response organizations (Sommer et al., 2013), information and experience-sharing (Argote et al., 2000), and organizational culture (Schein et al., 1987).

The respondents claimed that a common understanding of learning by experience-sharing should be established in the organization. They meant that every single person in the organization was responsible for contributing to the transfer of experiences. However, there was far less agreement on how to do it. To meet, talk and use visual effects such as pictures and videos were regarded effective by the emergency response personnel. There is a weak reporting culture in the organization. Written reports were not regarded as suitable for transfer of experiences or lessons learned after incidents, but rather as mandatory reporting for use in e.g. national statistics.

The management should put learning from experiences higher up on the agenda. The management is in general the most important "culture creators" in organizations. The emergency service organization had no formal system for sharing experiences between individuals or groups. Hence, the transfer became dependent on the different management styles in the organization. Formation of subcultures, partly due to different groups and sections, seemed to preclude learning in general, and especially through experience-sharing.

There was not drawn a clear line between "experience-sharing" and "information flow" in the department. Information flow that works well does not guarantee learning, but it increases the potential and is recommended to form a specific requirement.

A challenge with experience-sharing is often said to be the tacit knowledge amongst individuals (Eraut, 2000). Very few respondents saw learning by employing experience-sharing as a problem. The respondents appreciated competency based on tacit knowledge. Ways of forwarding subjective experiences to other individuals or groups were neither not seen difficult. There was much stronger focus on the missing system for collecting and distributing valuable experiences, than on challenges with sharing those experiences.

A system that can accommodate experience-sharing in the department requires cultural and attitude changes that directly interfere with working practices. Articulating personal mistakes or misjudgments are associated with negative outcomes, which contribute to hide important knowledge within the department. In practice there are many barriers to overcome to make experience-sharing and learning functioning. To prevent tacit knowledge from becoming hidden knowledge the understanding of performance needs to change. The learning aspect of experience-sharing must be internalized instead of revealing individual's misjudgments and errors.

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Objectifying performance based design for life safety by a probabilistic approach

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Keywords: Performance Based Design, Reliability, Failure probability, Life safety

Context of PBD for life safety:

When looking at the history of performance based design [1], there has been little evolution since the early 2000's. Neither the concept of ASET vs RSET, the type of tools (CFD and evacuation model), nor the definition of "reasonable worst-case" have changed. The fire engineer should decide on a reasonable Safety Factor, dependent on the level of conservatism in the assumptions of the input parameters to demonstrate the safety level is acceptable. Consequently, different results can be expected from different fire engineers and no uniform safety level can be expected in fire designs. Several countries have tackled this issue by changing their legislation from a performance based to a prescriptive performance based framework [2]. As these apply to a wide range of building types, the fixed input parameters might be conservative for some and not conservative enough for others.

Challenges for objectifying the safety level:

In current state of the art PBD-analyses, following challenges need to be addressed in order to objectify the safety level of a design:

[C1] The level of conservatism in the input parameters of both the ASET (HRR, soot, growth curve, …) as the RSET (pre-movement time, walking speed, impact of smoke, …) are left open as a choice to the fire engineer, which is subjective.

[C2] When multiple scenarios are to be investigated in order to determine its impact on the risk, many combinations might be necessary. When uncertainties of certain parameters are addressed by sensitivity studies, the number of scenarios quickly grows, which might make both the engineering as the computational resources excessive to the added value of the analysis for the client.

[C3] The main assumption in the current fire safety designs is that the safety systems put in place (e.g. smoke control, sprinkler, compartmentation, …) will function in all cases. This is correct in theory, but in practice there will be a wide range of reliabilities. These should be taken into account in the process to go from theoretic to practical safety level.

Proposed solutions for objectifying the safety level:

In this research project, a framework is being developed for objectifying the safety level in PBD, where the previous mentioned challenges are tackled by following solutions:

[S1] A probabilistic distribution is applied to all input parameters, representing the level of conservatism of the design scenario (methodology is similar to [3], applied to buildings).

[S2] In order to reduce the required number of simulations (CFD or evacuation model), an interpolation method was developed. A multi response surface model (RSM) is suggested for the probabilistic analysis of the entire input domain. Based on a few supports samples the RSM represents the results for the entire spectrum of possibilities. This is described in [4].

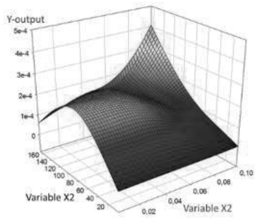

Figure 1: Response surface model [4].

[S3] By using Fault Tree Analysis, the reliability of each safety system is taken into account by accounting for the failure probability of each component (e.g. redundant pump, electrical supervision of main valve, …) and of the maintenance.

Ongoing work:

The method is currently examined for several challenging case studies. One of the main challenges remains to integrate the important submodels of smoke spread to adjacent compartments (e.g. staircases) and fire brigade intervention and the verification and validation of the new methodology.

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Measuring incident heat flux and adiabatic surface temperature with plate thermometers in ambient and high temperatures

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***Keywords:** temperature measurements, heat flux, incident radiation, adiabatic surface temperature, heat flux meters.*

The theory and use of plate thermometers measuring incident radiation heat flux and adiabatic surface temperature are presented. A new more insulated and faster responding PT is introduced which has been developed for measurements in particular in air at ambient temperature as a cheaper and more practical alternative to water-cooled heat flux meters. Comparisons of measurements with PTs and HFMs are made. Finally it is concluded that incident radiation in ambient air can be done with HFMs as well as with the new insulated type of PT. In hot gases and flames, however, only standard type PTs can by recommended. Convection makes then measurements with HFMs inaccurate as well as difficult to interpret and use for calculations.

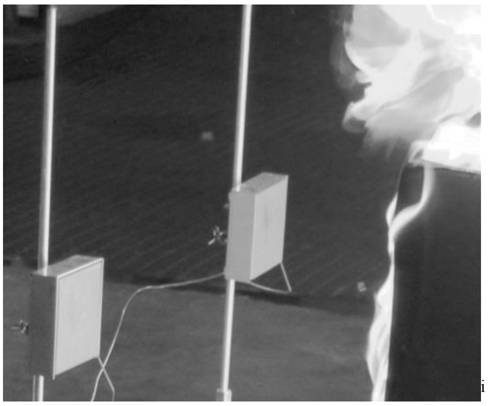

Figure 1 Two insulated Plate Thermometer Heat Flux Meters (PTHFM) mounted in front of a burning item measuring incident radiant heat flux and adiabatic surface temperature.

Theory of plate thermometers

Plate thermometer temperature measurements yield in general the adiabatic surface temperature AST. This now since many years established and recognized parameter and is being used by fire engineering scientist worldwide [1]. It is for instance an output parameter of the CFD code FDS and can be used as a simple boundary condition by computer codes for calculating temperature in fire exposed structures.

In addition to the AST, the incident radiation $\dot{q}''_{inc}$ can be derived from plate thermometer measurements as [2-6]

$$\dot{q}''_{inc} = \sigma \cdot T_{PT}^4 - \frac{1}{\varepsilon_{PT}}\left[(h_{PT} + K) \cdot (T_g - T_{PT}) - C \cdot \frac{dT_{PT}}{dt}\right]$$

where T_PT and T_g are the measured PT and surrounding gas temperatures, respectively, while ε_{PT} and h_{PT} are the emissivity and the convection heat transfer coefficient of the PT, respectively. K and C are parameters characterizing the PT in terms of heat losses by convection and inertia. The magnitudes of these parameters are generally small and can often be neglected depending on the design of the PT and the fire scenario studied.

For the special purpose of measuring $\dot{q}''_{inc}$ in room temperature a well-insulated PT with a thin sensing plate has been developed as shown in Figure 1. A prototype has earlier been used [7].

In the new textbook from Springers [6] a thorough background on theory measurements and calculation in fire safety engineering is outlined.

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Simulation of smouldering combustion based on multi-layer cellular automata

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Smouldering is the slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phase fuel [1]. It is also one of the most common and powerful hazards related to any reactive porous media, including different aspects as residential fires or megafires in natural deposits of peat and coal.

Although current deep understanding of smouldering is still limited, it is well-known that it, in its simplest form, can be divided in three chemical steps, as a combustion process: drying, pyrolysis and oxidation.

One of the main characteristic of a combustion process is its self-sustainability, which means that the heat generated during the exothermic oxidation process has to be sufficient for the two endothermic processes of drying and pyrolysis. The two mechanisms controlling the propagation of the smouldering fire are the oxygen supply and the heat transfer, so a complete understanding of these mechanisms is essential.

Conditions sufficient to initiate smouldering might not be sufficient for self-sustaining the process. Predicting under which conditions a smouldering fire is going to be self-sustained, and determining the propagation of these events can make a large decrease on the consequences of these fires.

In the current research, cellular automata methodology has been developed for smouldering. A cellular automaton is a discrete model consisting of a regular grid of cells with five fundamental characteristics: (1) discrete lattice of cells, (2) evolution in discrete time steps, (3) finite set of possible values, (4) value evolving according to rules depending only on local neighbourhood. Cellular automata have been used in several fields due to its capacity of modelling complex processes through relatively simple models.

This model consists of a two-dimensional cellular automaton formed by three different layers: fuel layer, heat layer and oxygen layer. The fuel layer represents all the changes occurring at the solid fuel, and the evolution of the different species that can appear: fuel (wet), fuel (dry), char and ash. The heat matrix concerns the heat transfer processes that take place during any smouldering process: the emission of heat due to oxidation processes, the consumption of heat due to drying and pyrolysis, and the heat diffusion that takes place afterwards. Finally, the oxygen layer represents the flow of oxidizer needed for oxidation. When oxidation takes place, oxygen is consumed modifying the availability of oxygen present in the system.

Different parameters are studied in order to define a wide range of scenarios. The rate of drying, pyrolysis and oxidation can be modified as percentages of occurrence, varying each one of them from 0 to 1. Heat transfer can be controlled by a non-dimensional parameter that can be modified from 0 to 0.15. The heat needed for undergoing drying and pyrolysis can be controlled by the heat threshold (from 0 to 1), while the oxygen flow is defined by the velocity of advance of the oxygen front, calculated as the number of cells that it advances per unit time.

The model has been tested with an initial configuration consisting on an ignition in the centre of the biomass sample. This ignition causes a radial front, with an almost circular shape. The growth rate of this front has been determined as the amount of biomass that evolves per time unit, and it has been studied according to different probabilities and heat threshold values.

To summarize, this model presents two main novelties. Firstly, it represents the smouldering process of a generic biomass, so all the parameters used are non-dimensional. Secondly, the multi-layer approach used for developing is very adaptable and hence it can be aligned with the real physical processes that take place.

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Aerosols from smoldering

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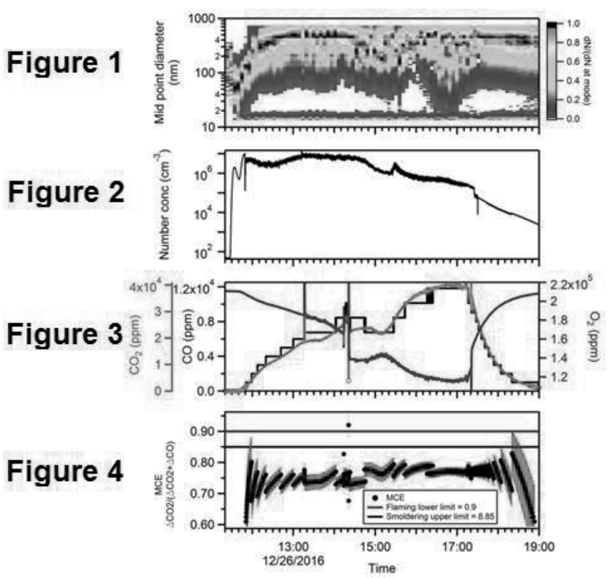
Keywords: Aerosols. Smoldering. Combustion. Wood Pellets. Carbon Emissions

Direct emission from smoldering fires include large amounts of aerosols and trace gasses that influence the chemical and radiative properties of the atmosphere and thus affect the global climate [Myhre et al., 2013] and pose a concern for human health [Naeher et al., 2007]. A recent study showed that nanoparticles formed by engine combustion are found in human brain tissue [Maher et al. 2016]. Emitted aerosols include various organic compounds, soot particles, trace amounts of non-carbon inorganic material and vary in size by three orders of magnitude from the nanometer to the micrometer scale [Urbanski, 2014]. The Emerging Risks from Smoldering Fires (EMRIS) project studies the physical and chemical properties of primary and secondary aerosols produced by smoldering fires of wood pellets fuel [Madsen et al., 2016]. Specifically the size distribution, mass fraction of different components, intrinsic optical properties and the potential health effects on human lung tissue are investigated. In order to produce and evaluate aerosols from smoldering fires, a new experimental combustion chamber set-up was developed. Results of the preliminary tests of the experimental set up show reproducible levels of aerosols size distribution (Figure 1), aerosols concentrations (Figure 2) and of the modified combustion efficiency (MCE) parameter (Figure 4) determined from measured CO2 and CO concentrations (Figure 3).



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Reaction to fire of glass/ hemp/ furan composites

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Keywords: furfuryl alcohol, ignition, pyrolysis, hemp & glass fibers

Composites made of glass or hemp fibers and furfuryl-alcohol are an alternative for fossil fuel based conventional materials [1]–[3]. Such composites have excellent strength and furfuryl alcohol is manufactured from agricultural residues [4]. In general, many different sustainable bio-composites are developed in many different areas as they are seen as excellent alternatives to conventional materials with regard to their weight-strength ratio.

Nevertheless, biomaterials are combustible and therefore their application depends on the actual fire performance of these compounds. These have to follow the fire safety regulations.

The paper is investigating the reaction to fire for two composites using a resin of furfuryl alcohol and glass fibers as well as hemp fibers. The composites are made at DTU wind energy using vacuum compression moulding and are tested for their mechanical strength. The samples used for the fire tests had been stored for some years under ambient conditions inside a laboratory environment. Different methods are used to investigate the reaction to fire:

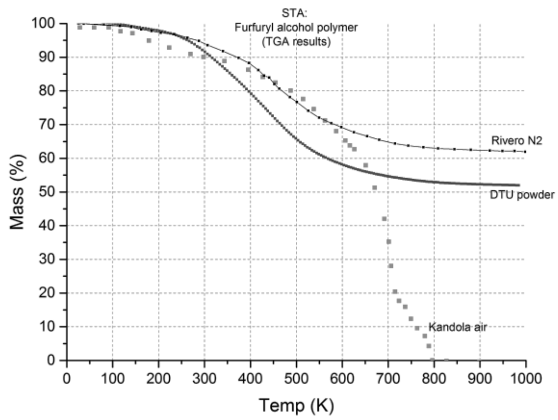
a) Vertical upward flame spread

b) Bomb calorimeter

c) Mass loss cone calorimeter

d) STA tests under inert atmosphere

Both, the glass fiber furan and the hemp fiber furan composites were found to be difficult to ignite, as no ignition occurred in the flame spread tests using a normal lighter. It needed a gas burner to ignite the samples. The flame spread was moderate, but no self-extinction occurred in the case of glass fiber furan composite. This is also reflected by the preliminary results of the STA analysis showing that the degradation under nitrogen atmosphere is giving a residue of above 50% of the sample mass both for a literature example measured by Rivero et al [5]and by DTU. Changing the atmosphere to air the main combustion is taking place at about 700 K leading to complete degradation [6].



All the findings will be more detailed presented and it will be argued about the benefits and constraints using these types of composites in applications, as e.g. as materials for wind mills or marine applications.

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Part time firemen and community resilience.

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Keywords: (5 key words)

Resilience, Fire & Rescue Services, Emergency preparedness.

In this paper we discuss the role of part time firemen as a resource for local emergency management in Norway. Informal social relations, the trust between practitioners and generally the social capital of the organization, has been recognized as a resource for emergency management, particularly as it contributes to improvisation and coordination between actors belonging to different professional groups. Likewise, social capital, the trust among citizens, has been identified as a resource for societal resilience in crises. In this paper we discuss a combination of these forms, how the social embeddedness of emergency professionals in rural communities contributes to their handling of emergencies. Our primary data is based on studies of the fire and rescue services in Norway. In particular we are concerned with the role of part- time or "volunteer" firemen in rural districts. This group, which forms the backbone of the fire and rescue services in rural Norway, consists of personnel with basic training and certifications. They have other main jobs, but are contracted in tiny fractions of a position by the fire department, and they are on call in a variety of arrangements. Some carry their radios at all time. The paper is also based on recent studies on municipal emergency preparedness managers in small municipalities. This formal position is normally handled by an experienced public official in a fraction of his position in the municipality. In several recent events, fires and other emergencies, a striking observation has been that the improvisation involving resources from the entire community, improvisation in which the multiplexity of roles has been pivotal. By multiplexity we refer to the fact that the involved practitioners have social networks and several professional roles connecting them to resources and information beyond what is within the grasp of their normal position. They are hunters, carpenters, farmers or machine operators. They know each other and the community through several different social roles, and have resources beyond the formal capacities their position should suggest. Based on an analysis of reports from recent events supplemented with selected interviews, we discuss how role multiplexity (that one person has several professional and social roles in a community) and social networks may provide a functional redundancy that provides increased resilience in the handling of fires and emergencies. We also discuss some of the reasons for how these abilities – this social capital for emergency management– are hard to make visible in planwork, and is hard to include in exercises. In Norway there are developments towards professionalization of and centralization of the fire and rescue services. There are good reasons for that. But still, we believe that understanding the role of part-time firemen in emergencies will give us a better understanding of how rural communities are resilient.

Environmental impact of structure fires and fire service response

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Keywords: fire effluent, life cycle assessment, structure fires, fire service

Concern for the health of the natural environment is growing as human population grows and as new levels of contamination of scarce resources are revealed. Structure fires contribute to contamination of air and possibly also to surface water, groundwater, sediment, and soil [1-3] in the natural and built environments. The impact of firefighting operations, including both tactics and use of suppression media, can also have a negative effect on the environment [4]. Fire debris and ash often contain many harmful constituents, depending on the fuel and burning conditions of the fire [5].

A prototype tool has been developed that provides information about the risks to the environment resulting from structure fires and firefighting operations. This information could be useful to municipalities, community/urban planners and other organizations that perform hazard/risk assessments. Fire brigades could use it during their pre-planning and training activities to learn about the consequences of decisions made on the fire ground.

The tool in its initial form was developed to be used on a case-by-case basis for warehouse fires in which the fire vented through the roof and water was the only cooling/suppression media used during the defensive response, but the scope will be expanded to other situations in the future.

There are two scenarios. First, there is a baseline case in which the fire service responds to a fire in a warehouse. This would ordinarily be an incident for which information is available from reports, investigations, and/or interviews with involved parties such as first responders, owners or managers of the warehouse, and fire investigators. In the second (theoretical) scenario a fire starts in the same warehouse under the same conditions. It is assumed that the fire continues to burn without intervention from the fire service and may spread to adjacent structures.

Quantitative risk assessment (QRA) is used to predict the fire behavior and damage for the theoretical second scenario in which the fire service does not respond. The QRA models the main mode of fire spread from large warehouse fires, i.e. by radiation from flames ejected through a partially collapsed roof.

The tool estimates the impact of replacing the damaged portions of the warehouse structure/contents, including adjacent structures and contents if the fire spreads. It also includes the impact of the fire effluent from the burned structures/contents and firefighting operations. The impact of the fire service response (equipment, personnel and sup-pression media) is included in the first scenario, but not the second scenario. Results are given in terms of global warming, acidification, smog, eutrophication, ozone depletion, ecotoxicity and energy use for both scenarios.

An analysis of feedback from peers and potential users regarding the further development of the tool indicates three major areas of improvement:

- Automate the user input as much as possible. In most cases default values are provided. Online mapping algorithms and municipal databases can be used to populate much of the tools input, given the address of the incident.
- Enable tool to handle incipient fires. A fire growth model and estimate of the time between the ignition of the fire and the arrival of the fire service will be necessary.
- Expand the tool to different structure types. Residential structures are a particularly important application.

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CFORT – a new centre of excellence supporting resilient buildings and constructions

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Keywords: Total defense, resilience, protected buildings, fortification

Fortification protection of buildings and constructions has during long time been an important function within the Swedish Total Defense. The need of protected and protective structures, above or under ground, to secure personnel, functions or infrastructure has varied over time. Traditionally Sweden has had a high level of fortification competence, but the latest decade's military disarmament and the earlier changed focus to international operations, has led to a loss of competence within the area.

Changes in the security policy and the new threats on the society have again put focus on the protection of functions, buildings and critical infrastructure1.

To restore the national fortification competence with both civil and military demands in mind the Swedish Fortification Administration (SFA) and Research Institutes of Sweden (RISE, former SP Technical Research Institute of Sweden) together initiated CFORT – the Swedish Centre of Excellence for Fortification.

The aim of the initiative is to create a profound knowledge base within the fields of explosive load and conventional weapons effects, electrical environment threats, robust energy supply, fire protection, physical perimeter protection, CBRNE, fortification design and robust urban development. Establishing state of the art competence for further use in the field of fortification is important to create a robust and resilient society and support the national Total Defense.

The strategic management of CFORT will be shared between SFA and RISE, while the operational management is located at RISE with support from SFA. The basic activities within CFORT are state of the art analyses, expert assistance, applied research and development, collaboration and education. Both research and education will be performed in cooperation between CFORT and universities as well as other research agencies. The goal is to again make Swedish fortification competence internationally recognized and leading in the chosen fields.

The development to make CFORT fully operational in all the chosen areas – with established research cooperation, education and expert assistance – is planned between 2017 and 2021. Requirement analyses have been initiated in each field and important areas identified for further studies are for example protection of existing facades in official buildings with vital societal functions exposed to new threats, protected command and control centers for secured long time use and fossil free alternatives for emergency power. Targeted applied research activities have already started and the first results are expected in the end of 2017.

Fire in a building or construction with vulnerable operations and a reinforced perimeter protection can severely affect both personnel safety and endanger the function by exposing them to external threats. Fire can also be used to cover, or ease, an attempt to force the perimeter of the building. Evacuation from facilities with high perimeter protection can be obstructed and delayed due to turnstiles, locked escape routes or the need of phased evacuation. Fire and rescue operations in high security buildings or constructions often present great challenges for the first responders, as the response routes can be long, the access to the building can be limited and that the radio communication can be disturbed by the high amount of reinforcement in the concrete walls2.

To meet new threats and support the knowledge development of both the working professionals and future engineers it is important that existing knowledge and best practice on designing resilient buildings and constructions is implemented in higher and further education.

The knowledge gained within CFORT can also be adapted for use in critical infrastructure protection or to protect other buildings with similar threat scenarios. The broad area in which the results can be implemented and the cross-use of demands and solutions will lead to synergies in the safety and security field as well as an effective use of research funding.

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FIRESAFE *Study investigating cost effective measures for reducing the risk from fires on ro-ro passenger ships*

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Keywords: EMSA, RO-RO, RO-Pax, Fire, RCO

This is a study commissioned by the European Maritime Safety Agency, EMSA. It consists of two parts, investigating risk control options (RCOs) for mitigating the risk from fires on ro-ro decks. The first part considers RCOs in relation to Electrical Fire as ignition risk and the second part considers RCOs to mitigate the risk of Fire Extinguishing Failure (with focus on drencher systems). The study considers both new buildings and existing passenger ships.

The ships included in the analysis were selected based on criteria as agreed by EMSA and the fleet at risk consisted of 490 ships. EMSA provided information about which ships were engaged in international trade.

Historical risks and hazards have been found and complemented with two fire hazard identification (HazId) workshops. The project developed three risk models to be used to investigate the effects of RCOs on the PLL and costs.

Six RCOs were selected for quantitative analysis in the risk models for the risk of electrical fire ignition and six for drencher failure. Many other RCOs are very promising and could be further analyzed in the future. The selected RCOs for this study were:

Electrical faults:

- Robust connection boxes
- Only ship cables
- IR camera
- Training for awareness
- Only crew connections
- Cable reeling drums

Drencher failure:

- Remote control
- Rolling shutters
- Efficient activation routines
- Fresh water activation/flushing
- CCTV
- CCTV + Remote control

These RCOs were analyzed in a cost benefit analysis which calculated the GCAF and NCAF values for the different RCOs. After analyzing the outcome of the cost benefit assessment, conclusions and recommendations could be drawn.

False alarm

An organizational study of the effects of false alarms

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Keywords: (False alarms, fire and rescue services, organization)

Fire and rescue services in Norway dispatch as often to different types false alarms than to real fires and accidents. During the first six months in 2016, 54% of the emergency dispatches were conducted on the basis of false or unnecessary alarms. These are typically automatic systems going off due to different perturbations or errors, smoke detectors reacting to cooking or dust or people triggering alarms by error or intentionally. These unnecessary deployments are costly in terms of time and resources spent, and can in some cases lead to a weakened preparedness towards real incidents. Hence, there are good reasons to work to reduce the number of false alarms. On the other hand, one may also argue that there can be some positive effects of a certain number of mobilizations for the fire crews. Many of the false alarms are also triggered in buildings (such as care centers for elderly) and areas where the fire risk is high, or where there are vulnerable groups, so the presence there might give them better knowledge for future scenarios. As such it might help the fire crews prepare for future genuine alarms and can also be a source for preventing false alarms in the future. Based on interviews with firemen (and other relevant professionals) as well as analyses of existing statistics and reports we will discuss the effects of false alarms from an organizational perspective. In this discussion we draw some comparison with studies of false alarms in other sectors, such as process industries and the petroleum sector. An interesting point is that the number of emergency deployments conducted on the basis of false alarms varies a lot between different municipalities in Norway, some have 40% and some as high as 75% (numbers from 2010). There is currently little knowledge about why this is so, but it can be due to variation in number of buildings with direct connection to the alarm center or the emergency controllers could have different formal procedures and different assessments of response to incoming alarms. Also the big variations in demographics, housing stock and municipal organization may count for some of the variation.

Recognizing the increasing number of false alarms several fire departments in Norway are seeking to develop measures to reduce these numbers. This includes different technical measures and operational measures as well as fines for building owners. We will study the effects of these measures, both in terms of reducing the number of false alarms, but also how they may affect the overall safety. It is possible that measures used to reduce false alarms directly or indirectly harm the emergency preparedness or the response time to some types of fires. Fines may, for example lower the threshold for disconnecting automatic sensors. There are also interesting element in this where some fire and rescue services are developing internal buyer-supplier-models, internal markets, and where emergency dispatches are invoiced internally between different departments of the fire and rescue services.

The data will be collected spring 2017 and preliminary results will be presented at NFSD 2017.

Risk analysis and performance-based structural fire expertise of a semi-buried railway station

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Keywords: Railway station structures fire expertise

The tracks and platforms of a semi-buried railway station in Switzerland were covered in 1963-1972 by reinforced concrete structures (pre-stressed and pre-cast beams and slabs, steel columns) to form a watertight roof.

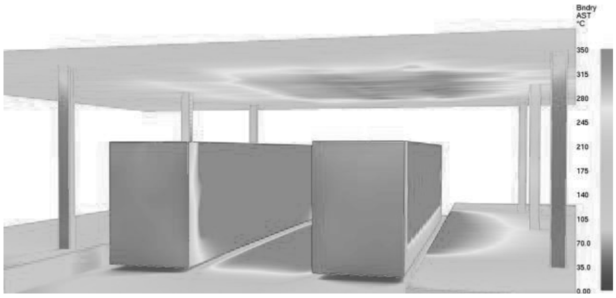
A first study of fire protection determined the resistance of the structures with respect to the fire risk using the standard calculation methods of EN 1992-1-2. The results obtained from calculations failed to achieve the objectives set by the fire resistance requirements for all the elements analyzed, for 90 or 120 minutes. The results showed that :

- The simplified methods of EN 1992-1-2, mainly tabulated, are suitable for a first security approach. The heating of the sections is considered in a simplified way.
- The warm-up / structural behavior relationships are not considered.
- The heating source is the ISO fire curve (per ISO 834), which considers a closed compartment continuously supplied with fuel, which is unrealistic and unfavorable in the case of a widely open space with relatively little thermal load compared to the important surfaces involved.

To avoid full and very expensive passive protection, it is then necessary to determine more precisely the fire resistance rating of the supporting structures using performance based approach and advanced analysis methods, involving calculations on 2D and 3D finite elements (SAFIR) and fire simulations by computational fluid dynamics (FDS). The steps to achieve are:

- Consider several fire scenarios (simple or real scenarios, based on scientific studies and / or full-scale tests) [1,2,3,4,5];
- Determine the resistance time, before the loss of resistance and / or stability, of the structures supporting the roof of the semi-buried station,
- Determine the need for possible passive protection of the structures which would enable them to meet the resistance requirements (resistance criterion "R" according to Swiss standards AEAI 2015).
- If the resistance of the unprotected structures is not sufficient, optimize the passive protection and define an implementation of possible organizational measures.

Several natural fire scenarios were developed, after discussion with the authorities. This made it possible to prove that the structural resistance was higher than expected from previous calculations.



The FDS fire simulations showed reasonable gas temperatures, even on heavy loaded wagons fire up to 120 MW, did confirm the sufficient safety margin, verified by FE complex analysis with SAFIR® software, of the existing unprotected concrete, beams and plates, and steel columns.

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Experimental study on the mechanical properties of fire exposed concrete

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Keywords:
Concrete; Stress-strain relation; Fire; High temperature, Compression

Abstract

The recent complete collapse of a 17-storey commercial building in Tehran, Iran, due to a fire triggered on 19 January in one of the building premises [1] has renewed the concern for the behavior of concrete building exposed to fire. However, in the past decades, several has been the examples of concrete buildings that collapsed either during or after a fire, as a consequence of the degradation of the mechanical properties of the material. The collapse of buildings with a primary concrete structural system such as the Windsor Tower (Spain, 2005) [2] or of the Architectural faculty building of Delft University (Netherlands, 2009) [3], as well as buildings with concrete or composite deck system, such as the WC7 of New York (US, 2001) [4] are just few renewed but non-exhaustive examples.

The high vulnerability of concrete to fire is due micro-cracks that develop around 300 C, as a consequence of material dehydration and thermal expansion of the aggregates: at this point the strength loss is permanent, leading to high costs of repairing even in case the structure survives the fire without any collapse [5]. Despite of this, our current understanding and modelling of the degradation of the mechanical properties (compressive and tensile strength, stiffness, and ductility) is quite limited and several discrepancies are found in literature on the material models at high temperatures [6][7][8].

This study focused on the experimental investigation of the compressive behavior of concrete exposed to compression and elevated temperatures. In particular, both non transient and transient test were carried out on concrete cylinder inserted in a compressive machine and surrounded by a special oven capable of heating the specimen up to about 700 C. The test set-up is described in details and the outcomes are analysed with particular focus on the peak strength and deformation. The results are compared with literature results and the model presented in EN/1991-1-2 [9] and an evaluation on the reliability and limits of validity of current material model is provided. The project builds on the results of a previous experimental study carried out at DTU [10], the results of which have also been submitted for presentation in the conference.

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Fire protection of wooden houses with several floors

"Brandsikring af træhuse i flere etager"

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Keywords: Solutions for combination between passive and active fire protection systems. Guidelines for charring rates. Fire classification of Cross-Laminated-Timber (CLT)-elements. Climate focus and reduction of CO2. Use of flammable material, for primary structures in buildings.

The climate debate has focus on reducing CO2 and the political focus is moving towards sustainable and green housing. This way of thinking reflects on the building industry and challenges the traditional way of building houses, and not least the traditional use of building materials, such as concrete, steel and masonry.

This project is focused on looking into the possibilities of making the transition towards implementing more wood-based structures, into the Danish building industry. If this transition can be made liable there will be a positive effect to the environmental and climate conditions.

Despite the functional requirements for fire safety stated in the Danish building code (Bygningsreglement, 2015), the tendency to use (or not use) flammable materials is deeply rooted in the prescriptive solutions stated in the guidance paper "Eksempelsamling om brandsikring af byggeri" (Eksempelsamling, 2016). Unfortunately, the predefined solutions do not allow the use of flammable material, such as wood, for primary structures in buildings where the top story is more than 9,6m above ground.

Based on the above knowledge the primary focus of this project is centered around an investigation of a relevant contemporary phenomenon, and the main goal is to:

"Asses opportunities to build apartment buildings of 4 stories or more in Denmark (application category 4) with load-bearing CLT-timber structures, without compromising the fire safety."

To be able to assess this,, the emphasis is centered around wood structures such as glulam and CLT-elements. International projects and experience have been taken into account, and experience and solutions from similar countries are listed. Passive fire protection in the form of plasterboards and active fire protection in the form of sprinklers are considered in this project. Indications are made that these two solutions, used in combination, are a necessity for maintaining an adequate level of safety. The international experiences are evaluated in conjunction with calculations and research on CLT-elements.

The final recommendations are based on the accumulated knowledge through the project and it is concluded that the opportunities to build apartment buildings of 4 stories or more in Denmark (application category 4) with bearing CLT-timber structures, without compromising fire safety is definite opportunity. Under some given preconditions:

1. The use of CLT-bearing timber structures for over 4 stories is only recommended as a combination solution between passive fire protection (plasterboard) and active fire protection (sprinkler).
2. Insert the fire class R-90 min for load-bearing elements for mid-rise buildings in Denmark.
3. Develop guidelines that differentiate values for charring rates based on types of glue, the thickness of each layer and element configuration and installation direction, vertically and horizontally.

Future studies:

Fire testing is primarily performed at product level and according to Standard fire ISO 834 (ISO 2014), consisting of a very rapid fire development and continuous heat gain throughout the fire testing, completed at a given time. These tests lack knowledge about the "fire decay phase" and the last time of the fire where the room temperature and fire intensity decreases (Gerard, et al., 2013) and (Barber, et al., 2015).

Fire testing on full scale CLT-building systems. As few building systems are tested, this type of test could explain the fire characteristics of a CLT-based system, as well as increase knowledge of load distribution. It will be beneficial to have conducted experiments which partly includes the entire fire process, and partly built into a larger system attempts (Gerard, et al., 2013) and (Barber, et al., 2015).

Installation Penetrations are also relevant to examine. The challenge is that all the systems on the market which are fire tested, are all tested in non-combustible structures. Therefore, the function of the combustible structures is unknown (Gerard, et al., 2013) and (Barber, et al., 2015).

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Security officers responding to residential fire alarms: modelling the effect on survival and property damages

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Keywords: residential fires; response time; fire services; security officers, cost-benefit analysis

Decreasing the response time to residential fires leads to more people saved, less injuries, less property damaged and environmental impact. The purpose of this study is to evaluate how an agreement by the Fire and Rescue Services (FRS) of Helsingborg, Sweden and a private security officers' firm could save lives and property for residential fires. To estimate the effect on survival rates and property damages, we use geographic information systems (GIS) simulation to estimate the marginal changes in time to emergency work start. We combine these results with data on the relation between response time and fatalities as well as the relation between response time and property damages. Finally, we summarize the effects in an economic evaluation of costs and benefits of the intervention.

The results show that the average response time is 45 seconds faster at daytime and 61 seconds faster at nighttime using security officers for residential fires, or 52 seconds on average. Combining this gain in response time with the relation to fatalities, and adjusting for less efficiency than the FRS, implies a decreased death rate by 0.0105 or 1.3 percent per year. In other words one life could be saved about every 100th year in Helsingborg.

The economic evaluation shows that adding the property value and the monetary value for saved lives together the totally saved benefit would be SEK 4,800 per alarm or SEK 403,000 per year on average. Comparing the benefit to the costs, SEK 195,000 (preliminary!) this means that the project outcome is deemed to have positive economic effects. We would think that the economic effect would be even more positive for a municipality with a larger geographic area, a more geographically dispersed population and less closeness to full-time fire stations.

Three different fire suppression approaches used by Fire and Rescue Services

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***Keywords:** fire suppression, firefighting, water flow rate, suppressive capacity, Fire and Rescue Service.*

At firefighting operations the applied water flow rate, depending on the fire area, has traditionally been regarded as a continuous relationship. This study shows that it is not. Firefighting operations can rather be distinguished by three different approaches: The standard nozzle approach, the perimeter approach and the maximum flow approach. The transition between the first two can be identified as the optimum water flow rate or optimum water density. The second transition point can be identified as the critical flow rate or the critical water density.

There are no previous studies showing the extrapolation limits of small scale fire suppression tests into a larger context. Therefore, suppression methods and equipment validated for one scale of fire may fail to perform in a different scale.

The aim of this study is to describe the relationship between the water flow rate applied by the Fire and Rescue Service (FRS), and the area of a fire and to explore the limitations of the FRS in terms of water flow rate. Four papers, consisting of five data sets, showing the correlation between applied water flow rate and fire area were examined. The largest, the Grimwood & Sanderson [1] Metro data set, consisting of 4173 fires from a metropolitan area FRS, was used to identify patterns in the relationship between applied water flow rate and fire area. The remaining four data sets were used for validation and comparison.

This study, described in more detail in a separate paper [2], shows a fundamental difference in fighting a small fire compared to fighting a large one. The result is that there is no continuous correlation over the whole area range to describe the relationship between applied water flow rate and fire area. It has to be treated differently in different area intervals. However, it is possible to determine the correlation factor for each part of the relationship. A high correlation factor means an efficient suppression.

For small area fires, the correlation is weak but increases rapidly with the area. Here, a standard nozzle approach can be identified. In the Metro case, a single 100 l/min high pressure nozzle is applied for small fires and an additional one for fire areas slightly larger. At the lower end of the interval, the tool is over powerful and therefore used with a poor efficiency. At the upper end of the interval, the efficiency is very high as the tool reaches its upper limit of its capacity.

In the next area interval, the correlation factor decreases to around 0.5. In this interval, the water flow rate is directly proportional to the square root of the area; the same as directly proportional to the perimeter of the fire.

For really large fires, the correlation factor decreases further. The correlation becomes weak, close to 0. The FRS uses its maximum water flow rate regardless the size of the fire. The water density is low in spite of application of the highest water flow rates available. Most likely, these fires are not extinguished, but rather contained until they run out of fuel.

The transition from a standard nozzle approach to a perimeter approach can be distinguished by the optimum water density, as described by Särdqvist & Holmstedt [3]. Similarly, the transition from a perimeter approach to a maximum flow approach can be distinguished by the critical density or critical flow rate.

Since five sets of data were available, the same calculations were made for the remaining four. They all showed the same pattern, with different approaches in firefighting.

The transition points differ between the different data sets. This means that the fire area limit for the different approaches and corresponding water flow rate and water density varies. The critical flow rate is more than a physical parameter: it varies with the context. As an example, modern firefighters apply much lower water flow rates than their predecessors at equal size fires.

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An operationalization of capabilities for fire and rescue operations

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Keywords: Capability, Resuce services

Providing fire and rescue services is arguably one of the fundamental services of society. It is therefore surprising that very little, if any, research has been conducted into which capabilities are needed by the fire and rescue services to achieve its objectives and goals.

There are studies on locating fire station (e.g. [1]), but no research has been identified that study more in detail what these apparatus and the crews are doing on scene and how imperative this is to reducing the consequences of events. An example of a hypothesis is that in order to save lives in residential fires it is more effective having two fire fighters responding to the scene in 5 minutes with a mobile ladder than a crew of five arriving 5 minutes later with a motorized ladder. Such hypothesis has not been systematically investigated and there is a great need for quantifying the efficient use of resources during fire and rescue operations [2].

The word "Capability" is defined in Webster's encyclopedia as being capable of something. It can therefore be seen as a latent ability to do something. The word is not connected to a specific need or event so a capability can be more or less useful for a given purpose, but it is still a capability. When responding to a fire the ability to play the piano is a useless capability for a fire fighter, but it is however still a capability of the crew. When it comes to our quest to investigate important capabilities for fire and rescue operations the events, the needs generated by the events to which the fire fighters respond serve as a basis for relevant capabilities to include in our analysis. It is however important to disentangle capabilities from the specific events. This differs from many definitions of capability in the literature [3].

A model of capability is found in the figure below. A specific event (e.g. a fire) generates a need (e.g. extinguish a fire confined to one object within an apartment). This can be achieved by a number of different tasks and therefore the need is matched with the tasks that can be performed by the available units.

The need will not only dictate the set of relevant tasks (e.g. interior attack or external extinguishment) but will also dictate a maximum response time and a minimum persistence for the task to be fruitful. The specific task is tied to certain resources needed to perform the task and matching these to available resources determines both the response time and the persistence.

Formally capability can be defined as the set of tasks that a specific unit or organization can perform together with its respective response and persistence times.

This definition/operationalization can be used in a number of ways;

i. Analyze actual events to identify need for tasks generated and the limit on response time and persistence
ii. Use a predefined set of tasks (ideally identified trough i above) to analyze the capability of a fire and rescue service at a specific geographical region
iii. Perform cost-benefit-analysis of specific resources by connecting them to events through tasks.
iv. Prioritize training of fire fighters based on importance of tasks.

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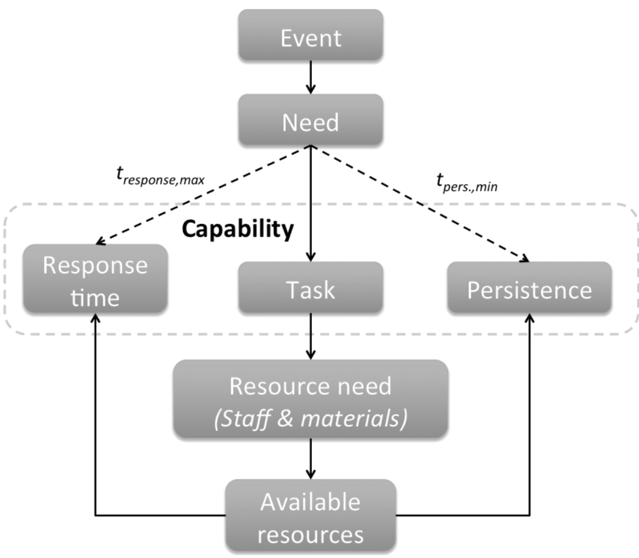

99 years of standard fire - success or failure?

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Keywords: Standard fire curve, parametric fires, travelling fires

I. INTRODUCTION

The standard fire curve was defined 99 years ago by the American Society for Testing and Materials (ASTM). This was done without any knowledge of fire dynamics as no real fire dynamics experiments had been performed in USA at that time. Further, knowledge of experiments performed in Europe was lacking [1]. The coupling between the standard fire curve and real fires was later justified by the equal area concept developed by Ingberg [2]. With Ingeberg's approach the severity of two fires is assessed as equal if the area under the time temperature curve over a certain reference temperature is equal. Using this method, every fire could be recalculated to a standard fire exposure . Although the standard fire curve was defined in ASTM E 119, the standard fire curve in different countries was in fact slightly different in each country for a long time, especially after long time of exposure [3].

II. CRITISISM AGAINST THE STANDARD FIRE CURVE

During the last half century, more refined alternatives to the standard fire have been developed. This short summary cannot cover all such alternatives, but noteworthy work includes the efforts by:

- Kai Ödeen, developing a methodology for calculation of fire temperatures based on fire load, opening factor and thermal properties of the surrounding walls [4].
- Magnusson and Thelandersson development of the set of fire curves later defined as the Swedish curves. This set of curves includes the effect of variation of the opening factors, fire load and thermal properties of the surroundings [5].
- Kirby et al. [6] and Sleish et al. [7], who investigated the fire development in large rooms.
- Steiner- Gotfried investigating the effect of traveling fires in large compartments [8].

In addition, the new development of sophisticated CFD tools allows the definition of a variety of realistic fire exposures deviating from the standard fire curve.

III. DISCUSSION

Although the scientific basis of the choice of a universal standard fire curve for fire testing is weak it has one major advantage. In a system based on a standard fire exposure, products can be assessed and compared to each other without knowing the final use of the product. In other words, you can rank the level of compartmentation a product in a structure can provide without knowing the fire load, geometry of the fuel, opening factor and thermal properties of the surroundings.

Obviously, this is a rough tool which lacks precision, especially in some applications where products can perform differently during alternative exposures; but, the enormous investment required to optimize all products to the specific geometry and fire load in the local surroundings is not justified. However, this is not to say that more detailed special designs and structural fire safety engineering is unnecessary. This is to say that the standard fire curve although not scientifically developed is a success as a baseline for fire resistance ratings but should be supplemented by more detailed methods when appropriate.

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A Swedish approach to define a standard for fire safety design in BIM

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Keywords: fire safety design, standardization, verification, BIM, review

Det ställs allt oftare krav från olika kravställare att projektering ska ske i BIM-baserade miljöer. BIM (Building Information Modeling) är av strategisk betydelse för utveckling av effektivare metoder att skapa, samordna och dela bygginformation över olika faser av ett byggprojekt. Som resultat av detta arbetar arkitekter, konstruktörer och installationsprojektörer mer och mer i BIM med fokus på processer för att åstadkomma god stadsbyggnad, arkitektur och brukarnytta. För att byggprocessen ska kunna dra full nytta av projektering i BIM bör så många parter som möjligt arbeta i eller ha förståelse för denna arbetsprocess och i dagsläget är brandskydd som disciplin inte en del av dessa processer.

Idag levererar brandskyddsprojektörer enbart textbaserat underlag, eller i bästa fall skissbaserat underlag till arkitekter och konstruktörer. Berörda projektörer sedan över relevant brandskyddsteknisk information sina olika BIM-modeller, vilket kräver kontroll för att säkerställa att rätt information beaktats förståtts och inarbetats i modellerna. Ett dubbelarbete som kan, och bör effektiviseras. Detta skapar utrymmen för fel i kommunikationen, eftersom brandskyddsprojektörerna då inte har kontroll över hur olika brandskyddstekniska funktioner redovisas i modellen eller i de ritningar som tas från modellen under byggnation. Genom bristerna i kommunikation ökar antal fel och genererar stora kostnader som kan reduceras om det finns en standardiserad process att integrera brandprojektering i övriga disciplinerς processer och BIM-modeller.

Om brand som disciplin skapar och implementerar en metodik för att själva ha möjligheten att arbeta med en specifik BIM-modell med sin information uppnås större kontroll och effektivitet. Därmed blir det enklare att säkerställa rätt funktioner och kvalitet inom hela byggprocessen.

Som ett led i att skapa detta har ett projekt initierats under senhösten 2016 och som leds av Briab Brand & Risk ingenjörerna AB. Projektet finansieras av SBUF (construction industry’s organisation for research and development).

Syftet med projektet är att utveckla och testa en arbetsmetodik och arbetsprocesser för att implementera brandrelaterade krav och funktioner i en BIM miljö och standardisera arbetsflödet. Syftet med projektet är även att undersöka möjligheten att, via utvecklad arbetsmetod, definiera en systematiskt och effektiv granskning- och kontrollfunktion för att reducera möjliga fel och avvikelser och generera högre kvalitet i byggprojekten.

Målet är att öka förståelsen för brandskyddets funktion i byggprocessen och minska fel i produktionen och säkra ett bättre kommunikationsflöde inom projekteringsgruppen och över olika skeden av byggprocessen.

Inom projektet har inledningsvis en litteratur- och intervjustudie genomförts med användare och kravställare för att kartlägga hur man inom Sverige och internationellt arbetar med brandskydd i BIM-miljöer i byggprocessens olika skeden.

Resultatet av genomförda studier är att brandskydd och brandskyddsprojektering inte har inkluderats på ett systematisk och strukturerat sätt vid tidigare projekt inom Sverige eller internationellt. Men intervjustudien har gett en välgrundad bas för vidare metodutveckling och förslag på arbetsflöde för att inkludera och kommunicera olika brandskyddstekniska krav för olika discipliner.

Den metod som håller på att utvecklas för att modellera olika brandskyddstekniska krav i en BIM-miljö utgår från att på rumsnivå tydliggöra och konkretisera olika krav och möjliggör för att i nästa steg genomföra olika nivåer av samgranskning mellan olika discipliner. För att utvärdera föreslagna processer och funktioner kommer dessa att utvärderas i verkliga projekt för att undersöka hur väl föreslagna processer fungerar i praktiken.

Under konferensen kommer resultatet av litteratur- och intervjustudien och en preliminär metodik och process för att inkludera brandskydd i en BIM-miljö att presenteras. Presentationen kommer även belysa den praktiska erfarenhetsåterföringen projektet fått från pågående projekteringar och som kommer beaktas innan föreslagen process kan fortsättas utvecklas till en svensk standard för brandskydd i en BIM-miljö.

Nordic standard for review & control of fire safety engineering

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Keywords: fire safety design, stardization, review and control, INSTA, performance-based regulations

In 2014 a new three year research project entitled "fire safety engineering for innovative and sustainable building solutions" commenced under the leadership of SP Technical Research Institute of Sweden. The project consortium has 15 members in total from Denmark, Finland, Iceland, Norway and Sweden representing academia, building regulatory bodies, construction companies, engineering consultants, research institutes and standards bodies.

The project had been in response to a call from Nordic Innovation which sought projects where new standards are created or implemented as a main driver for innovation within a specific sector. The project addresses a number of challenges that face the construction sector in relation to sustainable and innovative building solutions.

One of the concept of this project is to develop a new INSTA standards that could be used throughout the Nordic region; a new standard that defines a standard process to review and control fire safety engineering in building projects, [1].

The future standard provides guidance on review and control in the building process relating to the planning phase (conceptual design, the fire safety strategy, detailed design, and consent), the construction phase (building and construction, and approval) and the service life phase of the building (inspections, maintenance and service, staff education, and drills).

The scope of the standard is to facilitate verification of building solutions including innovative and sustainable solutions and to harmonize the process for control within the field of fire safety engineering within the Nordic countries.

The goal for the standard is to give guidance on a general level for review and control, independent of national legal matters in the Nordic countries, with a primary focus on defining procedures within the planning and building process. But the process has also, to some extent, given guidance on how the fire safety engineering process can be a normal part of the overall control and review of the building process and define eligibility criteria for those doing the control.

The first part of the future standard describes an overall process regarding an ideal planning and building process with a corresponding review and control process for fire safety aspects within the building process. The different steps within the planning and design phase, construction phase and operational and maintenance aspects that may be important to consider, to ensure the fire safety within a building´s lifespan, are described in more detail in separate chapters. In each section there is a description define when, how and why to perform different reviews and controls.

There are many different types of guidelines and standards used today for fire safety engineering in the Nordic countries. The future standard regarding control in the building process, however, mainly focuses on the concept and method rather than detailed guidance. The adoption of nationally determined parameters is also significant for the new standard. Since regulation of fire safety is a national matter the specification will give options to have nationally chosen parameters and processes, but the specification shows the direction with certain recommendations. The chosen approach is similar to the system used earlier for INSTA/TS 950 - Fire Safety Engineering – Comparative method to verify fire safety design in buildings

[2, 3]. The Nordic countries may harmonize approaches by using the standard, but may also maintain flexibility by using national options. This is important in connection to the different legal systems within the Nordic countries.

The proposed presentation that is the subject of this abstract will mainly focus on providing details of a range of topics associated with development of building processes for control and review on a Nordic level including:

- Why the review and control should be done and the purpose of it
- When to perform review and control within the building process and within the specific fire safety engineering process.
- How to perform the review and control
- Recommend eligibility criteria for the one performing the control

The presentation will also provide some hands-on guidance on how to perform a review and control when working with fire safety engineering.

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Furnace setup for preliminary fire resistance testing

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Keywords: fire resistance, fire testing, computational fluid dynamics, physical model, ISO curve

In the context of fire safety engineering, a full-scale physical model deemed to be the most suitable way for understanding a real fire behavior of a construction. Among the standard size of a specimen with dimensions of 3.0 m by 3.0 m, even larger tests are being held to ensure a direct application. On the other hand, such testing represents the most expensive method, which limits its actual applicability. Since a number of products, e.g. timber-based facades enable various compositions, it is not always possible or feasible to declare fire resistance by a direct or extended application for each and every different composition. The question then arises whether a smaller furnace for preliminary fire resistance testing could be set, where such variants could be tested and being developed?

Some methodologies for evaluation of fire behavior using smaller testing furnaces are present. For example, Czech Timber Research and Development Institute offers a fire behavior test for vertical constructions with maximal dimensions 500 x 500 mm. Although any thermal stress can be simulated, the most frequent option used in this testing method is the ISO curve. This solution for fire testing with particular dimensions of a specimen has, nonetheless, some drawbacks: Firstly, the dimensions of the specimen do not enable to fully investigate an impact of joints and spans presented in a sandwich construction. Secondly, due to the limited dimensions of the furnace the specimen is more loaded by direct flames more than by uniform thermal load of convective heat. Those effects might be the reason, why the results of the small-scale test show a lower agreement with tests executed in full-scale according to Standards EN 1363-x and EN 1364-x [1].

The current study presents a novel fire furnace setup for small-scale fire testing. The clear testing dimensions of the specimen are 800 x 1000 mm. On the one hand, the area is 1/10 of the standard fire resistance specimen – expenses should be much smaller then. On the other hand, area specimen of such dimensions is large enough to have joints and load-bearing elements in real spans.

Inside, the furnace is 800 mm wide, 1200 mm deep and 1000 mm high. For the furnace walls, the aerated concrete blocks 150 mm thick are used, the ceiling is made from aerated concrete lintels 125 mm. One of the front walls is kept clear where a specimen is to be placed. The specimen should be at least 1000 mm wide and 1150 mm high. The furnace is assembled from aerated concrete blocks mounted without mortar, so it can be put together and dismounted very easily and damaged blocks can be replaced without any great financial loss. In the longer lateral walls (both in the lower part and near the ceiling), ventilation holes are designed in order to provide oxygen inlet and smoke outlet. Inside the furnace, a sand propane burner with variable power is placed on the floor in the middle and 4 thermocouples are installed in the upper part of the inner space. According to preliminary pilot tests based on results given by the simultaneously developed virtual furnace model in Fire Dynamics Simulator, the maximal power of 150 kW is needed for reaching the temperatures given by the ISO curve.

In December 2016, the first pilot testing was conducted in order to evaluate and confirm so far computed (virtual) data and presumed behavior. The pilot testing consisted of two experiments: a reference 15 minutes test with a specimen wall made of aerated concrete blocks (same material as used for the other walls); in the second test, a timber-based external wall, previously tested in a full-scale experiment, was used to get results for a comparison of inner temperature and overall fire behavior in the furnace. The test was planned for 60 minutes.

The first test has shown a very good agreement between the ISO curve and the obtained data: in the first 15 minutes, a deviation between the ISO curve and the temperature averaged from 4 inside thermocouples did not exceed 10 %. During the latter test, some complications were encountered: Firstly, the power needed to be manually adjusted due to a fire growth contribution of a decomposed combustible material; secondly, the testing program was suddenly ended after 20 minutes because of a wrong factory setup of the control unit and it was not able to proceed. Since the tested timber-based construction was protected by a gypsum plaster board and a layer of a mineral wool insulation, the damages were undetectable. Nevertheless, the correlation between the temperatures behind the covering board in the full-scale and the presented small-scale test were quite satisfying.

In summary, the observed results shown that the proposed setup offers a good solution for the preliminary and variant small-scale testing of fire behavior of constructions that may be a useful and relevant step before examination of fire test in full scale, such as EN 1363-x and EN 1364-x.

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Investigation of eurocodes design fires and national deviations

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Keywords: Design fires, Revision of EN 1991-1-2, DK:NA

The implementation of the Eurocodes in 2007 required the introduction of several respective national annexes. National annexes are used in part to provide additional non-conflicting information for a specific country and in part to overrule specific parts of the Eurocodes that, for different reasons, have not been accepted at a national level. Despite of this, there is a desire of gradually reducing national deviations from a common European design, since the purpose of the Eurocodes is to establish a set of harmonized technical rules [1].

The present study serves the purpose of looking into different design methods provided by the Eurocode for fire actions. In particular, design methods provided by the fire action code EN 1991-1-2 [2] are being rejected and replaced by alternatives by several countries, as presented by table 1.

Application of the EN 1991-1-2 Design Method of:	Great Britain BS [3] (2002)	Germany DIN [4] (2010)	Denmark DK [5] (2014)	Sweden SIS [6] (2015)
Parametric fire	Yes	No	No	Partly
Localised fire	No	Yes	Yes	Yes
Fire load density	No	No	No	No
Equivalent time of fire exposure	No	No	No	No
External fire curve	Yes	Yes	No	Yes

In order to comply with the clear purpose of the Eurocodes, it becomes worth investigating the EN 1991-1-2 design methods and comparing these primarily with the Danish national deviations and other recognized models.

The first part of the study presents theoretical parts of the investigated methods, whereas the second part of the study applies the methods on a case study, which is a hospital building currently being erected in Copenhagen, Denmark.

From the investigations, it is concluded that the fire load densities seem to be affected by unsubstantiated partial coefficients and incorrect net calorific values of different fuels. The version of the parametric fire presented by the Danish national annex shows a more realistic fire development and is slightly more conservative with higher opening factors. The EN 1991-1-2 parametric fire is assessed to represent a less realistic fire development, especially with regard to the representation of the cooling phase, but is concluded to be more conservative for compartments with the smallest opening factor.

Furthermore, it is concluded that neither Germany, Great Britain, Sweden nor Denmark have accepted the EN 1991-1-2 design for fire load densities nor the equivalent time of fire exposure which seem to lack in the connection to the world of physics. Finally it is concluded, that the external fire curve and the simplified calculation method for the external flame spread, do not conform in terms of maximum temperature and that a mistake might be implemented in the expression for the compartment temperature under forced draught circumstances. Based on the investigation the rejections of the EN 1991-1-2 design procedures can be justified.

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Material modeling of concrete under compression and high temperatures

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Keywords: (5 key words)

Concrete exposed to high temperatures,

Strain behavior of preloaded concrete exposed to high temperatures.

Strain behavior of preloaded concrete during cooling phase.

Stress-strain behavior of concrete exposed to high temperatures. Transient and non-transient tests.

During the last decade, a number of fire exposed concrete buildings have collapsed. A look at the current codes for structural fire safety design concerning concrete could, therefore, be interesting to examine. This is a part of a larger experimental study on fire exposed concrete, carried out at DTU[1].

The scope of this thesis is to investigate the concrete structures under compression and high temperature.

The investigation is carried out by conducting a variety of experiments. Both transient tests, where the stress applied is constant, and the temperature is varying, and non-transient tests, where the temperature is stabilized, and the stress is applied until failure is occurring are performed. The strain behavior from the test results are analyzed and compared to a number of theoretical models. This includes models from the EN/1992-1-2[2] and various authors such as Anderberg and Thelandersson[3], [4], Hertz[5], Lie[6], and Terro[7].

The experiments are performed at the fire lab at DTU with a special circular oven, where pressure can be applied simultaneously. Both the heating and cooling phase of transient tests at several preload levels are examined as well as the strain due to chemical changes in a transient test at 300°C with a preload level of 60%. Additionally, non-transient tests are carried out at a range of temperatures.

The results of the investigation regarding transient test show that the strain behavior is very dependent on the preload level and the failure of concrete occurs sooner than what is expected in the current design codes. Furthermore, the cooling phase has also revealed that the strain behavior during the initial cooling exhibits more or less the same behavior, however, as the temperature decreases further, especially the concrete with high preload level contracts more than measured at the highest temperature. The results of the transient test at 300°C with a preload level of 60% also indicate that the strain development is expanding due to the chemical changes in the concrete.

The non-transient tests prove compliance between some of the reviewed models regarding the degradation of the ultimate strength and the test results. The strain at peak stress, the results indicate that the strain development is more in correspondence with the theoretical models suggested by Hertz and Terro. Furthermore, an over-estimation of the strain in the EN, which also leads to a higher prediction of the ductility.

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Residential fires in Denmark

A statistical analysis

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Keywords: characteristics, fatal residential fires, dwelling, care homes, statistic analysis

During 1998 and 2015 about 69-85 people have yearly died in residential fires in Denmark. The trend has not changed during the years. To be able to improve fire safety for people in residential homes, it is important to identify the risk factors of residential fires and hence, to determine, which groups are more likely to be killed in fires. Danish Emergency Management Agency has previously published two reports on fatal fires in Denmark considering the period from 2000 – 2005[1] and one study from 2007[2]. The current work focuses on the characteristics of fatal residential fires in Denmark and on identifying some of the characteristics of these fires, in the period from 2007 – 2015. The results for Denmark are then compared to data on fatal residential fires from Norway and Sweden.

For the study data from databases from fires in Denmark, Norway and Sweden were considered. The Danish database applied in this work, "Redningsberedskabets statistikbank"[1] is maintained by Danish Emergency Management Agency. It contains data originating from reports by the fire brigade, the police, and data from Rigshospitalets department of plastic surgery and burns treatment. The results were compared to data from the Norwegian database from Direktoratet for samfunnssikkerhet og beredskap [2] and data from the Swedish Myndigheten för samhällsskydd och beredskap [3].

The study has the following findings: In the selected years, most fatalities occur in the age-group 50-66 years. In general men are more likely to die in fires than women. However, the number female fatalities increases from age 30 and exceeds the number of male fatalities at the age group above 79. Both men and women have most fatalities in the age group 50 – 66 years.

Residential fires are more likely to occur during winter than during summer. Previous studies from Sweden and Norway have shown that a high number of the fatal residential fires happen at late evening and night time. It is assumed, that long detection time, due to the situation that people are asleep lead to further progression of the fires compared to day times. Furthermore, it was found that most residential fires occur in the kitchen, while about 50% of fatal fires break out in bed- or living room. 21% of the fires start in the bed and 34,3% in an unknown object. 50% of the fires in the years 2007-2015 were related to smoking. In the years 2007-2015 124 fatalities occurred in apartment fires, 88 in single houses and 76 people were killed in care homes, housing 1,49% of the Danish population. Hence, people living in care homes and protected residents in Denmark are more likely to die in fires than people living in other dwelling types. Similar studies have been carried out in Sweden and Norway. Figure 1 shows the number of fatalities in care homes in the years 2007-2015 for the three countries. The results for Denmark are overrepresented, especially considering the size of the population. One explanation can be the number of places offered in care homes in the different countries. In 2015 0,82% of the population in Norway and 0,89% of the Swedish population lived in care homes.

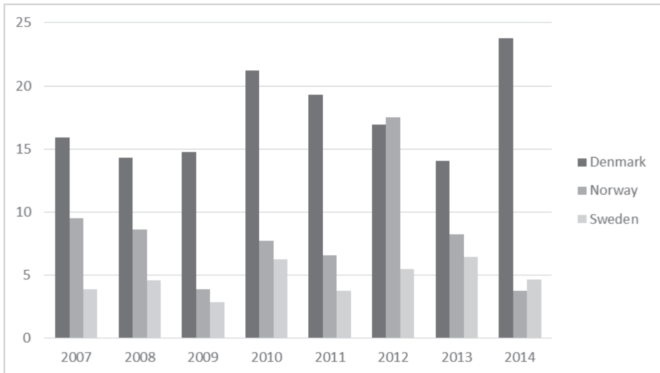

Figure 1: Fatalities in care homes. % of total number fatalities

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Residental fire solutions in the building sector

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Keywords: Fire retardents, biomaterials, residental fires

Residential fires are still frequently occurring in the world, which have the potential growing into disaster that can cause many casualties. As stated in literature and policy papers, biomaterials are needed to obtain more sustainable solutions in the building sector. All building materials need to sustain a series of fire testing, and the application of coatings might be needed before the materials are acceptable to use. This is in order to establish a high safety level with concern to fire, especially in the case of biomaterials, as they have to be considered combustible.

Hence, the application of flame-retardants is a common solution, but many flame-retardants have adverse effects to human health and the environment. Therefore, the fire behaviour of the materials in combination with flame-retardants need to be studied. An example are boron compounds, which are widely used as flame-retardants to reduce the ignitibility of biomaterials, despite the fact that a number of these compounds are on the ECHA list of candidates of very high concern for authorization.

It is a well-established fact that borates tend to wash out, and may impact the surrounding environment. Therefore, its application may become questioned in the future.

Hence, in the current work, sustainable solutions using biomaterials in construction with a focus on fire safety are examined.

As part of a starting PhD project, different methods for production and fire testing of bio-based materials and composites are reviewed including wooden products (e.g. board, fibre, LVL (Laminated Veneer Lumber)). Hereunder, the fire properties of bio-based resins as lignin and furfuryl-alcohol are investigated. The study provides basic information on the material's potential to give better products, i.a. to use less flame-retardants giving less adverse environmental effects.

Towards an evidence-based vision zero policy on residential fires – an update

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Keywords: Fire prevention, Residential fire, Vulnerable groups

Background: Sweden has adopted a national "vision zero" policy on fire, stating that nobody should be killed or seriously injured in fires. Despite this, some 100 people are killed annually with most victims being of poor health, elderly or disabled. A multi-center research project from 2014 to 2017 involving more than ten researchers, aims to investigate why these groups are at excessive risk of dying or getting seriously injured in residential fires, and to explore further preventative possibilities with special regard to these vulnerable groups. The aim of this presentation is to give an overview of findings from the project.

Methods: The project consists of seven work packages, derived from a tentative generic model of the residential fire process. Quantitative and qualitative approaches are applied.

Results By 1st of April 2017 the project has yielded seven peer-reviewed international publications (1-7), plus four submitted for publication (8-11). Additional publications are in progress. While fire onset is most common among younger and well-educated households, serious injury and death from fire almost entirely strike the elderly and socially or medically disadvantaged groups. The opportunity for rescuing declines very rapidly with time and distance. National statistics on fire fatalities systematically underestimate the true situation by 20 %. Over time, significant reductions in unintentional fire-related death rates are seen in all age/sex groups, most strongly in children. A comprehensive framework, summarizing all findings, is underway.

Conclusions In line with vision zero philosophies in parallel policy fields, such as traffic safety, merely preventing accidents (crashes or fires) and rescuing victims appear insufficient strategies for protecting human life and health from residential fires. Individual capacities are crucial for survival, and fire safety programs should take these insights into better account by compensating for deficiencies in human performance.

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On analyzing structures based solely on human safety

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Keywords: Structural fire safety design; Load-bearing structures; design fire

INTRODUCTION

A new approach for the analysis of load-bearing structures subjected to fire is launched.

The general goal of structural fire safety design is to protect humans and to some extent the building itself. This new approach tries to describe this goal as functional objectives from a human safety perspective and how to apply these objectives in practical design.

By following the approach, two distinct levels of safety are identified, collapse is or is not tolerable. This distinction can be observed already as some buildings have very high structural fire resistance requirements while some buildings have no require¬ments for structural stability in case of fire. To find out how to classify structural elements, see the flow chart of Figure 1 with accompanying calculation methods for relevant key decisions.

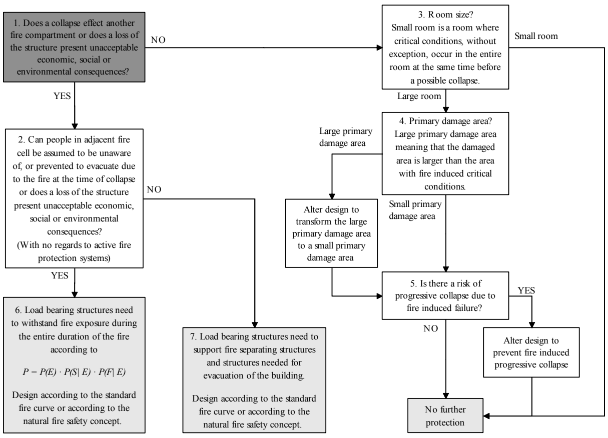

Figure 1 Flow chart for finding the functional objective for the structural fire safety design.

TOLERABLE COLLAPSE

The concept of tolerable collapse in structural fire safety design codes are supported by the international comparison performed in 2014 [1]. In this study, however, buildings with tolerable collapse but with requirements for structural fire safety protection were identified, a category of buildings in bet¬ween the two previous distinct levels where collapse was or was not accepted.

Figure 2 Image of building in Sweden with tolerable collapse but with some fire protection requirements.

This category of buildings is understood by comparing the fire design time to the survival time. By altering the failure criterion from solely focusing on time to structural failure, to focus on time to structural failure when human safety is no longer an issue, i.e. when survival is impossible.

A fire large enough to inflict harm on structural elements is devastating to humans. Thus a compartment filled with hot gases constitutes lethal con¬ditions, meaning no humans can survive. Then a structural collapse does not present any additional risk of harm to humans.

If a structural collapse inflicts danger to humans outside of the distance of direct harmful condition, such a collapse must be delayed, prevented or limited. Smart structural fire safety design can often achieve this delay without the need to apply unnecessary and costly fire protection as is often needed today due to ineffective regulations.

The work on this design approach is a part of the PhD studies of Joakim Sandström, funded by SBUF, Sveriges Byggindustriers Utveck¬lings¬¬fond.

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Post-earthquake fire behavior of steel frames

Part I: Collapse Mechanism

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Keywords: Fire following earthquake, collapse mode, moment resisting frame, steel structures, performance-based design

This project is part of a cluster thesis aimed to investigate the effects of fire consequent to earthquake. This part covers the collapse mechanism while the second focuses on the influence of damaged fire insulation.

Post-earthquake fires represent a serious threat as they are known to cause significant losses, adding up to the damage provoked by the seismic motion [1][2]. In current design codes, the super-imposed effects of fire and earthquake are not considered, which is a matter of interest in seismic active regions. The fire resistance of the building may be reduced by damage to the fire insulation protecting the structural members [3] or permanent deformations and residual stresses [4]. Modern seismic design codes provide structures with a minimum ductility requirement to be able to sustain a certain amount of damage, resulting in an additional decrease of the resistance due to the ductile behavior [2].

Steel structures in particular should be given special attention as they are provided with insulating materials in most cases, as steel suffers a great reduction of resistance at high temperatures. The mechanical properties suffer a gradual decay as the temperature rises [5]. Assuring that the building does not collapse when exposed to fire is critical to provide a safe evacuation of the occupants and access for the emergency response crew [6].

The main topic of interest in this thesis is investigating the collapse mode of steel frames subjected to fire following earthquakes. A moment resisting steel frame is designed to earthquake according to the Eurocode. Several aspects are investigated such as the variation of the building height related to the collapse mechanism and the times to failure. The interpretation of the collapse mode is one of the main challenges in this subject.

The model validation is done with a case study building taken from another research done on this matter by Zaharia and Pintea [1] which investigated the behavior of moment resisting steel frames. They concluded that damaged structures have a reduction in fire resistance which is proportional to the damage sustained. Della Corte et al. [2] also came to a similar conclusion that the resistance of the frames is reduced, but it is rather significant for very rare earthquakes.

The structure is modelled in a finite element software as a 3-dimensional frame and a FEM analysis is performed in three steps. After assessing the gravitational loads, the next step is subjecting the loaded structure to seismic action in the form of time history acceleration and a non-linear time-history analysis is performed to evaluate the damage sustained. The final step consists of evaluating the structural response to fire action, using a non-linear time history analysis after applying a standard fire curve to the structure affected by the horizontal motion.

A better understanding of the phenomenon can be attained by studying the different failure mechanisms which may be local or global failure. The final scope is to determine if a special performance-based design for fire after earthquake is deemed necessary for buildings located in seismic active areas.

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Post-earthquake fire behavior of steel frames

Part II: The effect of the Insulation

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Keywords: Post-earthquake fire, fire insulation, steel structure, parametric study, steel frame

This project is part of a cluster thesis aimed to investigate

the effects of the fire following the earthquake. This part focuses on the influence of the damage of the fire insulation caused by the earthquake while the other part investigates the collapse mechanism.

Earthquakes are the common reason for the damages to the buildings in the seismic regions. However, the records show [1][2] that in some cases it is not the earthquake that causes the biggest losses (both in terms of human lives and properties) but the fire that occurs afterward. The post-earthquake fire (PEF) is not an unprecedented action. It usually starts as a result of the ground vibrations (e.g. the fallen heat source or damaged electrical wires) and due to the confusion after the earthquake is usually harder to discover. However, in current design codes for the structural design the post-earthquake fire is not considered. The fire design and seismic design are treated as separate design situations and in that case the effect of the PEF is not investigated [3].

The event of the fire following the earthquake is an event of low probability but high consequences. Buildings in seismic regions are designed separately to withstand the ground motions and to keep the structural integrity during the fire. However, the fire that occurs after the earthquake finds the building that has different properties than the structure before the earthquake (e.g. formation of the plastic hinges, damage of the active and passive fire protection systems). That means the time available for the occupants to evacuate from the building may shorten significantly. The uncertainties caused by insufficient consideration of the PEF event are also dangerous for the rescue services that enter the building which structural behavior is unknown.

The purpose of the thesis project is to investigate the insulated steel frame subjected to the earthquake followed by the fire. The outcome of the project should indicate if it is necessary to take into account the post-earthquake fires in the codes used for the steel frame design. The project is based on the previous thesis results for the unprotected steel frame [4]. Steel structures behave in a particular way when subjected to high temperature. The mechanical strength of the steel decrease rapidly during the fire, because of that steel structures are usually protected with fire-proof insulations [5]. However, during the earthquake this protection may be damaged which leads to significant decrease of the fire resistance.

The influence of the damaged insulation was not studied at the literature, often the structure is assumed to have no fire protection from the beginning [1]. However, as mentioned before steel structures are usually insulated thus to achieve more practical results the model [4] is modified and designed to be fire resistant. The model was validated with the thermal model performed in FEM software and few simplification were assumed. The temperature in the element is assumed to be evenly distributed and the damage of the insulation occur in the plastic hinges. Different percentages of the insulation loss and its impact on the structure is investigated as a parametric study.

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Validation of FDS on the SP retail store

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Keywords: cfd, fds, validation, turbulence, experiments

The project Quality scenarios for validation of the four CFD-codes CFX, FDS, SMAFS and SOFIE was started in 2005 as a collaboration between Lund University, Brandskyddslaget and SP, Technical Research Institute of Sweden. In 2008 a report was produced with the same name as the project that included eight different experimental scenarios. These scenarios were used to evaluate the possibility for using the four above-mentioned CFD programs to model the spread of combustion gases [1].

The present work is based on one of the experimental scenarios and the analysis of one of the used programs in an up-to-date version [2]. The experimental scenario chosen was a retail store in the model size 1:2 with limited ventilation with the aim of creating an under ventilated environment. The program used was Fire Dynamics Simulator (FDS), version 6.1.2.

The following three sensitivity validations studies were conducted to verifying that the simulations were valid:

- Effects of the geometrical simplifications connected to the coarsest used grid size
- How the outer boundaries effects flows and temperatures in the vents
- Grid independency

The first sensitivity validation concluded that there was no negative outcome, because of the geometrical simplifications.

Regarding the analysis of the effects of the outer boundaries, two different sizes of boxes on the opening were used. Only minor differences were identified and the larger outer boundary, which was 10 times the hydraulic diameter of the opening, was determined to be used further on.

The final sensitivity analysis showed that grid independency could be achieved for D*/dx between 8 and 16 for the parameters of interest in this study. Some differences were still found concerning other parameters.

The finer grid D*/dx = 32 could not be evaluated because of a too large computational cost. With a conservative objective, D*/dx = 16 was chosen for further simulations.

Simulations were conducted for two different combustion efficiencies due to uncertainty connected to the available experimental data. The results were compared to experimental data and the results from simulations previously done with FDS version 4.0.7 that were presented in the report from Holmstedt et al. [1].

The results showed that lower levels of oxygen connected to characteristic under ventilated environments could not be found in the simulation. The new simulations showed better agreement for temperatures, especially for the upper gas layer temperatures over the whole area of the room, compared to previous results that overestimated the temperatures with up to 25%.

An overestimation of temperatures for the lower gas layer were found for the new FDS 6 simulations in a similar manner as for the previous simulations in FDS 4. This could be the result of a too large turbulence mixing in the lower area.

Further simulations were carried out using all the different sub-grid turbulence models in FDS in order to investigate the increased mixing in the lower part of the retail store. These simulations did not give a clear indication why there is an increased mixing in the lower part of the room. Therefore, choice of sub-grid model seems to have limited effect on the mixing in the lower zone.

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Validation of sub-grip scale particle model for cable fire spread

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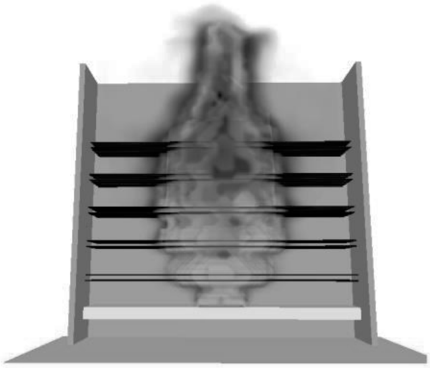
Keywords:
Fire modeling, cable fire, fire spread, sgs models, lagrangian particle



Predicting fire spread and heat release rates is an active research topic in fire model development. Predictive simulations allow more accurate simulation results in different environments, reduce conservatism and help to identify the critical elements of the scenario. Fire spread is a challenging phenomenon to model as it requires computation both in solid and in gas phase, involves chemical reactions, and length scales from mm (ignition) up to tens of meters (room scale). Fire spread in cables is even more challenging due to the complex structure and non-rectangular shape of the cables. Modern cable types also typically include flame-retardants. The composition of these flame-retardants is often not known.

Fire spread in cables is a subject of interest for nuclear industry. Cables form a significant portion of the fire load in the nuclear power plants. In addition, cables are not only fire load, but also active part of the critical safety systems controlling the safe shutdown of the plant. Therefore, the capability of accurately predicting fire spread in the cable rooms is be very important.

In this paper, we describe the state-of-the-art of the cable simulations, and identify the challenges. Our approach is to use sub-grid-scale particles for modelling the cables for more accurate geometry. Improvements to the modelling capability of the Fire Dynamics Simulator (FDS) by modifying the calculation of the drag coefficient and the heat transfer between particles is considered. We present the simulation results covering the whole modelling chain; from the small-scale pyrolysis model up to the large-scale validation simulations.

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Modern building fires

Modern buildings contain more combustible materials than before. Nowadays furniture has foam-filling, whereas previously flax fillings or the like were used. Also the many plastic-based products in the form of plastic bowls, folders, blinds, cushions, etc. contributes to a more intense fire development today than 50 years ago. There are other synthetic materials in homes today, for example carpets, laminate sheets and these contribute to a larger fire intensity and spread of fire. Last but not least; modern buildings contain many more plastic-based building materials. Among other EPS, XPS, PUR, PIR and PF which are used in different parts of the building, especially as insulation. Today, it is allowed to use foam insulation as exterior façade insulation in several countries, and as inside mounted, up to two floors (in Denmark), when the insulation is covered by applicable coverings. The plastic-based materials result in faster and more intense fire developments and furthermore, many of the plastic-based materials emit toxic compounds.

In recent years, a number of energy renovation projects of blocks of flats, detached houses and townhouses have been taking place.

This energy renovation can contribute to an increased temperature during a fire, due to their good insulating effect. In addition, certain energy-saving windows have more difficulty to rupture during a fire, in particular 3-layer panes. This reduces the natural smoke ventilation during a fire that otherwise could remove smoke to the benefit of residents as well as firefighters.

The combination of new plastic-based materials like furniture with foam-fillings, foam insulation etc. and the present requirement to high insulated buildings, gives reason to fires developing faster, to higher peak values and emit more toxic compounds.

All of the above results in a need for modern buildings to be studied analytically, in order to achieve as good a basis as possible, to design appropriate fire safety. With good knowledge of the facts, we can set up more realistic design fires. In addition, an updated knowledge of realistic fire development and intense, can be attractive for emergency, preparedness and sizing of firefighting equipment.

The focus will be on residential fires in the project. The project should elaborate and consider challenges with focus on modern building fires development, intensity and toxicity and how this can compromise the evacuation conditions. The project will also include mitigation and prevention possibilities.

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Fire safety of car parks

Addressing current shortcomings in fire modeling and structural design

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Keywords: car combustible, fire spread, well-ventilated fire, open and semi-open car park, steel elements, concrete elements, insulation.

Steel and concrete car parks may exhibit a high vulnerability to fire, as a consequence of the well-known degradation of the mechanical properties at high temperature and the type and amount of combustible materials in the vehicles. The latter aspect in particular has been enhanced by a drastic increase of combustible products in new car models.

On the other hand, according to some guidelines and research studies [1, 2], fire protection of steel elements should not be necessary in open car parks, as the fire severity caused by the high combustible content may be mitigated by a short duration and a supposedly limited spread of the fire, induced by the high ventilation of the premises.

The assumption behind this conclusion is that at most 3-4 vehicles would be on fire at the same time. This number comes from the result of an old statistical study [3] and, more recently, from a real scale open steel car park carried out in the framework of a European research project [4]. However, the outcomes of these tests were later put into question [5] by the occurrence of some real fire accidents in open steel car parks, which showed a much faster fire spread and a larger number of vehicles involved than indicated in these studies. An example of a major fire spread in an open car park is shown by the fire occurred in October 2002 in an open car park near the Schiphol airport, were around 30 cars have been seen on fire at the same time [6]. Another example is the fire in the open car park adjacent to the Aquatic Centre of the Sydney Olympic Park, in October 2013, where up to 100 cars were damaged by fire and 47 were completely burnt [7]. More recently, in March 2016, some cars were set on fire under an open shelter in Brøndby Øster, Denmark [8]: although it is not clear how many cars were initially ignited, a clear fire spread was observed to all the cars under the shelter, showing again the potential danger of fire spread in well-ventilated car parks.

These examples clearly indicate that the assumed fire spread provided by the above-mentioned guidelines and research projects is not entirely reliable, as their predictions do match neither with the real-life fires nor with recent theoretical studies. A recent numerical study carried out at DTU has shown a strong dependence of the fire spread on the parking distance between cars [9], while ongoing studies are considering the effect of hydrogen-fueled vehicles. However, further and more comprehensive research is needed, in order to establish a complete and more reliable guideline on fire safety of car parks, which can provide the necessary safety level against fire.

The challenge of such research consists in the strong interaction between different areas of fire safety, which require broad competences in various fire-related disciplines: 1. the study of fire ignition and flame propagation along different car materials require competences on fire chemistry; 2. the study of the fire propagation requires competences in fire dynamics; 3. the investigation of the structural response requires competences in structural design. The last aspect involves competences on different material behaviors at high temperatures and, in particular, steel and concrete structures will be considered in this project. In addition to theoretical knowledge, experience in carrying on experimental work is needed for extensive testing on single vehicles (different types of new cars as well as hydrogen-fueled and electric cars) and for large-scale test of fire spread in the open. Further experience is also needed in implementing reliable computational fluid dynamics (CFD) models and Finite Element Models (FEM) for the investigation of the fire development and the structural response, respectively.

Figure 1 shows the organization of the main scientific Work Packages (WPs), which follows the distinction of the different research areas above mentioned. In addition to the four scientific WPs in the picture, WP0 will be devoted to the project coordination and management, while WP5 will focus on the dissemination of the results. In particular, a report summarizing the results of each WP work will be produced by WP1-4.

The reports will be used in WP5 to develop two design guidelines, one focused on design fires and one focused on structural design. The guidelines are expected to provide a simple but reliable methodology for design car parks against fire as well as assessing the safety level of existing and new car parks. As such, the guidelines will serve as essential tools for industry and administrations.

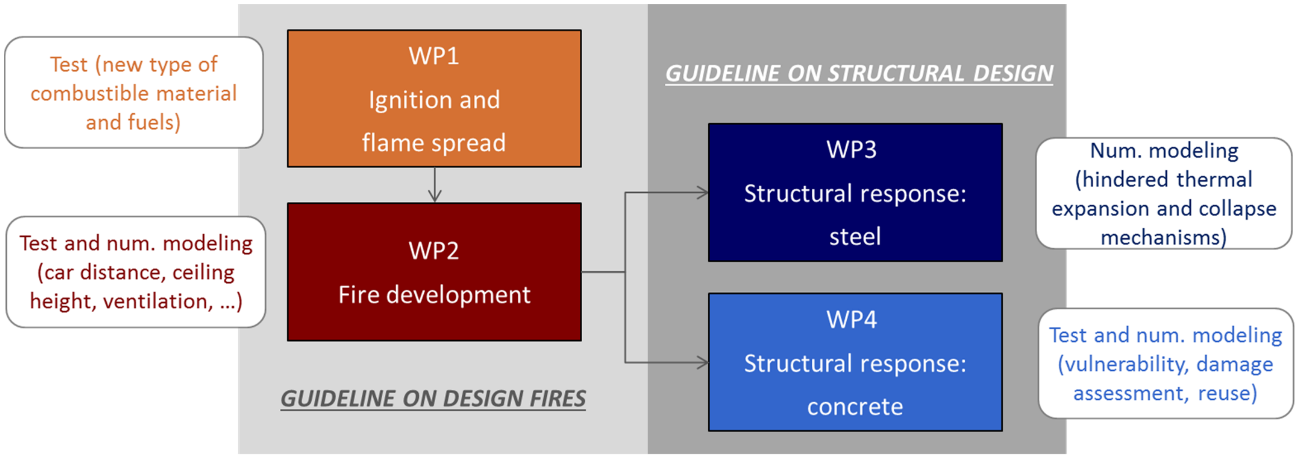

Figure 1: Organization of the main scientific work packages

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