Proposed Topic

Sustainability assessment of building envelope solutions based on fire experiments at different scales

Motivation and State-of-the-art

The “energy crisis” in the 1970s resulted in a large focus on saving energy consumption in buildings [1], because saving energy in the construction sector was found to be the one of simplest and most efficient ways to reduce energy consumption [2]. As a result, a significant amount of work has been carried out in relation to improving the energy efficiency of residential and other buildings in the past 50 years [1]. Since buildings have been shown to be responsible for up to 30 % of the total energy consumption in the world, the decision to work on improving the energy efficiency of buildings is still a natural focus [3]. One of the ways to improve the building’s energy efficiency is by adding thermal insulation [4]. For renovation projects, this is usually accomplished by attaching an additional layer consisting of cladding and insulation materials to the building’s envelope [4].

Such an additional layer to the building’s envelope is an efficient way to improve its thermal insulation. However, the current sustainability-driven decision-making process implemented to choose the materials is not considering the fire safety aspects in an adequate way. The problem arises because the materials used for this kind of application are often flammable, which requires a systematic analysis of the implemented solutions. Traditionally, the fire safety strategy for building fires counted on the fact that there would be no vertical spread of fire [5], but the use of more flammable materials and changes in the design of the preventive measures in recent years is shown to be contributing to the increasing number of façade fires over the last 30+ years [6]. Based on the available current data for the number of fires, there can be a probabilistic prediction for a given number of buildings to be involved in a fire in their lifetime [7].

Therefore, the choice of the materials used for the building envelope can contribute critically to safety concerns and consequently appalling ramifications in case of fire, such as property losses, injuries and even deaths. In fact, it has been estimated that over 5000 people die from residential fires in Europe every year and the number of people injured could be as much as 10 times higher than the number of fatalities [7]. In one of the last instances of a building fire with a catastrophic outcome (the Grenfell Tower fire in London with 72 fatalities), the building envelope was the system that failed [8]. It should be noted that the building envelope does not only contribute to the thermal insulation of the building but can also serve aesthetic or other purposes. Regardless of purpose when the cladding materials are flammable, they always contribute to impaired fire safety [9].

Considering all that, the current standard methodology of fire testing is not providing the required data so the range of outputs from fire safety tests should be reassessed and potentially expanded to allow for obtaining more useful results. The current façade fire tests

are designed to evaluate vertical fire spread from floor to floor via external walls. Their design also allows for investigating the differences among diverse insulations, wall claddings and geometries [10]. The SP Fire 105 test procedure, for instance, was designed to enable the determination of the reaction to fire of an external wall assembly or a façade wall cladding when exposed to a simulated apartment fire with flames emerging out through a window. The flame spread can be studied directly on the outside and indirectly on the inside of the external wall assembly or façade cladding. [11] The results from the tests like this are then often considered in the sustainability assessments. But since the test themselves were not designed with later sustainability assessment in mind, the results of them are not necessarily appropriate to be used like that. Also, they cannot reflect the characteristics of the tested material, façade system or its components in regard to the sustainable aspects.

As mentioned, one of the possible and important reasons that the fire safety aspect is not considered to the extent that it should have been, is that the data presented to the providers of the sustainability assessment is not sufficient or relevant or even available in a way that could provide adequate information. Taking into account a plethora of currently valid standards dealing with façade testing [11]–[16], the majority of them just has a pass/fail result at the end. This does not allow for a subsequent comprehensible assessment and comparison of different risk factors for different systems or different configurations of the same façade systems. On the other hand, it is important, that the sustainable aspect or the quality of living for the occupants in the buildings is not compromised due to the proposed fire safety requirements.

Further to the above, there is a variety of tools available that enable sustainability assessments [17], though without considering fire safety aspects adequately. Familiarising with their general methods, procedures, required inputs and understanding of their overall design is important to be able to propose the improvement of the fire tests in a way that would allow for a collection of appropriate data. These data would later be used for sustainability assessments to provide more comprehensible results. These results would then equip the decision-makers to be better able to decide on the use of the building envelope solutions regarding the relevant legislation requirements, sustainability expectance, fire risk, costs etc.

In terms of other solutions that are also added to buildings to make them more sustainable (in current accounting systems), building applied photovoltaic (BAPV) systems are one of the main challenges when it comes to fire safety. As the roof that they are placed on can be considered part of the building envelope, the fire safety and sustainability aspects of such systems will also be considered [18]–[20].

Aim and objectives

The aim of my research will be to propose the parameters that fire testing should provide for a sustainability assessment of the fire safety of a building envelope solution along with an improved fire safety assessment based on high fidelity measurements. The proposed parameters will be based on the test conditions that allow for medium-scale experiments to be performed instead of full-scale experiments without losing data quality and quantity. This would allow reducing the time needed to perform them, cut down on the overall material consumption for the experiments and in the end slash the emissions and the amount of produced waste.

Methods

To be able to reach the proposed objectives, a thorough literature review of the currently available methods/guidelines and general state-of-the-art of the field is required in the beginning. Hands-on familiarisation with the procedures will also be needed at first. The next step will be to design and develop a mid-scale rig and also the parameters that would suffice to communicate the fire safety of the tested materials should be proposed before the execution of the first experiments. Subsequently, tests using the designed rig will be performed and their results evaluated. At last, also some full-scale experiments will need to be performed to validate and compare the acquired results from the mid-scale tests. The optimisation should allow for an adequate collection of data about the materials without the need to perform full-scale tests. Lastly, a way to communicate the obtained data efficiently down the supply chain to the relevant parties will be recommended.

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