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Experimental study of corner fires—Part I: Inert panel tests

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ABSTRACT

Corner fires are known to spread more intensely in comparison with single wall fires. In view of the challenges associated with prediction of such fire behavior, the fire growth in a corner configuration of Medium Density Fiberboard (MDF) panels is investigated to provide a set of experimental data, performing Single Burning Item (SBI) tests. First, though, test results with inert calcium silicate panels are discussed for three values of HRR (10, 30 and 55 kW), allowing to address the main physics involved. The experimental data for 30 kW, the default SBI HRR, is used for detailed discussion of the observations. The SBI testing methodology, materials, and set-up are described. The results of total Heat Release Rates (HRR) and Smoke Production Rates (SPR), as well as the panel temperatures and total heat fluxes at several characteristic locations are analyzed. Moreover, the puffing frequency of the corner fire is characterized thanks to Video Fire Analysis (VFA) of the experimental footage. Additionally, flame heights are discussed, including the concept of mirroring. A new correlation for mean flame height is introduced, using the hypotenuse of the triangle as characteristic length for entrainment of air into the fire plume, and expressing that the flame height increases proportional to the square root of the fire heat release rate. The 30 kW propane burner of the standard SBI test is shown to feature a mean flame height of nearly 0.9 m and a puffing frequency of 2 ± 0.3 Hz, and an average total heat flux exceeding 44 kW/m^2 near the burner early on in the test. The completeness of the dataset is expected to be useful for testing and development of CFD codes for corner fire scenarios.

1. Introduction

In fire safety problems, corner fire scenarios are often considered in flame spread scenarios [1] since fires spread more intensely in such a configuration in comparison with single wall fires. This is because the rate of mixing with ambient air in a corner fire plume is less than that of a free burning fire plume [2], leading to extended flame heights and high plume temperatures [3]. This causes the walls to heat up more effectively in a corner fire configuration. Reduction in radiation losses to the surroundings and also re-radiation among the walls are other influencing factors [4]. Accordingly, an accurate description of pyrolysis of combustibles and surface flame spread in such a configuration by means of pyrolysis codes and Computational Fluid Dynamics (CFD) software is of great interest to the fire safety community. Correspondingly, numerous tests have been conducted to study the behavior of fire in corner configurations and to obtain suitable data for evaluation of fire modeling codes in this area, as in [2,5–12], often resembling ISO Room Corner tests [13].

The corner fire tests in our experimental campaign comprise several Single Burning Item (SBI) tests [14]. From an experimental perspective, SBI constitutes a key fire spread test since it forms the basis for classification of linings in Europe [15] and is an intermediate-scale test aiming to bridge the gap between bench-scale tests such as Fire Propagation Apparatus (FPA) tests [16] and full-scale tests such as ISO Room Corner tests [13]. Subsequently, being able to accurately predict the corner fire behavior in SBI is equally important and of interest [17,18]. More specifically, as the results of a previous study suggest [12], predicting the global HRR evolution in modeling of a SBI corner fire is more challenging than for ISO Room Corner or Cone Calorimeter tests [19], showing higher sensitivity to the boundary condition at the backside of the walls. In this view, our experimental campaign focuses on the corner fire behavior in SBI experiments through several tests conducted with Medium Density Fiberboard (MDF) panels as well as inert calcium silicate panels. We monitor the fire behavior in the tests using cameras from two different angles and measure the evolution of panel temperatures, total Heat Release Rates (HRR)

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and Smoke Production Rates (SPR), as well as the total heat fluxes at the standard thermal attack calibration points of SBI [14]. In Part II [20], the results obtained for MDF panels are discussed. Here, we focus on all the details of the experimental methodology and set-up.

In the present work, the evolution of the panel temperatures is investigated via through-thickness temperature measurements at various locations over the burning panels. In addition, the evolution of temperatures at the backside of the burning walls is discussed. This is an essential component since it helps quantifying the heat losses from the backside. Earlier numerical studies of corner fires have indicated the need for experimental quantification of this heat loss [12,21] and have highlighted its significance when transitioning from the small scale of Cone Calorimeter tests [19] to larger scales of SBI tests [14] and ISO Room Corner tests [13]. To the best of the authors' knowledge, this has not been investigated experimentally in a systematic manner before. Another relevant subject is the level of symmetry of the thermal attack on the two panels. This is investigated in our study via analysis of the evolution of the through-thickness panel temperatures, and Video Fire Analysis (VFA) [22,23]. Furthermore, the puffing frequency of the corner fire is characterized in order to provide experimental data for comparison with that of free burning fire plumes [24].

Table 1
Material properties of the CS panels (from the source supplier).

Property	Value
Thickness [m]	0.0123 ± 0.001
Density [kg/m^3]	1005 ± 5%
Moisture content [%]	5–10
Thermal conductivity [W/(m K)]	0.17[a]
Specific heat capacity [J/(kg K)]	920[b]

[a] The nominal value of thermal conductivity is 0.17, 0.19 and 0.21 W/(m K) at temperatures of 293, 373 and 473 K.
[b] The nominal value at 673 K.

Tests with inert Calcium Silicate (CS) panels are discussed, as in [5,25–27]. The basic test ('CSCS') has the default SBI heat release rate of 30 kW. Two additional tests have been performed for HRR = 10 kW ('CSCS10kW') and 55 kW ('CSCS55kW'). While quantitatively obviously different, quantitatively no fundamental differences are observed. Therefore, the 30 kW results are used herein as the basis for the analysis of the phenomena observed.

2. Methods and materials

The material properties of the CS panels are presented in Table 1, as obtained from the technical specification sheet provided

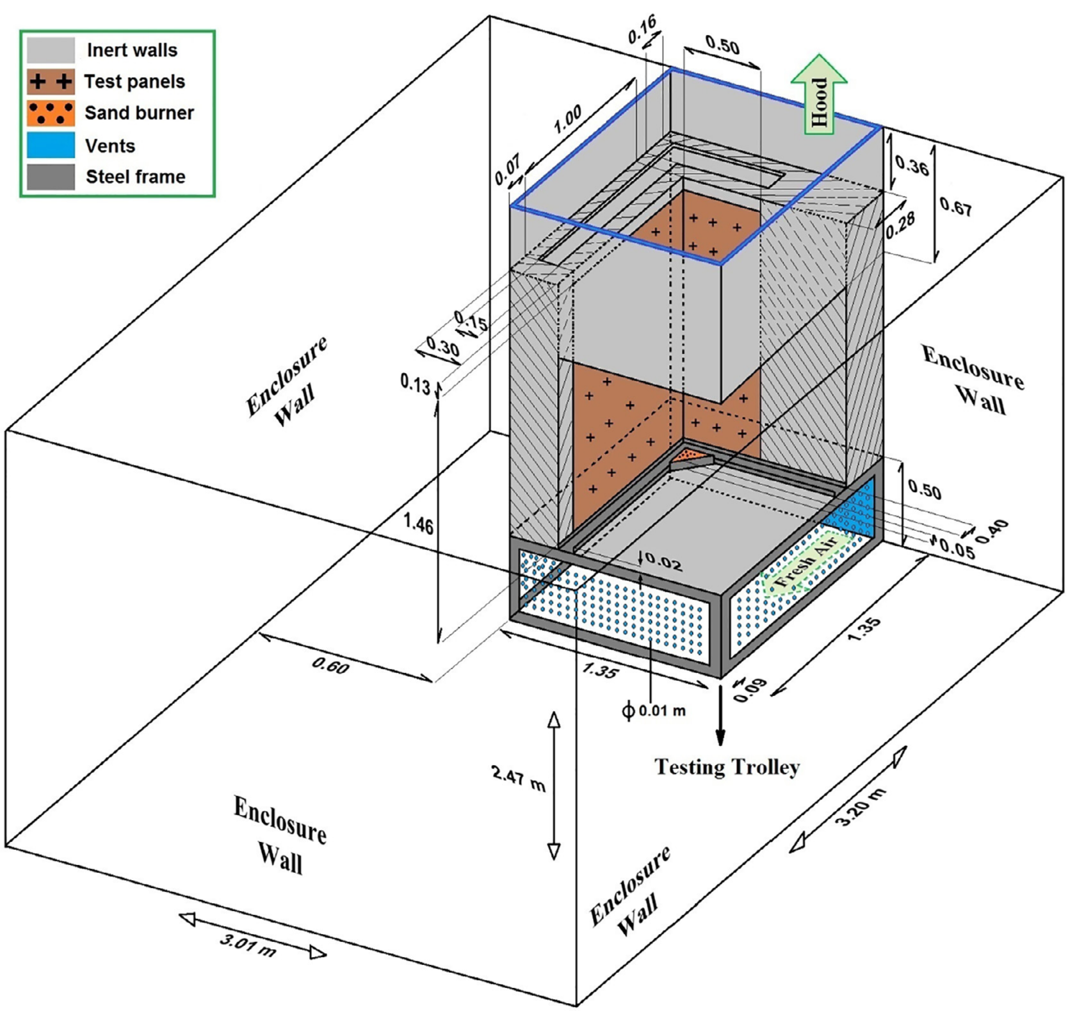

Fig. 1. The geometry of the SBI tests' enclosure (units in m): there are two openings in the enclosure, namely the hood on top of the testing trolley, which extracts the gases (0.6 N m^3/s), and the vent at the bottom of the backside of the trolley (1.16 m by 0.32 m) where fresh air enters the enclosure. The bottom sides of the trolley are covered with perforated steel plates (50% open area), to produce a more uniform airflow. The total exposed height of the panels is 1.46 m, and there is an air gap behind each panel, i.e., 0.30 m wide behind the long panel and 0.28 m wide behind the short panel. The image is not to scale.

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