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Fire tests of non-load bearing light gauge steel frame walls lined with calcium silicate boards and gypsum plasterboards

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ABSTRACT

Light gauge Steel Frame (LSF) wall systems are made of cold-formed steel studs and tracks, and lined with wall lining materials. Conventionally, gypsum plasterboards are used as wall lining material in LSF wall systems. The fire performance of LSF walls is mainly dependent on the type and configuration of wall lining material, which delays the heat transfer through the wall and protects the steel studs from being heated rapidly. Recently, calcium silicate board lining is increasingly used in LSF wall systems because of its improved physical and thermal properties while being lightweight, cost effective, impact and moisture resistant. However, their fire performance has not been investigated in detail. Hence two full scale fire tests were conducted on non-load bearing LSF walls lined with calcium silicate boards. For comparison purposes two fire tests were also conducted on conventional gypsum plasterboard lined LSF walls. This paper presents the details of this experimental study on the fire performance of LSF walls and the results including fire resistance levels and time-temperature profiles across the wall panels. Effects of using calcium silicate board lining are discussed by comparing the fire test results of LSF wall lined with gypsum plasterboards and previously conducted studies on magnesium oxide board lined LSF walls. The results showed that the fire performance of calcium silicate board lined walls was similar to that of conventional gypsum plasterboard lined walls, but was superior to that of magnesium oxide board lined walls. The failure criterion of these calcium silicate board lined walls was found to be insulation as opposed to being the integrity failure observed in previous studies.

1. Introduction

Cold-formed Light gauge Steel Frame (LSF) wall systems are commonly used in buildings as both load bearing and non-load bearing walls. They are made of cold-formed steel studs and tracks and lined with boards. During fire events, LSF walls act as separating elements between rooms/compartments and resist fire spread. In general LSF walls are exposed to fire from one side. Thus they develop a temperature gradient across the cross-section, and thermally bow towards the fire side due to differential thermal expansion. This temperature gradient will induce non-uniform distribution of strength and stiffness across the steel stud. Also the thermal-mechanical properties of cold-formed steel studs deteriorate at elevated temperatures, and cause structural failures of thin-walled studs in load bearing walls with continuing fire exposure. Therefore fire protective wall linings are provided in LSF walls to protect steel studs from direct fire exposure and to delay their temperature rise. LSF wall fire performance is mainly dependent on the wall configuration and wall lining material. LSF wall configuration includes studs lined with single and double boards with and without insulation. The insulated wall panels can be either cavity insulated or externally insulated, i.e. insulation layer sandwiched between boards. The wall lining not only protects the studs from rapid temperature rise but also provides adequate restraint against buckling of the studs about their minor-axis and twisting.

The Fire Resistance Level (FRL) of LSF walls when exposed to the standard fire time-temperature curve on one side is determined based on three criteria [1]. They are: 1) Structural adequacy: ability to maintain the stability and carry the design loads, 2) Integrity: ability to resist the passage of flames and hot gases and 3) Insulation: ability to keep the temperature on the unexposed surface below the limits (i.e., the maximum and average unexposed wall surface temperature should not exceed the room temperature by 180º C and 140º C, respectively).

Gypsum plasterboards are commonly used as lining material in LSF walls. Pure Gypsum, known as Calcium sulphate di-hydrate ($CaSO_4 \cdot 2H_2O$), consists of Calcium sulphate with 4–5% of free water and 15–18% chemically bound water by weight [2–7]. The free and chemically bound water in gypsum plasterboard is important because it contributes to the fire resisting behaviour. When exposed to fire, gypsum plaster-

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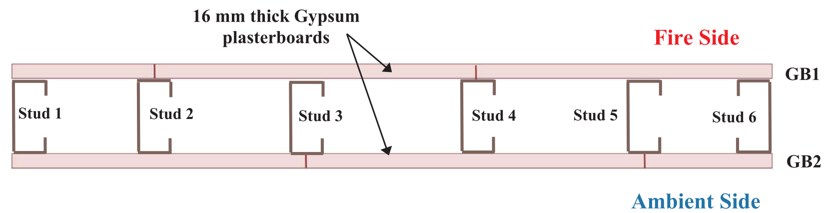
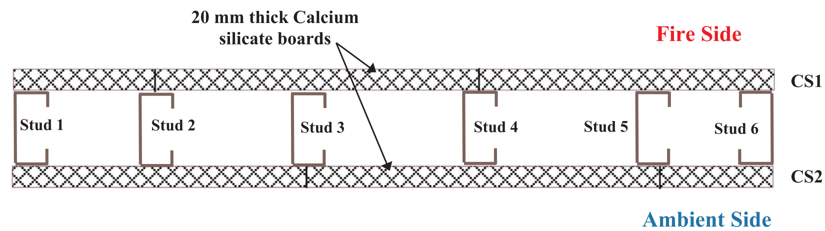
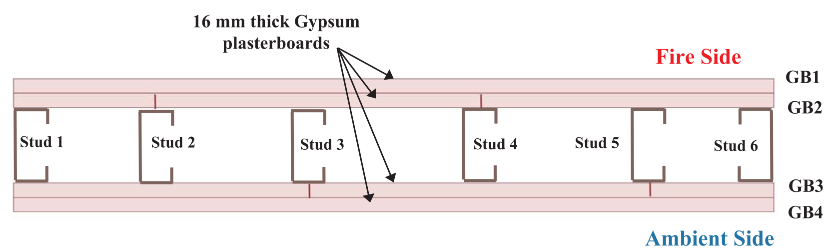


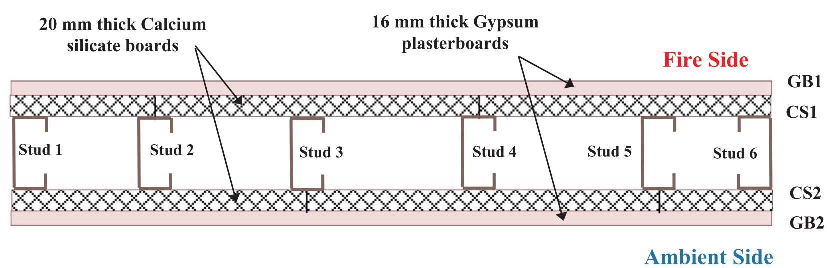
(a) LSF wall panel with single layer of gypsum plasterboard – Test specimen LSF1



(b) LSF wall panel with single layer of calcium silicate board – Test specimen LSF2



(c) LSF wall panel with two layers of gypsum plasterboards – Test specimen LSF3



(d) LSF wall panel with combination of calcium silicate boards and gypsum plasterboards – Test specimen LSF4

Fig. 1. LSF Wall configurations used in Fire Tests.

board undergoes reactions in which the water is gradually driven off at temperatures above 100° C. Significant heat energy is required to evaporate the free water and for the chemical reaction to release the water in the crystal structure. Gypsum plasterboard also consists of glass fibre, vermiculite and perlite additives, which improve the durability and fire performance. Many experimental and numerical studies [8–20] were conducted to determine the effect of different wall configurations on the fire performance of LSF walls, such as thickness and number of layers of gypsum plasterboards, grade and thickness of cold-formed steel stud sections, stud shapes and wall configurations, when exposed to both standard fire and realistic design fire curves.

Recently, calcium silicate boards have been increasingly used in LSF walls because of their improved physical and thermal properties while being lightweight, cost effective, impact and moisture resistant. Chen et al. [21] conducted two full scale fire tests of load bearing LSF walls (3.38 m × 2.98 m) lined with calcium silicate boards. The first fire test wall panel had two layers of 12 mm thick calcium silicate boards while the second test panel had a combination of 12 mm thick calcium silicate board and 12.5 mm thick gypsum plasterboard (face layer). The results showed that calcium silicate board had explosive spalling at elevated temperatures, thus resulting in lower FRL than gypsum plasterboard lined LSF walls. Although the failure in the first fire test was based on the integrity criteria at 58 min, the second wall panel fire test with the combination of calcium silicate board and gypsum plasterboard suffered a structural failure at 92 min. The studs exhibited both major axis flexural buckling and local compression failure of the cold-flange. The cracking of the ambient board surface i.e. gypsum plasterboard surface was not observed, thus integrity failure was not the governing failure criterion in this test. Wang et al. [22] conducted one full scale (3 m × 3 m) and five small scale (1.2 m × 1.2 m) tests of LSF walls lined with 9 mm thick calcium silicate boards focusing on the behaviour of embedded electrical junction box on the fire performance. The study was focused on the opening in the wall panel due to the fixing of junction boxes, thus FRLs of the tested wall panels were not reported. However, they reported that cracking and spalling of calcium silicate board and explosive noises were observed during the fire test. The study