Fire Safety Journal 90 (2017) 15–27

Contents lists available at ScienceDirect

Fire Safety Journal

journal homepage: www.elsevier.com/locate/firesaf

Fire tests of Magnesium Oxide board lined light gauge steel frame wall systems

Mohamed Rusthi, Anthony Ariyanayagam, Mahen Mahendran*, Poologanathan Keerthan

Queensland University of Technology (QUT), Brisbane, Australia

ARTICLE INFO

Keywords:
Magnesium Oxide board
Thermal properties
Fire test
Fire performance
Light-gauge steel frame wall systems

ABSTRACT

Recently, Magnesium Oxide (MgO) board has been widely used in LSF wall systems because of its improved acoustic properties, impact resistance, structural strength and serviceability. However, their thermal properties and fire performance have not been fully investigated. Therefore, in this research study thermal properties of two different types of MgO boards available in Australia were measured and their fire performance was investigated using three full-scale fire tests of LSF walls lined with two types of MgO board. Although the tests were conducted on two different types of MgO boards with different configurations, the fire test results gave a fire resistance level (FRL) of 30 min, in which the failure was initiated by integrity of the board with either board cracking or board joint opening. This paper presents the details of the thermal property tests and the three full-scale fire tests, and their results. In addition, the effects of different MgO boards, joint configurations and compounds, noggings, screw fastening techniques and cavity insulation on the fire performance of LSF walls are also presented.

1. Introduction

Conventional light-gauge steel frame (LSF) wall systems are made of cold-formed steel stud wall frame, gypsum plasterboard and cavity insulation materials as shown in Fig. 1. When LSF walls are exposed to fire, the mechanical properties of cold-formed steel studs degrade rapidly beyond about 500 °C, which may cause premature structural failure of the wall compared to ambient temperature. Therefore, it is necessary to provide sufficient fire protection to the steel stud wall frame to avoid direct fire exposure as well as delay the temperature rise of steel to improve the fire resistance of LSF wall systems.

When there is fire on one side of the LSF wall, gypsum plasterboard lining on the fire side keep the stud temperatures below the failure limits. Also, the wall board temperatures on the unexposed side are kept below their limits. In addition to these, plasterboards provide lateral restraint to the steel wall frame, all of which leads to increased stud failure times and hence improves the fire resistance levels (FRLs) of LSF wall systems. The FRLs are defined in AS 1530.4 [1] based on three criteria when LSF wall panels are exposed to the standard fire time-temperature profile on one side. They are: 1) structural: wall must continue to carry the design loads, 2) integrity: wall's integrity is not affected to allow the passage of hot gases or flames through the wall and 3) insulation: wall's insulation to restrict heat passing through the wall (i.e., the change in ambient or unexposed wall surface temperature should not exceed 140 °C on average or 180 °C at any point.

LSF wall fire performance is mainly dependent on the fire resistant wall board lining, which delays the heat transfer through wall and the temperature rise in steel studs. Recent research studies performed by Gunalan et al. [2] and Ariyanayagam and Mahendran [3] focused on full-scale fire tests of load bearing LSF walls made of conventional lipped channel section (LCS) studs and gypsum plasterboard lining. Test wall panels (2.1 m×2.4 m) were exposed to standard and realistic design fires in their studies. Kesawan and Mahendran [4] and Jatheeshan and Mahendran [5] performed full-scale standard fire tests on LSF walls made of hollow flange channel section studs and gypsum plasterboard lining while Nassif et al. [6] also conducted a full scale standard fire test of LSF wall made of LCS studs but used a larger LSF wall panel (3 m×3 m). These fire tests provided comprehensive time-temperature profiles for various LSF wall configurations made of different stud sections, gypsum plasterboard lining and cavity insulation materials that can be used to predict their fire performance.

Recently, Australian building industries have been using new wall lining materials in LSF wall system to enhance their acoustic properties, impact resistance, structural strength and serviceability. However, the fundamental understanding of the new lining materials such as Magnesium Oxide (MgO) boards is lacking in relation to their performance in fire. In contrast to the LSF walls lined with gypsum plasterboards, there are only limited research studies on LSF walls

* Corresponding author.
E-mail address: m.mahendran@qut.edu.au (M. Mahendran).

http://dx.doi.org/10.1016/j.firesaf.2017.03.004
Received 27 May 2016; Received in revised form 19 February 2017; Accepted 20 March 2017

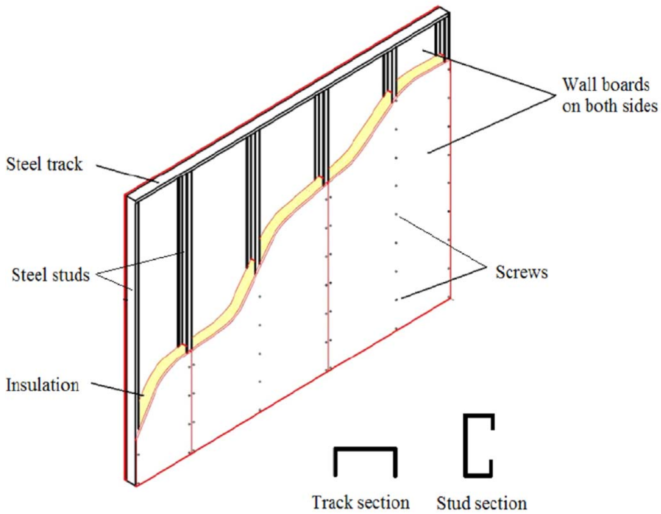

Fig. 1. Conventional LSF wall configuration.

lined with MgO boards. In addition to that, there are no full-scale fire test time-temperature profiles for MgO board lined LSF walls and the thermal property variation with temperature is also not available for Australian MgO boards. Chen et al. [7–9] performed full-scale fire tests on load bearing LSF walls made of LCS studs and lined with a combination of gypsum plasterboard and MgO board. These LSF walls (3.4 m×3.0 m) were tested under standard fire time-temperature exposure. Their fire test results showed that the combination of one layer of MgO board and one layer of gypsum plasterboard gave increased failure time than two layers of gypsum plasterboard. However, the LSF wall configuration with only MgO board was not tested in their experimental study.

Hanna et al. [10] carried out full-scale standard fire tests on load bearing LSF walls (3.0 m×2.7 m) made of LCS studs and MgO boards and the time-temperature profiles of the LSF wall components were measured at various locations. Although cracks were observed on the ambient side at about 40 min, the test was continued until the cracks were wide open at about 50 min to allow hot gases to pass through the cracks that could ignite a piece of cotton on the unexposed surface. Post-fire observations indicated that partial wall board fall off and bowing occurred on the fire exposed surface. As Hanna et al. [10] focused on the post-fire behaviour of the steel studs, no further details are provided on the fire performance of MgO board. As this is the only full-scale fire test with MgO board lining reported in the research literature, further studies are necessary to understand the fire performance of MgO board lined LSF wall systems.

Full-scale standard fire tests were therefore conducted in this study to gain additional information on the fire performance of MgO board lined LSF wall systems. In addition, thermal properties including specific heat, mass loss and thermal conductivity of these boards at elevated temperatures were also measured to support the fire test findings. This paper presents the details of the experimental study on the thermal properties of two types of MgO boards (referred to as Types 1 and 2 in this paper) available in the Australian market and the three full-scale fire tests conducted on MgO board lined LSF wall systems.

2. Properties of Magnesium Oxide (MgO) boards

2.1. Chemical composition

The main constituents of the boards are Magnesium Oxide (MgO) and Magnesium chloride ($MgCl_2$) as shown in Table 1 based on their manufacturer data sheets. In contrast to Type-1 board, Type-2 board has higher MgO and lower $MgCl_2$ contents. Other constituents such as Perlite, woodchip and fiberglass are added to enhance the properties

Table 1
MgO board chemical composition.

Chemical name	Weight percentage	
	Type 1	Type 2
Magnesium Oxide (MgO)	40%	50–53%
Magnesium chloride ($MgCl_2$)	27–35%	20–28%
Perlite	5–10%	0%
Woodchip	15%	2–10%
Fiberglass	5–8%	18–19%

such as lightweight, insulation, workability and acoustic properties. Instead of Perlite, additional fiberglass is used in Type-2 board. The chemical composition of MgO board can be written as $Mg(OH)_2 \cdot MgCl_2 \cdot H_2O$.

2.2. Thermal property tests

Thermal properties are required to understand the thermal behaviour of wall lining materials, especially when they are used in fire rated wall systems. Thermal properties that include specific heat, mass loss and thermal conductivity were measured using representative samples collected from the wall board component. Thermal properties of Type-1 and 2 MgO boards were measured in an experimental study using simultaneous thermal analyser (NETZSCH STA 449F3), which is capable of measuring the specific heat variation using differential scanning calorimetry (DSC) technique and the mass loss or relative density using thermo gravimetric analysis (TGA) technique. Thermal property tests were conducted in a purged Nitrogen environment within a temperature range of 50–1200 °C at a constant heating rate of 20 °C/min. Tests were conducted according to the standard procedures stipulated in ASTM E1269 [11] using platinum (Pt) crucibles lined with Alumina (Al_2O_3) liners and pin holed lids.

The measured specific heat variations with temperature are shown in Fig. 2. The specific heat peaks for Type-1 and 2 boards are considerably different from each other. There are two major peaks observed in both MgO board types with Type-1 board having higher specific heat values compared to Type-2 board. Although both boards exhibit similar peak patterns, an increase in specific heat for Type-1 board can be observed at about 200 °C, which is about 3000 J/kg/°C higher than Type-2 board. There are five specific heat peaks as shown in Fig. 2 and they are attributed to the chemical reactions and dehydration processes given in Eqs. (1)–(5) [9].

The specific heat peaks are observed at the same temperature for both types of MgO boards. For Type-1 and 2 boards, the first two peaks occurred at 180 °C and 230 °C, which were induced by the dehydration of magnesium oxychloride (Eqs. (1) and (2)) where evaporation of water can be observed during this process. The third and fourth peaks occurred at 400 °C and 475 °C, which indicate the hydrolysis (Eqs. (3) and (4)) and pyrolysis reactions where HCl is released. The final peak was observed at 520 °C, which is the further release of chemically

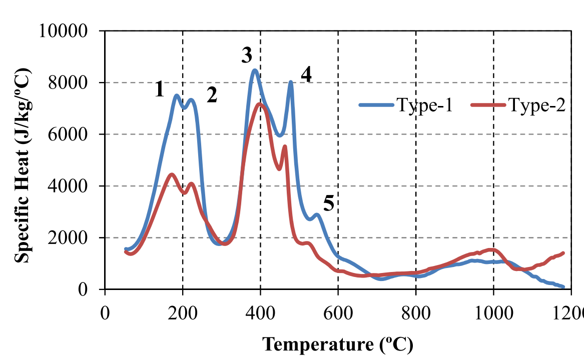

Fig. 2. Specific heat variation with temperature.