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Experimental studies of non-load bearing steel wall systems under fire conditions

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ABSTRACT

Fire safety of buildings has been recognised as very important by the building industry and the community at large. Traditionally, increased fire rating is provided by simply adding more plasterboards to light gauge steel frame (LSF) walls, which is inefficient. Many research studies have been undertaken to investigate the thermal behaviour of traditional LSF stud wall systems under standard fire conditions. However, no research has been undertaken on the thermal behaviour of LSF stud walls using the recently proposed composite panel. Extensive fire testing of both non-load bearing and load bearing wall panels was conducted in this research based on the standard time-temperature curve in AS1530.4. Three groups of LSF wall specimens were tested with no insulation, cavity insulation and the new composite panel based on an external insulation layer between plasterboards. This paper presents the details of this experimental study into the thermal performance of non-load bearing walls lined with various configurations of plasterboard and insulation. Extensive descriptive and numerical results of the tested non-load bearing wall panels given in this paper provide a thorough understanding of their thermal behaviour, and valuable time-temperature data that can be used to validate numerical models. Test results showed that the innovative composite stud wall systems outperformed the traditional stud wall systems in terms of their thermal performance, giving a much higher fire rating.

1. Introduction

Fire safety of cold-formed light gauge steel frame (LSF) stud wall systems is critical to the building design as their use has become increasingly popular in all areas of building construction. Partition wall panels composed of a cold-formed steel frame lined with one or two plasterboards are being widely used as they are very easy to assemble, thus improving the speed of construction. In Australia, plasterboard manufacturers provide fire resistance ratings of non-load bearing LSF stud wall systems. They prescribe steel stud walls with single or multiple plasterboard linings achieving fire resistance ratings, ranging from 60 min to 120 min. These systems are based on full-scale fire tests using the standard fire curve recommended by AS1530.4 [1] and ISO 834 [2]. With increasing demand for higher fire ratings of these walls, more than two layers of plasterboards are being prescribed, which not only make the construction process very laborious but also the resulting walls very heavy.

Efforts have also been made to improve the fire ratings of the wall systems by using different types of insulations in the wall cavities, but contradicting results were obtained [3–12]. Sultan and Lougheed [10] performed several small scale fire tests of gypsum board clad steel wall assemblies (914 mm × 914 mm) using glass fibres, rock fibres and cellulose fibres as cavity insulation. They noted that the rock and cellulose fibre cavity insulations improved fire resistance rating by approximately 30 min when compared with non-insulated wall assemblies, whereas only a small benefit was noted for specimens using glass fibres. The cavity side of the exposed gypsum board of insulated wall assemblies heated up more rapidly reaching temperature levels of 700 °C much earlier in comparison to non-insulated wall assemblies. Following the calcination of exposed plasterboard, the exposed side of the cavity recorded higher temperatures in comparison to non-insulated wall assemblies. Sultan [11] conducted full scale fire resistance tests on non-load bearing gypsum board wall assemblies and noted that when rock fibre was used as cavity insulation the fire resistance rating increased by 54% over the non-insulated wall assembly. Use of glass fibre as cavity insulation did not affect the fire performance while cellulose fibre insulation reduced the fire resistance. Feng et al. [12] conducted fire tests on non-load bearing small scale wall systems and reported that the thermal performance of wall panels improved with the use of cavity insulation.

In summary, past research has produced contradicting results about the benefits of cavity insulation to the fire rating of stud

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wall systems and hence further research is needed. There is also a need to develop new LSF wall systems with increased fire rating. This paper introduces an LSF wall system with a new composite panel that uses a thin external insulation layer between the two plasterboards on each side of wall frames instead of cavity insulation. It then presents the details of a series of fire tests of non-load bearing walls, examines and compares their thermal performance, and makes suitable recommendations.

2. Experimental studies of LSF walls

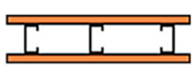
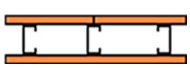
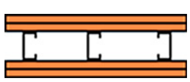
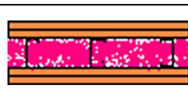
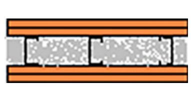
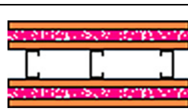
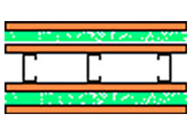
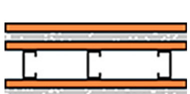
2.1. Test specimens

Fire tests were conducted on nine small scale steel wall frame assemblies of 1280 mm width and 1015 mm height. The wall assemblies consisted of three commonly used cold-formed steel lipped channel section studs (90 mm × 40 mm × 15 mm) spaced at 500 mm. The studs were fabricated from G500 steel sheets with a nominal base metal thickness of 1.15 mm and a minimum yield strength of 500 MPa. Test frames were built by attaching the studs to the top and bottom tracks made of 1.15 mm G500 steel unlipped channel sections (92 mm × 50 mm) using 12 mm long self-drilling wafer head screws. Test specimens were built by lining the test frames with one or two layers of gypsum plasterboards (FireSTOP) manufactured by Boral Plasterboard [13]. The plasterboards used were 1280 mm in width and 1015 mm in height with a thickness of 16 mm and a mass density of 13 kg/m^2. The nine wall specimens built were divided into four categories as shown in Table 1. Fig. 1 shows the details of test specimens.

2.2. Construction details of test specimens

Test Specimen 1 steel frame was lined on both sides by a single layer of plasterboard without any joints. The plasterboards were attached to the three studs by 25 mm long self-drilling bugle head screws at 300 mm centres and to the top and bottom tracks at 250 mm centres. K type thermocouple wires were located on the steel frame, three on each stud at mid-height to measure the temperatures of the hot flange, web, and the cold flange. These thermocouples allowed the determination of the average stud temperatures and the temperature gradient across the stud at mid-height. Additional thermocouples were attached at the mid-height of the plasterboard to measure temperatures inside the wall cavity and on the fire exposed surface. To measure the temperature of the ambient surface of the wall assembly, five more thermocouples were attached to the unexposed surface of the plasterboard, one thermocouple at the centre of the wall and one at the centre of each quarter section of the wall, giving a total of 20 thermocouples. Test Specimen 2 was identical to Test Specimen 1, but with a vertical joint in the exposed plasterboard located on the hot flange of the central stud. A screw spacing of 200 mm was adopted along each of the two plasterboard edges forming the joint. Test Specimen 3 was built with two plasterboard layers on each side. The base layer plasterboards

Table 1
Details of wall specimens.

Category	Specimen no.	Configuration	Objective
I	1		To study the effect of single layer of plasterboard (1 × 1) on both sides of frame on the fire rating of wall specimens
	2		To study the effect of vertical joint in the exposed plasterboard over the central stud
II	3		To study the effect of dual layers of plasterboard (2 × 2) on both sides of frame on the fire rating of wall specimens
III	4		To study the effect of glass fibre used as cavity insulation in a wall specimen with two layers of plasterboard (2 × 2)
	5		To study the effect of rock fibre used as cavity insulation in a wall specimen with two layers of plasterboard (2 × 2)
	6		To study the effect of cellulose fibre used as cavity insulation in a wall specimen with two layers of plasterboard (2 × 2)
IV	7		To study the effect of glass fibre used as external insulation in a wall specimen with two layers of plasterboard (2 × 2)
	8		To study the effect of rock fibre used as external insulation in a wall specimen with two layers of plasterboard (2 × 2)
	9		To study the effect of cellulose fibre used as external insulation in a wall specimen with two layers of plasterboard (2 × 2)