Fire Performance of Sustainable Materials Made from Renewable Sources

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Abstract:
This paper presents the results of a fire test on newly developed green materials made from renewable sources. It is known that fire resistance rating of a new material is an important factor for material selection in buildings. The fire-resistance rating of building elements, components or assemblies shall be determined in accordance with the test procedures set forth in ASTM E119 or UL 263 or in accordance with requirements specified in Clause 5 of BS 476.

The material tested is a drywall partition system composed from 9 mm thick MgO board as the first layer on both sides and 9 mm thick patented bamboo ply-board as the finishes. The internal steel frame comprised of steel studs C channel fixed to the RSJ steel frame. The first layer of 9 mm thick MgO board was laid horizontally over the wall frame on both sides and fastened to the studs with screws. The test was terminated after a period of 120 minutes.

The purpose of the test is to determine the fire resistance of the skin of wall panel partition system assembly when tested with BS 476: Part 22: 1987 "Method for determination of the fire resistance of non-load bearing elements of construction: Clause 5 –Determination of fire resistance wall.

This paper describes the outstanding results related to the specimen performance under the fire conditions. The results exceed the specified requirements of Clause 5 of BS 476: Part 22, for non-bearing wall, in term of integrity and insulation.

1. Introduction:

Building components need to have resistance to prevent excessive heat transfer, noise, as well as fire spread and smoke diffusion together in a certain period of time, to allow inhabitant to leave the building without casualty. Fire resistance is a performance that building unit to survive fire and maintain its structure and function, and (or) the ability to limit the fire in a certain space. In general, fire resistance helps to prevent a fire from spreading throughout a building or jumping between structures.

A fire resistance test was carried out for a system, based on the experimental test, data analysis and the test surveillance, based on standard to assess the fire resistant performance. The fire resistance performance is assessed by the fire endurance time for the fire resistance test, to protect the building from the multiple risks and losses caused by fire.

To control the spread of fire, fire protection methods are divided into active ones, such as sprinklers and passive ones, such as fire resistance, both of which are incorporated into building codes. The building codes include a variety of prescription, as well as alternative solutions. Code trends generally emphasize sprinkler installations by providing trade-offs that encourage their use. These active systems offer valuable protection, but they also include trade-offs such as more liberal fire-separation areas and other changes that decrease required wall and floor performance.

There are two primary fire test methods that are used to establish the fire ratings of components, at neutral pressure; and at positive pressure. The difference between the two test methods concerns the location of a neutral pressure plane in the test furnace. In the late 1990's, the test method required in building codes changed to a positive pressure test method. This change was adopted in the Uniform Building Code (UBC) and the International Building Code (IBC).

The infinity Board is a new revolutionary patented structural board that can be made from either bamboo, or the perennial grass, Arundo Donax. Both raw materials are eco-friendly, and share identical structural properties. Since bamboo and Arundo Donax are non-wood based material, this new material is contributing to mitigating deforestation of the world's forests.
Certified Test Result Comparison of Centric's Infinity Board™ to conventional plywood and OSB [1].

Centric's Infinity Board™ shows [1]:

- Three times lighter and stronger than conventional plywood and OSB (oriented strand boards).
- Waterproof, and perfect for use in marine applications
- The characteristics of this material makes it insect proof, including wood destroying insects, and highly fire resistant.
- Less expensive to manufacture than plywood and OSB products.
- Adaptable for manufacturing of dimensional lumber and furniture making.

In this paper, a new construction has been developed and fire resistance test was carried out for a fire wall, based on the experimental test, data analysis and the observation, combined with relative standard evaluate the fire resistant performance of this wall.

2. Fire-resistance Test

2.1. Specimen Description

The test specimen consisted of a symmetrical, non-load bearing drywall panel system constructed onto a test frame. The overall specimen size was 3,000 mm x 3,000 mmm inclusive of a 40 mm wide vertical gap along one edge to provide no lateral restraint to the specimen. The 40 mm vertical gap was the filled with ceramic fiber insulation.

The drywall partition system was constructed from 9 mm thick MgO board as the first layer on both sides and 9 mmm thick bamboo ply-board as the finishes. The internal steel frame comprised of steel studs C channel fixed to the RSJ steel frame. The first layer of 9 mm thick MgO board was laid horizontally over the wall frame on both sides (see Figure 1) and fastened to the studs with screws. This is repeated for the next piece of Bamboo Ply board laid vertically

fixed to the MgO board and cut to sizes (see Figure 1) to accommodate over the wall frame. The board were cut to suit where necessary to allow staggering of joints for first and second layer of board. The inner core of the drywall panel between the board was in filled with Rockwool of brand name 'ThermalRock S60', with a nominal density of 60 kg/m^3. All exposed joints were plastered flush with joining compound.

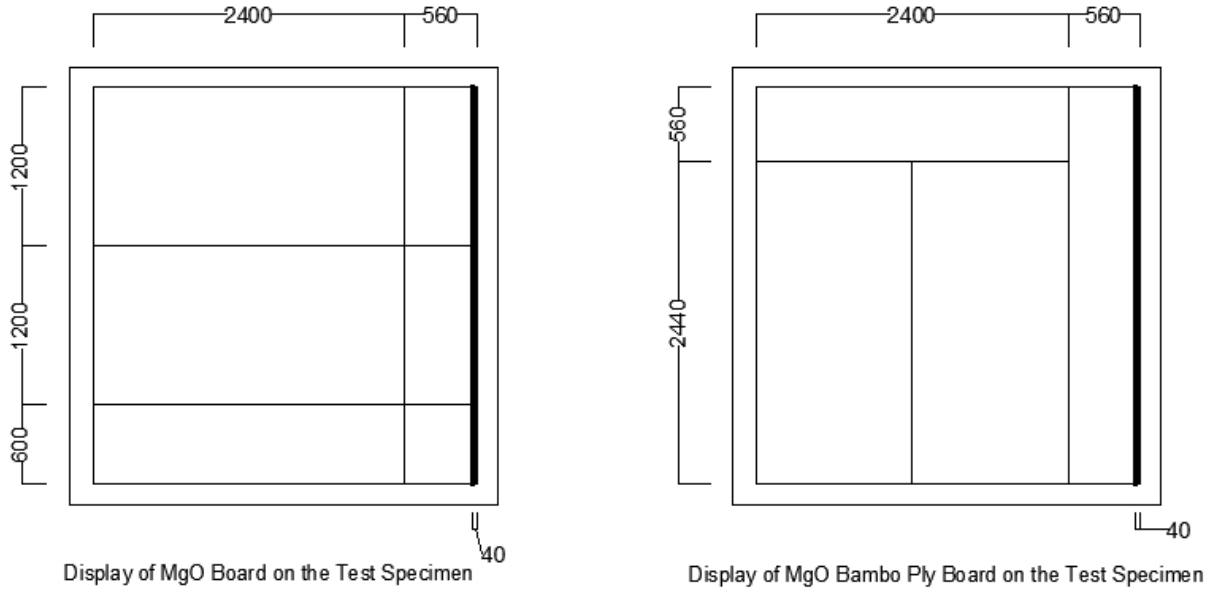

Figure 1: Detail of the MgO and Bamboo Ply Board display.

2.2. Test Process

The test assembly consisted of a symmetrical, non-load bearing drywall panel partition system. The drywall was constructed using steel studs as the inner framework sandwiched between 9 mmm MgO boards and finishes with 9 mm bamboo ply-board on bothsides. The cavity between the MgO boards is in filled with rockwool of brand name 'ThermalRock S60', with a nominal density of 60 kg/m^3.

The actual overall dimension of drywall panel partition were 3000 mm length, by 2960 mm width, by 111 mm thickness. A free edge clearance of approximately 40 mm wide filled with ceramic fibre was provided along one vertical side of the constructed wall panel. Method for determination of the fire resistance of non-load bearing elements of construction: Clause 5 – Determination of fire resistance wall.

As a process of the fire endurance test, the system was install in an opening vertical furnace test frame before the test. The test exposes a test specimen to a standard fire controlled to achieve specified temperatures throughout a specified time period, evaluated the fire resistance performance of the specimen through the measurements, observations and the temperature rising record on the unexposed surface[2-4].

Inspection was carried out during the construction of wall assembly to verify on its dimension used in FPL laboratory only. The construction of the wall was arranged and carried out by Centric Intl. LLC.

2.2.1. Installation
The *non-load bearing drywall panel partition system* was mounted in a standard supporting construction in advance, and the specimen had been cured for a standard condition, and moved in front of the furnace for the fire exposure before tested. The temperature of the unexposed face of the specimen was measured by means of 7 chromel / alumel thermocouples.

2.2.2. Fire endurance test
The furnace employ gaseous fuels to ignite the burner to providing the standard fire exposure conditions with respect to thermal exposure, and the furnace temperature is measured by means of 7 thermocouples distributed evenly in the furnace.

During the test period, the temperature of burner will be controlled by adjust the gas proportion; insure the mean of the 7 thermocouple readings followed as closely as possible the time/temperature curve.

It is require that there is no collapse of the specimen, no sustained flaming on the unexposed surface and no loss of impermeability. This requirement were satisfied for 130 minutes after which the test is discontinued.

2.2.3. Performance criteria
The fire resistance performance of the system is mainly considered with integrity and insulation.

Integrity: Failure is deemed to occur:

a) When collapse or sustained flaming for not less than 10s on the unexposed face occurs;
b) When cracks, gaps or fissures allow flames or hot gases to cause flaming or glowing of a cotton fiber pad;
c) A 6mm-diameter gap gauge can penetrate through a gap into the furnace and be moved in the gap for a distance of at least 150mm;
d) A 25mm-diameter gap gauge can penetrate through a gap into the furnace.

Insulation: Failure is deemed to occur:

a) When the mean unexposed face temperature increases by more than 140ºC above its initial value;
b) When the temperature recorded at any positions on the unexposed face is in excess of 180ºC above the initial mean unexposed face temperature.

3. Test data and analysis

The test was terminated after a period of 120 minutes at the requests of the applicant, and a hose stream test carried out immediately with a 184 seconds period. Base on the test recording data

and the results analyses, and combined with the standard at home and abroad, evaluation of the fire resistant performance of this non-load bearing drywall panel partition system as below:

The graph in Figure 2 shows the actual temperature/time curve of the furnace heating conditions in relation to the standard temperature /time curve.

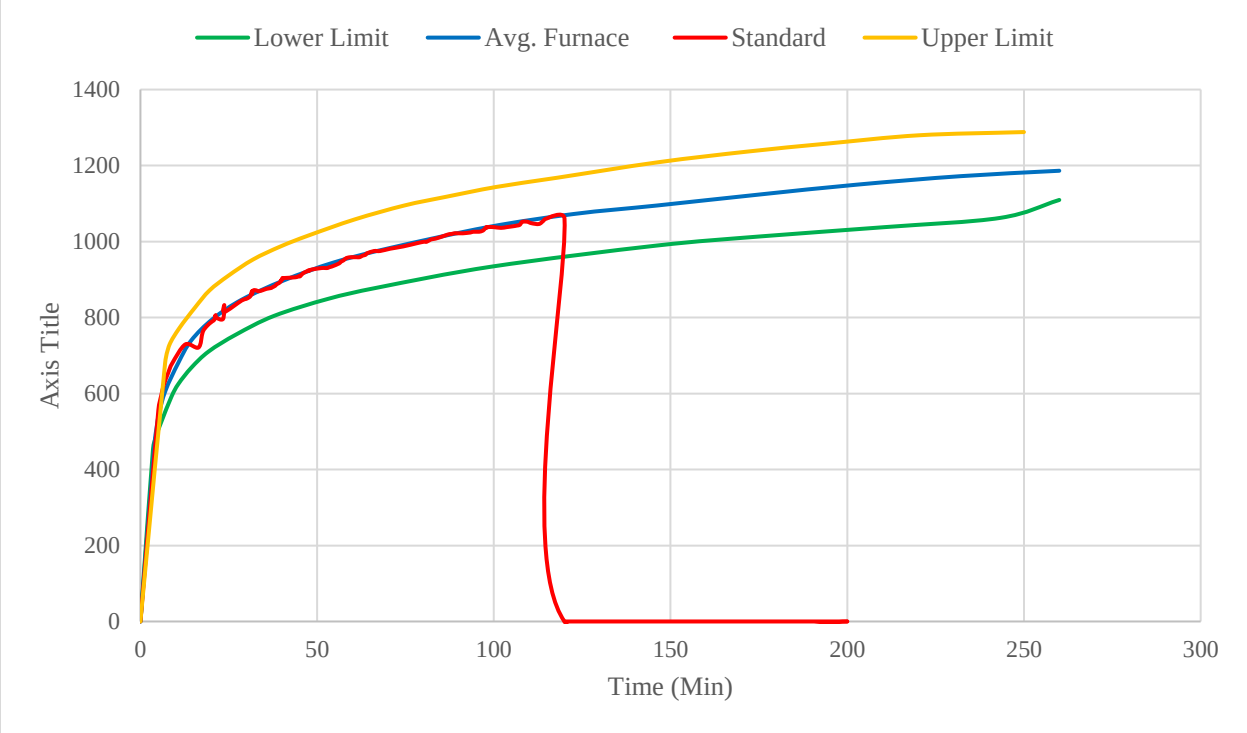

Figure 2: Actual Furnace Average Temperature / Time curve.

Plate 1. Before the test. (during the construction showing the rockwool infilled and studs)

Plate 2: Before the test. (Time taken: 0 mins)

Plate 3. During the test. (Time taken: 95 mins)

Plate 4. During the test. (Time taken: 106 mins)

Plate 5. During the test. (Time taken: 120 mins).

Plate 6. After the test.

Figure 3: The photograph of the unexposed face of the specimen

Photographs of the test are shown in Plate 1 to 6 (Figure 3). Photographs taken using laboratory's camera facing problem to retrieve data from the memory card.

3.1. Insulation

Failure shall be deemed to have occurred when one of the following occurs:

a) If the mean unexposed face temperature increases by more than 140°C above its initial value.
b) If the temperature recorded at any position on the unexposed face is in excess of 180°C above the initial mean unexposed face temperature.
c) When integrity failures occur.

3.2. Integrity

During the test period of 2 hours, there was no collapse of this specimen, no sustained flaming on the unexposed surface and no loss of impermeability. The integrity of this steel fire door was not failure. The photograph of the unexposed face of the specimen sees Figure. 3.

In general, a failure of the test construction to maintain integrity shall be deemed to have occurred when collapse or sustained flaming for more than 10 seconds on the unexposed face.

Under criteria for impermeability, failure shall be deemed to have occurred when one or other of the following conditions prevail:

a) Where cotton pad test is performed, flame and/or hot gases cause flaming and glowing of the cotton pad.
b) Where the use of cotton pad is not suitable, failure shall be deemed to have occurred when either:
    - A through gap into the furnace exceeding 6 mm diameter in width and 150 mm in length exists or develops in the specimen; or
    - A through gap into the furnace exceeding 25 mm diameter exists or develops in the specimen

4. Conclusion

In summary, this non-load bearing drywall panel partition system has good integrity performance (integrity 2.00 hours), as well as the insulation material structure, and result in its good insulation performance (insulation 112 minutes). It has decent integrity performance. The specimen satisfied the requirements of BS 476: Part 22: 1987: for the following period: Integrity: 120 minutes; Insulation: 112 minutes. The test was terminated after a period of 120 minutes at the requests of the applicant.

5. References:

[1] Centric Intl. LLC web page: www.centric.com
[2] Xin Wu, Jianyong Liu, Xia Zhao, Wensong Yu, Yulong Wu. 2009. Temperature and Pressure Controlling Analyzing about Building Elements Fire Resistance Test from GB/T 9978-2008. China Building Materials Science & Technology 03, p 94-99.
[3] GB/T 9978.1-2008. Fire-resistance tests Elements of building construction Part 1: General requirements.
[4] BS 476-20-1987 Fire tests on building materials and structures - Method for determination of the fire resistance of elements of construction (general principles).