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Publisher's version / Version de l'éditeur:

2005 Fire and Materials Conference [Proceedings], pp. 131-137, 2005-01-01

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NRCC-47635

A version of this document is published in / Une version de ce document se trouve dans:
Fire and Materials Conference, San Francisco, Jan. 31-Feb. 2, 2005, pp. 1-6

IMPACT OF THE VARIABILITY OF TYPE X GYPSUM BOARD

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ABSTRACT

The National Research Council of Canada (NRCC) has completed a multi year study of the fire resistance and acoustical performance of a range of traditional and innovative wall and floor assemblies. One of the major components that influences the duration that these assemblies are able to resist the impact of fire, is the gypsum board material used to line walls and the floor assembly ceiling. Traditionally, the gypsum board material used in fire-rated assemblies, such as those studied by NRCC, has been designated as Type X gypsum board. Type X gypsum board can provide up to 90 minutes of fire resistance protection for building assemblies. The classification for this material is based on the product meeting or exceeding a fire-resisting threshold established using a standard test method such as ASTM C 36/ 36M - 03[1].

Although a threshold-type classification system establishes a lower boundary to the material's performance, it makes no provisions for specifying a normal performance or upper performance boundary or any indication of the normal variance (uncertainty) to be found as a result of variability in the base material composition or manufacturing process. This threshold type classification is further complicated by the application of designations such as Fire code C to Type X board by many manufacturers or even of a further (non standardized) designation of a Type C material that is claimed to exceed the performance of a Type X designated product. This can cause confusion in users and regulatory authorities,

Studies undertaken at NRCC, and presented in this paper, indicate that there is a fairly broad range of variation in the finished product to be found in material designated as Type X both between different manufacturers and within single manufacturers. The existence of this wide variation in component material and its performance raises concern in situations such as the use of modelling software and similar tools that are used in predicting the fire performance of proposed new assemblies. Many of these models are based on empirical data and use a general designation of a Type X material without providing any indication of any other facets of the material's composition or actual performance.

This paper outlines the results of these studies and discusses the implications of the use of a material classification system that results in the existence of a high degree of uncertainty (variance) in the product's final performance. As building and fire codes move into a performance-based approach, the ability to have a fairly high level of confidence in the ultimate performance of the specified material will become increasingly important along with the need to have confidence in the level of uncertainty (variance) associated with the measure.

INTRODUCTION

The ASTM C 36/ 36M - 03[1] standard, which is often used in North America to establish the product's performance as conforming to the Type X designation, is based on establishing a minimum performance threshold that all certified products shall meet or exceed. There is no specification of the

material content or composition and it is based on the overall performance of a gypsum board assembly and not on the characteristics of the material itself. As far as establishing a minimally acceptable level of performance for the product, this standard, up until now, has proven to meet the needs of industry and the regulatory authorities. The move from prescriptive-based codes and regulations towards ones based on performance-based solutions is beginning to point out some of the weaknesses in a system using a minimum performance threshold. For an engineered performance-based design, the designer needs to have some confidence in the expected level of performance of a material and some understanding of the variance in performance (uncertainty) that can reasonably be expected in a product meeting a specific type designation. Like any other materials, the characterization of gypsum board should be based on the material itself and not as a part of a building assembly. Factors that play a key role in this material could include the composition of the core material and water contained in it, thermal and mechanical properties as well as density and shrinkage.

One of the objectives of NRCC's studies into the fire performance of various floor and wall assemblies is the development of a set of generic assemblies that meet or exceed the requirements of the Canadian building codes. When establishing these generic assemblies, it is important to ensure that the materials that are used in such an assembly represent a combination of the lowest performing materials that still meet the individual material standards. This approach is taken to try and ensure that any subsequent assembly constructed to the generic design is assured to perform as well as, if not better than, the design tested in NRCC's studies.

The role of gypsum board in the performance of wall and floor assemblies

For many years, it has been clearly identified that one or more layers of gypsum board provide the first line of defence (up to 90% protection) in resisting the impact of fire on an assembly. Studies by Benichou and Sultan[2] and others (Cramer, Sriputkiat and White[3]; Richardson[4]) have indicated the role that water, in both free and crystalline form, contained in the gypsum plays in retarding the failure of the gypsum board as a fire barrier. There are other characteristics of the material that also play an important role in determining the time during which the boards are able to provide some level of fire protection. Perhaps the two most important of these latter characteristics are those of crack resistance and material shrinkage.

For most assembly designs, the critical characteristic that determines the fire resistance is the delay in heat penetration provided by the evaporation of the water contained within the gypsum. For practical purposes, and given a relatively similar material composition of the board among manufacturers, the board density can provide a first level approximation of the available water mass contained within the boards.

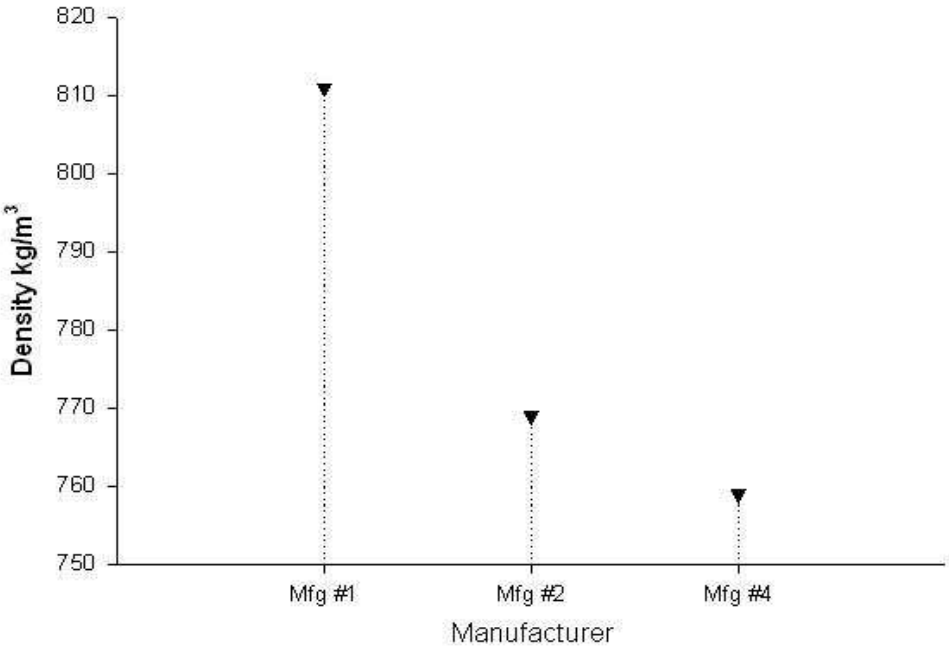
Following this approach, NRCC undertook to collect a representative sample of the gypsum boards that are available within Canada from various manufacturers and studied a number of their characteristics. The remainder of this paper will focus only on one of these characteristics, namely that of board density as a surrogate of the water mass available within the boards.

RESULTS

Density as a function of board thickness

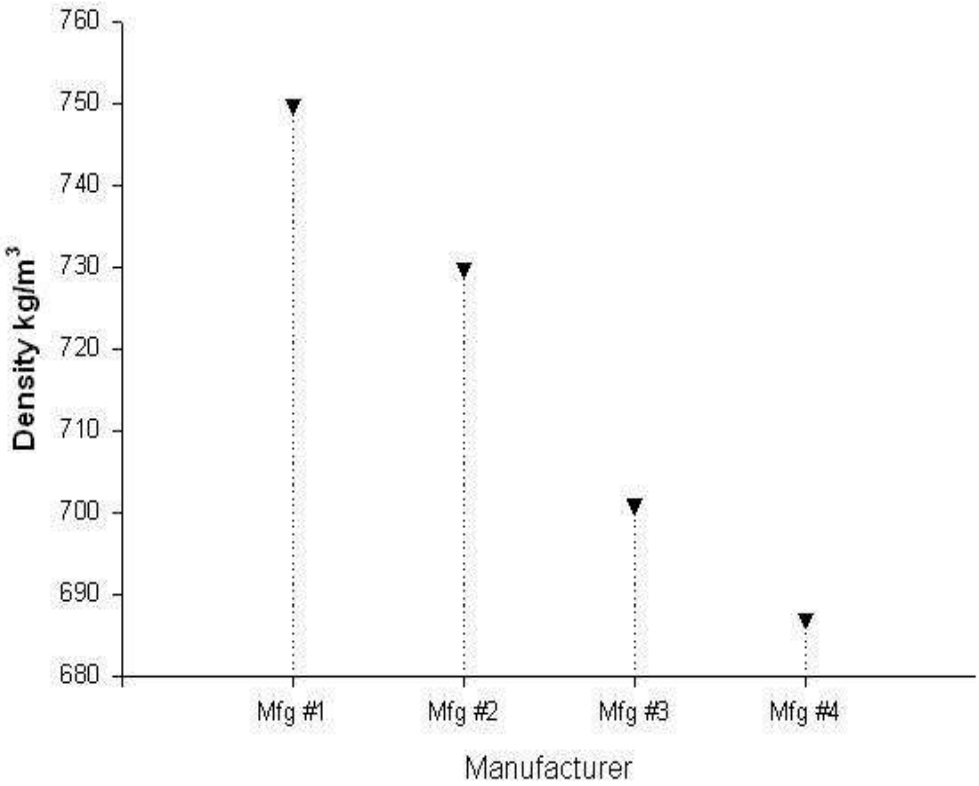
We obtained samples of 12.5 mm (½ inch) gypsum board offered in Canada by three different Type X manufacturers. As can be seen in Figure 1, there are significant differences ($F(2,505)=473$, $P< 0.001$) in the density of the boards produced by the three manufacturers.

Figure 1. Average board density of 12.5mm gypsum board



When we looked at the situation with the 15.8 mm (5/8 inch) Type X boards we obtained samples from four manufacturing sources of Type X board available in Canada. Again, we found the same trend in the resulting density measurements with the boards sourced from Manufacturer # 4 significantly lower ($F(3,191)=341$, $P< 0.001$) than the other sources (See Figure 2).

Figure 2. Average board density of 15.8mm gypsum board



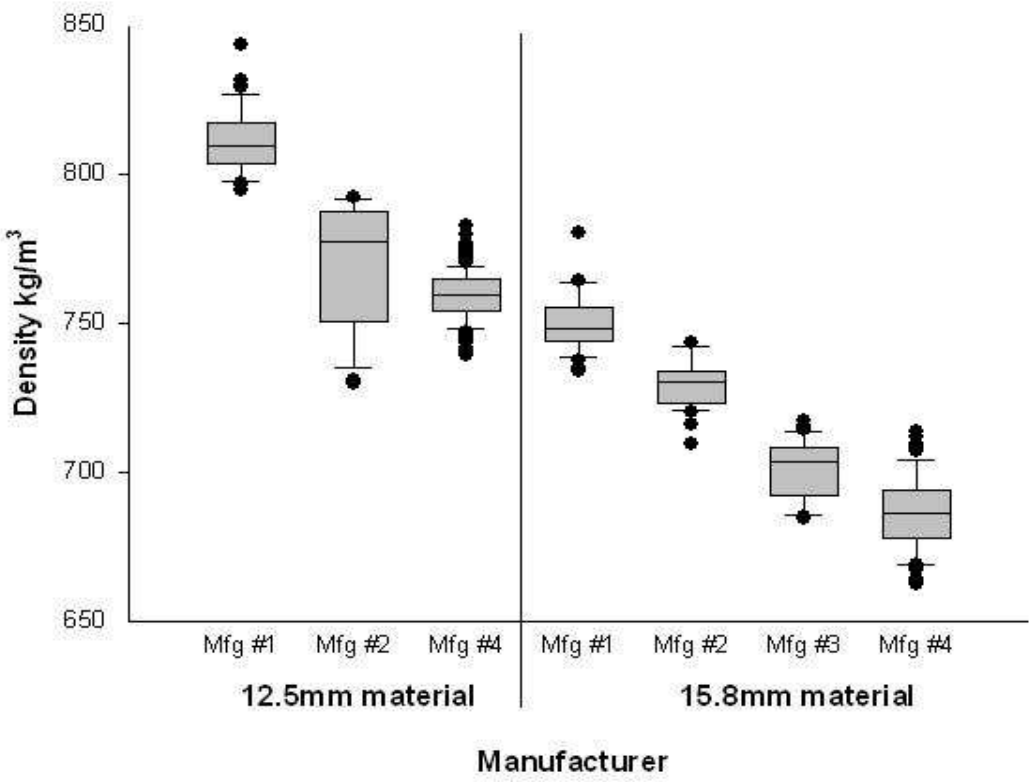
Variability of gypsum board density

The variance in board density both within and between manufacturers of 12.5mm Type X gypsum board was fairly large (see Figure 3 and Table 1). The within manufacturer variance was not as evident with the 15.8mm board but there was considerable between manufacturer variance.

Table 1. Mean and Std., Deviation of board density by manufacturer and thickness

Board thickness	12.5mm			15.8mm			
Manufacturer	1	2	4	1	2	3	4
Mean	811	769	759	750	730	701	687
S.D.	10.6	20.9	8.1	9.6	8.3	9.6	12.5
# Samples	35	35	438	35	35	35	90

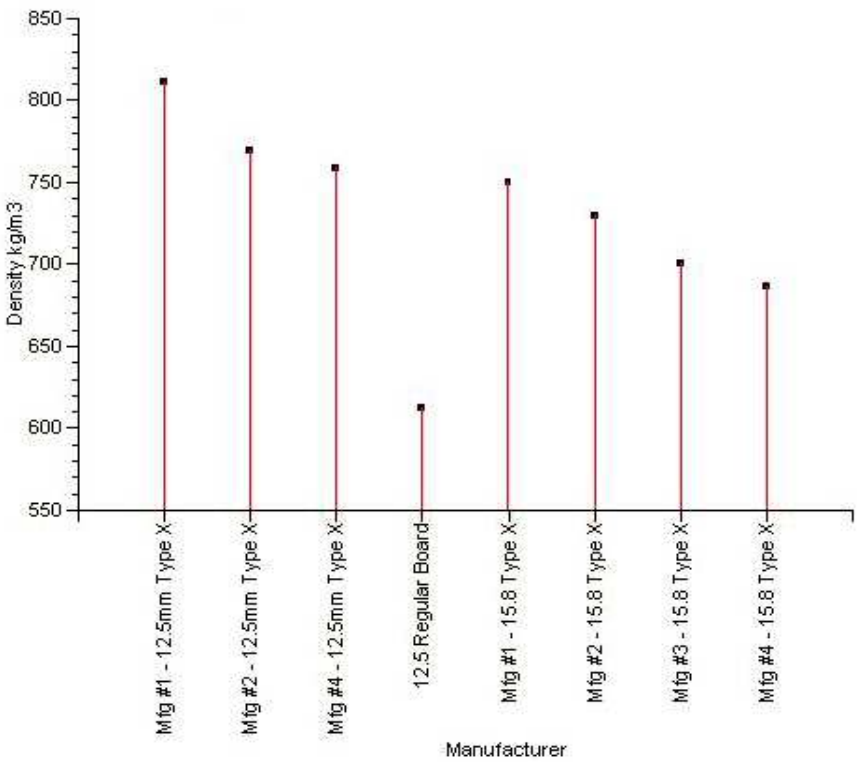
Figure 3. Box-plot of density of 12.5mm and 15.8mm gypsum board



It is interesting to note that Manufacturer 4 consistently produced the lowest density type X board for both 12.5mm and 15.8mm boards.

As a final indication of this trend in board density, a sample of regular 12.5mm gypsum boards was measured from a single manufacturing source. This produced a mean density of 612 kg/m^3 and a Standard Deviation (SD) of 8.6 kg/m^3 with a sample of 19 boards. Looking overall at the density values for all of the board types and manufacturers (Figure 4), it is clear that the density of the regular gypsum board is substantially below that of 12.5mm Type X boards. This regular board demonstrates anywhere between 75% to 80% of the density of an equivalent Type X board.

Figure 4. Gypsum board density by board type and manufacturer



DISCUSSION

In the studies previously cited that were undertaken at NRCC, the decision was made to use the lowest density boards from Manufacturer #4 as these effectively represented the lowest likely performing boards that were available in the Canadian marketplace at that time. Although board density is only one of the parameters, it is probably the key parameter that dictates the delay in the failure of the gypsum when subjected to a fire source. It is therefore critical to ensure that minimally compliant material is used in establishing generic complying assemblies for regulatory purposes.

In a prescriptive regulatory environment, where acceptance of an assembly is based on compliance with the specified design and materials that are compliant with the relevant standards, it is beholden upon those establishing such assemblies that they take full account of the variability of the products in the marketplace. For example, without drawing specific estimates on the impact of board density on delay of failure of the gypsum barrier, it is clear that if material from Manufacturer #1 were to be used in establishing a generic assembly and the assembly just met the standards criterion value then subsequently using material from another manufacturer could result in a 7-9% lower level of performance (depending on the use of 12.5mm or 15.8mm material).

In terms of variability within a single manufacturer, it is clear, for example, that even though the average density of Manufacturer #2's 12.5mm Type X board is higher than that of Manufacturer #4's 12.5mm Type X board, over 30% of the measured product (which came from a single production plant) had a lower density than the material from Manufacturer #4 (see Figure 3). In each case, except for Manufacturer #4, the measured material came from a single batch of material and therefore from a single production unit. From other observations, it is clear that, due in part to different sources of the raw gypsum material that the various production units of a manufacturer draw on, there is evidence of considerable variation in the density of the boards between plants of the same manufacturer. This would further exacerbate the issue that has been identified here in terms of the resulting uncertainty associated with the product's actual performance. With the increased use of fire-engineered designs, it is crucial that engineers have reliable information on the performance of

materials that play a critical role in their designs. Products and materials with a high degree of uncertainty (variance) associated with their performance will result in the designers having to over-design their systems to compensate for the uncertainty and losing much of the benefits that could come from a performance design approach.

CONCLUSIONS

It is clear that the marketplace has a need for material that has superior performance over and above the minimal performance required for regulatory purposes. One of the current problems associated with the gypsum board standard is due to its open-ended classification, with any material that exceeds the minimal criteria as being compliant with the standard. A review of the Type X standard is likely in the near future and, to help address both the regulatory and marketplace needs, it is strongly recommended that the standard recognize a range of levels of compliance. This would provide an opportunity for the regulators to establish their own regulatory minimum and for the market place to establish a range of superior performing products that would aid clarity in market and product differentiation.

REFERENCES

[1] ASTM (2004) Standard Specification for Gypsum Wallboard, C 36/C 36M – 03, ASTM International, West Conshohocken, PA, USA.

[2] Benichou, N., Sultan, M., (2005) Thermal properties of lightweight-framed construction components at elevated temperatures. Fire and Materials (in Press)

[3] Cramer, S.M., Sriprutkiat, G., and White, R.H. (2003) Engineering analysis of gypsum board ceiling membranes at elevated temperatures. In, Designing structures for Fire, Conference Proceedings, September 1 – October 1, Baltimore, MD, USA.

[4] Richardson, L.R. (2001) Thoughts and observations on fire-endurance tests of wood-framed assemblies protected by gypsum board. Fire and Materials, 25, pp. 223-239.