INFLUENCE OF FIRE RETARDANT ON SELECTED THERMAL INSULATING MATERIALS ON NATURAL BASE – WOODEN FIBREBOARD

Linda MAKOVICKÁ OSVALDOVÁ
University of Zilina, Faculty of Security Engineering
Univerzitná 8215/1, 010 26 Žilina, Slovakia
tel.: +421 41 513 6796, e-mail: linda.makovicka@fbi.uniza.sk

Abstract:
This paper focuses on flammability of soft wooden fibreboards, which are used as thermal insulation of buildings. The influence of fire retardant and its reaction to fire for selected thermal insulation materials on natural basis – wooden fibreboard treated with fire-retardant – have been tested. Fire retardant has been applied onto the sample by various techniques – spraying, coating and dipping. The paper is divided into five chapters: the first focuses on classification of building materials into fire reaction classes, wooden fibreboards and their fire retardant treatment. The second chapter defines the objective of this paper. The third chapter includes the methodology of the work, description of test samples, testing device and the experiment itself. In the fourth chapter are shown the measured values from two experiments. The fifth chapter is devoted to the evaluation of the values from the experiment and discussion. The result of this paper is comprehensive information about flammability of thermal insulating materials and recommendation of the most suitable way of protecting wooden fibreboard surface using flame retardant.

***Key words**: wooden fibreboard; flame retardant; fire reaction classes; insulation material.*

INTRODUCTION

Fiberboard is a large material made from wood fibers of coniferous trees, mostly spruce, or other lignocellulosic materials. This composition, however, has resulted in its inclusion into fire reaction class "E" i.e. to a group of products capable of withstanding a small flame for a short period of time without a significant extension of the flame. The first product resembling hard fibre board was established in England in 1898, but it was hard pressed paper. The first board of wood fibres was produced in 1925. In our region, the production of first fibre board called Hobra was launched after the end of World War II (ÖSTMAN et al. 2002).

Fibreboard is according to its density divided into:

- Isolated – density 250 - 400kg.m$^{-3.}$
- Semi-hard - density 480 - 850kg.m^{-3}.
- Hard - density 850 - 1100kg.m^{-3}.
- Particularly hard (hardened at a high temperature) - density 1100 - 1300kg.m^{-3}.

Fibre boards are produced in two different ways - wet and dry. At the beginning of both procedures there are wood chips - free of dirt and cut up. (FEIST 2016) Wet production is energy consuming and more obsolete. Wood fibres are soaked in water, hydrophobic chemical and binders are added into this mixture. The mixture is spread onto a screen where it drains, dries and is pressed. Dry process means that fibre is cut and dried, mixed with adhesive, usually formaldehyde resins and other additives. These fibres are layered and then pressed (Mitterová and Zachar 2013). Soft fibreboard used for thermal and acoustic insulation is usually made using wet process. Adhesives as well as hydrophobic additives, usually paraffin, are added. Pressing takes place under high pressure, resulting in lower strength of hard or semi-hard boards. Therefore, it cannot be used as the sole structural material. On the other hand, it is resistant to anisotropic properties in different ways and has good sound and thermal insulation properties, it is biologically harmless and easy to process. Thermal insulation boards are commonly produced with a thickness of 6-200mm.

FLAME RETARDANTS

Flame retardants are chemical compounds whose chemical, physical, or combined composition protects the material from rapid ignition and subsequent burning. Their main task is to influence those events that result in the cessation of burning. It means a reduction in the rate of heat generation, and increasing the speed of its removal from the reaction zone of combustion. Flame retardants cannot change the intensity of heat flow, but may alter the process and its flammability. This function of flame retardants works in the early stages of a fire, their influence in the later stages is limited since the protected material causes very high heat fluxes. (Gašpercová 2015)

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FIBRE BOARD

Soft fibre board (Fig. 1) for the thermal insulation of external walls of buildings, attics, ceilings, roofs and floors was used for the experiment. The material is made of thin and soft wood fibres. Their consistency is ensured by adding glue. Boards were pressed under high pressure. Compared to semi-hard and hard fibre boards, this material has lower strength and cannot be used as the sole structural material. The test samples consisted of two glued layers of wood fibre boards with a thickness of 20mm.

a. b.

Fig. 1.
Fibre board
a - fibre board; b - size of test sample 250 x 90 x 40 mm.

Test equipment - consisting of a burner, smoke discharger and a sample holder to ensure their stable position - was used for the experiment. The source of ignition is a small propane - butane gas burner. Flame size for all samples was constant - 25mm. The test samples were exposed to the flame of the burner at the angle of 45°. The burner was placed so as to ensure that the flame of 25mm is reaching to the surface 40mm from the bottom edge of the sample. Time was measured using a device with an accuracy of 0, 1s. Weight loss was recorded by a digital instrument with an accuracy of 0.01g. The samples were of the constant size of 250x90x40mm. 5 pieces of the sample were available for each type of fire retardant application.

EXPERIMENT

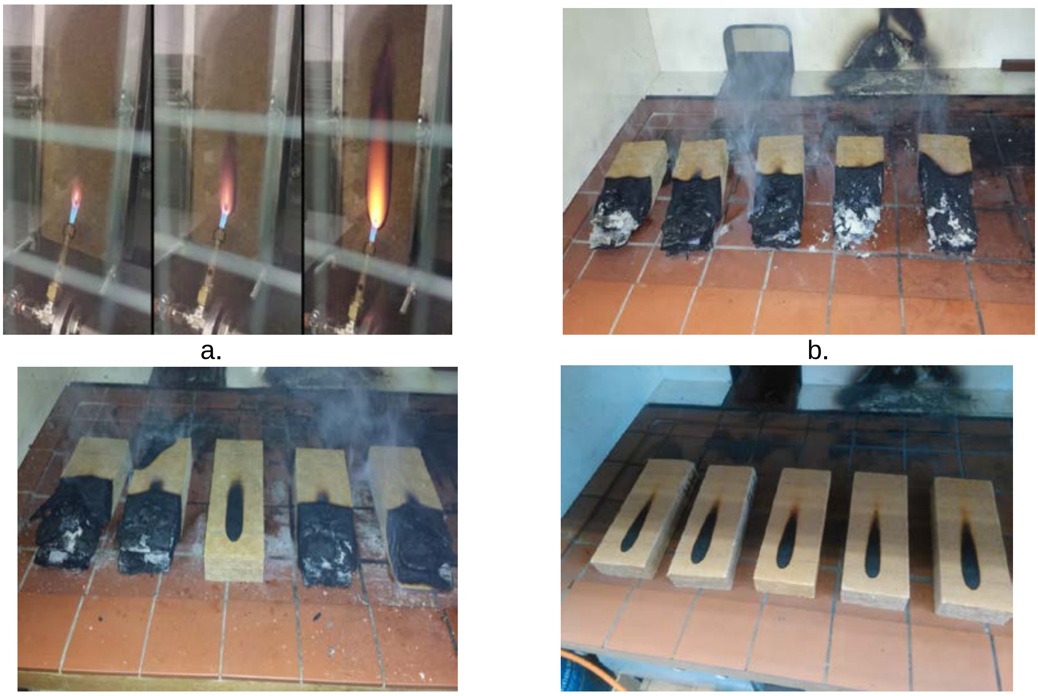
Fibreboard treated with a flame retardant has been tested. Ohňostop (Firestop) flame retardant (flame retardant based on inorganic salts) was employed. Retarder was applied onto the sample by using various techniques – spraying, coating and dipping (200ml for each sample and each technique). For each application, 5 pieces of samples were available. Marking of the samples was as follows: B1-5 non – treated sample, S1-5 spraying, N1-5 coating, M1-5 dipping (for second test, we tested the samples M 6 – 20 for dipping only). After the application, we reweighed the samples and recorded their weight gain after the treatment. This procedure was repeated with all technological processes (dipping, spraying, and coating).

The samples were drying for seven days and reweighed afterwards. Each sample was then marked by a line 40mm from the lower and upper edge which determined the maximum upper limit of the flame. Before testing, total weight of the dried samples was recorded again. The samples were then mounted to the test device and exposed to the open flame of the burner for 30 seconds. During the measurement, the behaviour of the samples was observed - creation of smoke and the time when the flame exceeded the upper line. Finally, the weight of each sample determining the weight loss - was measured. Weight loss of the test samples - calculated according to following equation - was the evaluation criterion (1):

$$\Delta m = \frac{m_1 - m_2}{m_1}.100 \quad \textbf{(1)}$$

where: Δm is the weight loss (%),
m_1 is the sample's weight before the test (g),
m_2 is the sample´s weight after the test (g)

Since none of the applications did not show significantly better results compared to untreated samples, we decided to carry out an additional measurement. Based on the previous tests, we found out that dipping was the best application process. Therefore we wanted to determine whether soaking time of the specimen in flame retardant solution will also affect its reaction to fire. After dipping, the fiber board was soaked into the fire retardant for 6, 9, and 12 minutes, the amount of retardant the material could absorb was monitored. (Fig.2) (Marienka 2016)



a. b.

c. *d.*

Fig. 2.
Fiber board after dipping:
a – pre-test; b- dipping after 6 min; c – dipping after 9 min; d - dipping after 12min.

RESULTS AND DISCUSSION

The main evaluation criterion was the weight loss of fire retardant treated test samples and the possible formation of smoke and burning particles. Based on the measured values, we found out that the surface protection of fire retardant treated fibreboard can be moved from the fire reaction class E into fire reaction class D. Another criterion was to determine the most appropriate technological process of fire retardant application (dipping, coating, spraying). Considering the measured results, we can conclude that the best technique for the application of flame retardant onto fibreboard is soaking at a time interval of at least nine minutes. With the given data, we were able to propose a number of recommendations for practical purposes, either further testing with different types of flame retardants such as the latest flame retardants based on nanotechnology, but mainly natural based retardants so as to maintain unity by using natural materials. (Fig. 3)

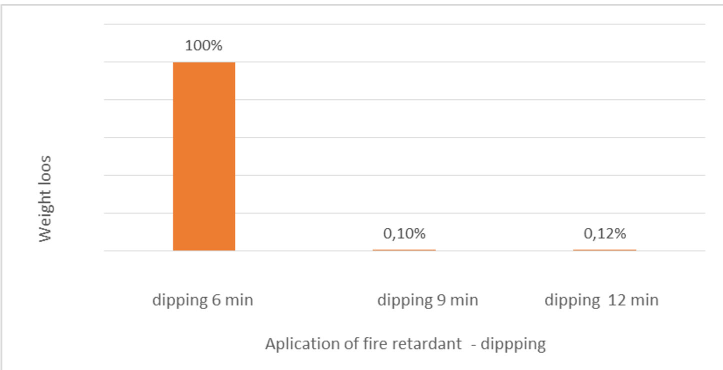


Fig. 3.
Various techniques of fire retardant application (dipping).

Based on the measurements, we came to the following conclusions: Among all flame retardant applications (coating, spraying and dipping), only dipping seemed to withstand fire exposure. Spraying and coating failed the test, as the flame disrupted the protective layer formed by flame retardants and the degradation of the inner structure of the fiber board led to complete decay of the material. These results were observed with all the tested samples and flame retardant applications.

Smoldering of the samples was quite difficult to extinguish since smoldering constantly renew until the boards were not completely soaked in water. The samples dipped in flame retardants for three minutes failed the test (Fig. 4). The only exception was the sample M2, which was the sole one withstanding the flame exposure. (Marienka 2016).

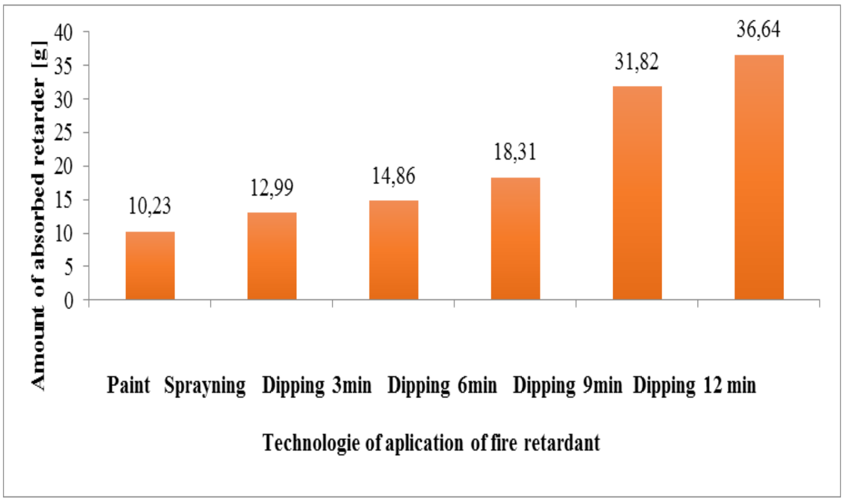


Fig. 4.
Various technique of retardant application.

Based on the improved results, we made additional measurements in order to determine whether longer soaking time affects fire resistance of the material.

In the second experiment, we tested the samples soaked in flame retardant for 6, 9 and 12 minutes. The length of soaking significantly increased the amount of flame retardant absorbed. During the 6-minute interval, the sample absorbed 18.31g of the flame retardant on average, 31.82g after 9 minutes and 36.63g after 12 minutes. Out of the five specimens, only two (M7 and M8) were measured for the 6 minute dipping test. Their weight loss was minimal - 0.06 and 0.09% of the total weight of the sample. This weight loss was caused by scorched surface of fiber board – the inner structure of the samples was not damaged, not even the point of greatest flame exposure. Other samples did not pass the test.

The desired results were achieved with the samples dipped in Firestop solution for 9 minutes. All of the samples tested met the requirements. This result was achieved thanks to the amount of flame retardant absorbed. From all of these samples, the sample which absorbed the least amount of fire retardant was the one labeled M14 - 27.43g of the solution. This represented 16.02% of the total weight of the sample just after soaking. This amount of flame retardant created a salt layer on the surface of the material, preventing the flame from penetrating the board. Weight loss ranged from 0.03 to 0.15%. The average weight loss was 0.10%.

Longer soaking time caused that the sample absorbed from 34.22 to 42.68g of the solution. The only exception was the sample M17 which - because of its composition - absorbed 26.03g of the flame retardant. This represents 15.47% of the weight of the sample immediately after application. This sample did not withstand the test, its weight loss was 100%. Other samples showed a weight loss of 0.10 to 0.16%. The test samples lost 0.12% of its original mass on average. The relationship between the absorbed amount of the flame retardant and the % of weight loss for the sample is represented by the following graph (Fig. 5).

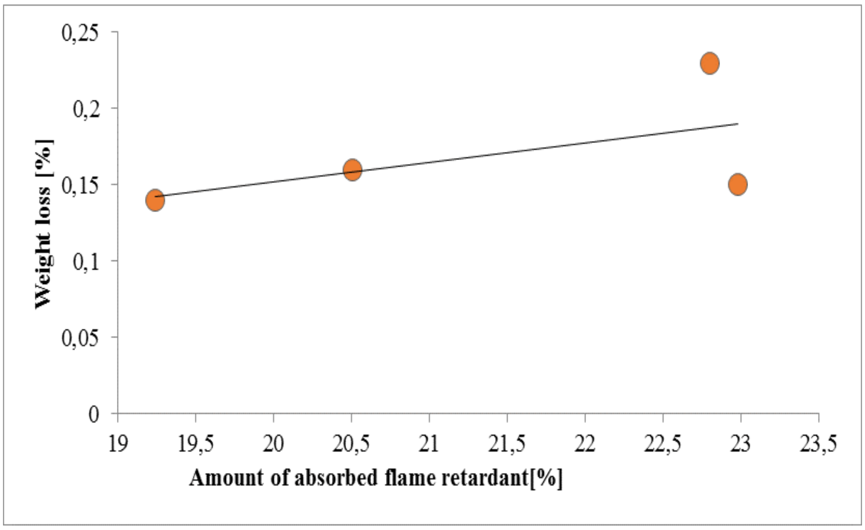


Fig. 5.
Graph of the amount of absorbed retarder in percentage and its weight loss after 12 minutes of soaking.

CONLUSIONS

Based on the results, we can conclude that the most appropriate method of applying the flame retardant is dipping. In our case, it was necessary to soak the samples in Firestop solution for at least 9 minutes to get reliable results. If we wanted the samples to pass the test, each sample had to absorb at least 16, 02% of the sample weight immediately after flame retardant application. Another observation was that the flame does not burn on the surface, but thanks to thermal degradation of the board the burning continues even after turning off the flame source. Attempts to extinguish the test specimens have been unsuccessful several times despite having applied an extinguishing agent (water) firmly, smoldering within the material tend to restore. In one of the tests, the sample smoldered internally and the entire length of the sample was burnt through. We managed to extinguish the samples when immersed into water for a few seconds. As a result, the water permeated the inner layers of the board and interrupted the smoldering.

This poses problems for intervention units. In case of a real fire, there is a risk of fire recurrence or its hidden paths. The problem may also be the amount of water needed to extinguish the fire and the subsequent damage it has caused. Adding flame retardant additives in the production process might solve the problem. That way, the surface as well as individual fibers and thus the inner structure of the board would be protected. The question is – would the change affect the other properties of the material such as mechanical strength, and vapor permeability?

Another problem was the amount of smoke produced during smouldering. This poses additional problems for rescue services having to use protective equipment. In practice, there are flame retardants of different chemical compositions, some of which are toxic to man. In case of a fire, the release of these fumes are a threat to rescue services. Since the presence of such substances is not immediately apparent, adding such data into database might represent the solution. The data would be provided by the operations chief or by physical identification represented by labels used directly on the site.

According to the given data, a number of recommendations for practical purposes were proposed – either it is tests of different types of flame retardants such as the latest flame retardants based on nanotechnology or retardants on natural basis so as to maintain the unity using natural materials.

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