

ABSTRACT

The paper examines three types of natural insulation materials, such as fiberboard, hemp and straw, from the point of view of fire safety. Cellulose-based materials allow a wide range of applications when used for insulation and weatherproofing of buildings, in particular floors, roofs, ceilings, attics, sound barriers, etc. The use of these materials is increasing in ecological constructions as well as for weatherproofing wood-based structures. In terms of fire safety requirements, the question is: Which insulating material is the safest in terms of fire propagation? The article focuses on natural products used as external insulation systems which are covered by a facade plaster. Each type of insulation is briefly described in terms of its composition, use, and production process. We describe the process of preparation of samples as well as the testing and measurement procedures. Three tests were carried out for each type of material. For a more objective evaluation, results were averaged. The results of the cone calorimeter were used to obtain data for comparison. The aim is to clarify the behavior of the natural insulating material with regard to the heat release rate, ignition time, burning duration, and maximum heat release rate. These are the essential parameters for comparison. The values were compared to determine the safest material from the point of view of fire safety.

TEST MATERIAL

We evaluated the natural products that are used as exterior insulation. Insulation materials in the form of hard boards were used for the test. Three types of thermal insulations, which are often used in ecological constructions, are described below. We now describe their composition, production process and usage. We describe three types of natural insulating materials such as hemp, straw and fiberboard, in more detail. Three pieces of samples of 100 x 100 mm were made from each type of material. This dimension follows the ISO 5600-1-2002 standard, taking into account the size of the holder. The thickness depends on the manufacturer. The number of pieces corresponds to the number of measurements per material, so that we can average the results for a more objective assessment. Each sample was labelled by a number and weighed. Then the samples were placed into the climate chamber. The climatic chamber Memmert Peltier HPP 260 provided homogenous humidity for all samples. The chamber was set to a constant moisture of 60 % and 23 °C.



METHOD

A cone calorimeter is a measuring instrument which can determine heat release rate (HRR - Heat Release Rate) using model materials on the basis of oxygen consumption and the measurement of carbon monoxide and carbon dioxide concentration under thermal load during small-scale tests. About 13,1 MJ of energy is released per one kilogram of oxygen consumed. This device monitors the creation of heat during the burning process, weight loss rate, and time to ignition. The name is derived from its cone-shaped heating element, which is the source of radiant heat. One of the other reasons we use this calorimeter is that it shows exactly how the products behave under heat load conditions and how the material can contribute to the development of a fire. Consequently, we monitored the following:

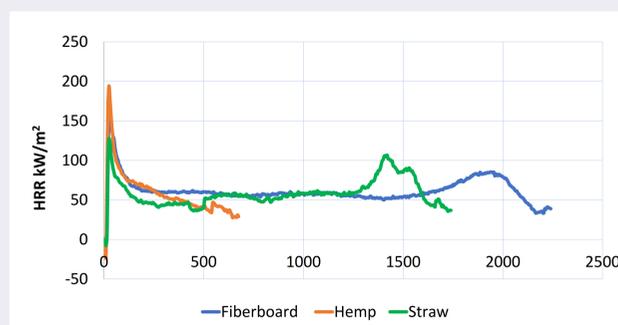
- Maximum heat release rate HRR – the basic parameter used to compare or detect a certain material's behavior, as heat release rate generally affects the development of fire. HRR is one of the basic characteristics of fire which should be taken into account when estimating fire hazard, since it has an important impact on the development of fire in a building.
- Average heat release rate after 60, 180, 360 seconds of test.
- Ignition of the sample – the beginning is determined when thermal degradation occurs.
- The end of burning, when the material is burning flamelessly and the sample is only smoldering.
- Total burning length – from ignition up to the end of burning.
- Weight loss.

The above mentioned parameters are a simple way to compare the results. The maximum heat release rate can be used to classify the material into groups of materials with similar reactions to the heat flow.



MEASUREMENT RESULTS

| | | 35 kW/m ² | | Hemp | | Straw | | Fiberboard | |
|-------------------|-------------------------------|------------------------------------|--------|----------|--------|----------|--------|------------|-------|
| | | parameter | unit | value | value | value | value | value | value |
| Times of the test | Ignition time | s | | 9 | | 12 | | 11 | |
| | flameless burning time | s | | 527 | | 1620 | | 2166 | |
| | end of the test | s | | 675 | | 1740 | | 2240 | |
| Peak values | parameter | unit | value | time (s) | value | time (s) | value | time (s) | |
| | HRR | kW.m ⁻² | 195,41 | 27 | 129,27 | 25 | 155,93 | 30 | |
| | wight loss | g.s ⁻¹ .m ⁻² | 0,17 | 17 | 0,13 | 83 | 0,12 | 22 | |
| Test results | parameter | unit | value | value | value | value | value | value | |
| | total heat release rate | MJ.m ⁻² | 35,58 | | 75,04 | | 109,73 | | |
| | average HRR after 60 seconds | kW.m ⁻² | 127,04 | | 89,62 | | 119,33 | | |
| | average HRR after 180 seconds | kW.m ⁻² | 92,86 | | 68,54 | | 88,79 | | |
| | average HRR after 360 seconds | kW.m ⁻² | 75,34 | | 56,66 | | 74,55 | | |
| | average weight loss rate | g.s ⁻¹ .m ⁻² | 5,44 | | 5,19 | | 4,14 | | |
| | weight loss | % | 11,94 | | 41,83 | | 33,64 | | |



We can see that hemp, due to its structure, composition, and density, contributes most to the development of a fire. In each time interval, it has the highest HRR value. The second sample, with a slightly lower HRR, is the fiberboard sample. Among the three materials, the straw sample has the best results. Its composition does not contribute to the development of fire as much as the other samples. The first one to start burning was a hemp sample in 9 s followed by a fiberboard sample in 11 s and finally the straw sample in 12 s. After ignition, a rapid increase in HRR occurred equally in all three samples. The maximum HRR was recorded for hemp samples 195,41 kW/m², over a period of 27 seconds. The lowest HRR was reached for straw samples (green) and was only 129,27 kW/m² at 25 seconds. The straw and fiberboard sample is composed of two parts which are glued in the center. First, one layer must burn away and then the second follows. Therefore, there are two peaks appearing on the graph. Hemp insulation does not consist of two layers. The measurement detected only one HRR peak. At 527 seconds, hemp samples started burning heterogeneously, showing no signs of flame burning. The longest duration of the test was 2240 s for fiberboard.

FIBERBOARD SAMPLE



a) before the test



b) after the test

CONCLUSIONS

The hemp sample had the shortest ignition time out of the three types of insulation. Its weight loss percentage was the lowest - 11,94 % - from these samples. Straw insulation has the lowest heat release rate, so we can thus conclude that out of the three sample types, it contributes to burning the least. Ignition of the sample occurred 3 seconds later than in the hemp sample. Weight loss was 41,83 %. This confirms the greatest resistance of the insulation to thermal degradation. On the other hand, the observed HRR parameter and ignition time showed that hemp has the greatest impact on burning behavior. The behavior of the material or the product in the phase of fire development can therefore be very reliably assessed by monitoring its behavior under radiant heat flow. However, we must emphasize that this is only a relative comparison, since the test conditions and the conditions differ in a real fire. In a real fire, it is justifiable to assume there is an intensive flow of gases (including air), which also has a significant impact on the time of initiation.

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