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Fire Safety Assessment on Seven Flooring Materials

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Abstract

Seven flooring material were tested in order to find out their properties from fire safety point of view. Following three indexes were measured: mass loss, flame spread rate and emissions of CO, NO_x, SO_2, O_2 were monitored. The fire safety characteristics of synthetic materials are mostly negative due to faster mass loss comparing to the natural materials. Based on the results one of the materials is no more recommended for the use due to health and safety risk character. Fast mass loss in hand with its toxic emissions of phthalates and dioxin make PVC a very risky flooring material. We do not recommend its use. Nylon (polyamide) carpets should be not used due to their high flammability. Wooden based floorings such an oak parquet, spruce board, OSB boards are high recommended. Linoleum and Laminate floorings, especially due to low flammability are recommended, too.

Keywords: Fire safety, flooring, burning, mass loss, flame spread rate, emissions.

Introduction

Variety of flooring materials is used at the time. Natural materials as wood and wood imitations combining natural and synthetic materials have becoming popular in constructing and interiors. There are widely common laminate and PVC floorings. Carpets from natural or synthetic fibers represent another group. The base is usually made of non-flammable materials such as concrete or stone tiles. In case of fire the behavior of mentioned materials varies. It depends on the physical and chemical properties of each type. There are different initiating combustion temperature, rate of flame spread, mass loss and chemical composition of emissions that are released during combustion. In terms of STN EN 13501-11 flooring materials represent all classes of flammability from non-flammable Class A (concrete, granite, etc.) to flammable Class F. The wood-based floorings belong to class C, D, E (moderate flammability). Polyamide or nylon carpets belong to the class F, group of easily flammable materials.

The aim of laboratory measurements was to determine the behavior of the various types of flooring standard thickness at building fires. The main indicators clearly show the mass loss, the rate of flame propagation and release of emissions into the air. The samples of beech wood flooring, OSB boards, spruce flooring (decking), linoleum, laminate flooring, PVC and synthetic carpets .were tested. Mass loss of OSB was studied by Galla[1]. Thermal quantities of various wood spices including fire retardants were deeply studied by Martinka,[2] Kačíková[3], or Osvald[4]. Emissions measurement is a fundamental part of thermo-chemical works. The variability of emission results when combusting or burning the same wood spices was proofed by numerous studies by Müllerová[5-7], Valíček.[8] Health risk and environmental risk should be always considered when dealing with harmful emissions[9]. Combustion of natural material is not always ecological and harmless as was proofed by Benčíková[10] and Müllerová[11] in their wood combustion studies. Especially high CO_x is problematic.

Characteristics of tested materials: Beech parquet belongs to flammability class C_{fl}[12] (table-1), flame retardant with limited development of smoke s1. A typical thickness is 21mm, humidity 9% ± 2%. They are sought after the long life (minimum 75 years), heat and sound insulation properties. Parquet floors without surface treatment were used for laboratory tests.

Spruce courtside is milled from a dry timber with a moisture content of 10% ± 2 %. Each board has a tongue on one side and on the other side of the groove. Individual pieces fit together and form a perfect connection, without spaces, without the use of adhesives. Thickness is 22mm. It is mainly used in holiday cottages and private houses.

OSB boards (OSB - Oriented Strand Board) is made from large particles of wood pressed flat chips, which are pressed under the influence of high pressure and temperature, with the use of synthetic resins based on formaldehyde. Formaldehyde at higher concentrations causes nausea, headaches. At concentrations of 120 g/m^3 is fatal[13].

Linoleum is a material made from jute fabric that forms the backbone of the flooring substrate, linseed oil and cork, wood or limestone flour, natural resins and color pigments. The advantages include linoleum elasticity, good thermal insulation at the current suitability for use with under-floor heating, static character, tough inflammability, resistance to temperature

changes, cigarette butts, oil and grease, and partly acids and solvents. Linoleum is bacteria-static material.

Laminate floating floor is rough only six to eight millimeters, its core is in the form of densified wood or pressed wood fibers. Decorative foil or paper is pressed onto a layer of melamine resin, and protective coating is applied. Stability is ensured by the bottom layer. Among the harmful chemicals that are found in floating floors include phenol and formaldehyde. Phenol and formaldehyde is a part of adhesives used to join the individual layers together[13].

PVC floorings are produced either with a single-layer or multi-layer decoration and transparent top layer. Their danger lies in the chemical composition and emissions that are released during combustion. The smoke released by its burning is toxic, containing phthalate, chlorinated paraffin, and sometimes lead or tin compounds. When incomplete combustion of propane and chlorinated hydrocarbons occurs, after the contact with hot metal they can be converted to phosgene. The properties of PVC compounds are described by European[14] and American[15] institutions and well known authors[16,17].

Polyamide carpets are dominant due to the competitive prices in the market. Fire resistance polyamide is very low comparing to carpets made of natural fibers. The basic material of synthetic carpet fibers is nylon (polyamide, nylon) which is extracted from the oil. At temperatures from 40°C to 100°C does not change the properties at temperatures above 150°C starts to degrade. Nylon carpets are characterized by high strength, elasticity, resistance to moisture, abrasion with a relatively low weight. The main disadvantage of carpet is accumulation of dust and dirt. Carpets can accumulate filth and dust 8 times higher than its own weight. We tested a polyamide carpet, which was tufted into a synthetic jute grid, so-called AB base. When incomplete combustion dangerous carbon monoxide (CO), very toxic hydrogen cyanide (HCN), hydrogen chloride (HCl), carboxylic acid, ether and ammonia are released[14].

Methodology

Laboratory measurements were conducted at room temperature of 23°C ± 2°C and a relative humidity of 50% ± 20%. The chamber was formed party firmly embedded plates. The floor of the test chamber is made with ceramic tiles of approximately 1m. Front of the chamber formed by transparent glass panel. The ceiling of the chamber is made of metal and glass and one exhaust chimney fan. The end edge of the burner is at a distance of 25mm horizontally and 30mm vertically from the surface of the floor covering. The longitudinal axis of the burner corresponds to the longitudinal axis of the sample. The size of the burner flame is adjusted on the gas bomb. Fuel source is propane, which we shall be discharged under pressure of 0.5 bar (50kPa). Flame spread rate was measured by a stopwatch to the nearest tenth of a second, the weight of the samples was determined with a precise digital weighing 0.1 grams. For each type of material 10 samples were tested. Values expressed in graph and tables are the arithmetic average of the measured values. Each sample was weighed before the experiment and after extinguishing the samples at the end of the experiment.

Results and Discussion

Tests flooring wood-based materials were milder than synthetic materials tests. PVC and polyamide carpet completely burnt through while in materials containing wood it didn't happened. Percentages of mass loss measured after 10 min permanent flame exposure are on graph at figure-1. The lowest mass loss was recorded in natural flooring materials - wood-based floorboards from spruce (4.85 %), OSB (5.34 %) and beech parquet (8.69 %), the mass loss was less than 10%. Highest mass loss was measured with a polyamide carpet (21.96%). The second highest average value was recorded for PVC (17.33 %).

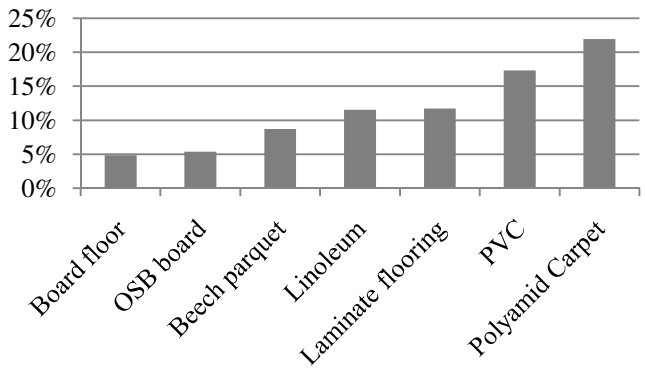

Figure-1
Average mass loss values of tested flooring materials

Times measured at 10cm intervals confirmed the anticipated slowing down of the flame spread. This is reflected in the decreasing mass loss. Laboratory measurements at Technical University Zvolen confirmed that samples with increasing distance from the source of heat radiation decreases the total mass loss.[18] Linear trend of mass loss was proofed for majority of the samples. The similar results were obtained in the National Institute for Fire Technology and Expertise[19].

Measurements focused on emissions released by burning beech wood and laminate floating floors have been made by Uysal.[20] according the American standard ASTM E – 6. Duration of measurement was consistent with our measurements, i.e. 10 min. Experiments conducted in the Testo 300 M, the measurement of the emission was recorded by XL flue gas analyzer. Samples of beech wood and laminate flooring contain the emissions of standard gas monitoring (table-2)[20].

The values in table-1 recorded distance of flame spread rate for different flooring types after the first minute of the experiment. Continuously, the spread rate had been slowing down. Table-2

show that emissions from laminate flooring especially in the case of NO_x are almost three times higher than for the same size sample of beech wood. Mass loss values correspond to our measurements, which also recorded doubled value of mass loss laminate floating floor as beech parquet.

Thermo-mechanical properties as conductivity can be read out from the results referring to flame spread rate.[20] Carpet and PVC have visibly higher conductivity comparing to wooden material floorings. This topic is well described in study materials by Krišśák[21] and Müllerová[22] or Kumar[23].

Table-1
Flammability classification of materials due to flame spread rate

Flooring material	Flame spread rate [mm. min^{-1}]	Class of fire reaction according STN EN 13501-1:2010
Board floor	118	D fl – moderately combustible
OSB board	127	E fl – moderately combustible
Beech parquet	102	C fl – combustible with difficulty
Linoleum	122	D fl – moderately combustible
Laminate flooring	137	E fl – moderately combustible
PVC	175	E fl – moderately combustible
Polyamid Carpet	235	F fl – easily combustible

Table-2
Average emission values and mass loss of laminate flooring[8]

Emission	Laminate flooring[8]	Beech timber
CO (ppm)	983	726
NO_x (ppm)	25.1	9.95
SO_2 (ppm)	0.57	1.52
O_2 (ppm)	17.6	18.3
Mass loss (%)	21	12.1

Conclusion

Careful choice of flooring materials in buildings, offices, apartments and other properties should be done considering the fire resistance of chosen material including their typical behavior when they come in touch with some ignition source. Tests mentioned above indicates that natural wood-based materials (floors, OSB boards, floorboards) out of seven tested are more suitable for the use in sense of fire safety. Laminate floating floor had also very good resistance. Compared with beech wood but has a significantly higher CO and NO_x emissions. The greatest mass loss had polyamide carpet and due to law ignition temperature also represents highest fire safety risk. At the same time the burning release small amounts of formaldehyde and hydrogen cyanide. Alternative carpets are made of polyester or of polypropylene fibers (PP, olefin) but less rigid with shorter lifetime. PVC is becoming one of the worst material with negative impact on human health due to the phthalate emissions released also in standard room temperatures. Several countries, including the Czech Republic already have taken steps to reduce or eliminate the use of PVC in public buildings. Using PVC in some products is completely prohibited (e.g. toys). Moreover, tests have shown its high flammability. Slow burning of PVC is sometimes invisible with transparent flame and can cause dangerous fire effects[24].

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