VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

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FLAMMABILITY QUALIFICATION WITH OXYGEN INDEX (LOI) OF TEXTILES USED AS BUILDING MATERIALS

Abstract

Today, plastics are increasingly used as a building material, and traditional silicates are starting to displace. The plastic industry was developed significant in the last decades. The application of plastics are increasing. Because of this it is a high risk factor. The characterization of the behaviour of plastics while being on fire is of great importance for the practical use of plastic materials. Toxic gases arose during combustion of plastics, that's dangerous for people and environment. Our paper presents the occurrence of the most common plastics in buildings: woven and non-woven textiles, and cables. These are subject to the same stringent flammability requirements as traditional products. Polyester (PES) is one of the most important synthetic polymers. Subject of my examination is the nonwoven geotextiles. They are widely used in many fields such as flat roof insulation. Conversely, it has various disadvantages such as highly flammable combined with dripping, smoking, shrinking effect. For these reasons, it is necessary to improve the anti-dripping and fire retardant properties of textiles, that used in buildings. The flue gas composition, the combustion temperature affect the survival chances in case of fire. The aim is, that analyze flame retardant properties of textiles with LOI. The method provides a classification of the burning behaviour.

Keywords: fire protection, polymers, polyester, geotextile, flammability, self-sustaining combustion, nonwoven geotextile

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NEM SZERKEZETI ÉPITŐANYAGOK ÉGHETŐSÉGÉNEK MINŐSITÉSE

Absztrakt

Ma már egyre gyakrabban használnak műanyagokat építőanyagként, a hagyományos szilikátok kezdenek kiszorulni. A műanyagipar jelentős mértékű fejlődésen ment keresztül az utóbbi évtizedekben. Felhasználási területe egyre bővül, így mennyiségük is rohamosan növekszik. Széleskörű elterjedését figyelembe véve kiemelt kockázati tényező, mivel az égése során keletkező toxikus gázok az emberre és a környezetre nézve is veszélyt jelentenek. Dolgozatunk bemutatja a leggyakoribb műanyagok előfordulását az épületekben: szőtt és nem szőtt textiliák, és kábelek. Ezekre ugyanolyan szigorú éghetőségű követelmények vonatkoznak, mint a hagyományos termékekre. Felhasználása széleskörűen történik, többek között lapos tetők szigetelése során elválasztó textíliaként alkalmazzák az építő iparban is. A poliészterek gyúlékony anyagok, melyre jellemző az égve csepegés, füstképződés és zsugorodás. Egy tűzeset során a füstgázok összetétele, az anyag gyulladási, illetve lángterjedési ideje meghatározza a menekülési esélyeket. Égésgátlók alkalmazásával késleltetni lehet a meggyulladást, időt nyerve a menekülésre. Emiatt szükséges az építő iparban, a lakóépületeken belül felhasznált műanyagok égésgátló tulajdonságának javítása. Dolgozatunk célja a vizsgált műanyagok égéskésleltetésének minősítése oxigén index méréssel, valamint a szövetek függőleges lángterjedésének vizsgálata. Ez alapján javaslat megfogalmazása a szövetek alkalmazhatóságára.

Kulcsszavak: tűzvédelem, polimerek, poliészter, geo textil, éghetőség, oxigén index, nem szőtt geotextil

1. INTRODUCTION

There are many problems to be solved in the field of fire protection [8] [9] [10] and fire investigation [11]. There are several methods to describe the flammability of various materials, such as the smoke temperature, the flame propagation in different directions, smoke densities and fume temperatures [6].

The flammability of materials can also be characterized by their minimal oxygen concentration required to maintain of burning.

The majority of flammable materials are capable of combustion at normal oxygen levels (21 vol %.), but there are materials that burn at lower or higher oxygen concentration in comparison. Oxygen index (LOI – Limited Oxygen Index) is not a commonly practiced laboratory measurement method, despite its being a significant parameter in the characterisation of flammable materials. This method has originally been developed to describe the flammability of plastics, but in principle it is applicable to all combustible solid materials [1].

The LOI parameter is used for fire protection qualification of several plastics: carbon fibres in the literature, oxidized fibres and materials made from those: woven and non-woven textiles, and outer plastic coating of electrical cables. The samples under investigation are to be produced locally, after solving initial problem [2].

One goal was to see how the traditional tests reflect the real fire requirements and the actual fire resistance of the cables. It is also necessary to investigate, that those cables, which received a fire resistant rating, they really correspond under real fire requirements. The actual fire resistance was the most suitable for the oxygen index (LOI) parameter.

2. METHOD OF MEASUREMENT

The precise circumstances of the measurement are regulated by standards. The standardised measurements are governed by both Hungarian standard (MSZ 10200-1989) *(Plastics - Determination of flammability by oxygen index)* and international standards (ISO 4589, ASTM 2863). By definition oxygen index is defined by the minimum oxygen content of the air, where the material is still capable of fire propagation or burning in a defined time interval.

The most important part of the measuring instrument for the oxygen index is shown in *Figure 1*.

The sample holder is a 6 x 16 cm, U shaped, double layered vertical metal frame, secured in a glass cylinder with its top end open. The ignition and the removal of the combustion products

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are made possible through this opening. The source of ignition is a 4 cm long gas-flame as prescribed by standards. The specimen is ignited along the upper edge applying the flame for maximum of 15 seconds. Burning proceeds downwards against the flow of the pre-adjusted gas mixture. Nitrogen and oxygen content are adjustable as required [5].

For the purposes of this International Standard, the following definition applies: Oxygen index the minimum concentration of oxygen by percentage volume in a mixture of oxygen and nitrogen introduced at 23±2 °C that will just support combustion of a material under specified test conditions. It is recommended that the first trial measurements are performed at a low (30-32%) oxygen concentration. Initially the material does not show any ignition phenomena, and is non-flammable. By increasing the oxygen content, initially only burning patches appear, then as the oxygen concentration increases, the length of the burnt area becomes greater.

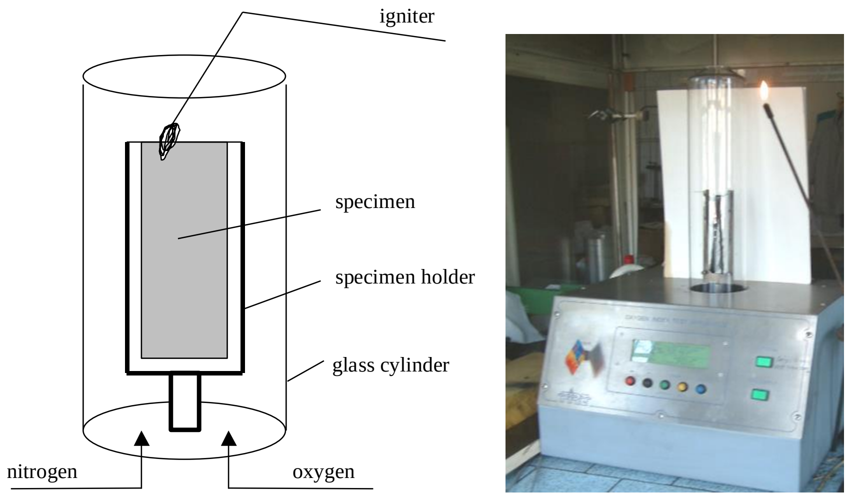


Figure 1 - Diagram of typical apparatus for determination of oxygen index. Created by the authors

Technical data of apparatus: FIRE Instrumentation and Research Equipment Limited, UK (ISO 4589 Part 2 Oxygen index test apparatus)

The oxygen index can primarily be applied to solid and composite materials. It was a separate task to work out a method for the application of the oxygen index to structurally completely different materials such as fibres, non-woven felted textiles (the use of terms, such as vlies or felt is accepted as well).

Samples based plastics

1. Felts based oxidise fibre

The most flame retardants and non-combustible nonwoven fabrics are made of oxidized and carbon fibres, due to their strong thermal stability. The burning of nonwoven fabrics consists of complex combustion mechanisms: their surface, micro- and macrostructures together define their combustion features. By microstructure we mean oxidized Poly Acrylic Nitrile (PAN) fibres, which finally constitute the base material of the macrostructure. The macrostructure represents the different forms of the product, in which the material results during production. The majority of carbon fibre-based samples can be characterized by a certain oxygen concentration, including standard LOI.

The area weight parameters are our own measurements. The typical fibre density was provided by the manufacturer at our request. For area weight, the following measurements were taken: 80, 100, 150, 200, 270, 500, 1700, 1850 gm-2. The tested materials and their parameters are given in Table 1.

Table 1- Micro- and macrostructure data for each sample. Created by the authors

	1	2	3	4	5	6
Sample IDs given by the producer	PN N1	PN N3	PN 5	PN TESA	PN ST	PN ACHILL
fibre density, gcm^{-3}	1.35	1.37	1.37	1.37	1.37	1.37
area weight, gcm^{-2}	150-190	150-190	600-700	500-600	190-300	150-250

Table 2 - The LOI values in function of fibre density. Created by the authors

density of fibre (gcm^{-3}) used in the felts	1.351	1.400
LOI (1)	24.5	31
LOI (2)	35	48

2. Non-woven geotextile based polyester

They are made of endless or cut polypropylene or polyester fibres by a special needle felting process. (are shown in Table 3. During production, they receive unilateral or double-sided heat treatment, which significantly increases their performance [7].

Use of non-woven geotextiles

- Separation: during road, railway and hydraulic construction and other foundation works, for the separation of high-quality primer layers and granular materials incorporated as subsoil and load-bearing layer [4]
- Filtration: for leaking systems
- Protection: for mechanical protection of the insulation of structures.
- As a vapor barrier layer for roof shells [3]

Table 3 - The characteristics of the polyester geotextile samples. Created by the authors

Sample	**Color**	Thickness **[mm]**	**Areal weight [g/cm^3]**	**Material**	**Thermoformed**
G1	white	5	1000	100 % Flame retardant PES	Yes
G2	white	1,6	300	100 % Flame retardant PES	Yes

G3	white	2,8	300	100 % Flame retardant PES	Yes
G4	white	1,2	200	100 % Flame retardant PES	Yes
G5	white	1,6	300	98 % PES, 2 % PA (polyamid 6)	Yes
G6	white		300	100 % Flame retardant PES	Yes
G7	white		500	100 % Flame retardant PES	Yes
G8	white		1000	100 % Flame retardant PES	Yes
G9	white		300	100 % PES	No
G10	white		1000	100 % PES	No
G11	brown		300	100 % PES	No
G12	black	1,38	500	100 % Flame retardant PES	Yes

3. TEST RESULTS

Felts: Two of the characteristics of compactness are thickness and area weight (gm^{-2}), i.e., how loose or compact a nonwoven fabric is. Their thickness is typically 5-6 mm during production. However, one can find, in some samples, thinner (4 mm) or thicker (5 mm) surfaces as well. The burning of low area weight (below 300 gm^{-2}) fabrics is characterized by surface flames, often at 25 to 28 oxygen index (Figure 2). Above a certain compactness (approx. 300-400 gm-2), there was no visible surface flame, only a standard downward burning spread without flame.

The disappearance of the surface flame occurs at the combustion in the air of 50% oxygen content (Table 2). Thus felts are also able to burn with flames, surface flames or just glow. The oxygen index of denser felts without surface flames is clearly defined by the area weight as shown in Table 3.

The oxygen index value is in a linear relation to area weight. As far as combustion phenomena, at an oxygen index above 50%, only glow appears without surface flames; it may happen above 500 gm^{-2} area weight

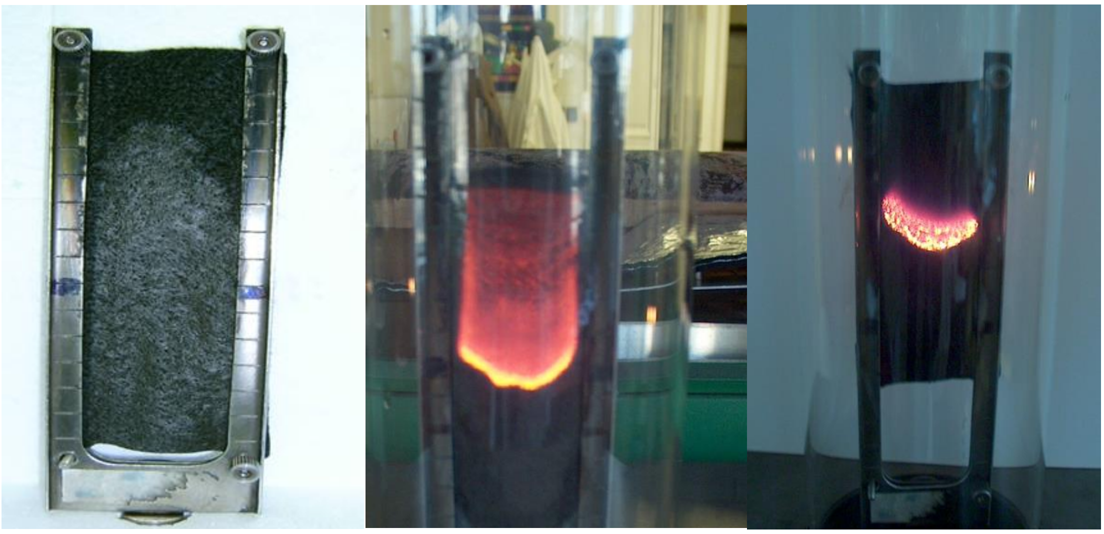


Figure 2 - Burning of nonwoven fabrics.

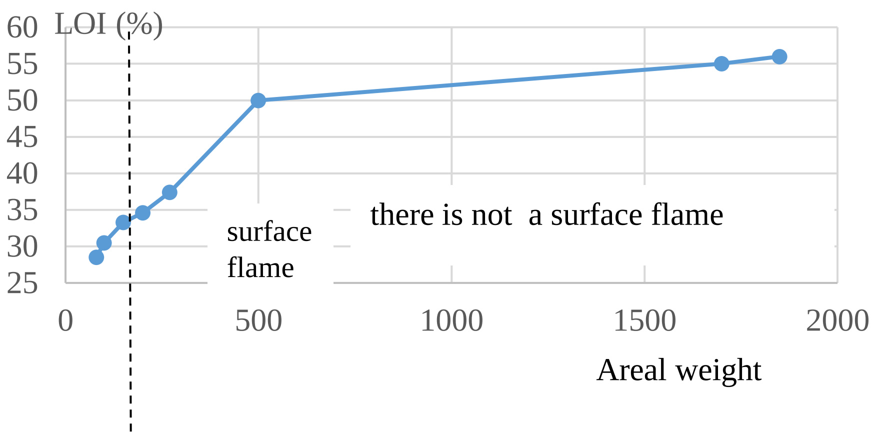
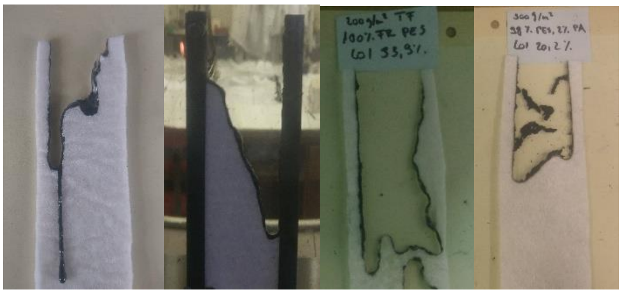


Figure 2 - Areal weight parameters influencing oxygen index of non-woven felts. Created by the authors.

2. Oxygen index (LOI) test results of Non-woven geotextile based polyester

During the measurement, the following was observed: When samples G1-G4 and G6-G10 were examined, no smoke was characteristic, but a melt was formed. Typically, the melt burns further. When G5, G11 and G12 samples were ignited, strong smoke was observed, but no melt. For some samples, the unevenness of the texture was detected during the examination, the same sample produced different results.

Figure 3 - Samples during burning. Source: Authors



G1 G2 G4 G5

G8 G9 G10 G11 G12

Figure 4 - Samples after burning. Source: Authors

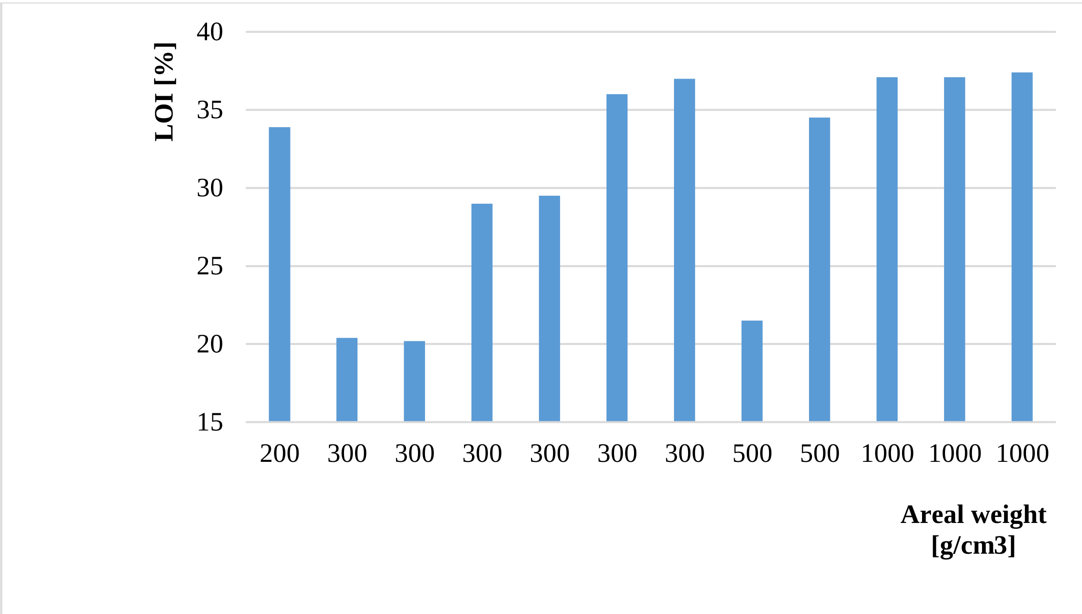


Figure 5 - Areal weight parameters influencing oxygen index of Non-woven geotextile based polyester. Created by the Authors.

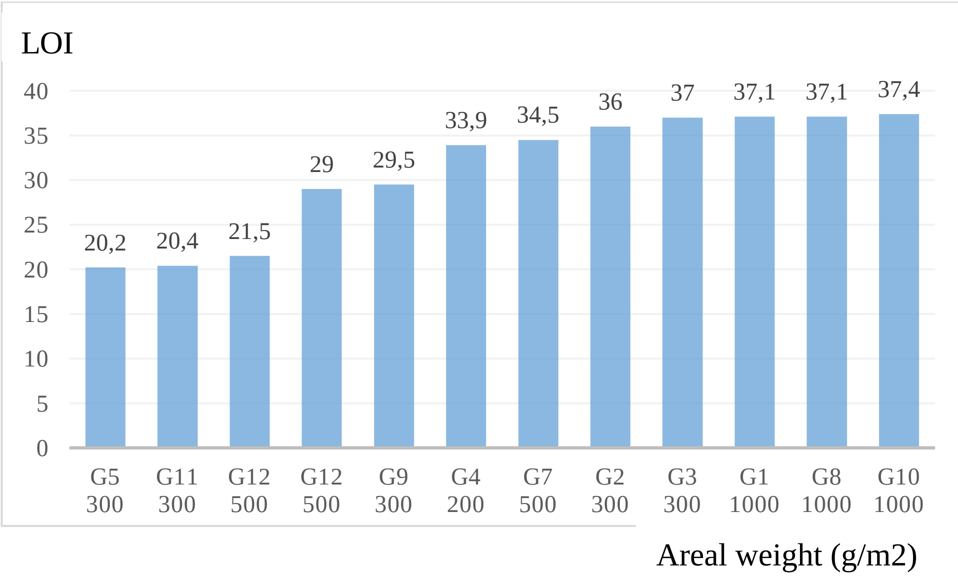


Figure 6 - Areal weight parameters influencing oxygen index of Non-woven geotextile based polyester. Created by the Authors.

4. SUMMARY

Only those woven and non-woven textiles can be considered as surely non-flammable, of which the oxygen-index value **is** above 50. This LOI can be reached with the following area weight: for woven textiles more then 370 g/m^2 and for felts more then 500 g/m^2.

If the LOI value of the base material (oxidised fibre) is more then 50, the micro structure of the fiber against combustion can be considered thermodynamically stable.

Only those non-woven textiles can be considered as surely non-flammable, of which the oxygen-index value is above 50. This LOI can be reached with the following area weight: for woven textiles more then 370 g/m^2 and for felts more then 500 g/m^2.

Vlies samples show most sensitively the degree of dependency on structure by LOI. The danger of re-ignition is most pronounced in these samples, because the presence of fuzzy piles is inherent to the material and it can't be influenced by mounting. Surface flame can appear in cases when the top of the sample cannot be ignited and therefore usual flame spreading cannot be observed. If the material is rather loosely structured (tread), even the surface flame is capable of burning through the whole thickness of the material.

The LOI values of the samples giving highly sooty smoke (G5, 11,12) are below 30. Polyesters with a LOI of 34-37 (solid, with a Areal weight of 1000 g / m2, self-extinguishing combustion) can already be safely used as building materials. A self-extinguishing, low flame spread is not yet sufficient information, giving an oxygen index means complete safety. A sample with a low surface density (200 g / m2) can also be flame retardant after appropriate treatment. Our studies show that the burning behavior of PES-based nonwovens is shaped by both surface density and burn delay. Our research can also be a good basis for other series of publications on similar topics [12].

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