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تحديد أفضل نسبة خلط لألياف وبرة السجاد المصنوعة من الصوف والبولي أستر لتقليل الإنبعاثات الناتجة عند حرقه

Determining the Best Mixing Ratio of pile Fibers for Carpet Made from Wool and Polyester to Reduce Emissions Produced when Burned

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ABSTRACT:
Despite the panic caused by seeing fire engulfing people and property, scientific studies and technical statistics issued by agencies and organizations specialized in fire incidents worldwide confirm that deaths resulting from burns do not exceed 3% of fire victims. Meanwhile, the victims of toxic gases from fires range between 42% to 50%. Therefore, the toxicity of smoke resulting from the fire constitutes the main cause of death, It is necessary to achieve the best specifications in carpets to ensure safety and security for human health in fire in buildings and establishments, This can be by reducing the emissions of toxic gases from combustion via controlling the carpets construction, The objective of the research study different emissions such as the amount of carbon monoxide, carbon dioxide, smoke density and heat of combustion by using cone Calorimeter device to determine the best mixing ratio of pile fibers made from wool and polyester to reduce emissions produced when burned, The study sample consisted of (27) carpet, and the experimental scientific method was used, The hypothesis of the study is that reducing the amount of synthetic fiber materials in carpets decreases the toxic gases produced from combustion. The results concluded that the smoke density , co, co2 and heat of combustion by the samples with mixing ratio of 50% wool 50% polyester to 90% wool 10% polyester is less than with mixing of 40% wool 60% polyester to 10% wool 90% polyester. Thus mixing 50% wool 50% polyester has achieves the required safety carpets specifications.

Keywords :
Carpets, Cone calorimeter, Combustion Products, Emissions

1-Introduction

Carpets have become an essential part of contemporary home furnishings, a major part of the decoration of offices and stores, and an important way to beautify the floors and change their shape in line with the furniture used around them. With the progress and the emergence of contemporary furniture and its spread.[8,p45]

The carpet industry produces a lot of harmful and choking pollutants, especially when exposed to combustion, even though it is a very tiny source of pollution when compared to the chemical industry and many other industries. It produces deadly CO and CO2, sulfur, nitrogen oxides, hydrogen cyanide, and hydrogen sulfide, among other dangerous substances. [1,p5]

we see that carpets are increasingly placed in new office buildings, where the use of open plan offices are rising. Moreover, in our experience, the advice given earlier by health authorities to reduce the use of carpets in such premises is often ignored. Most likely, this is a trend that is common in many countries due to a potential cost reducing effect of open plan offices.

That carpets are a common flooring material in large markets is reflected in the numbers reported on the home page of the Carpet and Rug Institute, which claims that carpets accounts for 51% of the total U.S. flooring market. Whether this number is on the rise or declining is not known to us.

In a health risk assessment of carpeted floor, two factors are of interest. One is that carpets may act as a repository for indoor air pollutants such as dirt, dust particles, allergens and other biological contamination that can build up in the carpets, Such pollutants may be processed, released and provide new exposure at a later time point. It should be emphasized that neither the presence of such pollutants in the carpet nor their resuspension is necessarily linked to health consequences unless the pollutants are hazardous and the exposure level is high enough to cause adverse effects.[2,p2]

Fires have the most devastating consequences on people, despite the fact that losing homes or other property is really unfortunate. However, technical statistics and scientific research released by the global authorities and organizations that deal with fire accidents reveal that burn mortality do not surpass 3% of fire victims, whereas the percentage of victims of poisonous fire gasses ranges from 42% to 50%.[3,p11]

According to the United States Fire Department, there is a fire in a residential area every 85 seconds and these fires account for almost 80 percent of all fire related deaths. In London, 78% of deaths from unintentional fires are related to fires in residential areas. Fire-related injuries are one of the major causes of death and disability.

In recent decades, even in high income countries (HICs), despite the reduction in mortality
rates, fire-caused deaths are still regarded as a major concern. Between 2007 and 2010, approximately 39% of fires in China occurred in residential areas. Thus, considering the high possibility of death and injury and the financial losses incurred as a result of fires in residential buildings, more attention should be paid to this
issue.[9,p2]

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Consequently, because smoke contains a lot of harmful gasses, the toxicity of the smoke is the primary cause of fire deaths in inhabited regions. Therefore, it is crucial to research carpet combustion products in order to identify the structures that will contribute to lowering emissions from carpet combustion while maintaining safety and security. To do this, a number of experiments were carried out to quantify the heat and harmful gas products of carpet burning[4,p5-5p9], Among these tests, there is the tunnel test where this test comprises testing building interior wall and ceiling finishes with carpets for their ability to support and propagate fire, and for their inclination to generate smoke[6,p3], There is also a test of the radiator, which is a way to evaluate the amount of essential energy needed to ignite the surface of flooring furnishings using a radiant heat source.(7,p4) , Thus Recent trends in the textile industry focused on producing and developing eco-friendly textile fibers. This aims to raise product quality. [10,p195]

In order to measure the amount of emissions from carpet combustion, as well as the type and percentage of toxic gases released from combustion, the combustion heat (Mg/kg), and the smoke density (kg/m3), amount of CO (kg/kg), amount of CO2 (kg/kg) resulting from combustion, we propose in this study to use the cone calorimeter test, which is part of the international standard.

Experimental (Materials and Methods)

It was used twenty-seven samples with different specifications were produced by Oriental Weavers Company specifically for this test, with a sample area of 100 cm2 (10 cm for width and 10 cm for length) as shown in Figure 2. The textile structure used in carpet backgrounds is the plain weave, where the warp is Polyester count 150 denier and the weft is jute count 14, pile yarn count 10/3 wool-6000 denier, 32 rows per 10 cm, open Pile, and 33 (door/10 cm) comb kit. (Table 1), The slight difference in the weight per square meter of the pile for each sample with the same mixing ratios is attributed to the precision of the sample cuts, While the slight difference in the weight per square meter of a single sample with the same mixing ratios is attributed to the weight of the pile and the variation in the underlay pile materials used

Table 1: Specifications of the samples

Sample Number	Pile material	Pile height (mm)	Total sample height (mm)	Sample weight (gm/m^2)	pile weight (gm/m^2)	The percentage of fiber weight to the total sample weight
1	10%Wool 90%Polyester	10	12	4178.5	2814.5	67.35%
2	10%Wool 90%Polyester	10	12	4185.5	2937.7	70.18%

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3	10%Wool 90%Polyester	8	10	4101	2991.2	67.96%
4	20%Wool 80%Polyester	8	10	3787.7	2434.5	64.27%
5	20%Wool 80%Polyester	8	10	3604.5	2497.7	69.29%
6	20%Wool 80%Polyester	10	12	3397.7	2261.2	66.55%
7	30%Wool 70%Polyester	10	12	3192.2	1972	61.77%
8	30%Wool 70%Polyester	10	12	3266	2062	63.13%
9	30%Wool 70%Polyester	8	10	3896.7	2531.2	64.95%
10	40%Wool 60%Polyester	8	10	3746.5	2407.7	64.26%
11	40%Wool 60%Polyester	10	12	3746.7	2429	64.83%
12	40%Wool 60%Polyester	10	12	3998.2	2628.2	65.73%
13	50%Wool 50%Polyester	10	12	3017	2814.5	57.14%
14	50%Wool 50%Polyester	8	10	3403.5	1724	63.42%
15	50%Wool 50%Polyester	8	10	2997	2158.7	62.10%
16	60%Wool 40%Polyester	10	12	3270.5	1861.2	62.27%
17	60%Wool 40%Polyester	10	12	4275.2	2036.7	63.96%
18	60%Wool 40%Polyester	8	10	4194.2	2734.5	65.48%
19	70%Wool 30%Polyester	8	10	3640	2746.7	61.29%
20	70%Wool 30%Polyester	10	12	3485.7	2231.2	59.22%
21	70%Wool 30%Polyester	8	10	3761.2	2064.5	55.43%

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22	80%Wool 20%Polyester	8	10	3787	2085.2	61.58%
23	80%Wool 20%Polyester	10	12	3147.2	2332.2	61.61%
24	80%Wool 20%Polyester	8	10	3702.2	1939.2	61.58%
25	90%Wool 10%Polyester	8	10	4016.7	2280	61.82%
26	90%Wool 10%Polyester	10	12	3047.5	2483.2	59.86%
27	90%Wool 10%Polyester	10	12	3486.5	1824.5	60.14%

The samples were tested using a device cone calorimeter (model FTT) is based on simulating the conditions under which materials can be exposed (Figure 1). A fire occurs by exposing the samples to heat by using the cone heater and the ignition source which is the electric spark that occurs after ignition in the manner of oxygen consumption in the atmosphere of fire using an oxygen analyzer device (model 540 a). The density of the smoke emitted from the tested samples is also measured using laser technology. The cone calorimeter can isolate the different emissions automatically to analyze their amounts and percentages independently. The system uses also CO and CO2 gas analyzer (model Ultramat 22) to determine the percentage of the toxic gases.

Figure 1: Cone calorimeter device

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2- Preparing test samples

In the beginning, the sample was weighed and its thickness was determined, So that the dimensions of a single sample are ($10cm^2$) before testing (Figure 2).

Figure 2 : The sample before test

3- procedure

The distance between the conical radiation source and the sample was adjusted according to the standard specification (STM E 1454 or ISO 5660), Then the device was turned on and the sample was placed in- side it to perform the incineration process, When the sample reached the ignition both CO, CO^2 and other gases, as well as smoke, were emitted and heat released (Figure 3).

Figure 3: The sample during the test

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The emissions were analyzed by the oxygen analyzer and the CO, CO^2 analyzer, Where the shape of the sample after the test is as (figure 4)

Figure 4: The sample during the test

4- Results and Discussion

Sample Number	Pile material	amount of CO (kg/kg)	amount of CO_2 (kg/kg)	smoke density (kg/m3)	combustion heat (Mg/kg)
1	10%Wool 90%Polyester	0.336	1.688	521.016	17.345
2	10%Wool 90%Polyester	0.317	1.658	503.07	17.124
3	10%Wool 90%Polyester	0.348	1.683	501.162	17.137
4	20%Wool 80%Polyester	0.161	1.197	620.249	19.166
5	20%Wool 80%Polyester	0.17	1.168	515.548	17.908
6	20%Wool 80%Polyester	0.191	1.177	496.509	19.462
7	30%Wool 70%Polyester	0.139	1.106	500.072	18.408
8	30%Wool 70%Polyester	0.186	1.182	469.319	18.9187
9	30%Wool 70%Polyester	0.336	1.672	490.378	17.148
10	40%Wool 60%Polyester	0.11	1.096	380.141	19.257
11	40%Wool 60%Polyester	0.12	0.986	590.144	17.632

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12	40%Wool 60%Polyester	0.329	1.676	529.944	17.41
13	50%Wool 50%Polyester	0.077	0.914	349.937	18.57
14	50%Wool 50%Polyester	0.094	1.03	349.917	18.754
15	50%Wool 50%Polyester	0.028	0.868	380.495	17.782
16	60%Wool 40%Polyester	0.091	1.022	353.502	18.716
17	60%Wool 40%Polyester	0.071	0.96	380.973	19.258
18	60%Wool 40%Polyester	0.081	1.012	367.237	19.177
19	70%Wool 30%Polyester	0.08	1.073	292.552	19.631
20	70%Wool 30%Polyester	0.047	0.925	315.335	19.049
21	70%Wool 30%Polyester	0.067	0.897	369.362	18.757
22	80%Wool 20%Polyester	0.067	0.883	250.82	19.453
23	80%Wool 20%Polyester	0.046	0.95	275.438	19.801
24	80%Wool 20%Polyester	0.015	0.725	243.587	18.658
25	90%Wool 10%Polyester	0.074	0.943	270.256	19.723
26	90%Wool 10%Polyester	0.074	0.969	224.283	19.40
27	90%Wool 10%Polyester	0.04	0.905	226.27	19.549

Table 2: Results of the test

Table 3: Highest and lowest emission rates of the test

Emissions	**Mixing ratios**	**From**	**To**
combustion heat	50% wool or more 50% polyester or less	18.57 Mg/kg	19.801 Mg/kg
	40% wool or less 60% polyester or more	17.124 Mg/kg	19.462 Mg/kg
smoke density	50% wool or more 50% polyester or less	224.283 kg/m3	380.973 kg/m3

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	40% wool or less 60% polyester or more	469.319 kg/m3	620.249 kg/m3
amount of CO	50% wool or more 50% polyester or less	0.015 kg/kg	0.094 kg/kg
	40% wool or less 60% polyester or more	0.11 kg/kg	0.348 kg/kg
amount of CO2	50% wool or more 50% polyester or less	0.725 kg/kg	1.073 kg/kg
	40% wool or less 60% polyester or more	1.096 kg/kg	1.688 kg/kg

It is clear from Table (2,3) that the rate of the released heat is variable in samples with different percentages of mixing But from most of the sample results, we find that samples with higher mixing percentages of synthetic fibers give lower heat released as shown in the results of samples (1, 2, 3, 8, 9, 11, 13, 14, 15,16). (Figure 5).

Samples with higher wool ratios give more released heat because the wool is inflammable and therefore the heat starts from it at the moment of ignition. In case of synthetic fibers, it does not ignite at the moment of exposure to flame, but takes time until its melting, which helps it to continue its ignition and therefore does not release the heat from the moment of exposure to flame.

It is also clear that the lower the combustion heat the better is the sample mixing ratios of 50% wool 50% polyester to 90% wool 10% polyester give combustion heat from 18.57 (Mg/kg) to 19.801 (Mg/kg). While the samples with mixing ratios of 40% wool 60% polyester to 10% wool 90% polyester give combustion heat relatively less than 17.124 (Mg/kg) to 19.462 (Mg/kg) due to the increase in the percentage of synthetic fibers. (Figure 5).

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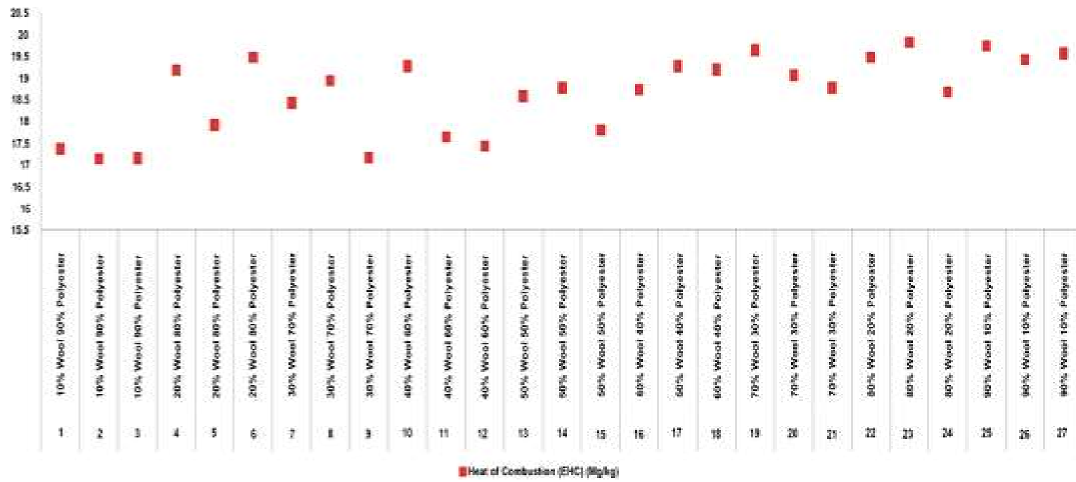

Figure 5(5): Results of the analysis of combustion heat

As for the density of the smoke, it is observed that the samples with mixing ratios 40% wool 60% polyester to 10% wool 90% polyester produce a smoke density of 469.319 (kg/m^3)to 620.249 (kg/m^3). But samples with mixing ratios 50% wool 50% polyester to 90% wool 10% polyester produce a smoke density ranging from 224.283 (kg/m^3)to 380.973 (kg/m^3), on the other hand, the smoke density by the samples with mixing ratio of 50% wool 50% polyester is less than the smoke density of by the samples with mixing of 40% wool 60% polyester to 10% wool 90% polyester. (Figure 6)

This suggests that the higher the quantity of wool, the lower the density of smoke produced during burning; hence, a 50% wool, 50% polyester blend satisfies the necessary safety carpet requirements.

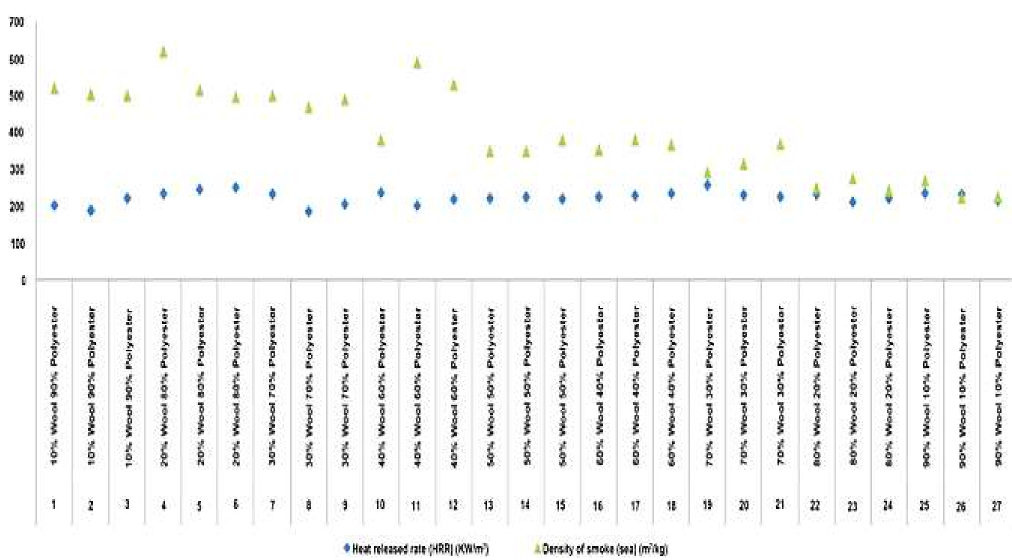

Figure 6(6): Results of the released heat and smoke density

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Given how crucial it is to remove CO for human safety, one of the cone calorimeter's most significant benefits is its capacity to measure CO levels. As a result, the findings can be separated into two categories. While the second portion demonstrates that the gas ratio in samples with a wool ratio between 10% and 40% ranges between 0.11 (kg/kg) and 0.348 (kg/kg), the first part demonstrates that the gas ratio in samples with a wool ratio between 50% and 90% ranges between 0.015 (kg/kg) and 0.094 (kg/kg).

As a result, it is demonstrated that the amount of CO released is significantly lower for the 50% wool, 50% polyester mixing ratio. This indicates that the more synthetic fibers a product contains, the more severe the CO poisoning.

Therefore, the amount of CO2 gas is quite lower for the higher mixing ratios of polyester. Additionally (Figure7) illustrates that the percentage of CO2 gas in samples with a wool ratio of 50% to 90% ranges between 0.725 (kg/kg) and 1.073 (kg/kg), while for samples with a wool ratio of 10% to 40% it ranges between 1.096 (kg/kg) and 1.688 (kg/kg). This indicates that the higher the percentage of synthetic fibers in products, the more severe the increase in the amount of CO2 gas emitted.

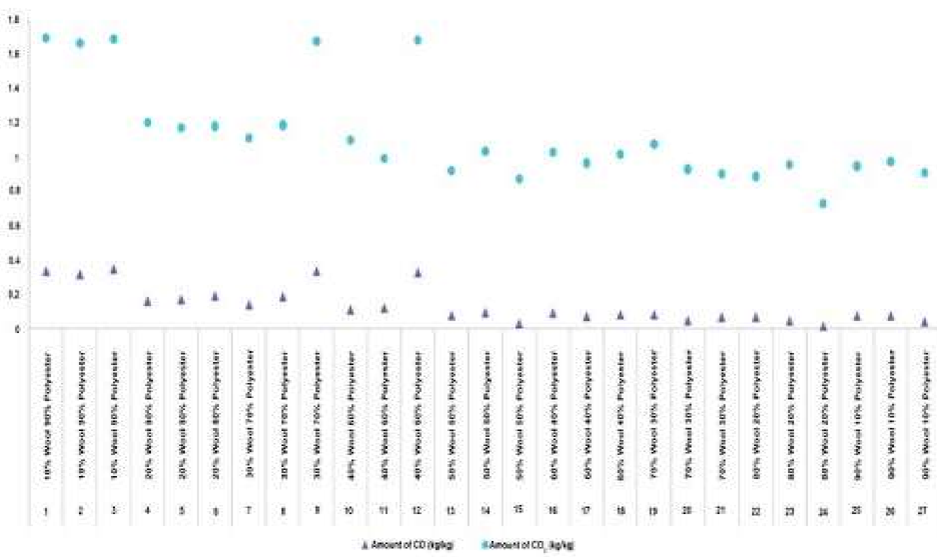

Figure 7[7]: Results of the analysis of CO and CO2

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5- Conclusions

In order to ascertain the optimal fiber mixing ratios for human safety, the emissions from the burning of carpets were examined in this study. In order to assess the released heat, combustion heat, smoke density, CO, and CO2 as well as to estimate the optimal mixing fiber ratios for carpets, 27 samples with various mixing fibers were tested under simulated conditions on a cone calorimeter. It was demonstrated through experimental and analytical work that samples that were mixed with 50% wool and 50% polyester, which decreased combustion emissions, met the standards for carpet mixing that are necessary for human safety. This led us to suggest using carpets with a greater structural composition than those made of wool.

Recommendation

1- Using carpets made from wool and polyester fibers to reduce harmful emissions when burned.

2- The carpet should not be produced and offered to consumers until after conducting tests according to standard specifications and obtaining product approval.

Author Contributions

The author conceived the work, prepared the samples and performed the experiments, conducted the sequence alignment and drafted the manuscript. The author read and approved the final manuscript

Availability Of Data and Materials

The data sets used and analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest Statement

The authors declare no conflicts of interest. Ethical approval There is no need for ethical clearance since it is a review article.

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الملخص:-

تؤكد الدراسات العلمية والإحصاءات الفنية الصادرة عن الوكالات والمنظمات المتخصصة في حوادث الحرائق حول العالم أن الوفيات الناتجة عن الحروق لا تتجاوز ٣% من ضحايا الحرائق، في الوقت نفسه تتراوح نسبة ضحايا الغازات السامة الناتجة عن الحرائق بين ٤٢% إلى٥٠%.، لذلك تشكل سُمية الدخان الناتج عن الحريق السبب الرئيسي للوفاة، فمن الضروري تحقيق أفضل المواصفات في السجاد لضمان سلامة صحة الإنسان في حالة نشوب حريق في المباني و يمكن تحقيق ذلك من خلال تقليل انبعاثات الغازات السامة الناتجة عن الاحتراق عبر التحكم في بناء السجاد، و يهدف البحث إلى دراسة انبعاثات مختلفة مثل كمية أول أكسيد الكربون وثاني أكسيد الكربون وكثافة الدخان وحرارة الاحتراق باستخدام جهاز الكون كالوريميتر طبقاً للمواصفة القياسية (ASTM E 1454 أو ISO 5660), لتحديد أفضل نسبة خلط لألياف الوبرة المصنوعة من الصوف والبولي إستر لتقليل الإنبعاثات الناتجة عند الاحتراق، تكونت عينة الدراسة من (٢٧) سجادة وتم استخدام المنهج التجريبي حيث تفترض الدراسة أن تقليل كمية الألياف الصناعية يقلل من الإنبعاثات والغازات السامة الناتجة عند إحتراق السجاد، حيث توصلت النتائج إلى أن نسبة غاز أول أكسيد الكربون (co) فى العينات ذات نسبة الصوف من ٥٠% إلى ٩٠% يتراوح بين 0.015 (كجم/كجم) إلى 0.094 (كجم/كجم) بينما العينات ذات نسبة الصوف من ١٠% إلى٤٠% يتراوح بين 0.11 (كجم/كجم) إلى 0.348 (كجم/كجم) ، أيضاً نسبة غاز ثاني أكسيد الكربون (co_2) فى العينات ذات نسبة الصوف من ٥٠% إلى ٩٠% يتراوح بين 0.725 (كجم/كجم) إلى 1.073 (كجم/كجم) بينما العينات ذات نسبة الصوف من ١٠% إلى ٤٠% يتراوح بين 1.096 (كجم/كجم) إلى 1.688 (كجم/كجم) وهذا يوضح أنه كلما زادت نسبة الألياف الصناعية فى المنتجات زادت خطورتها نتيجة زيادة تصاعد كلا من غاز أول أكسيد الكربون و غاز ثاني اكسيد الكربون، كما يتضح من النتائج أنه إبتداء من نسبة الخلط ٥٠% صوف٥٠ % بولى إستر كانت كثافة الدخان أقل بنسبة النصف من أقل نسبة من نتائج الخلط ٤٠% صوف٦٠ % بولى إستر إلى ١٠% صوف٩٠ %بولى إستر و هذا يدل على أن كلما زادت نسبة الصوف كلما قلت كثافة الدخان الناتج من الإحتراق و ذلك يحقق الأمان المطلوب بالسجاد لأن كمية الدخان تؤثر بشكل مباشر على صحة الإنسان ،إذن حقق الخلط ٥٠% صوف٥٠ % بولى إستر النتيجة المطلوبة – نوعا ما – بالمقارنه للنسب من ١٠% صوف إلى ٤٠% صوف، كما أوضحت نتائج حرارة الإحتراق أن العينات ذات نسب الخلط من ٥٠% صوف٥٠ % بولى إستر إلى ٩٠% صوف ١٠ % بولى إستر أعطت حرارة إحتراق من18.57 (ميجا جول/كجم) إلى 19.801 (ميجا جول/كجم) أما العينات ذات نسب الخلط من ٤٠% صوف٦٠ % بولى إستر إلى ١٠% صوف ٩٠%بولى إستر اعطت حرارة إحتراق نسبيا اقل من 17.124 (ميجا جول/كجم) إلى 19.462 (ميجا جول/كجم) و يرجع ذلك إلى زيادة نسبة الألياف الصناعية بها.

ومن ثم خلصت النتائج إلى أن كثافة الدخان وأول أكسيد الكربون وثاني أكسيد الكربون وحرارة الاحتراق للعينة ذات نسبة الخلط ٥٠% بوليستر أو أقل و٥٠% صوف أو أكثر أقل من العينات ذات نسبة الخلط ٤٠% صوف أو أقل و٦٠% بوليستر أو أكثر وبالتالي فإن نسبة الخلط ٥٠% صوف و٥٠% بوليستر قد حقق أقل نسب في الإنبعاثات الناتجة عند الإحتراق .

الكلمات المفتاحية:

السجاد، كون كالوريميتر، نواتج الإحتراق، الإنبعاثات

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