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DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

Low cost protection system of infrastructures against forest fires

Gilberto Vaz*[1,2]; Jorge Raposo[1,2]; Luís Reis[2]; Pedro Monteiro[2]; Domingos Xavier Viegas[2]

[1] *Coimbra Polytechnic - ISEC. Coimbra, Portugal, {gcvaz@isec.pt}*
[2] *Univ Coimbra, ADAI, Department of Mechanical Engineering, Rua Luís Reis Santos, Pólo II, 3030-788 Coimbra, Portugal {jorge.raposo, luis.reis, xavier.viegas}@dem.uc.pt, {pedro.mj.monteiro@gmail.com}*

**Corresponding author*

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Abstract

Forest fires are one of the main disasters that devastate many countries every year. The destruction caused by these phenomena generates social impacts putting at risk the population lives, environmental impacts due to the extreme deforestation and the high number of pollutants that are released to the atmosphere but also extremely important economic impacts caused by the destruction of a wide range of infrastructures and essential goods. Therefore, as it is impossible to remove all the infrastructures from the forest and from the wildland-urban interface, the development and installation of protection systems is essential. The main objective of this work is the development of a low cost protection system, with rigid panels, requiring a simple and easy installation, to protect outdoor infrastructures such as telecommunications stations, shelters, roadside enclosures, power cabinets, and other structures. A study was carried out on panels that could be used for the protection in order to determine whether the protective material would be more appropriate. Taking into account the fire resistance behaviour, thermal and structural properties and cost, the panels selected were the magnesium oxide fibreglass reinforced. The protection was constructed, installed on a telecommunication cabinet and experimentally laboratory tested in a wind combustion tunnel. To collect the data Infrared and video cameras, heat flux sensors and sheathed thermocouples were used to determine the fire propagation, heat flux and temperatures, respectively. The data obtained in the experimental tests show clearly that the simple low cost protection is effective for the protection of telecommunication cabinets and other similar infrastructures against forest fires.

1. Introduction

Forest fires are one of the main disasters that devastate many countries every year. The destruction caused by these phenomena generates impacts at several levels, whether social by putting at risk the population lives, whether economic through the destruction of a wide range of infrastructures and essential goods, or the environment. The forest fires that have been occurring in Portugal, and especially those in 2017, have highlighted the importance of infrastructures protection. In 2017, until October, 356 large forest fires (burned are larger than 1000ha) were recorded with an estimated burned area of 520,515 hectares (ANACOM, 2017). It was also in this year that the Pedrógão Grande fire occurred and it is known as one of the worst fires in Portugal and Europe. This terrible catastrophe took the lives of dozens of people, injured hundreds and caused a wave of destruction. During this fire, a lot of infrastructures were destroyed, including telecommunications stations, poles, copper and fiber optic cables, leading to numerous communication problems. "The failure of the communications system may have contributed to the lack of coordination of combat and rescue services, to the difficulty of people asking for help and to the worsening of the consequences of the fire" (Xavier et al., 2017). In the context of the high risk of forest fires in Portugal, a work has emerged whose objective is to develop a protection system applicable to infrastructures that are inserted in forest areas and that can be affected by forest fires.

According to (Andrade & Souza, 2015) the materials used for fire protection can be classified into three major groups: rigid and semi-rigid materials; intumescent paints; sprayed materials. (Takahashi, 2019) showed that the use of protective blankets made up of multiple layers of fibers allows the protection of infrastructures against fire. However, the application of this type of protection only becomes viable when the exposure time is relatively short, since for longer exposures, deterioration of the protection becomes evident. The work developed emerges as a continuation of previous studies (Brinca, 2020), in which a fiberglass blanket coated with aluminium was used in order to protect a telecommunications cabinet. This protection, in addition to being effective in protecting against fire, also showed that the temperature inside the cabinet increased even when there was no exposure to fire. Thus, the author left open the possibility of using another type of protection. As forest fires are transient phenomena, thermal inertia of the protection is important to reduce the temperature increase of the protection and air inside the cabinets or enclosures. So, in this work, rigid panels will be used and applied to cabinet stations to test the fire resistance, in adverse conditions.

2. Experimental methodology

The first step of the work was the study and selection of the most appropriate material panel for the protection. The panels to be used in the protection must be impact resistant, fire resistant, resistant to climatic adversities and must have low thermal conductivity and high thermal inertia to withstand outdoor ambient conditions and forest fire transient effects. Several panels were identified and compared as shown in Table 1. The selected panel was the MAGOOX Board panel with 9mm thickness (MGOBoard, 2020) since that the boards are produced with thicknesses of 4 to 18mm being the thickness of 9mm an average value that does not turn the protection into a heavy structure. This material meets all the requirements for the protection material and it is non-toxic, has a low environmental impact and low price. The current approximate European price of the selected panel is 12€/m^2. This panel is composed of fiberglass reinforced magnesium oxide and has a fire resistance of 60 to 90 minutes. Generally, forest fire fronts have a residence time of no more than 15 to 20 minutes and they can reach very high propagation speeds (Raposo et al., 2018).

Table 1 – Commercial panels identified for the study.

Commercial name	DuraSteel	Promatec-XW	WeatherKem	SpeedPanel	MAGOOX Board	TriplacM
Composition	2 perforated steel plates and fiber reinforced cement core	Gypsum board with mat reinforcement	Mixture of cement, cellulose fibers and silicon-based binders	Cement core and galvanized steel cladding	Magnesium oxide reinforced with fiberglass mesh	Magnesium, fiber reinforced and other refractory materials
Thickness [mm]	9,5	15	6-18	51; 64; 78;	4-18	24-30
Fire resistance [min]	240	≤ 60	are completely non-combustible	Varies with thickness (60; 90; 120)	60-90	180-240
Resistance to climatic adversities	Yes	Yes	Yes	Yes	Yes	Yes
Impact resistance	Yes	Yes	Yes	Yes	Yes	Yes
Thermal conductivity (20ºC aprox.) [W/m.K]	0.55	0.264	0.24	Varies with cement densities	0.213	0.29

The protection was constructed and installed on a telecommunication cabinet as shown in Figure 1.

Figure 1- a) Telecommunication cabinet; b) Protected telecommunication cabinet.

To study the thermal behaviour of the cabinet and its protection, they were subjected to a series of tests carried out at the LEIF-ADAI facilities using the Combustion Tunnel 3 (CT3), which has two 35kW fans that can generate air speeds of up to 8m/s. This tunnel has dimensions of 8m length, 6m width and sidewalls of 2m height. The experimental apparatus is shown in Figure 2. The fuel bed area was defined by fixed length and width of 4m, corresponding to the 16m^2, with a fuel load of 1.5kg.m^{-2} of typical Mediterranean shrubs composed by a mixture of *Erica umbelatta*, *Erica australis*, *Ulex minor* and *Chamaespartium tridentatum*.

Figure 2- a) Combustion tunnel CT3; b) General view of the tests.

The existence or not of protection and the existence of side walls (which avoid lateral air entrainment promoting the arrival of a structured front, without edge effect) were tested. The list of tests performed and the respective variables are presented in Table 2 and they were performed in random order.

Table 2 – Conditions of the experimental tests performed.

Ref.	**Wind speed (U [m/s])**	**Protection**	**Side walls**
01	0	Yes	No
02	1	Yes	No
03	3	Yes	No
04	0	Yes	Yes
05	1	Yes	Yes
06	3	Yes	Yes
07	0	No	No
08	1	No	No
09	0	No	Yes
10	1	No	Yes
11	3	No	Yes

In the tests it was used an InfraRed FLIR Camera SC660, a heat flux sensor (Hukseflux sensor IHF01) and five sheathed K-type thermocouples of inconel with 1mm diameter. The referred equipment was used to determine the fire propagation, heat flux and temperatures. Additionally, at all the tests, two optical video cameras were used. One (Sony FDR-AX53) placed in a lift platform and the other (Sony HXR-NX30E) at ground level. Experimental setup is shown in Figure 3**.**

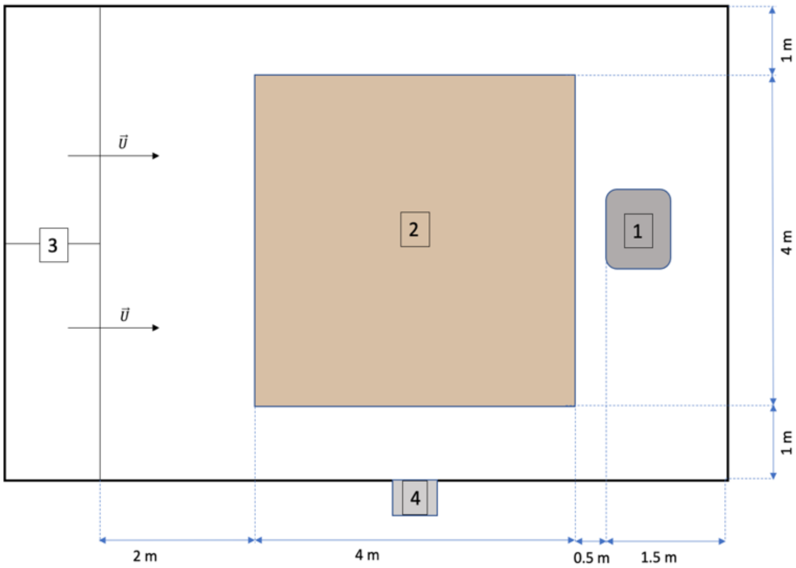

Figure 3- Experimental setup

(1 - Telecommunication cabinet, 2- fuel bed, 3- wind tunnel fans, 4- infrared and video cameras).

For the installation of thermocouples and heat flux sensor in the cabinet and respective protection, an acquisition board NI chassis cDaq 9174, a thermocouple board 9213, a voltage board 9211 and a computer with the *signalExpress* program with an acquisition frequency of 1Hz were used. The thermocouples and heat flux sensor were installed in the following positions:

Thermocouple 1(T_1): placed inside the cabinet (roughly in the center, about 1.30m from the ground) ;

Thermocouple 2 (T_2): placed on the inner front surface of the protection (about 1.30m from the ground) and in the tests carried out without protection, this was placed on the side of the cabinet;

Thermocouple 3 (T_3): placed on the outer front surface of the protection or cabinet (in absence of the protection), at about 1.30m from the ground;

Thermocouple 4 (T_4): placed behind the cabinet about 1m away in order to be able to assess the downstream air temperature;

Thermocouple 5 (T_5): placed on the sidewalls (when applicable);

Heat flux sensor: placed on the outer front surface of the protection (or of the cabinet, respectively, if testing with or without protection), approximately 1.30m from the ground. The flux and temperature values at the various points of the shield protection and cabinet were taken directly from the thermocouple data and converted into Microsoft Excel®.

3. Analysis and discussion of results

Figure 4 and 5 shows the temperature evolution in two tests performed with the protection applied to the telecommunications cabinet and 3m/s wind speed (highest wind tunnel speed which is the most critical situation tested and corresponding to the typical wind speeds of intense forest fires). Regarding the temperature inside the cabinet, it is possible to verify that the maximum temperatures do not exceed 30ºC, proving that the use of the protection under study is capable of protecting the cabinet against the high temperatures and heat fluxes of a forest fire.

Figure 6 shows the temperature evolution in the test performed without protection applied to the telecommunications cabinet and 3m/s wind speed. For this case, the evolution of temperatures is quite similar to that observed previously. However, there is a considerable difference with regard to the maximum temperature registered inside the cabinet, reaching a value above 60ºC. This value is considered critical for the normal operations of communication equipment.

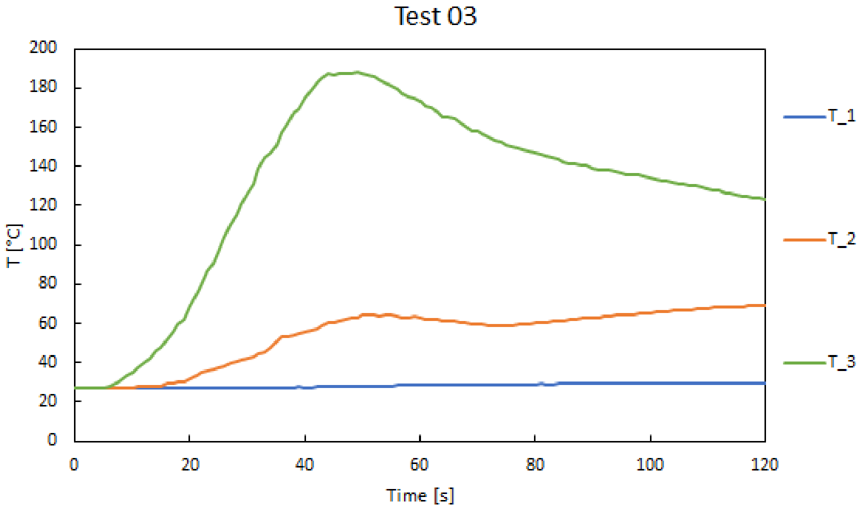

Figure 4- Evolution of temperatures in Test 03.

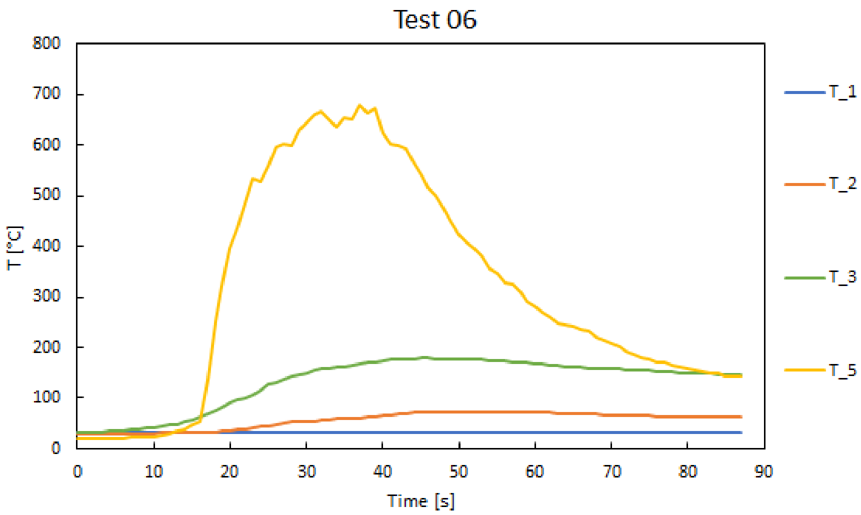

Figure 5- Evolution of temperatures in Test 06.

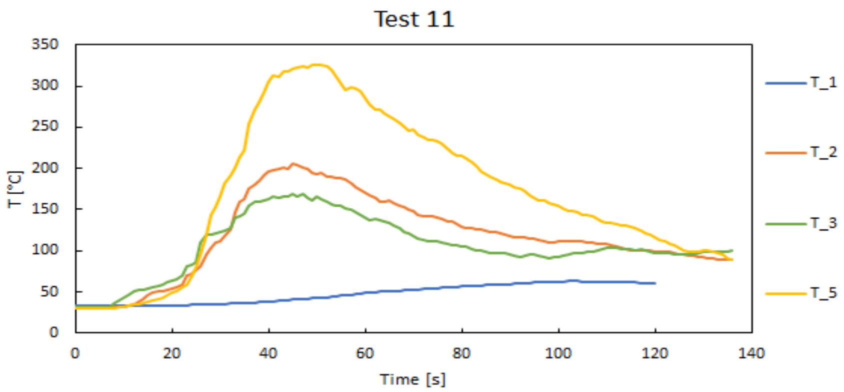

Figure 6- Evolution of temperatures in Test 11.

Table 3 presents a summary of the experimental results and it can be easily concluded that the protection system is effective as the maximum temperature inside the cabinet remains below 30°C, even with high fireline intensities.

Table 3 – Main results of the tests performed.

Test Reference	Protection	Wind speed [m/s]	Side walls	Max dimensionless rate of spread	Maximum fireline intensity [MW/m]	Maximum external surface temperature [ºC]	Maximum temperature inside cabinet [ºC]	Max Heat Flux [kW/m^2]
01	Yes	0	No	1.95	0.59	90.63	24.10	1.85
02	Yes	1	No	7.73	2.34	158.90	26.97	5.87
03	Yes	3	No	18.10	5.48	188.63	29.72	10.07
04	Yes	0	Yes	1.68	0.51	61.87	26.37	2.14
05	Yes	1	Yes	5.71	1.73	144.86	29.02	3.79
06	Yes	3	Yes	14.96	4.53	179.24	33.72	10.12
07	No	0	No	1.65	0.50	113.51	30.20	2.43
08	No	1	No	6.80	2.06	70.37	33.46	1.31
09	No	0	Yes	1.63	0.49	108.89	34.60	2.54
10	No	1	Yes	4.56	1.38	196.22	42.64	1.34
11	No	3	Yes	19.85	6.01	168.67	63.03	10.16

4. Conclusions

The data obtained in the experimental tests show that the simple low cost protection is effective to the protection of telecommunication cabinets and other similar infrastructures against forest fires. The protection avoided the high temperatures in the cabinet. The temperature obtained inside the cabinet, without protection, reached a value above 60ºC. This value is considered critical for the normal operations of communication equipment. Another great advantage of this protection is its low cost of material and labour for installation. In this case, the protection was built and installed at a cost of approximately 150 euros, increasing the protection of an asset that costs thousands of euros. Installing this type of protection does not compromise system operations at all. The access for maintenance or repairing is maintained since the plates are integrated in the movement of the openings of the cabinet.

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