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Drywall Panel Coated with Biochar for Electromagnetic Shielding Applications

Giuseppe Ruscica(1), Zahra Alinaghi(1), Isabella Natali Sora(1) and Patrizia Savi(2)
(1) Department of Engineering and Applied Sciences, Università di Bergamo, Dalmine, 24044 Bergamo, Italy, https://www.unibg.it/
(2) Electronic and Telecom Dept., Politecnico di Torino, Italy, http://www.polito.it

Abstract

Biochar, a material derived from biomass with a high carbon content, is a sustainable, renewable, eco-friendly, and cost-effective option in many applications. Recently, biochar has been added to construction materials in order to increase their electromagnetic shielding properties. In this work, commercially produced biochar, thermally treated at 750 °C, is applied in multiple layers on drywall panels aiming to develop a building component with increased shielding effectiveness for the construction sector. The transmission properties of drywall panels with several biochar layers are measured in the frequency band 1-12 GHz.

1 Introduction

Electromagnetic interferences (EMI) not only affect the performance of electronic equipment but also pose potential risks to human health, raising concerns about their impacts for safety and well-being [1]. Traditionally, metals with high electrical conductivity have been the primary choice for EMI shielding due to their excellent shielding properties [2]. Drawbacks of using metal shields are weight and density, high cost, corrosion susceptibility, and lack of flexibility [3]. Carbon-based materials can be a good substitute for metal shields. They provide several benefits, such as exceptional strength, high modulus, resistance to corrosion and fatigue, low density, and minimal thermal expansion [4]. However, the elevated cost of conductive fillers like carbon nanotubes, and carbon fibers, may hinder their application as EMI shielding materials in the construction sector. Current strategies focus on integrating EMI shielding into non-structural building components by emphasizing more cost-effective and sustainable alternatives, such as biochar [5, 6].

Biochar is a carbon-rich material produced by the thermochemical processing of biomass. Unlike metals and other synthetic carbon-based materials, biochar ehnanced exhibits the electromagnetic shielding properties of construction materials [7]. Incorporating biochar into innovative construction materials can provide economic advantages through carbon trading, encouraging the construction and building sector to significantly reduce overall carbon emissions [8]. In this work, the shielding effectiveness of drywall panels coated with several layers of biochar is measured and compared with a reference drywall panel.

2 Shielding effectiveness and sample preparation

Consider a dielectric slab of thickness d in air and a plane wave incident from the left. The shielding effectiveness (SE) is defined as:

$$SE = 20\log_{10}\frac{E_t}{E_i} \tag{1}$$

where E_i is the electric field of the plane wave incident on the left, E_t is the transmitted electric field. In case of drywall panel with and without biochar coating, the SE can be obtained from the measurements of the transmitted field. The SE measurement environment was prepared by cutting a 300x300 mm^2 square hole in a holder placed inside an anechoic chamber where the sample is inserted. The scattering parameter S_{21} is measured as a function of frequency without the sample (S_{21}, ref) and with the sample made of drywall coated with biochar coating present (S_{21}, sample) and the SE evaluated.

In this work, commercial drywall panels of 10 mm thickness are covered on one side with a coating based on commercial biochar (Carlo Erba). The wood biomass biochar supplied by Carlo Erba is treated at 750 °C for four hours. The coating is prepared by mixing biochar, water, methyl hydroxyethyl cellulose (MHEC), and ammonia (NH_3) in different proportions. The mixture is manually applied on the drywall panel. Then, the panel is cured in ambient conditions (T=25°C and relative humidity 50%) for 24 hours. This process is repeated multiple times until panels with the desired number of layers are obtained. A reference specimen consisting of a drywall panel itself is also considered for the experimental tests (see Figure 1).

3 Results

Transmission measurements were made in an anechoic chamber using double-ridged, linearly polarized broad-

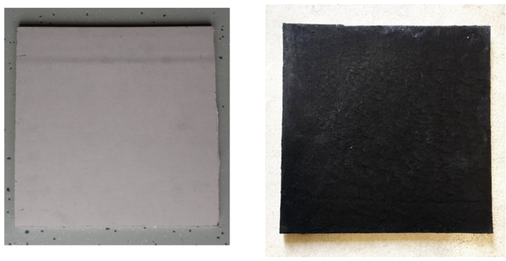

Figure 1. Drywall reference sample without coating (left) and drywall with multiple layers of biochar (right).

band horn antennas (1 GHz–12 GHz) mounted on a 3-axis positioner and connected to a vector network analyzer (Keysight, N5227A). The anechoic chamber (dimensions of 2 m × 4 m × 2 m) has the walls, ceiling, and floor covered with pyramidal microwave absorbers designed from 1200 MHz up to 90 GHz. The transmitting and receiving antennas, as well as the sample under test, are positioned inside the chamber, while the signal generator and receiver are placed outside to eliminate interference. The samples are mounted on a holder positioned between the two horn antennas. The antennas are spaced 2.5 meters apart. The wooden holder is covered with a metal sheet and has a window of 30 cm x 30 cm where the sample under test can be fixed. The Shielding effectiveness is determined by comparing the signal levels measured with and without the sample.

The SE of drywall panel of 10 mm thickness covered on one side with 2, 3, and 5 layers of biochar is measured. Results are shown in Figure 2 and compared with a drywall panel without any coating. Increasing the number of biochar layers on the drywall leads to an increase in the SE value. Considering f = 10 GHz, the drywall panel alone is almost transparent (SE = 0.5 dB) while the SE increases to 9.5 dB, 11 dB and 12 dB for the case of 2, 3, and 5 layers, respectively.

4 Conclusions

Commercial biochar has been used as a coating on standard drywall panels and the SE measured in the frequency band 1-12 GHz. Results show Drywall panels without coating have a very low SE, which can be considered approximately equal to 0 dB. By adding two or more layers of biochar to the drywall, the SE value increases. Panels with two and three layers of biochar perform almost similarly, but increasing the number of layers to five results in a improvement in SE, rising from approximately 7 dB for two layers to around 10 dB for five layers.

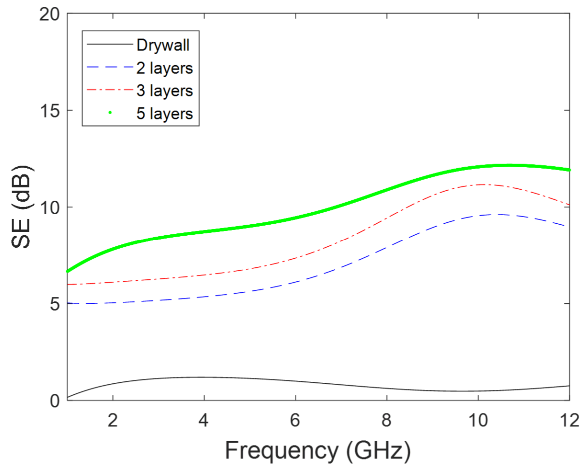

Figure 2. Shielding effectiveness of samples with 2, 3 and 5 layers of biochar

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