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IMPACT ACOUSTIC ISOLATION OF ETHYLENE VINYL ACETATE PANELS

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Abstract— Ethylene Vinyl Acetate (EVA) foam is used in fitness facilities floors because of its shock absorption and isolation properties. Varying some material properties such as density and thickness, a range of these materials have been studied in order to evaluate their dynamic and acoustic behaviour. Two material properties (dynamic stiffness, and sound absorption coefficient) have been characterized according to the corresponding standards: ISO 9052 and ISO 10534-2. The results provide useful information to evaluate the influence of the density and thickness in the dynamic and acoustic behaviour of these materials.

Keywords— Ethylene Vinyl Acetate, Dynamic stiffness, Acoustic impedance.

I. INTRODUCTION

BUILDING standards for the acoustic behaviour of the materials used on pavement slabs and walls in buildings are becoming more restrictive. Given these requirements, interest in research and the development of materials to improve acoustic insulation and conditioning in buildings is increasing.

In architectural acoustics, the behaviour of materials is defined mainly by sound transmission loss, acoustic impedance and dynamic stiffness. The determination of these parameters by means of different methods has resulted in today's standards.

The first method to measure the sound absorption coefficient and the transmission loss factor based on standard test method ASTM E1050 [1] was proposed by J.S. Bolton [2], who provided two other microphones located downstream of the sample and an anechoic termination. Another noteworthy work is that of P.S. Allan, which focused on investigating the property of sound transmission loss (STL) in a series of polymer and polymer composites [3].

Several studies about floor impact-noise isolation types of floating floors are available. One of the first approaches to this problem was the works of Cremer [4] and Ver [5]. To improve the impact-noise isolation of a structural floor, it is usual to add a floating floor using a resilient layer under a rigid floating slab. One of the parameters that determines the performance of these floors is the dynamic stiffness of the resilient material [6],[7]. in accordance with Standard EN 29052.

Regarding materials, one research field is the application of mortars with additives, such as expanded polystyrene, expanded cork and expanded clay granulates, and the comparison of the acoustic behaviour of these solutions using a small-sized acoustic chamber [8], [9]. For insulating applications, mortars have also been reinforced with recycled tyres to reduce pollution caused by noise [8]- [11].

From an environmental point of view, some works have developed recycled and/or natural materials for acoustic applications, such as corn cob particleboard, kenaf's fibres and others [12],[13].

Thermoplastic materials, such as polyurethane and polypropylene, can be an alternative to available sound-insulating materials [14], [15].

Due to the shock absorption and isolation properties of rubber compounds, several works have focused on determining dynamic stiffness and damping [16]-[19].

In the present work, ethylene vinyl acetate (EVA) samples of different densities and thicknesses were manufactured. EVA has many applications, such as hoses, medical tubing, greenhouse films, gloves, etc. When foamed in the microcellular form, it can be used to make parts of tyres, knee pads, flexible toys, sound proofing for automotive use or sports items.

In this study, we were interested in making full use of the acoustic and dynamic properties of EVA to find a new applicability in insulating and conditioning applications. To achieve the study aim, dynamic stiffness, acoustic impedance and sound transmission loss were the parameters used to evaluate the behaviour of the test specimens.

II. EXPERIMENTAL

A. Materials

Ethylene vinyl acetate (EVA), or *Expanded Rubber*, is a material that is copolymerised from ethylene and vinyl acetate, and is randomly distributed along the backbone. Its properties depend on the vinyl acetate level, crystallinity, the branching level, molecular weight and polarity [20].

Copolymers with a low vinyl acetate content (2-10%) have similar properties to those of low-density polyethylene. For a vinyl acetate content of 40-50%, the copolymer is an amorphous resin that is easily crosslinkable. Resins with a high vinyl acetate content (60-90%) are very often emulsions or dispersions in water used for the modification of other polymers, and also as carriers for plastic and rubber additives. When vinyl acetate content rises, polarity increases and crystallinity decreases. Among the mechanical properties, tensile strength, hardness and stiffness diminish with increasing vinyl acetate content [21].

For this work, plate EVA samples with a high vinyl acetate content were manufactured to pursue good sound insulating and conditioning properties. All the samples had the same chemical composition that was divided into a solid phase and a gas phase, including EVA copolymer crosslinked (70%), silica and calcium carbonate as a reinforcing filler (23%), process aids like wax (4%), pigments (2%) and peroxides as a crosslinking agent (1%). The mixture is introduced into a hold plate press at 80ºC for 25 minutes. It is possible to vary the pressure of the press between 10-20 MPa to obtain the different densities studied: 130 kg/m^3, 200 kg/m^3, 230 kg/m^3, 300kg/m^3, 360 kg/m^3.

TABLE I
MATERIALS

MATERIAL	DENSITY (kg/m^3)	THICKNESS (m)
Test specimen 1	360	0.01
Test specimen 2	300	0.01
Test specimen 3	230	0.01
Test specimen 4	200	0.01
Test specimen 5	130	0.01
Test specimen 6	300	0.029
Test specimen 7	300	0.020
Test specimen 8	300	0.016
Test specimen 9	300	0.012
Test specimen 10	300	0.01

B. Experimental Setup

To characterize these materials from the dynamic and acoustic points of view, two standard test methods were used: ISO 9052 for dynamic stiffness and ISO 10534-2 for acoustic impedance.

Specific acoustic impedance is the ratio of acoustic pressure to specific flow. According to Standard ISO 10534-2 specific acoustic impedance is the ratio of acoustic pressure to specific flow. According to Standard ISO 10534-2, the apparatus consists of an impedance tube, which has a constant circular section (interior diameter of 40 mm).

The sample is located at one end of the tube and a sound source generates plane waves from the other end. Acoustic pressures are measured by two microphones located close to the sample. From the measured signals, the transfer function is determined to calculate the complex reflection coefficient, the sound absorption coefficient and acoustic impedance. To calculate the specific acoustic impedance, according to the standard:

$$\frac{Z}{\rho \;\; c_0} = \frac{R}{\rho \;\; c_0} + j \;\; \frac{X}{\rho \;\; c_0} = \frac{(1+r)}{(1 \;\; r)} \tag{1}$$

Where R is the real component, *X* the imaginary component, $\rho{\cdot}c$ characteristic impedance, *r* is the reflection coefficient.

The reflection coefficient is:

$$r = \frac{H_{12} \;\; H_i}{H_R \;\; H_{12}} \;\; e^{2 \; j \; k_0 \;\; x_1}$$

(2)

H_{12}, is the transfer function from microphone positions 1 and 2, H_R, is the real part of H_{12}, H_i is the imaginary part of H_{12}, k_0 is the wave number, x_1 is the distance between the sample and the first microphone.

The frequency range is determined by:

$$f_1 < f < f_u \tag{3}$$

f_l is the lower frequency of the tube, f is the frequency, f_u is the upper frequency of the tube.

The impedance tube must be long enough to permit the waves to be planed before the sample. Matlab is used for controlling the analogue input and for processing signals.

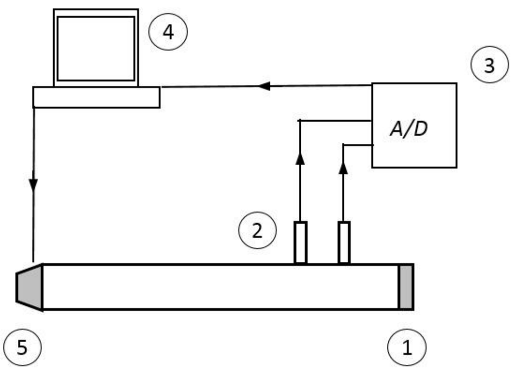

Fig. 1. Apparatus used to measure the sound absorption coefficient, where: 1) is the sample; 2) the two microphones (microphones G.R.A.S. model 40AO); 3) the data acquisition system (NI-9233); 4) the PC and 5) the sound source.

Dynamic stiffness is an important property for testing the impact sound insulating of materials. The lower dynamic stiffness is, the better the impact sound insulation becomes. Dynamic stiffness is often determined by measuring the resonant frequency of a Single-Degree-of-Freedom (SDOF) mass-spring system, which consists in a test sample of the insulating material under a known mass. Above this resonant frequency, the underlying material isolates the impact sound. Therefore, the resonant frequency of the assembly should be as low as possible.

Standard ISO 9052-1 utilizes an SDOF system for calculations. The test data are obtained from an accelerometer and an impact hammer.

$$\mathbf{s = 4\pi^2 m_t f_r^2} \tag{4}$$

Where m_t is the mass per unit length of the upper plate and f_r is the resonance frequency in Hz.

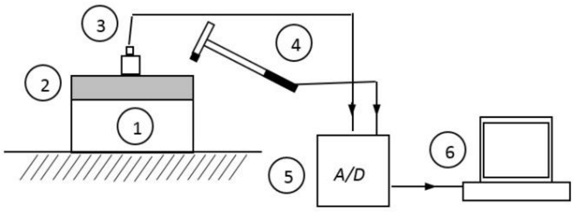

Fig. 2. Apparatus used to measure the dynamic stiffness, 1) is the test specimen; 2) is the upper steel plate; 3) the accelerometer (PCB 352C42); 4) the impact hammer (PCB 086C01); 5) the data acquisition card (NI-9233) and 6) the PC.

III. Results and discussion

For the sound absorption the results are low for all the densities in all the frequency range, and it can be concluded that the test specimens are not an efficient sound absorbing materials. However, at certain frequencies, the sound absorption coefficient is increased and differences between densities can be observed. So, for lower densities there are absorption peaks at certain frequency ranges. Variations in thickness show no clear trend in the sound absorption coefficient. It can not be concluded that a certain thickness has a better behaviour at a particular frequency range for the sound absorption coefficient.

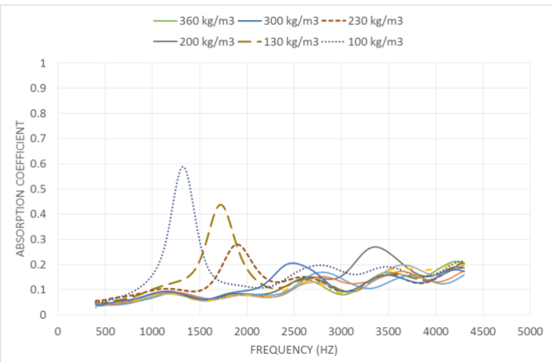

Fig.3. Shows the influence of the density in the sound absorption coeficient in EVA samples of thickness 10 mm.

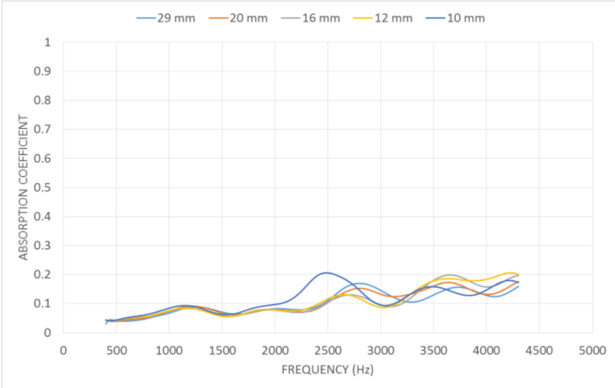

Fig.4. Shows the influence of the thickness in the the sound absorption coeficient in EVA samples of density of 300 kg/m3.

Variations in thickness show no clear trend in the sound absorption coeficient. It cannot be concluded that a certain thickness has a better behaviour at a particular frequency range for the sound absorption coefficient.

Dynamic stiffness is an important parameter when designing floating floors, and the lower the value, the better impact sound insulation becomes. Poor dynamic stiffness is desirable to obtain a low natural vibration frequency of floating floors. Figure 5 shows the influence of the density in the dynamic stiffness in EVA samples of thickness 10 mm. These results show that the increase in density of the material produces an increase in the dynamic stiffness. Figure 6 shows the influence of the thickness in the dynamic stiffness in EVA samples of density of 300 kg/m3. These results show that the increase in thickness of the material produces a decrease in the dynamic stiffness.

The dynamic stiffness for different polymers used as resilient materials, e.g., synthetic polystyrene or treated rubber material mixed with elastomer elements, was measured and their values were frequently lower than 30 MN/m^3 [22]. The dynamic stiffness values of the commercial rockwool samples for floor applications [23] were under 20 MN/m^3.

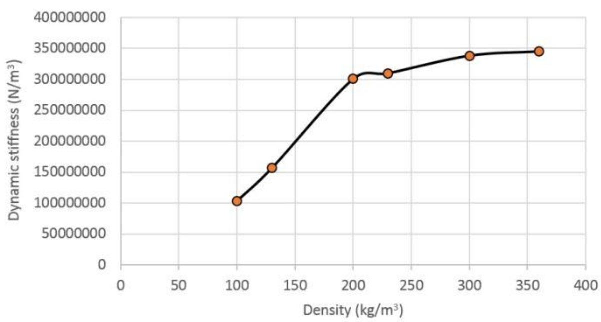

Fig.5. Influence of the density in the dynamic stiffness in EVA samples of thickness 10 mm.

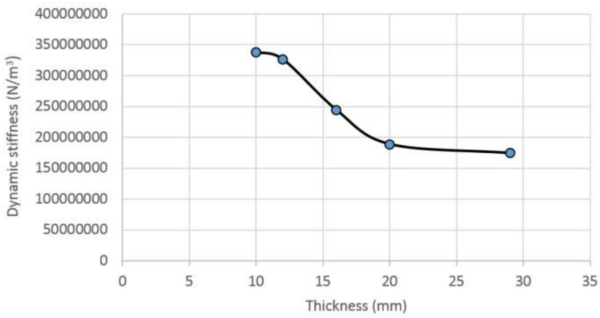

Fig.6. Influence of the thickness in the dynamic stiffness in EVA samples of density of 300 kg/m3.

IV. CONCLUSIONS

To evaluate the shock absorption properties, one of the most important characteristics are the dynamic stiffness that define the impact sound insulation. For a particular application in fitness facilities, it is desirable that the dynamic stiffness is low.

In general, these EVA modular plates present low sound absorption coefficients. This can be explained by the closed cell surface structure, with high sound impedance and sound reflection coefficients close to one. The results give us useful information in order to conclude that these materials maybe could be used for acoustic isolating, but not for acoustic conditioning.

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