DYNAMIC PROPERTIES OF A COMPOSITE MADE OF GRANULATED CORK AND RICE HUSK

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Abstract *The construction industry is responsible for serious environmental impacts because of its consumption of non-renewable raw materials and the use of large amounts of embodied energy in the constructive components. The quest for sustainability in the construction of buildings involves the use of renewable or natural raw materials in the building components. This study investigates the possibility of using rice husk and granulated cork as a composite material. Composite boards were manufactured and preliminary tests performed to characterize the dynamic properties of the composite with a view to assessing its ability to attenuate vibration. Samples of different thicknesses and dimensions were tested for different loads and excitation frequency using an appropriate laboratory test rig. The dynamic stiffness and frequency transmissibility curves of the samples were obtained for each test.*

1. INTRODUCTION

A large amount of resources are used over the life cycle of a building (design, construction, use and demolition) and significant impacts are produced, including effects on the environment, energy consumption and climate change. The impacts can be reduced by creating more sustainable buildings. The use of raw materials can be reduced significantly by incorporating recycled or reclaimed materials in construction projects and reducing waste disposal by converting waste materials into useful new products [1].

To meet policy requirements of using materials with low environmental impact researchers have investigated ways to introduce sustainable materials (natural or recycled) in building construction. For acoustic applications in buildings, tea-leaf fiber waste [2], coir fiber [3], cotton, flax, ramie, wool, jute, hemp, sisal (fibers), straw and reeds have been studied for sound absorption purposes [4].

Rice husk is an agricultural residue that was largely considered a waste product and was often burned or dumped in landfills. However, recently it has been reclaimed to produce electricity [5] and some research has been performed to use rice husk ash as cement replacement [6], as a partial replacement for clay in bricks [7], and to produce particleboards manufactured from wood, bamboo and rice husk [8]. Cork is a renewable and recyclable material and is an abundant resource in Portugal, which is, in fact, one of the largest cork producers worldwide. This material is widely used for insulation and as a vibration attenuator in stands and supports for machines [9, 10].

Research is underway to explore the possibility of using rice husk and granulated cork to produce a composite material. Composite boards were manufactured to study their properties to ascertain whether they could be used in buildings for acoustic or thermal applications. In this paper we present results of preliminary tests performed to characterize the dynamic properties of the composite and assess its capacity to attenuate vibration in buildings. Samples of different thicknesses and dimensions were tested for different loads and excitation frequency using an appropriate laboratory test rig. The dynamic stiffness and frequency transmissibility curves of the samples were obtained for each test.

2. METHODOLOGY

The main objective of the tests was the dynamic characterization of the composite. The dynamic properties can be determined from parameters such as dynamic stiffness, vibration transmissibility and loss factor.

For a single-degree-of-freedom forced vibration model, the ratio between the maximum force transmitted to the support system and the amplitude of the applied force is known as the transmissibility (T). The experimental procedures described in this work follow the methodology presented in ISO 10846-3:2002 [11], which sets out a method for determining the dynamic transfer stiffness of resilient supports, under specified preload. The method concerns the measurement of transmissibility.

The present method is called an indirect method and the transmissibility of a resilient element is measured with the output loaded by a compact body of known mass. We measured the accelerations to compute the transmissibility. The test apparatus comprises a vibration exciter connected to an excitation mass that holds the test sample, on which is placed a blocking mass that works as static preloading system (see Figure 1).

The dynamic transfer stiffness is the ratio of the complex force on the blocked output side of a resilient element to the complex displacement on the input side during sinusoidal vibration. The transmissibility is computed as the ratio of the complex accelerations, $T = a_2/a_1$. For sinusoidal vibration and using complex notation, the relation between the dynamic transfer stiffness of the element under test and the measured vibration transmissibility is given by

$$k_{2,1} \approx \frac{\underline{F_2}}{\underline{u_1}} \approx -\left(2\pi f\right)^2 m_2 T \quad \text{for } |T| \ll 1 \tag{1}$$

where m_2 is the blocking mass.

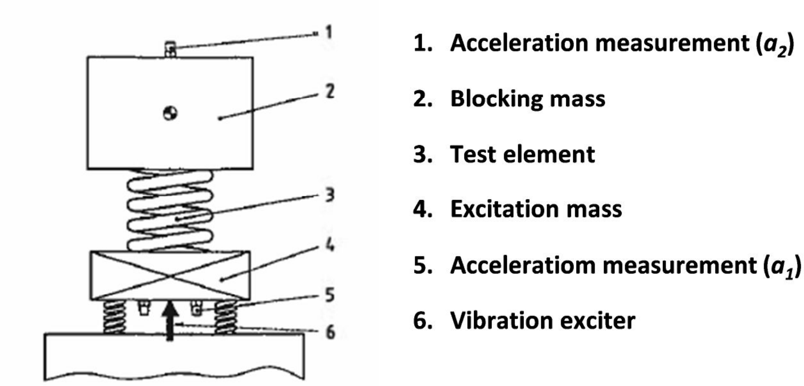

Figure 1. Scheme of laboratory test rig for measuring the dynamic transfer stiffness for normal translations.

3. LAB SETUP AND SAMPLES

3.1. Measurement chain

The measurement chain was built at ITeCons. The dynamic excitation is provided by the movement of four eccentric rotating masses through an SEW servomotor, model CMP63M. The excitation frequency is controlled via Movitools®Motion Studio, version 5.70. The excitation mass, lying on a base supported by four springs with a total stiffness of 1031 kN/m, holds the test sample. The static preloading system (blocking mass) is placed above it. Three Endevco 752A12 accelerometers are mounted as follows: one on the output side of the sample (on the blocking mass), and two under the excitation mass. They are connected to an HBM MX840A datalogger. The datalogger works with Catman Easy v3.4 data acquisition software.

The excitation mass and the blocking mass are composed of steel blocks with a mass of around 74 kg each, fixed by screws.

3.2. Samples and procedure

Three thicknesses and dimensions were tested to assess the influence of the thickness and dimension of specimens on the dynamic properties (see Table 1). Figure 2 shows an example of a test specimen.

The sample is placed on the excitation mass and a specified blocking mass is then placed on the sample. The test starts with the lowest frequency chosen and ends at the highest specified frequency. The accelerations in the output side and input side are registered for each frequency, which allows the transmissibility and dynamic stiffness values to be calculated. Those results permit the representation of a complete transmissibility curve over the frequency range tested. The test is then repeated for different loads. A similar procedure is used for the other specimens to be tested.

Sample	S11	S12	S13	S21	S23
Thickness (mm)	31	31	31	21	21
Dimensions (mm^2)	490x490	300x300	200x200	490x490	200x200

Table 1. Dimensions of test specimens.

Figure 2. Example of test specimen.

4. RESULTS AND ANALYSIS

4.1. Transmissibility curves

In this section we present the transmissibility curves for the different test specimens, for different mass loads. Table 2 presents the identification of the various loading masses.

Figure 3 shows the transmissibility curves for test samples S11, S12 and S13 with thickness of 31 mm and dimensions of 490mmx490mm, 300mmx300mm and 200mmx200mm, respectively.

Designation	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Mass (kg)	73.80	147.50	221.40	295.20	369.00	442.80	516.60	590.40	664.20	738.00

Table 2. Identification of loading masses.

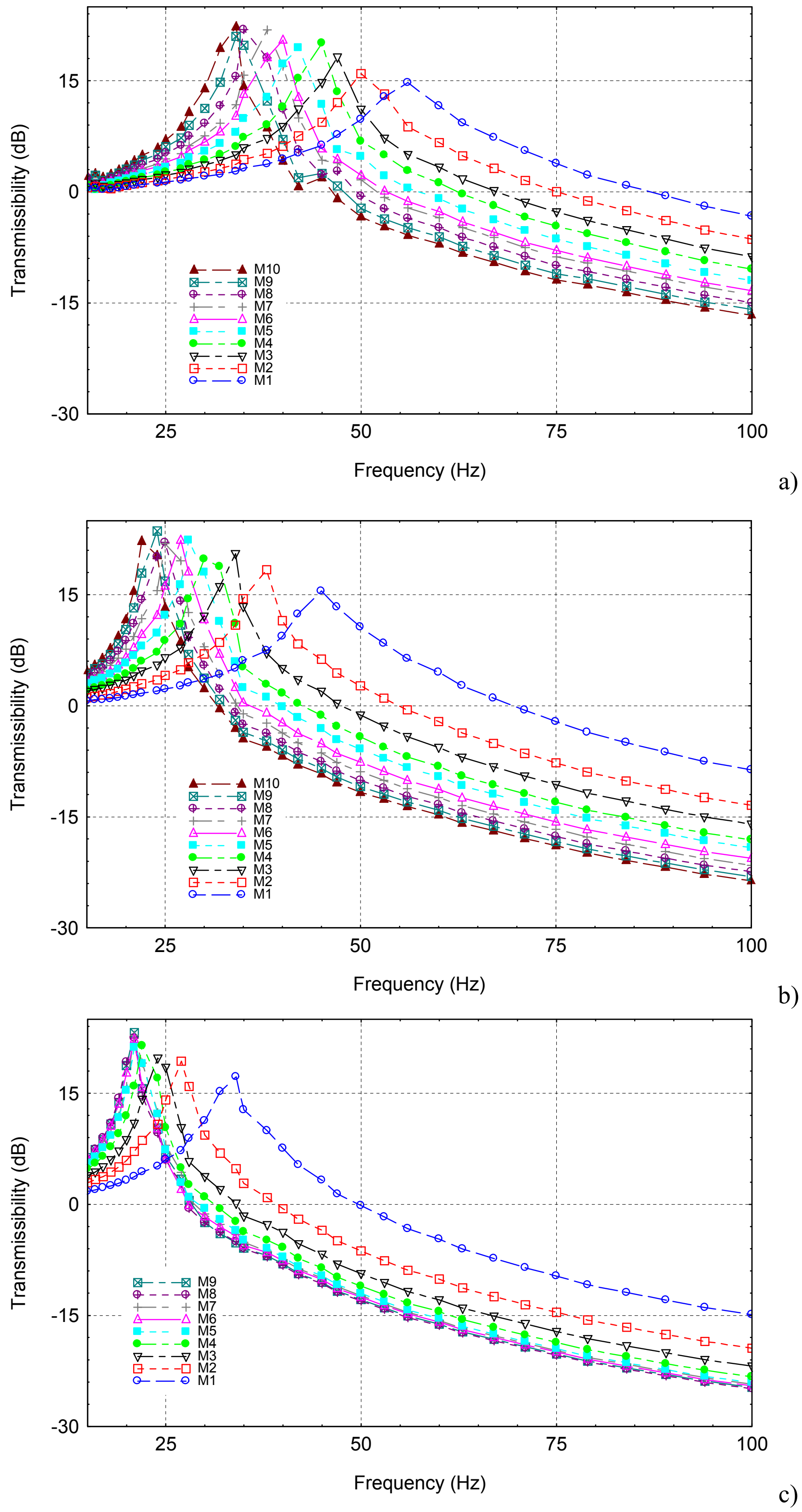

Figure 3. Transmissibility curves for specimens: a) S11; b) S12; c) S13.

In Figure 3 it can be seen that increasing the load mass leads to a decrease in the resonance frequency of the spring-mass system. For a given frequency, outside the resonance zone the transmissibility diminishes with the increase in load mass, which corresponds to higher vibration isolation levels.

When test specimen S11 was subjected to low loading masses (M1, M2, etc.) it did not have vibration isolation properties in the frequency range tested. The vibration isolation is only effective for higher masses. When the dimension of the test specimen decreases, for a given mass load the resonance frequency decreases and the vibration isolation increases for each frequency, in the isolation zone (compare Figures 3a, 3b and 3c).

In Figure 3c, for the higher loading mass, M9, the transmissibility is around -24 dB, which corresponds to about 93% of isolation. For test specimen S13, the transmissibility curves for higher masses overlap and thus the loading mass, M10, was not tested. For test specimens with the same thickness the best results are for specimens with smaller dimensions. However, the performance of those specimens does not improve if the mass is increased from a given loading mass.

Some of the transmissibility curves are not very smooth, maybe because of some heterogeneities in the cork and the rice husk mixture.

Figure 4 represents the transmissibility for test specimens 21 mm thick for the higher and the smaller dimensions, S21 and S23.

Comparing Figures 4a and 4b, the findings are similar to those shown in Figure 3 when comparing specimens of different sizes. The influence of the thickness can be seen by comparing Figure 4a with Figure 3a and Figure 4b with Figure 3c. The resonance frequency increases for smaller thicknesses. The vibration isolation is lower for a given frequency and a given mass. The best vibration isolation is achieved for higher thicknesses and smaller dimensions.

4.2. Dynamic stiffness

The dynamic stiffness has been calculated according Equation (1), for all the frequencies tested. Although standard ISO 10846-3:2002 recommends that the dynamic stiffness should be presented in one third octave bands, in this paper the values for all frequencies tested are presented. Figure 5 gives the dynamic stiffness curves for specimens S11, S12 and S21. The results are shown on a vertical logarithmic scale. The dynamic stiffness increases with the frequency until the resonance zone and decreases afterwards, with a tendency to stabilize. After the resonance zone the dynamic stiffness is lower for lower masses.

Since Equation 1 is only valid for values of transmissibility much lower than 1 (isolation zone), the values of dynamic stiffness to characterize the material should be chosen for frequencies where this state is achieved. In some cases for low loading mass, this state is not attained.

In Figures 5a and 5b it can be seen that the reduction of specimen size results in lower dynamic stiffness. From Figures 5a and 5c, it is evident that reducing the thickness leads to higher dynamic stiffness.

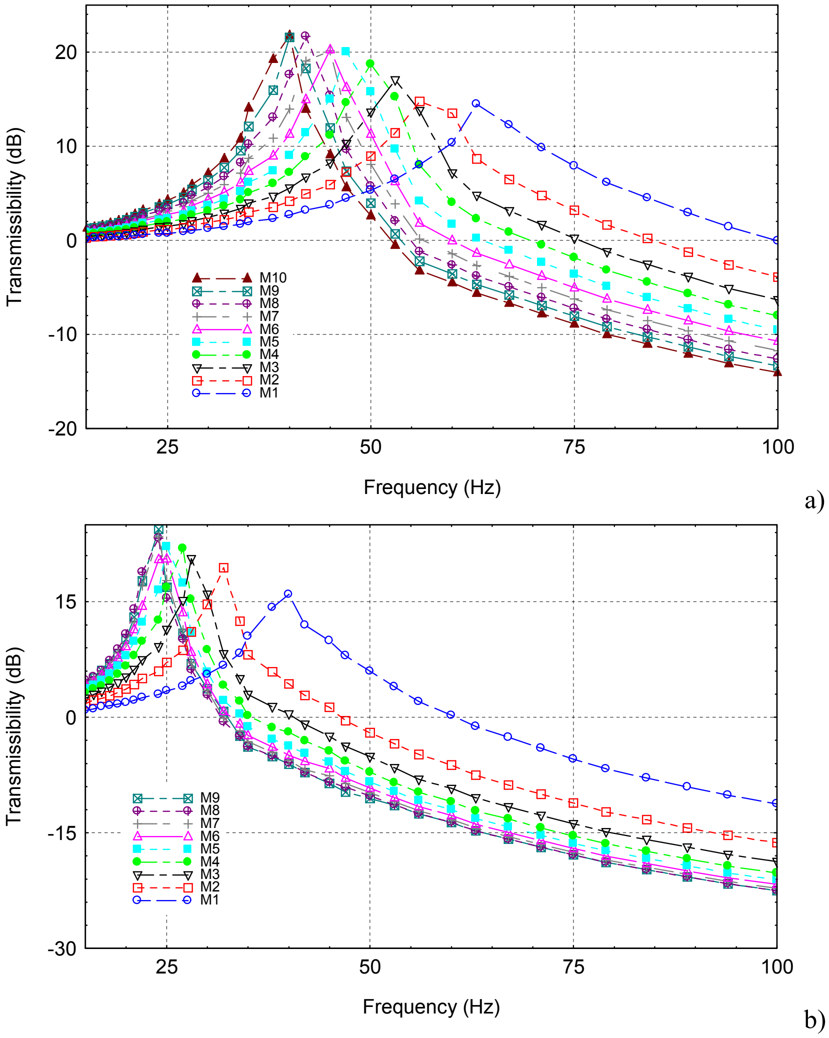

Figure 4. Transmissibility curves for test specimens: a) S21; b) S23.

4.3. Damping factor

Additionally, another test was implemented to assess the damping factor of the composite.

The test specimen is loaded with a mass, a steel plate, and then the plate is struck with a hammer and the vibration of the plate is measured in time domain by an accelerometer. The damping factor is determined by adapting an exponential curve to the amplitude decay of the time vibration signature. The test has been performed with the 490mmx490mm test specimens, and has been repeated for different masses. For the different thicknesses and loading masses tested, the mean values of the damping factor are between 0.08 and 0.1.

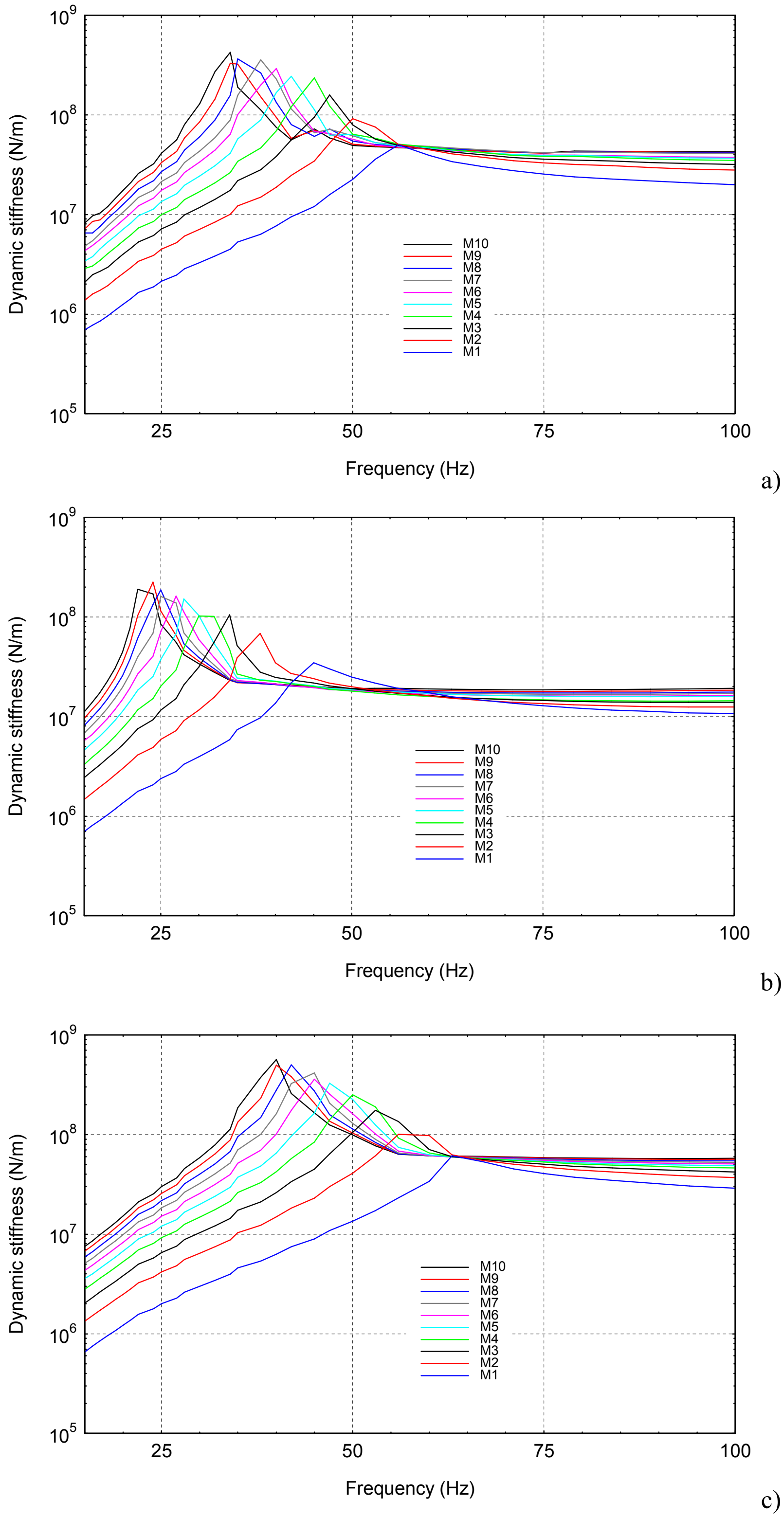

Figure 5. Dynamic stiffness curves: a) S11; b) S12; c) S21.

5. CONCLUSIONS

This study presents results from an ongoing investigation to assess the possibility of using rice husk and granulated cork as a composite material to attenuate vibration. The work involved subjecting the test specimens to dynamic loads, and the transmissibility curves, dynamic stiffness and damping factor were determined. The highest values of vibration isolation are achieved for the specimens with the highest thicknesses and smallest size. For a given size of a specimen, it appears that the vibration isolation can be improved by increasing the thickness of the specimen. The dynamic stiffness results agree with the transmissibility results, since low dynamic stiffness values are found for smaller specimens and higher thickness. Our results show that the composite under investigation could well be a promising material for vibration isolation. This material can be used to support equipment in buildings to reduce vibration, for insertion in lightweight wall cavities to reduce sound transmission and vibration, and as a resilient layer in floating floors to reduce the impact sound transmission.

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REFERENCES

[1] A. Sev, “How can the construction industry contribute to sustainable development? A conceptual framework”, *Sustainable Development*, vol. 7(3), pp. 161–173, 2009.

[2] S. Ersoy, H. Küçük, “Investigation of industrial tea-leaf-fibre waste material for its sound absorption properties”, *Applied Acoustics*, vol. 70(1), pp. 215–220, 2009.

[3] M. H. Fouladi , M. J. M. Nor, Md. Ayub, Z. A. Leman, “Utilization of coir fiber in multilayer acoustic absorption panel”, *Applied Acoustics,* vol. 71(3), pp. 241–249, 2010.

[4] D. J. Oldham, C. A. Egan, R. D. Cookson, “Sustainable acoustic absorbers from the biomass”, *Applied Acoustics*, 72(6), pp. 350–363, 2011.

[5] A.K.M. Sadrul Islam, Md. Ahiduzzaman (2013): Green Electricity from Rice Husk: A Model for Bangladesh. Thermal Power Plants - Advanced Applications, Ed. Mohammad Rasul, InTech.

[6] G. A. Habeeb.; H. B. Mahmud, “Study on properties of rice husk ash and its use as cement replacement material”, *Materials Research*, vol. 13(2), pp. 185-190, 2010.

[7] T. Hossain, S. K. Sarker, B. C. Basak, “Utilization potential of rice husk ash as a construction material in rural areas”, *Journal of Civil Engineering (IEB)*, vol. 39 (2),

pp. 175-188, 2011.

[8] R. R. de Melo, D. M. Stangerlin, R. R. C. Santana, T. D. Pedrosa, "Physical and mechanical properties of particleboard manufactured from wood, bamboo and rice husk", *Materials Research*, vol. 17(3), pp. 682-686, 2014.

[9] L. Gil, "Cork Composites: A Review", *Materials*, vol. 2, pp. 776-789, 2009.

[10] S. P. Silva, M. A. Sabino, E. M. Fernandes, V. M. Correlo, L. F. Boesel, R. L. Reis, "Cork: properties, capabilities and applications", *International Materials Reviews*, vol. 50, pp. 776-789, 2005.

[11] EN ISO 10846-3, Acoustics and vibration – Laboratory measurement of vibro-acoustic transfer properties of resilient elements Part 3: Indirect method of the dynamic stiffness of resilient supports for translation motion, CEN (2002).