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MECHANICAL AND ACOUSTICAL BEHAVIOR OF STARCH-HEMP BIO-COMPOSITE MATERIALS

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Abstract

The starch-hemp is a bio-composite materials and it consisted of starch binder and hemp shives. This bio-composite material is a new durable material for construction and building. In this work, the study on mechanical and acoustical behavior of the starch-hemp bio-composite materials was carried out. The starch-hemp bio-composite materials specimens with three Hemp/Starch ratios (H/S=6, 8 and 10), were manufactured by using the optimal binder and the hemp shives mixtures (0-5 mm+0-15 mm and 0-5 mm+0-20 mm). Influence of the H/S ratio and hemp shives size on density, ultimate compressive stress, tensile strength, elasticity modulus and Poisson's ratio of the starch-hemp bio-composite materials was studied and analyzed. The study on acoustical behavior shows that the starch-hemp bio-composite materials are a very good sound absorber material for medium and high frequencies with a value around 0.7. The influence of the H/S ratio on the absorption coefficient is small. The results show that the starch-hemp bio-composite materials have a good mechanical and acoustical performance and can be used as building materials.

Keywords:

Starch, hemp shives, mechanical behavior, acoustical behavior

1 INTRODUCTION

To build sustainable and affordable building it is needed to design efficient building materials (thermal insulation, sound absorption and sound insulation) with lower environmental impact especially in regard to the carbon footprint.

There is currently a significant growth in the development of use of natural fibers like as hemp, straw, flax and bamboo, specially the hemp shives, as building materials. Hemp shives is more resistant to biological decay than some other bio-based building materials (e.g. straw). The hemp plant can grow up to 4 m in some months, with low fertilizer and irrigation demand, making it very efficient in the use and material resources [Shea 2012], [Elfordy 2008], [Arnaud 2012] and [Barclay 2014]. Hemp is one of the most interesting renewable materials. Like many natural fibers, it has been used for centuries as a reinforcing binder in concrete, in drainage work and for rope and cloth making [Kidalova 2012].

The mechanical, thermal and hydric properties of the lime-hemp concrete are influenced by the drying stage in manufacture. The initial moisture can be also decreased by spraying process [Colinart 2012] and [Collet 2012]. The properties mechanical and thermal stability of the hemp shives can be improved after some chemical treatments on the fiber surface. The flexural strength can be increased 40%. However, the elasticity modulus lightly decreases [Terpáková 2012], [Sedan 2008] and [Troedec 2008]. Up to now, all studies show that the lime-hemp concrete has a low compressive strength and a low elasticity modulus and the lime-hemp concrete in its present form cannot be used as a load-bearing material [De Bruijn 2009].

The lime-hemp concrete are generally used in the construction for filling a wood frame, prefabricated slabs, wall coverings, bricks or blocks. The advantages of the lime-hemp concrete are that [Elfordy 2008], [Arnaud 2012], [De Bruijn 2009], [Walker2014 a], [Benfratello 2013], [Walker 2014 b], [Glé 2011]and [Collet 2008]:

- The lightweight particles impact, on the strength/density ratio, on the deformability and the matrix (formed by the binder) in the mechanical behavior;

- The porosity between the particles which provide low thermal conductivity;

- The same porous aspect that includes pores of varying sizes (micro-pores of the constituent materials and macro-pores related to their imperfect arrangement) strongly influences the exchange of water vapor;

- Finally, the appearance of porous surface that gives the material a good sound absorption.

This paper focuses on the mechanical and acoustical performances of new starch-hemp bio-composite materials. This type of the starch-hemp bio-composite materials is made by the binder solution based on the starch as matrix and the hemp shives. The starch-hemp bio-composite materials are entirely natural material. In the first section of this paper, the different constituents of the starch-hemp bio-composite materials were presented, as well as the results of their measurement characterization. Two critical parameters, the dynamic viscosity and the surface tension were applied to select the binder solution as adhesive in this work. The variation of mechanical resistances like compressive and flexural strength as a function of the starch/hemp ratio was analyzed and discussed. The results obtained by test, using the measurement of the reverberation time T_{60}, show that the starch-hemp bio-composite materials is a very good sound absorber material for medium and high frequencies and that the influence of the H/S ratio on the absorption coefficient is small.

2 MATERIALS

2.1 Hemp

One kind of hemp shives were used to manufacture the bio-composite materials (Fig.1). They are given by a French company "Technichanvre®" located in Riec sur Beloncity. The length, thickness and the width were obtained by sieve analysis; their maximum values as well as other characteristics are given in the Tab.1.

(a) (b) (c)

Fig. 1: Hemp shives dimension:
(a) Hemp shives 0-5 mm; (b) Hemp shives 0-15 mm and(c) Hemp shives 0-20 mm.

2.2 Wheat starch

The hemp shives are embedded in optimal binder solution composed of wheat starch (density 453 kg/m^3) and water. The aim of the binder is to hold the fibers together in order to give and maintain the shape of the bio-composite structure as well as to transmit the shear forces between the hemp shives.

Starch is a carbohydrate composed of a large number of glucose units joined by glycoside bonds. It is contained in large quantities in staple foods such as potatoes, wheat, maize (corn), rice and cassava. The pure starch is a white, tasteless and odorless, which is insoluble in cold water or alcohol. The dissolution of the starch in hot water gives wheat dough which can be used as a thickening agent, a stiffener or adhesive. The industrial use (non-food) of the starch is mainly as an adhesive in the paper manufacturing.

Tab. 1: Properties of hemp shives.

Properties	Size (mm) 0-5	0-15	0-20
Max length (mm)	5	15	20
Max width (mm)	0.60	2.87	3.78
Max thickness (mm)	0.10	0.98	1.34
Loose fill density (kg/m3)	135	105	110
Water retention capacity (ml/l)	370	370	370
Thermal conductivity (W/m K)	0.048	0.048	0.048

2.3 Determination of optimal binder solution

The failure in the hemp concrete design is often due to a non-adequate binder composition or a competition between the binder solution and the hemp for absorbing water. The binder must contain wheat starch as much as possible (which has the effect of increasing the viscosity of the binder) but if the binder has insufficient water for the hydraulic components to set, then the result can be a mixture of damp hemp and dry powder (starch in this study). In our precedent works [Le 2014] the optimal binder was studied. The optimal binder solution can be obtained by the analysis of dynamic viscosity and the surface tension. Indeed, the penetration and adhesive quality of the binder solution within the hemp shives may be characterized by the wettability (surface tension) and the sheer stress induced by the viscosity of the fluid. Wettability could be improved with surfactant/wetting aids. With reduced surface tension, the binder based starch can penetrate through smaller openings and spread over a greater area. However, an increase in the viscosity of the binder solution will decrease the wetting coefficient, the amount of water absorbed and the rate of absorption. Diminishing the water absorbed by the hemp shives is beneficial for drying rate and allows therefore a low time processing and a high quality concrete, free of bacteriological development.

Based on the obtained experimental results, there are two optimum starch/water (S/W) ratios (0.18 and 0.22) where the dynamic viscosity is the highest (more than 2.2×10^{-3} Pa.s) and the surface tension is the lowest (about (45-50) $\times10^{-3}$ N/m). The binder solution (S/W) chosen for the specimens elaboration is 0.18 [Le 2014].

3 MECHANICAL PROPERTIES

3.1 Experimental procedure

A series of two specimen sizes 15x15x15 cm and 10x10x40 cm are fabricated for each of two hemp shives size mixtures of (0-5 mm + 0-15 mm) and (0-5 mm + 0-20 mm). For every mixture five different mass percentages of the 0-5 mm hemp shives have been used: 15%, 20%, 25%, 30% and 35%. Moreover, three hemp/starch (H/S) ratios: 6, 8, and 10 have been used for every percentage.

Compression test and bending test in four-point (Fig.2) are realized by using Instron 8800 machine with a constant rate 0.2mm/s for the compressive test and 0.1 mm/s for the bending one. Due to the fabrication process, most hemp shives tend to stack in planes normal to compacting pressure. Compression and bending test were always performed in the pressure direction. The tensile strength is determined by using the relation $\sigma_t = (3F)/(a^2)$ with F: the maximum load, a: the thickness and the height which they both are equal 100mm.

(a) (b)

Fig. 2: Experimental devices:
(a) Compressive tests (b) Bending test

In this work, both the elasticity modulus and the Poisson's ratio are obtained by the use of an Aramis optical system.

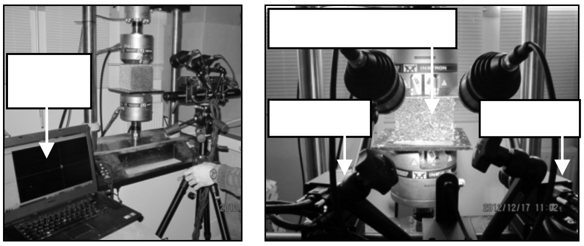


Fig.3: Aramis stereo optimal system

Aramis is a high performance optical system which gives displacement and strain of the specimen during loading through digital image correlation methods. It is a robust method and has the capability to give a non-contact field displacement and strain measurement. The stereo camera has two lenses with the same distance from the specimen and takes two pictures at the same time [Jonathan 2011].

In this work, two ARAMIS stereo cameras were rigidly connected and allow the measurement of displacement fields and 2D deformations from one pair of images corresponding to different instants of the hemp/starch specimenstrain.

Before measuring, the specimen must be placed at an adequate distance from the camera in order to make it possible to capture the image. This distance has been fixed at 47 cm (Fig.3).

3.2 Results and discussions

In the following results, every value is obtained as the average value of three measures realized on three specimens.

Influence of the hemp shives size distribution

Starch-hemp concrete density

Fig.4 shows the variation of the density of the completely dried bio-composite materials as a function of the % of the 0-5 mm hemp shives size. The dry density range evolved from an average of 181.0 kg/m^3 and 193.8 kg/m^3 (mixtures0-5 mm+0-15 mm, H/S=6) and 183.8 kg/m^3 and 194.9 kg/m^3 (mixtures0-5 mm+0-20 mm, H/S=6). The density of the starch-hemp bio-composite materials is lower than that of the hemp-lime concrete which is generally between 250 kg/m^{3}and 660 kg/m^3 [Elfordy 2008] and [Arnaud 2012].The dry density of starch-hemp bio-composite materials with the mixtures 0-5 mm+0-20mm, H/S=6 is greater than that of the other size mixtures 0-5 mm +0-15 mm, H/S=6. It can be partially explained by the density of hemp shives: 110 kg/m^3 for size 0-20 mm against 105 kg/m^3 for size 0-15 (Tab.1).

The relation between the density ρ and percent of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (1):

$$\rho = C_1H^2 + C_2H + C_3 \qquad (1)$$

C_1, C_2, C_3 are obtained by experimental test (Tab. 2).

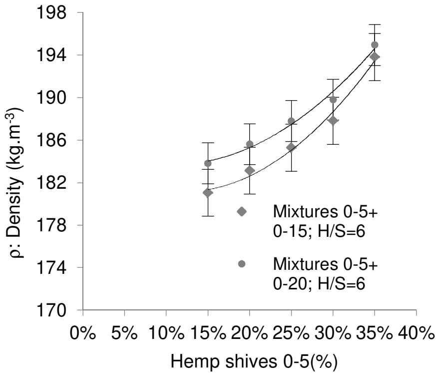


Fig. 4: Variation of density in function of the hemp shives0-5 mm (%)

Variation of tensile stress

The average tensile strength varies from 0.088 MPa to 0.105 MPa for the mixtures0-5 mm +0-15 mm, H/S=6 and from 0.085 MPa to 0.104 MPa for the mixtures0-5 mm+0-20 mm, H/S=6, when % of the 0-5 mm hemp shives varies from 15% to 35% (Fig.5).The results show that the tensile strength increases when % of the 0-5 mm hemp shives increases from 15% to 25% and decreases when % of the 0-5 mm hemp shives>25% (25%-35%).These values are less than those obtained for the lime-hemp concrete 0.7-1.2 MPa [Elfordy 2008].It is also confirmed that when hemp shives is finer (0-5 mm+0-15 mm), the hemp particles are better coated by the binder during the manufacturing of the bio-composite materials[Arnaud 2012].However when hemp shives 0-5 mm is very present in the mixture (>25%) the load transfer decreases because hemp shives is finer and the tensile stress decreases. The bio-composite materials present better tensile strength for 25% of the 0-5 mm hemp shives.

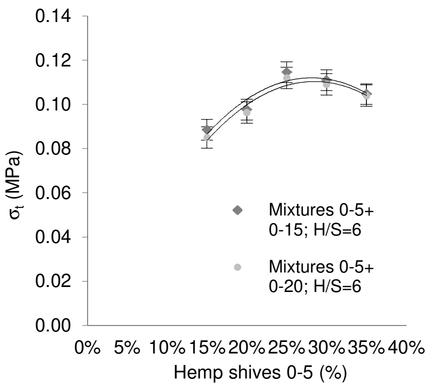


Fig. 5: Flexural strength-% of the 0-5 mm hemp shives curves

The relation between the tensile stress σ_t and % of the 0-5 mm hemp shives(H)is not linear and can be illustrated by parabolic equation (2):

$$\sigma_t = C_4H^2 + C_5H + C_6 \qquad (2)$$

C_4, C_5, C_6 are obtained by experimental test (Tab. 2).

Elasticity modulus and Poisson's ratio (Aramis stereo camera system)

The elasticity module curves measured by compression test were presented in Fig.6. The elasticity modulus increases from 1.59 MPa to 2.13 MPa for the mixtures0-5 mm+0-15 mm, H/S=6 and from 2.18 MPa to 2.79 MPa for the mixtures0-5 mm+0-20 mm, H/S=6. The % hemp shives0-5 mm increases from 15% to 35%.The elasticity module of starch-hemp bio-composite materials with mixtures 0-5 mm+0-20mm, H/S=6 is greater than that with size mixtures 0-5 mm +0-15 mm, H/S=6. It can be partially explained by the density of starch-hemp bio-composite materials (Fig. 5).

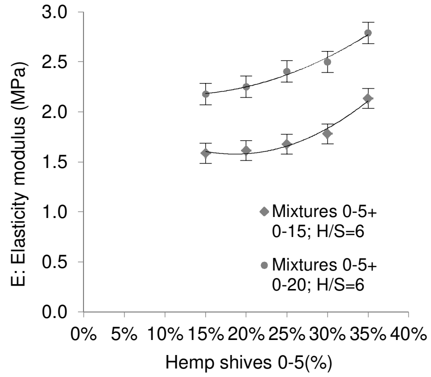


Fig. 6: Elasticity modulus in function of the hemp shives 0-5 mm (%)

The relation between the elasticity modulus E and % of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (3):

$$E = C_7H^2 + C_8H + C_9 \tag{3}$$

C_7, C_8, C_9 are obtained by experimental test (Tab. 2).

Tab. 2: The coefficientC_1-C_{12}

	0-5 mm+0-15 mm	0-5 mm+0-20 mm
C_1 kg/m^3	234.5	185.6
C_2 kg/m^3	-56.8	-40
C_3 kg/m^3	184.6	185.9
C_4 MPa	-1.469	-1.467
C_5 MPa	0.826	0.835
C_6 MPa	-0.004	-0.008
C_7 MPa	19.81	10.76
C_8 MPa	-7.38	-2.43
C_9 MPa	2.27	2.30
C_{10}	-1.876	-2.226
C_{11}	1	1.37
C_{12}	-0.02	-0.015

For the lime-hemp concrete, the value of the elasticity modulus is between 5 MPa and 35 MPa [Elfordy 2008]. The difference is principally due to the lower density of the starch-hemp bio-composite materials.

Fig.7 shows the variation of Poisson's ratio with the % of the0-5 mm hemp shives. The variation range of the Poisson's ratio is from 0.087 to 0.102 for the mixtures 0-5 mm+0-15 mm, H/S=6and from 0.140 to 0.191 for the mixtures 0-5 mm+0-20 mm, H/S=6. The Poisson's ratio increases when the % of the 0-5 mm hemp shives size increases. Poisson's ratio of the mixtures0-5 mm+0-20 mm, H/S=6 is greater than that of the other sizemixtures0-5 mm+0-15 mm, H/S=6. The relation between the Poisson's ratio and % of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (4):

$$\vartheta = C_{10}H^2 + C_{11}H + C_{12} \tag{4}$$

C_{10}, C_{11}, C_{12} are obtained by experimental test (Tab. 2).

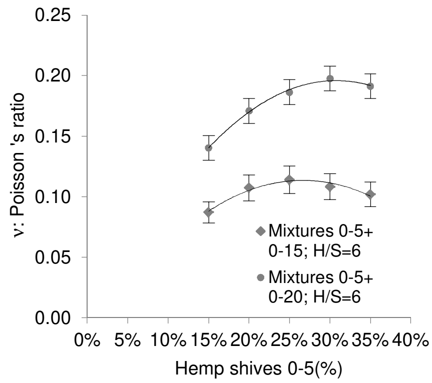


Fig. 7: Poisson's ratio in function of the hemp shives 0-5 mm (%)

Influence of type binder

Starch-hemp concrete density

Fig.8 shows the variation of the density of the starch-hemp of bio-composite materials as a function of the % of the 0-5 mm hemp shives. The dry density range evolved from an average of 181.0 kg/m^3 and 193.8 kg/m^3 for the mixtures 0-5 mm +0-15 mm, H/S=6; from 177.3 kg/m^3 to 189.1 kg/m^3 for H/S=8 and from 173.7 kg/m^3 to 184.7 kg/m^3 for H/S=10. The results show that the density decreases when the H/S ratio increases (H/S=6-10).The density of the starch-hemp bio-composite materials is lower than that of the hemp-lime concrete which is generally between 250 kg/m^3 and 660 kg/m^3 [Elfordy 2008;Arnaud 2012].

The relation between the density ρ and % of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (5):

$$\rho = C_{13}H^2 + C_{14}H + C_{15} \tag{5}$$

C_{13}, C_{14}, C_{15} are obtained by experimental test (Tab. 3).

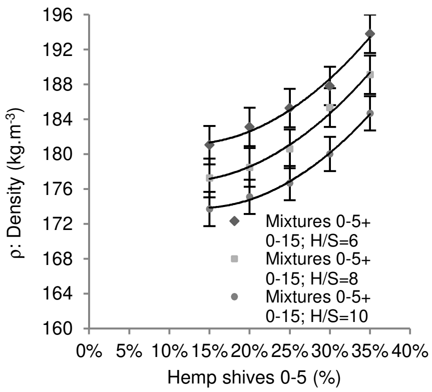


Fig. 8: Variation of density in function of the hemp shives 0-5 mm (%)for different H/S ratios

Variation of tensile stress

The average tensile strength varies from 0.088 MPa to 0.105 MPa for the mixtures 0-5 mm +0-15 mm, H/S=6; from 0.083 MPa to 0.103 MPa for H/S=8 and from 0.079 MPa to 0.096 MPa for H/S=10, when % of the0-5 mm hemp shives varies from 15% to 35% (Fig.9).The results show that the tensile strength decreases when the H/S ratio increases (H/S=6-10). These values are less than those obtained on the lime-hemp concrete 0.7-1.2 MPa [Elfordy 2008].

The relation between the tensile stress σ_t and % of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (6):

$$\sigma_t = C_{16}H^2 + C_{17}H + C_{18} \tag{6}$$

C_{16}, C_{17}, C_{18} are obtained by experimental test (Tab. 3).

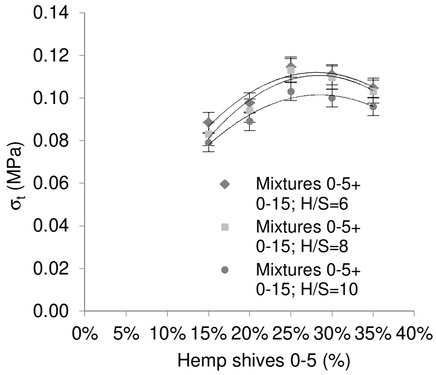


Fig. 9: Flexural strength- % hemp shives 0-5 mm curves for different H/S ratios

Tab. 3: The coefficients C_{13} – C_{24}

	0-5 mm+0-15 mm H/S=6	H/S=8	H/S=10
C_{13}kg/m^3	234.5	221.5	236.7
C_{14}kg/m^3	-56.8	-49.7	-64.7
C_{15} kg/m^3	184.6	179.6	178.2
C_{16}MPa	-1.469	-1.648	-1.286
C_{17}MPa	0.826	0.935	0.733
C_{18} MPa	-0.004	-0.022	-0.003
C_{19} MPa	19.81	13.14	9.05
C_{20} MPa	-7.38	-4.25	-2.42
C_{21} MPa	2.27	1.87	1.61
C_{22}	-1.876	-1.771	-1.557
C_{23}	1	0.966	0.859
C_{24}	-0.02	-0.022	-0.017

Elasticity modulus and Poisson's ratio (Aramis stereo camera system)

The elasticity module curves measured by compression test were presented in Fig.10. The elasticity modulus increases from 1.59 MPa to 2.13 MPa for the mixtures 0-5 mm+0-15 mm, H/S=6; from 1.52 MPa to 2.01 MPa for H/S=8 and from 1.44 MPa to 1.89 MPa for H/S=10. The % of the 0-5 mm hemp shives increases from 15% to 35%.The elasticity module decreases when the H/S ratio increases. For the lime-hemp concrete, the value of the elasticity modulus is between 5 MPa and 35 MPa [Elfordy 2008]. The difference is principally due to the lower density of the starch-hemp bio-composite materials.

The relation between the elasticity modulus E and % of the0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (7):

$$E = C_{19}H^2 + C_{20}H + C_{21} \qquad (7)$$

C_{19}, C_{20}, C_{21} are obtained by experimental test (Tab. 3).

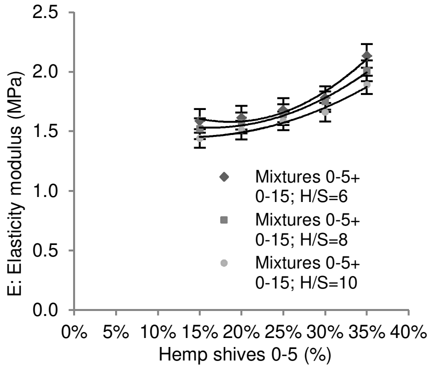


Fig. 10: Elasticity modulus in function of the hemp shives 0-5 mm (%) for different H/S ratios

Fig.11 shows the variation of Poisson's ratio with the % of the0-5 mm hemp shives. The variation range of the Poisson's ratio is from 0.087 to 0.102 for the mixtures 0-5 mm+0-15 mm, H/S=6; from 0.082 to 0.100 for H/S=8 and from 0.076 to 0.094 for H/S=10.The Poisson's ratio decreases when the H/S ratio increases.

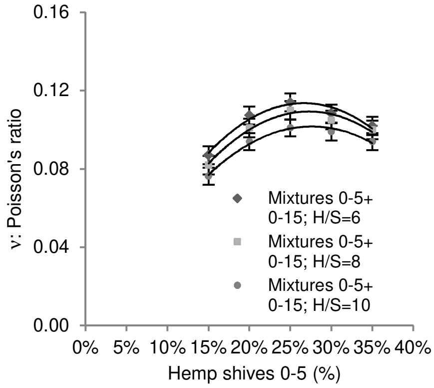


Fig. 11: Poisson's ratio in function of the hemp shives 0-5 mm(%) for different H/S ratios

The relation between the Poisson's ratio and % of the 0-5 mm hemp shives (H) is not linear and can be illustrated by parabolic equation (8):

$$\vartheta = C_{22}H^2 + C_{23}H + C_{24} \qquad (8)$$

C_{22}, C_{23}, C_{24} are obtained by experimental test (Tab. 3).

4 ACOUSTICAL PROPERTIES

The other aim of the study is to determine the absorption coefficient by using the measurement of the reverberation time T_{60} which is carried out according to NF EN ISO 3382.

Laboratory tests were carried out on three starch-hemp bio-composite materials panels placed in a reverberation room. The volume and the total surface of the reverberation room are 17 m^3 and 41 m^2 respectively. There are no parallel walls to avoid the formation of standing wave and eight speakers are used to obtain an Omni directional sound. The dimensions of each panel are 48cm x 68cm x 3.5cm.To reduce the diffraction effect on the sample edges, the edges are covered with reflective material.

The absorption coefficient is determined for two hemp shives size mixtures of (0-5 mm + 0-15 mm) and (0-5 mm + 0-20 mm). For every mixture five different mass percentages of the 0-5 mm hemp shives have been used: 15%, 20%, 25%, 30% and 35%. Moreover, three hemp/starch (H/S) ratios: 6, 8, and 10 have been used for (0-5 mm + 0-15 mm) mixture but only one H/S=6 ratio was used for the (0-5 mm + 0-20 mm) mixture. The measurements are carried out by third octave bands.

We prefer the use of the Millington formula equation (9) (where V is the volume of the reverberation room, a_i and S_i are the materials absorption coefficients and the panel surfaces respectively) which gives more realistic values than the Sabine formula especially for high absorbent materials.

$$T_{60} = \frac{0.161V}{-\sum S_i\, ln(1-a_i)} \qquad (9)$$

Figures 12-15 show the results of absorption coefficient with Millington formula for the different H/S ratios and for both mixtures hemp shives. It can be observed that the starch hemp concrete is a good sound absorber material for medium and high frequencies with a value around 0.7. This is due to the porous nature of the material. However, it is not the same case for low frequencies, under 200 Hz, and is an acceptable one for frequencies between 250 and 500 with an average value of 0.32 for H/S=6, 0.44 for H/S=8; 0.48 for H/S=10 (0-5 mm + 0-15 mm) and 0.38 for H/S=6 (0-5 mm+ 0-20 mm).

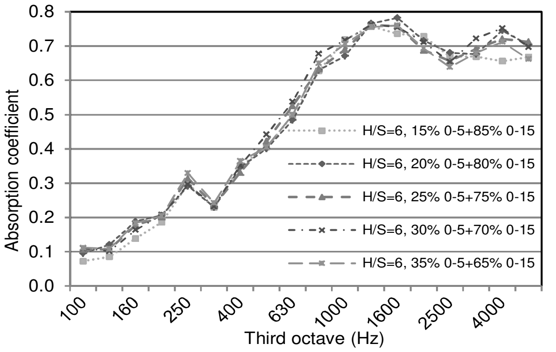


Fig.12: Absorption coefficient for mixtures hemp shives 0-5 mm +0-15 mm; H/S=6.

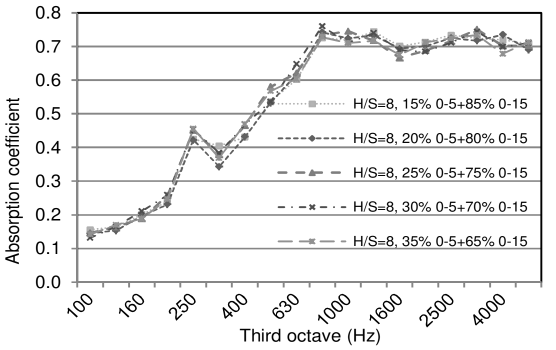


Fig.13: Absorption coefficient for mixtures hemp shives 0-5 mm +0-15 mm; H/S=8.

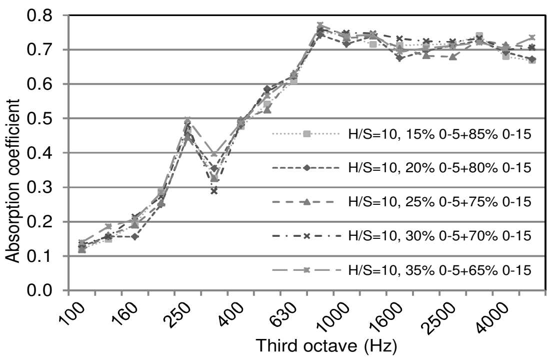


Fig.14: Absorption coefficient for mixtures hemp shives 0-5 mm +0-15 mm; H/S=10.

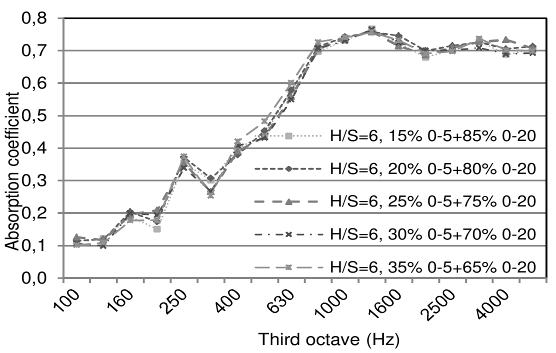


Fig.15: Absorption coefficient for mixtures hemp shives 0-5 mm +0-20 mm; H/S=6.

4.1. Hemp shives sizes distribution

In order to study the influence of the hemp shives sizes, Fig 16 shows a comparison of the absorption coefficients for the same H/S ratios (H/S=6) for both mixtures hemps shives (0-5 mm+0-15 mm and 0-5 mm+0-20 mm).

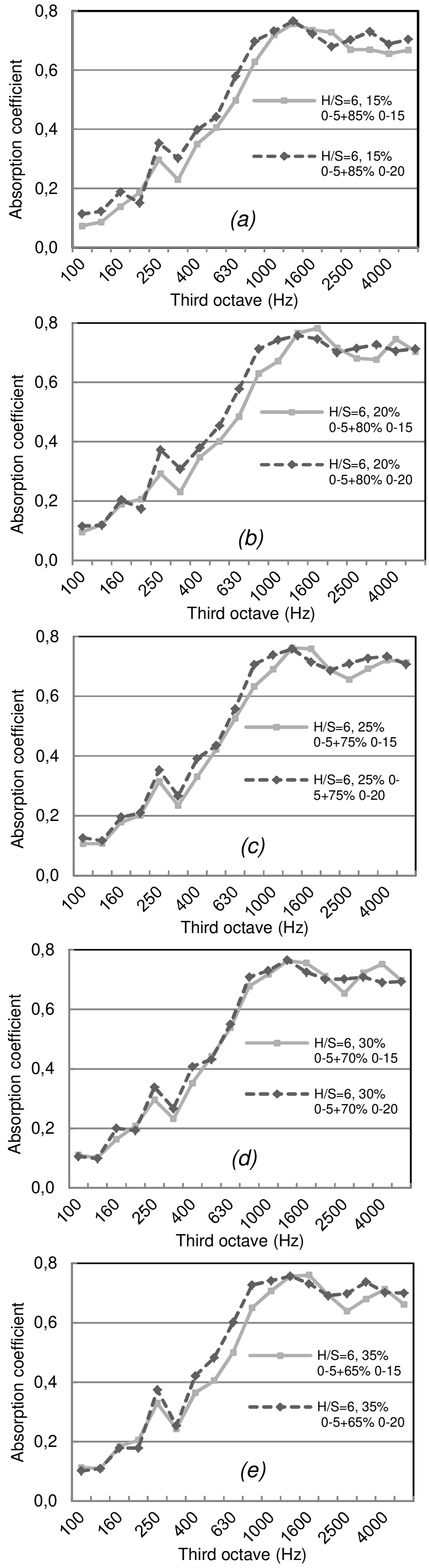
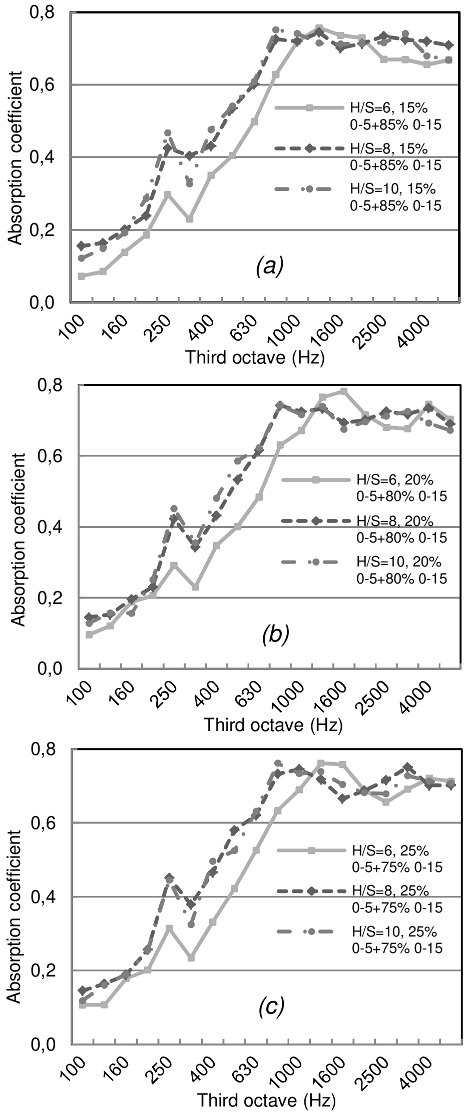


Fig.16: Sound absorption of starch-hemp bio-composite materials for various hemp shives sizes

It can be also observed that the mixtures hemp shives 0-5 mm+0-20 mm gives better results than the other one (0-5 mm+0-15 mm). The bigger hemp shives are better than the little ones especially for low H/S ratios; this is due to the elasticity and continuity of the material which can absorb better this range of frequencies. As the H/S ratio increases the hemp shives size has little effect on the absorption coefficient. For the H/S =10, the values obtained by test are almost the same for the two hemp shives sizes.

4.2. Type of binder

As mentioned before, the H/S ratio has an influence on the absorption coefficient in the low frequencies with smaller hemp shives sizes. Fig.17 shows the results for the low frequencies as well as the first medium band 500 Hz. The big differences are observed for the lower H/S ratio (H/S=6). For higher ones the difference is negligible. So to preserve the acoustical performance of the hemp shives the composite material must have the minimum of binder. It seems that the H/S =10 is the better choice for the absorption coefficient especially in low frequencies. The results obtained show that starch hemp bio-composite materials are good acoustical insulation material and it can be also incorporated into the manufacturing of soundproof wall.



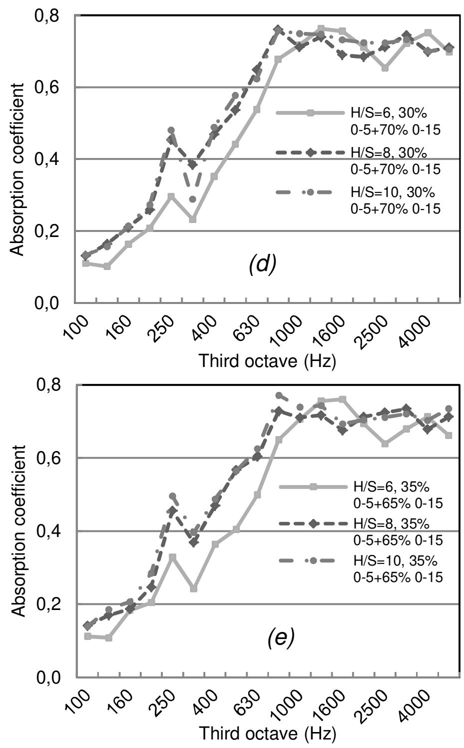


Fig.17: Sound absorption of starch-hemp bio-composite materials according to the ratios H/S=6-10

5 CONCLUSION

In this paper, the mechanical and acoustical performance of two mixtures starch-hemp bio-composite materials was studied. The results were also discussed with those of the lime hemp concrete.

Dry density of the starch-hemp bio-composite materials varies with the H/S ratio. For a given H/S ratio, the dry density of the bio-composite materials increases with the increase of the binder. The density of the starch-hemp bio-composite materials is lower than that of the hemp- lime concrete which is generally between 350 kg/m^3 and 550 kg/m^3.

The maximum average tensile strength varies from 0.088 MPa to 0.105 MPa for mixtures 0-5 mm+0-15 mm, H/S=6, when % of the 0-5 mm hemp shives varies from 15% to 35%. These values are less than those obtained on the lime-hemp concrete 0.7-1.2 MPa [2]. The relation between the compressive stress and the strain is not linear. However, the relation between the tensile stress and % of the 0-5 mm hemp shives (H) can be represented by a parabolic equation.

The maximum elasticity modulus increases from 2.18 MPa to 2.79 MPa for the mixtures 0-5 mm+0-20 mm, H/S=6 when % of the 0-5 mm hemp shives increases from 15% to 35%. For the lime-hemp concrete, the value of the elasticity modulus is between 5 MPa and 35 MPa [2]. The difference is principally due to the lower density of the starch-hemp bio-composite materials. The variation range of the maximum Poisson's ratios from 0.140 to 0.191 for the mixtures 0-5 mm+0-20 mm, H/S=6 when the % of the 0-5 mm hemp shives increases from 15% to 35%. The Poisson's ratio increases when the % hemp shives 0-5 mm increases. The variation of the elasticity modulus and the Poisson's ratio is also not linear.

Due to the porous nature of the material, the starch hemp bio-composite materials are a good sound absorber material for medium and high frequencies with a value around 0.7. The influence of the H/S ratio on the absorption coefficient is small. The results obtained by test show that starch hemp bio-composite materials are good acoustic insulation material and it can be also incorporated into the manufacturing of soundproof wall.

The numerous mechanical tests show that there is an optimal formulation for the mixture 25% 0-5 mm + 75% 0-20 mm, H/S=6. For acoustical behavior, the optimal formulation with the mixture 35% 0-5 mm + 65% 0-15 mm, H/S=10.

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