ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 11, pp.8076-8081, November, 2019

DOI: https://doi.org/10.24941/ijcr.36593.11.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

STUDY OF THE EFFECT OF HUMIDITY ON THE SOUND ABSORPTION COEFFICIENT OF SOME LOCAL MATERIALS USED IN THE CONSTRUCTION OF RESIDENTIAL BUILDINGS IN BENIN

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ARTICLE INFO

Article History:
Received 24th August, 2019
Received in revised form
28th September, 2019
Accepted 25th October, 2019
Published online 26th November, 2019

Key Words:
Moisture, sound absorption coefficient, stabilized earth, mortar, cement-wood composite, Kundt tube.

ABSTRACT

In the building sector, noise is a source of deterioration in the health status of the population. The choice of building materials is essential to ensure the acoustic comfort of buildings. Our study focused on the stabilized earth, and the cement-wood composite where each sample is acoustically characterized using the Kundt tube where the absorption coefficient of these materials was measured according to the water content. It shows that the humidity influences the acoustic absorption coefficient of each material in the standardized frequency zones ranging from 315 Hz to 2000 Hz.

***Citation: DJIKOU M. Sylvain, HOUNGAN C. Aristide, KIKI Gratien Jesugo Dieudonné, AGBOMAHENAN Macaire, ANJORIN Malahimi, VIANOU Antoine, DEGAN Gérard.* 2019.** "Study of the effect of humidity on the sound absorption coefficient of some local materials used in the construction of residential buildings in Benin.", *International Journal of Current Research*, 11, (11), 8076-8081.

INTRODUCTION

In the building sector, noise nuisances such as traffic, walking, talking and equipment noises are the source of inconveniences, which can range from a deterioration in the quality of life, to repercussions on the health of the inhabitants. occupants. Indeed, the middle ear is damaged by noise when the sound level is higher than 120 dB (decibels). This can lead to rupture of the eardrum [1]. The fight against noise has therefore become an important issue that results in regulations, acoustic standards that set minimum acoustic performance to be achieved inside buildings to ensure acoustic comfort to occupants and users [2]. Every building constructed must verify the standard of airborne and impact sound insulation, the insulation of facades, the noise produced by technical equipment or the reduction of the reverberation of certain rooms [3]. Our research consists of determining the sound absorption coefficient of stabilized earth and cement-wood composite two materials involved in the construction of the building. Then study the influence of the moisture content on the acoustic absorption of these two materials to ensure the acoustic comfort or insulation of residential buildings. Our research consists of determining the sound absorption coefficient of stabilized earth and cement-wood composite two materials involved in the construction of the building. Then we will study the influence of the moisture content on the sound absorption of these two materials to ensure the comfort or acoustic insulation of residential buildings. To do this we will present the materials and the method finally used the results and discussion.

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MATERIALS AND METHOD

Presentation of materials

- Stabilized earth: earth + cement + water [1]

Dosage: 2 wheelbarrows of bar ground (1900 kg / m^3); 25 kg of cement; 60 l of water

- Composite cement - wood ... [4]

Dosage: 3 wheelbarrows of 15,5kg of sawdust; 65 kg of cement; 110 l of water.

- The materials are immersed in water for 24 hours to determine their absolute humidity, then the latter are dried in the microwave to obtain their relative humidity at two different positions. To finish the materials stay for 24 hours in an oven at a temperature of 105 ° C to make them anhydrous (0% humidity).
- The weighing of the mass of each sample taken respectively in the contexts described above is obtained using a precision balance and the results are recorded in Table 1:
- Starting from the different masses determined, the moisture content of each type of material is calculated by using formula (1)

$$\tau = \frac{m_e}{m_s}.100 = \frac{m_h - m_s}{m_s} \quad (1)$$

With:
m_e: The mass of water contained in the material in (kg)
m_h: The mass of material immersed completely in water (kg)
m_S: The mass of the dry material in (kg)
τ: Absolute humidity or water content of a material in (%)

The moisture content results are shown in Table 2:

Method

- The device used for the sound characterization of the two study materials is the Kundt tube. Measurements of the sound absorption coefficient are made with the acquisition bench of photo 2:

- For data acquisition, it is necessary to:
- Carry out the assembly of the acquisition chain by wiring between the different devices.
- Insert the rod with microphone into the sample holder.
- Put the study material in the sample holder.
- Turn on the Low Frequency Generator and the oscilloscope (A table is displayed on the oscilloscope screen showing the characteristics of the signal)
- Read the value of the no-load voltage across the U_0 preamplifier on the oscilloscope
- Select the appropriate frequency on the GBF by entering the value and then confirm with the button marked "Hz" or "kHz".
- Press the "output" button on the GBF to send the signal to the speaker. The loudspeaker generates a sound wave then the microphone picks up the standing wave in the tube.
- Slowly move the rod carrying the microphone and read the value of the voltage U'_{max} on the screen (the value of "max") of the oscilloscope when the signal becomes sinusoidal and the amplitude is maximal (the bellies)
- Slowly move the microphone rod, read and read the value of the voltage U'_{min} on the screen (the "max" value) of the oscilloscope when the signal becomes sinusoidal and the amplitude is minimal (the nodes)
- Calculate for each frequency U_{max} and U_{min} with the formulas $U_{max} = U'_{max} - U_o$ and $U_{min} = U'_{min} - U_o$

- The value of the reflection coefficient g according to equation (2) and that of the absorption coefficient α of the tested material according to equation (4) are then calculated.

The reflection coefficient g of material is given by relation:

$$g = \left(\frac{U_{max} - U_{min}}{U_{max} + U_{min}}\right)^2 \quad (2)$$

Where U_{max} is the maximum voltage measured at the terminals of the microphone and U_{min} is the minimum voltage measured at the terminals of the same microphone

$$g + \alpha = 1 \quad (3)$$

We then deduce:

$$\alpha = 1 - g \quad (4)$$

RESULTS AND DISCUSSION

Results

Using the Kundt tube, the two materials under study were characterized respectively after several measurement tests. Taking into account the repeatability of the measurements, the uncertainties on the measurements are determined through the formulas [6]:

$$\alpha = 1 - \left(\frac{U_{max} - U_{min}}{U_{max} + U_{min}}\right)^2 \quad (5)$$

$$\Delta\alpha = \left|\frac{\partial \alpha}{\partial U_{max}}\right| \Delta U_{max} + \left|\frac{\partial \alpha}{\partial U_{min}}\right| \Delta U_{min} \quad (6)$$

Où :

$$\frac{\partial \alpha}{\partial U_{max}} = \frac{-4U_{min}(U_{max} - U_{min})}{(U_{max} + U_{min})^3} \quad (7)$$

$$\frac{\partial \alpha}{\partial U_{min}} = \frac{-4U_{max}(U_{max} - U_{min})}{(U_{max} + U_{min})^2} \quad (8)$$

$$\Delta U_{max} = \sqrt{\frac{\sum_{i=1}^{n}(U_{max} - \overline{U_{max}})^2}{n(n-1)}} \quad (9)$$

$$\Delta U_{min} = \sqrt{\frac{\sum_{i=1}^{n}(U_{min} - \overline{U_{min}})^2}{n(n-1)}} \quad (10)$$

With:

α: the absorption coefficient of the material;
U_{max}: the maximum voltage given by the V oscilloscope;
U_{min}: the minimum voltage given by the V oscilloscope;
Δα: the measurement uncertainty;
$\frac{\partial \alpha}{\partial U_{max}}$: the partial derivative of the absorption coefficient with respect to the maximum tension;
$\frac{\partial \alpha}{\partial U_{min}}$: the partial derivative of the absorption coefficient with respect to the minimum voltage;
ΔU_{max}: the uncertainty associated with the measurement of the maximum voltage;
ΔU_{min}: the uncertainty associated with the measurement of the minimum voltage;
n: the number of measurements (n = 3).

Photo 1: Stabilized earth and cement-wood composite

Photo 2. Stabilized earth and cement-wood composite immersed in water

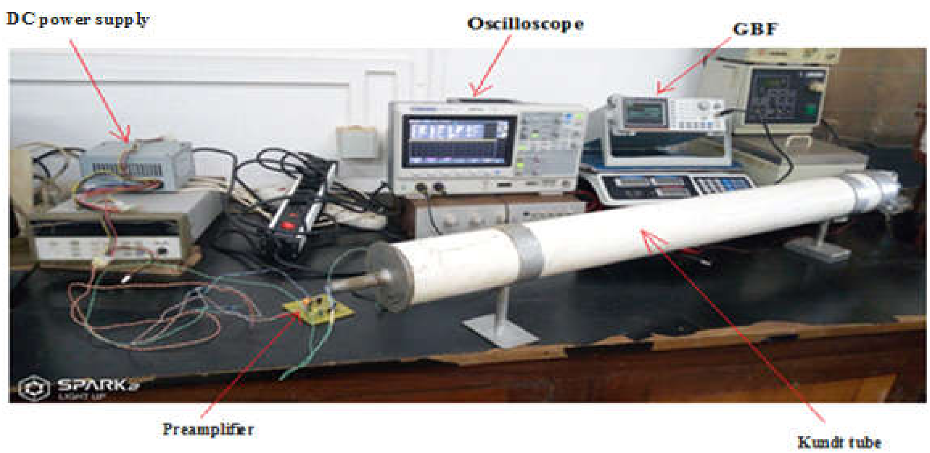

Photo 3. Measurement bench of absorption coefficient and acoustic impedance of materials

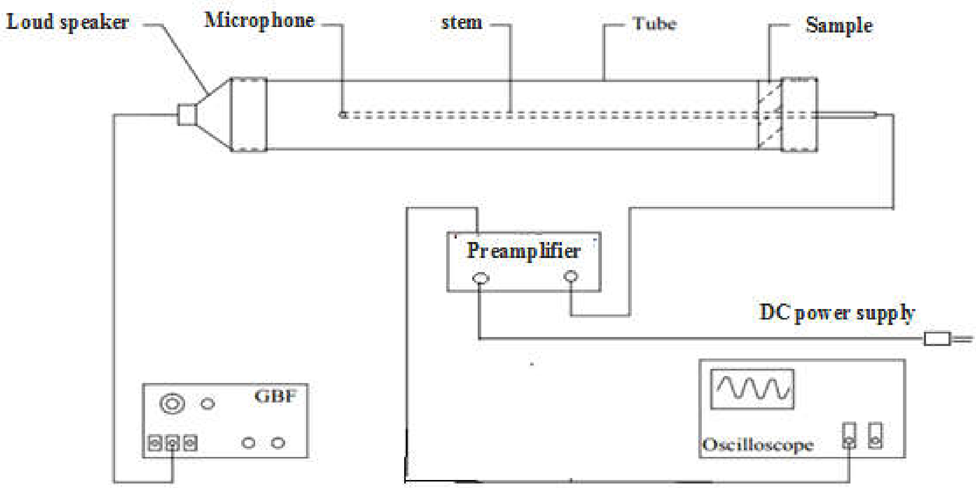

Fig 1. Diagram of the data acquisition bench

Table 1. The different masses of each material

Materials	Mass ai in the open air (t = 38 ° C) in kg	Moist m_h mass (t = 16 ° C) in kg	Mass m_1 at the microwave outlet 1 (t = 52 ° C) in kg	Mass m_2 at the exit of microwave 2 (t = 80 ° C) in kg	Mass m_S at the outlet of the oven (t = 105 ° C) in kg
Stabilized earth	0,645	0,765	0,735	0,685	0,620
Composite cement-wood	0,450	0,660	0,620	0,560	0,420

Table 2. Moisture of materials

Materials	Humidity in the open in %	Absolute humidity in %	Moisture at the microwave exit 1 in %	Moisture at the microwave exit 2 in %
Stabilized earth	4,03	23,39	18,55	10,48
Composite cement-wood	7,14	57,14	47,62	33,33

Table 3. Earth stabilized in the open air *(m_{To} = 0,645kg)*

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}(V)	5,1	4,7	4,9	5	5,1	4,5	4,7	4,7
U_{min}(V)	2,4	2,5	1,5	1,9	2,1	1,7	1,4	1,9
g	0,13	0,09	0,28	0,20	0,17	0,20	0,29	0,18
α	0,87	0,91	0,72	0,80	0,83	0,80	0,71	0,82

Table 4. Stabilized immersed earth *(m_{T1}= 0,765kg)*

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,94	5,02	4,94	5	4,78	5,02	4,73	3,38
U_{min}	1,42	1,66	1,26	1,08	1,34	1,34	3,82	0,82
g	0,31	0,25	0,35	0,42	0,32	0,33	0,01	0,37
α	0,69	0,75	0,65	0,58	0,68	0,67	0,99	0,63

Table 5. Stabilized earth exit of the microwave (m_{T2}= 0,735kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,56	4,80	4,64	4,72	4,56	4,72	4,80	2,80
U_{min}	1,84	1,76	0,96	2,96	0,83	0,80	1,28	0,56
g	0,18	0,21	0,43	0,05	0,48	0,50	0,34	0,44
α	0,82	0,79	0,57	0,95	0,52	0,50	0,66	0,56

Table 6. Stabilized earth leaving the microwave (m_{T3}= 0,685kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,40	4,24	4,00	4,48	4,16	4,40	4,43	3,76
U_{min}	1,52	0,80	0,86	2,43	0,72	0,40	0,88	0,72
g	0,24	0,47	0,42	0,09	0,50	0,69	0,45	0,46
α	0,76	0,53	0,58	0,91	0,50	0,31	0,55	0,54

Table 7. Dry stabilized earth (m_{Ts}= 0,620kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,48	4,64	4,32	4,56	4,32	4,4	4,48	2
U_{min}	2,24	1,52	1,28	2,96	0,96	0,64	1,28	0,32
g	0,11	0,26	0,29	0,05	0,40	0,56	0,31	0,52
α	0,89	0,74	0,71	0,95	0,60	0,44	0,69	0,48

Table 8. Cement-wood composite in the open air (m_{Co}= 0,450kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,4	4,4	4	4,1	4	3,6	4	2,8
U_{min}	1,2	1,6	0,7	0,89	0,8	0,7	0,9	0,1
g	0,33	0,22	0,49	0,41	0,44	0,45	0,40	0,87
α	0,67	0,78	0,51	0,59	0,56	0,55	0,60	0,13

Table 9. Submerged Cement-Wood Composite (m_{C1}= 0,660kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,7	4,3	3,9	4	3,9	4,2	4,46	3,02
U_{min}	1,5	1,9	0,7	1,2	1,1	0,9	3,8	0,54
g	0,27	0,15	0,48	0,29	0, 31	0,42	0,006	0,49
α	0,73	0,85	0,52	0,71	0,69	0,58	0,994	0,51

Table 10. Cement-wood composite taken out of the microwave (m_{C2}= 0,620kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,82	4,56	4,4	4,64	4,72	4,8	4,8	4
U_{min}	2	2,16	1,84	4,4	1,76	1,52	4,08	2,8
g	0,17	0,13	0,17	0,001	0,21	0,27	0,007	0,03
α	0,83	0,87	0,83	0,999	0,79	0,73	0,993	0,97

Table 11. Cement-wood composite taken out of the microwave (m_{C3}= 0,560kg)

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,4	4,8	4	3,6	4	4	3,6	3,2
U_{min}	1,6	2,4	0,8	3,2	0,4	0,4	2,8	0,2
g	0,22	0,11	0,44	0,003	0,67	0,67	0,02	0,78
α	0,78	0,89	0,56	0,997	0,33	0,33	0,98	0,22

Table 12. Dry cement-wood composite *(m_{Cs}= 0,420kg)*

f(Hz)	315	400	500	640	800	1000	1250	1600
U_{max}	4,4	4,16	4,32	4,4	4,4	4,4	4	3,76
U_{min}	1,6	2,96	0,88	1,1	1,44	1,38	0,9	1,12
g	0,22	0,03	0,44	0,36	0,26	0,27	0,40	0,29
α	0,78	0,97	0,56	0,64	0,74	0,73	0,60	0,71

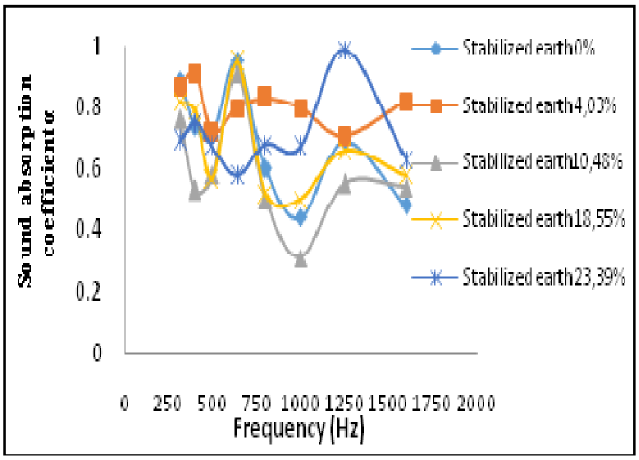

Fig. 2. Demonstration of the effect of moisture on the absorption coefficient of the stabilized earth

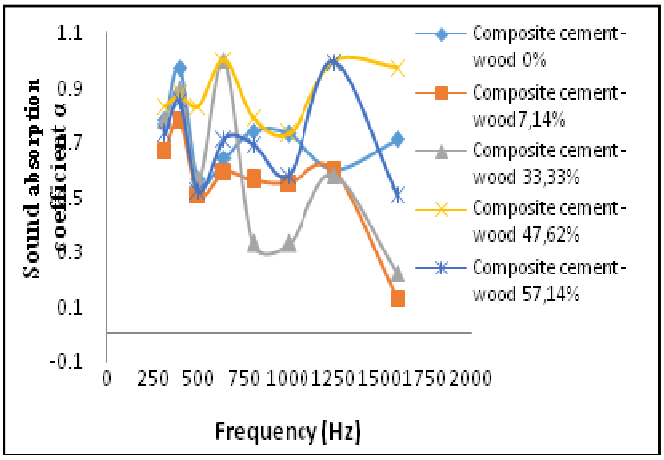

Fig. 3. Demonstration of the effect of moisture on the absorption coefficient of the cement-wood composite

From this uncertainty study, the values of the acoustic absorption coefficients for the two samples are obtained with an uncertainty of between 0.6% and 5% according to the frequencies. Measurements carried out over the tolerable frequency range (255 Hz to 2000 Hz) by the Kundt tube allowed according to the normalized frequencies to obtain the results presented in the tables below:

Stabilized earth

Composite cement-wood: The treatment of the different results resulting from the measurements made it possible to carry out the histograms of figures 1 and 2 below:

DISCUSSION

- The curve in Figure 2 shows the variation of the sound absorption coefficient of the stabilized earth as a function of humidity (0% for the anhydrous stabilized earth at 23.39% absolute humidity of the stabilized earth). Looking closely at this curve, we notice that in the frequency ranges (from 315 Hz to 750 Hz), the absorption coefficient of the stabilized earth decreases when its humidity increases, which means that the moisture content clogs the pores. of the material, that is to say decreases its porosity and prevents sound absorption. From 750 Hz to 1000 Hz, the absorption coefficient of the material increases or decreases in this frequency range when the humidity increases, the amount of water in the pores of the material also decreases or increases its porosity and favors or not the absorption of sound [7]. From 1000 Hz to 1600 Hz, the absorption coefficient of the material increases with absolute humidity; the water enlarges the pores of the material further, that is to say increases its porosity which is manifested by a better absorption of the sound.

- The same phenomena are observed at the level of the acoustic absorption of the cement-wood composite and is translated as follows:

The moisture content of the cement-wood composite varies from 0% for the dry material to 57.14% for the material completely immersed in water for 24 hours (absolute humidity). This variation of the moisture content in this material causes an increasing or sometimes decreasing variation of the sound absorption coefficient over given frequency areas as shown in the curve of Fig. 3.

- From these analyzes, the two samples are good sound absorbers over the different frequency ranges, but their acoustic absorption coefficients are strongly influenced by their moisture content. We note the structure of the material (its porosity) has an influence on the sound absorption coefficient.

Conclusion

The Kundt tube made it possible to determine the values of the maximum and minimum electrical voltages which were used to calculate the reflection coefficient of each type of material even if it is necessary to deduce the acoustic absorption coefficients of the materials previously whose humidifies have been determined. A detailed study clearly shows that the moisture content of each type of sample influences their sound absorption coefficient on the frequency zones given by increasing or decreasing. This state of affairs reflects the behavior of water in the pores of the material on the sound absorption quality of the samples. It should be noted that the samples tested are very good absorbers (because having $\alpha \geq 0.5$) that can be used to ensure the acoustic comfort or insulation of buildings despite the influence of their water content.

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