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Research Article

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Use of Typha Australis in the Habitat for the Improvement of Energy Efficiency of Buildings

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Abstract In order to reduce the energy consumption of the habitat which occupies a large part, several materials are used as thermal insulation. This is the case of typha australis, a rhizomatous and perennial herb which inhabits aquatic environments. Thus, in order to meet social demand (bioclimatic habitat ...) and ensure a hygiene of life (water-borne diseases ...), studies have been carried out on the valorization of this herb in the habitat. These studies concern both the mechanical strength of typha-based materials and their thermal transfer properties. This study will make it possible to pronounce on the thermomechanical behavior of typha-based concrete while opening a prospect of valorization of the plant fibers in the habitat.

Keywords Typha australis, compressive strength, thermal conductivity, bioclimatic, bio-sources materials

Introduction

The bioclimatic habitat aims to integrate innovations in the different compartments of buildings. These innovations range from foundations to simple coatings. Their role is to increase occupant comfort and reduce investment costs while preserving the balance of nature [1]. It is within this framework that several researches have been carried out on the valorization of by-products, resulting from agricultural discharges or even of plants considered as hurtful, in the habitat [2-3]. This sector offers prospects for recovery of several bio based materials insofar as the basic elements (hemp, millet waste, rice bales or typha australis) have a relatively low cost [4-6].

The housing sector is responsible for a large amount of energy consumption (47.8% according to SIE-Senegal [7]) and indirectly greenhouse gas emissions. The development of new insulation materials capable of increasing the energy efficiency of buildings and reducing their energy bill contributes to the development of bioclimatic habitat [8-9]. At the same time, the integration of bio-sourced materials such as hemp, millet waste, rice husks and typha into the habitat contributes to reducing the emission of greenhouse gases such as CO_2. .

Therefore, the use of typha in the habitat offers new prospects for valorization [10] of this herb considered as harmful and meets the need to produce insulating materials to reduce the energy bill.

Context and motivation

The realization of High Environmental Quality building requires to take into account a set of requirements including Eco construction. It offers buildings a harmonious relationship with their immediate environment but also to make an integrated choice of processes and construction products. Cause for which, the building materials must answer certain properties in order to have respectful structures of the environment and economic in terms of investment than consumption of energies. That’s why it is important to produce materials of suitable heat insulation to the tropical climate, respectful of the environment with a low cost. Studies, referred to above, showed that the integration of certain vegetable by-products and even certain grasses in building materials can prove to be beneficial for the production of insulating materials (thermal and/or acoustics). It is within this framework that the typha australis is used in this present work to study its mechanical and thermals properties after its integration in a cementing matrix.

In addition, this herb causes enormous damages with the bordering populations of the wetlands where it pushes. Without occulting the threats on fishing in the level of the Senegal River valley where its presence increases the eutrophication of water and constitutes a trap for the fishes, populations health disquiet because of the recrudescence of certain diseases (bilharzia, malaria…). In the field of agriculture, the threat is without call insofar as many terrains reserved for agriculture are invaded by the typha, by the same occasion the irrigation canals [12]. The list of the threats generated by the non-exploitation of the typha is far from being exhaustive so much domain are concerned with this threat. It is within this framework that we undertook the valorization of this herb considering its lightness and its porosity, to reduce the heat transfers of the envelope of the building. This work is a draft for the promotion of new local materials of heat insulation containing typha. In term, it will contribute to the production of local materials of insulation being able to be useful for a solution of passive air-conditioning, to reduce the negative socio-economic impacts of the typha and to generate profits for the bordering populations.

Materials and Methods

To conduct the experimental campaign, we made concrete test-tubes at base typha according to the norm XP P 18-545 which defines the density of the light aggregate concretes.

- Confection of the test-tubes

In this present work, Typha is used as light aggregates within the concrete. It is added to the classic components such as sand, cement, gravel and water.

The study is done in two parts with a first one related to the mechanical resistance of materials that contain typha. Cylindrical test-tubes (11x22 cm^2) are made according to several formulations; three samples are preserved in water and three others at the free air for each formulation. These methods of conservation will enable us to know the ripening place impact on the mechanical properties of typha concrete.

During the process of the test-tubes, we started by setting up samples only made up of cement, sand, gravel and water used as test-tubes of reference. Thereafter, other formulations having a percentage of typha in mass going from 0.5 % to 2.5 %, with a variation step of 0.5 %, are made. To avoid the segregation of the typha aggregates, one uses a table of shock regulated with 60 blows. First of all the molds are filled fully and pressed on the table then filled for the second time and pressed last before being dried. The test-tubes are unmolded 24h after casting and are placed in their environment of ripening.

- Performance test

The mechanical performances of materials are measured at the 7th and 28th days after smoothing of the faces having to be in contact with the hydraulic press. From the threshold of loading (*f*) causing the destruction of material, one determines the compressive strength (*Rc*) according to the relation (1):

$$R_c = \frac{f}{S} \qquad (1)$$

Whith: R_c: the compressive strength;

f: force necessary to the rupture of material;

S: surface contact material-press (basic surface of the test-tube).

After these mechanical tests, we carried out bricks hollow block containing typha to study their impact on heat exchange on the level of the flagstones of our building test. The bricks used result from the formulation with less cement (c/g = 0.2) thus generating a weak cost.

Figure 1: Bricks hollow block containing typha australis (c/g=0.2)

These bricks will be integrated in one of our rooms-tests. Our objective is to measure the impact of typha bricks, compared to the traditional bricks hollow block, on heat exchange of the rooms.

With this intention, we installed the sensors of relative humidity and temperature in order to follow heat exchange within our building test (flagstone and environment).

To model the properties of heat insulation of the typha concrete, we started by making bricks hollow block starting from the formulation with 2% of typha (c/g=0.2).

This building in question was built with geo-concrete in 1986 within the framework of a research project. It was rehabilitated and equipped to be used as demonstrator building.

In this present report, one is interested in two contiguous flagstones of which one is done with classic bricks hollow blocks and the other with hollow blocks containing typha (formulation of 2% with c/g=0.2). Figure 2 shows, coast at coast, the demonstrator building and the two rooms used for the transfers study.

Figure 2: geo-concrete building-test in Polytechnic School of Thies

The two parts are exposed to the sun in the same way and have even surface built.

- Measurement and monitoring

A device of measurement composed of sensors relative humidity and temperature are used on the site. These sensors are connected to a central unit which is used as web server of the system. Two types of sensors are used on each part to follow the temperature change on flagstones and environment. One of the temperature sensors is fixed on the flagstone and the other positioned at the middle of the part as shown in figure 3. They record the temperature and the relative humidity with a frequency of 10 mn.

The central processing unit is equipped with an antenna without wire allowing the exploitation of the data with a remote connection. Measurements concern the flagstones temperature and the ambient temperature and relative humidity of the rooms.

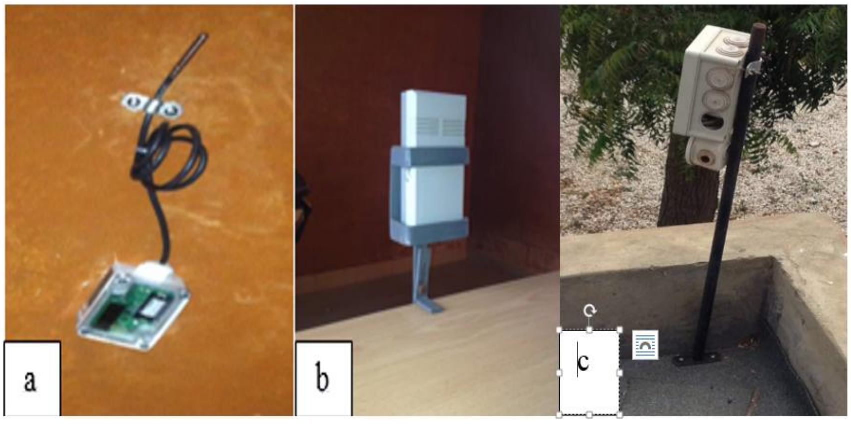

Figure 3: a) Sensor in contact with the flagstone, b) Sensor of temperature and relative humidity ambient, c) external sensor

Outside, we also have sensors intended to measure the speed of the wind and the ambient temperature and external relative humidity.

Results and Discussions

The compressive strength of materials determines the bearable threshold of loading for a given material.

For a ratio of cement on aggregates (c/g) of 0.3, figure 4 makes it possible to see the mechanical characteristics of the various formulations. The formulations ranging between 0 and 1.5% shows the mechanical resistance increase from the 7th day to the 28th day. Fewer there is typha, more the compressive strength with the 28th day deviates from the 7th day. This shows, for the samples with less typha, mechanical resistance increasing moderately.

The increase of typha in material reduces the mechanical performances. They pass from 11.62 MPa to 5.92 MPa for an addition of 0.5% in mass of typha. The typha is an obstacle with the deployment of the cementing matrix (chemical bond) responsible for the mechanical resistance of the concrete. Contrary to the rigid aggregates, the typha is very deformable and does not have an impact on the improvement of the mechanical resistance of material. This is more visible on the formulations of 2% and 2.5% where the typha is more present.

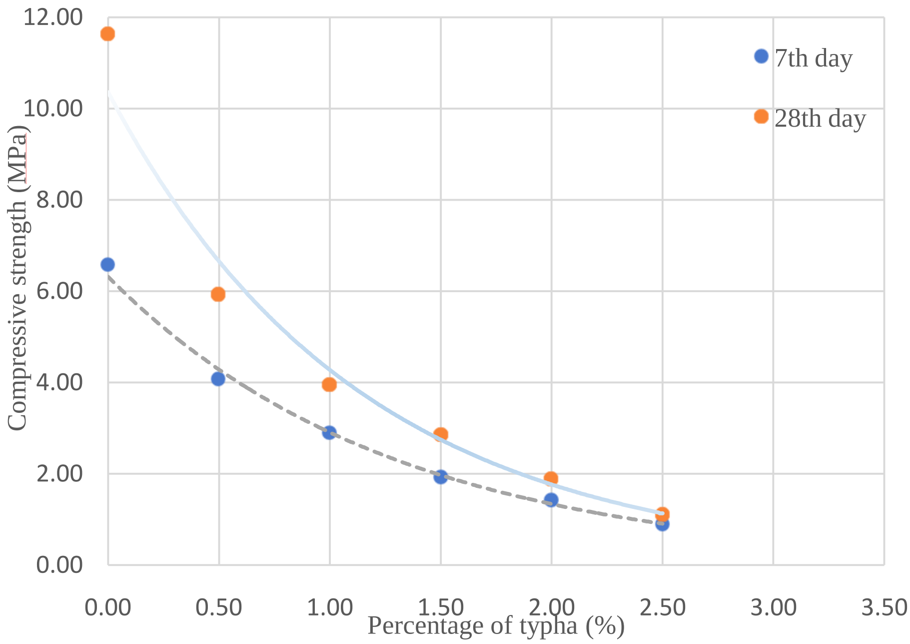

Figure 4: Mechanical resistance of the concrete (c/g=0.3) according to the percentage of typha

Consequently, the increase of the typha in the concrete decreases the density of material and consequently its mechanical resistance. The following figure 5 illustrates the relation between the density and the mechanical resistance of materials.

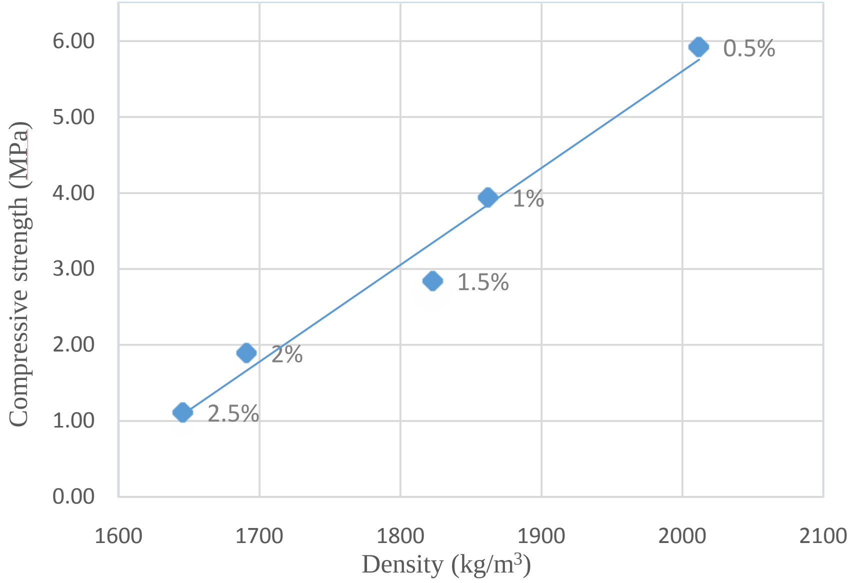

Figure 5: Evolution of the compressive strength according to the density

Larger is the density (less typha), more the compressive strength is significant. In addition, the quantity of cement present in the formulation contributes to increase the resistance of material but also its cost. A material containing typha with less cement (weak cost) would be an answer adapted to the social habitat. In this part, one second formulation which aims to decrease the content of cement (c/g=0.2) of material is studied. Following figure 6 gives the evolution of resistance in compression for a variation of the content of cement.

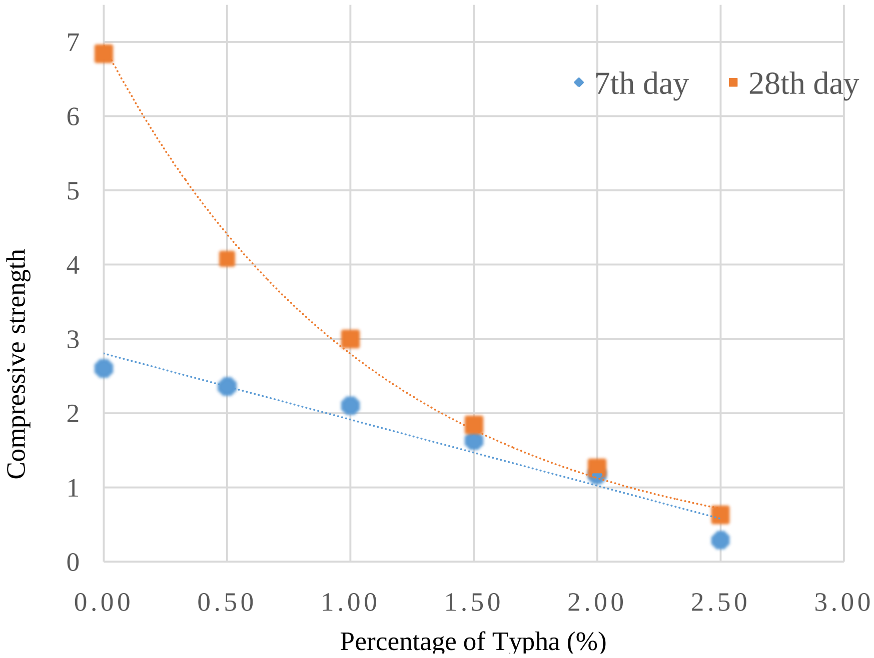

Figure 6: Compressive strength according to the percentage of typha (c/g=0.2)

One notes a reduction in the compressive strength for the 7^{th} and 28^{th} day. This reduction in is dependent on the reduction in the quantity of cement. Nevertheless the shape of the curves remains identical to that of figure 4 except that in this case the difference between the compressive strengths for the 7th and 28th day is not visible any more starting from an addition of 1.5% of typha.

Figure 7 provides a comparison of the compressive strengths for the 28th day of the two studied formulations. It is noted that resistance in compression for the 28th day of the formulations with a c/g=0.2 ratio is similar to the compressive strength to the 7th day of the formulations with a ratio c/g=0.3. This reduction in the compressive strength is quite normal for this formulation of c/g = 0.2 as the quantity of cement brought into play is reduced.

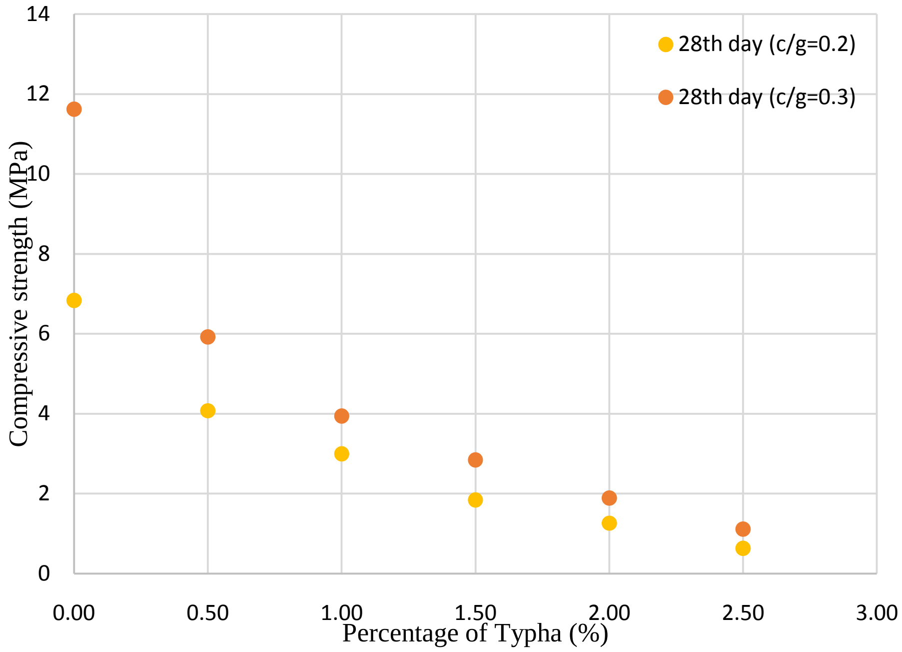

Figure 7: Comparison of the compressive strengths with the 28th day for formulations 0.2 and 0.3 (c/g)

The typha, being a porous material, finds the importance of its use in the habitat from its lightness and its porous structure. As a harmful herb causing the hydrous diseases and the obstruction of the irrigation canals, its porous structure suggests that its integration in building materials would allow the production of heat insulation materials.

Thermal Results

With the measuring apparatus, we carried out a data acquisition over a long period. To facilitate study, we chose to carry out the analysis in over three months period (February to April, 2017) corresponding to the data on the figures below. The temperature change of the flagstones shows that the flagstone containing the typha hollow blocks lets pass less heat compared to the flagstone containing classic hollow blocks. This difference in temperature can go up to 2°C at peak hours.

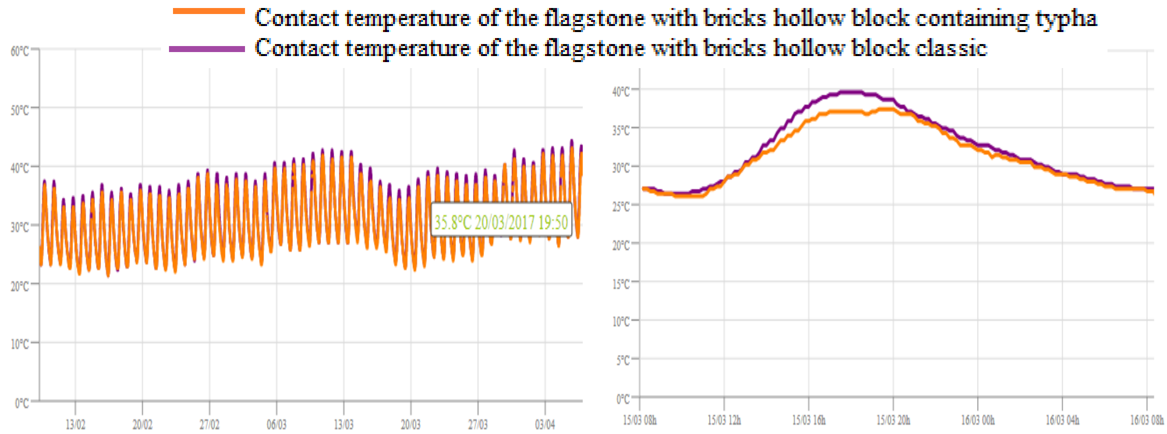

Figure 8: Evolution of the flagstones temperatures

This shows that the typha concrete plays a role of thermal filter with respect to the solar radiation. Its use makes it possible to reduce heat exchange.

Typha concrete permits heat insulation because the typha is porous, imprisons motionless air (λ= 0,025 $W.m^{-1} K^{-1}$) which gives a good insulating. Mixed with the concrete which thermal conductivity turns around of **λ**= 2 $W.m^{-1} K^{-1}$, the typha tends to decrease the conductivity of the mixture. One recognizes oneself with a lower temperature on the internal facade of the flagstone containing typha compared with the temperature of the traditional flagstone internal facade. This difference in temperature is also noted in the environment of the two rooms studied. Indeed, following figure 9 illustrates the recording of the change of the ambient temperatures.

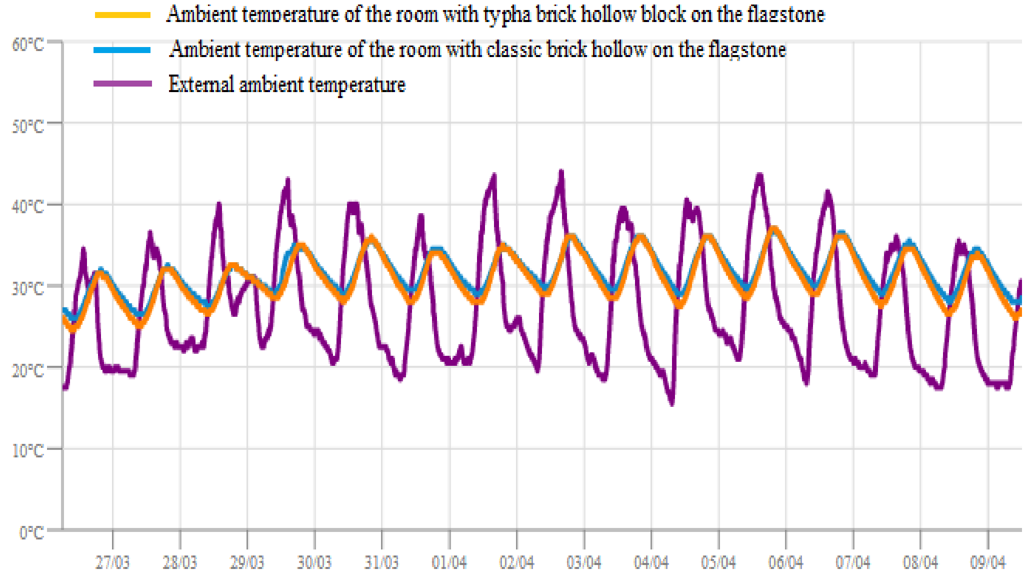

Figure 9: Variation of internal and external ambient temperatures

In spite of significant fluctuations of the external temperature, the two rooms studied keep relatively stable ambient temperatures and have a certain thermal resistance able to modulate their thermal variation on a limited beach.

This property of stabilization is due to the thermal inertia of laterite materials grounding which constitutes the walls. Nevertheless a difference in temperature is raised on the comparison of environments (1.5 °C to 2 °C). In addition the heat insulation of the flagstone increases the thermal comfort of the room from where a better feeling. It is also noted that the humidity within the buildings-test are very neighboring for the two rooms studied even if the humidity of the external environment records significant variations.

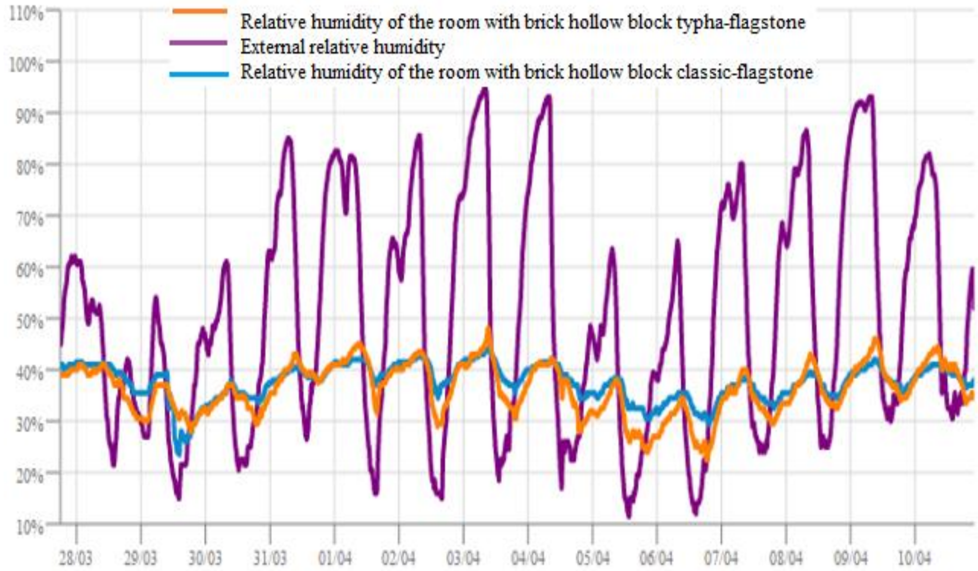

Figure 10: Variation of internal and external humidity

5. Conclusion

The use of the typha australis opens a new field of bio-sources products valorization, considered as waste in the habitat. The results obtained on thermal comfort, suggest that the bio-sources spinneret has a future in the field of the valorization of materials. However, the weakness of the mechanical resistances indicates that typha concrete should be improved for a structure use but can be used as filler concrete. The performance evaluation of the rooms-test by real measurements made it possible to validate our hypothesis according to which the use of typha-australis increases the capacity of thermal insulation of the walls.

Acknowledgements

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