



Mechanical and Water Characterization of a Light Concrete Based on Typha Australis

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ADM, AA and SG managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This article is devoted to the study of the mechanical and water properties of concrete of Typha australis. The concrete is achieved by the mixture cattail aggregates with cement, sand and water.

Mechanical study showed that the density and the mechanical compressive strength decreases with the dosage of typha aggregates, and increases with the dosage of cement. However, the values obtained do not allow using this concrete in supporting structures. However, the value obtained is 0.16 MPa for the first series (S1), and 0.26 MPa for the second series (S2), for a high dosage of typha of 3.5% is sufficient for a wall of three meters high can support its own load.

With a constant intrinsic porosity, these aggregates are compressible and porous. This physical condition makes the vegetable particles of typha very lightweight and sensitive to water.

The lightweight concrete became sensitive to water. Increasing the dosage of typha aggregates

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increase the water absorption of concrete. More than 50% of the water content is absorbed during thirty minutes of immersion. It is therefore strongly recommended to waterproof the wall with typha australis.

Keywords: *Typha australis; Typha aggregates; lightweight concrete; cement on sand ratio; water absorption; density; compressive strength.*

NOMENCLATURES

F	: Maximum force (N)
M_{se}	: Dry mass of the sample (kg)
$M(t)$: Mass of the sample at time t (kg)
W_a	: Relative mass gain (%)
S	: Sample area (m^2)
σ	: Compressive strength (MPa)
ρ	: Density (kg/m^3)
S_1	: First series
S_2	: Second series

1. INTRODUCTION

The *Typha australis* is an aquatic plant that grows in abundance in stream, rivers and lake. Therefore it degrades water quality and seriously disturbs the use of agricultural and fisheries resources. Several eradication attempts have been made in order to enhance its use in a number of economic sectors: domestic energy, agriculture, paper production [1] and the construction sector for the production of building materials [2] (thermal insulation, elements for roofs, walls, etc.). The use of "bio-sourced" materials [3] among the construction materials allows to improve the energy efficiency of buildings [4,5,6,7]. Several studies have been conducted in this direction [8,9,10,11]. In addition, the concrete of *Typha australis*, subject of this study, is being tested.

Thus, in our study, we have incorporated *Typha australis* aggregates in a cement mortar to analyze their influence on the mechanical, thermal and water behavior of the concrete.

This article is devoted to the study of mechanical and water behavior. Thus, after determining the characteristics of *Typha*, we proceeded to manufacture test specimens for the determination and analysis of the mechanical and water characteristics of concrete.

2. EXPERIMENTAL PROCEDURES

2.1 Materials Used

In this study, we used fine dune sand (0/2 mm), cement (CEM II / BM 32,5R), and aggregates of

Typha australis (1/20 mm), coming from the cutting of the plant chopped and dried typha.

2.2 Procedure

The sand and cement are mixed in a tank and well homogenized before the introduction of the aggregates. The aggregates are wetted before their introduction into the dry mixture and well mixed; which neutralizes the high absorbency of typha aggregates, and allows good cement setting when adding the mixing water. After mixing, the homogeneous mixture is introduced into cylindrical molds 11cm in diameter and 22cm in height. The same molds were used for the water and mechanical test.

2.3 Formulation

We made two sets of samples with two different ratios of cement to sand. For the first series (S_1), we used a ratio ($C / S = 1/4$); and for the second series (S_2), we used a ratio ($C / S = 1/3$). The water to cement ratio is 0.7 for both series ($W / C = 0.7$). The percentage of typha which was introduced by replacing an equivalent mass of sand varies from 0% to 3.5% with a step of 0.5% relative to the total mass of the test piece. The absolute density of typha is approximately $145 \text{ kg} / \text{m}^3$, and the intergranular porosity is 24.23%.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Density

The densities were measured after drying in an oven controlled at 105°C for 24 hours, until their masses remained constant. Fig. 1 shows the change in density for the two series, as a function of the mass fraction of typha.

From Fig. 1, we notice that the density decreases very sharply with the dosage of typha. The low density of the typha particles explains this decrease. The trends show that for the two series (S_1) and (S_2), the difference in their densities is small. This slight shift is due to the difference in the binding dosage. The (C / S) ratio

(cement on sand) is $\frac{1}{4}$ for the first series (S1), and that of the second series (S2) is $\frac{1}{3}$. In all cases, the (W / C) (water to cement) ratio is kept constant. Under these conditions, and with oven-dried samples, we can conclude that the mass of the binder can also influence the difference observed in the measurement of the densities of the concrete.

3.2 Measurement of Mechanical Compressive Strength

The measurements of the mechanical compressive strengths at 28 days are carried out by crushing the cylindrical specimens using an electromechanical press (TINUS OLSEN) equipped with a dial graduated from 0 to 800kN [7]. Each graduation corresponds to 1kN. The crosshead moves at a speed of approximately 5 mm / min [2].

The mechanical compressive strength is given by the following relation:

$$\sigma = \frac{F}{S} \quad (1)$$

Where:

- F: Maximum force (N)
- S: Sample area (m²)
- σ : Compressive strength (MPa)

Thus, we have shown in Fig. 3, the variation of the compressive strength as a function of the mass fraction of typha. Then in Fig. 3, we have shown the variation in compressive strength as a function of density.

We find that the mechanical compressive strengths decrease with the dosage in typha and increase with the density. For mass fractions of typha varying from 0% to 3.5%, the compressive strength of the first series (S1) decreases from 10.53 M Pa to 0.16 M Pa, or 98.4%. That of the second series (S2) decreases from 13.95 M Pa to 0.26 M Pa, or 98.1%. In both cases, the values of the mechanical compressive strengths obtained for a high dosage of typha allow a wall three meters high to support its own load. This material can therefore be used for filling concrete or partition walls.

Although for the same mass fraction of typha, concretes made with a ratio (C / S = 1/3) have higher strengths than those made with a ratio (C / S = 1/4). But given the results obtained, it is

therefore not necessary to increase the cement dosage. A ratio (C / S = 1/4) is sufficient to achieve this concrete.

3.3 Hygrometric Behavior

3.3.1 Water absorption kinetics of typha aggregates

The water absorption coefficient is defined as the ratio of the increase in mass of the sample after immersion in water, to the dry mass of the sample. The dry mass is obtained by placing the sample in the oven at 105 ° C for 24 hours. The absorption coefficient is given by the following relationship:

$$w_a = \frac{M(t) - M_{se}}{M_{se}} \times 100 \quad (2)$$

Where:

- M_{se}: Dry mass of the sample (kg)
- M (t): Mass of the sample at time (t)
- W_a: Relative mass gain (%)

We carried out measurements of water absorption by typha aggregates according to the procedure of standard EN 1097-6. Table 1 shows the measurement results.

The change in the absorption coefficient (w_a) as a function of time over the first ten minutes is represented by the curve in Fig. 5.

We find that typha aggregates absorb water very quickly. More than half of their total content is absorbed during the first two minutes. Thereafter absorption increases monotonously and tends towards saturation after ten minutes.

3.3.2 Absorption kinetics of concrete

The hydric behavior of concrete is analyzed through absorption kinetics. As the samples were initially in equilibrium, we chose three different formulations (0.5%; 1%; 1.5%) from each series (S1 and S2). These samples are immersed in water, and the mass water gain is measured after thirty minutes, and then after each hour for ten hours of immersion. We therefore calculate the relative gain in mass from these measurements by the ratio between the mass gain and the initial mass of the sample. The measurement results are given in Tables 4 and 5 below, and the curves giving the variation in the

relative gain in mass as a function of time are presented in Figs. 6 and 7.

From these figures, it can be seen that more than half of the water content is absorbed during the first thirty minutes. After an hour, almost 90% of their total content is absorbed. Subsequently, this absorption increases linearly and slowly, and seems to stabilize after 10 hours of immersion. The differences between the curves are due to the difference in formulations. The incorporation of typha aggregates into the concrete increases the porosity and therefore promotes its capacity to collect water. Thus, for the first series (S1), the first formulation (0.5% of Typha) seems to saturate for a mass gain of 3%, the second formulation (1% of Typha) for a mass gain of 5%, and the third formulation (1.5% of Typha) for a mass gain of 7%. This result seems consistent taking into account the step of the dosage in typha which is 0.5% by mass. For the second series (S2), we find that the mass gains are low compared to the first series. This difference is

certainly due to the cement to sand ratio which is 1/4 for the first series, and 1/3 for the second series.

The incorporation of the typha aggregate in the mortar made it possible to greatly reduce the density and the mechanical resistance of the material. A mechanical strength of 0.16 M Pa for the first series and 0.26 M Pa for the second series was obtained. These values do not allow this material to be used in heavy load-bearing structures, but this material can be used in the construction of partition walls because the values obtained allow a wall 3m high to bear its own load.

Thypha aggregates are very sensitive to water, this sensitivity affected concrete. Concrete becomes very sensitive to water because more than 50% of its water content is absorbed after 30 minutes of immersion, which is why it is strongly recommended to waterproof the wall built with Thypha australis.

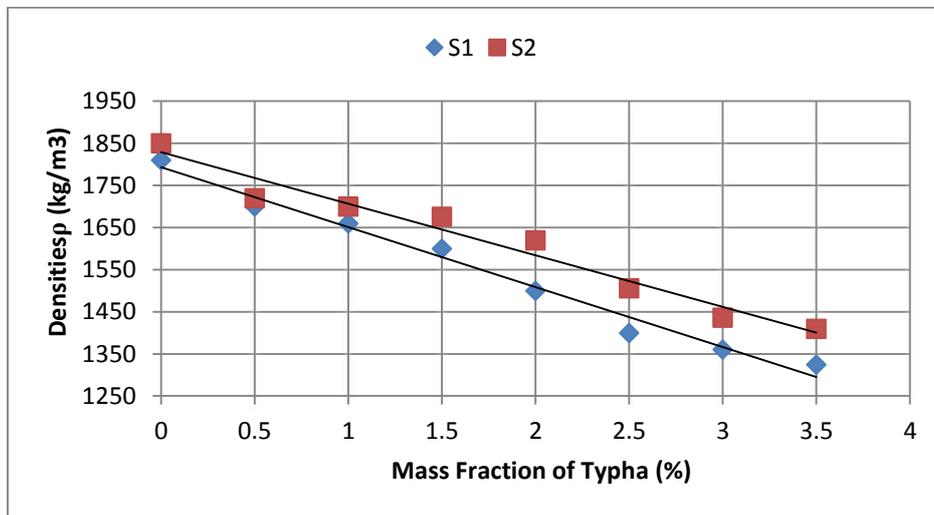


Fig. 1. Variation of the dry density as a function of the mass fraction of typha

Table 1. Masses composition (kg) of the 1er series (S1)

	0%Typha	0,5%	1,5%	2,5%	3%	3,5%
Sand	3,09	3	2,8	2,6	2,4	2,2
Cement	0,77	0,77	0,77	0,77	0,77	0,77
Typha	0	0,019	0,054	0,086	0,098	0,11
water	0,65	0,64	0,54	0,6	0,62	0,63
W/C	0,84	0,83	0,7	0,77	0,80	0,81
C/S	0,25	0,257	0,276	0,297	0,32	0,35

Table 2. Masses composition (kg) of the 2nd series (S2)

	0%Typha	0,5%	1,5%	2,5%	3%	3,5%
Sand	3	2,98	2,84	2,6	2,3	2
Cement	1	1	1	1	1	1
Typha	0	0,02	0,0585	0,092	0,102	0,108
water	0,7	0,7	0,7	0,7	0,7	0,7
W/C	0,7	0,7	0,7	0,7	0,7	0,7
C/S	0,33	0,335	0,35	0,384	0,43	0,5



Fig. 2. Samples for mechanical

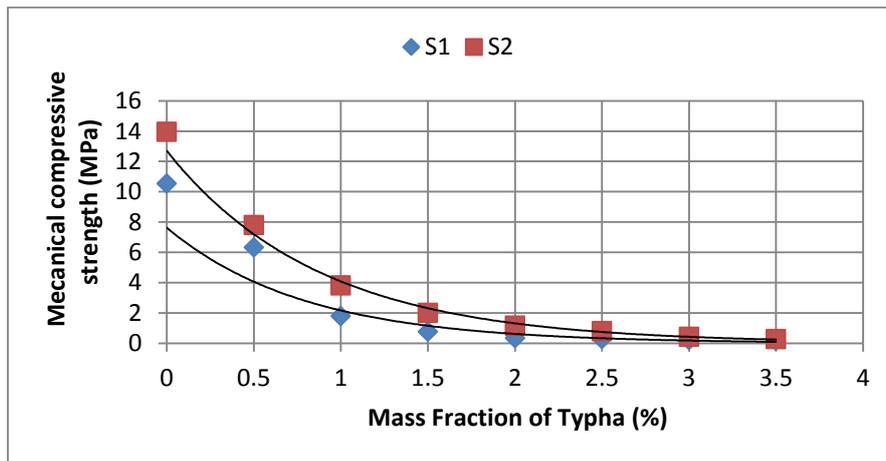


Fig. 3. Variation of mechanical compressive strength as a function of the mass fraction of typha

Table 3. Variation in mass gain as a function of time

Time (mn)	0	1	3	5	7	10
Mass Gain wa (%)	0	300	501	615	648	690

Table 4. Relative mass gain as a function of time of the first series (S1)

Time (h)	0	1	3	5	7	9	10
Wa(0.5%)	0	2.01	2.27	2.4	2.5	2.6	2.65
Wa(1%)	0	4.25	4.44	4.6	4.8	5.0	5.1
Wa(1.5%)	0	5.74	6.02	6.3	6.6	6.8	7

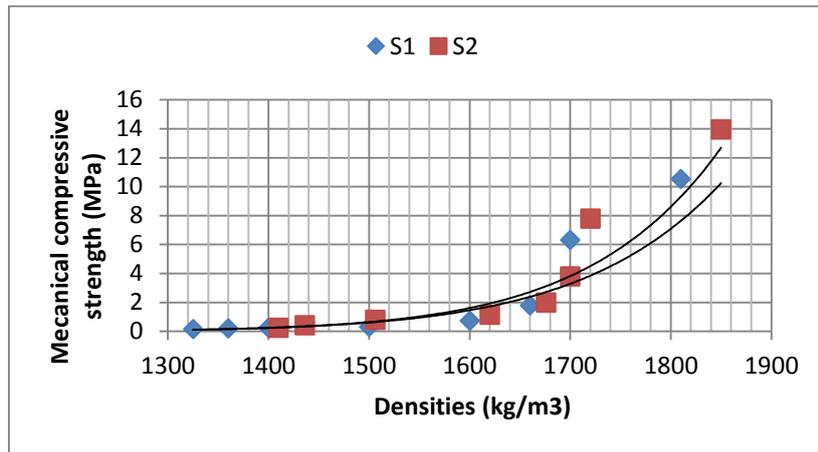


Fig. 4. Variation of mechanical compressive strength as a function of density

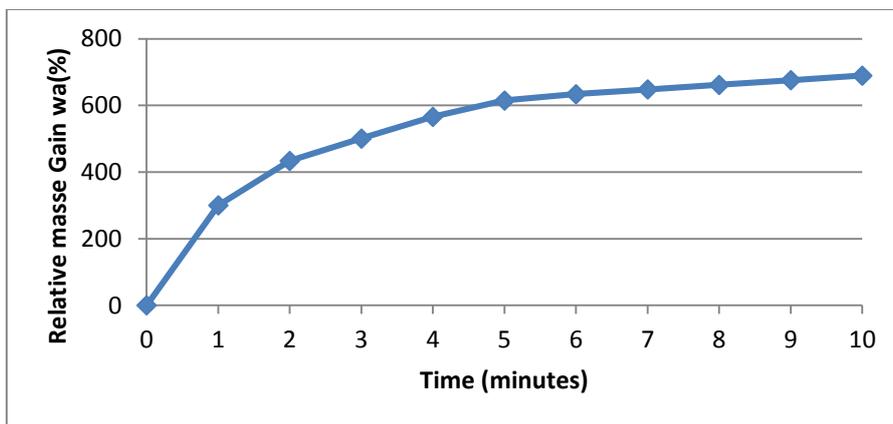


Fig. 5. Variation of the relative mass gain of typha aggregates as a function of time

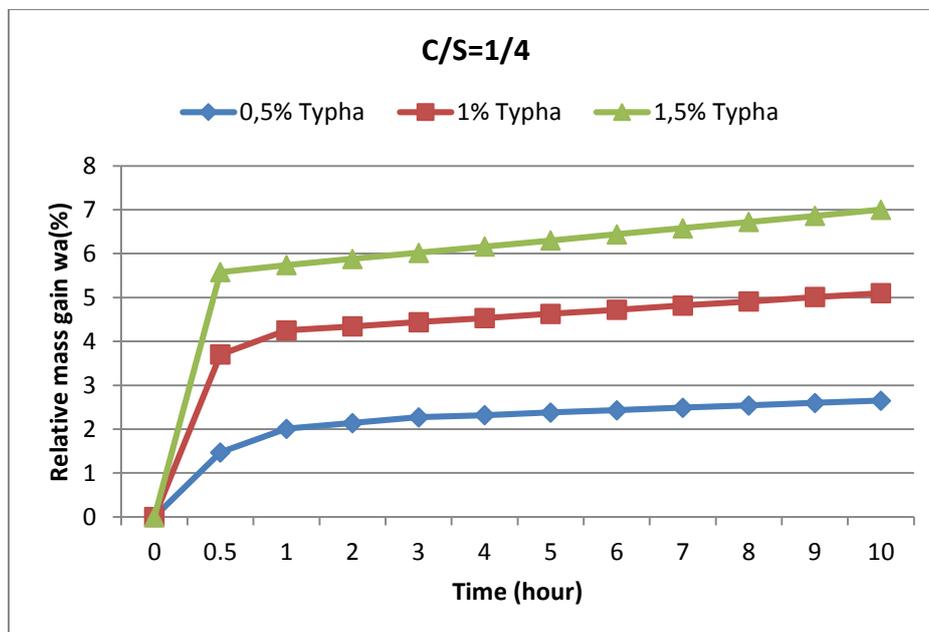
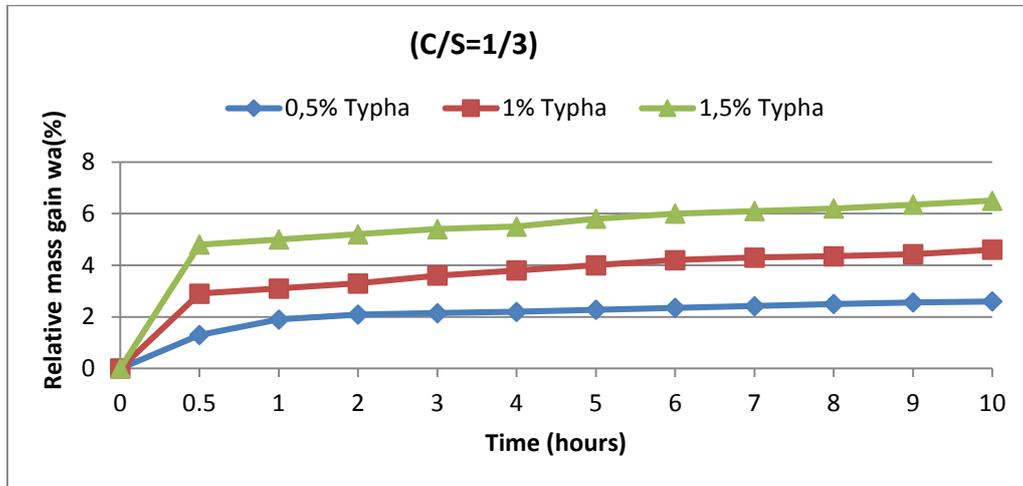


Fig. 6. Variation of the relative mass gain as a function of time of the first series (S1)

Table 5. Relative mass gain as a function of time of the second series (S2)

Time (h)	0	1	3	5	7	9	10
Wa(0,5%)	0	1.9	2.15	2.28	2.42	2.56	2.6
Wa(1%)	0	3.1	3.6	4.0	4.3	4.43	4.6
Wa(1,5%)	0	5.0	5.4	5.8	6.1	6.35	6.5

**Fig. 7. Variation of the relative mass gain as a function of time of the second series (S2)**

4. CONCLUSION

The integration of *Typha australis* aggregates in the manufacture of concrete makes it possible to lighten the structures by causing a notable reduction in density and compressive strength. However, the resistance values obtained for a high dosage of typha allow the use of this material for partition walls or filling concrete. The water behavior of concrete is influenced by that of aggregates and also by the cement to sand ratio. The incorporation of typha aggregates in concrete increases its water absorption. In view of the results obtained, it is not necessary to increase the cement dosage. It is therefore strongly recommended to waterproof the wall with *Typha australis*.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. UNDP, Project document, Technology transfer: Production of thermal insulation materials based on typha in Senegal; 2010.
2. Adam Gaye, Mamadou Babacar Ndiaye, Oumar Diallo, Harouna Mamadou Bal, Salif Gaye. Article. Optimization of the mechanical formulation of Typha concrete. IJITEE. 2021;10(3):54-58.
3. Bernard Boyeux. Study report, Arene. The Ile-de-france sectors of bio-sourced materials and products for construction; 2014.
4. Marthe Tatiana Diatta, Salif Gaye, Ababacar Thiam, Dorothé Azilinson. Article. Determination of the thermophysical and mechanical properties of typha australis. Applied energy laboratory, Ecole

- Supérieure Polytechnique de Dakar, Senegal. 2011;1-6.
5. Diaw AS, Sow D, Ndiaye MB, Azibert OA, Wade M, Gaye S. Article. Valorization of Typha australis by its integration in building construction materials. IJETAE. 2016;6(1): 34-37.
 6. Azibert Oumar Abdelhakh, Ahmat Mahamat Saleh, Malloum Soultan, Djibril Sow, Gilbert Menguy, Salif Gaye "Improving energy efficiency of buildings by using a light concrete based on Typha australis" [2016 3rd International conference on renewable energies for developing countries REDEC]. IEEE; 2016.
DOI: 978-1-5090-1864-2 / 16 / \$ 31.00 / 2016 IEEE.
 7. Azibert OA. Amélioration de l'Efficacité énergétique des bâtiments par l'utilisation d'un béton léger à base de Typha australis. Thèse de doctorat. Thermique, systèmes énergétiques et environnement. Université de Thiès, Sénégal; 2016.
 8. Cerezo V. Mechanical, thermal and acoustic properties of a material based on plant particles: Experimental approach and theoretical modeling. Doctoral thesis. Mechanics, energetics, civil engineering and acoustics. INSA of Lyon; 2005.
 9. Gourlay. E, Arnaud. L. From raw materials to hemp concrete: Optimization of thermal and mechanical properties. University of Lyon. ENTPE. Civil Engineering. Besançon. 2011;29-2.
 10. Chamoin. J. Optimization of the physical, hydric and mechanical properties of hemp concrete by mastering the formulation. Doctoral thesis, INSA Rennes. Civil Engineering; 2013.
 11. Taoukil D, El Bouardi A, Ajzoul T, Ezbakhe H. Article. Mechanical and water characterization of lightweight concrete with wood residues. Energy laboratory. Abdelmalek essaadi university. Faculty of sciences. Tetouan Morocco. 2011; 43(2011):1-7.

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