Scientific Research Publishing

Materials Sciences and Applications, 2025, 16(12), 555-565
https://www.scirp.org/journal/msa
ISSN Online: 2153-1188
ISSN Print: 2153-117X

Thermomechanical Characterization of Concrete Reinforced with *Typha* for Use in Construction

Brahim Tchou[1,2], Soultan Malloum[3], Abakar Ali[4], Abdallah Dadi[1], Salif Gaye[5]

[1]Energy and Materials Research Laboratory (LREM) of the National Higher Institute of Science and Technology of Abéché (INSTA), Abéché, Chad
[2]Department of Electrical Engineering of the National Higher Institute of Science and Technology of Abéché (INSTA), Abéché, Chad
[3]Department of Technology, University of N'Djamena, N'Djamena, Chad
[4]Building and Public Works Laboratory (LBTP) of the ENSTP, N'Djamena, N'Djamena, Chad
[5]Laboratories of Materials, Energy, Electricity, and Economy (LM3E), Iba Der Thiam University of Thies, Thies, Senegal
Email: brahimtchou@gmail.com

How to cite this paper: Tchou, B., Malloum, S., Ali, A., Dadi, A. and Gaye, S. (2025) Thermomechanical Characterization of Concrete Reinforced with *Typha* for Use in Construction. *Materials Sciences and Applications*, **16**, 555-565.
https://doi.org/10.4236/msa.2025.1612033

Received: October 5, 2025
Accepted: December 13, 2025
Published: December 16, 2025

Abstract

This study examines the use of sand from the Chari River in N'Djamena as a partial addition to Portland cement, aiming to improve the characteristics of *Typha australis*-based concrete. Concrete samples with *Typha australis* fibers were tested, revealing that fine sand contributes through physico-mechanical effects. The use of *Typha australis* aims to reduce construction costs and energy consumption. Three cement contents (6%, 8%, and 10%) and six Typha fiber contents (0.5%, 1%, 1.5%, 2%, 2.5%, and 3%) were tested, with curing times of 7, 14, and 28 days. Typha is used for insulation and non-load-bearing building blocks, providing good thermal insulation. Increasing cement content improves compressive strength, while low content causes sintering. The results show an improvement in compressive strength at 10% cement, of 1.98 MPa on the 7th day and of 2.75 MPa on the 14th day, with the addition of 0.5% Typha. The compressive stresses are 4.21 MPa and 2.03 MPa for Typha contents ranging from 0.5% to 1% on the 28th day.

Keywords

Typha australis, Cement, Chari River Sand, Mechanical Characterization

1. Introduction

The city of N'Djamena is facing a growing demand for housing due to the attraction it exerts on the Chadian population. Construction is, however, complicated by the nature of the soil. One solution envisaged is the use of sustainable materials such as *Typha australis*-based concrete; the plant resources available in the building are vast and varied. We plan to carry out an experimental study on 4 × 4 × 16 cm prismatic samples in order to manufacture materials industrially, complying with the normative and regulatory requirements of construction [1].

Typha australis is an aquatic plant, considered harmful, which disrupts agriculture and the quality of water. We wish to promote its use in construction for its insulating properties and its humidity management, thus transforming an invasive plant into a sustainable resource. It is used as an additive in Typha concrete.

The objective of the research is to develop standardized construction practices in N'Djamena and study the mechanical properties of a mixture of sand, cement, and *Typha australis* for its potential use in the construction of walls and partitions. The study aims to determine whether this mixture can serve as a local material for construction [1]-[3]. It is used as a renewable energy source in the domestic energy sector. In agriculture, it is used as fertilizer. Typha is also used in other economic sectors, such as papermaking and construction [4]. Typha, a plant fiber, acts as an insulator and is combined with cement and earth to form a covering in building construction [5]. This study contributes to the valorization of *Typha australis* in the field of biocomposites [6].

According to the study by Ahmadou Diop *et al.* (2020), the mechanical compressive strength of the material treated with 10% by mass of Typha is 0.71 MPa [7]. The objective of this study is therefore to determine the mechanical properties of a mixture of sand, cement, and *Typha australis*, using an appropriate characterization method developed by Gaye S. *et al.* (2001) [8]. This research focuses on the mechanical constraints of this mixture in order to evaluate its suitability for use as a local material for the construction of walls and partitions.

2. Materials and Methods

2.1. The Materials

Sand from the Chari River, in the city of N'Djamena in Chad, CIMAF-CPJ35 cement from N'Djamena, and *Typha australis* extracted from the rainwater irrigation canal in the Amerigué district of N'Djamena were used for the manufacture of the various test tubes. These tubes are reinforced with *Typha australis*, a plant fiber and a composite material belonging to the category of eco-materials.

To do this, different devices and machines were used: scissors to cut the Typha into fine twigs, a sieve to measure the particle size of the sand, and an electronic balance to weigh the sand, cement, Typha, and mixing water according to progressive mass proportions, in accordance with the formulations. A 60-shot impact testing machine was used to prepare the samples, as well as a CONTROLAB mechanical press designed to crush the previously manufactured prismatic samples by bending and compression.

2.1.1. The Typha

The literature review indicates that Typha has existed for a long time, but that the construction of dams has created favorable conditions for its spread [9]. As a result, its proliferation has become a threat to the regions where it grows. The Typha invades the irrigation canals of rainwater and fresh water from rivers and lakes, promotes the development of water-borne diseases, and prevents animals from drinking [10]. For these reasons, Typha is considered a potential solution to this problem [11]. The Typha fiber in the composite plays the main role of reinforcement while improving its mechanical properties, notably resistance to bending, and giving the material insulation properties. The fire resistance test of Typha carried out at the LERMAB laboratory of the University of Lorraine in Nancy, France, revealed the different characteristics illustrated in **Table 1**. Typha attracts great interest in ecology and biotechnology, thanks to its various applications in the fields of water purification, energy biomass, and composite materials.

Table 1. Biomass composition of *Typha australis*.

Typha australis				
Ash (%)	Extractables (%)	Klason Lignin (%)	Hémiicellulose (%)	Cellulose (%)
12.3	**2.4**	**13.6**	**28.2**	**43.5**

2.1.2. Cement

The cement used is CIMAF-Chad CPJ35 type, a cement manufactured locally in N'Djamena. CPJ35 enriched Portland cement complies with the quality standards applicable to CPJ class cements (Portland cement with additives). The number 35 indicates a minimum compressive strength of 35 MPa at 28 days, making it an intermediate quality cement suitable for different types of construction. It is composed of at least 65% clinker, the remainder being limestone, milk, pozzolans, etc., followed by calcium sulfate to balance the setting. CPJ35 is used in various fields, both in reinforced and unreinforced concrete constructions, for massive structures in general [12]. It is Portland cement which gives masonry mortar its mechanical strength, in particular its initial strength, essential at a time when construction rates are such that a wall must be able to support a significant load from the day after its construction. Portland cement mortars lack plasticity, present low water retention, and are difficult to implement. **Table 2** summarizes the mechanical properties of this cement.

Table 2. Physics and mechanical properties of cement CPJ 35 NGA 197-1 [12].

Composition	**The homogeneous mixture of at least 65% Portland clinker and 35% addition Addition of calcium sulfate to regulate intake.**			
Compressive strength of mortar (MPa)		2 days	7 days	28 days
	Minimum guaranteed according to NI 05.06.001: 2018	10.00	-	32.5
	Medium factory	13.98	24.72	33.68

Continued

	Minima NI		Average plant
Reject 45µ (%)	--		6.20
Fineness of grind	Mini SSB (cm^2/g) 3000		3445.85
SO3	Maxi en (%) 3.5		2.62
Expansion	Maxi mm	10	0.78
Start of setting	Mini en min 75		167.35
PAF (%)	Maxi en min 600		226.91
MgO (%)	- - - -		11.37
CI- (%)	Maxi en % 5		4.15
C3A (%)	Maxi en % 0.1		0.01
	Maxi (%)	10	8.45
Typical areas of use	All types of work, reinforced or unreinforced concrete, for standard structures and engineering structures		

2.1.3. Sample Preparation

The values of the physical characteristics are those of Brahim TCHOU *et al.* (2025) [9], determined from the selected geotechnical tests. The particle size analysis gave a fineness modulus of 2.53, which indicates that the sand is fine. This sand is very suitable for concrete, in accordance with the different sand equivalents tested (E_SVmoy > 80).

This type of test is carried out with the aim of improving the mechanical, thermal, and acoustic qualities of the construction material. It should be noted that the samples are prismatic in shape and measure 4 cm × 4 cm × 16 cm. The mass percentages of Typha used are as follows: 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%, each percentage substituted for standardized sand. The concrete is a mortar used to define certain characteristics of cements, notably compressive strength. This concrete is produced in accordance with standard NF EN 196-1. The process consists of mixing 1350 ± 5 g of standardized sand, 450 ± 2 g of cement to be tested, and 225 ± 1 g of water. Before being used to identify its physical and/or mechanical characteristics, this concrete is mixed for 4 minutes in accordance with the requirements of the standard. To prepare the samples, we followed the steps in **Table 3**.

Table 3. Mass composition of constituents (g).

	0% Ty	0.5%	1%	1.5%	2%	2.5%	3%
Sand	1350	1343.25	1336.5	1329.75	1323	1316.25	1309.5
Cement	450	450	450	450	450	450	450
Typha	0	6.75	13.5	20.25	27	33.75	40.5
Water	225	225	225	225	225	225	225
W/C	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C/S	0.3	0.335	0.336	0.338	0.340	0.342	0.344

The sand is steamed at 105˚C for 24 hours. The cement and sand are first mixed dry, then the measured quantity of mixing water is added to obtain a plastic mortar. This mortar is then placed into prismatic molds, ready for filling and mounted on a 60-oscillation vibrating table. The samples are demolded after 24 hours, and the water curing process is carried out during the desired duration (7, 14, and 28 days).

2.2. Methods Used: Crushing Tests on Prismatic Specimens in Flexure and Compression

2.2.1. Flexion

Figure 1. Resistance to flexion.

$$\sigma_f = \frac{1.5 f_{t\max} L}{b^3} \quad (1)$$

σ_f : Flexural stress in MPa;

$f_{t\max}$: Breaking force in bending in N;

L : Distance between supports in mm;

b: The base with: $L = 100$ mm and b = 40 mm.

2.2.2. Compression

Figure 2. Compression strength.

$$\sigma_c = \frac{f_C}{b^2} \quad (2)$$

σ_c: Compressive strength in MPa;

f_C: Breaking force in compression, in *N*;

b: Base in mm ($b = 40$ mm).

3. Results and Discussions

Particle size analysis of Chari River sand revealed that it is mainly composed of medium-sized grains and is a sand of preferential quality. The fineness modulus ($M_f = 2.53$) confirms that this sand allows obtaining resistant concrete. Sand is very suitable for making concrete. The methylene blue index obtained during the tests is greater than 12. This sample can be classified as sandy soil. The samples were designed in accordance with standard EN 196-1. In these samples, the sand will be replaced by Typha, with a mass ratio respecting that of cement. The concrete will be tested at 7, 14, and 28 days. In order to maintain the samples in homogeneous conditions, they will be kept in a water tank for the desired curing time. This measurement is necessary because samples disintegrate over time when immersed in water. For this test, a CONTROLAB C0049N mechanical press with a capacity of 250 kN in compression and 15 kN in flexion (Figure 1) is used. The two specimens from the three-point bending test are subjected to this test, and the value retained for each specimen corresponds to the average of the recorded loads (Figure 2). Table 4 presents the different formulations used to design the control samples without Typha.

Table 4. Percentage of formulations of the samples manufactured.

$S_{98}C_2$	$S_{97}C_3$	$S_{96}C_4$	$S_{95}C_5$	**$S_{94}C_6$**	**$S_{92}C_8$**	**$S_{90}C_{10}$**	**etc.**

We see that the formulations $S_{98}C_2$, $S_{97}C_3$ to $S_{95}C_5$ sinter quite well (Figures 3(a)-(b)). This sintering is due to the low percentages of cement (2%, 3%, and 5%). This is why we decided to prepare a mixture of 94% sand and 6% cement, in order to increase the cement content and establish control samples. These control samples contain 6%, 8%, and 10% cement. Therefore, we eliminated the first four formulations, as they are not cohesive.

Figure 3 illustrates samples $S_{98}C_2$, $S_{97}C_3$, and $S_{94}C_6$, composed respectively of 98% sand and 2% cement, 97% sand and 3% cement, and 94% sand and 6% cement.

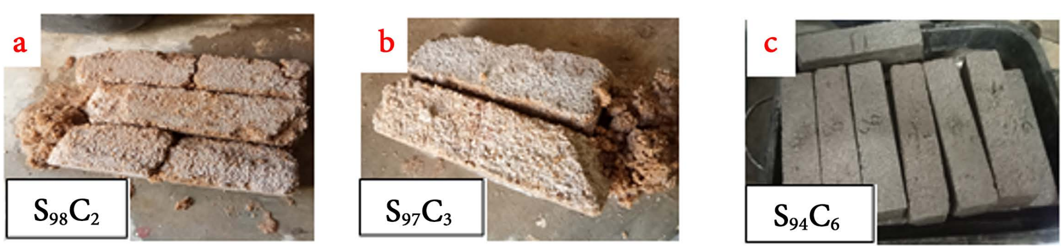

Figure 3. Prismatic samples of types $S_{98}C_2$, $S_{97}C_3$, and $S_{94}C_6$.

Our study aims to limit the use of cement to 10%. Indeed, cement is a hydraulic binder, mainly composed of clinker, produced by cooking limestone and clay in a powerful oven. This process releases a significant amount of carbon dioxide, which is harmful to the environment. The three percentages of cement used in the control concrete formulations gave rise to the histograms (**Figures 4-5**) below.

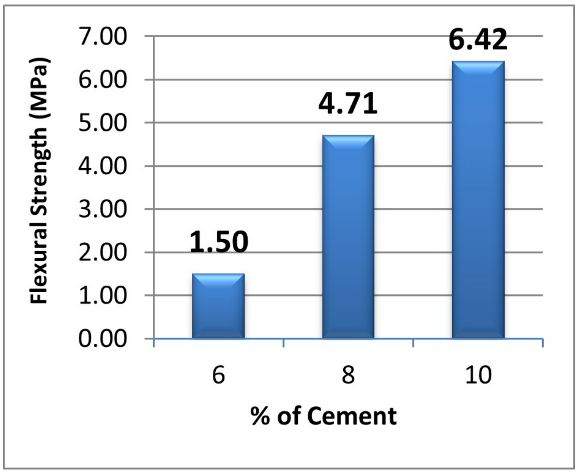

Figure 4. Flexural strength (after 28 days of curing).

It can be seen in **Figure 4** that the resistance values increase with the percentage of cement. This is explained by the high resistance of cement, an essential binder which, combined with sand and other components, makes it possible to waterproof and coat the concrete.

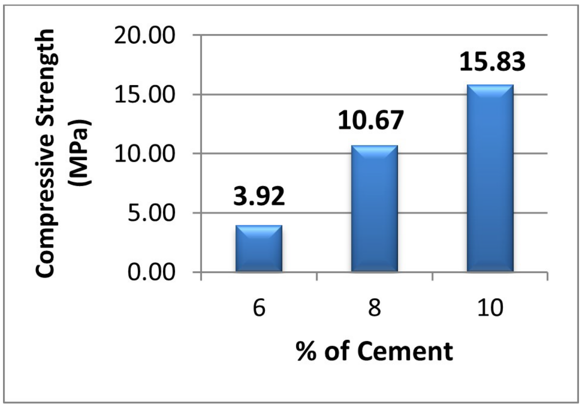

Figure 5. Compressive strength after 28 days of treatment.

Figure 5 is based on the crushing of samples after a 28-day curing period. The histogram shows that the compressive strength exceeds the standard of 2 MPa for three percentages of cement.

We carried out three series of percentages for the different samples in order to analyze the effects linked to their dosage. Typha was introduced in mass proportions from 0.5% to 3% in 0.5% increments. Typha is used as a sand substitute. Each formulation was repeated to fill numbered metal molds to create three prismatic specimens of 4 cm × 4 cm × 16 cm. The mold was assembled and fixed on the shock test bench, set to 60 shots. The specimens were then subjected to mechanical tests on the 7th, 14th, and 28th days.

Figure 6 summarizes the results of the flexion tests after 7 days of treatment. It was observed that at 6% cement, the average strength is 0.515 MPa. The average value obtained for 8% cement is 0.772 MPa, slightly higher than that obtained by Ahmadou Diop *et al.* (0.71 MPa for a sample treated with 10% by mass of Typha 2020 [7]). With 10% cement, we get 2.56 MPa.

Figure 7 shows that the 10% cement series has a compressive strength close to 2 MPa when the Typha percentage is 0.5%. On the other hand, the 6% and 8% series have very low resistance values, below 1 MPa. Figure 6: Flexural strength (MPa) after 7 days of curing.

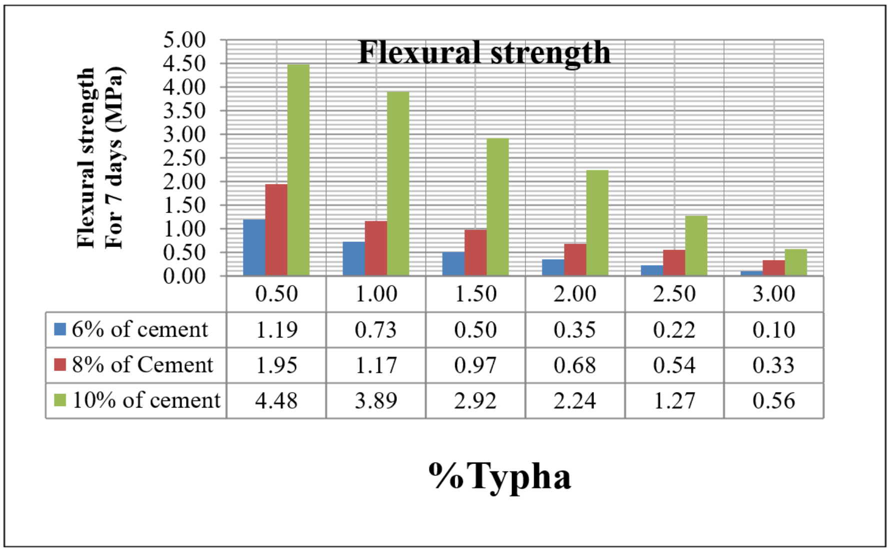

Figure 6. Flexural strength (MPa) after 7 days of curing.

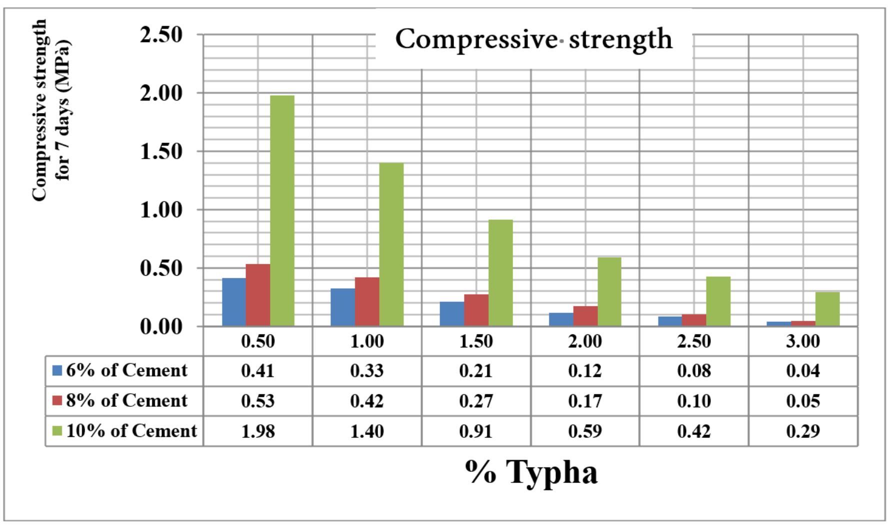

Figure 7. Compressive strength (MPa) after 7 days of cure.

Figure 8 summarizes the results of the flexural tests after 14 days of curing, which show values above 2 MPa for a cement content of 10%. The average values obtained for cement contents of 6% and 8% are 0.867 and 1.48 MPa, respectively.

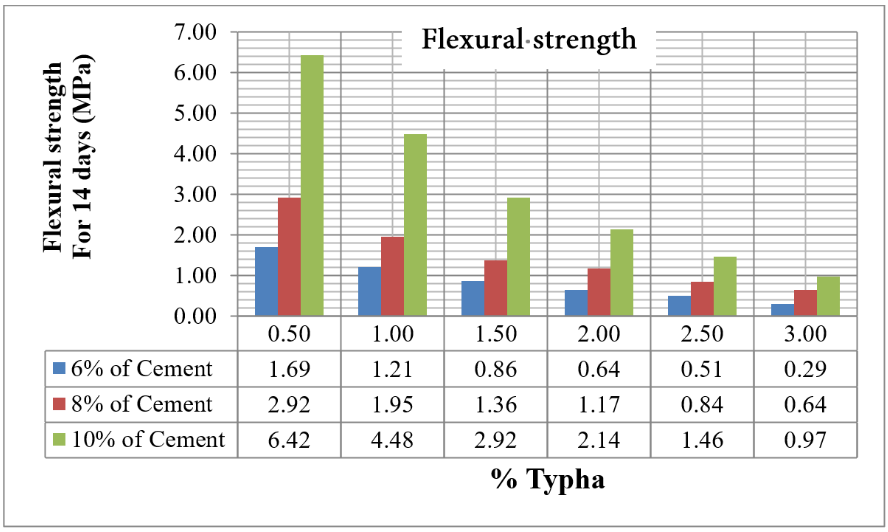

Figure 8. Flexural strength (MPa) after 14 days of curing.

Figure 9 shows a significantly improved value of 2.75 MPa at 0.5% Typha during the 14th day of curing with 10% cement compared to the same percentage of cement at the end of the 7th day.

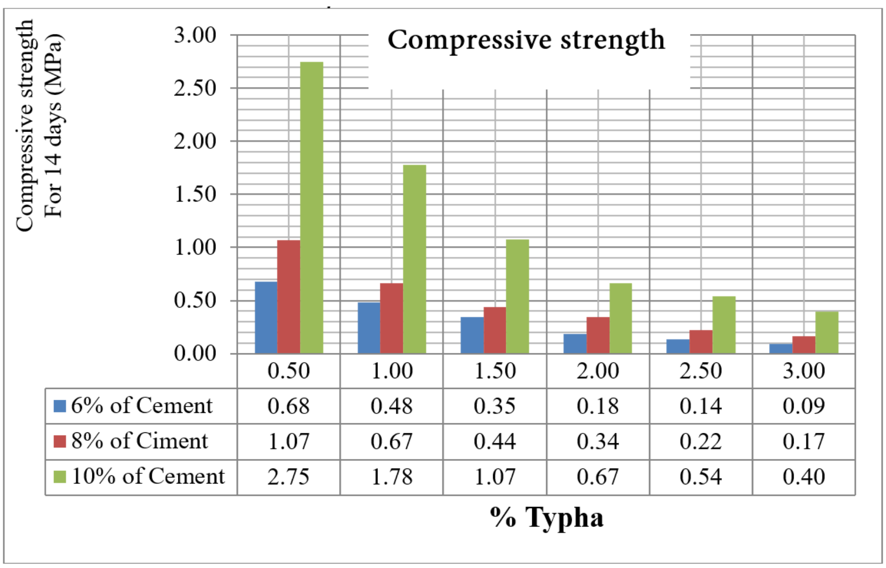

Figure 9. Compressive strength (MPa) after 14 days of curing.

From Figure 10, the 8% and 10% cement series have flexural strength values above 2 MPa, while the percentages of 1.5% and 10% Typha cement are almost identical. On the other hand, the 6% series has too low strength, less than 1 MPa.

Figure 11 shows that the 10% cement series has compressive strength values of 4.21 and 2.03 MPa for Typha percentages of 0.5% and 1%, respectively. The 6%

and 8% series show very low values, with the exception of the 8% cement for a Typha content of 0.5%, which reaches 2.17 MPa.

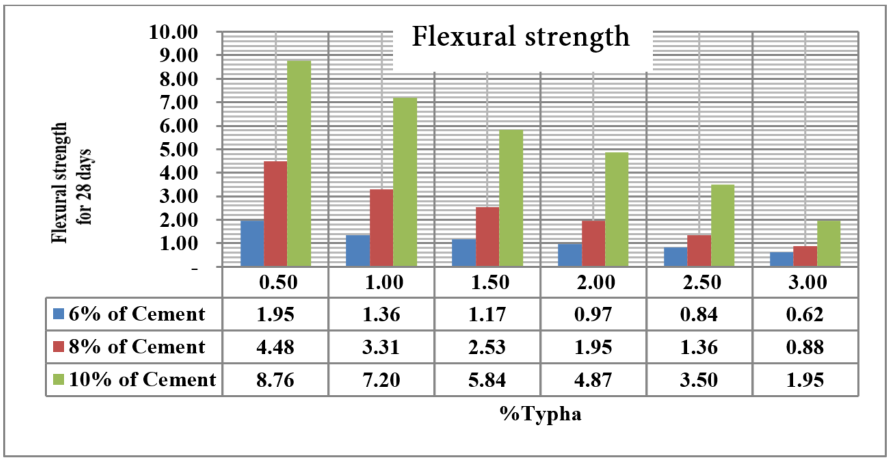

Figure 10. Flexural strength (MPa) after 28 days of curing.

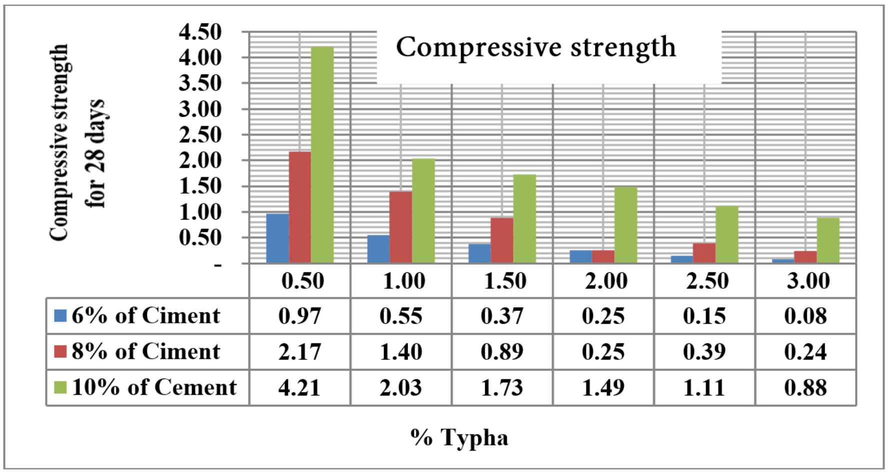

Figure 11. Compressive strength (MPa) after 28 days of treatment.

4. Conclusion

This research aims to improve the presentation of the characteristics of the materials used in concrete, particularly those based on Typha cement, Australis, and sand. The study made it possible to characterize these materials before their formulation, which is crucial for the mechanical behavior of concrete subjected to stress (flexion and compression). Strength tests were carried out with different proportions of cement. Crushing tests were conducted by varying the percentages of cement at 6%, 8%, and 10%. Below these percentages, the samples disintegrate due to a lack of cohesion. However, concrete with a low percentage of Typha exhibits very limited compressive strength in Typha-based concrete, resulting in low compressive strength, while increasing the cement dosage and drying time improves the strength. The samples studied seem suitable for the construction of buildings three meters high. This research highlights the importance of green solutions to urban expansion, with future studies potentially beneficial for the quality of life and economic and ecological sustainability.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Gassama, A., Diouf, B., Ly, E.B., Manga, M. and Ndiaye, D. (2023) Characterization of the Mechanical and Thermal Properties of Materials Based on Cement, Typha Domingénis and Clay. *Journal de Physique de la Soaphys*, **3**, C23N23. http://www.soaphys.org/journal/

[2] Khoudja, D., Taallah, B., Izemmouren, O., Aggoun, S., Herihiri, O. and Guettala, A. (2021) Mechanical and Thermophysical Properties of Raw Earth Bricks Incorporating Date Palm Waste. *Construction and Building Materials*, **270**, Article ID: 121824. https://doi.org/10.1016/j.conbuildmat.2020.121824

[3] Taallah, B. and Guettala, A. (2016) The Mechanical and Physical Properties of Compressed Earth Block Stabilized with Lime and Filled with Untreated and Alkali-treated Date Palm Fibers. *Construction and Building Materials*, **104**, 52-62. https://doi.org/10.1016/j.conbuildmat.2015.12.007

[4] Dieye, Y., Sambou, V., Faye, M., Thiam, A., Adj, M. and Azilinon, D. (2017) Thermo-mechanical Characterization of a Building Material Based on *Typha australis*. *Journal of Building Engineering*, **9**, 142-146. https://doi.org/10.1016/j.jobe.2016.12.007

[5] Abdelhakh, A.O., Saleh, A.M., Soultan, M., Sow, D., Menguy, G. and Gaye, S. (2016) Improving Energy Efficiency of Buildings by Using a Light Concrete Based on *Typha australis*. 2016 3*rd International Conference on Renewable Energies for Developing Countries* (*REDEC*), Zouk Mosbeh, 13-15 July 2016, 1-5. https://doi.org/10.1109/redec.2016.7577512

[6] Boukar, A.K.M. (2019) Test of Valorization of *Typha australis* in the Systems of the Korama Valley in the Southeast of Niger. *Afrique Science*, **15**, 242-250.

[7] Diop, A., *et al*. (2020) Analysis and Mechanical Exploitation of the Soil Clay of Diamniadio with *Typha australis*. *Journal of Engineering and Applied Sciences*, **15**, 3741-3746.

[8] Gaye, S. (2001) Characterization of the Mechanical, Acoustic and Thermal Properties of Local Building Materials. Ph.D. Thesis, Cheikh Anta Diop University (UCAD). (In French)

[9] Tchou, B., Mahamat, A.D., Soultan, M., Ali, A. and Gaye, S. (2025) Effect of *Typha australis* Aggregate on the Mechanical Strength of Concrete. *International Journal of Innovative Technology and Exploring Engineering*, **14**, 19-24. https://doi.org/10.35940/ijitee.f1094.14070625

[10] Samin, E. (2017) PNEEB-TYPHA_National Program for Reducing Greenhouse Gas Emissions through Energy Efficiency in the Building Sector—Project for the Production of Thermal Insulation Materials Based on Typha_R&D Report_Final.

[11] Henning, R.K. (2002) Valorization of Typha as a Domestic Fuel in West Africa and Europe. *Workshop on Typha*, Saint Louis, 23-25 July 2002, 1-7.

[12] NF EN 197-1. European Standard PORTLAND COMPOSED CEMENT CEM II/B-L 32.5R. https://cimentsafrique.com/storage/projects/November2021/LbzgdCzZ37OcLlQ1B5f3.pdf