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Effect of Typha Australis Aggregate on the Mechanical Strength of Concrete

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***Abstract**: As part of this work, different dosages of Typha Australis aggregate, mixed with fine sand from the Chari River in the city of N'Djamena and cement, were used to formulate samples of Typha concrete that we characterized with a view to its use in construction. With this in mind, we carried out a particle size analysis of the sand. This allowed us to notice that the soil is purely sandy and has good characteristics for manufacturing concrete. The proportions of Typha used fluctuate between 0.5% and 5% in steps of 0.5. On the other hand, we produced sixty-six (66) prismatic samples (one for each scenario), measuring 4x4x16 cm, with Typha percentages ranging from 0.5% to 5% in increments of 0.5%, and control samples with no Typha additives for each scenario. We carried out two analysis scenarios. In the first scenario, S1, the ratio of cement to sand is 1/4, while in the second scenario, S_2, the ratio of cement to sand is 1/3. The study focuses on the curing processes after 7 and 28 days. The results obtained showed that the Typha concrete studied possesses the required mechanical characteristics, making it a practical material for use in partitions and low-load-bearing structures with low heights. However, increasing the proportion of Typha decreases the mechanical characteristics, rendering the concrete less suitable for its intended purpose. The flexural test shows a strength of 1.05 MPa for the S_1 series on the 7th day and 1.28 MPa for the S_2 series on the 28th day. The compressive test indicates strength of 0.32 MPa for the S1 series on the 7th day and 0.33 MPa for the S2 series on the 28th day. The results indicate that incorporating Typha into the concrete develops a material suitable for use as wall infill.*

***Keywords**: Typha Australis; Cement; Chari River Sand; Mechanical Characterization.*

Abbreviations:
CS: Cement/ Sand
CPJ: Composite Portland Cement
NF: French Standard
CIMAF: Cement of Africa

I. INTRODUCTION

The durability of homes is one of the main concerns of the modern world. Thus, technology has allowed modern man to have at his disposal during this century a wide variety of construction materials never known [1]. According to residents, they utilize materials because of their mechanical strength and ecological and environmental sustainability. However, in response to climate change, some construction materials have been developed to improve the energy efficiency of buildings [2]. For example, many researchers have begun to study sustainable materials such as earth-based concretes, which offer significant ecological and economic benefits for sustainable habitats [3]. Due to the high cost of materials, it is rare for the construction industry in Chad to concentrate on studying the formulation of Typha concrete. It is uncommon to research local granular materials to optimize concrete composition based on the desired structural performance, local environmental conditions, and available BioSource materials. At the end of the 21st century, a new generation of materials based on renewable plant resources was developed to meet environmental challenges and climate change [4]. For example, this study focused on exploring the reuse of fine sand from the Chari River in Ndjamena by combining it with Typha Australis, a wild, harmful, and bio-sourced plant [5]. This demand is growing, particularly in sub-Saharan countries. This research aims to analyze the thermomechanical properties of Typha concrete. Typha Australis is an aquatic plant that grows in abundance in streams, rivers, and lakes [6]. Therefore, it degrades water quality and seriously disturbs the use of agricultural and fisheries resources [7].

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

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II. MATERIALS AND METHODS

A. The Materials

Our samples were made using sand from the Chari River in the town of N'Djamena, mixed with CIMAF-CPJ35 cement from N'Djamena and Typha Australis extracted from the rainwater irrigation canal in the Amerigué district of N'Djamena.

To conduct our experimental study, we utilised various devices and machines, including a sieve to analyse the granulometry of the sand and an electronic measuring device to determine the mass of the sand, cement, Typha, and mixing water in progressively increasing mass proportions of the formulations.

The Typha used is in the form of small twigs, cut with scissors. The samples were prepared using a 60-shot impact bench and tested with the CONTROLAB machine, a mechanical press designed to apply flexural and compressive force.

i. The Typha

Typha Australis, commonly known as cattail, is a herbaceous plant belonging to the Typhaceae family [8]. It is characterized by a stem bearing an inflorescence composed of male flowers at the top and female flowers at the bottom. This plant thrives in fresh, calm waters, particularly in conditions of high temperatures [9]. It is found in large numbers on the banks of the Senegal River [10], around Lake Chad, and in the irrigation canals of N'Djamena (figure 1a), where it creates dense colonies. Although semi-aquatic, Typha is considered a harmful invasive species.

Incorporation of Typha Australis in construction, particularly as an aggregate in concrete, requires special instructions to ensure safety and efficiency. In our case, the Typha was harvested, dried, and then cut into small, twig-like pieces approximately 1 cm in size (Figure 1b).

Compressive, flexural, and tensile strength tests on concrete should be conducted with Typha. The addition of Typha Australis to concrete as an aggregate can influence the mechanical and physical properties of the mix. However, specific results may vary depending on the exact proportions and mixing conditions. Tests such as those mentioned above, along with durability analysis, should be conducted to obtain the results.

[Fig.1: (a) Typha in the Ndjamena Rainwater Irrigation Canal and (b) Dried and Cut Typha]

ii. Cement

Enriched Portland cement CPJ35 complies with the quality standards for class CPJ cements (Portland cement with Additives). The number 35 indicates a minimum compressive strength of 35 MPa (Mega Pascals) at 28 days, which makes it an intermediate class cement suitable for various forms of construction [11]. It is composed of at least 65% clinker, the remainder limestone, milk, pozzolans, etc, followed by calcium sulfate to balance the setting. CPJ 35 is used in different fields, whether for reinforced concrete constructions or not, for general mass structures. Table 1 presents a summary of the mechanical properties of this cement.

Table-I: Areas of use with CPJ 35 NGA 197 – 1 Cement [11]

Composition	The homogeneous mixture of at least 65% Portland clinker and 35% addition Addition of calcium sulfate to regulate intake.			
		2 days	7 days	28 days
Compressive strength of mortar in Mpa	Minimum guaranteed according to NI 05.06.001 : 2018	10.00	-	32.5
	Medium factory	13.98	24.72	33.68
Reject 45µ (%)	Minima NI	Average plant		
Fineness of grind SO3 Expansion Start of setting PAF (%) MgO(%) CI-(%) C3A (%)	-- Mini SSB (cm2/g) 3000 Maxi en (%) 3.5 Maxi mm 10 Mini en min 75 Maxi en min 600 - - - - Maxi en % 5 Maxi en % 0.1 Maxi (%) 10	6.20 3445.85 2.62 0.78 167.35 226.91 11.37 4.15 0.01 8.45		
Typical areas of use	All types of work, reinforced or unreinforced concrete, for standard Structural Engineering structures			

iii. Sample Preparation

Typha's mass percentages are as follows: 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5%. Each percentage of Typha is substituted for regular sand. The compressive strength of cement is one of its properties, as it contributes to the overall strength of concrete, a composite material.

The production of this concrete complies with regulations [12]. To examine the effects of binder dose and rigorous aggregate integration, we will conduct two distinct sample series. Two different formulations will be used to study water's behavior. The samples we provide are manufactured by current guidelines and are subject to regular testing.

Analysis of the particle size of river sand and Typha Australis: The Typha is first cut, then dried in the open air for a week, then cut with a chisel to the nearest 1cm. In this study, the sand (0/2 mm) was treated by sieving and dried in an oven at 105°C.

The latter was combined with CPJ 35 CIMAF cement from Chad and Typha Australis aggregates by the standard NF EN 206/CN, which specifies the requirements applicable to concrete constituents. The cement and sand were weighed according to the formulations selected and then mixed. We weighed the cement and sand according to the chosen formulations and proceeded to mix them. The mortars were mixed for 4 minutes using a precise method: first, water was poured into the mixer, followed by cement, and then mixing was carried out slowly.

After 30 seconds, the sand is added gradually, and then the mixer is set to maximum speed for 30 seconds. Finally, the mixer is stopped for 1 minute and 30 seconds, during which the mortar stuck to the walls is scraped off. The casting uses vibrated test pieces on a shaking table, which applies 60 blows per layer (Figure 2). The inside of the moulds (Figure 3) is first coated with oil and then filled with pasta. The concretes obtained (Figure 4) are soaked in water tanks for 7 to 28 days of curing in the test room. The study focuses on two scenarios. The first mixture (scenario S_1) includes 450 g of cement, 1350 g of standardized sand, and 225 g of water, while the second (scenario S_2) contains 600 g of cement, 1200 g of sand, and 300 g of water. A total of 132 samples were produced, including 66 for testing after 7 days of treatment and 66 after 28 days in both scenarios.

[Fig.2: (a) Shahnig Table]

[Fig.3: Prismatic Mold 4x4x16]

[Fig.4: Molded Samples]

B. Methods used: Crushing Tests on Prismatic Specimens in Flexion and Compression

i. Flexion

[Fig.5: Resistance to Flexion]

$$\sigma_f = \frac{1{,}5 * f_{tmax} * L}{b^3} \quad ... \quad (1)$$

σ_f: Flexural stress in MPa;
f_{tmax} : Breaking force in bending in N;
L: Distance between supports in mm;
b: The base with:
L=100mm et b=40 mm

The test was conducted in compliance with [13] and the NF P 18–407 standards, which were utilized by [14]. The specimens were supported by two single supports spaced 100 mm apart, and the load F was applied symmetrically to the specimen's centre relative to the supports. The normal tensile stress is applied to the prismatic beam's cross-section, as it is believed that the composites of the cross-section (b x b) are homogeneous (Figure 5).

ii. Compression

Experiments like those for natural stone were carried out using a mechanical press type C0049N from CONTROLAB machine, with a compression capacity of 250kN and a bending capacity of 15kN, as shown in Figure 6 [15]. These tests for compressive strength of natural stone in the standard measure the compressive strength of samples crushed flat, perpendicular to the veneer [16].

[Fig.6: Compression Strength]

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

σc: Compressive strength in MPa
fc: Breaking force in compression in N;
b: Base in mm, (b=40 mm).

After correcting the compression faces in compliance with standard NF P 15-471, or if required after surfacing, a prismatic specimen must be compressed with a mechanical press until it breaks [17]. The half-tests from the bending test are used to examine the specimens' nominal compressive strength using a press for hard materials. Each half-prism's mould faces receive the compressive load in a 4x4x16 cm portion. After that, the prismatic specimen is centred between the mechanical press's platens and subjected to a constant load until it collapses entirely. Lastly, Figure 6 shows the maximum load the sample can sustain during the test.

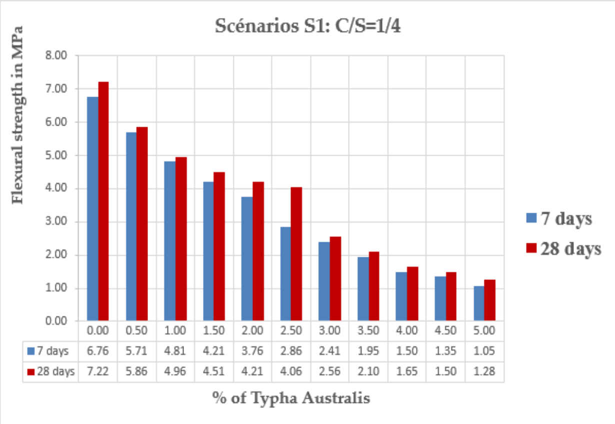
III. RESULTS AND DISCUSSION

According to the statistics listed above in the tables, the flexural strength (R_f) and compressive strength (R_c) of Typha concrete were measured for two situations (S_1 and S_2) on days 7 and 28.

A. Flexural Strength (Rf) of Typha Concrete on the 7th Day

The measurements of the flexural and mechanical compressive strengths of the prismatic specimens of the Typha concrete of two scenarios, S1 and S2, for the

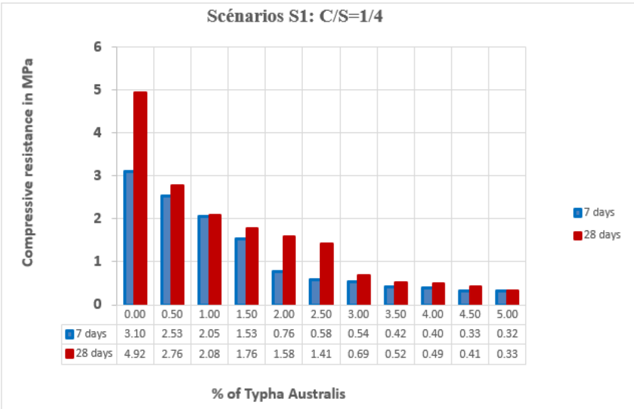
7th day and the 28th day of curing, were carried out under a mechanical press of type C0049N from CONTROLAB.



[Fig.7: Flexural Strength Change on Day 7 as a Function of the Percentage of Typha (1/4 Cement)]

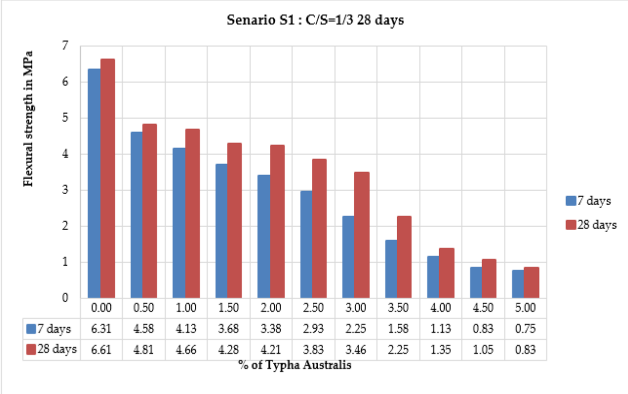
The flexural strength is calculated by applying the formula in equation 1. The results of these measurements of the bending stresses of the S1 scenario, where the ratio of cement to sand (C/S) is one-quarter (1/4) for day 7 and day 28, are almost identical, as shown in Figure 7.

B. Compressive Strengths (Rc) of 7th Day Typha Concrete



[Fig.8: Evolution of Compressive Strength as a Function of the % Rate in Typha (1/4 Cement) on the 7th Day]

The calculation of the compressive strength is obtained by applying the formula from equation 2. The results of the compression test for scenario S1, in which the cement-to-sand (C/S) ratio is set at one-fourth (1/4), are presented for both the 7th and the 28th day. We notice that the stress values after 28 days of curing are slightly higher than those after 7 days of curing. Thus figure 10 shows that on the 28th day, the control sample shows 4.92 MPa and drops by about 55% when 1% Typha is added, resulting in a stress value of 2.06 MPa; whereas on the 7th day, the control sample shows 3.10 MPa and drops by about 35% when 1% Typha is added, resulting in a stress value of 2.08 MPa. The discrepancy is because the concrete remained soaked in water. However, when the proportion of Typha increased from 3% to 5%, the stress values decreased significantly and tended to approach zero as the substitution of sand with Typha Australis increased.

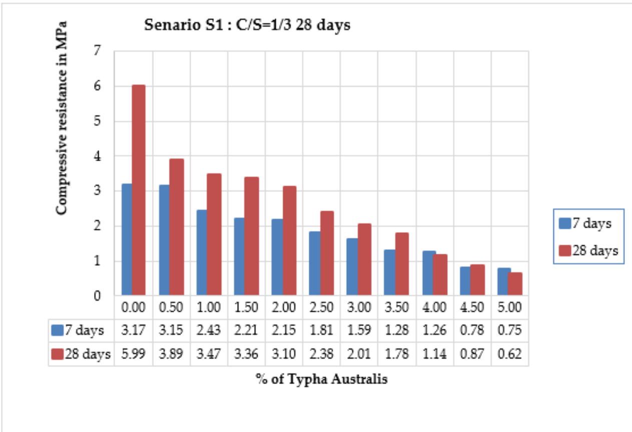


[Fig.9: Evolution of Flexural Strength as a Function of the % Rate in Typha (1/3 Cement) on the 7th Day]

The results of bending measurements (figure 9) for scenario S2, where the ratio of cement to sand (1/3), for the 7th day and the 28th day are:

After the 7th day of treatment, the stress values are 5.94 MPa at 0% Typha and regress to reach 2.10 MPa when the percentage of Typha is 3.50%, i.e., a 64% loss. The slight increase in cement improved its strength by more than 45%.

On the 28th day, it reaches 60% of its stress, with a maximum of 6.31 MPa at 0% and a minimum of 2.41 MPa at 4% Typha.



[Fig.10: Évolution of Compressive Strength as a Function of % Rate in Typha (1/3 of Cement) on the 28th Day]

In this case, adding one-third (1/3) more cement results in higher compressive strength than in the prior situation. At 0% Typha, we improve 3% on the 7th day and 18% on the 28th day, according to the measurement findings of scenario S2 under compression for the 7th and 28th days. The same is true for 1% Typha, where we get 37% on day 7 and 26% on day 28. There is no difference in the resistances at 3% Typha and higher, as observed in Figure 10.

IV. CONCLUSION

This research aimed to identify and characterise materials for formulating high-performance concrete in Chad. It involved studying the physical and mechanical properties of the materials to gain a better understanding of their nature. The results support the use of these materials in producing lightweight concretes incorporating Typha Australis, suitable for applications such as infallible concrete or partition walls up to four meters high.

The text discusses using Typha Australis, a locally available material, in addition to cement and sand from the River Chari in Ndjamena, to produce lightweight concrete. It underlines the importance of the choice of materials to guarantee the mechanical strength of the concrete. Two test scenarios are presented: the first with a cement/sand ratio of 1/4 (S_1) and the second with a 1/3 (S2) ratio. The results show that compressive strength increases, indicating an improvement associated with both cement dosage and curing time. The addition of Typha Australis aggregate to the concrete will enable the assessment of crushing resistance. By maintaining the proportions of conventional concrete while replacing part of the sand with Typha Australis at specific percentages, the aim is to improve the mechanical qualities of the material.

The prismatic samples showed a slight decrease in strength with a dosage of 0.5% typha, but the compressive strength improved between days 7 and 28. The strengths decrease exponentially with increasing typha dosage, although the difference is slight from 3% upwards. The low strength values indicate that this concrete cannot be used for load-bearing structures. Typha-based concrete, as suggested, could be used as a filler and in masonry.

In perspective, we suggest evaluating Mechanical Properties (Strength Tests, Durability Analysis) and selecting materials for Specific Applications (Non-Structural Use, Pilot Projects), followed by Monitoring and Maintenance, etc. These guidelines aim to ensure that the use of Typha Australis in concrete is safe, effective, and sustainable while minimizing the risks associated with its use in load-bearing structures. There is a need to investigate the use of Typha Australis concrete for primary structures.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** No organisation or agency has funded this article. This independence ensures that the research is conducted objectively and without external influence.
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- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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