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Research Article

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Formulation of handmade mud bricks, with the addition of typha australis, sand and/or cement, for use in infill walls, with a focus on thermal performance

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Abstract Civil engineering, particularly building construction, is a major consumer of energy and natural resources, as well as a major emitter of greenhouse gases. A number of studies are being carried out on bioclimatic construction and the use of bio-sourced materials to achieve eco-responsible buildings with less negative impact on the environment. This study proposes the formulation of artisanal raw earth bricks, with a mixture of crushed typha, sand and/or cement, for use in infill walls. These characterizations are designed to ensure optimum strength, while increasing the brick's thermal resistance.

The bricks were manufactured under the same conditions as the cement mortar bricks normally used in house construction in Senegal.

Eight samples of solid bricks, measuring 10 cm x 10 cm x 30 cm, were produced, with different percentages of earth, typha, sand and cement.

A 12x20x40 mud brick and a 15x20x40 cement mortar hollow brick were added to these samples for crushing tests.

The study showed that the addition of sand was not beneficial for brick strength; crushed typha, which was added for thermal resistance, provided more strength than cement, whose main role was to statbilize the brick, for greater compressive strength.

Keywords raw earth, typha, bio-based materials, bioclimatic construction

1. Introduction

As part of its green policy, the State of Senegal aims to move towards resource-efficient and ecologically sound growth, as well as climate resilience (adaptation and mitigation) and social inclusion. Indeed, the country is facing an exceptional urban development process, implying a significant need for resources, particularly in the field of civil engineering.

High energy consumption in buildings is a major challenge in the fight against climate change [3]. The use of bio-sourced building materials helps to reduce greenhouse gas emissions from building construction, and suggests ways of thinking that lead to sustainable, eco-responsible and shared development.

It should be noted, however, that the lack of raw earth standards is an obstacle to widespread use. [1]. (https://www.boutique.afnor.org).

Laterite is also found throughout the Thiès region. [2] ("A la découverte des sciences de la terre" document from the Senegalese Ministry of Mines and Geology, March 2021).

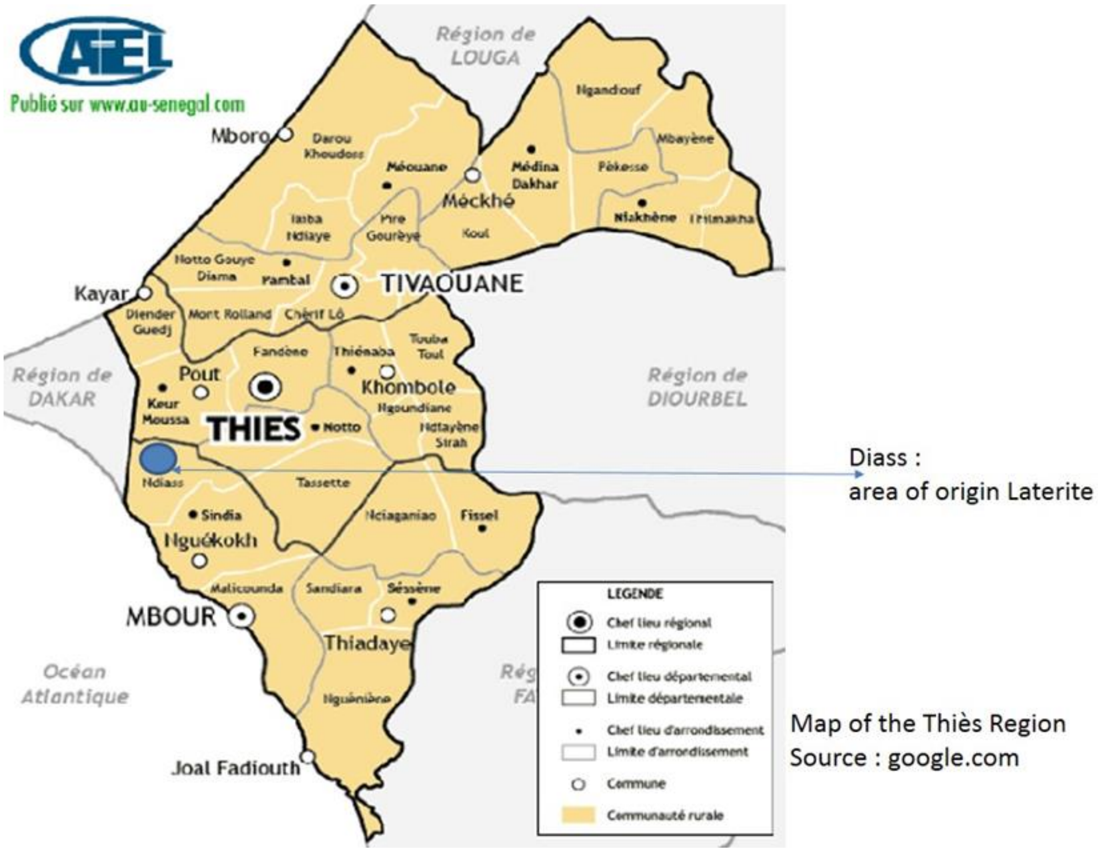

Figure 1: Location of laterite supply area. Source: google.com

The aim of this study is to demonstrate the reliability of a construction whose infill walls are made with raw earth bricks. These bricks are made in a hand-crafted mold, with the addition of crushed typha, sand and/or cement, to achieve gains in compressive strength or thermal resistance

2. Materials et methods

The study was carried out in the Thiès region, using laterite from the Notto Diobass area.

The typha comes from Bango, not far from Saint Louis in Senegal. It was cut and dried on site, before being transported to the Thiès Polytechnic and ground in a traditional grinder.

The grinder is a handcrafted machine with blades that cut the typha into very fine pieces. It is a millet mill that has been modified to cut typha stems.

Typha is very fibrous and still contains moisture when crushed, despite the fact that drying is incomplete due to its composition.

Drying in the sun to a moisture content of 20% takes between 7 and 10 days, depending on ambient conditions [3] (Henning 2002) "capitalization of research results and experiences on typha".

The sand is quarry sand from Thiénaba, near Thiès, and the cement comes from a local cement works.

View of the production laboratory upstairs and laterite to be sieved

Dried typha stems, for grinding

Artisanal molds for brick production

The 35 mm and 36 mm sieves used for sieving laterite

Figure 2: Production laboratory and equipment used

The bricks were manufactured under the same conditions as the cement mortar bricks usually used in house construction in Thiès and elsewhere in Senegal.

Artisanal molds are usually used to make bricks of dimensions 15x20x40, 12x20x40, 10x20x40, rarely 20x20x40.

The bricks we're offering for trial are made of raw clay, compressed by hand in a traditional metal mold. The bricks produced measure 9cmx9cmx29cm.

The clay is obtained by sieving laterite from a quarry near the village of Diass. We used 35 mm and 36 mm sieves, to obtain an aggregate size of 36 mm or less.

The mold is a metal frame into which the mortar is filled, tapped by hand at hand-height on a rigid surface, placed in the drying oven and removed from the mold.

Using this process, we produced solid brick samples with eight (08) different formulations based on percentages of earth, typha, sand and cement.

Crushed typha

Sieved laterite, sand and cement

Production of bricks in the artisanal mould

Figure 3: Production conditions for bricks

We started with the mortar from the sieve without any additions; then we added either cement or crushed typha, or both, or by adding sand to these mixtures.

These additions, for stabilization purposes, are intended to enhance certain of the earth's performances: increasing its strength and thermal resistance, and reducing its sensitivity to humidity.

Cement is used to increase consistency, typha to increase thermal resistance and lighten the material, which is only used for filling, and sand to reduce the clay content if necessary.

We have limited ourselves to a maximum of 10% for these stabilization materials, so as not to lose the interest of the earth material, which is the material we are seeking to valorize.

To provide a basis for comparison, we added a sample of 12x19x40 mud brick and 14x5x19x40 cement mortar hollow brick for the compressive strength tests.

The soil used to make the 12x19x40 brick comes from laterite found around the rainwater drainage canal that surrounds the Diakhao and Thialy districts in the city of Thiès. The earth is not sieved, but contains a relatively large amount of aggregate. The bricks produced cost around 8 times less than artisanal cement mortar bricks, and are used for very low-cost construction in the above-mentioned districts.

The 14.5x19x40 hollow brick, compressed in a traditional mold, is made with 42.5 R cement from local cement works, mixed with sand from dunes or local quarries.

These bricks are used for infill walls in house construction in many neighborhoods in Thiès and elsewhere in Senegal.

Handmade bricks around the canal

Usual cement mortar bricks

Brick samples earth/typha/cement/sand

Testing machine for compressive strength

Figure 4: Samples, comparison bricks and test machine

The eight samples of hand-compressed raw clay bricks, in a traditional mold, were manufactured on January 20, 2021. The mortar was relatively damp, to facilitate demolding.
After drying in the shade, inside the production room, an initial compressive strength test was carried out on February 03, 2021, i.e. 15 days of drying in the shade, without watering.
A second test was carried out on January 20, 2023, after two years of exposure in the open air, inside the same room.
The results obtained are shown below.

3. Results Et Discussion

3.1. Presentation Of The Results

Here are the results obtained after 15 days of drying inside the production room.

N°	Description, size in cm	Brick weight (kg)	Compressive strength in bar (kg/cm²)	Load in kg/cm² on a 3 m high wall	Resistance/Load ratio on a 3m wall
01	Hand-compressed solid mud brick. Dimensions: 9x9x29. Aggregate diameter less than or equal to 36mm.	4,9	28,76	33x4,9=161,7kg/(9x29=261)cm² =0,61	47,14
02	Ditto 01+10% cement 32.5R	5	17,26	165/261 =0,63	27,39
03	Ditto 01+10% crushed typha	4,9	25,29	161,7/261 =0,61	41,45
04	Ditto 01+5% 32.5R cement + 5% crushed typha	5,2	9,72	171,6/261 =0,65	14,9
05	Ditto 01+10% sand	5,7	11,13	188,1/261	15,4

	+ 10% cement 32.5R			=0,72	
06	Ditto 01+10% sand + 10% crushed typha	5,4	15,87	178,2/261 =0,68	23,33
07	Ditto 01+10% sand + 5% cement 32.5R + 5% crushed typha	5,3	10,51	174,9/261 =0,67	15,6
08	Ditto 01+10% sand + 10% cement 32.5R + 10% crushed typha	5,2	8,62	171,6/261 =0,65	13,2
09	Solid mud brick with unscreened laterite. Dimensions: 19x12x40	15	18,16	15x15 = 225/480 =0,46	39,4
10	Hollow brick in cement-sand mortar, dosed at approx. 180 kg/m3. Dimensions: 19x14.5x40	15	64,96	15x15= 225/580 =0,38	170,9

Here are the results obtained after two years of exposure inside the production room.

N°	**Description, size in cm**	**Brick weight (kg)**	**Compressive strength in bar (kg/cm²)**	**Load in kg/cm² on a 3 m high wall**	**Resistance/Load ratio on a 3m wall**
01	Hand-compressed solid mud brick. Dimensions: 9x9x29. Aggregate diameter less than or equal to 36mm.	4,9	12,57	33x4,9=161,7kg/(9x29=261)cm² =0,61	20,6
02	Ditto 01+10% cement 32.5R	5	2,29	165/261 =0,63	3,6
03	Ditto 01+10% crushed typha	5,2	9,35	171,6/261 =0,65	14,3
04	Ditto 01+5% 32.5R cement + 5% crushed typha	5,2	3,96	171,6/261 =0,65	6
05	Ditto 01+10% sand + 10% cement 32.5R	5,5	2,50	181,5/261 =0,69	3,6
06	Ditto 01+10% sand + 10% crushed typha	5,4	0,41	178,2/261 =0,68	0,6
07	Ditto 01+10% sand + 5% cement 32.5R + 5% crushed typha	5,2	7,55	171,6/261 =0,65	11,6
08	Ditto 01+10% sand + 10% cement 32.5R + 10% crushed typha	5,3	1,75	174,9/261 =0,67	2,6
09	Solid mud brick with unscreened laterite.	14,7	3,56	15x14,7= 220,5/480 =0,45	7,9

10	Dimensions: 19x12x40 Hollow brick in cement-sand mortar, dosed at approx. 180 kg/m3. Dimensions: 19x14.5x40	15,4	6,37	15x15,4= 231/580 =0,39	16,3

3.2. Discussion

First of all, it should be pointed out that the use of these bricks as linings is not the subject of this study. This is a study of monolithic infill walls.

The aim of this study is to present reassuring results, with a view to the use of these bricks in infill walls. The idea is to achieve the same conditions of use as the cement mortar bricks currently in use, in terms of construction, accessibility and cost.

The cement-mortar brick normally used weighs an average of 15 kg and has a variable average compressive strength, based on the two tests carried out. It weighs over 230 kg for a 3 m wall, and can support more than 16 times its own weight.

Our earth/typha/cement/sand bricks weigh an average of 5 kg, with varying compressive strengths in both tests. They weigh less than 190 kg for the heaviest, for a 3 m wall. Their ability to bear weight is also highly variable, on both tests.

Those that can bear more than ten times their own weight seem to us to be suitable for filling purposes.

The aim of the study is to propose bricks that are strong enough to satisfy the filling function, which is dedicated to them, while improving performance in terms of thermal resistance, water sensitivity and structural lightness.

The results obtained showed that earth bricks, made from laterite sieved to 36 mm, with the addition by volume of 10% ground typha or 5% cement and 5% ground typha, can be used to make the usual infill walls.

We have found that adding cement does not increase the compressive strength of the brick. Adding sand to "degrease" the brick is not equally beneficial for compressive strength.

On the other hand, the addition of ground typha is very beneficial for strength, even better than cement. This result was not expected, as typha was added to increase thermal resistance, not strength.

Cement was added to stabilize the soil, increase its coherence and reduce its sensitivity to water. It was also intended to improve compressive strength, but this was not the case.

It was also noted that the sieved material, without any additives, has good compressive strength.

It's also worth noting that, after two years' exposure to drying, our bricks have lost between 50% and 70% of their compressive strength. This phenomenon is also observed with the 12x19x40 brick, manufactured next to the drainage channel, with a loss of strength of over 80%.

This loss of strength suggests that these bricks will need surface protection against moisture to guarantee their durability. It also suggests that initial humidity at the time of manufacture and drying conditions may influence compressive strength over time.

A simulation is carried out here, not on the mixture, but on the supperposition of the layers of earth and typha. This enables us to anticipate the behavior of the wall, composed of the homogeneous earth/typha mixture, with regard to its thermal resistance.

- **THERMAL TRANSMITTANCE U, USING THE PRESCRIPTIVE APPROACH**

Name of the component	Wall		
	A	B	A/B
Material	Thickness (m)	Thermal conductivity (W/m².C)	Thermal resistance (m².C/W)
Compressed Earth Brick	0,1	0,70	0,14
Panel made of typha	0,04	0,05	0,8
	Total resistance (m².C/W)		0,94
	U coefficient (W/m².C)		1,1

Figure 5: Thermal simulation table.

Source: GIZ, PED program, Component 3 - Energy Efficiency

This simulation shows that with a 10 cm compressed mud brick, 4 cm of typha is required for good thermal resistance, i.e. 40% typha thickness. With a 20 cm brick, an additional 3 cm of typha is needed for good resistance.

The maximum thermal resistance required to comply with current regulations is 1.1 m².C/W. The total resistance corresponds to the sum of the resistances of the materials making up the wall.

Mixing and layering don't work in the same way, but we hope to achieve satisfactory results during thermal testing.

4. Conclusion

This research work has shown that the addition of crushed typha to a sieved lateritic earth mortar used to make mud bricks does not impair its compressive strength when used as a backfill wall.

The addition of sand to degrease and reduce the clay content of the soil should be controlled, as it can lead to a significant drop in compressive strength. Good moisture content during mixing is also important, as is slow evaporation.

Earth is good for its thermal inertia, and typha, which is a good thermal insulator, should make it possible to produce a medium-thick brick with good thermal resistance.

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