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Effect of Rice Husks Concrete Preformed Coffers and Bricks Use on Building Structural Elements

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Abstract: This article highlights the effect of rice husks concrete preformed coffers and bricks use on building structural elements (joists, beams, columns and footings). For this purpose, 15 cm thick of preformed coffers, hollow and solid bricks are made from cement - rice husks, cement - rice husks - sand and sand –cement mixtures to determine their characteristics: density, surface weight, brick compressive strength and preformed coffer bending strength. These characteristics were used to calculate building structural elements (joist, beam, column and footing). The results show that the preformed coffers and bricks of rice husks concrete are lighter than those made of sand - cement mortar. The compressive or bending strengths of these elements are similar. The use of rice husks concrete preformed coffers reduces dimensions and reinforcing steels of building structural elements.

Keywords: Preformed Coffers, Bricks, Rice Husks Concrete, Compressive Strength, Bending Strength, Beam, Column, Footing

1. Introduction

Rice husks concretes are cement, water and rice husks mixture to which sand can be added to improve these concrete characteristics and to reduce the cement dosage [1-4]. These concretes have for interest, environment protection and rice husks valorization in civil engineering. A lot of work is done to better understand these concretes [1-28]. It turns out that rice husk concretes is a light material with the main disadvantage of cement high dosage. Indeed, to obtain a compressive strength of 10 MPa at 28 days of age, it requires a cement dosage exceeding 700 kg per meter [3]. Current dosages (between 250 and 500 kg of cement) resistances are of 1 to 8 MPa order [3]. One of these concretes applications is their use for the manufacture of preformed coffers and bricks used in building [3-4].

The objective of the present study is therefore to determine the characteristics of rice husks concrete preformed coffers and bricks and to analyze the effect of their use on buildings structural elements. Thus, 15 cm thick preformed coffers and bricks (thickness often used in Togo for the same elements made in sand-cement mortar) are made using cement - rice husks and cement - rice husks - sand mixtures. On these masonry elements, density, surface weight, bricks compressive strength and preformed coffers bending resistance are measured. The structural elements (joist, beam, column and footing) of a building are also calculated.

2. Materials and Methods

Rice husks concrete, due to rice husks special characteristic is, at the present stage of research, formulated using experimental method [1-3]. For this study, two types of concrete are selected: cement - rice husks and cement - rice balls - sand mixtures. Rice husks from Kovié Rice Farm, a village located at 27 km north of Lomé, of which characteristics are shown in Table 1, are mixed with CIMTOGO cement CPJ 35 (one of Togo's cement plants) and drinking water from the TdE (Togolese Water Company) to obtain cement - rice husks mixture. To this mixture, is added sand of Mission Tové quarry, located at 20 km north of Lomé, presenting characteristics shown in Table 1, to obtain the second type of rice husks concrete. Figure 1 shows rice

husks and sand grading size curve.

Because of their high absorption rate, rice husks are immersed in water for at least twenty four (24) hours before their use [1-4]. They are then drained to rid them of excess water. Then, rice husks, cement, water and eventually sand are mixed with a mixer for two to three minutes in order to obtain a homogeneous material. The formworks are then filled and compacted using shovels as for sand - cement agglomerates. Release is done immediately since the concrete used is dry.

The constituents' proportions of the two types of rice husks concrete and the sand-cement mortar are presented in Table 2 [3-4].

Table 1. *Characteristics of the materials used.*

Characteristics	Rice husks	Sand
Finesse modulus	3,79	1,81
Absorption rate (%)	82	-
Apparent density at dry state	0,101	-
Absolute density at dry state	0,750	-
Apparent density at wet state	0,142	-
Absolute density at wet state	1,050	-
Absolute density	-	2,58
Apparent density	-	1,51
Equivalent of sand (%)	-	61

Table 2. *Material quantity for one concrete cube meter.*

Concrete type	Cement (kg)	Rice husk (kg)	Sand (liters)	Water (liters)
Rice husk concrete without sand	500	391	0	210
Rice husk concrete with sand	350	375	100	166
Bricks sand – cement mortar	250	-	1 000	175
Preformed coffers sand – cement mortar	400	-	1 000	175

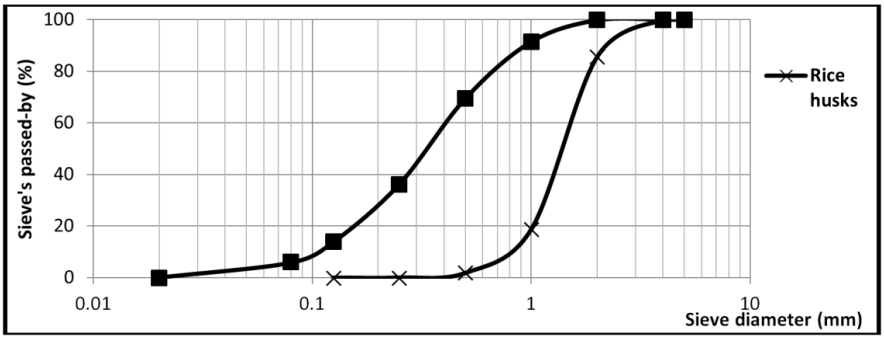

Figure 1. *Rice husks and sand grading curve.*

a)

b)

c)

Figure 2. *Rice husks concrete hollow (a) and solid (b) bricks and preformed coffer (c).*

With these compositions, samples of solid and hollow bricks of 40 x 20 x 15 cm^3 dimensions as well as preformed coffers of 60 x 20 x 15 cm^3 dimensions are manufactured. Figure 2 shows an image of solid and hollow bricks and preformed coffers. On these masonry elements, density, surface weight, bricks compressive strength and preformed coffers bending strength are determined at 28 days of age according to the European standard EN 772 [29]. The characteristics of rice husks concrete masonry elements are

compared with those made with sand - cement mortar, most often used in construction in Togo.

Using the BAEL (Reinforced concrete in the limit states, Béton Armé aux Etats Limites) 91 modified 99 rules [30-31], the dimensioning (geometric dimensions and reinforcement) of a joist, a beam, a column and a pad footing of a two-storey building with hollow pot floor slab is carried out. For this building, two situations are envisaged: at first the preformed coffers are in rice husks concrete with or without sand and in a second time, these elements are in sand-cement mortar. In both cases, the structural elements are made of ordinary reinforced concrete.

3. Results and Discussion

Table 3 shows the characteristics of bricks and preformed coffers in rice husks concrete and of those in sand-cement mortar. In this table is also presented the thermal conductivity of concretes and mortars used [3].

Table 3. *Bricks and preformed coffers characteristics.*

Masonry type	Density (g/cm^3)	Surface weight (N/m^2)	Compressive strength at 28 days of age (MPa)
Rice husks concrete without sand solid brick	0.98	1 480	1.26
Rice husks concrete with sand solid bricks	0.95	1 385	2.0
Sand-cement mortar solid bricks	1.39	2 090	1.29
Rice husks concrete without sand hollow bricks	1.04	1 090	1.03
Rice husks concrete with sand hollow bricks	1.00	1 020	1.52
Sand-cement mortar hollow bricks	1.93	1 970	0.93
Rice husks concrete without sand preformed coffer	0.90	1 100	-
Rice husks concrete with sand preformed coffer	0.85	1030	-
Sand-cement mortar preformed coffer	1.68	1 800	-

Table 3. *Continued.*

Masonry type	Bending strength at 28 days of age (MPa)	Thermal conductivity (W/m. K.)
Rice husks concrete without sand solid brick	-	0.638
Rice husks concrete with sand solid bricks	-	0.477
Sand-cement mortar solid bricks	-	1.30
Rice husks concrete without sand hollow bricks	-	0.638
Rice husks concrete with sand hollow bricks	-	0.477
Sand-cement mortar hollow bricks	-	1.30
Rice husks concrete without sand preformed coffer	2.99	0.638
Rice husks concrete with sand preformed coffer	2.06	0.477
Sand-cement mortar preformed coffer	2.34	1.30

By analyzing the data in Table 3, it appears that:

- compressive strengths of rice husk concrete bricks and sand - cement bricks are of the same order of magnitude with a slight dominance of rice husks bricks;

- rice husks concrete without sand bricks and preformed coffers consume more cement than sand-cement agglomerates; sand dosage makes it possible to reduce the cement dosage and to improve the resistance;

- rice husks concrete bricks and preformed coffers are lighter than those made of sand - cement mortar: there is a decrease in mass of about 46%; this lightness will contribute to reduce building permanent loads thus to obtain economical foundations;

- rice husks with sand preformed coffer bending strength is close to that of sand-cement preformed coffer while –that of rice husk without sand preformed coffers is 1.3 times higher: there is an increase in resistance of about 30%;

- rice husks concrete are more heat-resistant (lower thermal conductivity) than sand-cement mortar: rice husks concrete preformed coffers and bricks will provide better thermal insulation.

Table 4 presents loads and materials characteristics used to size considered elements.

Table 4. *Dimensioning Data.*

Designation	Rice husks concrete without sand preformed coffer	Rice husks concrete with sand preformed coffer	Sand-cement mortar preformed coffer
Floor:			
- Dead loads:			
Compressive slab	1.25 kN/m^2	1.25 kN/m^2	1.25 kN/m^2
Joist	1.125 kN/m^2	1.125 kN/m^2	1.125 kN/m^2
Preformed coffer	1.1 kN/m^2	1.03 kN/m^2	1.8 kN/m^2
Cement screed	0.8 kN/m^2	0.8 kN/m^2	0.8 kN/m^2
Under slab cement rendering	0.2 kN/m^2	0.2 kN/m^2	0.2 kN/m^2
Total dead loads	4.475 kN/m^2	4.405 kN/m^2	5.175 kN/m^2
- Working loads	1.5 kN/m^2	1.5 kN/m^2	1.5 kN/m^2
Concrete compressive strength at 28 days of age	20 MPa	20 MPa	20 MPa
Grade of steel for longitudinal reinforcement	Fe E 400	Fe E 400	Fe E 400

It appears from this table that floor made with sand-cement mortar preformed coffers is heavier than floor made with rice husks concrete preformed coffers. There is a decrease in weight of 13% to 15% depending on whether rice husk concrete is dosed with sand or not.

Tables 5 and 6 present joist and beam calculation results. The joist is simply supported at his extremities and has a span of 3m. The beam is a continuous beam, simply supported with two spans of respective 4.5m and 4m.

Table 5. *Joist calculation result.*

Designation	Rice husks concrete without sand preformed coffer	Rice husks concrete with sand preformed coffer	Sand-cement mortar preformed coffer
Dimensions:			
Length (L):	3 m	3 m	3 m
Width (b):	10 cm	10 cm	10 cm
Depth (h):	20 cm	20 cm	20 cm
Effective depth (d):	16 cm	16 cm	16 cm
Dead loads:	2,685 kN/m	2,643 kN/m	3,105 kN/m
Working loads:	0,9 kN/m	0,9 kN/m	0,9 kN/m
Dead loads bending moment (M_G):	3,021 kNm	2,973 kNm	3,493 kNm
Working loads bending moment (M_Q):	1,013 kNm	1,013 kNm	1,013 kNm
Bending moment at ultimate limit state (M_u=1,35M_G+1,5M_Q):	5,598 kNm	5,533 kNm	6,235 kNm
Bending moment at serviceability limit state (M_{ser}=M_G+M_Q):	4,034 kNm	3,986 kNm	4,506 kNm
Reinforcement section	1,51 cm^2	1,51 cm^2	2,07 cm^2

From this table, it appears that all joists require the same concrete amount despite their weight difference. Indeed, this difference is small to influence concrete amount. The reinforcements of the joists supporting rice husks concrete preformed coffers are inferior to those of the joists supporting sand-cement mortar preformed coffers. Admittedly, these preformed coffers are about 1.6 times heavier than those made of rice husks concrete which results in an increase of joist reinforcement of the order of 37%.

Table 6. *Beam calculation result.*

Designation	Rice husks concrete without sand preformed coffer	Rice husks concrete with sand preformed coffer	Sand-cement mortar preformed coffer
Dimensions:			
Width (b):	15 cm	15 cm	15 cm
Depth (h):	50 cm	50 cm	50 cm
Effective depth (d):	45 cm	45 cm	45 cm
Beam weight:	1,875 kN/m	1,875 kN/m	1,875 kN/m
Floor dead load	13,425 kN/m	13,215 kN/m	15,525 kN/m
Wall weight (Pm)	5,516 kN/m	5,516 kN/m	5,516 kN/m
Floor working load	4,5 kN/m	4,5 kN/m	4,5 kN/m
Loads at ultimate limit state	34,85 KN/m	34,57 kN/m	37,69 kN/m
Loads at serviceability limit state	25,32 kN/m	25,11 kN/m	27,42 kN/m
Span N° 1; Length = 4,50 m			
Moment at mid-span at ultimate limit state	57,15 kNm	56,71 kNm	61,61 kNm
Moment at mid-span at serviceability limit state	41,37 kNm	41,04 kNm	44,68 kNm
Reinforcement section	5,40 cm^2	5,40 cm^2	5,75 cm^2
Span N° 2; Length = 4 m			
Moment at mid-span at ultimate limit state	40,49 kNm	40,19 kNm	43,52 kNm
Moment at mid-span at serviceability limit state	29,22 kNm	28,99 kNm	31,47 kNm
Reinforcement section	3,83 cm^2	3,83 cm^2	3,93 cm^2
Intermediate support			
Moment at support at ultimate limit state	74,83 kNm	74,22 kNm	80,93 kNm
Moment at support at serviceability limit state	54,35 kNm	53,90 kNm	58,87 kNm
Reinforcement section	6,98 cm^2	6,98 cm^2	7,60 cm^2

The results of this table confirm the lightness of the floors made of rice husks concrete preformed coffers compared to those with sand-cement mortar preformed coffers. At equal section, beams supporting rice husks concrete preformed coffers are the least loaded and therefore require less reinforcement. There is a decrease in the amount of reinforcement of beam supporting rice husks concrete preformed coffers about 7% compared to that receiving sand-cement mortar preformed coffers.

Tables 7 and 8 show column and pad footing calculation result.

From these tables, it appears that rice husks concrete preformed coffers building column is the least loaded and therefore the least reinforced. The use of the rice husks concrete preformed coffers allows column reinforcement reduction of the order of 40%. Similarly, this use allows a reduction of pad footing dimensions of 10%, a reduction of 17% of concrete volume. The pad footing reinforcement

amount is reduced by 20%.

Table 9 summarizes the impact of rice husk concrete preformed coffers use on building structural elements.

Table 7. *Column calculation result.*

Designation	Rice husks concrete without sand preformed coffer	Rice husks concrete with sand preformed coffer	Sand-cement mortar preformed coffer
Ground floor level			
Dimensions:			
Height:	3 m	3 m	3 m
Length:	15 cm	15 cm	15 cm
Width:	15 cm	15 cm	15 cm
Column weight	1,575 kN	1,575 kN	1,575 kN
Load at ultimate limit state from beam	170,33 kN	168,96 kN	184,21 kN
Effort from upper floor (kN)	136,06 kN	134,70 kN	149,94 kN
Effort in column at ultimate limit state	308,52 kN	305,79 kN	336,28 kN
Reinforcement section	6,16 cm^2	6,16 cm^2	12,57 cm^2

Table 8. *Pad footing calculation result.*

Designation	Rice husks concrete without sand preformed coffer	Rice husks concrete with sand preformed coffer	Sand-cement mortar preformed coffer
Effort from column	308,52 kN	305,79 kN	336,28 kN
Sub-grade allowable stress:	0,35 MPa	0,35 MPa	0,35 MPa
Dimensions:			
Length:	100 cm	100 cm	110 cm
Width:	100 cm	100 cm	110 cm
Height:	30 cm	30 cm	30 cm
Reinforcement in length direction	4,02 cm^2	4,02 cm^2	5,03 cm^2
Reinforcement in width direction	4,02 cm^2	4,02 cm^2	5,03 cm^2

Table 9. *Comparison of structural elements for the three types of preformed coffers.*

Designation	Rice husks concrete (A)	Sand-cement mortar (B)	Rate (A/B)	Variation rate (%) ((B – A)/B)
Floor weight (kN/m^2)	4,405 – 4,475	5,175	0,85 – 0,86	13,5 – 14,8
Joist concrete (m^3)	0,06	0,06	1	0
Joist reinforcement (cm^2)	1,51	2,07	0,73	27
Beam concrete (m^3)	0,64	0,64	1	0
Beam reinforcement (cm^2)	16,21	17,28	0,93	6,2
Column concrete (m^3)	0,135	0,135	1	0
Column reinforcement ($cm^{2)}$	6,16	12,57	0,49	51
Pad footing concrete (m^3)	0,3	0,36	0,83	16,7
Pad footing reinforcement (cm^2)	8,04	10,06	0,80	20,1

The impact of rice husk concrete preformed coffers use is felt on all structural elements, especially at columns and footings level. This impact results in a decrease of concrete and reinforcement quantities of structural elements.

4. Conclusion

This work aims to study the effect of rice husks concrete (with or without sand) preformed coffers and bricks use in the realization of buildings structural elements (joist, beam, column and footing).

The determination of preformed coffers and bricks characteristics has shown that these masonry elements made with rice husks concrete are lighter and as resistant (even more) than those made with sand-cement mortars commonly used in Togo. They also have better thermal conductivity and therefore good thermal insulation. The lightest and most resistant elements are obtained with rice husks concrete dosed with sand: compared to cement-sand mortar elements, one obtains a weight gain of about 46% and a resistance increase of 30%.

The dimensioning a two-storey building with hollow pot floor slab structural elements has shown that rice husks concrete preformed coffers use has the advantage of reducing the dimensions and reinforcement of structural elements. In fact, compared to floor made with sand-cement mortar preformed coffers, rice husks concrete preformed coffers permit a reducing of floor weight (30%), footing concrete (15%) and joist, beam, column and footing reinforcement (from 6% to 51%).

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