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RESEARCH ARTICLE

STUDY OF THE RESISTANCE TO RUPTUREAND DEFORMATION OF A BENT BEAM MADE OF OIL PALM KERNEL SHELL (OPKS) CONCRETE REINFORCED WITH BORASSUS AETHIOPUM MART (RONIER)

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Abstract

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The present study is related to the simple bending performance of a structural element made of Oil Palm Kernel Shell Concrete (OPKSC) reinforced with Borassus Aethiopum Mart (ronier). An experimental program with the use of three (03) distinct approaches of formulation was developed. These are respectively the formulation approaches proposed by Gibigaye et al (Gibigaye et al., 2017) and Yasmine et al (Traore et al., 2015) for OPKSC and the one proposed by DreuxGorisse for conventional aggregate concretes that served as control concrete. Reinforced roast concrete beams of size 150 mm × 150 mm × 910 mm were developed in accordance with NF EN 12390-1 and subjected to four (04) point bending until failure. It was observed an improvement of the bending strength of the OPKSC compared to the conventional aggregate concrete with a rate ranging from 3 to 80% depending on the type of formulation used. Similarly, the use of plasticizers improves the bending strength of OPKSC by more than 75%. Moreover, we notice the appearance of the first cracks as soon as the applied load reaches 60% of the breaking strength in bending; which emphasizes the ductile behavior of OPKSC reinforced with roast. The OPKSC reinforced with ronier is a material suitable for use in the bent elements of the structure of lightly loaded buildings.

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Introduction:-

Materials such as Oil Palm Shells and ronier have been identified by the researchers as materialsthat can beusedrespectively as aggregates in concrete and as reinforcement in reinforcedconcrete structures. The OPKSC presentstechnical, technological and environmentaladvantages. As such, the authors are unanimous on the physical-mechanical performance of thislightweightconcrete and the possibility of its use as structural concrete [(Okafor, 1988); (Okpala, 1990); (Basri et al., 1999); (Jumaat et al., 2009); (U Johnson Alengaram et al., 2013); (Gibigaye et al., 2017)]. Similarly, the use of Borassus Aethiopum Mart (ronier) as reinforcement in association withconcreteisveryinteresting in view of the manyphysical-mechanical performances highlighted by the authorswho propose a partial or total replacement of steel in reinforcedconcrete by the ronier [(GbaguidiAisse, G. L., Gbaguidi V. S., Gibigaye M., 2009); (Gibigaye et al., 2010)]. The experimentalstudy of the mechanicalbehaviorcarried out in

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the perspective of usingit as plant reinforcement in concrete, shows that the roasttree has a stress of rupture and a high modulus of elasticity close to those of steelwith a zero longitudinal shrinkage rate (GbaguidiAisse G. L. et al., 2009). Thusthis plant reinforcementassociatedwith OPKS concretewhichis a light materialisveryinteresting for constructions in seismic zones (Gibigaye et al., 2017). The lightness of the supporting structure leads to itsflexibility and greaterflexibility. Relative to itsflexibilityitis important to know the performance of the materialused in order to proceed to the judiciouschoice of the suitable structure sections.

In fact, for the bending justification of reinforcedconcrete structures, one of the calculationprinciplesusedisbased on the allowable stress method. This design process involves essential parameterssuchas:resistance to bendingfailure and maximum deflection. The work of Teo (Teo et al., 2006) reported the bendingbehavior of oil palm shellbeamswithoutcement additions and that of Alengaram (U. J. Alengaram et al., 2008) provided the structural behavior (deformationcharacteristics, deflection, mode of failure) of steel-reinforced palm shellconcrete and itscomparisonwithsteel-reinforced normal weightconcrete. But no study to ourknowledge has been done on the determination of the bending performance of OPKS associatedwithronier plant reinforcement. Thus, itwouldbe important to beinterested in the determination of somemechanicalcharacteristics of the beams in OPKS reinforcedwithronierwhichwillmakeit possible to considerits optimal use in bentelements of structures of buildings of moderateloads.

Materials and Methods:-

Two (02) main categories of materials are used in the experimental program. These are the plant materials (reinforcementronier and aggregates of oil palm kernel shell) and the otherconstituents of concrete (sand, cement and water).

Vegetablematerials

Framework ronier (Borassus Aethiopum Mart)

The ronier (Borassus Aethiopum Mart) frameworksused come from the PahouAhozonforest at geographiccoordinates 6°37′16 "N ; 2°07′63 "E located in the commune of Ouidah (Republic of Benin). These frames are fromtreeswith an averageage of more than 50 years (i.e. 2 bulges) [Gibigaye et al., 2010]. Table 01 presents the characteristics of the ronierframeworkused.

Afterfelling, the stipe iscut to remove the bulge, whichisveryspongy. The log isthencollected and cutintoseveralpieces forming slats.

Duringthisoperation, the central part of the log, i.e. the pith, iscarefullyremoved and leftasidebecauseit rots veryquickly. Only the hard, rot-proof outer crown is of mechanical value. It isverydifficult to saw or plane because of itsfibrous structure but iseasily split intoslats. Theseslats are generallytriangular or trapezoidal in shape. The length of the slats varies from 1 metre to 3 metres. The machining phase isverydelicate. It consists of making square (20*20) cm^2 frames. It wascarried out in a carpentry workshop. This machining phase ispreceded by the conditioning or drying phase duringwhich the laths are dried to a relative moisture content of 12% ; the drying time varies from 28 to 30 days.Table 01 shows the characteristics of the ronier frame used.

Table 01:- Mechanicalcharacteristics of the ronierused (GBAGUIDI V. S. et al., 2010).

Mechanical characteristics	**Values obtained**
Basal density	0.69 ± 0.07
Density at 12% moisture	0.89 ± 0.03
Total longitudinal shrinkage rate (%)	Null
Total tangential shrinkage rate (%)	5.92 ± 0.71
Total radial shrinkage rate (%)	5.77 ± 0.93
Total volume shrinkage rate (%)	9.61 ± 2.57
Yield stress in tension parallel to the fibres at H=12% (MPa)	201.34 ± 12.28
Tensilestrengthparallel to the fibres at H=12% (MPa)	303.04 ± 37.39
Fracture stress in compression parallel to the fibres at H=12% (MPa)	82.17 ± 27.29
Fracture stress in compression perpendicular to the fibres at H=12% (MPa)	22.56 ± 2.10
Fracture stress in 04 point bendingparallel to the fibres at H=12% (MPa)	186.34 ± 19.85
Young's modulus in 04 point bendingparallel to the fibres H=12% (MPa)	17196.86 ± 1145.19

Shear stress perpendicular to the fibres (MPa)	13.59 ± 1.02
Shear stress parallel to the fibres (MPa)	0.88 ± 0.22

Oil Palm Kernel Shell aggregate (OPKS)
The Oil Palm Kernel Shell (OPKS) used as aggregate come from the commune of Akpro-Missérété at geographiccoordinates 6°56′63 "N; 2°58′42 "E (Ouémé Department, Republic of Benin). The shells are residuesfrom the exploitation of palm nuts. Afterharvesting, the bunches are cooked (sterilization), de-stemmed and the fruit ispressed. Afterdecanting, weobtaincrude palm oil. Twoproducts are alsoobtainedfromthisprocess: the fibers, which are residues of the pulp, and the palm kernel. The latter isthenbroken (using a machine or industrialway) and thenproceeded to the separation of the kernel to serve for the production of palm oil. The residuethusobtainedis a mixture of shells, pulp and all the otherwastecomingfrom the exploitation of the palm oil. The mixture obtainedisthendusted and sortedusing a screen. The residuethusobtainedisthenpassedthrough a sieve to separate the shellsthemselvesfrom all the otherwaste, includinganyremainingpulp. The collectedoil palm kernel shell are brought back to the laboratory for treatmentbeforebeingused as aggregate.

Several modes of OPKS treatment are available in the literature.Theseinclude:

1. Lime treatment, sodium silicate treatment, polyvinylalcoholtreatment, heattreatment, pre-saturation of OPKS (Traore et al., 2015) ;
2. Partial oxidation of organicaggregates, waterproofing, neutralizationwith alkali or tanningprecipitation, or sulfate treatment, mixingwith lime or calcium chloride for better performance of concrete as a gaspedal, treatment of aggregateswith water boiledwithferrous sulfate and removal of oilcoatingwithdetergent and water (Y. Binta et al., 2018) ;
3. Treatment by washing OPKS withdetergent;treatmentwith soda marketed for artisanal soap making; treatmentwithpotashmarketed for householdpurposes; treatmentwith hot water; heattreatment in an oven (Godonou et al., 2019).

Two (2) modes of treatmentwereused. These are potash-basedtreatment (Godonou et al., 2019) and lime-basedtreatment (Traore et al., 2015). Thesetwodifferent modes of OPKS treatment are known to have positive influences on the bond between the OPKS aggregates and the cementitious matrix and consequently the mechanical performance of oil palm kernel shellconcrete.

Treatment of OPKS withpotash
The treatment of OPKS withpotash can besummarised as follows:

1. take a mass m_c of OPKS to betreated ;
2. weigh a mass m_e of water suchthat $m_e = m_c$;
3. add to the mass m_e of water, a mass m_a of strong base (potash) ;
4. mixuntil the productisdissolved in the water ;
5. invert the OPKS into the alkaline solution and leave to soak for 48 hours ;
6. remove the OPKS from the alkaline solution ;
7. rewash the OPKS withdrinking water ;
8. dry the OPKS and store them in bags in a contamination-free environment.

For 1g of OPKS, 0.02g of potashisneeded.

Treatment of OPKS with lime
The lime treatmentoperation can besummarised as follows:

1. take a mass m_c of OPKS to betreated ;
2. weigh a mass m_e of water suchthat $m_e = m_c$;
3. add to the mass m_e of water a mass m_a of the lime to beused for the treatment ;
4. mixuntil the productisdissolved in the water ;
5. invert the OPKS into the alkaline solution and stir for 2 hours ;
6. get OPKS out of the solution ;
7. rewash the OPKS withdrinking water ;
8. dry the OPKS and store them in bags in a contamination-free environment.

For 1L of water youneed 40g of lime.

The OPKS have a curvature coefficient of 1.04 between 1 and 3, and are thereforewellgraded. As for itsuniformity coefficient, itis 1.6 < 3, and istherefore a tightlygradedaggregate. The real density of the shells (NF-EN 1097-6) is 1.429 Mg/m^3. The bulk density (NF EN 1097-3) is 0.529 Mg/m^{3}with an absorption coefficient of 20.87%. The sizingcurve for the OPKS aggregateisshown in Figure 01.

Otherconcreteconstituents

The other constituent materials of concreteused in thisstudy are sand, cement and water.

Cement

The cementusedis of the CEMII/B-2L 32.5R type in accordance with the NF EN 197-1 standard. It isproduced and marketed in the Republic of Benin. The cementused has a specific mass of 3.1 g/cm^3 ; aspecific surface of 3830 cm^2/g and a compressive strength of 32.5 to 52.5 Mpa.

Sand

The sandusedisquarrysand. It comesfrom a quarrylocated at 6°27'01"N ; 2°20'48"E in the commune of Abomey-Calavi (Republic of Benin). The physical and geometriccharacteristics of the sand, gravel and palm nutshellaggregates are shown in Table 02 and Figure 01 below:

Table 02:- Physical characteristics of aggregates.

Materials	Bulk density (Mg/m^3)	Absolutedensity (Mg/m^3)	Absorption coefficient (%)
Sand	1.282	2.556	-
Gravel	1.279	2.455	-
PNS	0.529	1.285	20.870

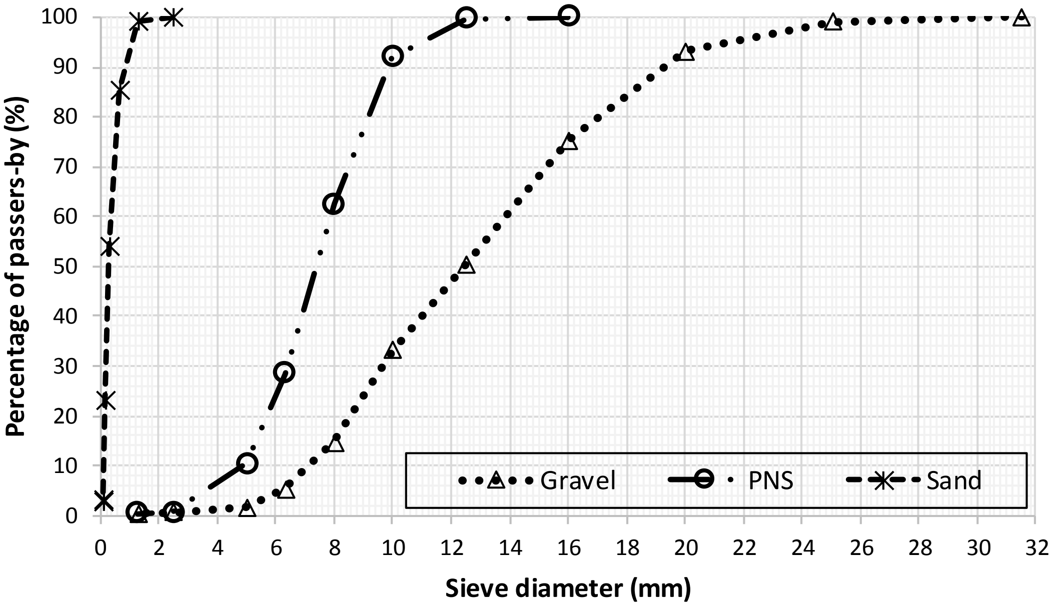


Figure 01:- Gradingcurve of the aggregatesused.

Adjuvant (superplasticizer)

The main function of the superplasticizeris to improve the workability of a mixture. The one usedis a new generation non-chlorinated high polyvalent water reducer (chloride ion content <=0.1% by mass) based on polycarboxylate-polyacrylate copolymer (SIKA VISCOCRETE TEMPO 12) for ready-mixed concrete, with a density of 1.060 ± 0.020, a pH of 5.5 ± 1.0 and a dry extract of 29.5% ± 1.4% (halogenmethodaccording to NF 085) and 29.5% ± 1.4% (NF EN 480-8). SIKA VISCOCRETE TEMPO 12 is a powerfulsuperplasticizerthatgivesconcrete the followingproperties: long rheology (>2h), robustness to segregation and facingquality. It is a light brownliquidwhich, for a mixture, isadded, either at the same time as the mixing water, or afterwards in the previouslywettedconcretewith or without a fraction of the mixing water.

Experimental program

The experimental program includes five (05) types of concrete. One (01) referenceconcrete and four (04)other types of concretefrom OPKS. Rolledgravelisused as coarseaggregate in the referenceconcrete. The OPKS are used as coarseaggregate in the four (04) types of concretefrom OPKS. The type of treatment, cement dosage and use of superplasticizer are the three (03) studyparameters.

The experimental program thusdesignedaims to evaluate the effect of the type of treatment (two types of treatment: potash and lime), the effect of the cement dosage (450 kg/m^3; 500 kg/m^3; 550 kg/m^3) and the effect of the use of the superplasticizer on the differentconcretes. The cement dosage of the referenceconcreteis 350 kg/m^3.

The referenceconcreteisnamed control. It consists of naturalaggregate (sand and rolledgravel). The other four (04) types of concrete are composed of palm kernel shells as coarseaggregates. The differenttypes of concrete are identified as follows:

1. **Control** (referenceconcrete, rolledgravel, dosage 350 kg/m^3, withoutadmixture) ;
2. **GC_550_A** (lime-treated OPKS concrete, cement content 550 kg, withadmixture) ;
3. **GP_550_A** (potash-treated OPKS concrete, cement content 550 kg, presence of admixture) ;
4. **GP_500_0** (potash-treated OPKS concrete, cement content 500 kg withoutadmixture) ;
5. **GP_450_0** (potash-treated OPKS concrete, cement content 450 kg withoutadmixture).

The ratios (W/C, OPKS/sand) are takenfrom the literature, in particular, studies on the treatment of palm kernel shellsby the potashmethod (Gibigaye et al., 2017) as well as those on the treatment of palm kernel shells by the lime method (Traore et al., 2015). The formulation methodused to determine the different proportions of the constituents of palm kernel shellconcrete are thosetakenfrom the literature (Gibigaye et al., 2017), (Traore et al., 2015). The referenceconcreteisformulatedaccording to the Dreux Gorissemethod. Table 03 shows the composition of the differenttypes of concrete.

Table 03:- Composition and characteristics of the fresh state.

Characteristics	**Control**	**GC_550_A**	**GP_550_A**	**GP_500_0**	**GP_450_0**
- W/C	0.56	0.40	0.40	0.45	0.45
- OPKS/sand	-	0.875	0.875	0.50	0.65
Composition					
- Water (kg/m^3)	195	220	220	225	202.5
- Cement (kg/m^3)	350	550	550	500	450
- Sand (kg/m^3)	797	913	913	998.32	991.20
- Rolled gravel (kg/m^3)	975	-	-	-	-
- OPKS (kg/m^3)	-	328.68	328.68	205.65	265.64
- Superplasticizer (ml/m^3)	-	11000	11000	-	-
Properties of fresh concrete					
- Subsidence (mm)	50	73	74	53	52
- Mass density (kg/m^3)	2291	1901	1923	1873	1877

Concrete production

The concretes are produced in the laboratoryusingbatches of 0.12 m^{3}produced in a mixer with a capacity of 0.15 m^3. The aggregates are first introducedwith 50% of the mixing water. After 90 seconds of mixing, the binder isadded and mixed for 90 seconds. The second half of the water containing the superplasticizerisadded and mixingiscontinued for 180 seconds.

Preparation of test specimens

Two types of specimenswere made (cylinders and beams). Cylinders (11 mm X 22 mm) for the determination of the compressive strength of concrete and beams (150 mm X 150 mm X 910 mm) for the determination of the flexuralstrength (NF EN 12390-1, 2001). It shouldbenotedthat the beams are reinforcedwithroastwood. The compressive strengths are determined at 7 days, 14 days and 28 days. The bendingstrengths are determined at 28 days.

In eachconcretebeam, steelreinforcement (2HA6) isarranged as assemblyreinforcement and ronierreinforcement (2BO20) isarranged in the tension zone. The transverse reinforcementis HA6 frames spaced at 10 cm. Figure 02 below shows the reinforcement of the developedbeams. Figures 03-a and 03-b show the appearance of the beamsbefore and after casting.

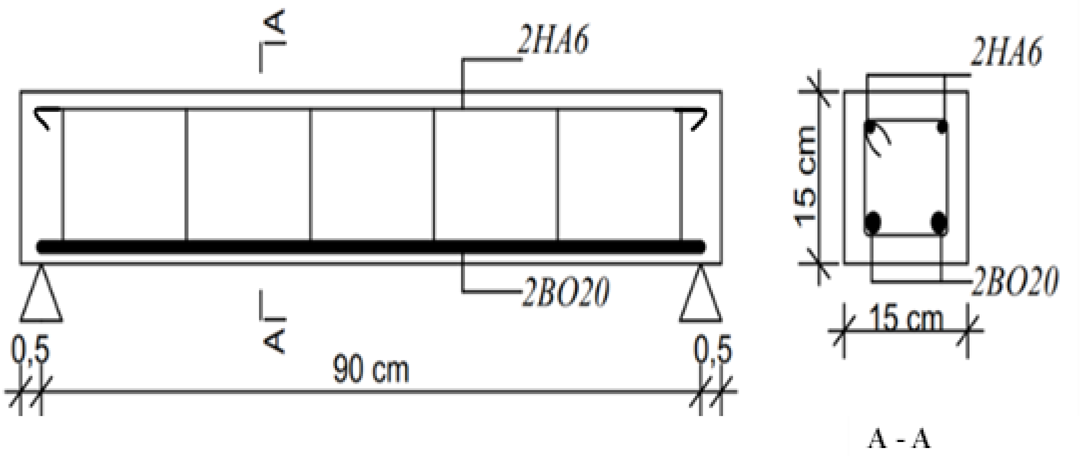


Figure 02:- Diagram of beam reinforcement.

Figure 03:- Appearance of the beams during casting: a) Reinforcement of the beam in the mouldb) Appearance of the beams cast in the mould.

Tests

Determination of compressive strength

The cylinders are subjected to uniaxial compression [NF EN 12390-5, 2001]. The equipmentusedis a hydraulicpresswith a capacity of 20 tonnes ensuring a constant loading speed of 2 mm/min and measuring the loadexerted. It isequippedwith a compression deviceconsisting of twocircular plates for uniform distribution of the compression force. The test consists of subjecting the cylindricalspecimens to an increasingloaduntilthey break. The compressive strengthis the ratio of the breakingload to the cross-sectional area of the specimen.

Determination of bendingstrength

The beams are subjected to four (04) point bending (NF EN 12390-5, 2001). The experimentaldeviceusedconsists of a hydraulicpresswith a capacity of 20 tonnes ensuring a constant loading speed : 2mm/mn and measuring the loadexerted. The pressisequippedwith a 4-point bendingdeviceconsisting of twoexternal supports on which the test specimenrests and twootherinternal supports. A displacementtransducer (comparator) witha 10 mm stroke and 0.01 mm accuracyplaced at mid-span of the beamallows the measurement of the beamdeformation.

During the test, the appliedloads are read on the pressure gauge of the press and the correspondingdeflectionisread on the comparator. The test iscarried out until the beam breaks.

The test consists of graduallyapplying a load at two points of a prismaticspecimenplaced on two supports, by increments in order to record the deflectionsthanks to a comparatoruntil the specimen breaks. Thesemeasurementswill enable the elasticitymoduli to beevaluated in the reference frame linked to the specimen. Figure 04 below shows the principle of the test. Figures 05-a and 05-b show the appearance of the beamsbefore and after the test.

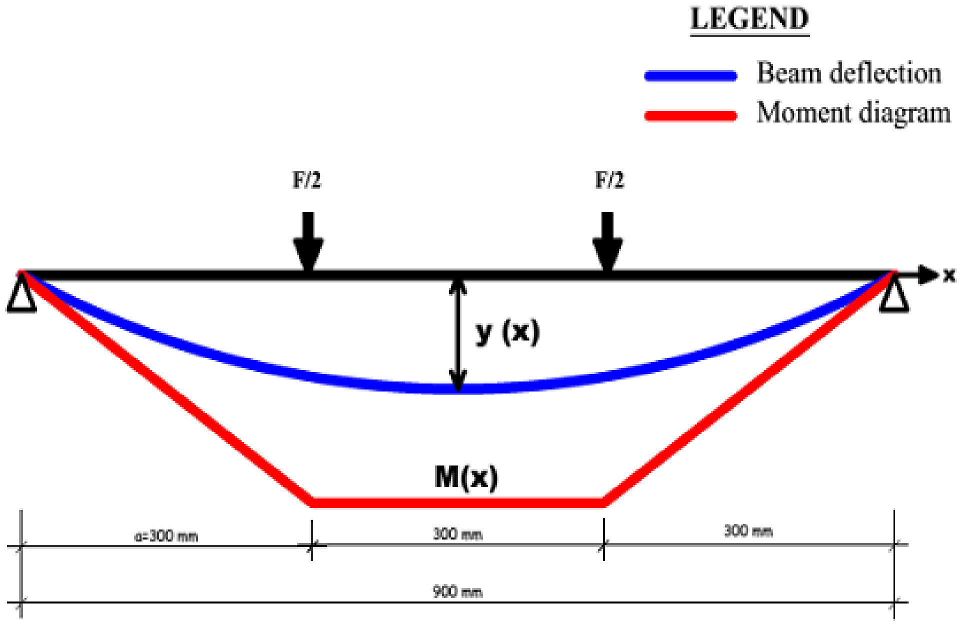
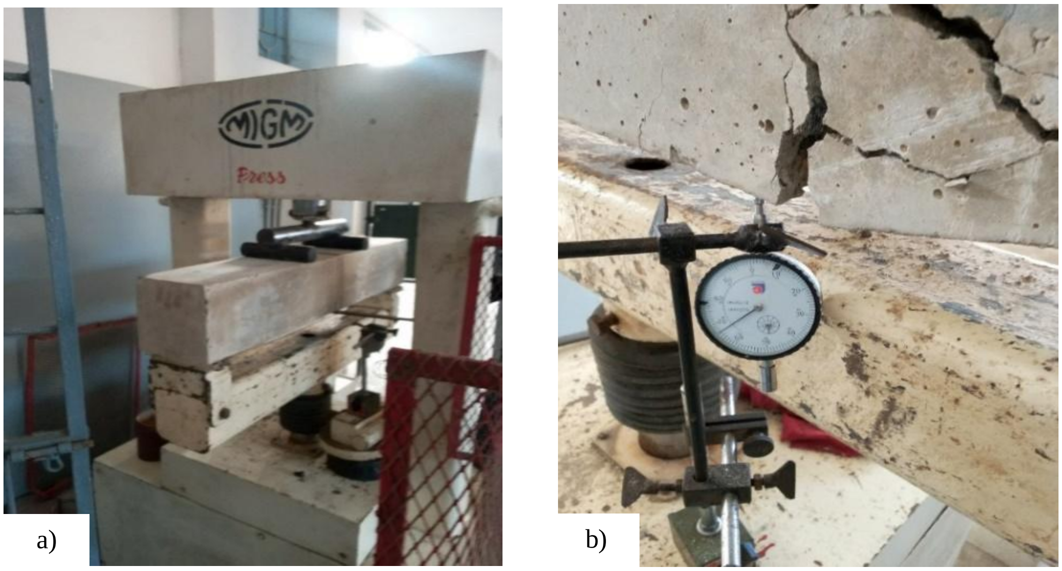


Figure 04:- 4-point bending test principle.



a) b)

Figure 05:- Appearance of the beams in the 4-point bending test : a) Beam placed on the pressbeforetesting b) Condition of the beamaftertesting and reading the deflection.

Results and Discussion:-

Results:-

Table 04 presents the results of the compressive strength and flexuralstrength of the concrete in Mega Pascal (MPa). The compressive strengths of the concretestudied are between 4.43 and 10.25 MPa at 7 days; 8.13 and 18.36 MPa at 14 days; and between 18.07 and 27.67 MPa at 28 days. Note that the referenceconcretehad compressive strengths of 10.25 MPa at 7 days, 15.38 MPa at 14 days and 22.40 MPa at 28 days. The flexuralstrengths of the concrete range from 3.31 to 5.97 MPa at 28 days.

The lowest value of flexuralstrength at 28 daysisobtainedwith the referenceconcrete. The flexuralstrength values obtained on the OPKS concretes are all higherthanthat of the referenceconcrete.

Table 04:- Composition and characteristics of concrete.

Compressed (MPa)	**Control**	**GC_550_A**	**GP_550_A**	**GP_500_0**	**GP_450_0**
- 7 days	10.25	10.36	11.46	4.81	4.43
- 14 days	15.38	17.92	18.36	8.13	9.74
- 28 days	22.40	27.47	27.67	18.07	18.21
Bending (28 jours)					
- Cracking stress (MPa)	2.46	3.78	4.01	2.66	2.65
- Tensile stress (MPa)	3.31	5.85	5.97	3.42	3.45
- Arrow (mm)	1.45	1.81	1.63	3.42	3.3
- Young'smodulus (GPa)	5.19	7.36	8.06	2.28	2.38

Discussion:-

Compressive strength

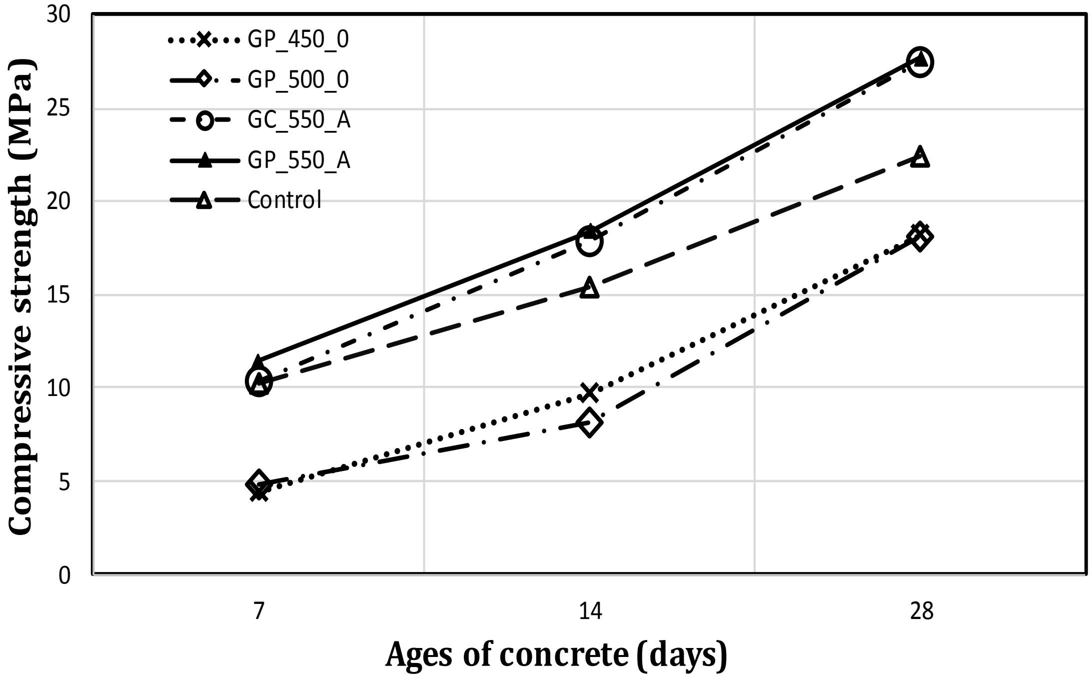


Figure 06:- Variation in compressive strengths of differenttypes of concrete over time.

The curves in figure 06 show the evolution of the compressive strengths of the different types of concretestudied as a function of age and type of concrete(cement dosages, treatment types, use or not of plasticizer). The curves in Figure 06 indicatethat the compressive strength of the different types of concreteincreasedwithage. The strength values obtained at 28 days are all higherthan 17 MPa. Theseconcretesmeet the ACI 213 standard and can beusedas structural concretes. In addition, the failure of OPKS concreteobservedunder compressive loadisrelatively non abrupt compared to that of the referenceconcrete. This mode of failurewaspreviouslyobserved by (U. Johnson Alengaram et al., 2013).

At seven (07) days, fourteen (14) days and twenty-eight (28) days, the compressive strengths of GC_550_A; GP_550_A (containingsuperplasticizer) concretes are higherthan GP_450_0 and GP_500_0 (not containingsuperplasticizer) concretes. Therefore, the use of superplasticizerimproved the compressive strength of the OPKS concretes.

The compressive strength of GP_550_A concrete (containing post-treated OPKS aggregates) ishigherthanthat of GC_550_A concrete (containing lime-treated OPKS aggregates). For the same lime treatment (Y. Binta et al., 2018), however, obtained a value of 25.5 MPa. Potashtreatmentimproved the compressive strength of OPKS concretes. Bothpotash and lime treatmentsmitigate the water absorption of NPCs, but the compressive strengths of concretescontainingpotash-treatedOPKS aggregatesare relativelyhigherthanthosecontaining lime-treated OPKS aggregates. The potashtreatmentmakes the aggregateslessporous and thusimproves the compressive strength.

Flexuralstrength and stress at cracking

The four-point bending tests performed on the different types of beamsallowed the determination of the cracking and failure stresses. The histogram in Figure 07 juxtaposes the cracking stresses and bendingstrengths (stress to failure) for the beamsstudied.

The flexuralstrength values of the studied OPKS beams (rangingfrom 3.42 MPa to 5.97 MPa) are above the flexuralstrength value of the referenceconcretebeam (3.31 MPa). Thus, the studiedOPKS concretesshow betterflexuralstrengthwhencompared to the referenceconcrete. The gain in strengthobtainedisfrom 3 to 80%. This iscontrary to the observation of Alengaram (U. J. Alengaram et al., 2008) wherehe states that OPKS concretegenerally has lowerflexuralstrengththanconventionalconcrete.

The same trend isobserved for stress values at cracking. The cracking stress values of the OPKS beams (rangingfrom 2.65 MPa to 4.01 MPa) are above the cracking stress value of the referenceconcretebeam (2.46 MPa). The OPKS concretesstudiedthus show betterresistance to cracking whencompared to the referenceconcrete. The strength gain obtainedis 64 to 77%.

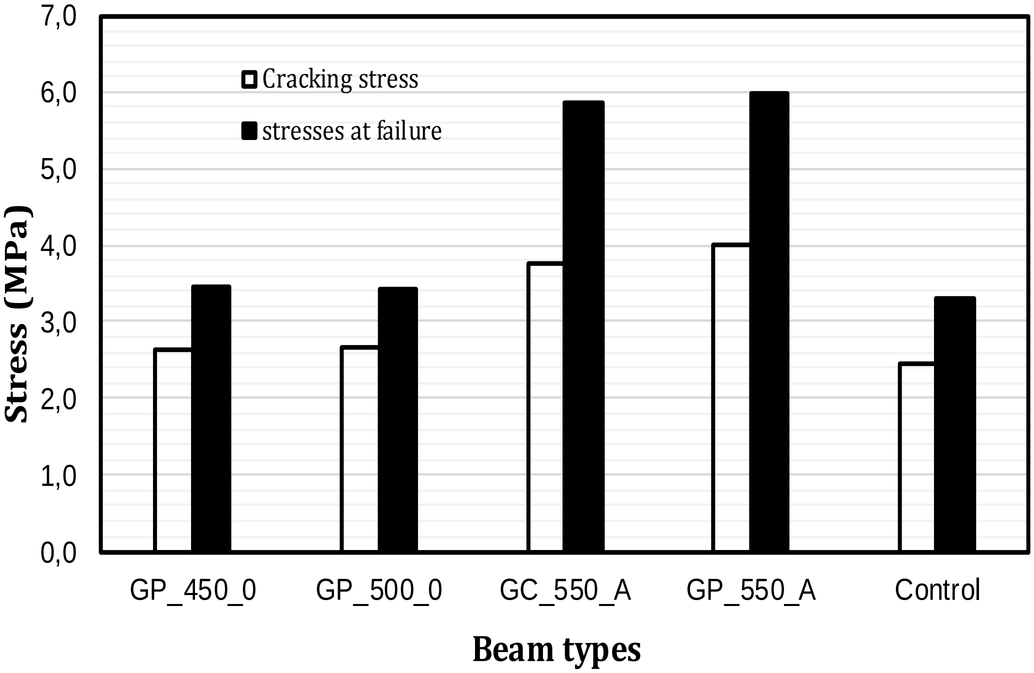


Figure 07:- Variation in cracking and fracture stresses.

These fracture stress values are consistent with the range of values obtained by (T. Y. Binta, 2018) for severalbeamswith OPKS aggregatesundergoing multiple treatments.

Maximum deflection at break

The four-point bending tests performed on the different types of beamsallowed us to collect the maximum deflections.

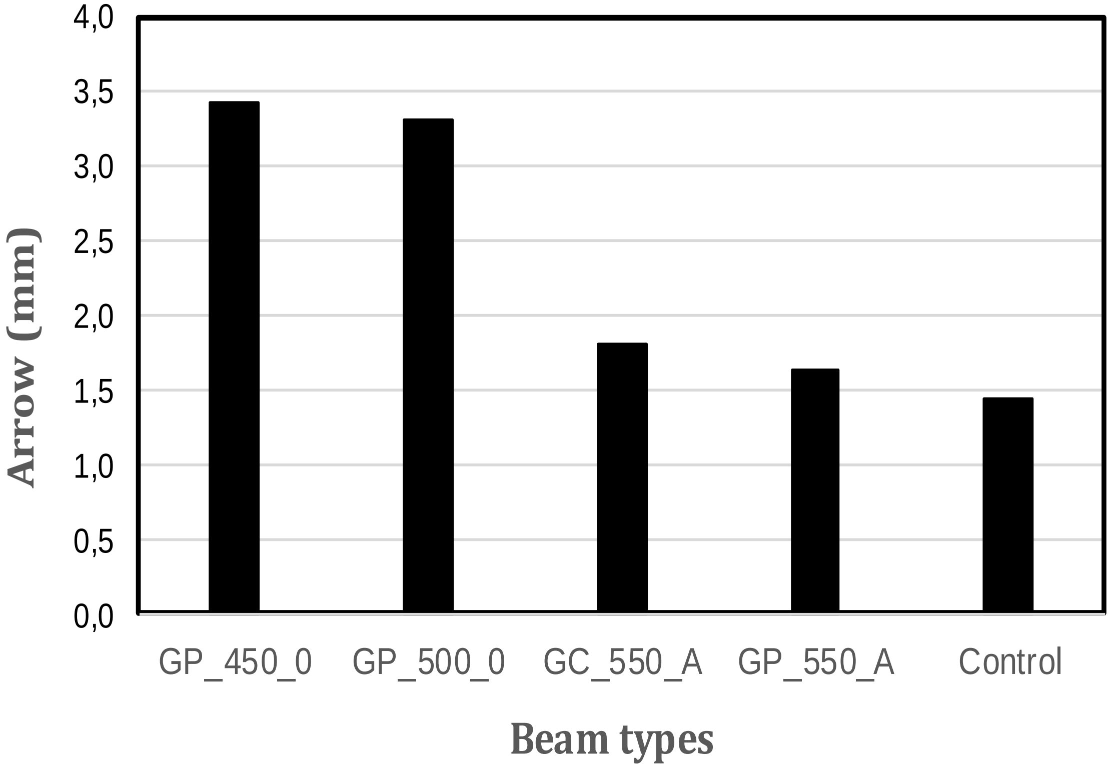


Figure 08:- Variation of maximum deflections at break.

Figure 08 shows the maximum deflections at failure of the differentbeamssubjected to four-point bending. The deflectionsobtained range from 1.63 mm to 3.42 mm for the OPKS concretesbeams; for the normal weightaggregateconcretebeamsitis 1.45 mm. This value fallswellwithin the range of deflection values obtained by (Sohounhloue J. et al., 2018) for normal-weightaggregateconcretebeamsreinforcedwithronierwhichis 0.60 mm to 1.55 mm. For ronier-reinforced OPKS concretesbeams, the deflection values are lower for beamswithhigherstrengths. Thesecharacteristics are confirmed by the work of Alengaram (U. J. Alengaram et al., 2008) for steelreinforcedOPKS concretesbeams.

Young'smodulus

Table 04 shows the Young'smodulus values of the roasttreereinforced OPKS concretesbeams. The histograms in Figure 09showthat the Young'smodulus values range from 2.2 to 2.4 GPa for the concretebeamscontaining palm kernel shells and no plasticizer addition. These values are consistent with the results in the literature (Gibigaye et al., 2019). Beamscontaining palm kernel shells and admixture (superplasticizer) have Young'smodulus values rangingfrom 7.3 to 8GPa. The Young'smodulus values of concretebeamscontaining palm kernel shells and plasticizer are higherthanthose of concretebeamscontaining palm kernel shells and no plasticizer, an increase of over 75%. The improvement in Young'smodulus of beamscontainingsuperplasticizer by 55% isfound in the literature (U. J. Alengaram et al., 2008).

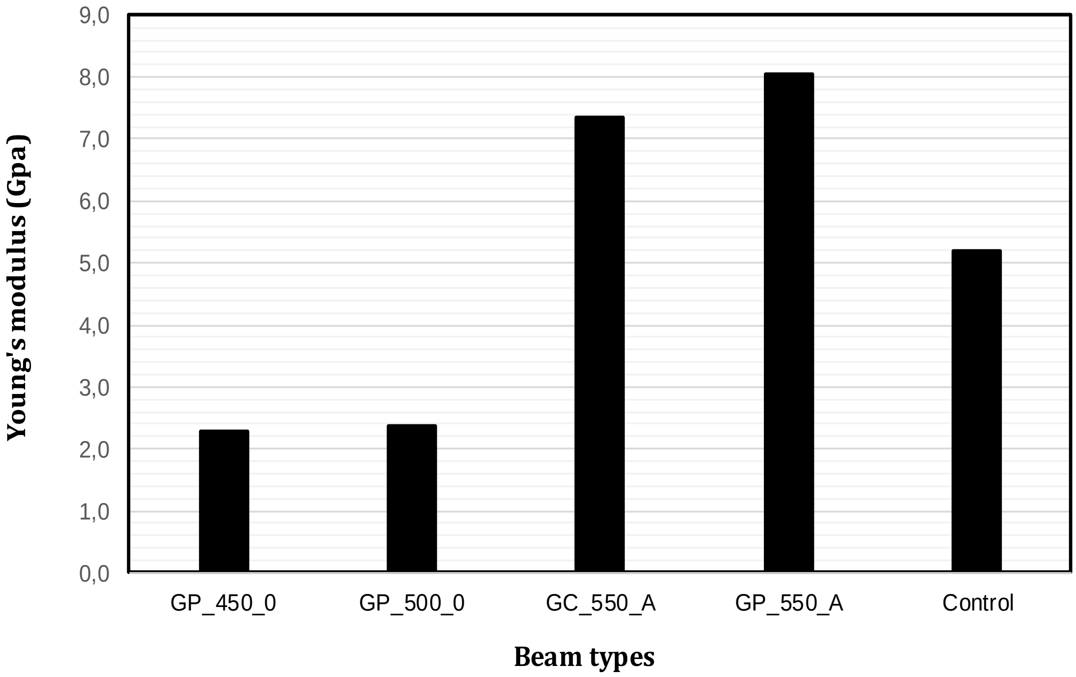


Figure 09:- Variation of Young'sModulus of the differentbeams.

Conclusion:-

The experimentscarried out show that the behaviour of a OPKS concretesbeamreinforcedwithronieris comparable to that of a conventionalconcretebeamreinforcedwithronierboth in terms of maximum deflection and failure stress. At the end of the testedtreatments, the potashtreatmentindicates maximum performance; thistreatmentimproves the mechanicalbehavior of the concreteswhencompared to the results of OPKS concretescontaining lime treatedshells.

However, the OPKS concretesbeams show a different mode of failurewhensubjected to four (04) point bending. The observed mode of failureindicates a ductilityeffectthatis not observed on normal weightaggregateconcretebeams.

Therefore, webelievethatitis possible to use palm kernel shellconcretereinforcedwithroastedwood in the bent structural elements, given the overallbendingbehavior of the beams, which shows better performance.

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