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Investigation of Red mud, Rice Husk and AnthillbasedGeopolymercomposite for Engineering applications

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Abstract
*Quite a lot of geological surveys concede that Guinea is home to 33% of the world's known bauxite reserves.The industrialscale conversion of rawmaterialssuch as bauxite intoproducts or intermmediates releases hugequantities of wasteposingenvironmentalconcerns,Red mud RM is a solid waste resulting from the digestion of bauxite ores with caustic soda for alumina production,treating and disposal of RM has become a concern,Riceis the second largestproducedcereal in the world,itiscomposed by approximately 20% of ricehusk RH, whichcontainsa fibrousmaterials and silica. Due to its high percentage in the grain composition, the RH isconsidered a by-productthatcreatesdisposal and pollution concern. Rice huskash RHA is an industrialwasteproduced by burningricehuskprimarily for the generation of electricity. Because of its high silicon content, RH has become a source for preparation of several engineering materials. The alkali activation convertsindustrialwasteintovaluable engineering materialscalledgeopolymers GP.In comparison to ordinaryporltlandcement OPC, GP are producedwithsignificantreduction of energyconsumption and CO2 emissions,Theyrepresent alternative bindingmaterialswithhugepotential for civil engineering applications or for waste management**[1]**.In thischapter RM, RH and anthill AH soil are used to prepare a ternaryblendedmaterial for building purposes in laboratory conditions. The effect of blending ratio on the compressive strengthwereinvestigated.Raw materials and the final products are characterized by several methods: XRD, SEM.*

Keywords:Bauxite, redmud, ricehusk ; anthill, geopolymer; compressive strength*

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I. INTRODUCTION

Due to the growth of population and the needs for infrastructure, itisobviousthat the demand for space, naturalresources, and energywillgrow, The increase of industrialactivitygivesrise to an increase of quantity of wastethat can have a negative impact on the environment and humanlife,Among thesolidwasteswe can cite red mud, fly ash, ground granulated blast furnace slag, rice hush ash.

In recentyear, thereis a growingdemand of development of new low-cost technologies that use the industrialwastescausing damages to health and environment,Inorganicpolymers or geopolymershave been recentlygaining attention as an alternative binder for concretebecause of itspotential to lower the environmental impact of construction, to utilizewaste as rawmaterials of alumino-silicates, and to enhance the material performance.

The involvement of OPC production to greenhousegas production in the world isestimated to beapproximately 1,35 billion tons per year or about 7% of the total greenhousegasemissionsintoenvironment**[2]**.

Investigations suggestedthat the production of a tonne of OPC releases as much as an equivalent tonne of CO2. In thiswayitis themostenergy-intensive materialproducedaftersteel and aluminium **[3]**.Because of the heavy and growingdemand for concrete, OPC producing industries still do not anticipate in the foreseeable future any major changes to reduce CO2 emissions

Fig.1 **[5]**illustrates the quantities of CO2 emitted by material binders depending on their OPC content.It shows that the in the earlierperiod, binders was made exclusively of OPC with about 1000.

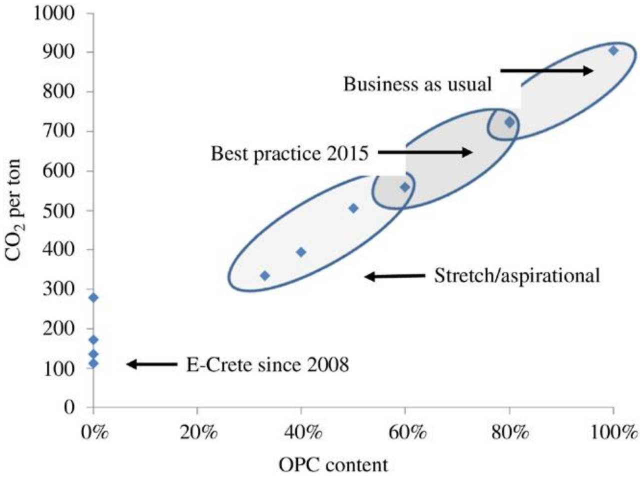


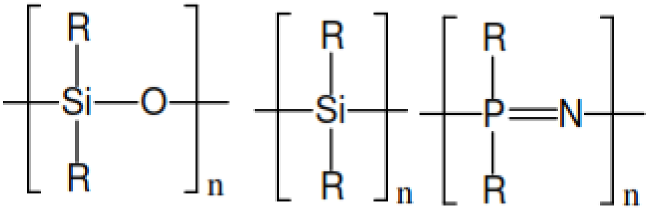
Fig.1 [5]:CO2 emissions of variouscement binders as a function of OPC content.

One of the reasons for developpingresearch on geopolymers are partlyenvironmental in order to reduce CO2 emissions and footprint relative to OPC, and partlyeconomical in particularwhenindustrialbyproductssuch as RK, RHA can beused as aluminosilicate source or puzzolanas.Inthisstudy, engineering properties of a GP materialproducedfrom the ternaryblend of RM, RHA, AHsoilandmixed in an alcali-solution are invetigated.

I. GEOPOLYMERS

Generaly apolymeris a molecule, consisting of the repeatedsequence of the same pattern, the monomer (from Greek monos: one or only one, and meros: part), connected to eachother by covalent bonds. In the molecule A-A-A-A-A-A-A = [-A-]. The constituent unit isA;itisformed of a group of atomsthatrepeatsitself, At the molecularlevel, mostpolymeres are in the form of "long and flexible thread. The chemicalreactionsallowing to passfrom a monomer A to the macromolecule [-A-] are calledpolymerization.

In addition to polymersthatcontainonlycarbon or other ‘organic’ atoms in thechain, polymerscontaining ‘inorganic’ atoms can alsobeformed,These compounds are of interestbecausetheyoffer the opportunity to developnew technological applications due to theirreactivity, structure, and physicalproperties, The mostwidelydevelopedcontainsilicon as polysiloxanes and polysilanes.Anothercommon class are the polyphosphazenes,



PolysiloxanesPolysilanesPolyphosphazenes

Polysiloxanesrepresent the most important inorganicpolymerswith regard to commercial applications : medical:prosthetics, catheters, contact lenses, drugdelivery capsules; non medical: e,g,elastomers, adhesives, lubricants, water repellents, molds,cosmetics.Polysilanes have a polymer backbone containingonlysiliconatoms. A siliconchainallowselectrondelocalisation of sigma electrons. Many uses of polysilanesderivefrom the electronmobility. Most uses are in the electronicsindustry as photoresists and precursors to siliconcontainingmaterials **[6]**.

A novel type of binding material with different labels, but generally known as “geopolymers”, appears like an option to reduce greenhouse gas emissions from the cementous material production **[7]**since it has a very small greenhouse footprint when compared to traditional concretes **[8]**. The technique still utilizes industrial wastes or by-products in their formulation and it can offer a possibility of a solution to the immobilization of toxic and radioactive wastes**[9]**. This explains the growing interest in academic and commercial areas recently, where the potential for CO2 emission reductions can be appointed as the key factor **[10]**.

I.1. Nomenclature and definition

The termgeopolymerswas first used by J,Davidovits in the 1970's for alkali-activatedalumina-silicate binders **[11]**.AfterDavidovits, the "geo-" part refers to the Greek *Gaia* whichmeansearth, as geopolymersmainlyconsist of aluminium and silicon oxide which are the mostcommonmaterials in the earth'scrust.Otherauthorsattribute the prefix "geo" to the constitutive relationship of the binder to geologicalmaterialssuch as natural stone and/or minerals**[12]**. The "polymer" part refers to the composition of the geopolymerswhichis a threedimensional network of monomersconsisting of aluminate and silicate tetrahedra.
The term *Geopolymer*coversaclassofaluminosilicatematerialswithpotential application in anumber of engineering areas, basicallyas asubstitutefor OPC and forinnovativehigh-techcomposites.Advancedcomposite materialsareproductsforspace,aerospace, defense, marine,petrochemicalsandeffluent treatmentetc.Thegeopolymerization processinvolvesachemicalreactionbetweenredmudandalkali metalsilicatesolutionunderhighlyalkalineconditions.Theproductofthisreactionisan amorphoustosemi-crystallinepolymericstructure,whichbinds theindividualparticlesofred mudtransformingthe initialgranularmaterialto a compactandstrongone.
GP can bepreparedfrom a range of aluminate and silicatematerialssuch as metakaolin,flyash,blastfurnaceslags,ricehuskash and otherpuzzolana,Pozzolanas are defined as siliceous or siliceous and aluminous materials which in themselves possess little or no cementing property, but will in a finely dispersed form in the presence of water chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties **[13]**.

I.1.Sustainability of GP development

The primaryfunction of a geopolymeris to act as a cementitious binder and replace OPC in civil engineering manufacture or providecomplementaryproducts.Some of the advantagesthatgeopolymers have over OPC istheir high compressive and flexuralstrength, theirvery high temperatureresistance, a high resistance to acid, and the ability to utilize multiple waste or byproductstreams**[14]**.
Geopolymers binders have the potential to incorporate cations, anions, and organicspecieswithintheirthree-dimensional structure **[15]**.OPC can also trap impurities, though the acidresistance of geopolymer binders allows for a muchwider range of safereceivingenvironments. A significantecological and marketing benefitreported for geopolymer binder over OPC is the reduction in CO2 emissions. One tonne of OPC releases 0,55 t of CO2 from the calcination of limestone and the combustion of carbon-based fuel for heat and power generationproduces an averageadditional 0,40 t of CO2 Comparatively, geopolymer production createsonlybetween 0,2 and 0,5t of CO2 per tonne of product, depending on inclusion of lifecycle and transport factors**[16]**.
An industrialsustainableapproach,utilizingsuchresiduesmoreeffectively,wouldmaximizethecommunitybenefitfromthe consumption of limitedresourcesand reducethe requirementfor productionof natural, virginresources,withitsassociatedenvironmentalimpacts,**[17]**.
The use of multiple and variedfeedstock in GPsynthesishas led to a focus on understanding the chemical basis of the amorphousreactivecomponents,ThisinturnallowsGPproductsto beformulatedwithpredictableperformanceproperties,withoutthe requirementfor trialand erroron the basis of newor variablefeedstockflows**[18]**.

II. FEEDSTOCK FOR GP PRODUCTION

The main parent materials for the large-scaleindustrial production of GP include:concentratedcaustic solution withdissolvedsilica or alumina ;

Figure 2 : a)RM b) AH

a source of caustic soluble alumina. Thesematerials must beavailable in sizeablequantities and at appropriatecost for commercial application. Basing on theirorigin, caustic soluble alumina or caustic soluble silica are natural (clayminerals) or industrial (mainly by-products).

In Guinea a substantialquantity of RM ascaustic soluble alumina resultsfrom the production of alumina at the ACGplant ; and the conversion of the huge bauxite reservesinto alumina willproduce an equivalentquantity of RM.Moreover the increase of riceproduction and itstreatmentwilldeliver RH containingenormousreserve of caustic soluble silica.Inthiswaysuitable conditions and framework for a sustainable GP industry are set.

II.1. Red med

RM ischaracterized by strongbasicityevenwith a high water content, because of the presence of hugeamount of sodium hydroxideused to extract silicates and alumina.The amount of bauxite required to produce one ton of alumina and, thus the resultingamount of RM variesconsiderablydepending on eachdeposit or district as shows Fig.3 [19].

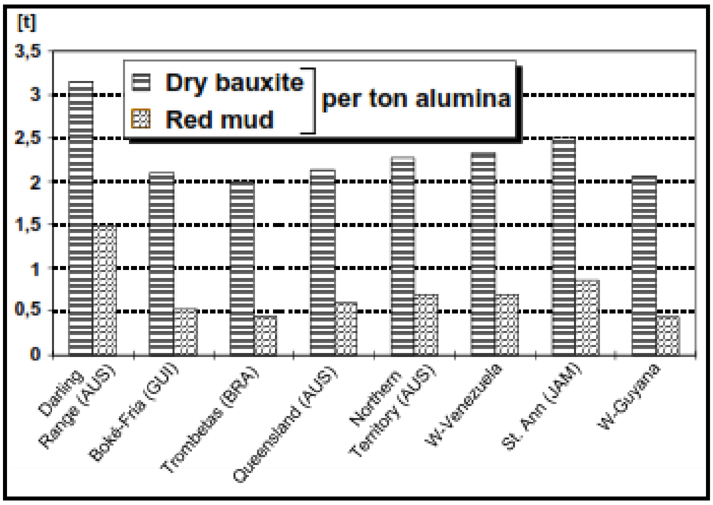


Fig.3 **[19] :** Bauxite required and redmudproduced per ton of alumina for eightselected major bauxite districts.

The amount of the RMgenerated, per ton of the alumina processed, varies greatlywith the type of the bauxite ore usedfrom 0,3 ton to 2,5 tons for high and verylow grade bauxites respectively. The storage of large quantities of RM is expensive (between 1 and 2% of the price of alumina), requiring large disposal areas (about 1 km^2 for five years of production for a factory producing 1 million tons of alumina per year) and causing serious environmental problems **[20]**.

II.2. Rice husk and Rice huskAsh

Riceis the second largestproducedcereal in the world.Its production isgeographicallyconcentrated in Asia with more than 90 percent of world output.Analysis of the Guinea'sfood balance sheet shows rice as the major foodproduced in the country, accounting for 61% to 69% of availablecereals.

Rice iscomposed by approximately 20% of RH, whichcontains a fibrousmaterials and silica. It isreportedthatapproximately 0,23 tons of RHisformedfromevery ton of riceproduced**[21]**. Therefore, due to its high percentage in the grain composition, the huskisconsideredas a byproduct in the mills and createsdisposal and pollution problems Itis one of the mostintractable agricultural wastesknown to man, becauseit's tough, woody and abrasive nature alongwith high silica content makesitsproperdisposalverydifficult.RHAis an industrialwasteproduced by burningricehuskprimarily for the generation of electricity, a kind of sustainablebiomassenergy. The main component of the ashissilica (90–95 wt. %), existingpredominantly in amorphous and partly in crystalline phases**.** Due to its high silicon content, RHA has become a source for preparation of elementarysilicon and a number of silicon compounds **[22]**,especiallysilica, siliconcarbide [9], Silicon and silicon compounds are utilized in semiconductors, advancedceramics, opticalfiber,

II.3. Anthill

Anthills ortemitariumare naturalclaysoilsthat are verycohesive in nature, and therefore must have a high plasticity index **[23]**.They are made up of soil grains thatare coatedwithstickyrapidlyhardeningsecretionsfrom the recta and mouths of ants

AHare built of soil and earth particles which are cemented together to form hard bricklike material which are very resistant to weathering; this mineral contains both silica and alumina. AHclay power has higher values of clay, liquidlimit, plastic limit and maximum dry densitythanlateritesoil,They are bettermaterialthan the ordinaryclay in terms of utilization for mouldinglateritic bricks **[24]**and this type of clay has been reported to performbetterthanordinaryclay in dam construction.

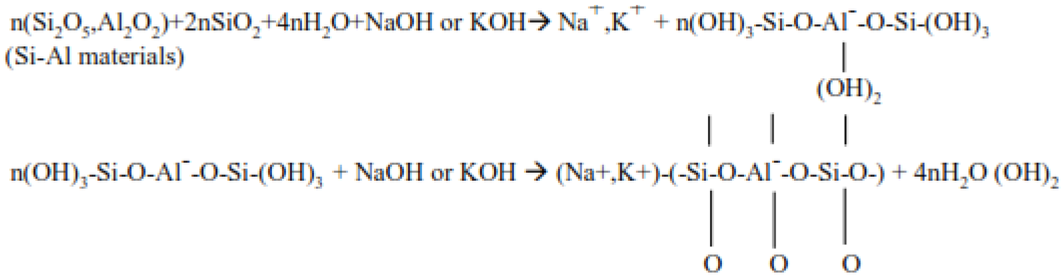
AH have been observed to endure extremely hot daytime tropical temperatures and verylow night temperatures, as well as heavy tropical rainfall.AH, beingcoatedwithstickyrapidlyhardeningsecretionsfrom the recta and mouths of ants [21], are cohesive, and an informedguesscouldbethattheycontain the samechemicals as thosefound in cement, such as calcium oxide CaO), silicondioxide (SiO2), aluminium oxide (Al2O3) and magnesium oxide (MgO) amongothers**[25].** It iswellknownthat the quantity of termite mound cannotbeenough for meaningful usage, itis good to beused as additive for other local materialsthat are available in large quantities. Therefore, thisstudyis to assess the effect of AH additive on GP characteristics.

III. GEOPOLYMERISATIONPROCESS

The polymerization process involves a substantially fastchemicalreactionunderalkaline condition on Si-Alminerals, whichresults in a three-dimensionalpolymericchain and ring structure consisting of Si-O-Al-O bonds

Mn [-(SiO2) z–AlO2]n**,**wH2O

Where: M = the alkalineelement or cation suchas potassium, sodium or calcium.The symbol**–** indicates the presence of a bond,n is the degree of polycondensation orpolymerisation; z is 1, 2,3, or higher, up to 32.
The geopolymerizationmechanisminvolves Si and Al dissolution from the startingmaterials to makeavailablepolysialateunitsexamplesialate [–Si–O–Al–O], sialatesiloxo [–Si–O–Al–O–Si–O] or sialatedisiloxo [–Si–O–Al–O–Si–O], depending on the Si/Al ratio) cross-linked [AlO4]- and [SiO4] tetrahedralunits, with charge balanceensured by Na^+ or K^+ ions. The sialateis an abbreviation for silicon-oxoaluminate.
Geopolymer isformed by the polycondensation of silica and alumina precursorwhich are reactedwith alkali to form the polymer. The key to geopolymer formation is the dissolution of silica and alumina in an alkalineenvironment, followed by reprecipitationto form an amorphoussolidpolymer. The overallreactions are representedbelow (Scheme 1 **[26]**.



$$\underset{\text{(Si-Al materials)}}{n(Si_2O_5,Al_2O_2)}+2nSiO_2+4nH_2O+NaOH \text{ or } KOH \rightarrow Na^+,K^+ + n(OH)_3\text{-Si-O-}\underset{(OH)_2}{\underset{|}{Al^-}}\text{-O-Si-}(OH)_3$$

$$n(OH)_3\text{-Si-O-}\overset{|}{Al^-}\text{-O-Si-}(OH)_3 + NaOH \text{ or } KOH \rightarrow (Na+,K+)\text{-(-}\underset{\underset{O}{|}}{Si}\text{-O-}\underset{\underset{O}{|}}{Al^-}\text{-O-}\underset{\underset{O}{|}}{Si}\text{-O-)} + 4nH_2O\ (OH)_2$$

Scheme 1. [26] : Silica and alumina dissolution process

$$\begin{array}{lr} \text{Al–Si material (s)} + \text{MOH (aq)} + \text{Na}_2\text{SiO}_3 \text{ (s or aq)} & (1) \\ \qquad\qquad\downarrow & \\ \text{Al–Si material (s)} + [\text{M}_z(\text{AlO}_2)_x(\text{SiO}_2)_y \cdot n\text{MOH} \cdot m\text{H}_2\text{O}] \text{ gel} & \\ & (2) \\ \qquad\qquad\downarrow & \\ \text{Al–Si material (s)}\ [\text{M}_a((\text{AlO}_2)_a(\text{SiO}_2)_b)n\text{MOH} \cdot m\text{H}_2\text{O}] & \\ & (3) \end{array}$$

Scheme 2. [28] : Geopolymerisation process

The scheme 2 illustrates the reactionsproposed for the polycondensation process, In the reactions (1) and (2) the amount of Al–Si materialsuseddepend on the particle size, the extent of dissolution of Al–Si materials and the concentration of the alkaline solution. The formation of [Mz(AlO2)*x*(SiO2)*y*·MOH·H2O] gel is a dominant step in the geopolymerization and essentially relies on the extent of dissolution of aluminosilicate materials (reaction 3). **[27]**.

IV. MATERIAL AND METHODS

In this study, RM, RHA and AH constitute the materials for the preparation of the geopolymer.Red mud was used as the primary source of reactive alumina, it was provided by the Alumina plant ACG/Fria in Guinea. The raw RH wasbroughtfrom a local ricemill in Sinko;Prefecture of Beyla; Guinea. It wasburned at 600°C for 1 hour,grinded for 30 minutes and thenprocessedinto RHA in the Laboratory for MaterialResearch;Polytechnic Institute, University of Conakry. Anthills were collected in savanna districts of Dinguirayeand Siguiriin Guinea. Sodium hydroxide (purityquotient: 99%, Merck KGaA, Germany), and deionized waterwerepurchasedatthe Pharmacie Centrale de Guinée in Conakry ; Guinea.RM, RHA and AH processing involves drying, crushing, grinding and determination of the chemical composition,The raw materials were initially oven dried to constant weightat 50°C during 72h to ensure that all the moisture had been removed. They were then crushed and grinded to pass a 0,30 mm meshsieveusing a pestle and mortar until a suitable ratio for coarse particles to fine particles was achieved.RM, RHA and AH as fine particles were characterized by X-ray diffraction (Shimadzu diffractometer, model XD-7A, with radiation Cu-Kα) and by scanning electron micrograph (SEM; Model 2000FX, JEOL Co). The mineral composition was determined by atomic absorption spectrometry (Analytik JENA, Vario 6, Germany). Chemical elemental analyses were performed by an energy-dispersive X-ray spectroscopy (EDXS). The mix-ratios were adapted from **[28]**wherethe specimen TGPX stands for ternarygeopolymer and x for the mix ratio as shows table 1.

Table 1: raw materials entering in the specimens amount (w %)

Specimen	Proportion (%)		
TGPx	RM	RHA	AH
TGP1	100	0	0
TGP2	0	100	0
TGP3	0	0	100
TGP4	50	50	0
TGP5	50	0	50
TGP6	0	50	50
TGP7	66	17	17
TGP8	17	66	17
TGP9	17	17	66
TGP10	33,3	33,3	33,3

For the mixture design, 3 replicates of eachspecimenwereprepared.

The10 molarNaOH solutionas alkali activatorwasadded at 20% by weight of dry materialsto the powder mixture, The mixing of the blends was carried out by Heidolph ST-1 Laboratory stirrer at two different speeds; 100 rpm for 2 min and 200 rpm for 15 min to insure their homogeneity and avoid bubbles and agglomeration into the sample and to make certain the reaction between the powder and NaOH solution, resulting in the formation of a product having a paste consistency.

The resulting products were immediately poured into cubic molds 50x50x50 mm and left at room temperature. Curing was carried out by keeping the geopolymer specimensduring 28 days in a laboratory ambient; the specimens were then demolded.

The compressive strength of the synthetized RM-RHA-AH presumed geopolymer materials were tested on a testing machine The compressive strengthwasmeasured on a Shimazduapparatus (Model: AG-X/R Refresh). The water absorption test wasalsoperformedafter the ASTM C140.

V. RESULTS AND DISCUSSION

Chemical composition of RM, RH, RHA and AH

The grinded and sieved RM, RHA and AH subjected to characterizationbeforemixing, arepresented in Fig.4a ; b and c relatively. The mehanicalprocessing of the materialintofinestparticlesdid not affect theircolor.

Fig.4 : a) GrindedRMb) RHAc) AH

The analysis shows severalminerals in parent materialssuch as Al2O3, SiO2, Fe2O3, Na2O, K2O, CaO, TiO2 and others (tabable2).Substantialquantities of Al2O3 and SiO2 as monomersrequired for the building of GP are present.

Table 2 : Chemical composition of RM, RH, RHA and AH

Raw Material	Al2O3	SiO2	Fe2O3	Na2O	K2O	CaO	TiO2	Others	LOI
RM	18,98	4,52	49,90	2,60	0,05	0,87	5,62	0,94	16,52
RH	0,06	23,77	0,13	-	1,08	0,25	-	0,81	78
RHA	1,12	90,90	0,54	-	4,66	1,41	-	0,60	0,77
AH	11,75	65,14	5,67	0,31	2,15	1,1	1,51	2,73	9,64

As main constituent of RHA and AH, SiO2 contributesmuch to the formation of the skeletal structure of GP. The figure 5below shows itspredominance in RH and AH ; 90% and 65,14% respectively. While the Fe2O3isrelatively high in RM and AH. The high LOI of RM and AH due to the burning of organiccompound, maycontribute to the formation of pores in the presumed GP specimens.

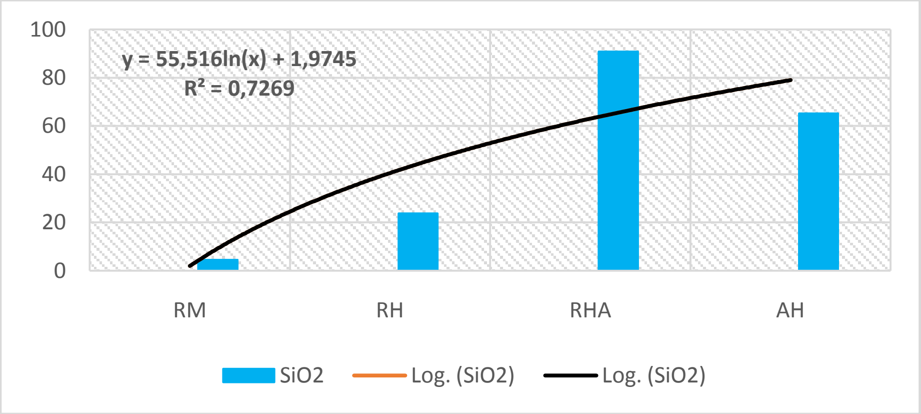


Fig.5: The silica content in parent materials

V.1. Microstructure of parent materials

RM

The XRD diagram (Fig.6) below shows someunidentifiedpeaks and a few sharppeaksthat are mainlyfromhematite and calcite, but no observable broadhumps, suggestingthat the amorphous phases are not present at large quantity.

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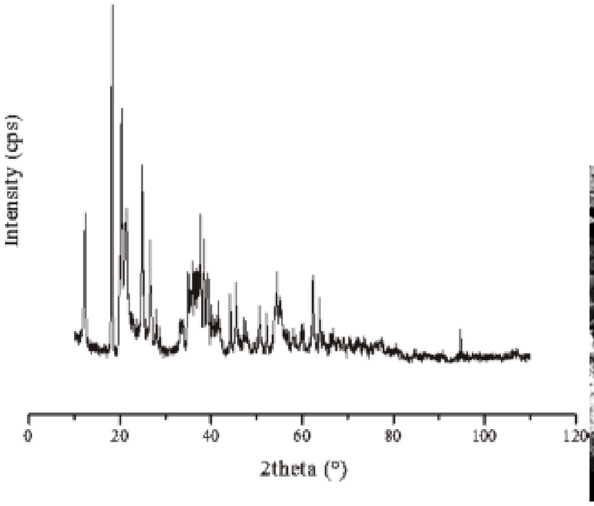


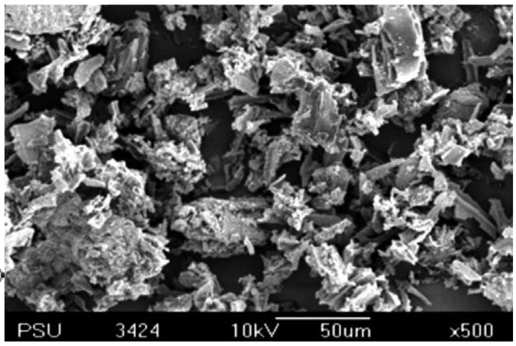


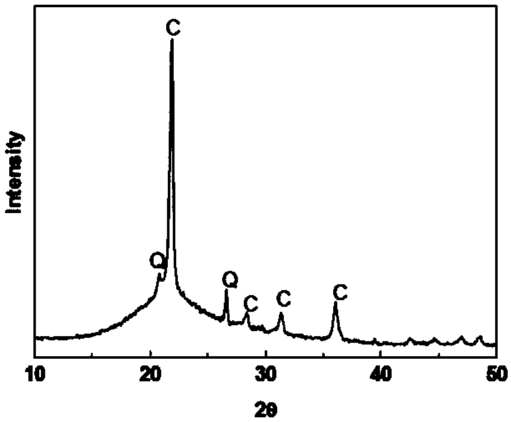
Fig.6. XRDiffractogram of rawRM **Fig.7.** SEM micrograph of raw RM

RM contains mainly hematite (Fe2O3), diaspore (AlO(OH)), gibbsite (Al(OH)3), calcite (CaCO3), quartz (SiO2), anatase (TiO2), and goethite (FeOOH). By comparisonwithitschemical composition (table 1), alumina mainlypresents as amorphousphases. Thus RM providesmainly Al (in the form of amorphous Al2O3 or dissolved NaAlO2) and NaOH but little Si to geopolymerization **[29]**.

The SEM micrographs of raw red mud (Fig.7) have a rough surface, different shapes, and different particle sizes. It has relativelyporous microstructure with the presence of dispersedparticles. The micrographs shows that the particles of the raw RM were roughly crystallized and the hematite was detected in the form of aggregates.

RHA

The RHA X-ray diagram (Fig,8) indicatesthatitisformed by silica in the crystallineform, resultingfrom the predominantpresence of cristobalite (2θ =21,9)**[30]**.Bothforms: crystalline and amorphoussilica are governedby the burningtemperature,RHA shows 2 huge and broadhumps at 5-15 and 15-30°2θ, respectively, indicating the presence of amorphous phases. A few sharppeaksalsoindicate the presence of crystalline phases such as quartz and carbon, By comparisonwithitschemical composition (table 2), silica in RHA are present as bothamorphous and crystalline (quartz) phases.Furthermore, the overwhelmingmajority of silicais in amorphousform, whichagreeswith the previousstudies.



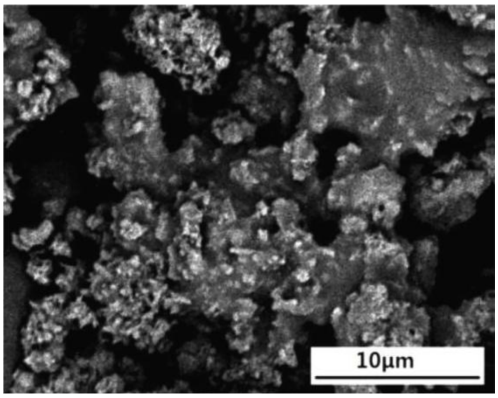


Fig.8. XRDiffractogram of RHA Fig.9. SEM micrograph of RHA

The micrograph of RHA (Fig.9.) shows a porous and multifacetedparticleshape and size. The foremostconstituents of ricehusk comprise hydratedsilica, cellulose and hemi cellulose component totaling a 55–60% and lignin component of approximately 22%. The porous and honeycombmorphologyseen can becredited to the burning out of theorganic component in the ricehuskduring combustion, The hydratedsilicaafterwardpolymerizes to form a skeletalsilica.

AH

Fig.10 represents the XRD diagramof an anthill soil.The qualitative analysis of the AH as depicted by the XRD pattern shows sharp high peaks for SiO_2, Al_2O_3, Fe_3O_4 andsharp but shorter peaks for K_2O, MgO, MnO, Na_2O and CaO. The peaksindicatethat the samplescontainmainlysilica and aluminosilicate phases. Someother oxides werealsopresent but in verynegligible proportions.
The SEM image of the AH ispresented in Fig.10. The micrographrevealedthat the particlesthat made up the materialagglomeratedtogether on its rough surface.

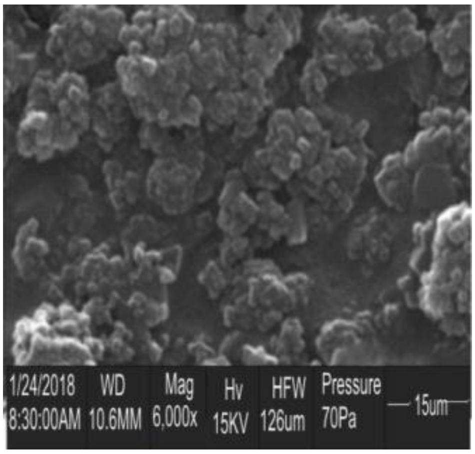


Fig.10. SEM micrograph of AH

V.2. Properties of the GP specimens
There are actually four parent materialsinvolved in the synthesis of RM-RHA-AH basedgeopolymers: RM, RHA, AH and sodium hydroxide solution. As show XRD and SEM characterisation, onlyamorphous phases in rawmaterialsparticipate in geopolymerizationreaction, Among the three parent materials, RM provides Al_2O_3, NaOH and $NaAlO_2$; RHA providesamorphous SiO_2; AH procvides SiO_2 and Al_2O_3; while the sodium hydroxide solution providesNaOH.
To facilitate the interpretation of the results, itshouldbenotedthat TGP1, TGP2 and TGP3 are respectively parent materials RM, RHA and AH not mixed withothers.The cubic GP specimensafter 28 dayscuringat ambient laboratorytemperatureare pressent in Fig.11 below. The predominentcoloristhatfrom RM.

Fig.11 : GP specimensafter 28 dayscuring

Figure 12shows the SEM micrograph of 33,33-33-33,33RM-RHA-AH geopolymer. The SEM analysis illustrates the finest contours and surfaces indicative of the extent of dissolution and polycondensation that occurred during geopolymerization for this mixture. The micrographrevealedlessnumber of unreactedparticles and the matrices appearedenoughdense.Thesampleswerepreparedwithrelatively high NaOHmolarity This is in line with the earlier report whichindicatedthat the use of solution with high molaritycouldaccelerate the geopolymerization process **[31]**.

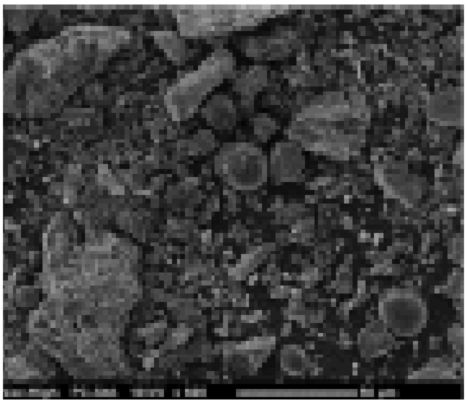


Fig.12. SEM micrographRM-RHA-AH

The experimental test done one the presumed GP specimens are presentedon fig.13 and fig.14

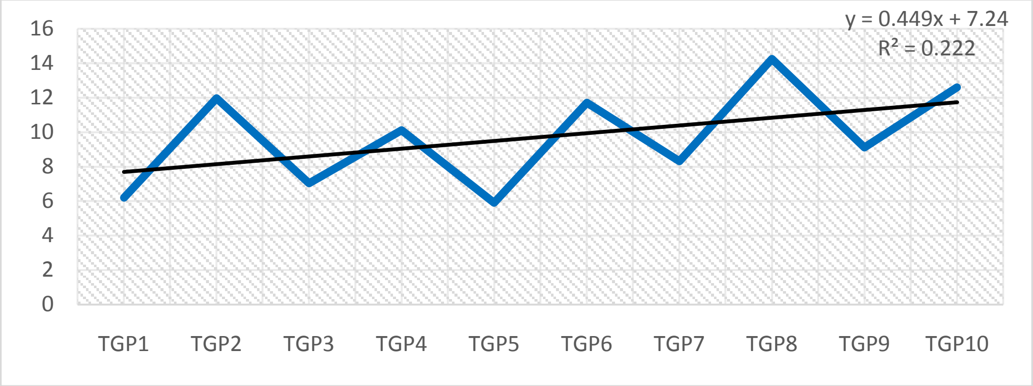


Fig.13: Compressive strengh (MPa; 28 days**)**

The 28-day compressive strength of the specimens range from 5,89 to 14,25 MPa, Specimens TGP8 and TGP10 corresponding to RM-RHA-AH mix ratios of 17-66-17 and 33,3-33,3-33,3 respectivelywereabove 11,7 MPa, i.e. the ASTM C55 prescribedstrength standards for the concrete brick. Amoung the 10 (ten) specimens, 4 areconform to the above standards. They are characterized by a high content of SiO2 in 2 parentmaterials RHA and AH. It maybethoughtthat the presence of SiO2 is the predominant factor whichcontributes to the resistance of the GP to compression.

With regard to water absorption, the TGP8 specimen has the lowest value (165 kg/m3)whereas TGP9 has the highest value (387 kg/m3).However, the water absorption values of the geopolymerwereenoughlowerthan 288 kg/m3 whichis the prescribedlimitaccording to ASTM C55 requirements for lightweightconcrete brick material. TGP2=RHA.

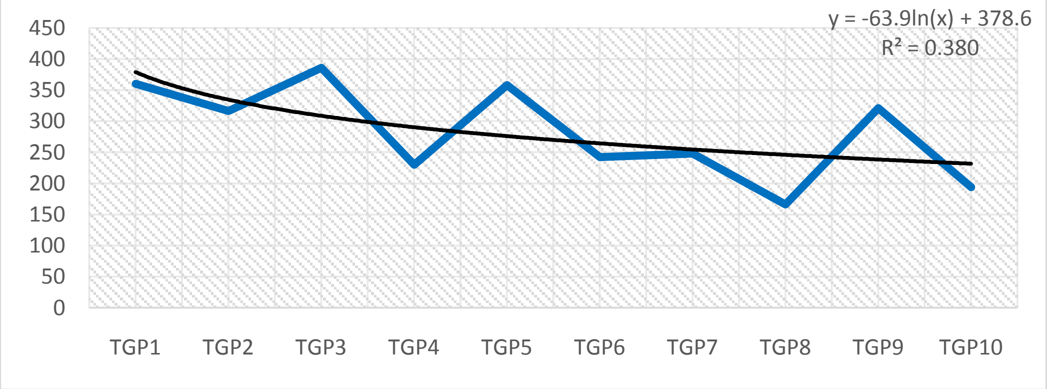


Fig. 14: Water absorption (kg/m3)

VI. CONCLUSION

The centralpurpose of thisstudyis to point out that an industrialwaste can beturnedto rawmaterial or valuableintermediate. The main ideawas to mitigate the environmentalconcernraised by dumping of the plentifulindustrialwastes as land fillers. Thus, the management of the RM resultingfrom the conversion of the enormous bauxite reservesmaybecome a sustainableindustrialopportunity. In thisstudy, with the additionalaim of including all threeparentmaterials, a ternaryblendof0-50-50; 17-66-17 and33,33-33,33-33,33 respectivelyby mass ratio of RM-RHA-AHwasdevelopedthatwas able to meet the requirements of the target application. These GP materialsshowed a water absorption lowerthan288 kg/m^{3}the prescribedlimitaccording to ASTMC55. In addition, the incineration of RH to produceenergy and the use of the resulting RHA product as cementitiousmaterial, contribute to recyclingaccording to the zerowasteprinciple.The high content of SiO2 and in AH coulddraw attention to thisnaturalresource for itssustainablevalorization.

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