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PHYSICAL CHARACTERIZATION OF COMPOSITE MATERIALS BASED ON PLASTIC WASTE (POLYETHYLENE TEREPHTHALATE) AND SAND

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ABSTRACT
Faced with the growing need for construction material resources as well as the concern maintaining a safe environment for durable development, it is necessary to study the re-use and valorization of waste in general and industrial by products in particular in the field of civil engineering. Recently there has been growing interest in plastic waste for using concrete, paving stones and tiles. To study the influence of the content of plastic on the physical parameters, seven classes were selected in the interval 20% to 50% (in weight) in step of 5 for the manufacture of materials and three sand granulometries 1.2, and 3.15mm.The determination of the density and porosity is made according to the NF ISO 5017 standard.The results obtained show that, the materials obtained have a maximum density of 1900 kg/m^3 lower than that of cementing materials (2000-2400 kg/m^3), this density varies according to the mass proportion of plastic. Thepermeability and porosity are at the same time functions of granulometry and of the mass of the plastic, the materials obtained between 40% and plastic 50% have a permeability and almost null porosity. The results of porosity obtained are lower than 5%, and vary between (3.8% and 0.05%) compared to the Portland cement material which have a porosity higher than 10%.The analysis of the influence of porosity on the density shows that, the density is proportional to porosity.In the same way the color of these materials varies proportionally with respect to the proportions of plastic and this color is strongly influenced by the parameter L which is brightness. For texture, it arises that the materials are rough when contrast and entropy are raised and when these parameters drop they become smooth.

KEYWORDS:

I. INTRODUCTION
For more than three decades, plastic waste has represented a significant share of municipal solid wastes Yazoghli-Marzoukand al.(2007). Thus, plastic waste management has become a major preoccupation considering their life span and also they are visible waste. Their management is thus necessary, that is from environmental, economic or social point of view. The first processes set up to treat these waste were the land filling (burying) and the incineration. However, the exponential growth of the use of plastic in human activities urged to imagine other sectors of recycling. Considerable work has been done in various countries for the disposal of some of these waste products and utilization of some other products and there is a long list of published papers dealing with different aspects of these challenging problems (Konin 2011). Taking into account that concrete will continue to be the main construction material in the future, several research projects have showed that it was possible to use plastic waste in concrete (Rebeiz and Craft, 1995, Sam and Tam, 2002, Turatsinze et al., 2005). Plastic waste recycling in construction follows manyways:

In the first way, most studies have been able to demonstrate that plastic waste can be used as a supplement to aggregates. In any case, the results show that the inclusion of plastic waste eliminates the shrinkage cracking of concrete and reduces the drying shrinkage to some extent (Albano et al., 2005, Turatsinze et al., 2005,Yazoghli-Marzouketal.,2007).

Yazoghli-Marzouk*et al*., (2007) have reported that when the percentage of plastic waste volume in concrete is below 50%, the compressive and flexural strength of concrete are not affected. In the same way it has, shown that the flow ability and thermal conductivity of mortar containing plastic waste as light aggregates are

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improved. Besides, Sam and Tam (2002) showed that the use of PET waste as a binder obtained from a chemical reaction to produce polymer concrete gave a material with better compressive and flexural strength than cement Portlandconcrete.

In the second way, plastic waste is used as modifier of bitumen to improve some of bitumen properties (Hinislioglu*et al.*,2004, Yildrim, 2007). These researchershave reported that the use of modified bitumen with the addition of processed plastic about 8% by weight of bitumen, helps to substantially improve the Marshall stability, fatigue life and other desirable properties of bituminous mixtures. Therefore, the life span of the pavement surfacing course using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.In factthe valorizationmethods of those waste, are not yet satisfactory because of their exponential increase in our cities. For that,most African countries, are testing an interesting procedure: the CERVALD procedure; initiated in 1998 in Tchad, this procedure has permitted to demonstrate that it is possible to transform waste by fusion, with the addition of sand, into diverse products of excellent quality, like traffic sign, pavements and tiles (Doublier*et al.,* 2009). The works realized by Konin (2011) have shown that using PE, PET and PP plastic wastes in proportions from 20% to 50% givematerials with high resistance to abrasion and slipping are obtained. These materials have porosities reduced by 5% with resistance to attraction of the same order as cement materials. The works of Doublier*et al.,* (2009), the effect of using flexible plastic waste instead of cement on the properties such as the breaking load, the compressive strength and punching, while varying the nature of sand, plastic the nature and sand/plastic mass ratios. At the end of these tests carried out, it was seen that materials with 40% and 50% plastic have better properties. With respect to all these studies, the impact of these processes on the environment has not been taken into account, thus the main objective of this study.

In this work we carry out the physical characterization of sand and plastics wastes materials packing out of polyethylene terephthalate with sand. The impact of the plastic/sand proportion and that of granulometry on these physical characteristics of materials are evaluated and analyzed.

II. MATERIAL AND METHODS

1. Material

The principal material used in this study is made of the samples manufactured according to the process presented by Edoun*et al*, 2014.This process is carried out starting from the proportions as presented by table 1 in methods part. Three sand granulometries are used in this work according to 1mm; 2 mm;and 3.15 mm. The samples used, contain plastic waste (PET) and sand whose characteristics are presented below.

Plastic wastes

Plastic waste used in this work are of type polyethylene terephthalate. These plastics are obtained from bottles of mineral water and juice bottles collected in the streets of the locality of Ngaoundéré sorted, cut out washed and dried.The mechanical and thermal characteristics of the plastics used are:the rate of absorption 0.016 %;breaking strength 42 MPa;density 1395 Kg/m^3;latent heat of fusion 115 J/g;mass heat capacity 1090 J/Kg°C and the melting point 250°C.

Image and texture study apparatus

It consists of one enlightened limps and of adigital camera of Fujifilm mark HS10.The acquisition limpsis a cube of edge 400mm, 4 fluorescent lamps to light the interior.The interior walls are covered with blank paper to homogenize lighting inside limps (Boukar, 2015).

2. Methods

Samples fabrication

The material samples which were used for the physical characterization in this work, come from seven ratios of plastic/sand mixture (table 1).For granulometry, three sieves were superimposed during sifting, and for 3.15mm one retained all the grains that crossed the sieve of 3.15mm and that was retained with the sieve of 2mm, one made in the same way for 2mm and for 1mm one retained all those that crossed the sieve of mesh 1mm. The material samples that were used for the physical characterization in this work, come from seven ratios of the plastic/sand mixtures like figure1 (b), and table 1 presents the different compositions of samples.

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Tableau 1 : Experimental Protocol

Plastic/Sand ratio (%)	50/50	45/55	40/60	35/65	30/70	25/75	20/80
Plasticquantity (PET) en g	400	360	320	280	240	200	160
Stream sand quantity filtered (g)	400	440	480	520	560	600	640

Seven compositions were studied. For plastic waste compositions, the experimental procedure adopted is detailed in Edoun*et al.*, 2014. This procedure is as follow:

1. Weighing of sand and plasticswastes,
2. Heating of plastic and progressive addition of sand. Mixture must be combined vigorously to be homogeneous. The melting point depends on plastic type,
3. Molding of samples

After their withdrawing from the mould, plastic/sand composite samplesare kept in ambient air until the day of the tests. For each ratio we produced 3 samples for the repetition of the tests.

Image and texture study

The study and the analysis of the color and the texture of the samples are carried out under ImageJ using extensions (plugins) conceived in language JAVA.ImageJ is a free software written in JAVA language making it possible to treat and analyze images in 2D or 3D. It offers many functionalities which one can supplement by the means of macros or of plugins.For each percentage of plastic three samples were used, for the total color it is given according to the relation (1) where**a** is the difference in color between the green and the red, **b** the difference in color between blue and the yellow and **L** is brightness.

$$E = \sqrt{a^2 + b^2 + L^2} \qquad (1)$$

Density

According to the NF ISO 5017 standard of 2013 density is obtained by measuring the displacement of the liquid using a spade graduated in ml. For that, the volume of water is noted, the sample is placed on it and the new volume is noted. The volume of the sample is the difference between the final and the initial volume of water in the spade.

Rate of absorption of water (porosity to water)

It consists of taking the weight of the sample (M_i) followed by its immersion in a bowl of water of 20±2°C over a minimum of 48hours and until a constant humid mass is obtained (M_h). Before weighing, it is wiped dry to eliminate surface water, then a desiccation of atleast 72 h is done until its dry mass (M_s) is obtainedin a drying cupboard at a constant temperature of 105±3°C according to Pinot (2015) and standard NF ISO 5017. The weight is considered constant when two successive weighings within 24hours do not give a weight difference of more than 0.1%(Ployaert, 2009).Water absorption is expressed in percentage of dried mass and calculated using the following relation:

$$p(\%) = \frac{Mi - Ms}{Mh - Mi} \times 100 \qquad (2)$$

Permeability of water

To calculate the permeability of our material, we assume that:

- We have done piling;
- We are dealing with a set of canals (set of pore linked in form of canals). That is to say that we have a capillary model;
- We have a streamline flow or are following Darcy's law

$$\upsilon = K\frac{(-\Delta P)}{L} \qquad (3)$$

With:
υ = Flow (m^3/s);
K = Coefficient of permeability of Darcy = permeability;
L = height of the sample (m);
ΔP = variation of the volume of water in the tube (m^3)

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With these assumptions, we can calculate the permeability which is the ability of a material to let a fluid go through it (Ibarzand Gustavo, 2003). Thus, Kozeny Carman described a law that links porosity to permeabilityas follows:

$$\frac{1}{\alpha} = \frac{1}{K''} \frac{\varepsilon^3}{(1-\varepsilon)^2 (a_{so})^2} \quad (4)$$

With:
α = permeability (m^{-2});
K''= 5 ± 0.5 (constant of Kozeny) ;
ε = porosity;
a_{so} = specific surface of the bed = surface of the bed/volume of the bed (m^{-1})

III. RESULTS AND DISCUSSIONS

1. Samples manufactured

Figure 1 presents pictures of the samples manufactured during this work. The long cylindrical ones have as dimensions 100 mm x 22 mm, and are conceived for mechanical characterization. Figure 1b presents short cylindrical samples of dimension 54 mm x 22 mm for physicochemical characterization while in thoseform of parallelepiped infigure 1 © are for thermo-physical parameters.

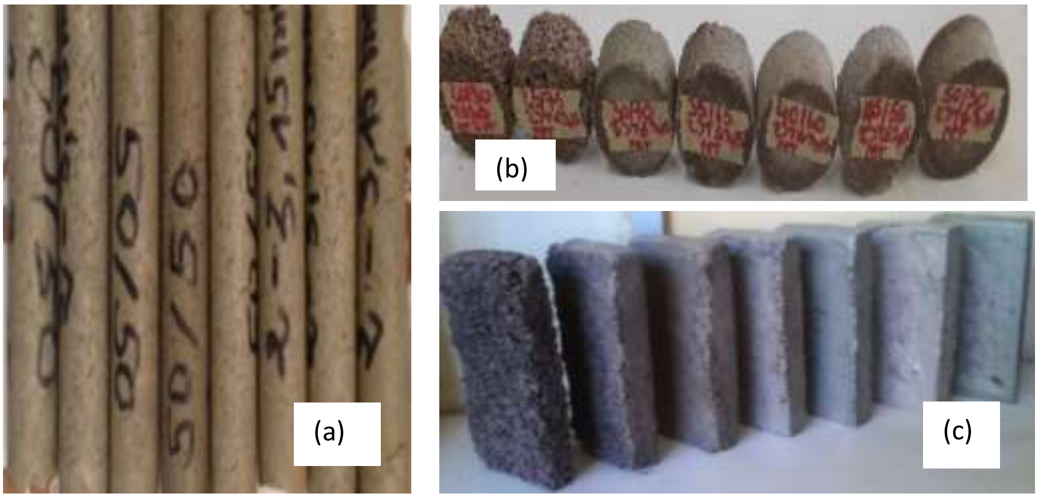

Figure 1: Sample (a) of long cylindrical form, (b) of short cylindrical form, (c) of prismatic form for sand whose granulometry is between 2 and 3.15 mm.

The difference of color and texture observed on figure 1 will be justified and analyzed in the continuation of this work

2. Influence of plastic percentage on the texture and the color of the samples

The study of the color parameters on ImageJ and the application of formula (1) give the values of table 2.The parameters presented in table 2 and figures 1(b) and 1(c) present a variation of the color of samples according to the mix design. For small proportions of plastic, the sample appears darker, there is the value of the total lowest color and it cleared up as the quantity of plastic increases in the mixture.This explanation is with the color of the plastic chosen for this study.Contrary to waste out of polyethylene and polypropylene or the mixture some is the proportions of sand or of the plastic, the color of material remains black, one obtains materials with colors which tend more to those of materials with cement.

Table2 : Variation of the color parameters and total color

Sample	Average (L)	Average (a)	Average (b)	Chroma Average	Hue Average	Totale color
P20	56.89	6.274	8.524	10.584	53.643	57.366
P25	58.310	4.542	6.588	8.002	55.417	58.838
P30	60.531	0.205	1.623	1.635	82.799	60.553
P35	62.909	-0.141	1.423	1.430	95.657	62.926
P40	65.954	-1.828	4.868	5.200	110.583	65.156
P45	67.690	-0.214	0.924	0.948	103.023	67.696
P50	68.476	-0.133	2.824	2.827	92.703	68.534

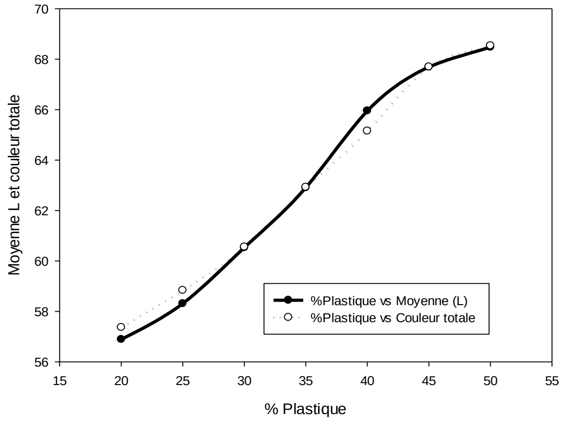

Figure2: Variation of the L (brightness) averageand the total color

Figure 2 presents the evolution of brightness and the total color of sampleswith respect to the content of plastic. It is noted that brightness and the color are proportional to the content of plastic.Indeed the plastic used,PET, has a higher brightness than sand, this is why its increase in proportion in the material brings about a rise in brightness.In this same light, the plastic having a color which tendstowards white goes also entail a rise in the color of the material.It is also notes that, when the parameters **a**and**b**have low values, the color tends to follow the variation of brightness.

The study of the texture gave the results presented in table 3

Tableau 3:Variation of texture parameters of material

Samples	Angle of second moment	Contrast	Correlation	Difference in moment opposite	Entropy	Summon
P20	0.0005	68.125	0.0010	0.203	8.148	1
P25	0.00016	48.250	0.0019	0.203	7.362	1
P30	0.0023	31.056	0.0027	0.365	6.910	1
P35	0.0030	25.998	0.0033	0.423	6.570	1
P40	0.0033	22.686	0.0035	0.430	6.469	1
P45	0.0036	21.278	0.0038	0.438	6.413	1
P50	0.0037	20.479	0.0041	0.435	6.369	1

From the parameters of table3 the variation and the significance of those parameters are studied on figures 3, 4, 5 and 6 below.These figures will make it possible to have a good knowledge on the texture of the samples on which the study is carried out.

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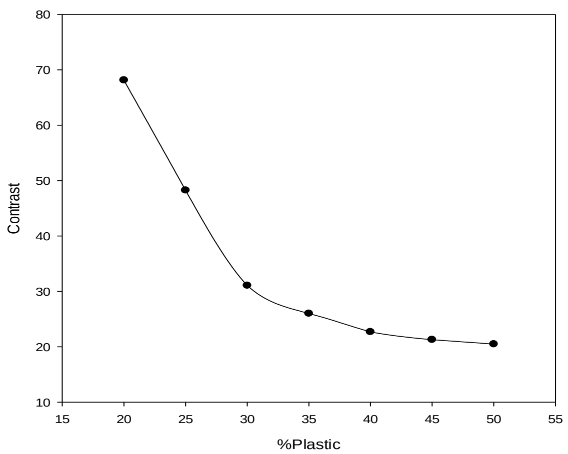

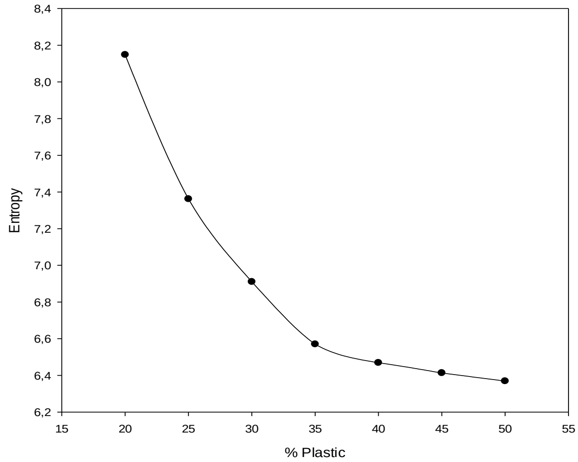

Figure 3: Contrast variationFigure 4: Entropy variation

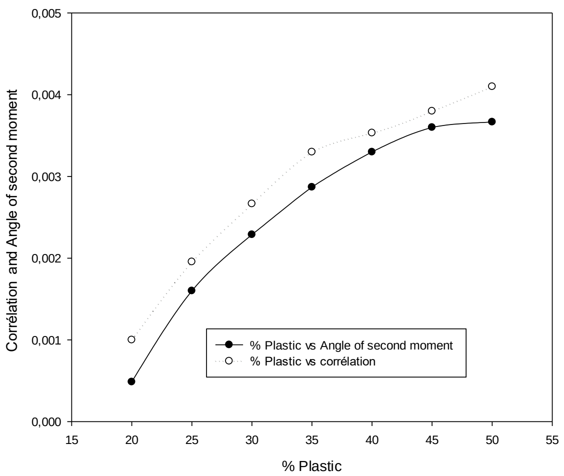

Figure 5: Correlation and angle of second moment variation

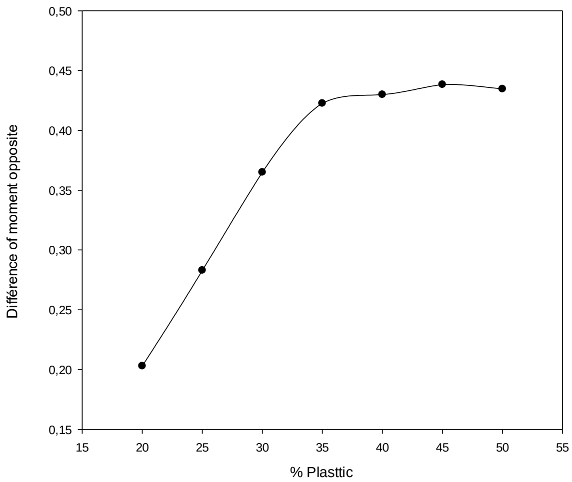

Figure 6 : Difference moment opposite variation

The results presented by figures 3 and 4 highlight the evolution of the texture parameters which are contrast and the entropy with respect to the plasticpercentage. It comes out from these figures that contrast and the entropy are inversely proportional to the percentage of plastic.Indeed contrast here informs about the homogeneity. When it is high the material is less homogenous, formless entropy about the direction of the disorder in material. When the entropy is high the disorder is also high in material. For these two first figures one can say that contrast and entropy are related to porosity but when the material is not very homogeneous, it consists of many vacuums which make material porous and when the percentage of plastic increases empty spaces are filled and the material becomes more homogeneous and smooth.Figures 5 and 6 have the results of three other parameters of texture, it acts of the correlation, the angle of second moment and the difference in opposite moment.It is noted that these parameters are proportional to the percentage of plastic. The correlation describes the bonds in material, when it is high that informs about more bonds between the components of material. The angle of second moment describes the periodicity of the reasons in material, the low values of this parameter show that the material does not have a periodic reason. The difference in opposite moment presents the orientation in texture, when this parameter is raised, the texture of the material has a privilege orientation.Indeed the low values of the correlation, the angle of second moment and the difference in opposite moment allow to conclude that this material has a no periodic texture and without orientation. Physically when the material has a raised entropy and such a high contrast, it is rough and when these parameters decrease it becomes smooth

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3. Influence of plastic percentage on the density

Plastic waste and sand used in this study have very different densitiesit is thus judicious to follow the evolution of the densities of the test-tubes obtained in this study.The results obtained with the 1mm sand granulometry are represented on the figure7. It arises that, the values of density are different according to the percentage from plastic. The values of these densities decrease when the content of plastics increases.

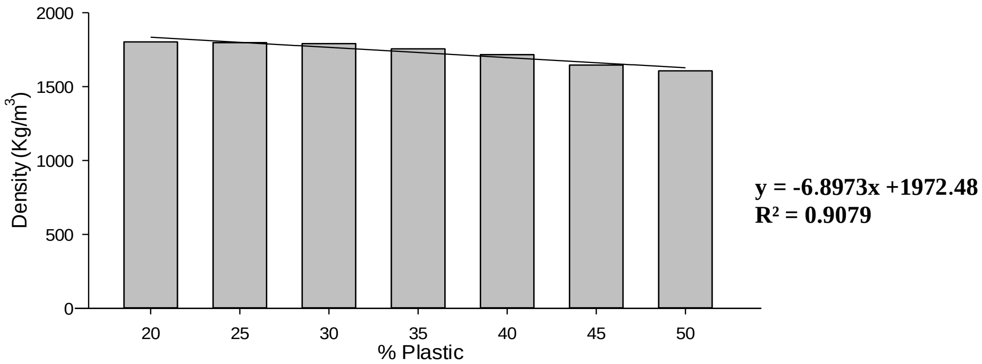

Figure7:Density of plastic/sand concrete sample of 1mm granulometry

The results presented in figure 7 show that the density follows a linear model which has a coefficient of regression of 0.9079 close equation (1). For the continuationof this work we used linear granulometry and the regression coefficients which are as follows for 2mm, Y = -7.4915x + 2044.3423 and R^2 = 0.9726;for 3.15mm there are Y = -4.6431x + 1883.2940 and R^2 = 0.978.

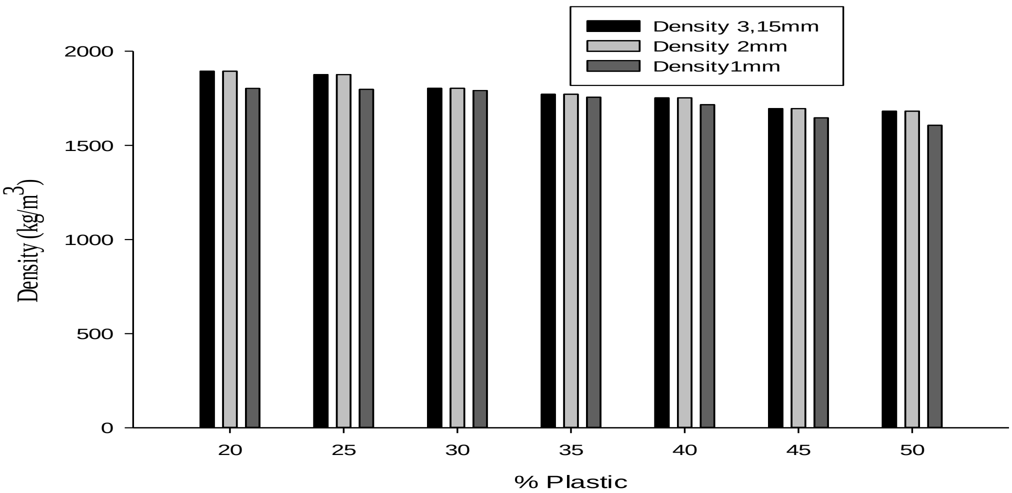

Figure 8: Influence of sand granulometry and percentage of plastic on the density of the samples

The experimental results presented by figure8show that there are weak variations of densities of the composites for the rates of substitution studied. Also, all these densities follow a linear law whose regression R^2 is situated between 0.907 and 0.978. The density of PET granules being much inferior to that of sand, a volume substitution of 50% is supposed to reduce the density of the composite concrete. Although the variations are not the same for each content according to granulometry in the densities, it arises that they all are lower than the value of cementing materials in Cameroon whose values are between 2000 and 2400 kg/m^3 (Meukam, 2004).View all the values of density which are found, it arises that, one of the aspects of valorization of plastic waste in building materials is checked with knowing lightness.

4. Porosity to water

Figure 9 has porosity according to the percentage of plastic waste (PET) and sand granulometry which were used to know 1mm, 2mm and 3.15mm.

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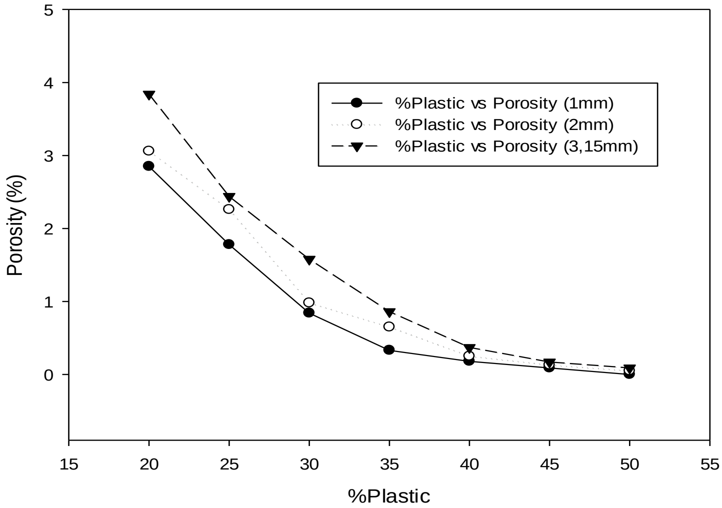

Figure 9: Porosity to water

Studies on the porosity to water show that it reduces with the increase in the percentage of plastic wastes (PET). Indeed sand has a high porosity relative to that of the plastic. This is why the addition of the percentage of plastic makes the value of this porosity to fall.These results show that all the composite material samples made from PET plastic wastes that have been analyzed have low water porosity values less than 5% that vary between 3.8 and 0.05% compared to cement materials that have porosity values higher than 10% (Konin, 2011). With respect to the shape of the curve, it was noticed that analyzing samples with 55/45 and 50/55, lower values are obtained (close to null). In a general manner, plastics are made up of macromolecules linked to each other by intermolecular and intra-molecular bonds. This makes any construction material made with plastic used as a binding medium to have a very low capacity of water absorption. From the above three curves, we can conclude that the rate of porosity to water depends on the sand granulometry but is also in relation to the plastic/sand ratio. It is also seen that the small sand granulometry has the tendency to reduce the rate of porosity.

5. Permeability to water

Figure 10 presents, the permeability to water according to the percentage of plastic waste (PET) and from the sand granulometry used knowing 1mm, 2mm and 3.15mm. Of this figure it arises that the permeability is inversely proportional to the percentage of plastic and it varies from 460 X 10^5 m^2 to 0.

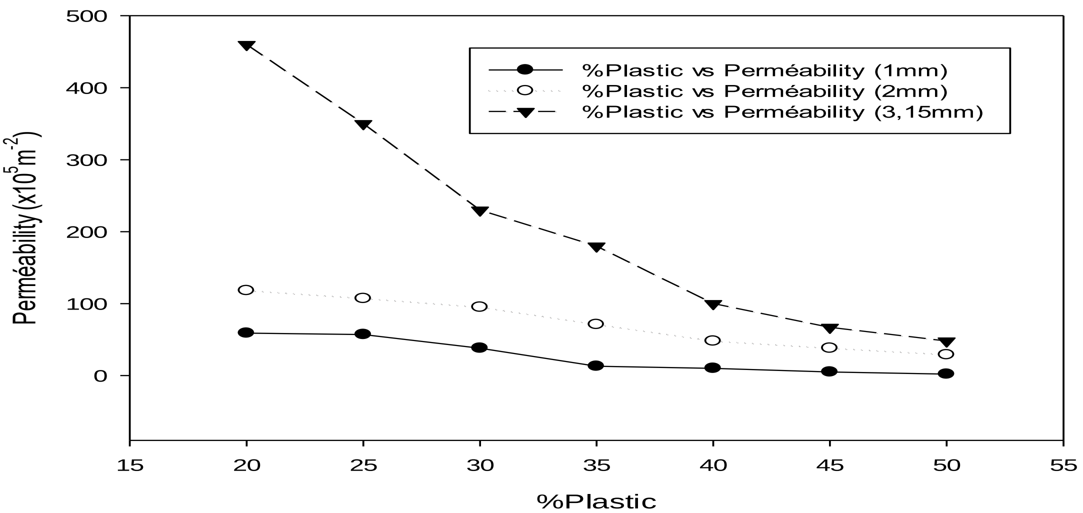

Figure 10: Permeability to water

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Figure 10, presents that, the various curves of permeability have the same pace. The permeability decreases, when size of the grains decreases. That can be explained by the presence of the significant vacuums between the grains for the tight size range and the little of vacuums existing for the spread out size range whose majority of the vacuums are occupied by fines. From these three curves, we can conclude that the permeability depends not only on the sand granulometry but also of the ratio plastic/sand. We also perceive that low sand granulometry tend to reduce the permeability to water. These materials, having a good permeability can be used like tile for construction and one can also use them for the comfort of buildings

6. Influence of porosity on the density

Figure11 shows that the densityis a function of porosity because when it increases, the density increases as well. This is explained because materials with high porosity are those with low percentages of plastic hence their high density.

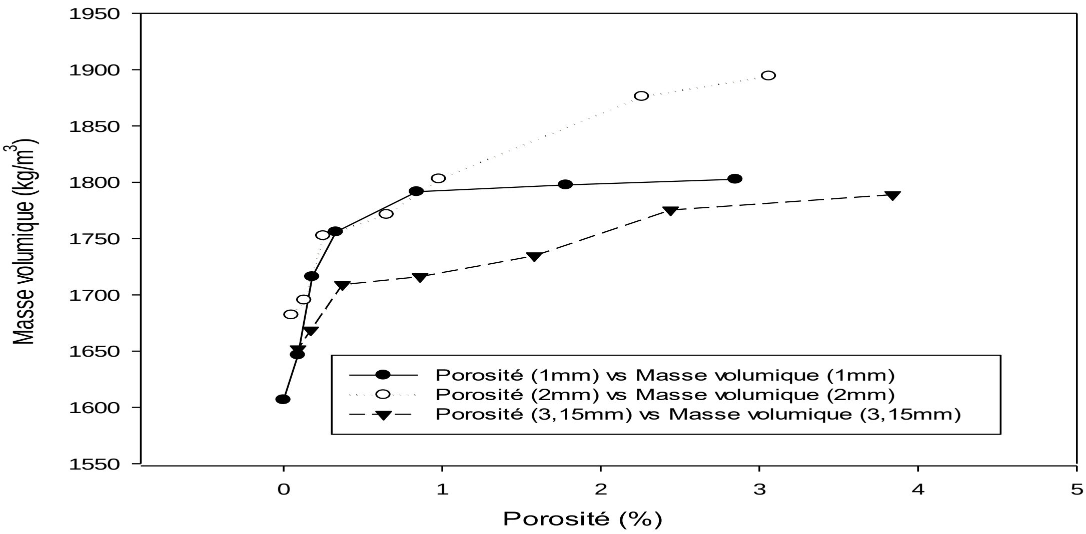

Figure 11: Influence of the porosity on the density

Figure 11 presented above, shows that the materials which have a low porosity are also those which have a low density. Indeed when the percentage of plastic increases in materials empty spaces between sand grains are filled by the plastic. On the other hand when the percentage of plastic drops we have more empty spaces in material and these spaces are occupied by air. This should lead to the fall of the density which is not the case, because it increases rather because of the high percentage of sand which consequently increases the density.

7. Influence of permeability on the density

Figure 12 shows that the density is a function of the permeability, because when it increases the density increases too.This is explained because the materials having a great permeability are those which have a small percentage of plastic therefore high density.

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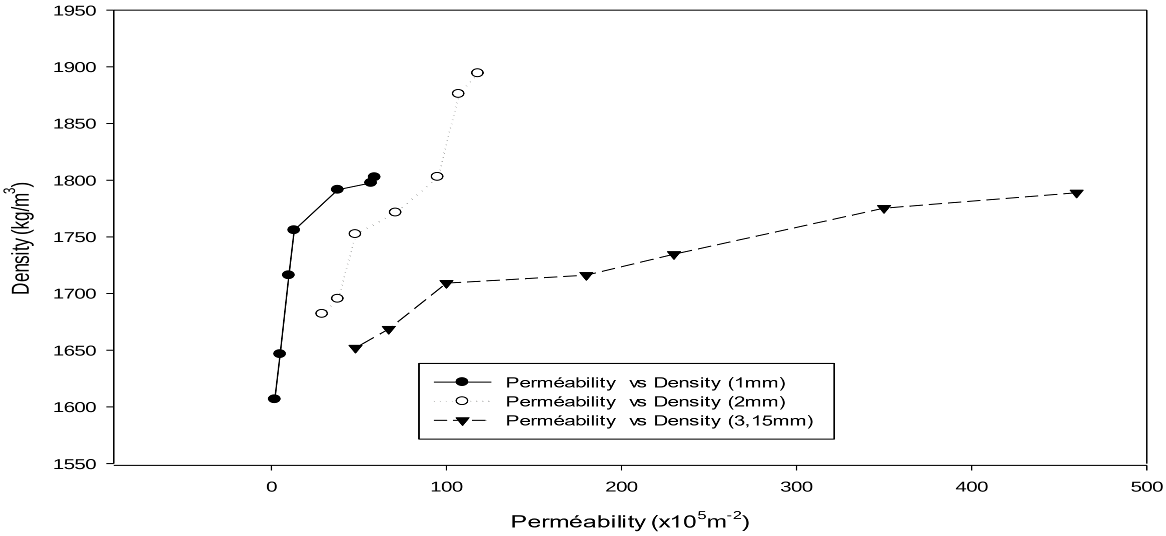

Figure 12: Influence of the permeability on the density

Figure 12, as the preceding figure, shows that the materials that have a low permeability are also those that have a low density. Indeed in this study we found that permeability's are connected to porosity by the law of Kozeny from where the conclusion drawn on porosity are valid for the permeability

IV. CONCLUSION

This work made it possible to study experiments using the color, texture, the density, porosity and the permeability of the mixtures correspond respectively to the contents of 20%, 25%, 30%, 35%, 40%, 45% and 50% in plastic aggregate mass.The samples used were manufactured starting from three sand granulometry. The principal observations to retain from the series of tests carried out on the various mixtures are:

- The experimental results show that the total color of the samples is located between 57 and 69 and this color is proportional to the content of plastic. In the same way the parameters of texture, contrast and the entropy are inversely proportional to the percentage of plastic whereas the angle of second moment, the correlation and the difference in reversemoment are proportional to the content of plastic. These results show that roughness is inversely proportional to the content of plastic.
- Other share, the results of the density show that it decreases with the increase in the content of plastic, this reduction is about 10,9% for sand 1mm granulometry;11.2% for the granulometry of 2mm and 7.6% for the granulometry of 3.15mm.The density of the aggregates of PET being much lower than that of sand, a voluminal substitution of 50% should decrease the density of the composite. For that it is possible to say that the use of plastic waste (PET) in the manufacture of composite materials gives materials with weak density between 1900kg/m^3 and 1600kg/m^3.
- It is also observed that porosity is relatively weak, lower than 5% and ranging between 3.8% and 0.05% compared to the cement materials which have a porosity higher than 10%.Moreover, it arises that low sand granulometry tend to reduce the proportion of air voids to water.This proportion of air voids depends not only on the granulometry of sand but is also a function of the content of plastic.
- In comparison with the bond which exists between the permeability to water and porosity it arises that the permeability undergoes the same modifications as porosity according to the content of plastic and sand granulometry and varies from 460 X 105 m2 with 0.One also observes starting from the relations between porosity and the permeability with the density that, the density is at the same time proportional to porosity and the permeability.

On the basis of conclusion suggested by the experimental results, this study shows that these mixtures from plastic 35% have good values that with respect to texture, the density, porosity and even the permeability to be used like tile forhouse-cover in the construction industry. However, thermal parameters still need to be evaluated to attest this use.

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